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FAILURE DATA HANDBOOK
-FOR NUCLEAR POWER FACILITIES-

A Guide for the Design, Construction, and Maintenance
of Nuclear Power Plants
from a Reliability Improvement Standpoint

VOLUME I
FAILURE DATA AND APPLICATIONS TECHNOLOGY

REVISION NOTICE

Latest revised pages supersede the same pages of initial issue. Insert revised pages into basic publication. Destroy superseded pages.

Liquid Metal Engineering Center

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the U.S. Atomic Energy Commission by Atomics International
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FOREWORD

The need for improved Quality and Reliability Assurance in the fabrication, construction, operation, and maintenance of nuclear power plants is recognized. This handbook is an initial effort to collect and evaluate records on past unscheduled events with systems and components in liquid metal cooled facilities, beginning with conceptual design through final shutdown, and coupled with establishment of a systematic reporting procedure for currently occurring incidents, malfunctions, or problems, will lead to eventual attainment of the goal of competitive product assurance for the LMFBR.

The handbook will maintain an updated record of events affecting the construction schedule or cost, safety, availability, or the maintainability of a nuclear power plant or test facility. Initial coverage will be limited to liquid metal facilities with emphasis on mechanical components. Future coverage will include other nuclear power plant types as well.

The value of this handbook will be realized only when it is used in the manner and for the purpose intended. The following factors should not detract from its value but point out fundamental limitations to the scope of its use.

1) Failure rate data printed herein, will for many years have a very low level of confidence. Inadequate source material and the fact that most failures to date are of the break-in or experimental-design type rather than classical random failures, necessitates extreme caution in their use.

2) Failure rate data for systems other than mechanical are recorded for the facilities currently operating but should be used only to weigh values obtained from other published sources having several orders of magnitude greater statistical confidence.

3) Emphasis is placed on the cause, mode, and effect of failures and associated engineering evaluation with recommendations. Careful examination of the description of the component or system must be made by a cognizant person in order to ascertain whether an event or associated recommendation is truly applicable for comparison to his particular need or situation.

The introduction of each part and subsection describes the reason for its development, the extent of coverage and growth expectation, its application, and its limitation. Expressed local assumptions and limitations are extremely important and should be rigidly adhered to.

Parts 1 and 2 of Volume I of the handbook will grow rapidly and continuously; Parts 3 and 4 on Reliability and Maintainability will have very slow initial growth; and Part 4 will take several years to attain a reasonable level of utility. In Voume II, the category identification system will grow with increased information volume and will be subjected to periodic revision to improve its usability. The Glossary should change very little.

All data in the handbook will eventually be recorded in greater detail in both LMEC's MIRACODE system (with original document records) and in a digital recording system. In addition, facility design and maintenance data will be similarly stored. An Electronic Accounting Machine (EAM) card is used for this storage, as shown in Volume II. Once in operation, this system will afford a rapid and effective means of retrieving information in response to detailed questions from contractor personnel.

This edition contains data retrieved from: (1) facility publications (i. e., progress reports, operation history reports, maintenance reports, failure reports, and incident reports); (2) maintenance work orders; (3) component history records; (4) verbal communication; and (5) miscellaneous documents. None of these sources were prepared or published with the intent of being applied to the express purpose of this handbook, nor was there an expectation of being subjected to this degree of scrutiny. As a result, it was rarely possible to clearly identify the cause of the event and many times it was even quite unclear as to exactly what part of which specific component failed and what final corrective action was accomplished. Numerous blank spaces exist in the tabulated data because present schedule and prohibitive cost did not warrant the lengthy research required to obtain this information from remote and sometimes poorly documented sources. In some cases, the material may be subject to misinterpretation by the reviewer. Every effort, however, has been made to minimize these problems. As the system improves and the need warrants, these data will be obtained.

Events specifically recorded at LMEC facilities on narrative-type incident report forms were equally lacking in the type of information of value to this handbook. This was due to lack of: clarity with respect to cause, clear description with respect to environmental circumstances surrounding the event, and formal followup on temporary corrective action and recommendations. In some cases the component which was considered to have failed, in reality may not have failed at all. For example, the case of a circuit breaker which opened causing a pump to trip — the breaker may have functioned in normal response to an overload. However, the circuit breaker is listed as having failed because of the lack of sufficient information. An improved LMEC reporting system has eliminated many of these problems and it is hoped that development of better communication with other reporting facilities and keeping abreast of current events in the future will develop considerable improvement in the completeness and validity of the information in the next edition.

The authorized level of effort for this edition did not permit specific identification and detailed classification (in the category format described in Volume II) of each of the components in the individual systems of each of the facilities participating in the reporting system. Thus, this edition does not fully describe the component with respect to each of the last six columns covering design specifications. Similarly, the numerical count of total component population in each facility could not be made except for isolated cases. This made it impossible to obtain population failure rates — even questionable ones. Most of the failure rates quoted are for the reported population that failed. That is, they approximate the mean-time-to-failure for those that failed.

During the next fiscal year, LMEC plans, as a minimum, to tabulate and record (in computer storage) fully identified component information for the heat transfer and process systems of LMEC's facilities and EBR-II. This identification will include both design specification and local system/component identification tag numbers. Once this is accomplished, better failure rate information on these facilities will begin to evolve. If possible, Fermi components will also be tabulated. In this issue, only sodium and related system component failure events were recorded for SRE, HNPF, and Fermi while a broader coverage of failure events were recorded for EBR-II, SCTI, and LCTL.

Operational period experiences associated with each of the major component and system categories described in Volume II are tabulated in Part 1. Each category and/or subcategory is accompanied by representations of relative frequencies and summaries or discussion in order to give:

1) The Designer - Knowledge of past problems and component or system weaknesses encountered under active operating conditions and repetition of which he should strive to avoid in his own design.

2) Project Management - A tool for estimating potential component or system reliability in order to assess required system complexity and design margin requirements.

3) RDT - A sound basis for specific R&D efforts to improve component design or methods of detecting failures while they are still incipient.

4) Operations - A human factor index for reduction of the human error potential.

5) Maintenance - A guide to improved maintenance methods, optimum inspection frequency, and incipient failure detection methods.

Sources of data and recommended ground rules for use of this section are described herein as a guide to the user. Applications, theory, and methodology are defined in Parts 3 and 4.

Each basic component is identified with its known failure experiences and these failures are categorized in a tabular presentation deemed suitable for ready design reference on problems to be avoided. Suggestions on how to avoid these problems are given along with statements as to the present state-of-the-art, test under consideration, and potential areas of future research and development. The information will be most useful to the designer with certain qualifications in its usage. Matching of component type, environment, and operating condition is, in most cases, very important for valid comparison of historical failure and expectation with respect to a specific design.

Very few mechanical failures recorded in this handbook will fall in the classification of random failures. All have been subjected to redesign, environmental adjustment, and procedural change in operation. It is the designer's responsibility to assess the reasoning behind the corrective actions taken, to apply this reasoning to his design, and to investigate other sources of failure data that may exist.

Failure detection effectiveness data are given where possible to assist the designer in improving the availability expectation of his facility. Also, recommendations of specific statements, to be included in procurement or acceptance specifications or standards, are presented as a guide to improvement of the reliability of the component.

Specific limitations should be placed on the use of indicated failure rates. The reasons for this are: (1) the failures are non-random, occurring mostly under test conditions, and in many cases the component was one of a kind; (2) actual component environmental history is not obtainable from the historical records. Failure rates given here have no level of confidence unless one is given. They should be used only for comparative purposes by qualified persons to evaluate the potential of improvement in component reliability or system availability that could be expected by a component change, rating change, or system redundancy modification. As the confidence level of failure rate data for specific compoents improves, curves of failure rate vs operating level will be included.

All failure data for each basic component is compiled under the heading of that component and is further broken down with respect to major subtypes. Basic components are listed alphabetically with accompanying introductory descriptions of the component/part classification code and figures of the most fundamental major types.

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I. COMPONENT FAILURE DATA FROM ALL CAUSES

In this section, all failure data for each basic component are compiled under the category heading for that component, and are further broken down with respect to major subtypes. Basic components have been categorized and listed alphabetically with accompanying introductory descriptions of the component/part classification code and illustrations of the most fundamental component types.

The data tabulated in this section were obtained from many sources, including: (1) facility publications (i. e., progress reports, failure reports, incident reports, etc.); (2) maintenance work orders; (3) component history records; (4) verbal communications; and (5) other miscellaneous documents. These source documents are noted in the failure data tables. A key to these source documents is presented in the following alphabetical listing as an aid to the reader.

SOURCE DOCUMENT KEY

DOCUMENT	SOURCE
AGC Internal Letter	"Aerojet-General Corporation Internal Letter," Aerojet-General Corporation, Van Karman Center
AGC TM	"Aerojet-General Corporation Technical Memorandum," Aerojet-General Corporation, Van Karman Center
AI Letter	"Atomics International Letter," Atomics International, Canoga Park, California
AI Monthly (HNPF)	See "Monthly Operating Report (HNPF)"
AI Monthly Hilites (HNPF)	See "Monthly Hilites (HNPF)"
AI Monthly Operating Report (HNPF)	See "Monthly Operating Report (HNPF)"
AI Monthly ROAP Report (HNPF)	"Atomics International Monthly Reactor Operations Analysis Program Report," Hallam Nuclear Power Facility, Hallam, Nebraska
ANL (EBR-II)	"Reactor Development Program Progress Report," Argonne National Laboratory, Experimental Breeder Reactor #II, Argonne, Illinois
ANL - Idaho Division - Operations Report	"Report of EBR-II Operations," Argonne National Laboratory - Idaho Division, National Reactor Testing Station, Idaho Falls, Idaho
ANS	"American Nuclear Society"
ANS-100 (EBR-II)	"American Nuclear Society, EBR-I and EBR-II Operating Experience," Fast Reactor Technology National Topical Meeting, April 26-28, 1965, Detroit, Michigan
APDA AECU	"Atomic Energy Commission, Unclassified," Atomic Power Development Associates, Inc., Detroit Michigan

DOCUMENT	SOURCE
APDA-CFE (Fermi)	"Enrico Fermi Atomic Power Plant Current Experience Series," Atomic Power Development Associates, Inc., Detroit, Michigan
Conference 650620	Sodium Component Development Program Information Meeting, Chicago, June 16-17, 1965
Construction Log (HNPF)	"Construction Log Book (HNPF)," Hallam Nuclear Power Facility, Hallam, Nebraska
Construction Log Book (HNPF)	"Hallam Nuclear Power Facility Construction Log Book," Hallam Nuclear Power Facility, Hallam, Nebraska
CPPD Monthly (HNPF)	"Consumers Public Power District, Hallam Nuclear Power Facility Monthly Report," Hallam Nuclear Power Facility, Hallam, Nebraska
Daily Site Wire (HNPF)	"Daily Site Wire (TWX)," Hallam Nuclear Power Facility, Atomics International, Canoga Park, California
Daily Wire (HNPF)	See "Daily Site Wire (HNPF)"
EF (Fermi)	"Enrico Fermi Atomic Power Plant Monthly Report," Power Reactor Development Co., Detroit, Michigan
EFAPP (Fermi)	"Enrico Fermi Atomic Power Plant (Fermi)" (unpublished internal document), Power Reactor Development Co., Detroit, Michigan
EFAPP Maintenance Report (Fermi)	See "EFAPP (Fermi)"
EFAPP-MR (Fermi)	See "EFAPP (Fermi)"
HNPF Construction Log	See "Construction Log Book (HNPF)"
IL NAA-SR-TDR (HNPF)	"Internal Letter for North American Aviation, Special Report, Technical Data Report," Atomics International, Canoga Park, California

DOCUMENT	SOURCE
IMPR	"Incident, Malfunction, and Problem Report," Liquid Metal Engineering Center, Canoga Park, California
IMR-MOR (HNPF)	"Initial Malfunction Report - Monthly Operating Report (HNPF)," Hallam Nuclear Power Facility, Hallam, Nebraska
Incident, Malfunction, and Problem Report	See "IMPR"
Incident Report (SCTI)	"Sodium Component Test Installation, Incident Report," Atomics International, Canoga Park, California
Incident Report (SRE)	"Sodium Reactor Experiment Incident Report," Sodium Reactor Experiment, Atomics International, Canoga Park, California
Initial Malfunction Report (HNPF)	"Initial Malfunction Report," Hallam Nuclear Power Facility, Hallam, Nebraska
Internal Letter (HNPF)	"Internal Letter," Hallam Nuclear Power Facility, Hallam, Nebraska
Internal Letter, A1-7518-9819	D.A. McGree to H.A. Gerber, "Repair of HNPF (Hallam Nuclear Power Facility) EM (Electromagnetic) Pump," Hallam Nuclear Power Facility, Hallam, Nebraska (January 3, 1962)
KAPL	"Knolls Atomic Power Laboratory," General Electric Company, Schenectady, New York
Lab Notebook (LCTL)	"Laboratory Notebook, Large Component Test Loop," Atomics International, Canoga Park, California
LMEC, NAA-SR	"Liquid Metal Engineering Center, North American Aviation Special Report," Atomics International, Canoga Park, California
Log Book (LCTL)	"Large Components Test Loop Log Book (LCTL)," Atomics International, Canoga Park, California

DOCUMENT	SOURCE
Log Book (SRE)	"Log Book (SRE)," Sodium Reactor Experiment, Atomics International, Canoga Park, California
Maintenance Log Book (SRE)	"Sodium Reactor Experiment Maintenance Log Book (SRE)," Atomics International, Canoga Park, California
Maintenance Report (EBR-II)	"EBR-II Maintenance Report," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho
Maintenance Report ANL (EBR-II)	See "Maintenance Report (EBR-II)"
Monthly Hilites (HNPF)	"Monthly Hilites" (TWX), Hallam Nuclear Power Facility, Atomics International, Canoga Park, California
Monthly Operating Report (HNPF)	"Hallam Nuclear Power Facility Monthly Operating Report," Hallam Nuclear Power Facility, Hallam, Nebraska
MOR (HNPF)	See "Monthly Operating Report (HNPF)"
MSA EP	"MSA Research Corporation Bulletin," MSA Research Corporation, Callery, Pennsylvania
NAA-SR	"North American Aviation Special Report," Atomics International, Canoga Park, California
NASA C.R.	"NASA Contractor Report," National Aeronautics and Space Administration, Washington, D.C.
Operating Log (SRE)	See "Log Book (SRE)"
Operating Maintenance Report (EBR-II)	"Operating Maintenance Report (EBR-II)," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho
Operating Monthly Report (EBR-II)	"Operating Monthly Report (EBR-II)," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho

DOCUMENTS	SOURCE
Operating Weekly Report (EBR-II)	"Operating Weekly Report (EBR-II)," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho
Operation Maintenance Report (EBR-II)	See "Operating Maintenance Report (EBR-II)"
Operations Log (SRE)	See "Log Book (SRE)"
Operations Maintenance (EBR-II)	See "Operating Maintenance Report (EBR-II)"
Operations Maintenance Report (EBR-II)	See "Operating Maintenance Report (EBR-II)"
Operations Monthly Report (EBR-II)	See "Operating Monthly Report (EBR-II)"
Operations Weekly Report (EBR-II)	See "Operating Weekly Report (EBR-II)"
Operation Weekly Report (EBR-II)	See "Operating Weekly Report (EBR-II)"
Oper. Maint. (EBR-II)	See "Operating Maintenance Report (EBR-II)"
Personal Communication, C.W. Griffin	"C.W. Griffin," Liquid Metals Engineering Center, Canoga Park, California
Plant Modification and Maintenance Report (EBR-II)	"Plant Modification and Maintenance Report," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho
PMMR (EBR-II)	See "Plant Modification and Maintenance Report (EBR-II)"
PRDC (Fermi)	"Power Reactor Development Company," Enrico Fermi Atomic Power Plant, Lagoona Beach, Michigan
PRDC-EF (Fermi)	See "EF (Fermi)"
ROAP Report (HNPF)	See "AI Monthly ROAP Report (HNPF)"
Shift Leader's Log Book (HNPF)	"Shift Leader's Log Book," Hallam Nuclear Power Facility, Hallam, Nebraska

DOCUMENTS	SOURCE
SNAP 8-D of A.G.C.F.C. MSA EM P.F.	Facility comments, SNAP-8 Division of Aerojet-General, "MSA EM pump Failures," recorded March 18, 1966 on the November 22, 1965 summary, Aerojet General Corporation, Von Karman Center
S.T.P. (EBR-II)	"Systems Training Program, Training Information," Experimental Breeder Reactor No. II, National Reactor Testing Station, Idaho Falls, Idaho
TWX	"Teletype Writer Exchange," Atomics International, Canoga Park, California
TWX to R.S. Baker (HNPF)	"Teletype Writer Exchange to R.S. Baker," "HNPF EM Pumps," (November 3, 1961), Atomics International, Canoga Park, California
Weekly Hilites (HNPF)	"Weekly Hilites," (TWX), Hallam Nuclear Power Facility, Atomics International, Canoga Park, California
Weekly Maintenance Report (EBR-II)	See "Operating Maintenance Report (EBR-II)"
Weekly Report (EBR-II)	See "Operating Weekly Report (EBR-II)"
Weekly Site Report (HNPF)	See "Weekly Hilites (HNPF)"
Weekly Site Wire (HNPF)	See "Weekly Hilites (HNPF)"
Work Request (HNPF)	"Hallam Nuclear Power Facility Work Request," Hallam Nuclear Power Facility, Hallam, Nebraska
WR (HNPF)	See "Work Request (HNPF)"

A. CHEMICAL SYSTEM COMPONENTS

1. Demineralizers

Failure data for demineralizers (ion exchange unit) are presented in Tables 1-1 through 1-3.

a. Reliability Information

Design Features:

Demineralizers are used to purify the feedwater feed to the steam generator.

Mode of Failure:

Mechanical vibration

Failure Description:

The pipe header which distributes the water flow cracked because of vibration.

Control Methods:

1) Use stainless steel headers and stronger pipes.

2) Anchor the pipes properly.

b. Discussion and Recommendations

The Poly-Vinyl Chloride pipe used in the demineralizer failed because of vibration. This pipe was held on the same supports as other plant piping. The vibrations from other pipes caused fatigue and finally pipe failure. Attempts to repair the pipe were unsuccessful.

Poly-Vinyl Chloride plastic pipe should not be used where any vibration can cause failure. The pipe leading from a demineralizer system should be either aluminum or steel with a Polyproplene liner.

TABLE 1-1

FAILURE DATA FOR DEMINERALIZERS (ION EXCHANGE UNIT)

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Demineralizer/ Distribution Header 2. Feedwater Supply and Treatment/Bypass Purification 3. 53 273100	1. SCTI 2. Treated water/condensate polishing system 3. 120 gpm, 100 psig 4. Incident report No. 30	MI 478	MI 53	MI 117	333	Direct observation	1. Distribution manifold pulled loose from tee due to thin-wall SS tubing. 2. Part replaced. 3. Scheduled monthly air mixing will prevent overpacking of resin on pipeline within the flanged vessel.
2	1. Demineralizer/ Plastic Tee 2. Feedwater Supply and Treatment/Condensate Demineralizing 3. 53 273200	1. SCTI 2. Treated water and chemical feed system/polishing demineralizer 3. - 4. Incident report No. 90	MI 128	MI 61	MI 136	2,606	Direct observation	1. Plastic tee cracked at threads due to vibration. 2. Local repair, replaced plastic piping with aluminum piping. 3. Upgrade QA procedures for installation of plastic pipe.
3	1. Demineralizer/ Plastic Pipe 2. Feedwater Supply and Treatment/Condensate Demineralizing 3. 53 273200	1. SCTI 2. Treated water and chemical feed system 3. 120 gpm, to 140°F, 100 psig 4. Incident report No. 305	MI 143	MI 53	MI 530	4175	Direct observation	1. Piping manifold inadequately supported. 2. Plastic influent header manifold replaced by SS flange and manifold. 3. Improve QA on original installation.
4	1. Makeup Water Demineralizer/ Plastic Waterline 2. Feedwater Supply and Treatment/ Demineralizer 3. 53 272200	1. SCTI 2. Polishing system 3. - 4. Incident report No. 68	MI 172	MI 59	MI 530	1560	During repair or inspection of system associated to failure component.	1. Cracked water line. 2. Part replaced. 3. Plastic piping should be carefully inspected before application.
5	1. Demineralizer/Acid Inlet Header 2. Feedwater Supply and Treatment/ Demineralizers 3. 53 272200	1. SCTI 2. Steam and feed system 3. 495°F, 19.6% flow 4. Incident report No. 328	MI 453	MI 59	MI 580	6300	Routine area watch	1. Weld holding acid inlet header support bracket to tank broke allowing header to tear loose from tank. 2. Substituted header (stainless steel flanges) and rewelded bracket of improved design. 3. Improve bracket design — replace plastic flange by SS.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-1

FAILURE DATA FOR DEMINERALIZERS (ION EXCHANGE UNIT)

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Demineralizer/ Manifold 2. Feedwater Supply and Treatment/ Demineralizers 3. 53 272200	1. SCTI 2. Upper manifold demineralizer D-1 3. 12,600 gal, 100 psig 4. Incident report No. 309 (10-17-66)	MA 186	MA 5Z	MA 520	2550	During preventive maintenance	1. Inspection found upper distribution manifold cracked in the threads at the supporting flange. Header material is plastic "Uscolite" and not strong enough to hold load. 2. Upper manifold replaced with SS header to provide adequate strength. 3. Resin beds should be mixed during long shutdowns to prevent excessive packing.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-2

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT DEMINERALIZERS (ION EXCHANGE UNIT)

COMPONENT SUBTYPE DEMINERALIZERS

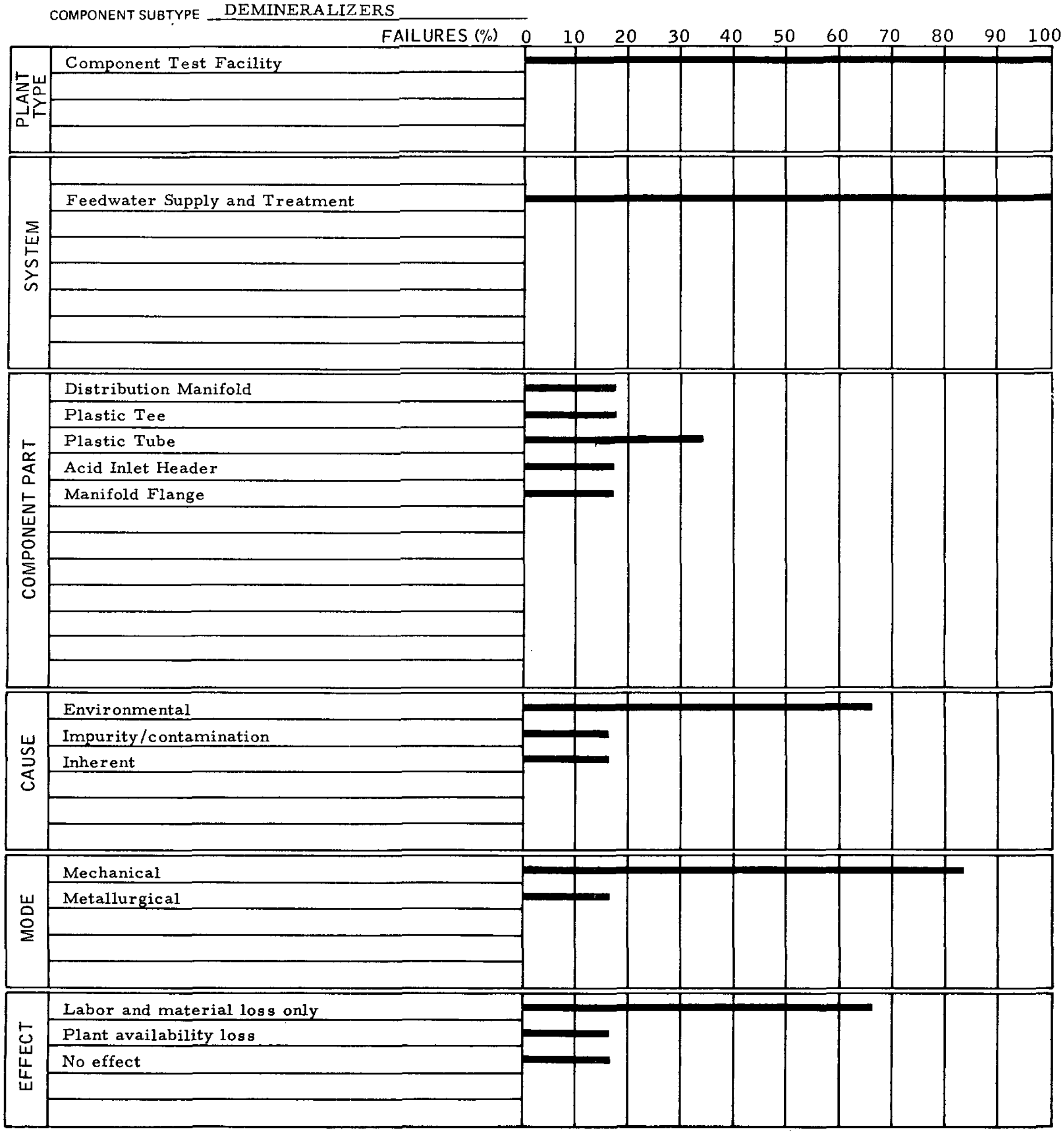
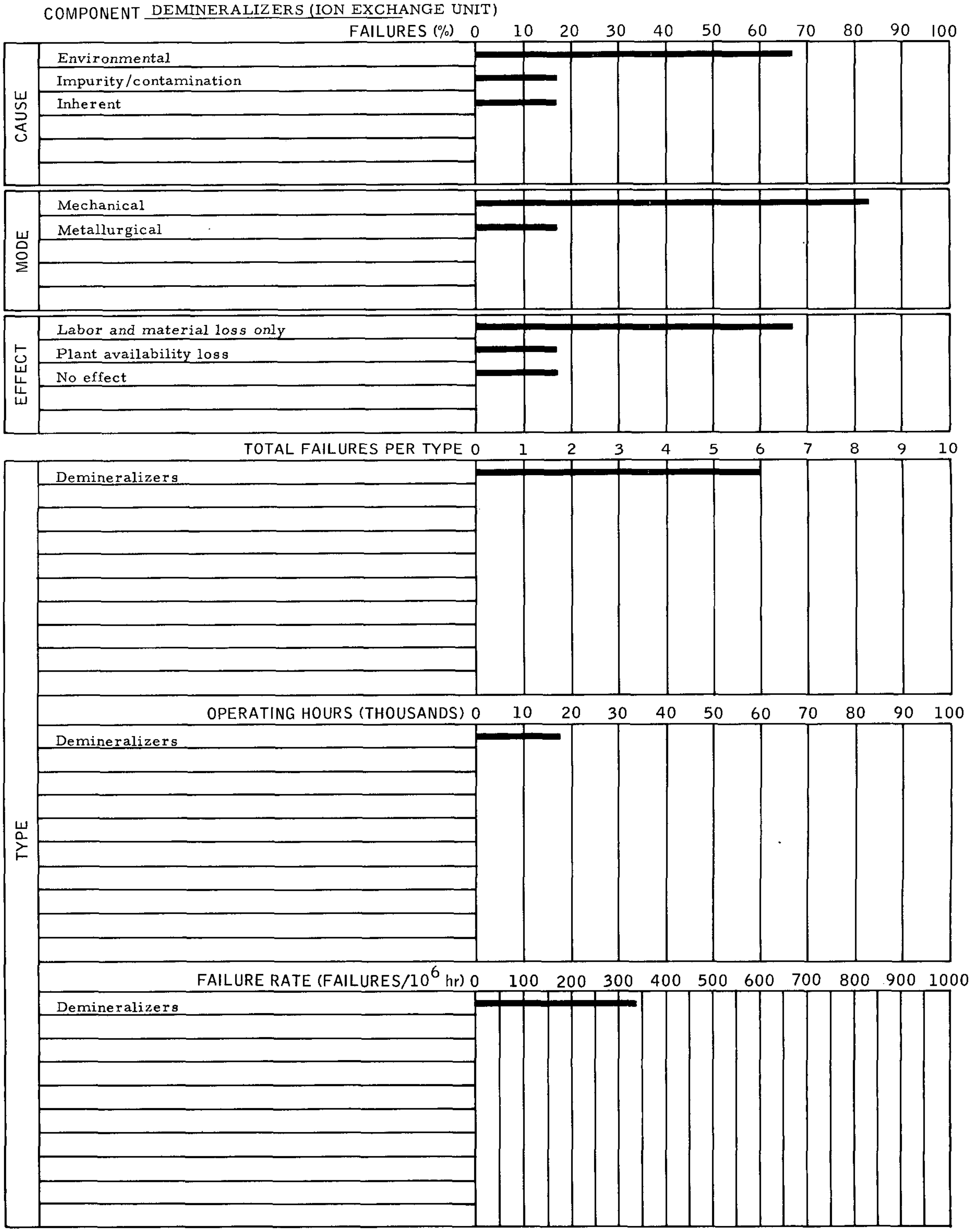


TABLE 1-3

GENERAL SUMMARY

COMPONENT DEMINERALIZERS (ION EXCHANGE UNIT)



B. CONTAINMENT SYSTEM COMPONENTS

1. Air Locks

Failure data for air locks are presented in Tables 1-4 through 1-8.

a. Reliability Information

Design Features:

Compartments with two doors and inflatable seal with inner lock to prevent opening both doors at once. Valve and piping for equalization of pressure.

Critical Characteristics:

Maintain reliable atmospheric isolation.

Mode of Failure:

1) Seal, gasket, and valve leakage
2) Switch malfunction
3) Penetration leakage.

Failure Description:

1) Inflatable seal valve leaked
2) Neoprene boot leaked
3) Door seal ruptured
4) Door switch inoperative
5) Equalizing valves leaked
6) Electrical and pipe penetrations leaked.

Control Methods:

1) Establish a regular schedule of inspection and testing for all seal equipment and specific procedures for maintenance and repair.
2) Optimum test period assumed to be about eight months.
3) Some facilities use continuous leak monitoring with no access during operation.

Failure Rates:

Approximate failure rates developed by Holmes & Narver, Inc. for air lock components used in water reactors are as follows:

1) 2.5×10^{-6}/hr for valves

2) 4.5×10^{-6}/hr for gaskets and seals

3) 4.5×10^{-6}/hr for penetrations

The frequency for LMFBR's appears comparable.

b. Discussion and Recommendations

None.

TABLE 1-4

FAILURE DATA FOR AIR LOCKS

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Air Lock/Door 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Equipment inner door 3. Ambient temperature 4. ANL 7132-7152	I 133	I 35	I 580	4,660	Direct observation	1. Door blown off causing damage to other components in the reactor building. 2. Part replaced. 3. None.
2	1. Air Lock/Inflatable Seal Valve 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Equipment lock/admission valve 3. Ambient temperature 4. PMMR-58 (4)	MI 500	MI 73	MI 530	9,300	Preventive maintenance	1. Valve cracked. 2. Part replaced. 3. None.
3	1. Air Lock/Seal Air Valve 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Equipment lock 3. Ambient temperature 4. PMMR-13	MI 500	MI 55	MI 550	1,200	Direct observation	1. Valve would not release air from seal. 2. Local repair. 3. None.
4	1. Air Lock/Neoprene Boot 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Interlock - air lock 3. Ambient temperature 4. PMMR-10/14/64 (4)	MI 500	MI BZ	MI 530	1,200	Preventive maintenance	1. Leak. 2. Local repair. 3. Establish regular inspection schedule for seals.
5	1. Air Lock/Seal 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-17 (4)	MI 500	MI 59	MI 550	1,200	Operational monitor	1. Leaking (pin hole leak). 2. Local repair. 3. None.
6	1. Air Lock/Hydraulic Unit 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-18	MI 500	MI BZ	MI 530	1,200	Routine inspection	1. Unknown. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-4

FAILURE DATA FOR AIR LOCKS

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
7	1. Air Lock/Door Switch 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-5	MI 500	MI BZ	MI 550	1,200	Direct observation	1. Faulty switch. 2. Part replaced. 3. None.
8	1. Air Lock/Seal 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-22 (4)	MI 500	MI 59	MI 550	1,200	Direct observation	1. Seal ruptured. 2. Part replaced. 3. None.
9	1. Air Lock/Seal 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-49 (4)	MI 500	MI 59	MI 520	7,800	Direct observation	1. Seal ruptured. 2. Part replaced. 3. None.
10	1. Air Lock/Seal 2. Reactor Containment/ Air Lock 3. 01 194220	1. EBR-II 2. Personnel air lock 3. Ambient temperature 4. PMMR-49 (4)	MI 478	MI 59	MI 520	7,800	Direct observation	1. Seal ruptured - improperly vulcanized. 2. Part replaced. 3. Maintenance/repair procedures and inspection methods should be clearly defined.
11	1. Air Lock/Electrical Conax Seal 2. Reactor Containment/ Process Penetrations 3. 01 194231	1. EBR-II 2. Emergency air lock electrical feed-through 3. Ambient temperature 4. PMMR-82	MI 500	MI 52	MI 530	7,400	Routine inspection	1. Seal leaking. 2. Part replaced. 3. None.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-5

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT AIR LOCKS

COMPONENT SUBTYPE EMERGENCY

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Test Reactor	
SYSTEM	Reactor Containment	
COMPONENT PART	Electrical Conax Seal	
CAUSE	Unknown	
MODE	Mechanical	
EFFECT	Labor and material loss only	

TABLE 1-6

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT AIR LOCKS

COMPONENT SUBTYPE EQUIPMENT

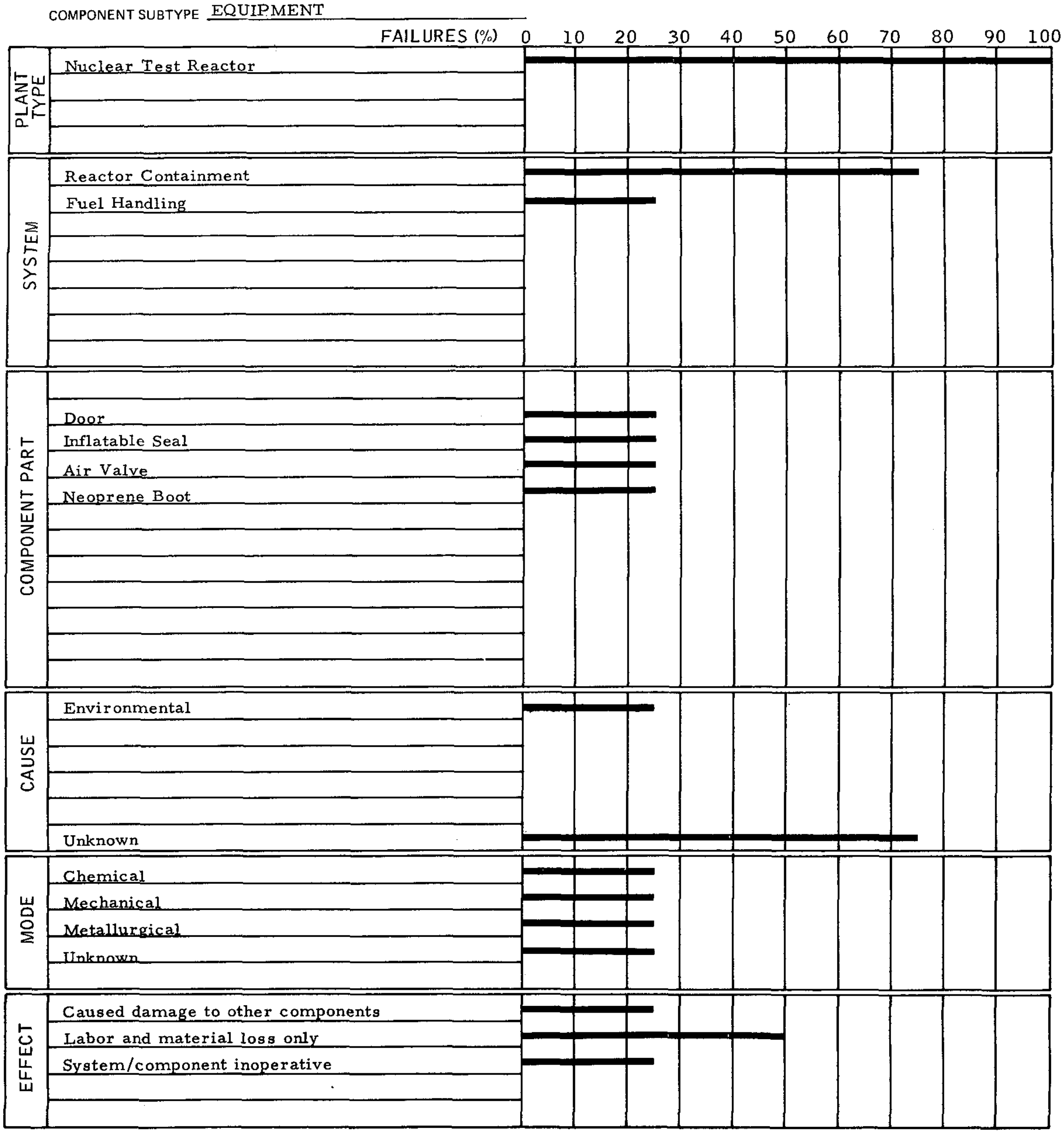


TABLE 1-7

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT AIR LOCKS

COMPONENT SUBTYPE PERSONNEL

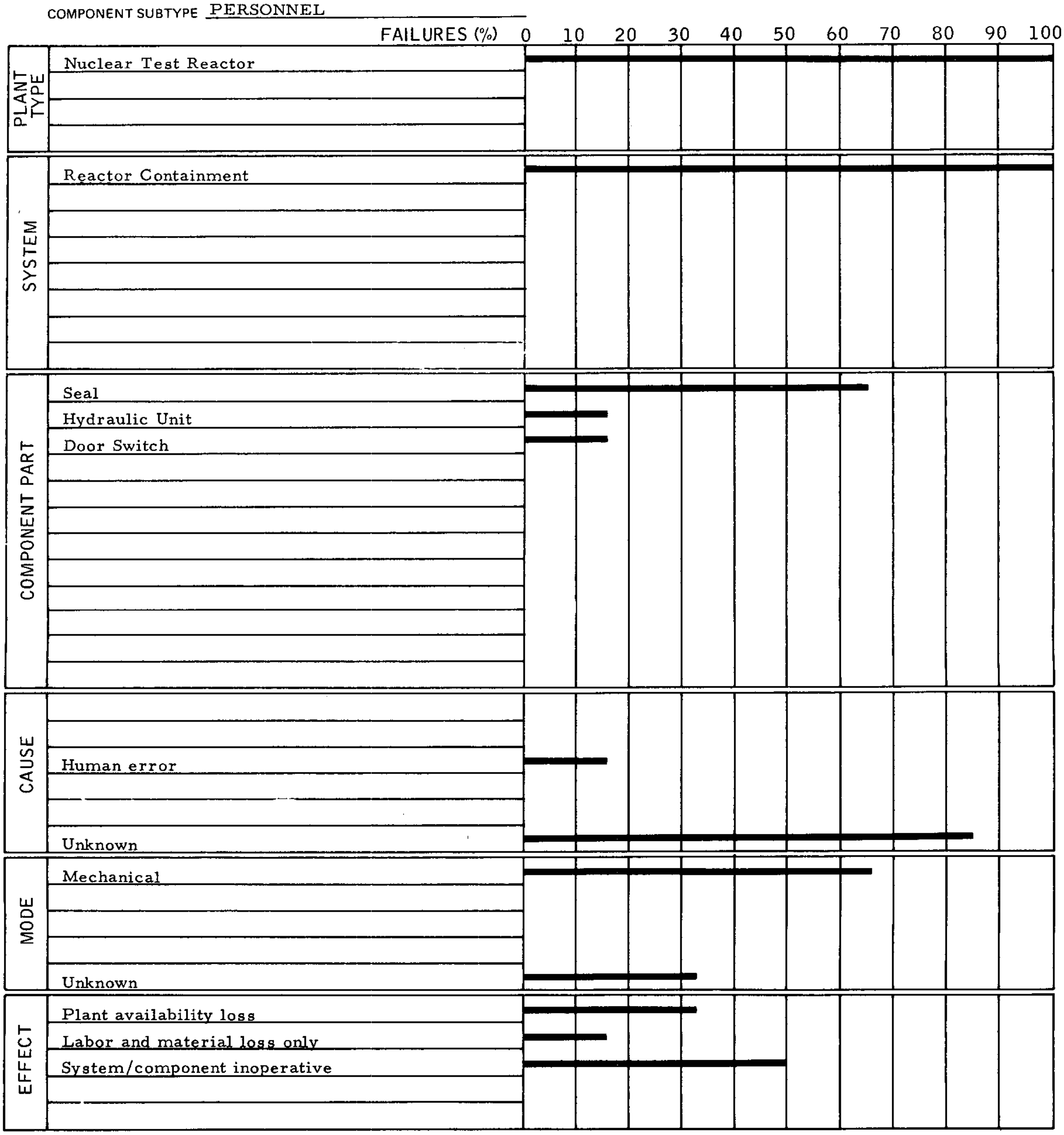
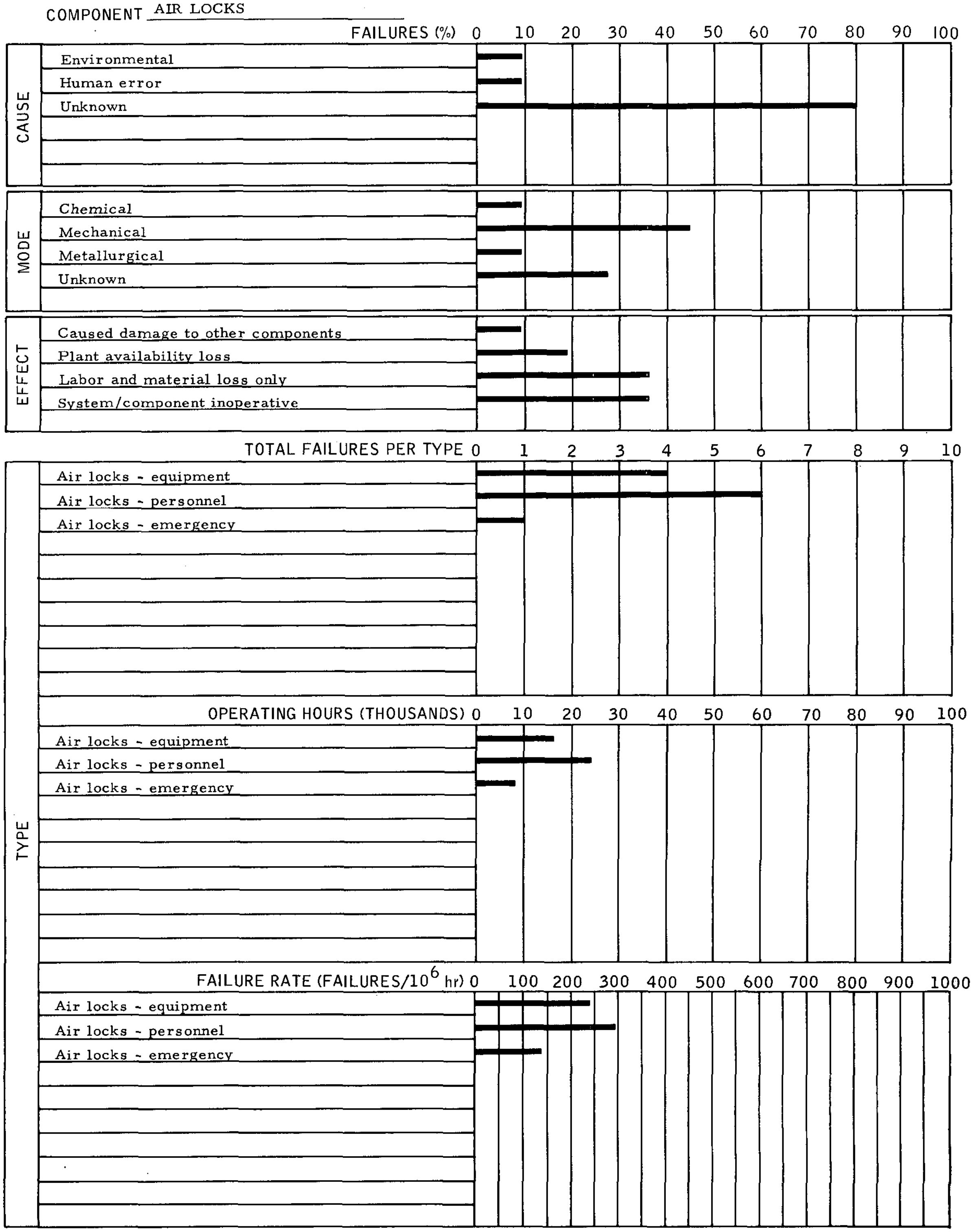


TABLE 1-8

GENERAL SUMMARY

COMPONENT AIR LOCKS



2. Hoist Units

Failure data for hoist units are presented in Tables 1-9 through 1-12.

a. Reliability Information

Design Features:

Grip and vertically position fuel elements.

Critical Characteristics:

Severe thermal, pressure, chemical, and radioactive environment; blind operation; precision movement; high reliability.

Modes of Failure:

1) Failure to provide, control, or cut off power
2) Failure to lift, halt, hold, and lower on command and at proper speed
3) Failure to grasp, hold, and release on command
4) Failure to indicate, limit, and control the position of gripper and load
5) Failure to shield and support.

Failure Description:

1) Defective electric components or an unreliable power supply
2) Broken or jammed cables, gears, bearings, and other parts of the lifting mechanism
3) Jammed or broken precision machined parts in gripper
4) Misaligned, jammed, or broken mechanical parts in control and sensing system
5) Insufficient shielding and loose connection in support structure.

Control Methods:

1) Provide a fail-safe system, a positive cut-off, and emergency power.
2) Avoid overloading the lifting mechanism.
3) Use proper materials, simplify the configuration, and provide adequate clearances and tolerances.

4) Provide fail-safe devices, emergency controls, and a verification of signal data.

5) Inspect and maintain the hoist.

Alternative Concepts:

Hydraulic or liquid metal lifting mechanism.

Suggested Incipient Failure Detection Methods:

1) Failure is sometimes preceded by detectable variations in certain operating parameters. The thermocouple to detect a hot bearing and the pressure gage to detect loss of oil pressure are well known. With respect to hoists, it should be possible to put a sonic detector in the drive box to sense abnormal chatter from misaligned or fouled gears, etc. Also, a power or work meter on the hoist motor could sense abnormal energy requirements in lifting stuck fuel elements or other hangups.

2) Failure often occurs with no detectable change in operation until the moment of catastrophy. The fraying of a load cable or the crack in a gripper are typical examples. The classic method used to avoid this type failure is routine maintenance and inspection coupled with periodic proof and other nondestructive tests. When this method is used with skill and diligence, it detects most surface defects. Hidden defects are much more difficult to ascertain. Improvement in flaw detection depends on the development of built-in, nondestructive scanners. Because of the complex configuration of hoisting mechanisms, this development effort will be costly.

b. Discussion and Recommendations

General:

The function of any hoist is to grip and vertically move a load. The principal parts of a hoist are the power source, the lifting mechanism, the gripper, the sensing and control system, and the support and shielding.

Hoists for fuel handling machines are specialized in that they primarily grip and move fuel elements inside a reactor. The fuel elements must be handled and maintained in a high-temperature, pressurized, chemically reactive, and also radioactive environment. The movements are mostly hidden from the operator. Under these conditions the hoist movement must be precise and reliable.

Power Source:

Electric, pneumatic, and hydraulic power can be used. The choice of power governs the operation and configuration of the other parts of the hoist. Most hoists use electric power.

A power failure is lost, unprogrammed, or runaway power. Power failures are caused by defective electrical components or an unreliable supply.

The best design and installation cannot prevent power failures with certainty. However, the catastrophic consequences of a power failure must be avoided by providing a fail-safe system, positive cutoff, and emergency power with the alternative of manual operation.

Lifting Mechanism:

The lifting mechanism transforms the power into controlled vertical motion. The mechanism usually consists of a gear drive, a drum, brakes, sheaves, guides, a cable (or chain), and gripper attachment.

A failure of the lift mechanism is failure to lift, halt, hold, or lower the load on command and at the proper speed. Failures of the lifting mechanism are due most often to broken gears and galled bearings. These result in stalled or uneven movement. A rupture or pull-out of the cable or lift chain is less frequent but can have catastrophic consequences.

Most failures can be prevented by avoiding overloads and by adequate inspection and maintenance.

Gripper Mechanism:

The gripper is the device that holds the load. The simplest gripper is the hook which is manually attached to the load. At the other end of the spectrum is the fuel handling gripper. It must remotely and precisely grasp, hold, and release the pickup attachment on a fuel element. This must be accomplished on command and in a severe thermal, pressure, chemical, and radioactive environment.

A failure of the gripper mechanism is failure to grasp, hold, or release the load on command. Failures of the gripper mechanism are due to jammed or broken precision machined parts.

Such failures can usually be avoided if, during design, the proper materials are selected, simplicity of configuration is stressed, and adequate clearance and tolerance are provided.

Control and Sensing System:

Hoists may be manually controlled by the operator based on direct observation or on remote indicators. Completely programmed control is also possible. The most common control mode is semi-automatic where the operator's command initiates a sequence of automatic movement.

Sensing devices are required for hidden hoist operations, for programmed sequences of events, and to automatically limit travel. Signals actuate indicators, alarms, protective devices, or controls.

A failure of the control and sensing system is a failure to indicate, limit, or control the position of the gripper or the load. Failures are most frequently caused by misaligned, jammed, or broken mechanical parts.

The control system should be designed like the power system with fail-safe devices, positive cutoffs, and emergency controls. The sensing system should have a method of verifying that signaled information is correct.

Shielding and Supports:

A housing contains the severe environment surrounding the lifted element, and shields operations surrounding the hoist from adverse effects of the environment. Conditioning equipment may be required to maintain the environment. The shielding may surround the entire hoist, some parts of it, or only the lifted element.

The support structure holds the hoist and shielding and transmits the dead and lifted loads to the building frame or foundation. The support structure may be either stationary or mobile.

Failure to shield or support can result in damage to the load, to personnel, to the surrounding facility, or to the operating process. Shielding failures are almost always due to failure to provide shielding. Support failures are due usually to deterioration or loosening of the connections.

Proper evaluation of the environment requiring shielding and detailed inspection and maintenance of the shield and support structure would reduce the possibility of failure.

TABLE 1-9

FAILURE DATA FOR HOIST UNITS

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Hoist Unit/Lifting Cable 2. Nuclear Fuel Handling and Storage of Equipment/Fuel Handling Machine 3. 50 235163	1. Fermi 2. Cask car 3. Min. 350°F, argon 4. PRDC-EF-47	MI 120	MI 59	MI 530	14,941	Direct observation	1. Cable broke. 2. Part replaced. 3. None.
2	1. Hoist Drum/Bearings 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 50 235163	1. Fermi 2. Cask car 3. Min. 350°F, argon 4. EF-24	MI 114	MI 68	MI 550	14,763	During actuation	1. Sodium deposition and dry bearing surfaces caused bearing to gall. 2. Vendor repair of component. 3. Select bearing materials compatible with sodium.
3	1. Hoist Unit/Fuel Gripper 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. ANL-6780	MI 218	MI 55	MI 550	1000	Operational monitors	1. Mechanism jammed. 2. Local repair. 3. None.
4	1. Hoist Unit/Fuel Gripper 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. ANL-6923	MI 218	MI 55	MI 530	1000	During preventive maintenance	1. Gripper jammed. 2. Local repair, gripper removed, cleaned, inspected, and reinstalled. 3. None.
5	1. Hoist Unit/Fuel Gripper Drive Gear 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. PMMR-14	MI 500	MI 59	MI 550	1200	Operational monitors	1. Gear broken. 2. Part replaced. 3. Check surface hardness (R_C) of material used to fabricate the gears; change material, if necessary, or heat treatment method (i.e., case harden).

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-9

FAILURE DATA FOR HOIST UNITS

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Hoist Unit/Fuel Gripper Funnel 2. Nuclear Fuel Handling and Storage Equipment/ Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/internal fuel handling equipment 3. 210 to 700°F 4. ANL-6944	MI 187	MI 54	MI 550	790	Operational monitor	1. Funnel of gripper contacted the hold-down. 2. Part replaced. 3. Reduce speed of insertion to 2 in./min to allow gripper to attain equilibrium temperatures.
7	1. Hoist Unit/Fuel Gripper Sensing Rod 2. Nuclear Fuel Handling and Storage Equipment/ Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. PMMR-108	MI 172	MI 54	MI 550	11,320	During actuation	1. Sensing rod bent. 2. Local repair, spare gripper installed. 3. Slower than 6 in./min insertion into liquid sodium.
8	1. Hoist Unit/Gripper Jaw Gears 2. Nuclear Fuel Handling and Storage Equipment/ Fuel Handling Machine 3. 50 235163	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. PMMR-43, 9-65	MI 219	MI 59	MI 530	3070	Operational monitor	1. Gear broken. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-10

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT HOIST UNITS

COMPONENT SUBTYPE FUEL HANDLING HOIST (EBR II)

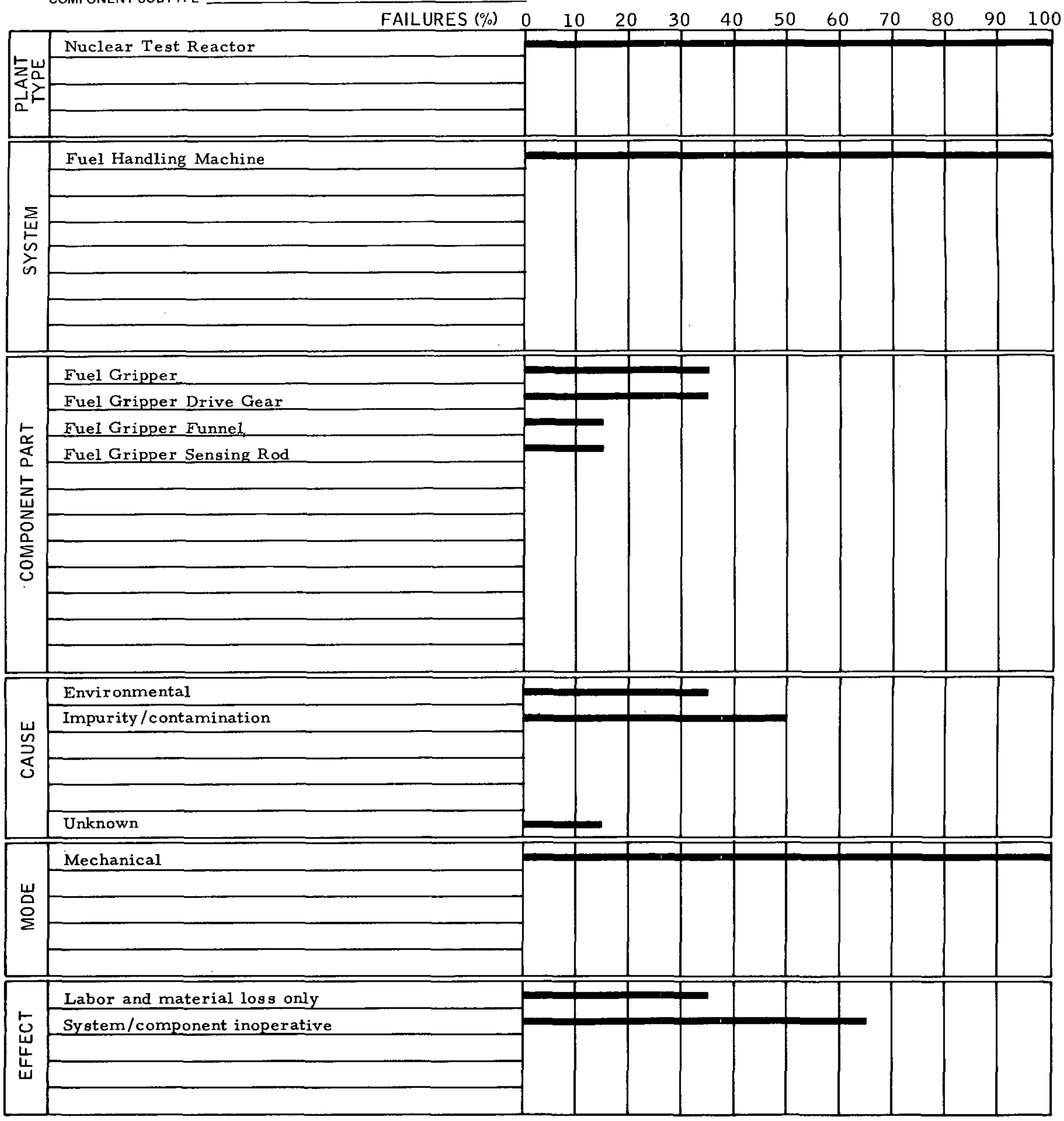


TABLE 1-11

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT HOIST UNITS

COMPONENT SUBTYPE FUEL HANDLING HOIST (FERMI)

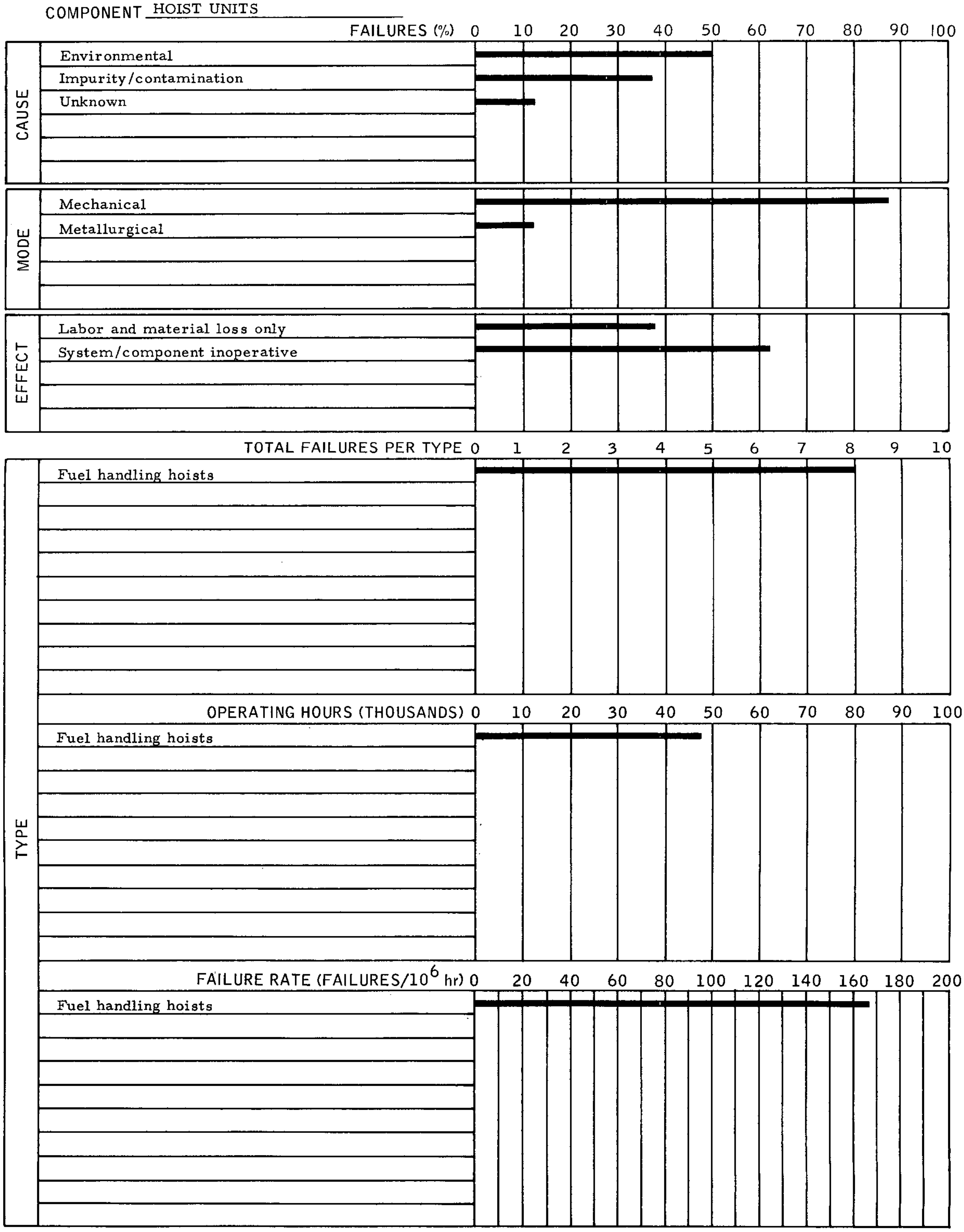
FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactor
SYSTEM	Fuel Handling
COMPONENT PART	Lifting Cable
	Bearing
CAUSE	Environmental
MODE	Mechanical
	Metallurgical
EFFECT	Labor and material loss only
	System/component inoperative

TABLE 1-12

GENERAL SUMMARY

COMPONENT HOIST UNITS



3. Shielding

Failure data for shielding are presented in Tables 1-13 through 1-15.

a. Reliability Information

Modes of Failure:

1) Binding due to oxide impurities of bismuth, tin, and sodium in seal.
2) Water-soaked plug caused violent sodium-water reaction and damage to components.

Failure Experience:

1) The reason for repeated occurrence of oxide impurity accumulation was not resolved, but cover gas impurities are a potential source.
2) Water soaking of the plug was an unusual and hopefully unrepeatable serious accident.

Control Methods:

1) Sources of impurities which can condense as oxides in rotating seals should be determined and eliminated whenever practical.
2) Sodium condensate in seals can sometimes be prevented by including louvered cooling baffles between the sodium surface and seal area to precipitate the vapors before they reach the seal region.

b. Discussion and Recommendations

None.

TABLE 1-13

FAILURE DATA FOR SHIELDING

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Shielding/O-rings 2. Reactor Equipment/ Reactor Shielding 3. 16 213000	1. Fermi 2. Reactor exit port shield plug 3. - 4. EF-46	MI 312	MI 52	MI 530	14,941	Direct observation	1. O-ring worn out, causing seal to leak. 2. Part replaced. 3. Increase preventive maintenance frequency.
2	1. Uranium Shield/ Column 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 16 235150	1. Fermi 2. Cask car 3. Minimum 350°F, argon 4. EF-APP-47	MI 117	MI 54	MI 530	6470	Direct observation	1. Column distorted. 2. Port replaced. 3. None.
3	1. Uranium Shield/ Rotor 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 16 235150	1. Fermi 2. Cask car 3. Minimum 350°F, argon 4. EF-APP-47	MI 117	MI 54	MI 530	6470	Direct observation	1. Rotor bound against the cask walls. 2. Part replaced. 3. None.
4	1. Shielding/Seal Trough 2. Reactor Equipment/ Shielding 3. 16 213000	1. EBR-II 2. Rotating plug 3. 281 to 355°F 4. ANL-7082, 7/65	MI 200	MI 55	MI 530	2590	During preventive maintenance	1. Impurities in seal, oxides of bismuth, tin, and sodium. 2. Local repair. 3. None.
5	1. Shielding/Metal Seal 2. Reactor Equipment/ Shielding 3. 16 213000	1. EBR-II 2. Rotating plug 3. 400°F 4. ANL-7115, 10/65	MI 200	MI 55	MI 550	3410	During inspection of system associated to failure component	1. Oxides and sodium in seal. 2. Local repair. 3. None.
6	1. Shielding/Metal Seal 2. Reactor Equipment/ Shielding 3. 16 213000	1. EBR-II 2. Small rotating plug 3. 281 to 400°F 4. Maintenance report 4/18/68	MI 25Z	MI 51	MI 530	14,150	During preventive maintenance	1. Oxides and sodium in seal. 2. Local repair. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-13

FAILURE DATA FOR SHIELDING

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
7	1. Shielding/Plug Seal Trough 2. Reactor Equipment/Shielding 3. 16 213000	1. EBR-II 2. Top shield plug auxiliary gripper 3. - 4. Operation monthly report, 2/68	MA 500	MA B6	MA 530	13,380	Direct observation	1. Shield plug soaked with water, trapped under labyrinth or end cap. 2. None. 3. None.
8	1. Shielding/Plug Seal 2. Reactor Equipment/Shielding 3. 16 213000	1. EBR-II 2. Rotating Plug 3. 281 to 400°F 4. Operation monthly report, 2/68	MA 315	MA 37	MA 530	13,380	Direct observation	1. Water trapped under labyrinth or end cap entered primary tank when plug was reinserted, sodium was expelled through the hole up around the plug. 2. Local repair. 3. Revise procedure to require inspections for water.
9	1. Shielding/Transfer Port O-ring 2. Nuclear Fuel Handling and Storage Equipment/Shielding 3. 16 235150	1. EBR-II 2. Primary/fuel unloading machine 3. - 4. PMMR-48	MI 126	MI 52	MI 530	3410	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. Replacement of O-rings and gaskets is desirable whenever parts are disassembled for maintenance or repair.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-14

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SHIELDING

COMPONENT SUBTYPE SHIELDING

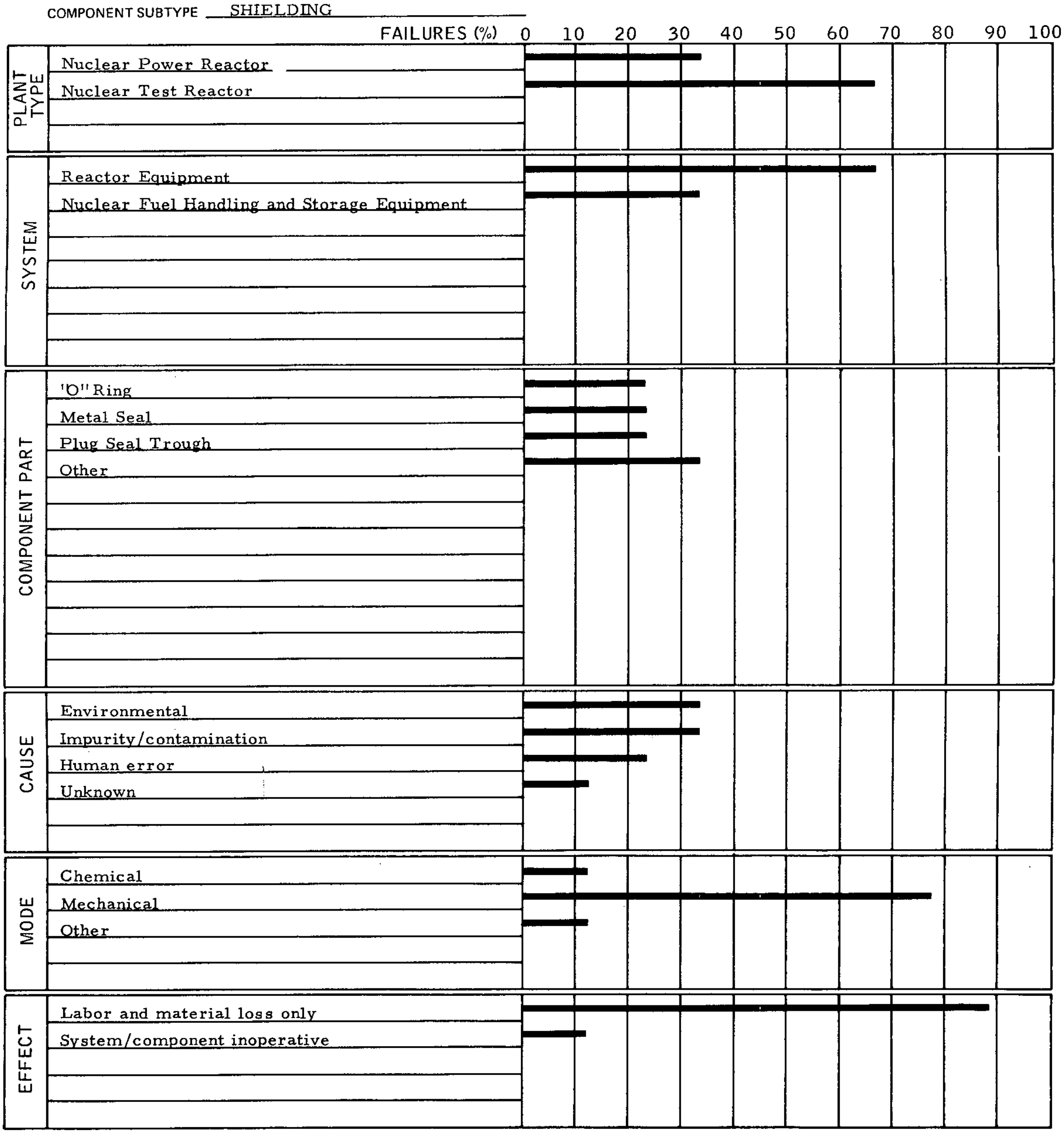
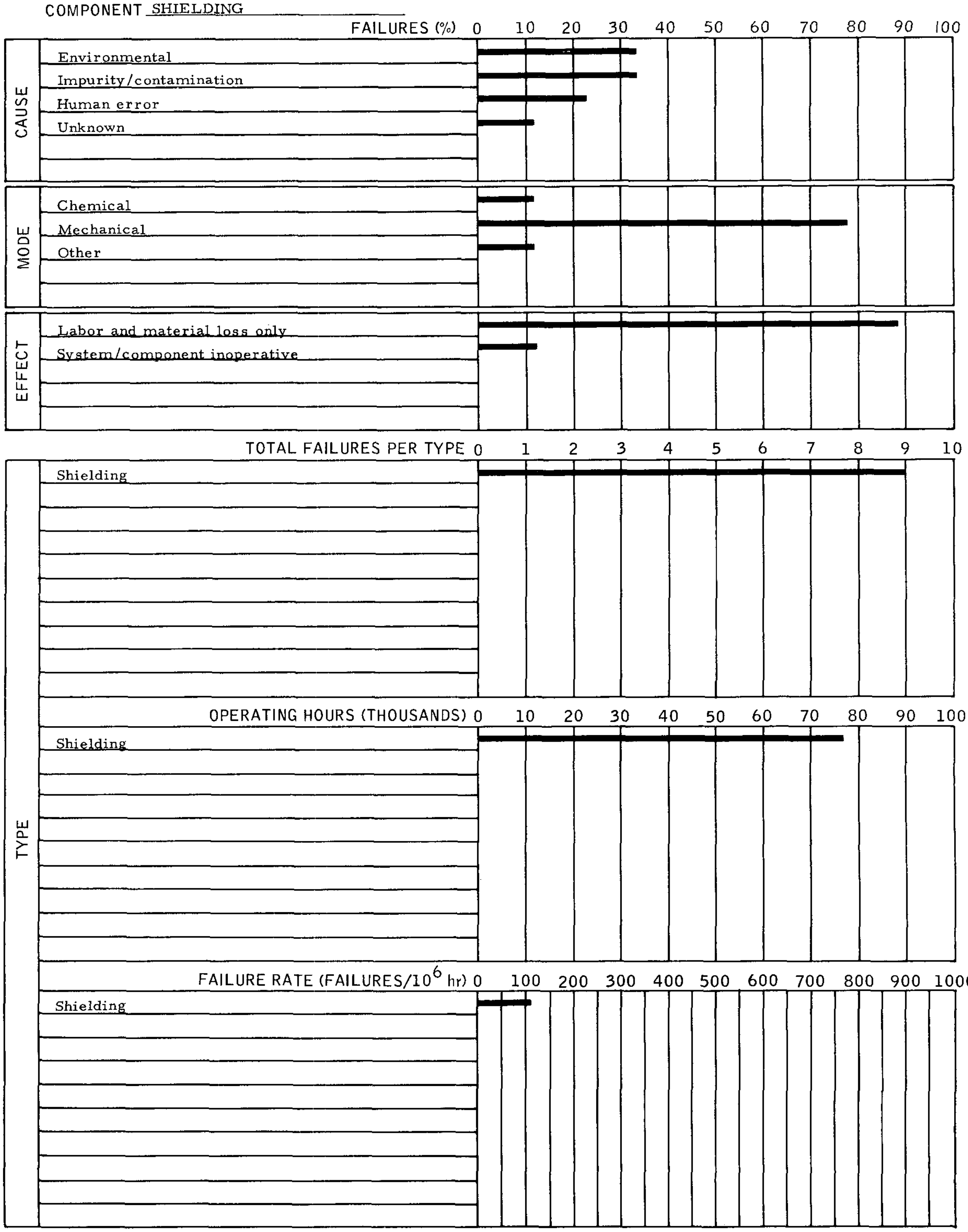


TABLE 1-15

GENERAL SUMMARY

COMPONENT SHIELDING



4. Vessel Internals (removable)

Failure data for vessel internals (removable) are presented in Tables 1-16 through 1-18.

a. Reliability Information

Design Features:

Control rod thimble.

Critical Characteristics:

Thin-wall tube encloses and guides the control rod absorber element in the reactor core. The thimble extends from the shield plug into the core and seals the reactor sodium out of the control rod internals and seals the shield plug holes.

Mode of Failure:

1) Installation procedure error
2) Embrittlement of metal.

Failure Description:

1) The holddown snap ring for the thimble had not been installed and the thimble came out of the shield plug hole.
2) The thin wall in the lower part of the thimble became brittle and cracked permitting leakage.
3) Personnel attempted to place a thimble in a maintenance cell which was already occupied.
4) A thimble was wedged against a control rod subassembly which caused the control rod to be damaged when it was removed.

Control Methods:

1) Installation and maintenance procedures must be adequate and must be used.
2) Care must be given to the selection of materials when parts are designed.

b. Discussions and Recommendations

Seven events were reviewed regarding failures of control rod thimbles. Three of the failures were due to operating or handling errors. The only solution to this problem is adequate and carefully followed operational and maintenance procedures using checklists for backup.

Four of the failures were a result of one prime failure. This was a design problem due to improper selection of materials. The solution is a complete knowledge of design requirements based on operating conditions.

Incipient failures in two cases studied would be impossible to detect because they were operator errors. The very nature of the thimble and its purpose makes it difficult to predict failures.

TABLE 1-16

FAILURE DATA FOR VESSEL INTERNALS, REMOVABLE

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. C-68 3. - 4. NAA-SR-10743 (6-1-63)	MA 121	MA 61	MA 550	Unknown	Operational monitors	1. Thimble leaking. 2. Replace thimble. 3. None.
2	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble channel XIII 3. Primary hot leg - 945°F Primary cold leg - 610°F 4. Monthly operating report No. 3	MI 330	MI 53	MI 530	1605	Direct observation	1. Hydraulic force of sodium sufficient to float thimble out of core position (approx. 10 in.); holddown ring inadvertently removed. 2. Spare installed. 3. None.
3	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble TZ-3 3. 350 to 925°F 4. Monthly operating report No. 13	I 442	I 84	I 520	4450	Direct observation	1. 1/2-in.-diameter piece fell out of thimble wall. 2. Part replaced. 3. None.
4	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble TZ-6 3. 350 to 925°F 4. Monthly operating report No. 13	I 442	I 84	I 520	4450	Direct observation	1. Thimble had become brittle and shattered during examination. 2. Part replaced. 3. None.
5	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble No. 12 3. 350 to 925°F 4. Monthly operating report No. 11	I 442	I 84	I 520	3710	Direct observation	1. Crack in thimble resulted in leakage. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-16

FAILURE DATA FOR VESSEL INTERNALS, REMOVABLE

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
6	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble No. 13 3. 350 to 925°F 4. Monthly operating report No. 11	I 442	I 84	I 520	3710	Direct observation	1. Thimble cracked and resulted in leakage. 2. Part replaced. 3. None.
7	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. HNPF 2. Control rod thimble TZ-13 3. 350 to 925°F 4. Monthly operating report No. 11	MI 330	MI 55	MI 550	3710	Direct observation	1. Attempt made to place thimble in occupied maintenance cell engaging thimble to plug pickup cup. 2. Operational procedure and/or training change. 3. None.
8	1. Vessel Internals/ Thimble 2. Reactor Equipment/ Core Components and Supports 3. 07 216400	1. EBR-II 2. Control rod grid position 5-C-3 3. 300 to 800°F 4. ANL-7419	MA 172	MA 54	MA 520	13,380	Inspection of associated systems	1. Bent flat was wedged against subassembly C-2039 and caused this and control rod L-446 to be scratched when they were removed. 2. Component replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-17

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VESSEL INTERNALS

COMPONENT SUBTYPE VESSEL INTERNALS

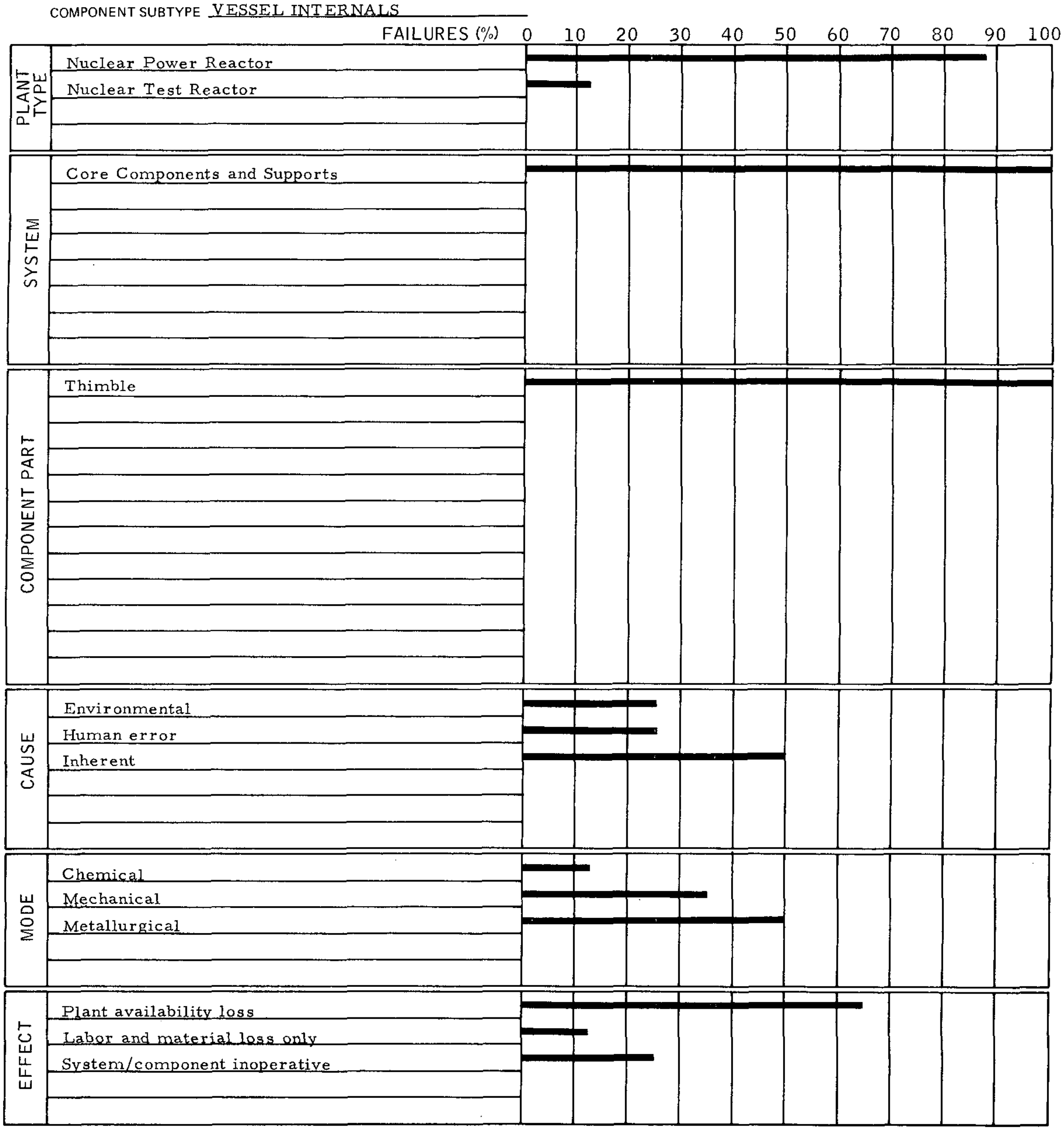
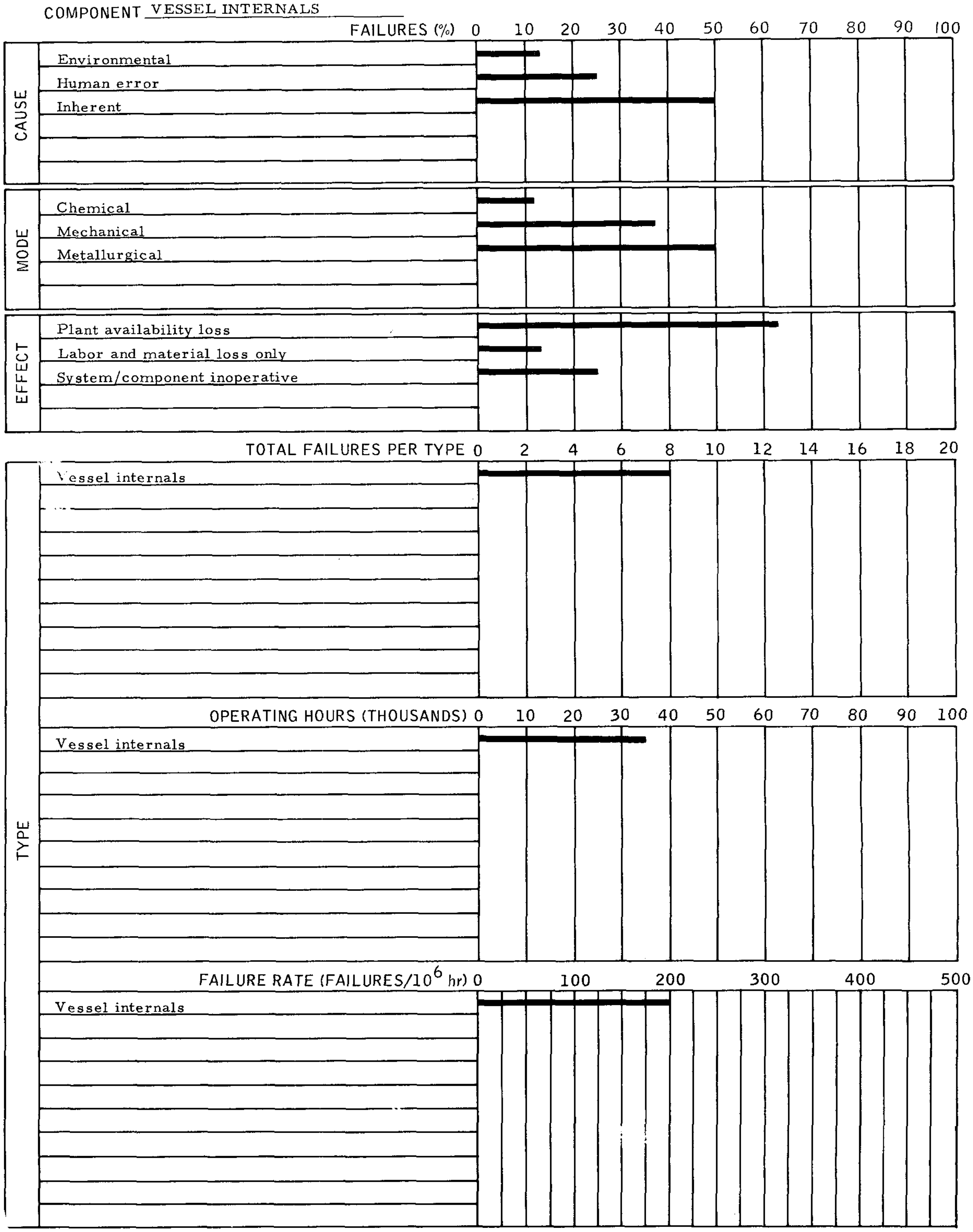


TABLE 1-18

GENERAL SUMMARY

COMPONENT VESSEL INTERNALS



5. Vessels and Tanks

Failure data for vessels and tanks are presented in Tables 1-19 through 1-22.

a. Reliability Information

Design Features:

The primary purpose is containment. In addition, reactor vessels have unique alignment requirements. Heating of the sodium vessels is also necessary.

Critical Characteristics:

The vessel is required to last the life of the plant (30 years) under extreme loading conditions of temperature and varying flow rates. Transient conditions resulting from seismic loadings and/or steam generator operating abnormalities also have to be considered.

Mode of Failure:

1) Broken parts
2) Clogging of lines
3) Crack
4) Fire.

Failure Description:

1) Bolts broken due to torquing
2) Lines were clogged
3) Stiffeners broken loose at weld
4) Cracks at pipe connections or worn because of rough edges
5) Gasket failure.

Control Methods:

1) Provide a procedure for torquing of bolts.
2) Stiffeners should be enlarged and flow rates lowered to prevent water hammer.

3) Operational procedures should be revised to minimize the possibility of fire while draining sodium.

b. Discussion and Recommendations

None.

TABLE 1-19

FAILURE DATA FOR VESSELS AND TANKS

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Tank/Brass Studs 2. Steam,Condensate and Feedwater Piping and Equipment/Condensate 3. 06 283000	1. EBR-II 2. Condensor water box 3. No information available 4. PMMR-100	MI 500	MI 59	MI 530	9345	Direct observation	1. Brass studs broken. 2. Part replaced. 3. Revise maintenance procedure to include torque limit for brass bolts.
2	1. Tank/Weld Condensate Storage 2. Steam,Condensate and Feedwater Piping and Equipment/Condensate 3. 06 283000	1. EBR-II 2. Drain pipe connection 3. No information available 4. PMMR-17	MI 500	MI 73	MI 530	1200	Direct observation	1. Crack in tank at drain pipe connection. 2. Local repair. 3. None.
3	1. Vessel/Weir Baffle Plate 2. Steam,Condensate and Feedwater Piping and Equipment/Condensate 3. 06 283000	1. SCTI 2. Steam and feedwater system 3. 200,000 lb rated flow out pressure 25 psia 4. Incident report No. 107	MA 175	MA 59	MA 117	5225	During repair or inspection of system associated to failure component.	1. Two Weir plate stiffener bars broke loose at welds in deaerator. 2. Local repair, new angle iron stiffeners of larger cross section installed; baffle holes and torn areas adjacent were patched and reinforced. 3. Maintain the polish flow rate low enough to prevent water hammer during steam generator preheat circulation.
4	1. Tank/Vacuum Line 2. Heat Transfer/ Purification System 3. 06 224230	1. EBR-II 2. Surge tank sodium primary 3. 300 to 700°F 4. Operations weekly report, 4-3-68	MI 195	MI 51	MI 530	14,000	Operational monitors	1. Vacuum line clogged. 2. Local repair, removed and cleaned. 3. None.
5	1. Tank/Vacuum Line 2. Heat Transfer/ Purification System 3. 06 224230	1. EBR-II 2. Surge tank sodium primary 3. 300°F 4. PMMR-106	MI 195	MI 51	MI 550	10,840	Operational monitors	1. Vacuum line clogged. 2. Local repair, line removed and cleaned. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-19

FAILURE DATA FOR VESSELS AND TANKS

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Tank/Rupture Disk 2. Heat Transfer/Intermediate Coolant 3. 06 222240	1. HNPF 2. Expansion tank No. 2 3. 4. Monthly operating report No. 25	MI 126	MI 59	MI 530	9420	Direct observation	1. Small hole worn through rupture disk by rough edge on inner backup plate. 2. Temporary repair, a second rupture disk in series with the original disk. 3. None.
7	1. Vessel/50 gal Drum 2. Other Reactor Plant Equipment/Maintenance 3. 06 292000	1. HNPF 2. Primary IHX cell No. 1 3. 300 to 500°F while filling and draining 4. Monthly operating report No. 5	I 136	I 34	I 530	2400	Direct observation	1. Sodium fire occurred in 50 gal, open-top drum while draining sodium. 2. Operational procedure change: use only drums with covered ends with two bung holes, one for sodium drain and one for purge line. Also insulate between barrel and rack. 3. None
8	1. Expansion Tank/Sodium 2. Heat Transfer/Intermediate Cooling 3. 06 222000	1. HNPF 2. Tank No. 2, secondary, 304 SS 3. - 4. WR-1902 (9-6-62)	MI 194	MI A7	MI 600	3744	Operational monitor	1. Velocity of sodium high enough to cause cover gas entrainment. 2. Installed bypass line so 90% of sodium flows around tank. 3. None.
9	1. Vessels and Tanks/Plug Gasket 2. Heat Transfer/Intermediate Cooling System 3. 06 222000	1. HNPF 2. Secondary Expansion Tank, 304 SS, 1/2-in. wall 3. - 4. AI monthly, 6-14-63	MI 500	MI BZ	MI 590	10,416	Direct observation	1. Level probe plug gasket failed. 2. Repaired gasket. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-20

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VESSELS AND TANKS

COMPONENT SUBTYPE TANKS - CONDENSATE AND WATER

PLANT TYPE	Nuclear Test Reactor
	Component Test Facility
SYSTEM	Main Steam
	Steam and Feedwater
COMPONENT PART	Weir Baffle Plate
	Brass Studs
	Weld Condensate Storage
CAUSE	Environmental
	Unknown
MODE	Mechanical
	Metallurgical
EFFECT	Labor and material loss only
	System/component inoperative

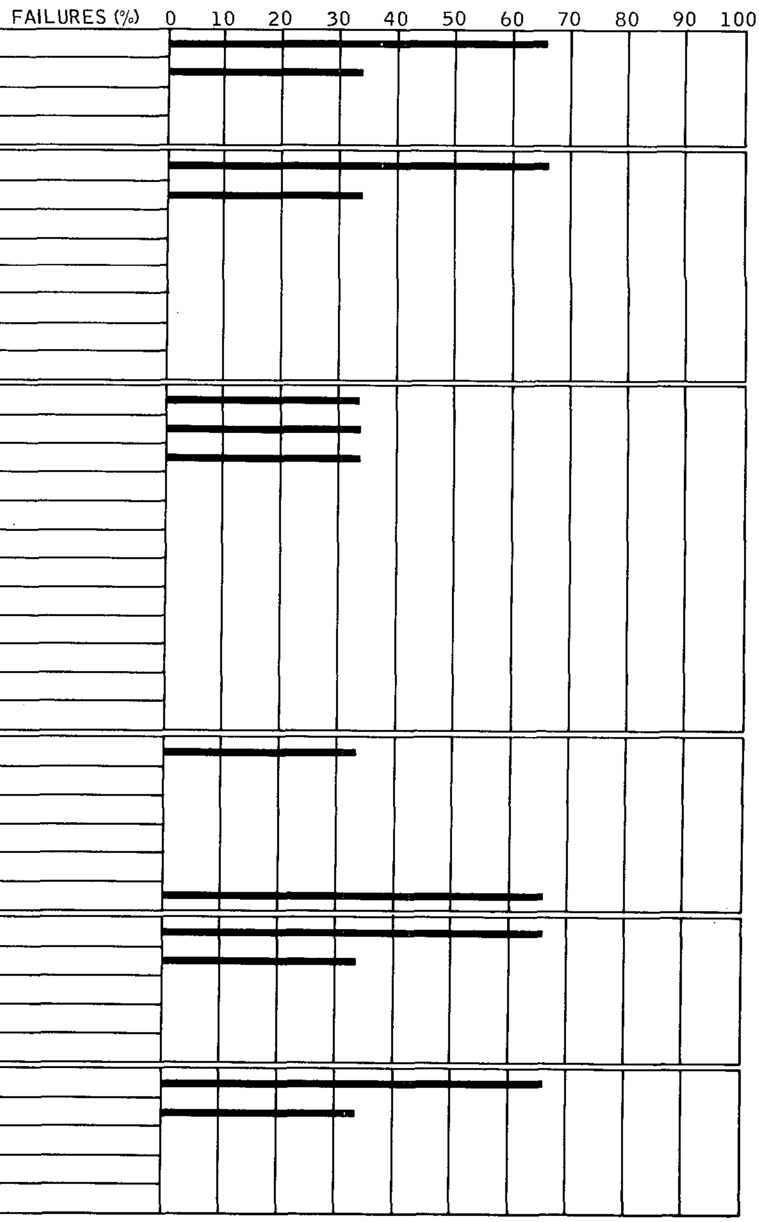


TABLE 1-21

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VESSELS AND TANKS

COMPONENT SUBTYPE TANKS - SODIUM

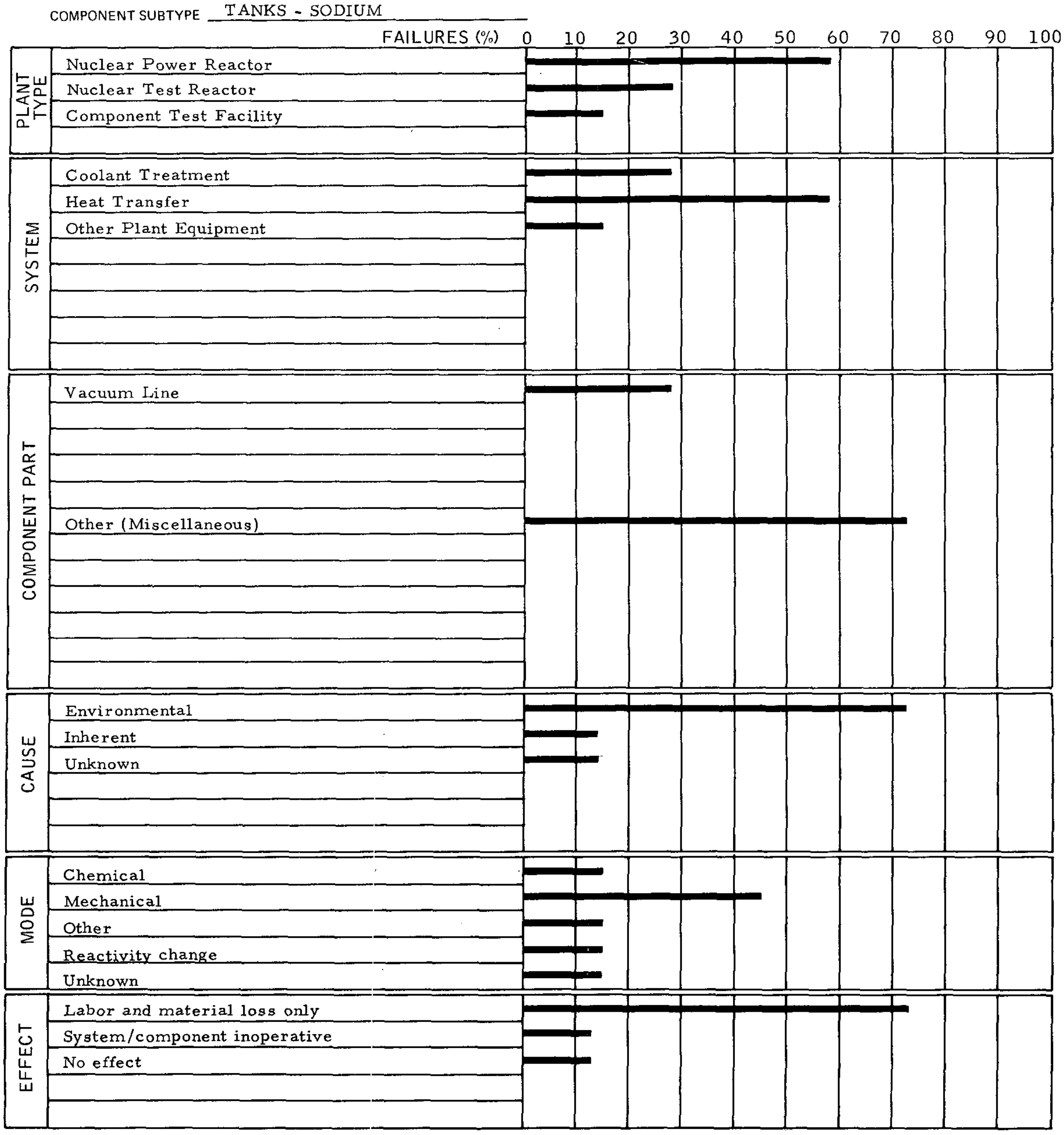
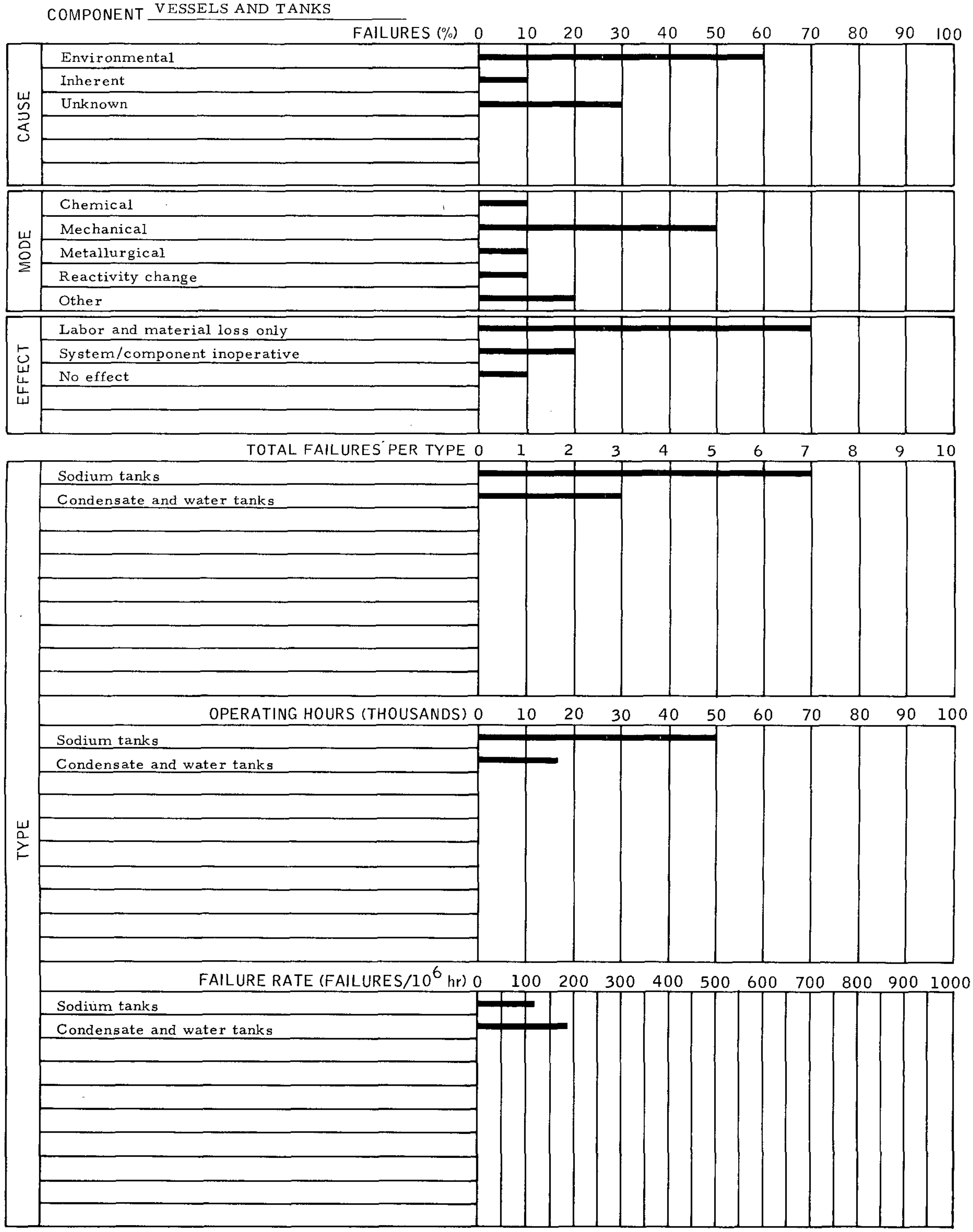


TABLE 1-22

GENERAL SUMMARY

COMPONENT VESSELS AND TANKS



C. ELECTRICAL SYSTEM COMPONENTS

1. Electrical Generators (emergency and auxiliary)

Failure data for electrical generators (emergency and auxiliary) are presented in Tables 1-23 through 1-26.

a. Emergency Diesel Generators

(1) Reliability Information

Design Features:

Diesel-generator sets are designed to provide emergency electric power to critical plant loads on loss of normal power. Undervoltage relays sense a loss of normal power, automatically start the diesel, either with battery power or compressed air, and actuate a transfer switch.

Mode of Failure:

1) Mechanical malfunctions in diesel engine.
2) Fuel supply malfunctions.
3) Control component malfunctions.
4) Generator problems.
5) System oriented malfunctions.

Failure Experience:

Experience throughout industry has shown that any of the above failure modes must be considered as possibilities.

Control Methods:

1) Good quality control in system component procurement.
2) Top quality electrical and mechanical maintenance.
3) An effective program of exercising the diesel generator under load.

Alternate Concepts:

An alternate power supply from an independent source.

(2) Discussion and Recommendations

Standby emergency diesel generators offer a wide variety of malfunction possibilities. Such malfunctions can be either component oriented or system oriented. By their nature their operating hours are limited and erratic. This opens a whole bay of malfunction possibilities which do not exist with continuous duty machines. They go from a cold start to full load in ten seconds or less. The generator is at the mercy of the diesel engine, which must itself be maintained in the best possible manner. Control components must be in perfect condition, because a malfunction in any one of many components can prevent proper operation.

A good preventive maintenance program is a must, including a plan to regularly exercise the diesel-generator under load.

b. Motors-Generator Sets

(1) Reliability Information

Design Features:

Generators driven by electric motor prime mover, operating from normal plant power. Output used as noise-free power supply, variable frequency power supply, or for isolation purposes.

Mode of Failure:

1) Bearing failure

2) Brush wear

3) Control component failure.

Failure Experience:

1) Bearing failure most common. Reasons not available.

2) Abnormal brush wear indicated in a few cases. Reasons not available.

Control Methods:

1) Install high-temperature alarms on bearing housings of large generators.

2) Verify adequacy of bearing lubrication.

3) Don't overload bearings.

4) Close maintenance surveillance.

b. Discussion and Recommendations

It is noted that most of the reported malfunctions relate to bearing and brush problems. This is normal for rotating electrical machines and if detected during routine preventive maintenance, and did not cause an unscheduled outage, perhaps would not even be considered a malfunction.

Bearings should last a minimum of one year under continuous operating conditions, and with proper maintenance can be expected to last two years. Brush life is more uncertain and is dependent on environmental conditions. Brushes can last a year or more.

Other less-common malfunctions are related to winding insulation failure. This is usually caused by generator overheating or insulation deterioration due to age. Overheating can be caused by poor ventilation, overloading, or dirt accumulation in the windings. To illustrate the effect of heat on electrical insulation, the operating life of insulation is reduced by a factor of 1/2 for each 10°C increase in operating temperature. For example, an insulation whose rated life is 20 years at 80°C would have a rated life of 10 years at 90°C, or 5 years at 100°C.

Every machine should be completely dismantled every two years and thoroughly cleaned and inspected. Coils, stators, and rotors can be redipped and baked or spray varnished. All windings should be meggered to detect any incipient insulation weaknesses.

TABLE 1-23

FAILURE DATA FOR ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

(Sheet 1 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Generator/Bearing (inboard) 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary sodium pump 3. 400 hp, 480 volts 4. PMMR-43	MI 500	MI BZ	MI 530	~3070	During preventive maintenance	1. Bearings worn out. 2. Part replaced. 3. Determine cause of bearing failure and institute procedures to prevent recurrence.
2	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 1 3. 400 hp, 480 volts 4. Operations weekly report, 2-14-68	MI 500	MI BZ	MI 530	~13,500	During preventive maintenance	1. Brushes worn out. 2. Part replaced. 3. None.
3	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 1 3. 400 hp, 480 volts 4. PMMR-80	MI 500	MI BZ	MI 530	~6900	During preventive maintenance	1. Dirty commutator. 2. Cleaned and polished commutator and reseated brushes. 3. The most common cause of commutator failure is the wrong type of brushes; therefore, determine that brushes are correct for the service.
4	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 1 3. 400 hp, 480 volts 4. PMMR-80	MI 500	MI BZ	MI 530	~6900	During preventive maintenance	1. Brushes worn out. 2. Part replaced. 3. None.
5	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 2 3. 400 hp, 480 volts 4. Operations weekly report, 2-14-68	MI 500	MI 52	MI 530	~13,500	During preventive maintenance	1. Brushes worn out. 2. Part replaced. 3. None.
6	1. Generator/Excitor 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 2 3. 400 hp, 480 volts 4. Operations monthly report, 7-31-68	MI 500	MI 19	MI 530	~15,240	Routine area watch, direct observation	1. Commutator was worn. 2. Part replaced. 3. Insufficient information to comment. Properly maintained commutator should last ~3 years without machining.
7	1. Generator/Bearing 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary/pump collector ring end 3. 400 hp, 480 volts 4. Operations monthly report, 10-2-68	MI 500	MI 52	MI 530	~15,240	During routine inspection	1. Bearing worn out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-23

FAILURE DATA FOR ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

(Sheet 2 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
8	1. Generator/Excitor 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 2 3. 400 hp, 480 volts 4. Operations monthly report, 10-2-68	MI 500	MI 19	MI 530	15,240	During routine inspection	1. Removed the Pure Carbon brushes from the excitor and replaced with National Carbon brushes. 2. Part replaced. 3. None.
9	1. Generator/Freq. Gen. 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump/M. G. set No. 2 3. - 4. Operations monthly report, 11-67	MI 500	MI BZ	MI 530	12,500	Operational monitors	1. Faulty frequency generator. 2. Part replaced. 3. None.
10	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump 3. 400 hp, 480 volts 4. Maintenance report, 2-14-68	MI 500	MI 52	MI 550	13,500	Protective system	1. Brushes worn out. 2. Part replaced. 3. Follow manufacturer's recommendations in care of brushes and commutators.
11	1. Generator/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump No. 1 3. 400 hp, 480 volts 4. Maintenance report, 2-29-68	MA 500	MA 13	MA 520	13,500	Operational monitors	1. Faulty brushes, worn too short. 2. Part replaced. 3. Up-grade preventive maintenance.
12	1. Generator/Bearings 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Plant constant power supply M. G. set 3. - 4. Operations monthly report, 10-2-68	MA 500	MA 52	MA 520	15,240	During routine inspection	1. Bearings worn out. 2. Parts replaced. 3. Increase preventive maintenance frequency.
13	1. Generator/Coupling Bearings 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Primary pump No. 1 3. 400 hp, 480 volts 4. PMMR-102	MI 500	MI 52	MI 530	10,000	During routine inspection	1. Bearings worn out. 2. Part replaced. 3. Check for proper alignment, proper lubrication and frequency of preventive maintenance on bearings.
14	1. Generator/Bridge Circuit Diode 2. Accessory Electrical Equipment/M. G. Set 3. 57 470000	1. EBR-II 2. Secondary sodium EM pump 3. - 4. Maintenance report, 2-14-68	MI 500	MI 24	MI 530	13,500	Operational monitors	1. Faulty diode. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-23

FAILURE DATA FOR ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

(Sheet 3 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
15	1. Electrical Generators/ Wiring 2. Accessory Elect.Equip. /Emerg. Diesel Gen. 3. 57 462100	1. SCTI 2. Emergency electrical system 3. 300 kw, 1800 rpm, 277/480 volts 4. Incident report No. 333	MA 327	MA 13	MA 580	58	Preventive maintenance	1. Maintenance personnel hit wires while lowering air filter causing short circuit in wiring. 2. Replaced damaged wiring. 3. None.
16	1. Electrical Generators/ Voltage Regulator 2. Accessory Electrical Equipment/Emergency Diesel Generators 3. 57 462100	1. SCTI 2. Emergency electrical system 3. 300 kw diesel, 457 hp, 1800 rpm 4. Incident report No. 319	MI 153	MI 25	MI 550	Unknown	Operational monitors	1. Severe power dip, incoming power, tripped circuits. Voltage regulator did not operate properly. 2. Manufacturer recommended removing damping transformer in circuit. This modification was completed. 3. None.
17	1. Generator/Emergency Diesel 2. Accessory Electrical Equipment/Emergency Diesel Generators 3. 57 462100	1. EBR-II 2. Emergency generator 3. 1200 to 1360 rpm 4. ANL-7017	MA 336	MA 46	MA 550	1200	Operational monitors	1. Diesel started, loaded normally, stopped, and could not be restarted. 2. Operating limits changed. 3. None.
18	1. Generator/Emergency Diesel 2. Accessory Electrical Equipment/Emergency Diesel Generators 3. 57 462100	1. EBR-II 2. Emergency generator 3. 1200 to 1360 rpm 4. ANL-7017	MA 344	MA 24	MA 550	1200	Operational monitors	1. Human error. The diesel control switch had to be switched to the off position, then to standby. This was not known by the operating personnel. 2. Operational procedure change. 3. Upgrade operator training on diesel engine operation.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-24

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

COMPONENT SUBTYPE MOTOR - GENERATOR SETS

PLANT TYPE	Nuclear Test Reactor
SYSTEM	Accessory Electrical Equipment
COMPONENT PART	Bearing
	Brushes
	Excitor
	Others
CAUSE	Unknown
MODE	Electrical
	Mechanical
	Unknown
EFFECT	Plant availability loss
	Labor and materials loss only
	System/component inoperative

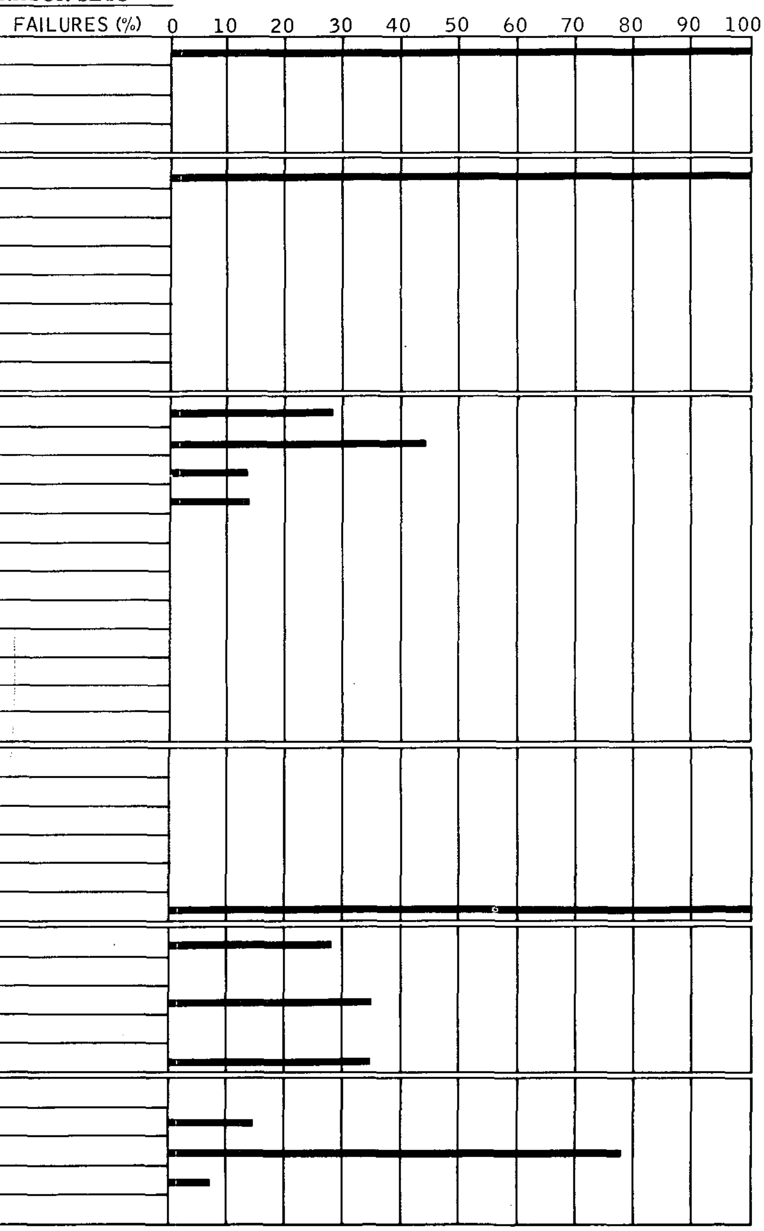


TABLE 1-25

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

COMPONENT SUBTYPE EMERGENCY DIESEL GENERATORS

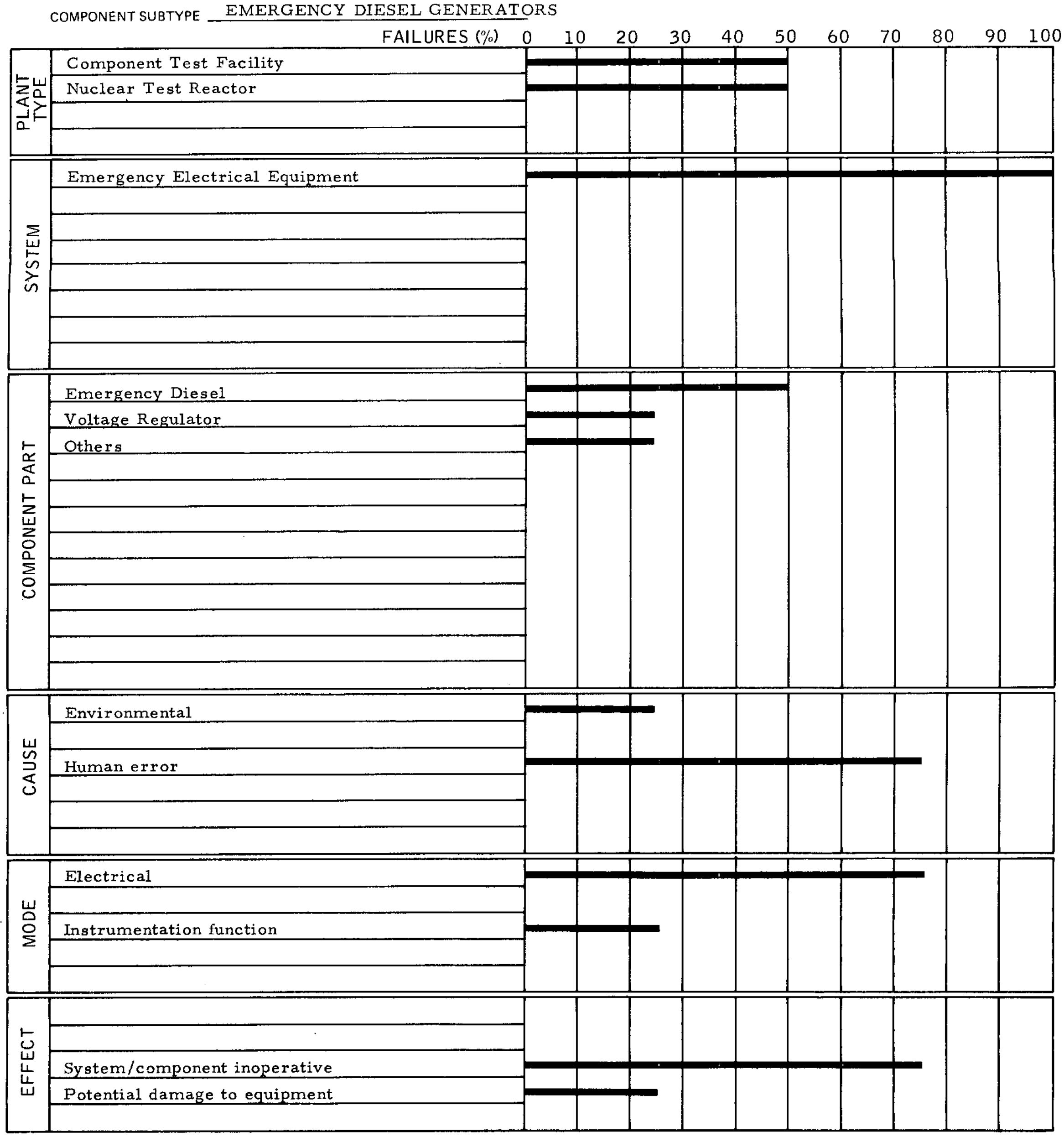
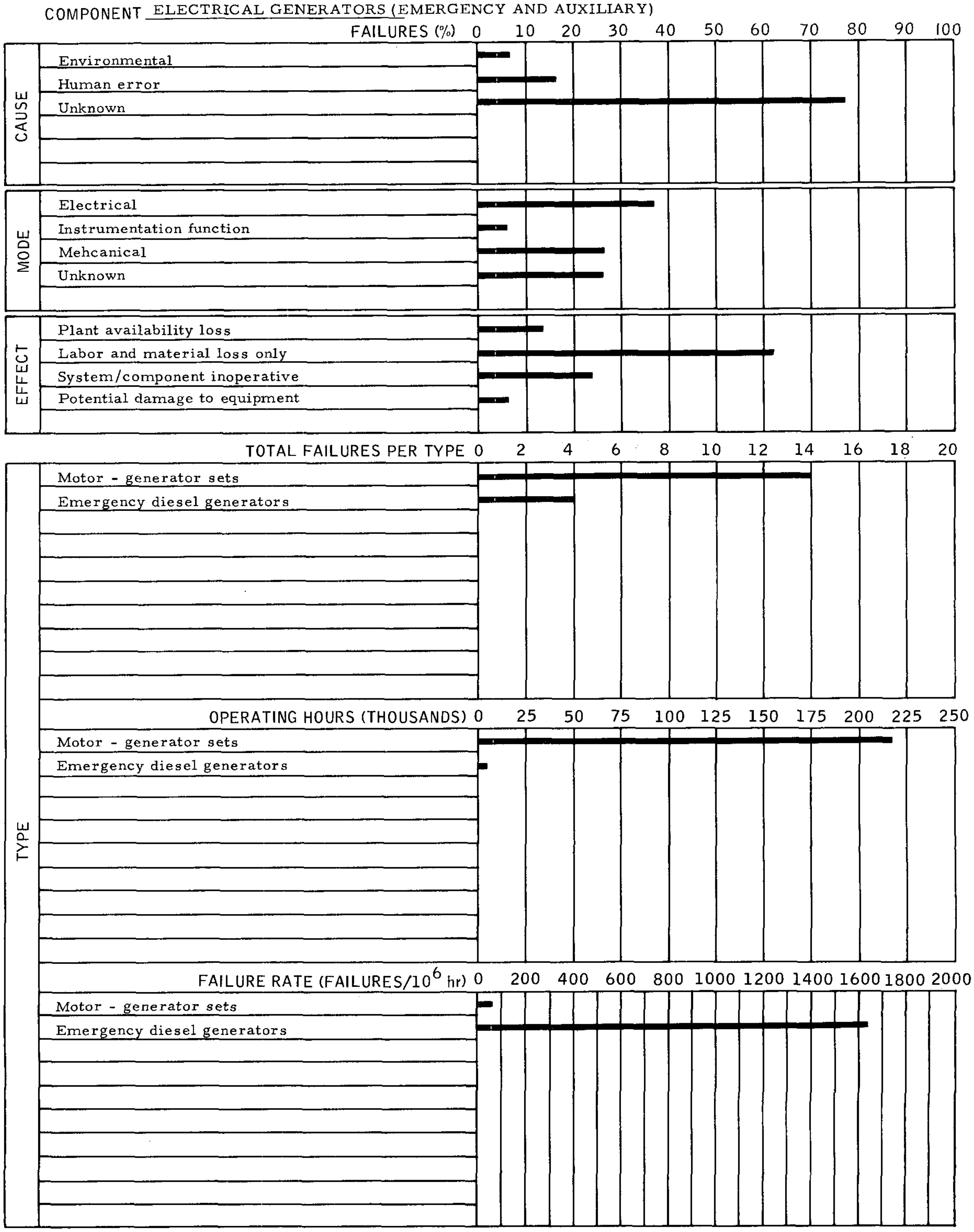


TABLE 1-26

GENERAL SUMMARY

COMPONENT ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)



2. Heaters (electrical)

Failure data for heaters (electrical) are presented in Tables 1-27 through 1-30.

a. Reliability Information

Design Features:

Resistance or induction type, electrically energized heaters used for the heating of liquid metal systems.

Critical Characteristics:

Provide a regulated heating capability for sodium pipes and vessels.

Mode of Failure:

1) Heating elements melted away or burned out.

2) Heater jacket ruptured.

3) Heater circuits opened or grounded.

Failure Description:

1) Poor heat sink caused excessive temperature.

2) Stagnant sodium, or foreign particles caused burnout.

3) Vapor bubbles on the surface of tubular heaters caused burnout.

Control Methods:

1) Provide rigid specifications to ascertain closed loop temperature control.

2) Provide adequate heat sinks.

3) Quality assurance should review all burnout failures to determine possible influence of the heater control circuit.

b. Discussion and Recommendations (See Figures 1-1 through 1-3)

Resistance Heaters:

The resistance heater malfunctions which were tabulated were not sufficiently described to accurately evaluate them individually. Heaters which were burned out did so because of poor heat sinks, conducting heat away from the

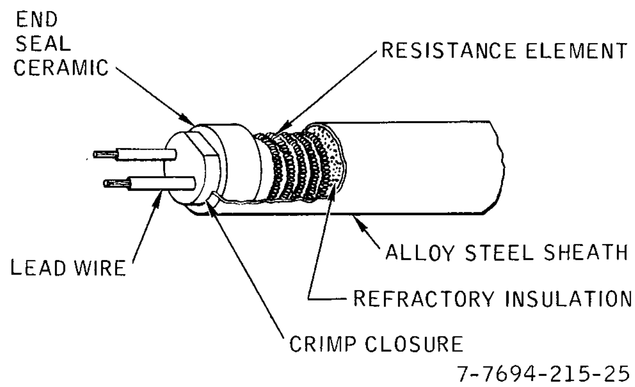


Figure 1-1. Cartridge Heater

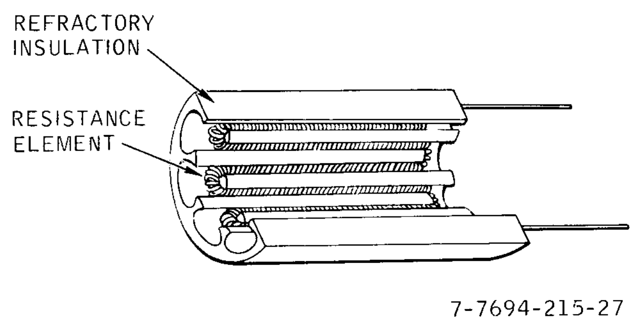


Figure 1-2. Clam Shell Heaters

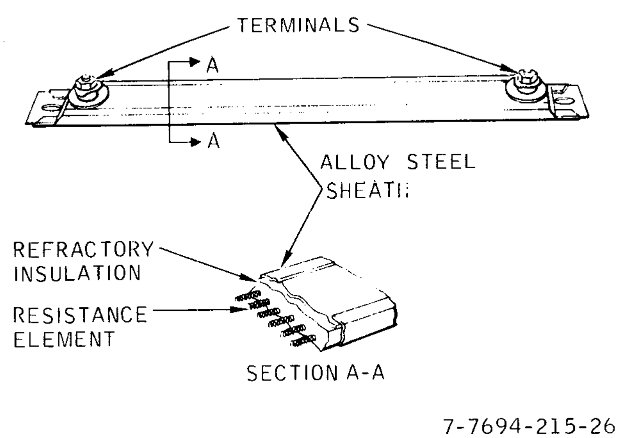


Figure 1-3. Strip Heaters

sheath material of the tubular heaters. In one case, insulating material fell and packed around a furnace-type heater on the outside of a hot trap, causing the heater to burn out.

In several other cases, tubular heaters immersed in sodium burned out for no apparent reason. Previous experiments with immersion heaters, operating at high temperatures in stagnant sodium, has shown that they frequently experience high-temperature excursions and burnout. Heaters with this type of malfunction have been examined and it has been determined that the nichrome elements in the heaters have vaporized, indicating a temperature in excess of 2600°F. It is suspected that sodium vapor bubbles collect on the surface of the tubular heaters, effectively preventing good heat transfer to the liquid sodium, and resulting in the heater burnout. If the sodium is flowing past the heaters, the situation is somewhat relieved since the bubbles are removed from the heater surface.

It is recommended that immersion heaters shall not be used in sodium heating applications in excess of 1000°F unless appropriate precautions are taken. One such precaution would be to place skin thermocouples on representative heater sheaths to control the heater maximum temperature. Another precaution would be to use a flow switch which would deenergize the heaters upon the loss of sodium flow.

Resistance-type heaters are very reliable if properly installed and controlled. The maximum heat density should be controlled to as low a value as is practical. This is usually accomplished by operating the heater at less than rated voltage.

Various types of heater control systems are available, ranging from a sophisticated solid-state proportional control to a simple off-on control. In general, reliability is usually enhanced by the simpler forms of control.

High-quality heaters can be built to very rigid specifications. Commercial-type tubular heaters also are considered to be highly reliable.

<u>Induction Heaters:</u>

Some induction heating malfunctions were also reported. As might be expected, most of the problems were related to grounded wiring, or open circuits. One weakness of induction heating is the large amount of wire which is exposed to mechanical damage, as well as the exposure of the wire insulation to high temperatures. This method of heating is not recommended except in special cases.

TABLE 1-27

FAILURE DATA FOR HEATERS (ELECTRICAL)

(Sheet 1 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Heater/Terminals 2. Heat Transfer/Liquid Metals Purification 3. 38 224237	1. SRE 2. Hot trap main primary sodium system 3. 1300°F, 26 kw 4. Maintenance log, 8/13/63	MI 320	MI 21	MI 530	Unknown	Protective system	1. Open circuit (furnace terminal connection burned). 2. Local repair. 3. Design hot trap vault to permit proper cooling of terminals and the performance of maintenance work space problem.
2	1. Heater/Heating Element 2. Heat Transfer/Liquid Metals Purification 3. 38 224237	1. SRE 2. Hot trap main primary sodium system 3. 1300°F, 26 kw 4. Operating log, 11/8/65	MI 156	MI 12	MI 530	Unknown	Protective system	1. Thermal insulation falling into furnace caused heating element to burn out. 2. Elements replaced. 3. Problem result of inadequate space for hot trap installation. Design hot trap vaults to provide adequate working room.
3	1. Argon Heater/Elements 2. Fuel Handling/Fuel Handling Machines (External) 3. 38 235140	1. Fermi 2. Cask Car 3. Minimum 350°F, Chromalox Type CABB-25 4. EFAPP No. 47	MI 187	MI 17	MI 550	4015	Direct observation	1. Heating elements melted. 2. Part replaced with type TDH-60 (derated to 50 kw). 3. None.
4	1. Heaters/Pot Head 2. Fuel Handling/Fuel Handling Machines (External) 3. 38 235140	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. EFAPP No. 59	MI 478	MI 17	MI 530	6470	Direct observation	1. Melted improperly made pot heads on heater terminals. 2. Part replaced. 3. Improve fabrication procedures.
5	1. Heaters/Heating Elements 2. Fuel Handling/Fuel Handling Machines (External) 3. 38 235140	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. PRDC-EF-14	MI 478	MI 17	MI 530	1460	Direct observation	1. Melted improperly made pot heads on heater terminals. 2. Local repair. 3. Improve fabrication procedures.
6	1. Heater/Element 2. Fuel Handling/Machine Cooling System 3. 38 235140	1. EBR-II 2. Fuel unloading machine 3. 10 kw, 440 v 4. PMMR-93	MI 500	MI 12	MI 530	9300	Operational monitors	1. Heater burned out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-27

FAILURE DATA FOR HEATERS (ELECTRICAL)

(Sheet 2 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Heater/Element 2. Fuel Handling/ Machine Cooling System 3. 38 235140	1. EBR-II 2. Fuel unloading machine 3. 10 kw, 440 v 4. Operation weekly report, 5/68	MI 500	MI 12	MI 530	14,300	Operational monitors	1. Heater burned out. 2. Part replaced. 3. None.
8	1. Heater/Element 2. Fuel Handling/ Machine Cooling System 3. 38 235140	1. EBR-II 2. Fuel unloading machine 3. 10 kw, 440 v 4. Weekly maintenance report, 5/68	MI 500	MI 12	MI 550	14,700	During actuation	1. Heater burned out. 2. Part replaced. 3. None.
9	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Rotating plug heater 3. 218 to 355°F 4. ANL-7071, 6/65	MI 500	MI 12	MI 530	2190	Operational monitors	1. Heater burned out. 2. Part replaced. 3. Install a fuse or circuit breaker in power leads to heater.
10	1. Heater/Jacket 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-2) 3. 27 kw each 4. Weekly maintenance report, 5/21/68	MI 500	MI 59	MI 530	14,400	Operational monitors	1. Heater jacket ruptured. 2. Part replaced. 3. Operate heater at slightly less than rated voltage to prolong life.
11	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-4) 3. 27 kw each 4. Operation weekly report, 5/21/68	MI 500	MI 13	MI 530	14,400	Operational monitors	1. Sodium shorted heater element. 2. Part replaced. 3. None.
12	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-4) 3. 27 kw each 4. Operation weekly report, 2/14/68	MI 500	MI 12	MI 530	13,500	During preventive maintenance	1. Heater burned out. 2. Part replaced. 3. None.
13	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-5) 3. 27 kw each 4. PMMR-69, 3/66	MI 500	MI 12	MI 530	4955	Operational monitors	1. Element burned out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-27

FAILURE DATA FOR HEATERS (ELECTRICAL)

(Sheet 3 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
14	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-5) 3. 27 kw each 4. Operation maintenance report	MI 500	MI 18	MI 530	15,240	During routine inspection	1. Low resistance reading on heating element. 2. Part replaced. 3. None.
15	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Primary sodium tank (W-2) 3. 27 kw each 4. PMMR-69, 3/66	MI 500	MI 12	MI 530	4955	Operational monitors	1. Heater element burned out. 2. Part replaced. 3. Operate heater at slightly less than rated voltage to prolong heater life.
16	1. Heater/Element 2. Reactor Equipment/ Preheating Systems 3. 38 214340	1. EBR-II 2. Secondary sodium tank (west nozzle) 3. 27 kw each 4. PMMR-91, 12/1/66	MI 500	MI 12	MI 530	8780	Operational monitors	1. Heater element burned out. 2. Part replaced. 3. None.
17	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 6, circuit 5, No. 1 IHX 3. - 4. EF-46	MI 16Z	MI 21	MI 530	14,941	During actuation	1. Open circuit. 2. Local repair. 3. None.
18	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 6, circuit 8, No. 1 IHX 3. - 4. EF-46	MI 16Z	MI 21	MI 530	14,941	During actuation	1. Open circuit. 2. Local repair. 3. None.
19	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 6, circuit 9, No. 1 IHX 3. - 4. EF-46	MI 16Z	MI 21	MI 530	14,941	During actuation	1. Open circuit. 2. Local repair. 3. None.
20	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 8, circuit 10, No. 3 30 in. pipe 3. - 4. EF-46	MI 16Z	MI 13	MI 530	14,941	During actuation	1. Grounded circuit. 2. Local repair. 3. None.

* I = INCIDENT   MI = MINOR MALFUNCTION
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TABLE 1-27

FAILURE DATA FOR HEATERS (ELECTRICAL)

(Sheet 4 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
21	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 6, circuit 4, pump No. 1 3. - 4. EF-46	MI 16Z	MI 13	MI 530	14,941	During actuation	1. Grounded circuit. 2. Local repair. 3. None.
22	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Panel 8, circuit 19, pump No. 3 3. - 4. EF-46	MI 16Z	MI 21	MI 530	14,941	During actuation	1. Open circuit. 2. Local repair. 3. None.
23	1. Heaters/Heating Element 2. Heat Transfer/ Purification 3. 38 224237	1. Fermi 2. Primary sodium service 3. - 4. PRDC-EF-53	MI 161	MI 12	MI 530	14,941	Direct observation	1. Circuits burned out. 2. Component corrective modification. 3. Recurring electrical problems should be technically analyzed and recommendations made.
24	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. Secondary/secondary sodium piping 3. - 4. PRDC-EF-43	MI 442	MI 1Z	MI 530	14,941	Direct observation	1. Insulation dried, cracked, and was falling off. 2. Part replaced. 3. Use high temperature insulation where temperature is a problem.
25	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. No. 2 and 3 circuit, 12-17 3. - 4. PRDC-EF-34	MI 15Z	MI 13	MI 530	14,763	Operational monitors	1. Heater circuit grounded. 2. Component corrective modification. 3. None.
26	1. Heaters/Wiring 2. Reactor Equipment/ Preheating 3. 38 214340	1. Fermi 2. No. 2 and 3 circuit, 12-18 3. - 4. PRDC-EF-34	MI 15Z	MI 13	MI 530	14,763	Operational monitors	1. Heater circuit grounded. 2. Component corrective modification. 3. None.

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TABLE 1-28

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT HEATERS (ELECTRICAL)

COMPONENT SUBTYPE INDUCTION HEATERS

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactor
SYSTEM	Reactor Auxiliary Cooling and Heating
	Coolant Receiving, Makeup and Treatment
COMPONENT PART	Wiring
	Heating Element
CAUSE	Environmental
	Inherent
MODE	Electrical
EFFECT	Labor and materials loss only

TABLE 1-29

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT HEATERS (ELECTRICAL)

COMPONENT SUBTYPE RESISTANCE HEATERS

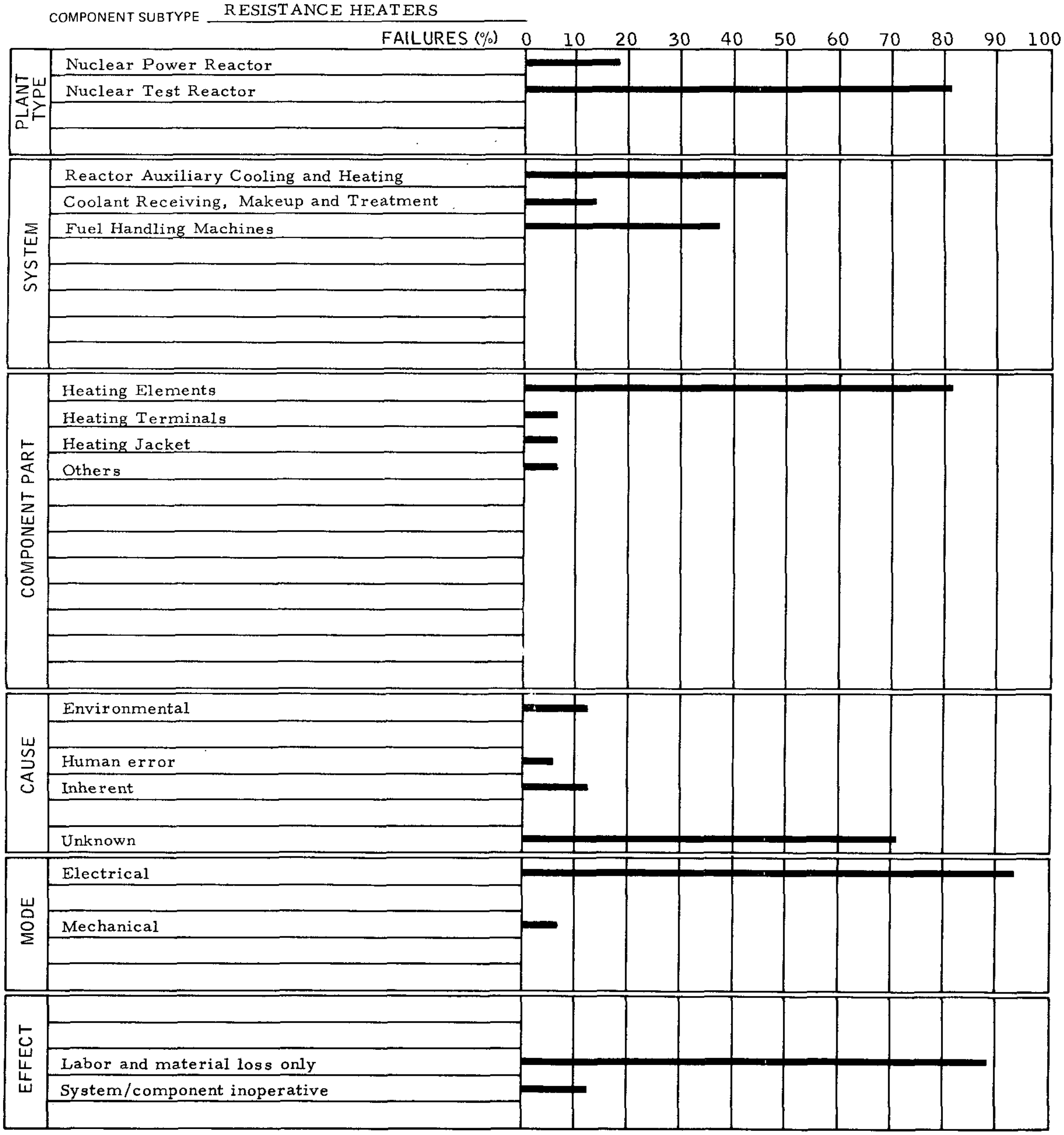
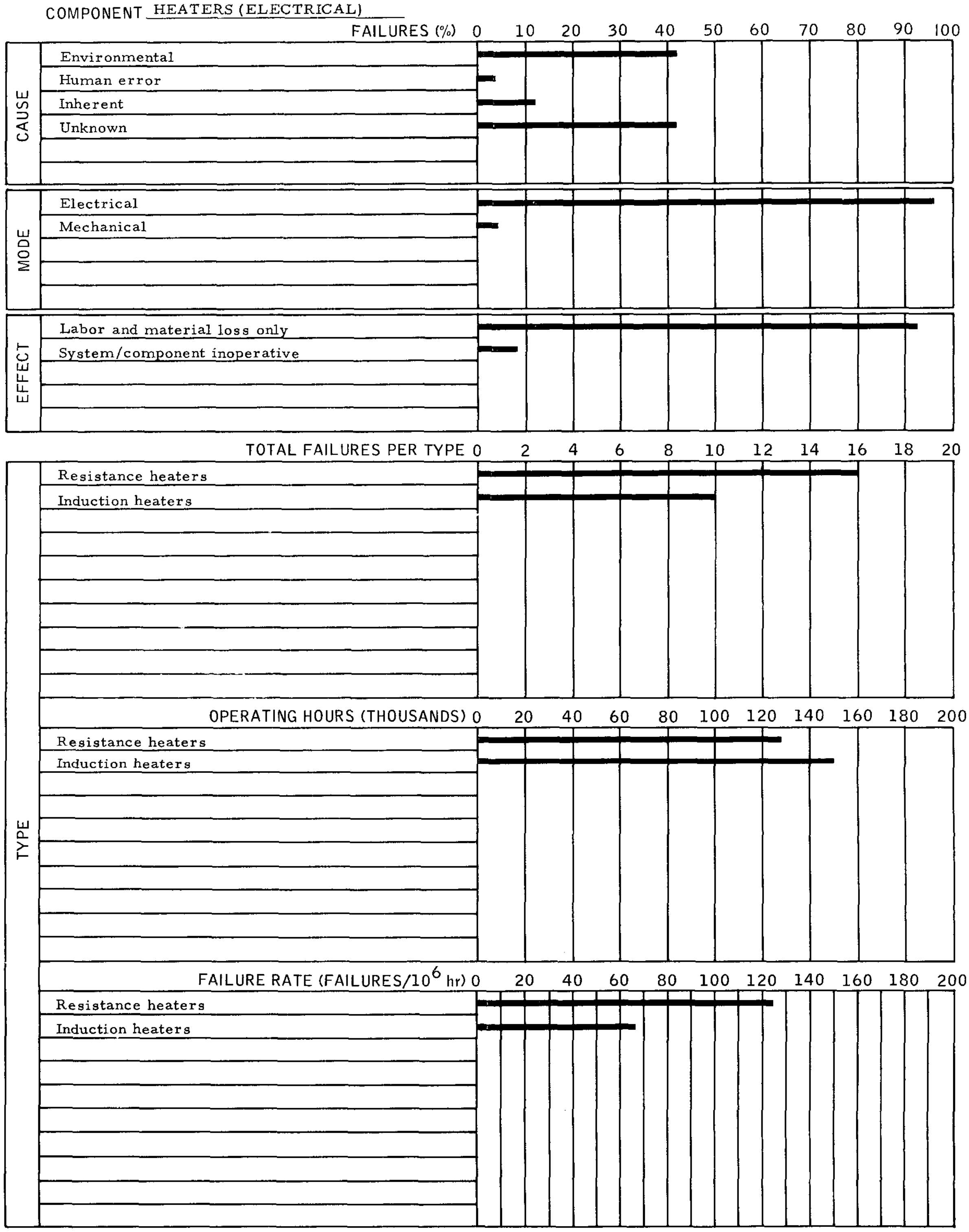


TABLE 1-30

GENERAL SUMMARY

COMPONENT HEATERS (ELECTRICAL)



3. Motors (electric)

Failure data for motors (electric) are presented in Tables 1-31 through 1-34.

a. Motors (200 hp and larger)

(1) Reliability Information

Design Features:

Electric motors, squirrel cage induction and synchronous types, 200 hp and larger, operating at 480 and 4160 volts, used as pump and fan prime movers. Motors are designed for both indoor and outdoor installation.

Critical Characteristics:

The maintenance with regard to lubrication, alignment, moisture and dirt protection is important.

Mode of Failure:

1) Bearing failure

2) Insulation failure

3) Brush failure.

Failure Experience:

1) Seven malfunctions due to bearing failure

2) One outage due to dirty brushes

3) Four malfunctions caused by insulation failure.

Control Methods:

1) The high bearing failure rate indicates that the machine maintenance in the facilities reporting is not as thorough as it should be. In most cases, failure was caused by improper lubrication. Misalignment or improper loading probably accounts for certain bearing failures. Proper installation and maintenance are necessary for satisfactory service.

2) Outdoor motors should have enclosures which will protect the motor windings from moisture.

3) Motors which see intermittent service should be provided with heaters which will keep the windings dry.

4) Motors with standard insulation should not be operated in an argon atmosphere, due to the low breakdown voltage characteristics of argon. If an inert atmosphere must be provided, nitrogen would be a better choice.

5) Open motors should be operated only in a clean environment.

(2) Discussion and Recommendations

A look at the failure experience records of the plants represented in this report shows that the predominant type of malfunction is bearing failure, with insulation failure running a close second. As is the case with all rotating machinery, proper equipment installation and lubrication plays a very important part in long bearing life.

If the experience of the electric utility industry is used as a basis of comparison, it is seen that the electric motor malfunction experience of the facilities reported on is far greater than the utilities standards. Since the installations reported on are either test facilities or prototype nuclear plants, it might be concluded that this difference in electric motor performance is due to less effective preventive maintenance, lower installation standards, or the difference in the mode of operation between these facilities and typical utility power plants. By their nature, test facilities are one-of-a-kind installations and are therefore not always adoptable to established design and construction standards. They are usually operated on an intermittent basis, which imposes unusual demands on electric motors. Continuous duty motors have a longer operating life than intermittent duty motors. A large motor sitting at rest for long periods of time will frequently suffer bearing damage. Motor windings which are not kept warmer than the ambient temperature will absorb moisture, which frequently causes an insulation breakdown. Large intermittent duty motors should be provided with heaters to prevent this situation.

An examination of electric utility maintenance and operating standards would be of value in establishing similar standards for nuclear facilities, particularly large LMFBR plants. Different utilities have a variety of operating philosophies which affect their maintenance procedures. The two electric utilities serving the Los Angeles area, for example, operate with different preventive maintenance philosophies. One utility operates its turbo-generator units from 18 months to 24 months continuously before they have a scheduled shutdown. During this shutdown period, of from two to three weeks, a thorough inspection of the unit and all of its auxiliary electric motors, is made and necessary maintenance is performed. At the next scheduled unit shutdown, all appropriate machines, including many electric motors, are dismantled and completely overhauled.

The other utility has a scheduled unit shutdown only once every five years. They are willing to take the risk of an unscheduled shutdown before the five-year period is over; and if this occurs, their major overhaul may be performed during the emergency shutdown. Operating procedures are a blend of engineering and economics.

Both of the utilities referred to maintain a highly efficient daily maintenance program. This includes visual inspection, complex instrumentation and alarm systems, and redundant standby systems in critical areas. Lubrication techniques are very well organized.

Appropriate methods should be borrowed from the electric utility industry and applied to the nuclear industry. With proper maintenance, facility shutdowns due to bearing failure could be virtually eliminated. These methods will be especially applicable to future LMFBR plants which will have a probable refueling shutdown about once a year.

Insulation failure in most motors can be traced to moisture in the windings or to overheating. Motors exposed to the weather should be either totally enclosed or weather protected. Motors must also be properly ventilated to prevent overheating. In some cases high-temperature insulation in the windings must be specified. Electric motors should never be operated in an argon cover gas environment. Experience has shown that insulation failure is quite common in such situations. This is due to the low breakdown voltage characteristics of argon. The same is true of certain other inert gases.

Probable insulation failure can be predicted by measuring the insulation resistance, with a Megger or other non-destructive methods, at regular intervals. Ten years is a reasonable life expectancy for large motor windings. Whether a motor is rewound or replaced is a matter of economics.

b. Motors (less than 200 hp)

(1) Reliability Information

Design Features:

Electric motors, squirrel cage induction, less than 200 hp, operating at 120 and 480 volts are for all types of applications. Most fractional horsepower motors are rated 120 volts, single phase. Some fractional horsepower and all integral horsepower motors are rated 480 volts, three phase.

Critical Characteristics:

The maintenance with regard to lubrication, alignments, and moisture.

Mode of Failure:

1) Bearing failure

2) Insulation failure

3) Brush failure.

Failure Experience:

1) Eleven malfunctions due to bearing failure

2) Seven malfunctions due to insulation failure

3) One reported brush failure.

Recommendations

1) The high incidence of bearing failures could be greatly reduced by proper maintenance. Most bearing failures were caused by improper lubrication. Other contributing factors to bearing failures are shaft misalignment and improper loading. Proper installation and maintenance of these motors would eliminate most bearing problems.

2) Winding insulation failures were caused in most cases by open type motors being exposed to the weather. In this type of location the motor should be either totally enclosed or weather protected.

3) Brush wear is to be expected, but it can be minimized by proper adjustment.

(2) Discussion and Recommendations

Refer to Paragraph 3.a.(2).

TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)

(Sheet 1 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Motor/Bearing 2. Accessory Electrical Equipment/Station Service Equipment 3. 09 461000	1. EBR-II 2. Auxiliary primary pump-rectifier cooling fan 3. 4. Operations weekly report, 12/20/67	MI 500	MI 52	MI 530	13,380	Operational monitors	1. Bearings worn out. 2. Part replaced. 3. None.
2	1. Motor/Stator Windings 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 09 330000	1. SCTI 2. Circulating cooling water system (P-2) 3. 200 hp, 4160 v, 26 amps 4. Incident report No. 118	MA 236	MA 11	MA 530	8,400	Direct observation	1. Motor shorted out causing circuit breaker trip when attempt made to start motor. 2. Vendor repair of component. 3. Use weather protected electrical motors if exposed to weather.
3	1. Motor/Brushes and Brush Rigging 2. Heat Transfer/Reactor Coolant 3. 09 221131	1. Fermi 2. Primary, pump 3/pony motor 3. 350 hp, 900 rpm 4. EF-28	MI 500	MI 5Z	MI 530	13,930	Audio noise	1. Brushes dirty. 2. Local repair, brushes and rigging cleaned. 3. Revise preventive maintenance inspection intervals to prevent unscheduled outage of equipment.
4	1. Motor/Bearings 2. Heat Transfer/Reactor Coolant 3. 09 221131	1. Fermi 2. Primary, pump 3/pony motor 3. 350 hp, 900 rpm 4. EF-28	MI 500	MI 5Z	MI 530	13,930	Audio noise	1. Bearings showed discolored ring. 2. Local repair, two bearings transposed and reused. 3. None.
5	1. Motor/Dust Cover 2. Heat Transfer/Reactor Coolant 3. 09 221131	1. Fermi 2. Primary, pump 3/pony motor 3. 350 hp, 900 rpm 4. EF-29	MI 136	MI 53	MI 530	14,360	Protective system	1. Argon leak past dust cover. 2. Local repair, installing gasket beneath dust cover and sealing with RTV 732. 3. None.
6	1. Motor/Field 2. Heat Transfer/Reactor Coolant 3. 09 221121	1. Fermi 2. Primary, pump 1/motor 3. 1000 hp, 900 rpm 4. PRDC-EF-16	MI 151	MI 13	MI 530	9,390	Operational monitors	1. Short circuit in field winding. 2. Vendor repair of component. 3. None.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)
(Sheet 2 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Motor/Bearings 2. Heat Transfer/ Reactor Coolant 3. 09 221121	1. Fermi 2. Primary, pump 1/motor 3. 1000 hp, 900 rpm 4. PRDC-EF-2	MI 472	MI 52	MI 530	2,920	Direct observation	1. Bearing failed due to shaft current. 2. Part replaced. 3. None.
8	1. Motor/Bearings 2. Heat Transfer/ Reactor Coolant 3. 09 221121	1. Fermi 2. Primary, pump 1/motor 3. 1000 hp, 900 rpm 4. PRDC-EF-13	MI 171	MI 5Z	MI 530	4,280	Alarm	1. Bearings worn out. 2. Part replaced. 3. None.
9	1. Motor/O-Rings 2. Heat Transfer/ Intermediate Cooling 3. 09 222121	1. HNPF 2. Secondary sodium pump 3. 350 hp 4. Work request No. 2675	MI 11Z	MI BZ	MI 530	6,541	During inspection of system associated to failure component.	1. O-rings replaced during inspection of upper motor bearing. 2. Component corrective modification. 3. None.
10	1. Motor/Bearing 2. Heat Transfer/ Reactor Coolant 3. 09 221121	1. SCTI 2. Primary sodium pump (P-5) 3. 200 hp, 480 v 4. Incident report No. 334	MA 500	MA 52	MA 125	12,185	Direct observation	1. Bearing noisy, motor radial bearing race broken. 2. Replaced. 3. Use of factory sealed bearings recommended.
11	1. Motor/Bearing 2. Heat Transfer/ Intermediate Coolant 3. 09 222121	1. SCTI 2. Secondary sodium system pump (P-6) 3. 350 hp, 4160 v, 3 phase 4. Incident report No. 86	I 114	I 58	I 45	555	Direct observation	1. Motor reported to have sealed bearings; therefore, bearing was not lubricated. 2. Replaced bad bearing with factory sealed type. 3. Improve Quality Assurance inspection procedures.
12	1. Motor/Shading Coil 2. Heat Transfer/ Intermediate Coolant 3. 09 222121	1. SCTI 2. Secondary sodium system pump (P-6) 3. 350 hp, 4160 v, 3 phase 4. Incident report No. 84	MI 127	MI 29	MI 520	450	Protective system	1. Shading coils of motor starter loose, caused contact chattering. 2. Remove coils, repair, reinstall. 3. Revise frequency of preventive maintenance inspections to prevent unscheduled outage.
13	1. Motor/Winding 2. Heat Transfer/ Intermediate Coolant 3. 09 222121	1. SCTI 2. Secondary sodium system pump (P-6) 3. 350 hp, 4160 v 4. Incident report No. 32	MI 167	MI 15	MI 550	115	Protective system	1. A phase-to-phase fault between a lead and coil caused the fuse to blow. 2. Component design change. 3. Air cooling should replace argon cooling.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)

(Sheet 3 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
14	1. Motor/Windings 2. Heat Transfer/ Intermediate Coolant 3. 09 222121	1. SCTI 2. Secondary sodium system pump 3. 350 hp, 4160 v 4. Incident report No. 2	MA 157	MA 13	MA 530	Unknown	During actuation	1. Motor winding insulation failed due to improper operating environment. 2. Vendor repair of component. 3. Air cooling should replace argon cooling.
15	1. Motor/Wiring 2. Reactor Equipment/ Reactor Shielding 3. 09 213000	1. EBR-II 2. Reactor cover holddown 3. 4. PMMR-80	MI 500	MI 52	MI 530	6,780	Preventive maintenance	1. Motor inoperative. 2. Local repair, motor rewired. 3. Revise preventive maintenance procedure to include inspection for oil leak.
16	1. Motor/Bearing 2. Other Reactor Plant Equipment/Blower 3. 09 290000	1. EBR-II 2. Secondary sodium expansion tank (level probe cooling) 3. Alternating current 4. Maintenance report, 5/21/68	MA 500	MA 52	MA 520	14,576	Audible noise	1. Bearings failed. 2. Temporary cooling applied until tests completed. 3. Power supply should be relocated to an area of lower ambient temperature.
17	1. Motor/Bearing 2. Reactor Equipment/ Preheating Systems 3. 09 214330	1. SCTI 2. Preheat furnace (H-2)/induced draft fan 3. 1.5 hp, 950 rpm 4. Incident report No. 111	MI 187	MI 57	MI 530	5,500	Direct observation	1. Motor bearings overheated and seized. 2. Part replaced. 3. Recommend use of high-temperature, factory-sealed bearings.
18	1. Motor/Starting Relay 2. Reactor Equipment/ Preheating Systems 3. 09 4. 214340	1. SCTI 2. Primary sodium air preheat furnace fan motor 3. 1/3 hp, 1725 rpm, 115 v 4. Incident report No. 312	MI 417	MI 57	MI 530	4,518	Direct observation	1. Single phase starting relay burned out. Probable cause bad bearings or sticking start to run relay. 2. Component part replaced, start and stop procedure modified. Protective hood installed over unit. 3. None.
19	1. Motor/Bearing 2. Feedwater Supply and Treatment/Makeup Water Treatment 3. 09 272300	1. SCTI 2. Treated water system pump 3. 75 gpm, 231 ft/head, 100°F 4. Incident report No. 44	MI 414	MI 17	MI 530	707	Direct observation	1. Motor bearing race guide broke because bearing overheated, short gage glass did not afford indication of low oil level. 2. Part replaced. 3. Design should specify adequate sight level indication; lubrication procedures should be reviewed.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)

(Sheet 4 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
20	1. Motor/Winding Insulation 2. Steam Condensate and Feedwater Piping and Equipment/Condensate 3. 09 283000	1. SCTI 2. Steam and feedwater system 3. 40 hp, 3550 rpm, 440 v 4. Incident report No. 99	I 236	I 13	I 530	3,544	During actuation	1. Motor shorted to ground winding, insulation failed. 2. Vendor repair, motor rewound and reinstalled. 3. Design should provide for totally enclosed motor (instead of drip proof) if exposed to weather.
21	1. Motor/Bearing 2. Accessory Electrical Equipment/M. G. Set 3. 09 470000	1. EBR-II 2. Secondary sodium system/M. G. set 3. Alternating current 4. PMMR-92-12-15-66	MI 125	MI 52	MI 530	9,045	Direct observation	1. Outboard thrust bearing badly worn. 2. Part replaced. 3. Require more stringent preventive maintenance inspections.
22	1. Blower Motor/ Windings 2. Heat Transfer/ Cold Traps, Hot Traps, Filters, Strainers 3. 09 224233	1. SRE 2. Primary cold trap blower 3. 4. Incident report, 11/27/61	MI 237	MI 13	MI 530	Unknown	During actuation	1. Water shorted out windings. 2. Repaired locally. 3. Purchase equipment for the environment.
23	1. Motors (Electrical)/ Wiring 2. Feedwater Supply and Treatment/Pumps and Drives 3. 09 271200	1. SCTI 2. Steam and feedwater 3. 7.5 hp 4. SCTI, incident report No. 52	MI 32Z	MI 13	MI 550	1,452	During preventive maintenance	1. Industrial maintenance man short-circuited treated water motor wires. 2. Circuit breaker reset, motor restarted. 3. Improve design layout and maintenance procedures.
24	1. Motor/Bearing 2. Fuel Handling/Cooling System 3. 09 235140	1. Fermi 2. Argon blower cask car 3. Minimum 350°F, 100 rpm 4. EFAPP-MR-47	MI 187	MI 50	MI 550	6,470	Direct observation	1. Bearings over heating. 2. Part replaced, two auxiliary fans installed to cool the new bearings (180 cfm of air). 3. Bearings operating under adverse thermal conditions should be considered during design.
25	1. Motor/Bearing 2. Fuel Handling/Cooling System 3. 09 235140	1. Fermi 2. Cask car No. 1 argon blower 3. Minimum 350°F, argon, 1000 rpm 4. EFAPP-MR-98	MI 111	MI 52	MI 530	11,740	Audio noise	1. Bearings worn out. 2. Part replaced. 3. None.

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TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)

(Sheet 5 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
26	1. Motor/Bearing Retainer 2. Fuel Handling/Cooling System 3. 09 235140	1. Fermi 2. Cask car No. 1 argon blower 3. Minimum 350°F, argon, 1000 rpm 4. EFAPP-MR-98	MI 127	MI 59	MI 530	11,740	Audio noise	1. Bearing retainer broken. 2. Part replaced. 3. Increase frequency of preventive maintenance inspections to detect developing problems before total failure.
27	1. Motor/Brushes 2. Accessory Electrical Equipment/M. G. Set 3. 09 470000	1. EBR-II 2. Secondary sodium system/M. G. set 3. 4. PMMR-80-6-19-66	MI 125	MI 19	MI 530	6,920	Preventive maintenance	1. Brushes worn. 2. Part replaced. 3. None.
28	1. Motor/Windings 2. Fuel Handling/Cooling System 3. 09 235140	1. EBR-II 2. Fuel unloading machine 3. 10 hp, alternating current blower 4. Operations monthly report 11/67	MI 126	MI 12	MI 530	12,500	Operational monitors	1. Motor burned out. 2. Motor replaced. 3. None.
29	1. Motor/Unknown 2. Reactor Equipment/Reactor Shielding 3. 09 213000	1. EBR-II 2. Reactor cover lock No. 3 3. Alternating current 4. Operation weekly report 2/14/68	MI 137	MI 12	MI 530	13,500	Operational monitors	1. Motor burned out. 2. Part replaced. 3. None.
30	1. Motor/Bearing 2. Turbine-Generator Units and Condenser/Central Lubricating System 3. 09 350000	1. EBR-II 2. Main turbine lubrication 3. 4. PMMR-18	MI 500	MI 52	MI 530	1,200	Audio noise	1. Noisy oil pump. 2. Part replaced. 3. Revise frequency of preventive maintenance inspections to detect problem before failure occurs.
31	1. Motor/Bearing 2. Turbine-Generator Units and Condenser Lubricating System 3. 09 350000	1. EBR-II 2. Main turbine/oil purification 3. 4. PMMR-89	MI 500	MI 52	MI 530	7,944	Preventive maintenance	1. Bad bearing. 2. Part replaced. 3. Revise frequency of preventive maintenance.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-31

FAILURE DATA FOR MOTORS (ELECTRIC)

(Sheet 6 of 6)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
32	1. Motor/Bearings 2. Other Reactor Plant Equipment/Auxiliary Cooling 3. 09 290000	1. EBR-II 2. Primary sodium system blower 3. 4. Operations weekly report, 12/20/67	MI 500	MI 52	MI 530	13,380	During preventive maintenance	1. Bearing bad. 2. A new blower motor was installed to replace existing motor which needs new bearings. 3. None.
33	1. Motor/Windings 2. Heat Transfer/Intermediate Cooling 3. 09 222121	1. SRE 2. Main secondary sodium pump 3. 4. Incident report, 9/16/65	MA 237	MA 13	MA 530		Alarm	1. Short circuit in windings due to water after a rain storm. 2. Removed and sent to vendor for repair. 3. Should be weather protected, or totally enclosed.
34	1. Motor/Windings 2. Heat Transfer/Intermediate Cooling 3. 09 222121	1. SRE 2. Main secondary sodium pump 3. 4. Operations log, 12/2/66	MA 237	MA 13	MA 530		Alarm	1. Short circuit in windings due to water after a rain storm. 2. Removed and sent to vendor for repair. 3. Motor should be weather protected or totally enclosed.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-32

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT MOTORS (ELECTRIC)

COMPONENT SUBTYPE MOTORS, ELECTRIC (LARGER THAN 200 HP)

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactor	
	Nuclear Test Reactor	
	Component Test Facility	
SYSTEM	Heat Transfer	
	Accessory Electrical Equipment	
	Generator Units and Condensor	
COMPONENT PART	Bearings	
	Windings	
	Other	
CAUSE	Environmental	
	Impurity/contamination	
	Inherent	
	Unknown	
MODE	Electrical	
	Mechanical	
	Other	
EFFECT	Plant availability loss	
	Labor and material loss only	
	System/component inoperative	

TABLE 1-33

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT MOTORS (ELECTRIC)

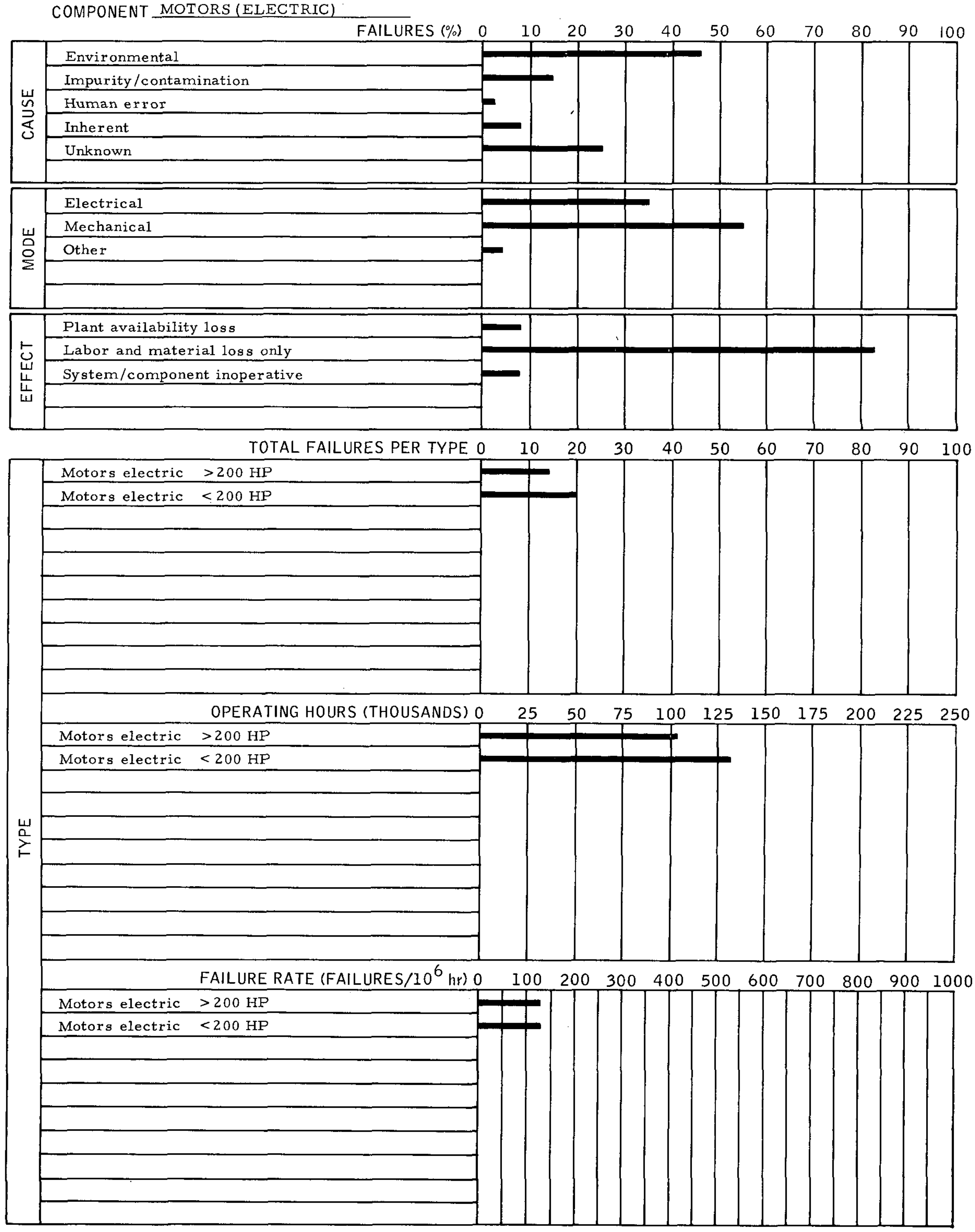
COMPONENT SUBTYPE MOTORS, ELECTRIC (LESS THAN 200 HP)

	FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Power Reactor
	Nuclear Test Reactor
	Component Test Facility
SYSTEM	Heat Transfer
	Fuel Handling
	Reactor Vessel
	Accessory Electric Equipment
	Turbine Generator
	Other Plant Equipment
	Other
COMPONENT PART	Bearing
	Winding
	Brushes
	Relays
	Unknown
CAUSE	Environmental
	Impurity/contamination
	Inherent
	Unknown
MODE	Electrical
	Mechanical
	Other
EFFECT	Plant availability loss
	Labor and material loss only
	System/component inoperative

TABLE 1-34

GENERAL SUMMARY

COMPONENT MOTORS (ELECTRIC)



4. Power Switch Gear, Circuit Breakers, Relays, Transformers

Failure data for Power Switch Gear, Circuit Breakers, Relays, Transformers are presented in Tables 1-35 through 1-40.

a. Circuit Breakers

(1) Reliability Information

Design Features:

Circuit breakers are used to interrupt electrical circuit because of malfunctions.

Critical Characteristics:

Circuit breakers may experience both electrical and mechanical malfunctions. The contacts must be kept clean and their interruption capacity must be adequate.

Mode of Failure:

1) Short circuits

2) Overheated

3) Open circuits

4) Erratic behavior

5) Broken.

Failure Description:

1) Wires were short circuited during construction.

2) A circuit breaker overheated.

3) Circuit breakers tripped.

4) Switch broke.

Control Methods

1) Improved supervision when construction work is being done

2) Improved cooling

3) Improved maintenance

4) More attention to vendor specifications.

(2) Discussion and Recommendations

The data contained in the tabulated malfunction report is so fragmentary and incomplete that it is impossible to arrive at any definite conclusions, or for that matter, to properly evaluate the malfunctions that have been tabulated. For this reason the following comments relate to known problem areas in the various equipment categories.

Circuit breakers fall into two general categories, air immersed and oil immersed. The great majority are air circuit breakers. All circuit breakers are subjected to both electrical and mechanical malfunctions and must have both types of maintenance to assure proper operation.

Molded case circuit breakers, are the most widely used type of air circuit breaker, and also the least reliable. When properly applied, they perform satisfactorily; but they should be frequently inspected to minimize malfunctions. Molded case breakers have their own trip elements, some adjustable and some not adjustable, which serve as overload sensing devices. These should be calibrated periodically to prevent false tripping. The mechanical action of all circuit breakers should be frequently checked and contact surfaces kept clean. Main contacts should produce equal pressure on all three phases and arc chutes should be kept clean. It is important that circuit breakers have an adequate interrupting capacity for the available fault current at the particular point of breaker installation. A breaker should not be relocated to a different circuit without first verifying the adequacy of its interrupting capacity.

b. Relays

(1) Reliability Information

Design Features:

Relays are specifically picked to fit their function and environment. They are control devices that are actuated by variations in conditions in an electric circuit.

Critical Characteristics:

This is somewhat dependent on their use. Cleanliness and proper adjustments are important.

Mode of Failure:

1) Burnout

2) Intermittent contact

3) Broken parts.

Failure Description:

1) The relays were electrically burned out.

2) Relays were not pulling in properly or there was chattering.

3) Contactor was broken.

Control Methods

Establish maintenance procedures for length of use.

(2) Discussion and Recommendations

Relays are precision instruments and must be treated as such. They should be tested and calibrated at regular intervals to assure proper operation. The frequency of such testing will vary with the relay type and the operating environment. The testing and calibration should be done by qualified individuals who have access to the proper test equipment. Since relays have many different characteristics, the test procedure must be tailored to the relay. Instantaneous pickup and dropout current values must be checked. Inverse overcurrent relays must have their time-current characteristics verified and calibrated. Certain relays contain timing devices which must be calibrated. Contacts must be cleaned and their movement must at times be adjusted.

In addition to the above, certain relays, such as overcurrent relays, must be externally adjusted to compensate for varying load conditions. Failure to do this may result in erroneous tripping.

c. Switch Gear

(1) Reliability Information

None

(2) Discussion and Recommendations

Most switches require only superficial inspection to make sure that handles, linkage, and the like are in good mechanical condition. Contacts are usually self-cleaning, but may require occasional adjustment.

Magnetic contactors require much the same type of maintenance that a circuit breaker requires. One difference is the holding coil in a contactor which is continuously energized and which may occasionally require replacement. When used as a motor starter, care must be taken to install the proper heaters in the contactor to provide the proper overload protection for the motor.

d. Transformers

(1) Reliability Information

Design Features:

A transformer is designed to convert current variations in one electrical circuit into current and voltage variations in a second circuit.

Critical Characteristics:

Transformers must be adequately cooled.

Mode of Failure:

1) Burned out

2) Short circuited

3) Overheated.

Failure Description:

1) Transformer shorted out.

2) Transformer overheated, smoked.

Control Methods:

Electrical contacts should not be exposed to the weather.

(2) Discussion and Recommendations

Transformers are generally considered to be the most reliable of all the general types of electrical equipment. In spite of this high reliability factor, transformers must be properly maintained in order to obtain optimum service.

Transformers fall into several general categories, among them power distribution, instrument, and control. Each type of transformer has its own unique characteristics and does not require the same type of maintenance. Adequate cooling is a requirement of all transformers, and most are either air or liquid cooled. Transformer windings and cooling fins must be kept clean and free of foreign material to assure proper cooling.

Among the tests which should periodically be performed on most transformers are the following:

1) Winding resistance

2) Insulation resistance

3) Ratio

4) Polarity.

TABLE 1-35

FAILURE DATA FOR POWER SWITCH GEAR CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

(Sheet 1 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Relay/Terminal Board 2. Turbine-Generator Units and Condenser/ Generator Side 3. 58 320000	1. EBR-II 2. Turbine generator exciter 3. 20,000 kw 4. ANL-7457	MA 148	MA 53	MA 520	14,650	Operational monitors	1. Burned out. 2. Part replaced. 3. None.
2	1. Relay/Terminal 2. Turbine-Generator Units and Condenser/ Generator Side 3. 58 4. 320000	1. EBR-II 2. Turbine generator exciter 3. 85 kw, 250 v 4. ANL-7457	MA 148	MA 12	MA 520	14,650	Operational monitors	1. Burned out. 2. Part replaced. 3. None.
3	1. Relay/Terminal 2. Turbine-Generator Units and Condenser/ Generator Side 3. 58 320000	1. EBR-II 2. Generator field 3. 20,000 kw 4. Operations weekly report, 5/8/68	MI 148	MI 12	MI 520	14,400	Operational monitors	1. Mounting board broke down causing terminal to loosen. Malfunction caused turbine to trip off the line. 2. Local repair. 3. None.
4	1. Relay/Over Current Relay 2. Accessory Electrical Equipment/Protective Equipment 3. 58 430000	1. LCTL 2. LCTL/sodium system pump relay 3. 750 rpm, sodium 740°F 4. LCTL log book No. 21-1, 1/3/65	MI 156	MI 14	MI 530	Unknown	Direct observation	1. Relay was not pulling all the way in. 2. Part replaced. 3. None.
5	1. Relay/DC Power Supply 2. Accessory Electrical Equipment/Protective Equipment 3. 58 430000	1. LCTL 2. LCTL/sodium system relay E 3. 110 v, 40 amp, variable speed to 1000 rpm 4. LCTL log book No. A-063347, 3/12/64	MI 500	MI 12	MI 550	Unknown	Direct observation	1. Relay "E" burned out. 2. Part replaced. 3. None.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-35

FAILURE DATA FOR POWER SWITCH GEAR CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

(Sheet 2 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Relay/Coil 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Secondary sodium P-6 sodium pump motor starter 3. 350 hp, 4160 v, 3 phase, class II 4. Incident report No. 32	MI 127	MI 14	MI 530	900	Audio noise	1. Faulty shading coil caused chattering noise. 2. Replaced shading coils. 3. Establish maintenance procedure providing for replacement after specified hours of use.
7	1. Relay/Contacts 2. Accessory Electrical Equipment/Protective Equipment 3. 58 430000	1. SCTI 2. Boiler feed pump motor 3. - 4. Incident report No. 329	MI 117	MI 59	MI 530	6,635	Routine inspection	1. Contactor broken between silver contact and bronze support segments. 2. Replacement of parts. 3. Design requirements and quality control improvement required.
8	1. Transformer/Coils 2. Accessory Electrical Equipment/Transformers 3. 58 411000	1. LCTL 2. LCTL/sodium system 3. Sodium flow from supply to core tank 4. LCTL log book No. B-104323, 8/28/63	MI 151	MI 17	MI 550	Unknown	Direct observation	1. Transformer overheated. 2. Part replaced. 3. None.
9	1. Transformer/Coil 2. Accessory Electrical Equipment/Transformers 3. 58 411000	1. LCTL 2. LCTL/sodium system 3. 110 v, 40 amp, variable speed to 1000 rpm 4. LCTL log book No. B-104322, 8/26/63	MI 500	MI 12	MI 550	Unknown	Direct observation	1. Power transformer burned out. 2. Part replaced. 3. None.
10	1. Transformer/Windings 2. Accessory Electrical Equipment/Transformers 3. 58 411000	1. SCTI 2. Control circuit auxiliary pump P-1 3. 50 w/110 v 4. Incident report No. 74	MI 157	MI 13	MI 530	3610	Auxiliary oil pump for boiler feed pump would not start	1. Transformer shorted. 2. Transformer and associated Mercoid switch replaced. 3. None.
11	1. Transformer/Coil 2. Accessory Electrical Equipment/Transformers 3. 58 411000	1. SCTI 2. Primary system/low flow EM pump 3. 480 v 4. Incident report No. 50	MA 200	MA 11	MA 530	3600	Protective system	1. Control transformer shorted, fuses blown. 2. Local repair, transformer cleaned of dirt and moisture and moved to a better protected area (switch gear room). 3. Electrical contacts should not be directly exposed to weather effects.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-35

FAILURE DATA FOR POWER SWITCH GEAR CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

(Sheet 3 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
12	1. Breaker/Contactor 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. EBR-II 2. Primary tank cover 3. - 4. OWR, 11/21/67	MI 500	MI 55	MI 550	12,425	Operational monitors	1. Breaker inoperative. 2. Local repair. 3. None.
13	1. Breaker/Bakelite switch 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. EBR-II 2. Primary-sodium purification/ silicone pump No. 2 3. - 4. PMMR-109	MI 500	MI 59	MI 530	Unknown	Operational monitors	1. Switch broken. 2. Part replaced. 3. None.
14	1. Circuit Breaker/ Contacts 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. LCTL 2. LCTL/2 by 3 pump 3. - 4. LCTL log book	MI 151	MI 17	MI 530	Unknown	Direct observation	1. Overheated breaker. 2. Local repair. 3. None.
15	1. D-2 Breaker/Trip Mechanism 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Primary sodium/P-5 pump 3. - 4. Incident report, 2/11/66	MI 157	MI 22	MI 520	Unknown	Protective system	1. Trip mechanism inoperative on D-2 breaker. 2. Part replaced. 3. None.
16	1. Breaker D-2/Over-current Relay 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Primary sodium pump (P-5) 3. - 4. Incident report No. 20	MI 500	MI BZ	MI 530	383	Protective system	1. Faulty breaker, open circuit. 2. Defective breaker was replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-35

FAILURE DATA FOR POWER SWITCH GEAR CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

(Sheet 4 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
17	1. Circuit Breaker/ Overload 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 58 330000	1. SCTI 2. Circulating cooling water system pump circuit breaker. 3. - 4. Incident report No. 10	MI 157	MI 22	MI 510	2205	Protective system	1. Thermal overload relay tripped pump circuit. 2. Time delay relay reset. 3. Review vendor specification.
18	1. Circuit Breaker/ Overload 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 58 330000	1. SCTI 2. Circulating cooling water pump (P-2) circuit breaker 3. - 4. Incident report No. 11	MI 157	MI 22	MI 510	2205	Protective system	1. Thermal overload relay tripped pump circuit off. 2. Time delay relay reset. 3. Review vendor specification.
19	1. Breaker D-2/Over-current Relay 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Primary sodium pump (P-5) 3. - 4. Incident report No. 124	MI 500	MI 21	MI 520	Unknown	Protective system	1. One wire to the circuit breaker was loose. 2. Local repair. 3. Improve electrical maintenance work control.
20	1. Circuit Breaker/ Microswitch 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Circulating water system (P-2) pump motor 3. 5 kv, 4160 v, 1200 amps 4. Incident report No. 322	MA 110	MA 53	MA 530	Unknown	During activation	1. Water pump failed to start. Circuit breaker could not close as screws worked loose on latching micro-switch and it did not operate. 2. Local repair. 3. Proper installation (lock washers, etc.)
21	1. Circuit Breaker/ Overload 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 58 330000	1. SCTI 2. Steam and feedwater system cooling water pump (P-2) 3. - 4. Incident report No. 12	MI 157	MI 22	MI 520	2205	Protective system	1. Thermal overload relay tripped pump circuit to open. 2. Local repair, thermal overload tripping point was increased from 100 to 110%. 3. Review vendor specification.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-35

FAILURE DATA FOR POWER SWITCH GEAR CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

(Sheet 5 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
22	1. Circuit Breaker/Wires 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Control panels A, B, C 3. Breakers engaged 4. Incident report No. 304	MI 324	MI 13	MI 43	2205	Protective system – tripped plant electric power	1. Construction men shorted wires while working on control panel (contractor personnel). 2. Vendor repair. 3. None.
23	1. Breaker/Bus Bars 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	1. SCTI 2. Motor control center 3. 480 v, 16 unit panel, ambient 4. Incident report No. 308	I 300	I 13	I 570	Unknown	During modifications	1. Contractor personnel shorted bus bars with electrical fish tape resulting in fire among bus bar cables. 2. Bus bar sections and circuit breaker connections rewired. 3. Improve supervision of construction work.
24	1. Circuit Breaker/Overload 2. Heat Transfer/Intermediate Coolant 3. 58 222121	1. SCTI 2. Secondary sodium system sodium pump (P-6) 3. 350 hp, 4160 v, 1180 rpm (operated at 680 rpm) 4. Incident report No. 31	MI 167	MI 21	MI 550	9	Protective system	1. Overload protective circuit breaker tripped. 2. Operating limits change. 3. Air cooling should replace argon cooling.
25	1. Circuit Breaker/Overload Coil 2. Heat Transfer/Electrical 3. 58 221121	1. SCTI 2. Primary sodium system sodium pump (P-5) circuit breaker 3. – 4. Incident report No. 1	MI 472	MI 22	MI 157	270	Protective system	1. Breaker tripped numerous times, initial startup or shakedown problem. 2. Local repair. Circuit breaker was replaced. 3. Stock replacement components.
26	1. Power Switchgear/Reversing Contactor 2. Accessory Electrical Equipment/Switch Gear 3. 58 410000	1. HNPF 2. Reactor core/dummy control rod No. 1 3. 350 to 925°F 4. Monthly operating report No. 6	MI 415	MI 15	MI 530	3250	During actuation	1. Contactor fused shut. 2. New contacts installed; breaker reset. 3. None.
27	1. Main Disconnect Switch/Contact Faces 2. Accessory Electrical Equipment/Switch Gear 3. 58 410000	1. EBR-II 2. Auxiliary primary EM pump 3. – 4. Operating maintenance report, 7/17/68	MI 500	MI 11	MI 530	15,240	During routine inspection	1. Faulty switch. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-36

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

COMPONENT SUBTYPE CIRCUIT BREAKERS

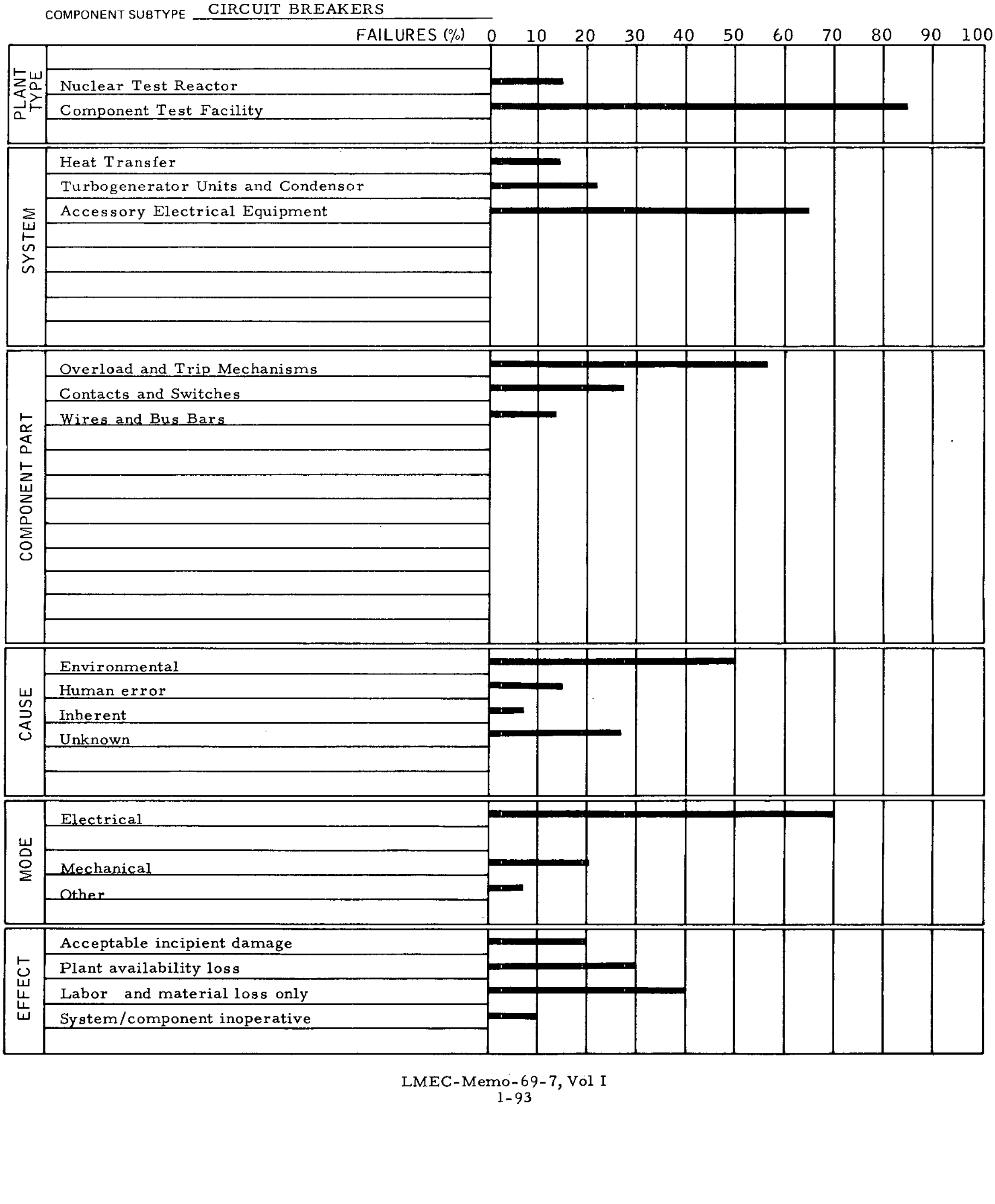


TABLE 1-37

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

COMPONENT SUBTYPE RELAYS

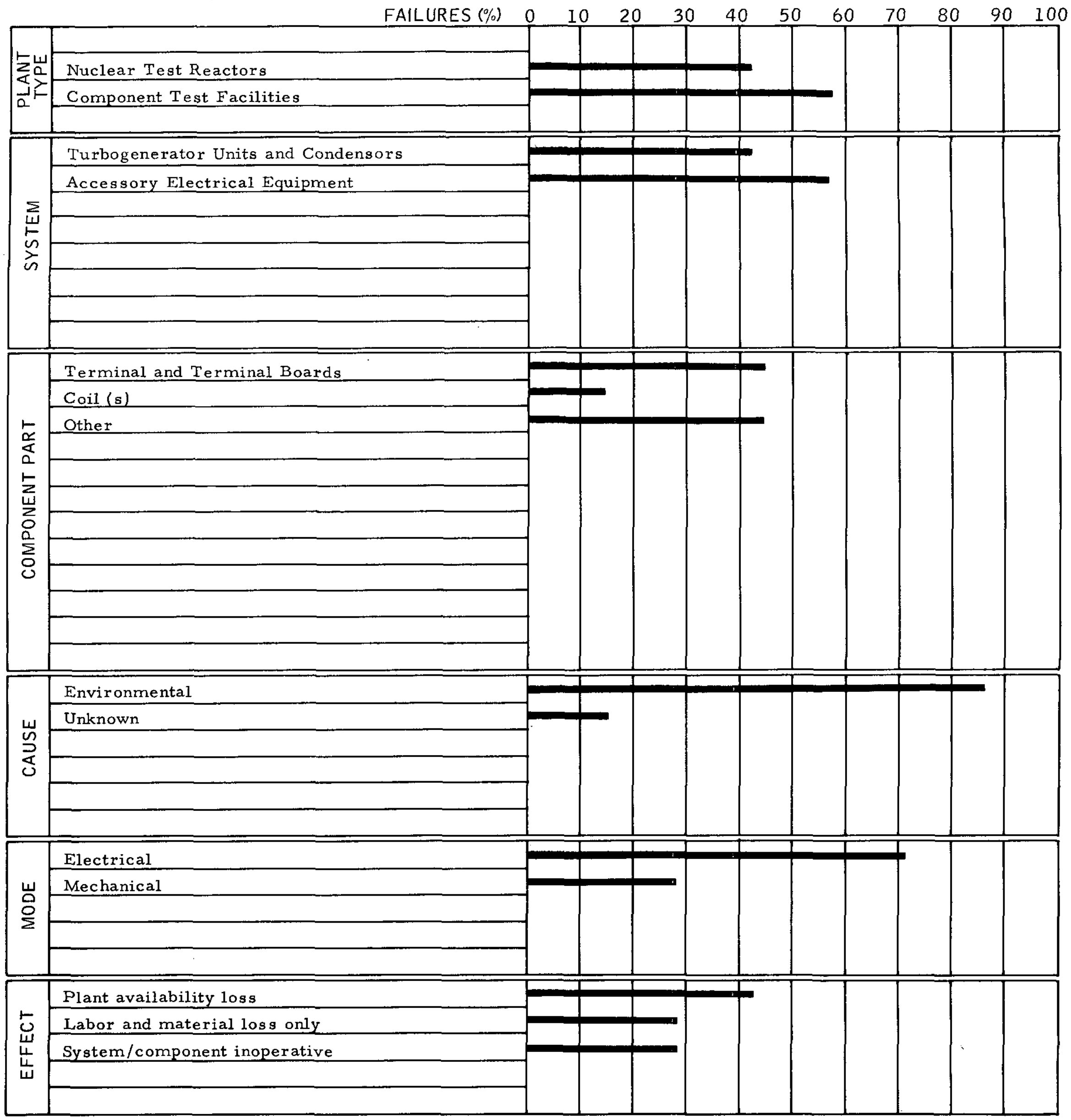


TABLE 1-38

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

COMPONENT SUBTYPE SWITCH GEAR

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Power Reactor	
	Nuclear Test Reactor	
SYSTEM	Accessory Electrical Equipment	
COMPONENT PART	Contacts	
CAUSE	Inherent	
	Unknown	
MODE	Electrical	
EFFECT	Labor and material loss only	

TABLE 1-39

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

COMPONENT SUBTYPE TRANSFORMERS

PLANT TYPE	Component Test Facilities
SYSTEM	Accessory Electrical Equipment
COMPONENT PART	Windings
	Other
CAUSE	Environmental
	Impurity/contamination
	Unknown
MODE	Electrical
EFFECT	Labor and material loss only
	System/component inoperative

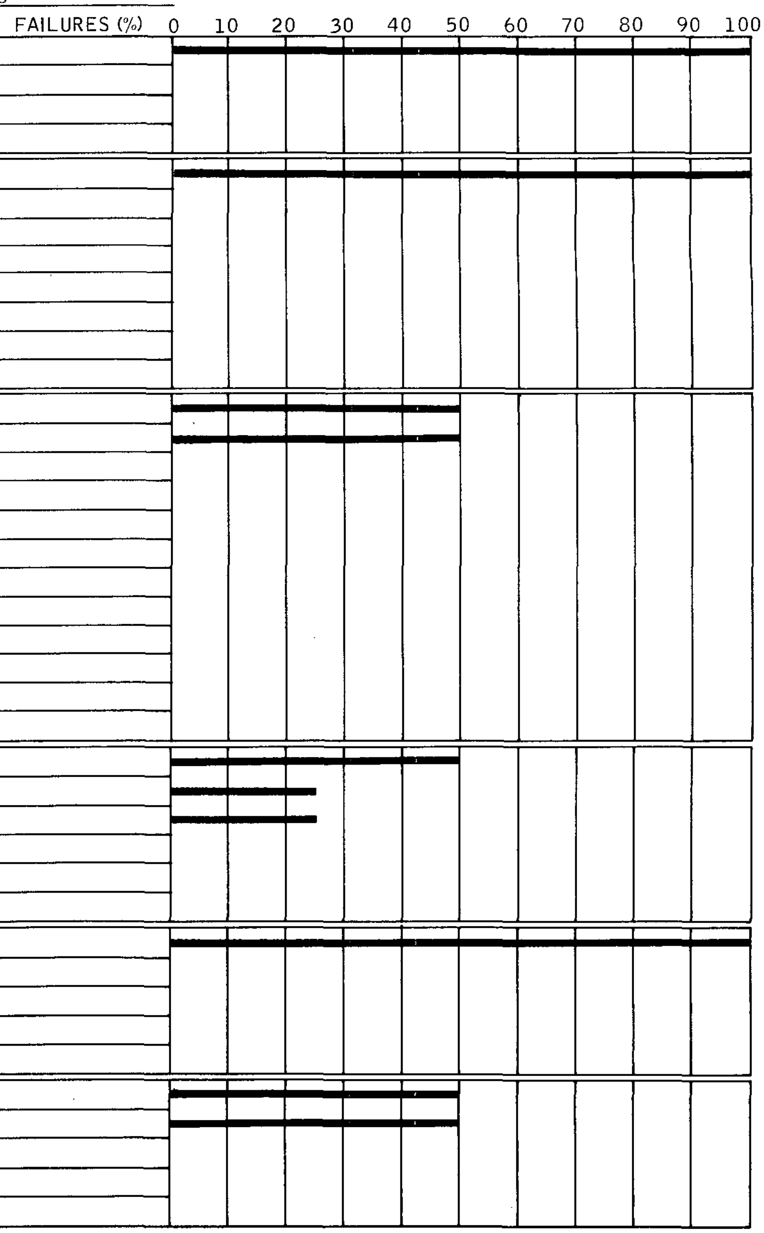
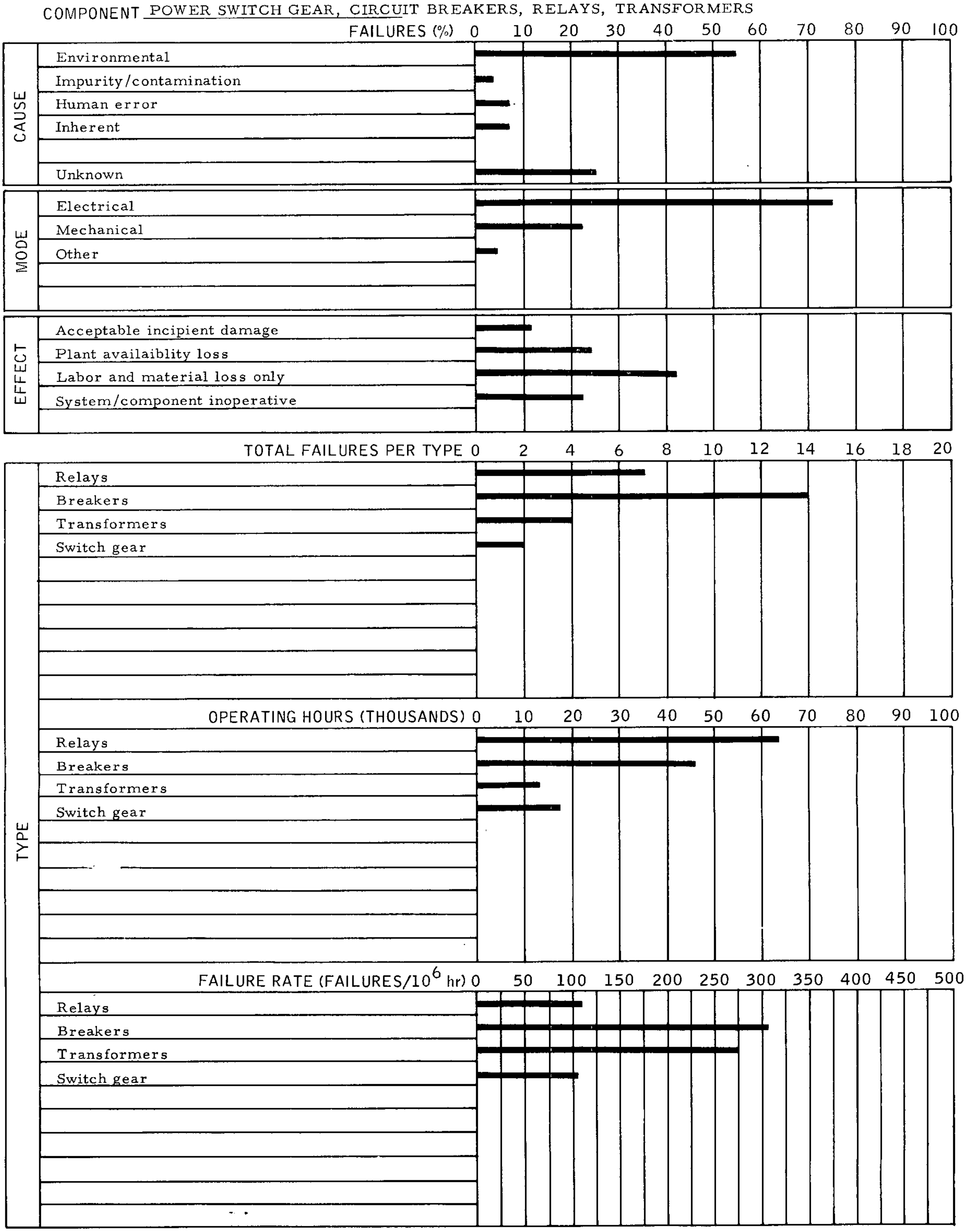


TABLE 1-40

GENERAL SUMMARY

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS



5. Turbine Generators (generator side)

Failure data for turbine generators (generator side) are presented in Tables 1-41 through 1-43.

a. Reliability Information

Design Features:

Power generator, with a steam turbine prime mover, generates electric power for commercial type usage. Malfunction data is limited to one unit, and therefore is not broad-based.

Mode of Failure:

1) Oil seal ring misalignment
2) Brush wear
3) Bearing wear
4) Misalignment or turbogenerator
5) Coil open circuited
6) Exciter bus bar insulation failed.

Failure Experience:

1) Two or more malfunctions caused by unit misalignment.
2) Brushes replaced or reseated in two instances.
3) Bearings were defective in two instances.
4) Generator coil defective on one occasion.
5) Exciter bus bar insulation defective once.

Control Methods:

1) Turbogenerator physical alignment should be accomplished with great precision when unit is installed.
2) Turbogenerator should be on turning gear whenever the unit is down.
3) Verify adequacy of bearing lubrication.
4) Have adequate preventive maintenance program.

b. Discussion and Recommendations

Malfunction data in this report is limited to one turbogenerator unit, and is therefore not broad enough to support general conclusions. From the events reported on, however, it is seen that several of the malfunctions were due to improper alignment. Precise alignment is extremely important on large generating units because of the possibility of harmonic vibrations developing which can be very damaging to high inertia machines.

Maintenance procedures for machines of this size, and larger, should follow the standards developed by the electric power industry. These procedures differ considerably from those followed by general industry. Different utilities evolve their own procedures which sometimes reflect such factors as spinning reserve and economics. One utility, for example, reports that their large generating units have a scheduled shutdown, after the first year, of only once every five years. They find it economically justified to risk an emergency trip of the unit during that 5-year period. A nuclear power plant would not have that option since they would be shut down at approximate 1-year intervals for reactor refueling.

The insulation resistance of all large generators should be measured at regular intervals. Data from such tests can be used to detect incipient weak spots in coil windings as well as other related coil conditions.

During a shutdown period, the generator should be on its turning gear, to prevent bearing damage, and lubricating oil pressure must be maintained. For this reason, lube oil pumps are usually powered by a motor connected to an uninterruptable power supply.

TABLE 1-41

FAILURE DATA FOR TURBINE GENERATORS (GENERATOR SIDE)

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Turbine Generator/ Seal Ring 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Generator/H_2 Seal 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. ANL-7255	MI 500	MI 56	MI 530	7,800	Routine inspection	1. Seal oil ring misalignment. 2. Local repair, ring remachined and reinstalled. 3. None.
2	1. Turbine Generator/ Commutator Brushes 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-76	MI 500	MI BZ	MI 530	6,300	Preventive maintenance	1. Brushes replaced. 2. Part replaced. 3. None.
3	1. Turbine Generator/ Bearing 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator/north end 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-81	MA 500	MA 56	MA 520	15,240	Direct observation	1. Generator-turbine combination not mounted at proper levels causing shaft misalignment. 2. Local repair. 3. Upgrade Quality Assurance surveillance on installation of generator.
4	1. Turbine Generator/ Bearing Cap 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator/north end 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-81	MA 500	MA 52	MA 520	15,240	Direct observation	1. Vibrating. 2. Part replaced. 3. None.
5	1. Turbine Generator/ Bearing 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator/south end 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-81	MA 500	MA 56	MA 520	15,240	Direct observation	1. Generator not mounted level causing shaft misalignment. 2. Part replaced. 3. Improve alignment procedures.
6	1. Turbine Generator/ Rotor 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-81	MA 500	MA 59	MA 520	15,240	Direct observation	1. Vibrating. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-41

FAILURE DATA FOR TURBINE GENERATORS (GENERATOR SIDE)

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Turbine Generator/ Coil Winding 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator 3. 3,600 rpm, 20,000 kw, 13.8 kv 4. PMMR-81	MA 500	MA 59	MA 520	15,240	Direct observation	1. Coil winding broken. 2. Part replaced. 3. None
8	1. Turbine Generator/ Bearings 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Main generator/amplidyne 3. 85 kw, 250 vdc 4. PMMR-96	MI 500	MI BZ	MI 530	9,345	Preventive maintenance	1. Faulty bearings. 2. Part replaced. 3. None.
9	1. Turbine Generator/ Exciter Brushes 2. Turbine Generator/ Generator Side 3. 56 320000	1. EBR-II 2. Generator exciter 3. 85 kw, 250 vdc 4. Weekly operations report, 7/3/68	MI 444	MI BZ	MI 520	15,240	Audible noise	1. Nosy brushes. 2. Local repair. 3. Follow manufacturer's recommendations on maintenance of brushes and frequency of inspections.
10	1. Turbine Generator/ Exciter Armature 2. Turbine Generator/ Turbine Plant Equipment 3. 56 370000	1. EBR-II 2. Turbine generator exciter 3. 85 kw, 250 vdc 4. ANL-7457	MA 191	MA 18	MA 520	14,650	Operational monitors	1. Bus bars in the exciter were reinsulated. 2. Corrective modification. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-42

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TURBINE GENERATOR (GENERATOR SIDE)

COMPONENT SUBTYPE TURBINE GENERATOR (GENERATOR SIDE)

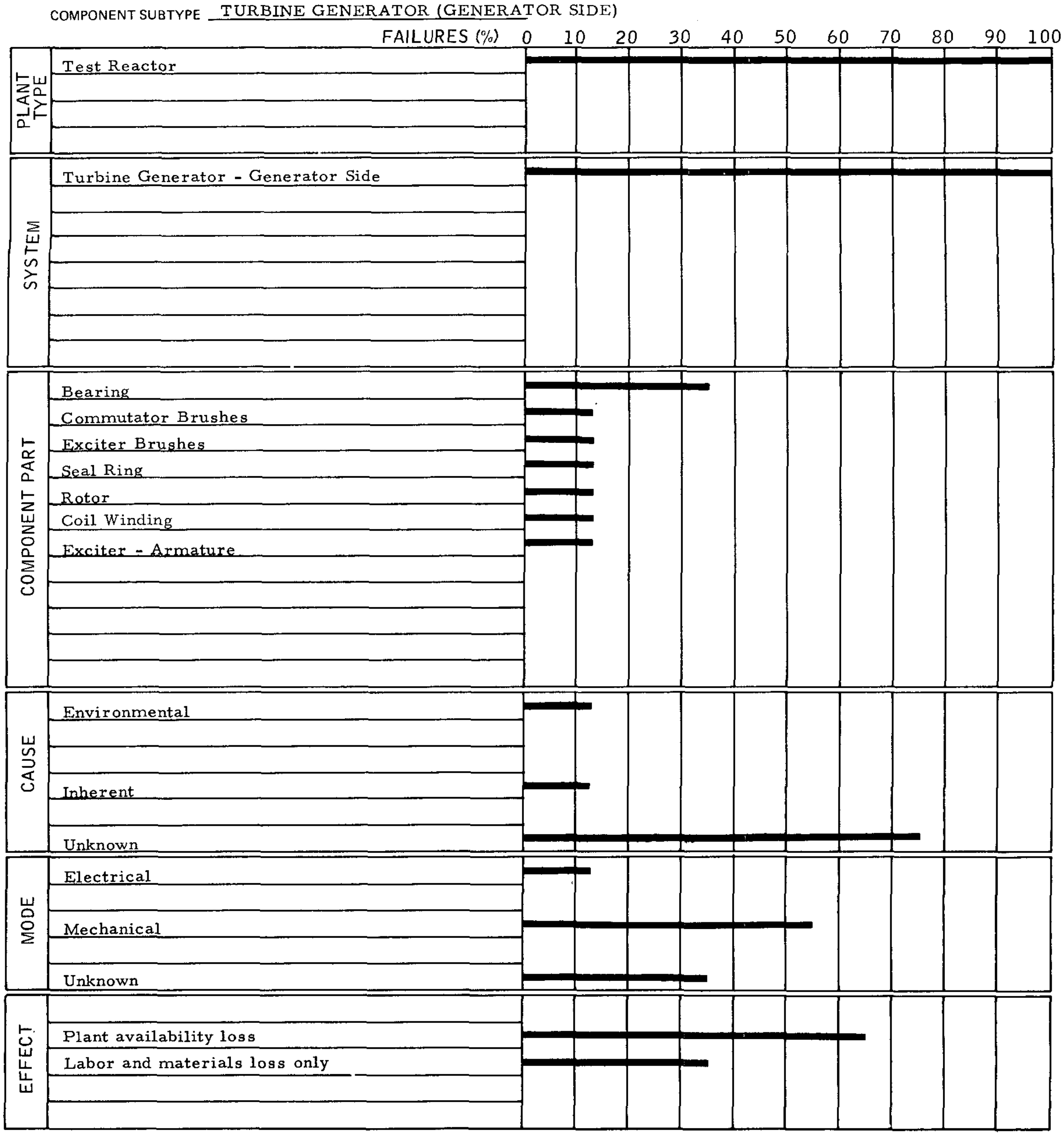
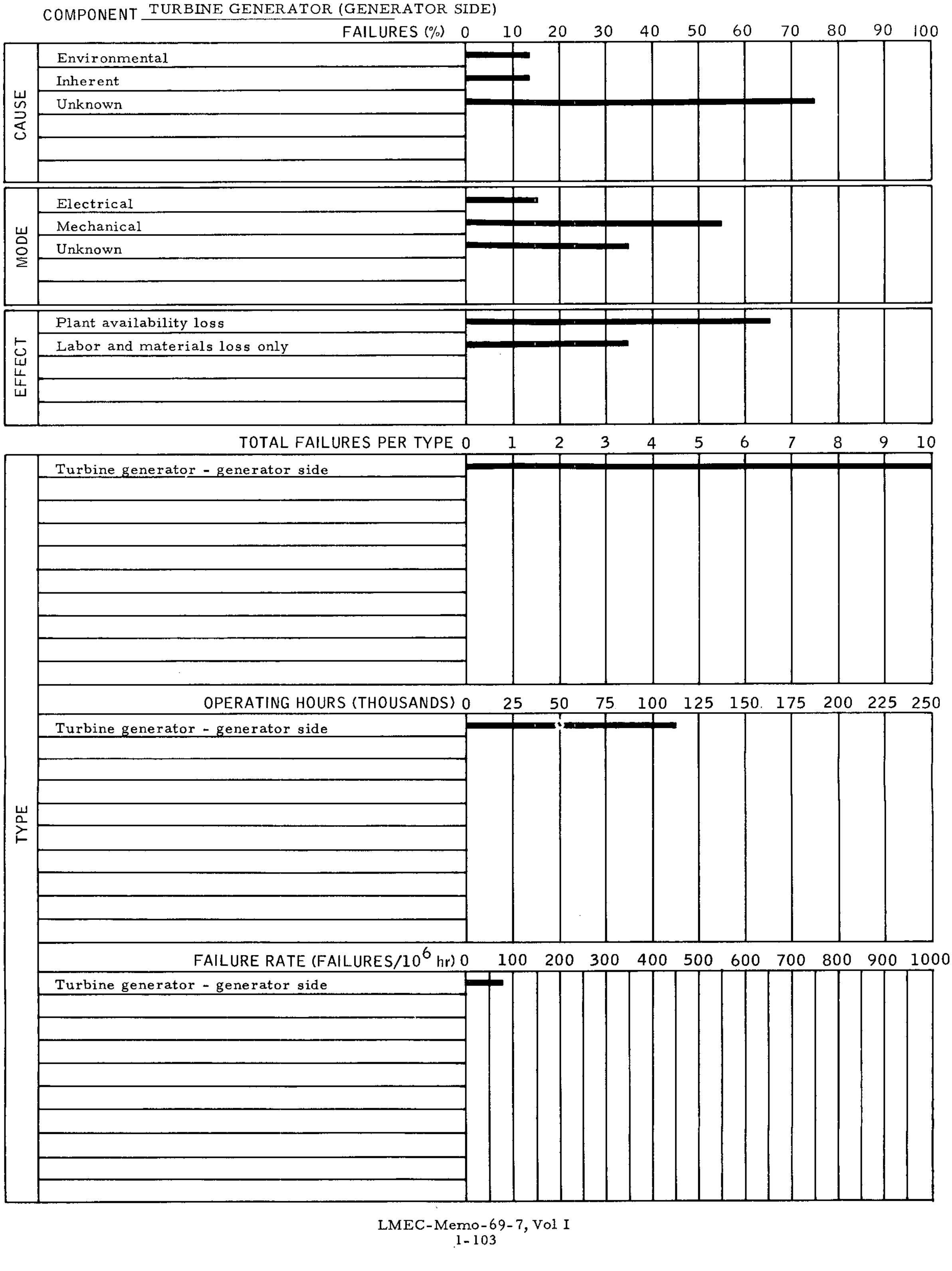


TABLE 1-43

GENERAL SUMMARY

COMPONENT TURBINE GENERATOR (GENERATOR SIDE)



D. ENERGY CONVERSION (MECHANICAL) SYSTEM COMPONENTS

1. Furnace Equipment

Failure data for furnace equipment are presented in Tables 1-44 through 1-46.

a. Reliability Information

Design Features:

Common knowledge

Critical Characteristics:

Common knowledge

Mode of Failure:

1) Improperly established maintenance schedule.
2) Thermal expansion difference causing stress cracks.
3) Insufficient reinforcing to support furnace refractory.
4) Operator caused malfunctions.

Failure Description:

1) Ceramic feedthrough insulator of the pilot light electrode cracked.
2) Flame rod cracked and electrical wire connector eyelet corroded; rain leakage shorted the electrical wires.
3) Sodium-smoke-type leak detector was actuated.
4) Hangers for supporting refractory protecting tubes broke loose.
5) Burner flamed out and plant was shut down when operator improperly adjusted gas and air flow.

Control Methods:

1) To avoid high local thermal and fatigue stresses, design should provide adequate clearance between materials with different thermal expansion coefficients if they are exposed to temperature changes.
2) Plant operator's manual should call special attention to those control and equipment adjustments where very small changes may cause heavy plant disturbances or even shutdowns.

3) Preventive maintenance frequency should be established for all critical subsystems, with special attention given to units exposed to outside environment. Special instructions should be given in cases where material compatibility and reliability is critical.

b. Discussion and Recommendations

Although equipment is available to detect furnace equipment failures, it is more economical to use preventive maintenance inspection than failure detecting instrumentation. In case of relatively inexpensive components, keep spares in stock and replace them before their expected lifetime expires.

Sodium-smoke sensors are sensitive enough to detect sodium leaks in their early stages; however, strategically placed strain gages can be utilized to detect incipient failures.

TABLE 1-44

FAILURE DATA FOR FURNACE EQUIPMENT

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Furnace/Pilot Electrode 2. Heat Transfer/Furnace 3. 41 227300	1. SCTI 2. Primary 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 348	MI 121	MI 13	MI 530	9807	Audible noise	1. Pilot electrode insulator cracked allowing short circuit 2. Replaced part. 3. None.
2	1. Gas Fired Furnace/ Pilot Rod 2. Heat Transfer/Furnace 3. 41 227300	1. SCTI 2. Heater H-1 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 340	MI 121	MI 61	MI 530	26,274	Alarm	1. Flame rod cracked and high temperature lead assembly eyelet soldered connection corroded. 2. Replaced parts. 3. None.
3	1. Gas Fired Furnace/ Tubes 2. Heat Transfer/Furnace 3. 41 227300	1. SCTI 2. Primary 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 302	I 136	I 61	I 520	9580	Operational monitor	1. Sodium leak indicated on smoke detectors — 4 gpm estimated from 8 in./hr loss of sodium level in primary expansion tank. 2. Local repair. 3. None.
4	1. Furnace/Pilot Burner 2. Heat Transfer/Furnace 3. 41 227300	1. SCTI 2. Primary 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 332	MI 156	MI 47	MI 119	Unknown	Operational monitors	1. Disturbance in Southern California Edison System resulted in power drip, causing automatic plant shutdown. 2. Normal power enabled restart. 3. None.
5	1. Furnace Equipment/ Supports 2. Heat Transfer/Reactor Coolant 3. 41 227300	1. SCTI 2. Sodium heat transfer 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 63	MI 416	MI 53	MI 520	9580	During routine inspection	1. The refractory protecting tube support hangers broke loose. 2. Wire mesh was installed to support the refractory material. 3. None.
6	1. Furnace Equipment/ Gas Pilot 2. Heat Transfer/Reactor Coolant 3. 41 227300	1. SCTI 2. Sodium heat transfer 3. Rating = 35 Mwt, 1200°F 4. Incident report No. 54	MA 339	MA BO	MA 520	4005	During activation	1. Operator improperly adjusted gas flowrate and combustion air flow, causing a burner flame out; this in turn, tripped the primary sodium pump. 2. Pilot lights were reignited and the primary pump restarted. 3. Improve operator training.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-45

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FURNACE EQUIPMENT

COMPONENT SUBTYPE FURNACE EQUIPMENT

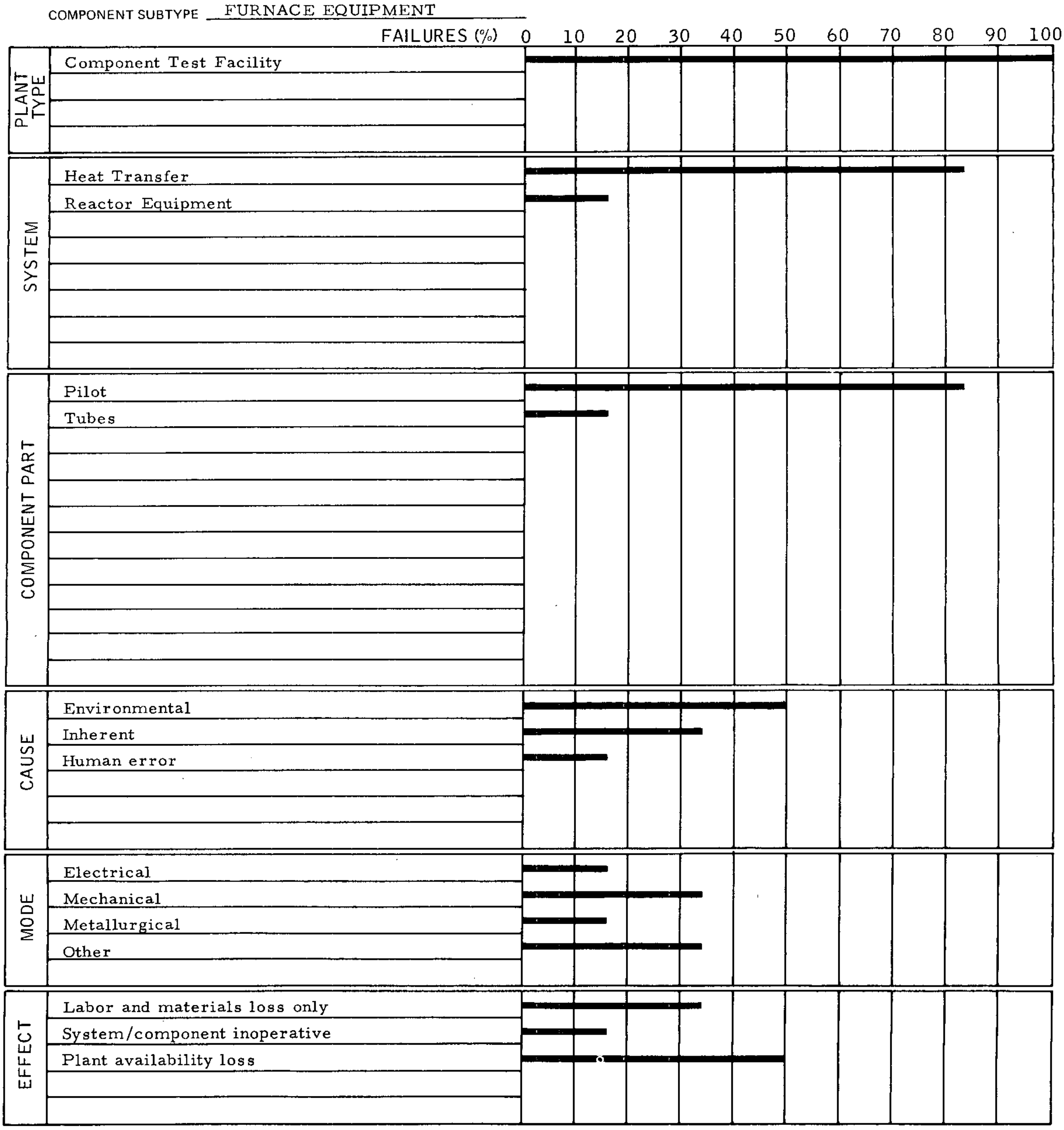
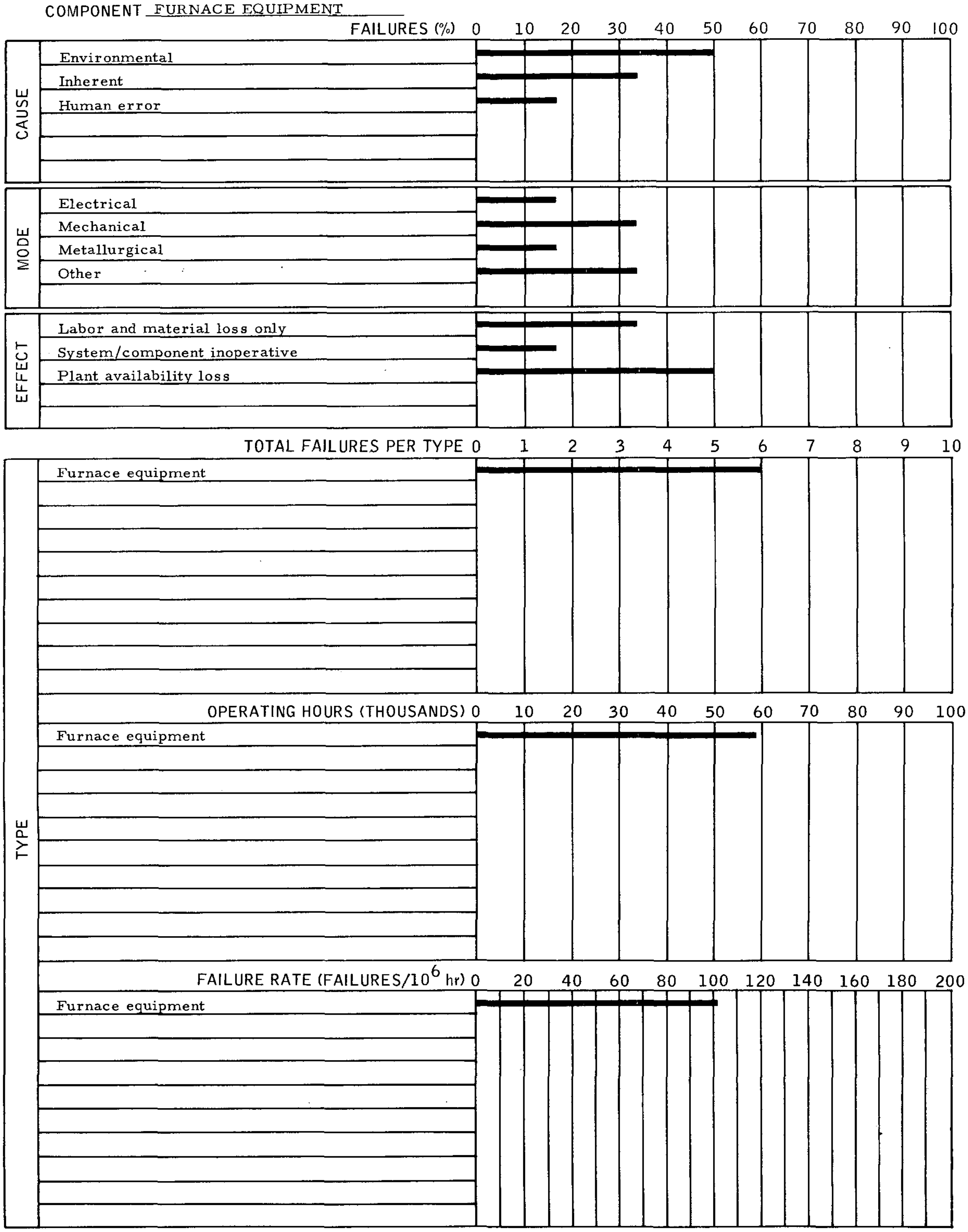


TABLE 1-46

GENERAL SUMMARY

COMPONENT FURNACE EQUIPMENT



2. Motors, Engines, and Turbines (hydraulic, pneumatic, steam)

Failure data for motors, engines, and turbines, (hydraulic, pneumatic, steam) are presented in Tables 1-47 through 1-49.

a. Reliability Information

Design Features:

Small high-speed rotating machinery designed for long trouble-free service life.

Critical Characteristics:

One or two-stage turbines, thin blading, close running clearances, shaft, seals, bearing.

Mode of Failure:

1) Turbine blade damage
2) Seal failure
3) Overheating.

Failure Description:

1) Turbine blades failed, apparently due to foreign object.
2) Turbine overheating resulted from excessive oil in system.
3) Turbine seal leakage resulted in bearing failure.
4) Improper size bearing caused unusual wear pattern.

Control Methods

1) Install debris catcher upstream of turbine steam inlet.
2) Ensure clean steam supply to turbine.
3) Maintain adequate surveillance and preventive maintenance procedure relative to seals.
4) Maintain adequate quality control and detailed installation procedures requiring checking of critical dimensions before installation of replacement parts.

b. Discussions and Recommendations

A total of five failure events were reviewed with this component. The failures were primarily mechanical failures and failures resulting from inadequate quality control and improper maintenance procedures.

A turbine blade failure was reported. Apparently something passed through the turbine causing a section of blading to be broken out and bending the remaining blades. Four pieces of wood were found in the pump; perhaps a fifth piece found its way into the turbine inlet. It is possible that blade fatigue was the cause, but this is not very probable. A vibration indicator with an electronic shutdown or alarm might have prevented the extensive damage observed but would not have prevented the failure. A debris trap upstream of the turbine inlet may have prevented the failure.

Two problems were reported. The first problem was caused by improper maintenance procedures; too much oil was added to the unit causing excessive smoking. The unit was shut down and the excess oil drained. On restarting, a rubbing noise was heard and the unit was shut down. A quantity of metal particles and nicked blades were found when the turbine was disassembled. Again the lack of cleanliness in the steam system appeared to be the problem. Either a clean system or a means of preventing contaminants from entering the turbine is required. Improper maintenance procedure or human errors may be prevented by service checkoff procedures and caution markings on the unit.

A turbine seal failure ultimately causing a bearing failure was reported. There is no indication that the seal was repaired or replaced. The bearing, however, was replaced and the unit returned to service. The seal leakage was undoubtedly corrected by increasing the load on the packing, replacing the packing or, if it was a mechanical seal, by replacing worn parts. The seal leakage was probably the result of normal wear but in view of the difficulties with debris in the system the possibility cannot be ruled out that the failure was caused by abrasive particles entrained in the steam system. Since seal leakage is a recurring problem it would be advisable to provide a means of preventing the steam leakage from condensing on the bearing. A preventive maintenance program could be initiated by which seals are periodically overhauled.

During preventive maintenance inspection, an incipient failure was discovered and reported. The bearing was found to exhibit an unusual wear pattern and it was found that the clearance was too small. This was obviously a quality control problem either at the factory or during a previous replacement. The incorrect-size bearing should not have been installed. The bearing was rebored to the correct size and reinstalled.

TABLE 1-47

FAILURE DATA FOR MOTORS, ENGINES, AND TURBINES

(HYDRAULIC, PNEUMATIC, STEAM)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	 MODE	 EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Turbine/Blading 2. Steam, Condensate and Feedwater/Boiler Feed Pump 3. 10 284100	1. EBR-II 2. Turbine-driven feed pump 3. 900 hp, 9700 rpm 4. PMMR-24	MI 500	MI 59	MI 550	Unknown	Routine area watch	1. Severe damage to turbine wheel blades 2. Damaged part replaced – local repair 3. Maintain clean steam system – install debris catcher at turbine inlet. Insure blade fatigue not problem.
2	1. Turbine/Turbine Blades 2. Steam, Condensate and Feedwater/Boiler Feed Pump 3. 10 284100	1. EBR-II 2. Feedwater/turbine-driven feed pump 3. 900 hp, 9700 rpm 4. PMMR-52	MI 273	MI 52	MI 530	Unknown	Direct observation	1. (a) Overheating and smoking because of too much oil in unit. (b) Failure due to turbine blade damage (minor). 2. Oil drained to proper level and turbine cleaned of metal particles – local repair 3. Maintain clean steam system – improve maintenance procedures (excess oil human error) – install debris catcher at turbine inlet.
3	1. Turbine/Turbine Seals 2. Steam, Condensate and Feedwater/Condensate Pump 3. 10 283100	1. EBR-II 2. Condensate/turbine-driven condensate pump 3. 122 hp, 1760 rpm 4. PMMR-113	MA 185	MA B8	MA 550	12,390	Operational monitors	1. Turbine seal failure eventually causing bearing failure. 2. New bearing installed, local repair. 3. Improve surveillance of shaft seals – redesign to prevent steam condensation on bearing housing – maintain clean steam system.
4	1. Turbine/Turbine Bearing 2. Steam, Condensate and Feedwater/Condensate Pump 3. 10 283100	1. EBR-II 2. Condensate/turbine-driven condensate pump 3. 122 hp, 1760 rpm 4. PMMR-94	MI 500	MI 52	MI 530	9345	Preventive maintenance	1. Bearing discrepance – unusual rubbing on top and bottom of bearing. 2. Bearing clearance found too small – bearing rebored and reinstalled with proper clearance. 3. Quality control problem – improve QC procedures.
5	1. Motor (air)/Control Valve Plunger 2. Heat Transfer/Intermediate Cooling 3. 10 222133	1. HNPF 2. Secondary/sodium system 3. - 4. Monthly operating report No. 16	MA 126	MA 59	MA 550	4560	Operational monitors	1. Direction control valve malfunctioned, resulting in slow response of reverse selection operation. 2. Control valve was overhauled, valve plunger and O-rings replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-48

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT MOTORS, ENGINES AND TURBINES (HYDRAULIC, PNEUMATIC, STEAM)

COMPONENT SUBTYPE TURBINE - STEAM

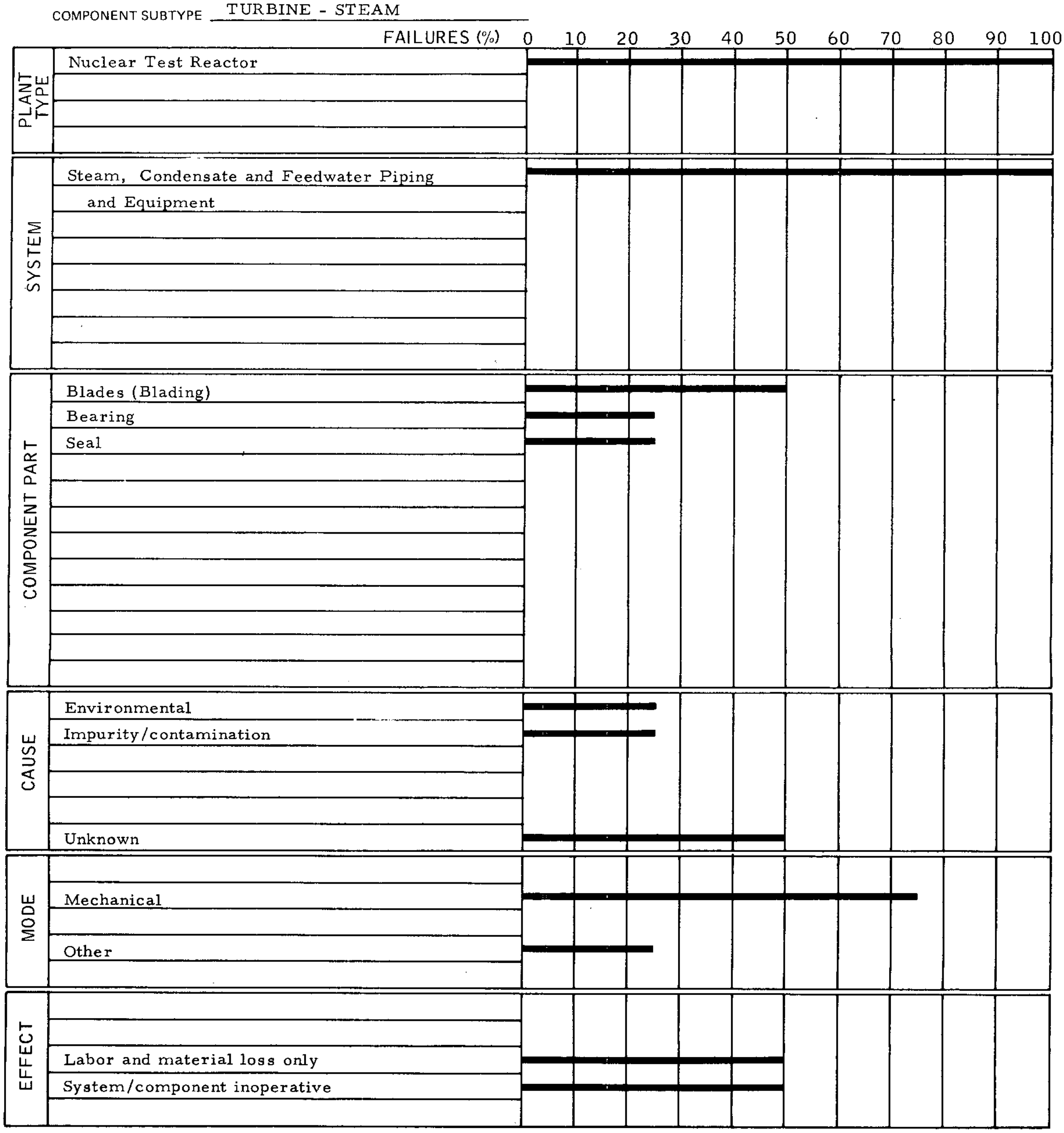
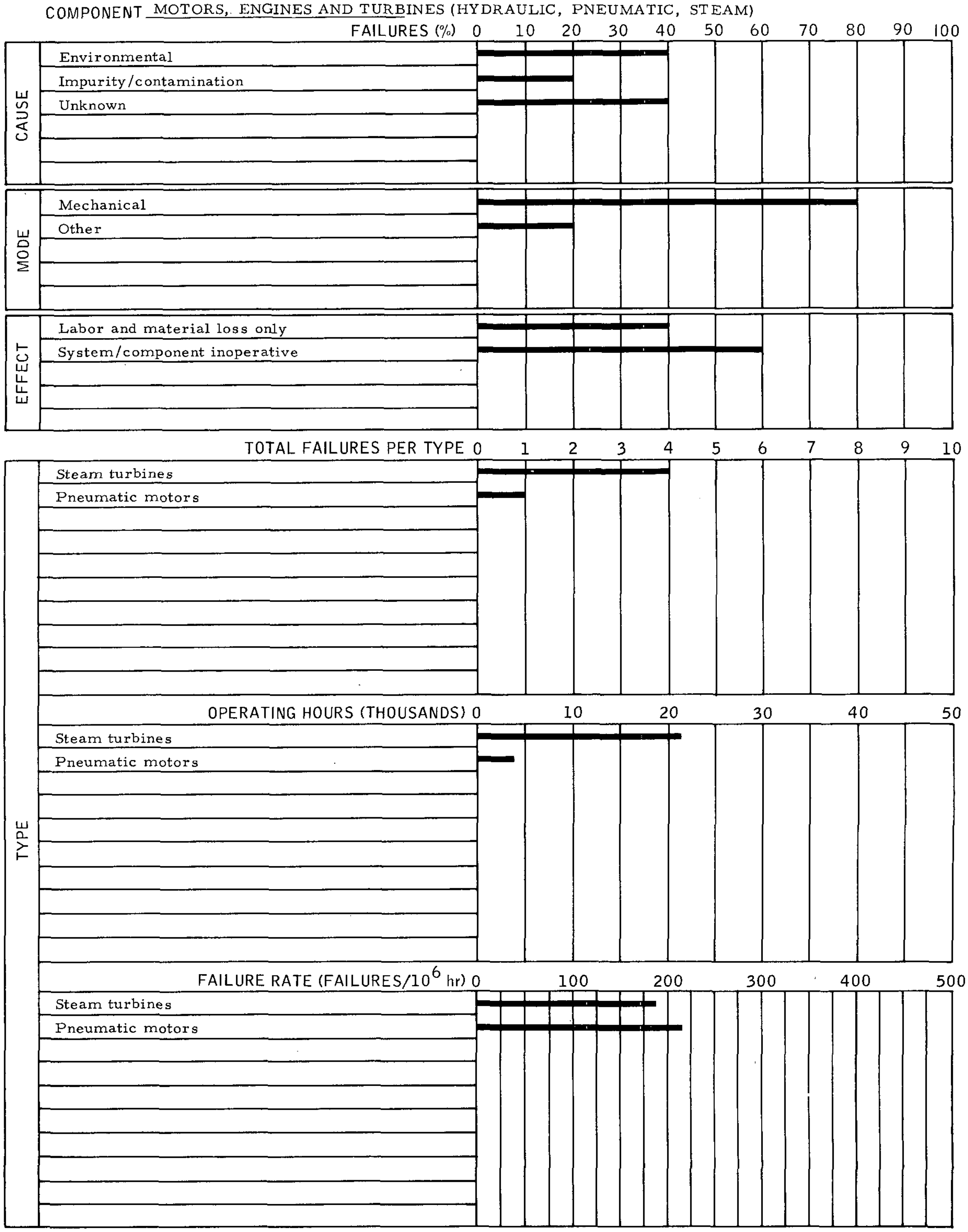


TABLE 1-49

GENERAL SUMMARY

COMPONENT MOTORS, ENGINES AND TURBINES (HYDRAULIC, PNEUMATIC, STEAM)



3. Transmissions and Drive Shafts

Failure data for transmissions and drive shafts are presented in Tables 1-50 through 1-52.

a. Reliability Information

Design Features:

Motor-driven machinery designed to do lifting, pushing, rotating, and stopping of a wide range of equipment as found in reactor systems.

Critical Characteristics:

Equipment must be able to drive and position or index its dependent mechanisms with high precision and accuracy.

Mode of Failure:

1) Couplings failed or overheated.
2) Shafts bent, worn out, broken or stuck.
3) Seals leaked.
4) Bearings broken, frozen to shaft, and worn out.
5) Gears damaged, broken, or worn out.
6) Snubbers leaked oil, stuck, and some had not been installed.
7) Clutches and brakes inoperative and worn out.
8) Keys, set screws, and pin - loose, worn out, or broken.
9) Switches and contacts loose or broken.
10) Bellows ruptured, leaked, or improperly welded.
11) Actuator rods, cables, and wires - stuck, jammed, or broken.
12) Structures broken or cracked.

Failure Description:

1) Mechanical couplings were badly worn; they had broken splines and other broken parts. A magnetic coupling (electrical) overheated. The mechanical failures seemed to be due to overloads or misalignments. The electrical heating of the magnetic coupling was probably due to improper cooling or overload which caused stoppage.

2) Shafts were generally bent, meaning they were overloaded. Others were stuck due to foreign objects getting into their guides or bearings.

3) Shaft seals leaked oil causing other components to malfunction.

4) Many mechanisms failed because bearings failed. Bearings failed due to misalignments, or loads, or improper use.

5) Gears failed because of overloads, misalignments, and spacing or support failures.

6) Snubbers (shock absorbers) failed because the static O-ring seals failed and leaked oil. The snubber failures resulted in damage to other parts of the control rod drives and pull rods. In one case snubbers had not been installed.

7) Clutches and brakes were worn out due to normal lifetime. Some clutches and brakes failed because oil and grease leaked onto them.

8) Keys, pins, and set screws worked loose and sheared, caused galling of shafts, and let gears loosen, resulting in other failures.

9) Switches and contacts were worn out or broken, causing motors and electric clutches to be inoperative.

10) Bellows ruptured due to fatigue, resulting in sodium leaks which caused push rod, etc., for grippers to become stuck.

11) Actuator rods, cables, and wires became bent, jammed, and broken. The results were inoperative control rods, fuel handling equipment, and interlocking mechanisms.

12) Structures such as gear box housing experienced cracks in the casting. A gear drive support was broken from overload conditions.

<u>Control Methods:</u>

1) Proper selection, installation, and maintenance of most mechanical components such as shaft coupling, bearings, gears, keys, set screws, and pins are necessary for trouble-free operation.

2) Installing of protective covers would eliminate damage to delicate components such as switches.

3) Selection of proper materials for seals and correct installation procedures will eliminate most seal problems.

b. Discussion and Recommendations

A total of 60 mechanical failures were studied. The mechanisms involved were control rods, fuel handling equipment, and gear drives for reactor shields. The failures can be classified in basic component groups such as bearings, keys, and gears. Sometimes failures are reported as mechanism failures when in reality a mechanism fails because of a small component part failure. Its component part may have failed due to overload, misalignment, improper selection of materials for service required, or improper use of component. In the study, five control rod snubber failures were reported. The actual failure was a static O-ring seal at the bottom of the snubber which lost its tension by cold flow of the material and let the snubber fluid leak away. The snubber's inability to cushion the control element drop during scram caused failures to other parts of the control rod.

Clutch and brakes failed to function properly because oil or grease from bearings and gear boxes had dripped on their linings. Here the actual failures were shaft seals.

Some other failures were due to improper assembly or failure to install parts.

Some bearings, splines, coupling, pins, and keys failed because they were overloaded. The overloads may be because of a design error or improper installation. In some cases bearings and splines failed due to lubrication failures or dirt working into the lubrication. Incipient failure of bearings, gears, and other moving elements may be detected by a change of sound or other operating characteristics. Seals will generally start to leak slowly before complete failure. Clutches and brakes will start to show signs of slippage before complete failure. Keys, set screws, and pins will become loose and demonstrate some backlash before breaking. Most of these pending failures should be detected with regular inspection and maintenance programs. If one part fails before the normal expected life, it may be because of a faulty part; but if replacements continue to fail, it is evident that the part is being overloaded.

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 1 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Drive/Magnetic Coupling 2. Heat Transfer/Transmission and Drive Shafts 3. 12 222140	1. Fermi 2. Secondary system No. 2 pump 3. 350 hp, 900 rpm, 12,000 gpm, 675°F, 35 psi 4. EF-12	MI 415	MI 12	MI 530	6470	Direct observation	1. Magnetic coupling burned out. 2. Part replaced. 3. Install temperature indicator on magnetic coupling and establish upper operating temperature limit for coupling.
2	1. Generator Drive Shaft/Seal 2. Turbine-Generator Units and Condenser/Generator Side 3. 12 320000	1. EBR-II 2. Main generator/turbine 3. Oil seal operated at 4.5 psig above hydrogen pressure in the casing 4. PMMR-104	MI 500	MI 52	MI 530	10,380	Operational monitors	1. Seal worn out. 2. Part replaced. 3. None.
3	1. Coupling/Insert 2. Steam Condensate and Feedwater Piping and Equipment/Condensate Booster Pump 3. 12 283200	1. EBR-II 2. Condensate/motor-driven condensate pump 3. 364°F at 1500 psig, 3580 rpm 4. PMMR-35	MI 500	MI 59	MI 530	2590	Preventive maintenance	1. Coupling broken. 2. Part replaced. 3. None.
4	1. Transmission and Drive Shafts/Coupling 2. Heat Transfer/Reactor Coolant Pump 3. 12 221110	1. LCTL 2. LCTL/sodium system pump coupling 3. 500°F, flow meter calibration check 4. LCTL log book, 10/25/63	MI 126	MI 52	MI 550	Unknown	Direct observation	1. Coupling worn out. 2. Part replaced. 3. None.
5	1. Transmissions and Drive Shafts/Coupling 2. Heat Transfer/Reactor Coolant Pump 3. 12 221110	1. LCTL 2. LCTL/sodium system pump coupling 3. 110 v, 40 amp, variable speed to 1000 rpm 4. LCTL log book, 10/24/61	MI 124	MI 73	MI 550	Unknown	During actuation	1. Sheared spline in lower half. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 2 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Drive Shaft/Coupling 2. Accessory Electrical Equipment/M. G. Set 3. 12 470000	1. EBR-II 2. Secondary sodium system/M. G. set 3. 4. PMMR-92-12-15-66	MI 125	MI 52	MI 530	8420	During repair of associated component	1. Coupling badly worn. 2. Part replaced. 3. None.
7	1. Transmission/Gears 2. Heat Transfer/Reactor Coolant System 3. 12 221140	1. Fermi 2. Primary/No. 1 pump expansion tank 3. 100 gpm, 75 ft discharge head 4. EFAPP No. 55	MI 348	MI 52	MI 530	1628	Direct observation	1. Gears worn out. 2. Part replaced. 3. None.
8	1. Transmission/Gear Box Shaft 2. Turbine-Generator Units and Condenser/ Circulating Water Pump 3. 12 330000	1. EBR-II 2. Cooling tower (south riser) 3. 83°F 4. PMMR-97	MI 500	MI 57	MI 550	9345	Operational monitors	1. Shaft frozen to bushing. 2. Part replaced. 3. None.
9	1. Transmission Box Bushing/Gear 2. Turbine-Generator Units and Condenser/ Circulating Water Pump 3. 12 330000	1. EBR-II 2. Cooling tower (south riser) 3. 83°F 4. PMMR-97	MI 500	MI 57	MI 550	9345	Operational monitors	1. Shaft frozen to bushing. 2. Part replaced. 3. Increase preventive maintenance inspections on valves to prevent shaft from freezing to bushings.
10	1. Transmission/Stem 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. EBR-II 2. Primary/fuel handling equipment 3. 700°F 4. PMMR-61	MI 500	MI 59	MI 530	4660	Preventive maintenance	1. Broken stem. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFT

(Sheet 3 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
11	1. Transmission/Transfer Arm, Clutch 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. EBR-II 2. Primary/fuel handling equipment 3. 4. PMMR-98	MI 500	MI BZ	MI 550	9345	During actuation	1. Clutch inoperative. 2. Local repair. 3. None.
12	1. Transmission/Transfer Arm, Elevation clutch Wire 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. EBR-II 2. Primary/fuel handling equipment 3. 4. Maintenance report, 4/18/68	MI 500	MI 59	MI 550	14,150	Operational monitors	1. Clutch wire broken. 2. Local repair. 3. None.
13	1. Transmission/Clutch Key 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. EBR-II 2. Primary/fuel handling equipment 3. 4. PMMR-108	MI 148	MI 52	MI 550	11,320	During actuation	1. Key worn out due to slippage. 2. Local repair. 3. Include in preventive maintenance inspection to prevent unpredicted recurrence.
14	1. Transmission and Drive Shafts/Rail Guide Bearing 2. Nuclear Fuel Handling and Storage Equipment/Support Structures 3. 12 235113	1. EBR-II 2. Primary/suel unloading machine 3. 4. PMMR-113, 11/62	MI 500	MI 59	MI 530	12,390	Direct observation	1. Bearings broken. 2. Local repair. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 4 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
15	1. Transmission and Drive/Rail Guide Bearings 2. Nuclear Fuel Handling and Storage Equipment/Support Structures 3. 12 235113	1. EBR-II 2. Primary/fuel unloading machine 3. - 4. Operation weekly report, 12/67	MI 500	MI 52	MI 530	13,212	Direct observation	1. Bearings worn out. 2. Part replaced. 3. None.
16	1. Transmission and Drive/Shaft Adapter 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing Equipment 3. 12 232100	1. EBR-II 2. Primary/fuel unloading machine 3. 210 to 700°F 4. Operation weekly report, 1/17/68	MI 315	MI 59	MI 530	13,380	Direct observation	1. Shaft adapter broken. 2. Part replaced. 3. Disassembly instructions should be carefully reviewed prior to repair or maintenance.
17	1. Transmission Extension/Takeup Reel Bearings 2. Nuclear Fuel Handling and Storage Equipment/Cooling System 3. 12 235140	1. EBR-II 2. Primary system/fuel unloading machine 3. - 4. PMMR-62, 1/66	MI 500	MI 59	MI 530	4955	Preventive maintenance	1. Bearings worn out. 2. Part replaced. 3. None.
18	1. Transmission Extension/Takeup Real Bearings 2. Nuclear Fuel Handling and Storage Equipment/Cooling System 3. 12 235140	1. EBR-II 2. Primary system/fuel unloading machine 3. PMMR-82, 8/66	MI 100	MI 59	MI 530	7400	Direct observation	1. Bearing broken. 2. Part replaced. 3. Design modification required, similar failure occurred before. See PMMR-62.
19	1. Transmission Extension/Takeup Reel 2. Nuclear Fuel Handling and Storage Equipment/Cooling System 3. 12 235140	1. EBR-II 2. Primary system/fuel handling machine 3. - 4. PMMR-113, 11/14	MI 500	MI 59	MI 530	12,390	Direct observation	1. Cable broken. 2. Part replaced. 3. Larger cable may accept more wear and cycles.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 5 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
20	1. Transmission Gear Box/Bolts 2. Reactor Equipment/ Reactor Shielding 3. 12 213000	1. EBR-II 2. Primary cover lock No. 3 3. 4. Operation weekly report, 5/1	MI 321	MI 68	MI 530	14,300	During repair of primary failure component	1. Set screws which lock into bolt thread caused galling. 2. Part replaced. 3. None.
21	1. Transmission Oil Seals/Seal 2. Reactor Equipment/ Reactor Shielding 3. 12 213000	1. EBR-II 2. Primary cover lock No. 2 3. 4. PMMR-81	MI 500	MI BZ	MI 530	6920	Preventive maintenance	1. Oil seals leaked. 2. New oil seals installed. 3. None.
22	1. Transmission Oil Seal/Seal 2. Reactor Equipment/ Reactor Shielding 3. 12 213000	1. EBR-II 2. Primary cover lock No. 1 3. 4. PMMR-80	MI 500	MI 52	MI 530	6780	Preventive maintenance	1. Oil seal leak. 2. Part replaced. 3. None.
23	1. Transmission and Drive Shaft/Cable Drive Clutch 2. Reactor Equipment/ Reactor Shielding 3. 12 213000	1. EBR-II 2. Small plug rotating drive 3. 4. Operation weekly report, 2/7/68	MI 500	MI 13	MI 550	1200	Operational monitor	1. Thermocouples were shorted by sodium leakage. 2. Part replaced. 3. None.
24	1. Transmission and Drive/Drive Gear 2. Heat Transfer/ Reactor Coolant 3. 12 221100	1. Fermi 2. No. 3 sodium pump, pony motor 3. 350 hp, 11,800 gpm, 900 rpm 4. EF-28	MI 148	MI 53	MI 530	13,930	Audio noise	1. Drive gear loose. 2. Local repair, tightened drive gear set screw. 3. Revise preventive maintenance inspection intervals to prevent unscheduled outage of equipment.
25.	1. Transmission and Drive/Follower Roller Shafts 2. Reactor Equipment/ Reactor Shielding 3. 12 213000	1. Fermi 2. Rotating shield plug drive 3. 4. PRDC-EF-6	MI 9ZZ	MI 54	MI 530	4015	Direct observation	1. Roller shafts bent. 2. Part replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS
(Sheet 6 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
26	1. Transmission/Clutch Support 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machines 3. 12 235110	1. EBR-II 2. Carriage drive-fuel unloading machine 3. - 4. PMMR-113, 11/67	MI 500	MI 59	MI 530	12,390	Direct observation	1. Support broken. 2. Local repair. 3. None.
27	1. Transmission/Storage Basket Drive Bearings 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. EBR-II 2. Primary system - ferguson drive 3. - 4. PMMR-102	MI 500	MI 52	MI 530	10,820	Routine inspection	1. Bearings worn out. 2. Part replaced. 3. None.
28	1. Transmission/Upper and Lower Radial Bearings 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal 3. 12 236100	1. Fermi 2. Sweep mechanism 3. - 4. EF-22	MI 114	MI 55	MI 530	11,740	During actuation	1. Upper drive mechanism bound up during folding of sweep arm. Lower radial bearing found frozen and shaft scored. 2. Provided manual operation during investigation. 3. An engineering review of the design should be undertaken to determine if a modification would prevent future malfunctions.
29	1. Transmission and Drives/Gear Reduction Unit 2. Nuclear Fuel Handling and Storage Equipment /Hoist 3. 12 235162	1. SRE 2. Fuel handling machine 3. - 4. Incident report, 5/12/62	MI 117	MI 73	MI 530	Unknown	During actuation	1. Gear reduction unit developed a series of brittle cracks. 2. Gear unit replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 7 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
30	1. Transmission Extension/Friction Compensator Shaft 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal (holddown) 3. 12 236100	1. EBR-II 2. Primary system/fuel handling subassembly holddown 3. 4. Operation weekly report, 1/10/68	MI 500	MI BZ	MI 530	13,380	Preventive maintenance	1. Shaft worn out. 2. Part replaced. 3. Revise preventive maintenance inspection interval to permit replacement before total failure.
31	1. Transmission Extension/Friction Compensator Bearings 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal (holddown) 3. 12 236100	1. EBR-II 2. Primary system/fuel handling assembly holddown 3. 4. Operation weekly report, 1/10/68	MI 500	MI BZ	MI 530	13,380	Preventive maintenance	1. Bearings worn out. 2. Part replaced. 3. Revise preventive maintenance inspection interval to permit replacement before total failure.
32	1. Transmission Extension/Friction Compensator Roll Pin 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal (holddown) 3. 12 236100	1. EBR-II 2. Primary system/fuel handling subassembly holddown 3. 4. Operation weekly report, 1/10/68	MI 500	MI BZ	MI 530	13,380	Preventive maintenance	1. Roll pin worn out. 2. Part replaced. 3. Revise preventive maintenance inspection interval to permit replacement before total failure.
33	1. Transmission/Push Force Mechanism Switch 2. Nuclear Fuel Handling and Storage Equipment/Liquid Metal Internal (holddown) 3. 12 236100	1. EBR-II 2. Primary system/fuel handling subassembly holddown 3. 4. Operation weekly report, 1/10/68	MI 500	MI 59	MI 530	13,380	Preventive maintenance	1. Backup switch broken. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 8 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
34	1. Transmission/Bellows 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Reactor control rod drive No. 7 3. 300 to 800°F 4. PMMR-74	MI 500	MI 59	MI 550	5990	Operational monitors	1. Bellows broken. 2. Part replaced. 3. Perform engineering study on cause of failure and make recommendations.
35	1. Transmission/Lower Drive Assembly 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Reactor control rod drive No. 6 3. 300 to 800°F 4. Operation weekly report, 12/20/67	MI 500	MI 55	MI 530	13,380	Operational monitors	1. Drive assembly inoperative. 2. Part replaced. 3. None.
36	1. Transmission/Bellows 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Mark II oscillator rod 3. 300 to 800°F 4. Operation maintenance report, 6/19/68	MI 500	MI BZ	MI 550	15,240	Direct observation	1. Found sodium in tube above bellows. 2. New spare control rod was installed in its place. 3. None.
37	1. Transmission and Drive Shafts/Drive Shaft 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Oscillator rod extension 3. Reactor environment 4. PRDC-EF-17	MI 328	MI 55	MI 530	9390	Direct observation	1. Axial binding attributed to a fragment of an old dust seal found in the upper housing. 2. Local repair. 3. Require more stringent inspection prior to closure of equipment and use proper assembly procedure.
38	1. Transmission and Drive Shafts/Bearing 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Reactor safety rod drive No. 7 3. 4. PRDC-EF-13	MI 500	MI 52	MI 530	7200	Direct observation	1. Badly worn shaft bearing. 2. Part replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 9 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
39	1. Transmission and Drive Shaft/Connection 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Safety rod extension No. 6 3. - 4. PRDC-EF-38	MI 324	MI 14	MI 530	14,941	During activation	1. Loose connection at terminal board caused safety rod flow speed drive motor to fail. 2. Local repair. 3. None.
40	1. Transmission and Drive Shafts/Extension Bellows 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Reactor system/No. 1 safety rod 3. - 4. PRDC-EF-13 and 14	MI 456	MI 67	MI 550	7930	Direct observation	1. Porosity in the flange weld at the bottom of the primary bellows resulted in a sodium leak. 2. Local repair. Rewelded flange. 3. Revise Quality Assurance procedures for acceptance of welds.
41	1. Transmission and Drive/Limit Switch 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Reactor system/No. 1 safety rod 3. - 4. PRDC-EF-15	MI 331	MI 59	MI 530	8660	Direct observation	1. Broken as a result of accidental movement between switches. 2. Part replaced. 3. Install protective brackets over switches to prevent inadvertent damage.
42	1. Transmission and Drive Shafts/Brake 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. Fermi 2. Safety rod drive 3. - 4. EFAPP-MR-45	MI 157	MI 13	MI 530	4913	Protective system	1. Drive brake inoperative. 2. Part replaced. 3. Revise preventive maintenance procedure to require inspection of drive brakes at schedule intervals.
43	1. Transmission/Bellows 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Reactor control rod drive No. 8 3. 300 to 800°F 4. PMMR-38	MI 500	MI 59	MI 530	2590	During preventive maintenance	1. Control rod bellows ruptured. 2. Part replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 10 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
44	1. Transmission/Bellows Reactivity 2. Reactor Equipment/ Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Reactor control rod drive No. 9 3. 300 to 800°F 4. ANL-7105	MI 500	MI 59	MI 550	3410	During inspection of system associated to failure component	1. Sodium leaked into area between bellows and gripper tube. 2. Part cleaned and freed. 3. None.
45	1. Transmission/Sensing Rod 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Reactor control rod drive 3. 300 to 800°F 4. ANL-7105	MI 500	MI 55	MI 550	3410	Operational monitors	1. Sodium leaked into area between bellows and gripper tube. 2. Part cleaned and freed. 3. None.
46	1. Transmission/Jaw Drive Clutch 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Control rod No. 3 3. 4. PMMR-102	MI 500	MI 59	MI 530	10,000	During routine inspection	1. Roll pins broken. 2. Part replaced. 3. None.
47	1. Transmission/Shaft 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Control rod No. 7 3. 4. ANL-6965	MA 500	MA BZ	MA 520	15,240	Direct observation	1. Clutch inoperative. 2. Part replaced. 3. None.
48	1. Transmission/Jaw Drive Clutch 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Control rod No. 9 3. 4. Operations monthly report, 9/18/68	MA 500	MA 55	MA 550	1200	Protective system	1. Control rod shaft was stuck in reactor vessel cover, and would not move even with air assistance. 2. Part replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 11 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
49	1. Transmission/Shaft 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Control rod No. 9 3. 4. ANL-6965	MA 500	MA 55	MA 550	1200	Protective system	1. Control rod shaft jammed. 2. Part replaced. 3. None.
50	1. Transmission/Clutch 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. EBR-II 2. Control rod No. 12 3. 4. Operations monthly report, 11/67	MI 500	MI 52	MI 530	12,000	During routine inspection	1. Clutch worn out. 2. Replaced with new unit. 3. Revise preventive maintenance inspection schedule to detect problem before total failure.
51	1. Transmissions and Drive Shafts/Snubbers 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod 3. 350 to 945°F 4. Monthly operating report No. 14	MI 137	MI 52	MI 530	4450	Operational monitors	1. Snubbers lost oil. 2. Corrective modification. 3. None.
52	1. Transmissions and Drive Shafts/Bushing 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod No. 2 3. 350 to 945°F 4. Monthly operating report No. 3	MI 337	MI 57	MI 530	1605	Direct observation	1. Bushing bent oblong, stopping rod movement. 2. Unknown. 3. None.
53	1. Transmission and Drive Shaft/Drive Unit 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod No. 8 3. 350 to 925°F 4. Monthly operating report No. 7	MI 500	MI BZ	MI 530	3250	Direct observation	1. Drive unit inoperative. No reason given. 2. Part replaced. 3. None.
54	1. Transmissions and Drive Shafts/Snubbers 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod No. 10 3. 350 to 945°F 4. Monthly operating report No. 24	MI 500	MI BZ	MI 550	8700	Direct observation	1. Unknown. 2. Part replaced. 3. None.

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TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS
(Sheet 12 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
55	1. Transmission and Drive Shafts/Snubbers 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod No. 10 3. 350 to 945°F 4. Monthly operating report No. 24	MI 500	MI BZ	MI 550	8700	Direct observation	1. Unknown. 2. Part replaced. 3. None.
56	1. Transmissions and and Drive Shafts/ Mechanical Interlock 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/automatic flux control rod No. 14 3. 350 to 945°F 4. Monthly operating report No. 6	MI 33Z	MI 55	MI 530	3250	Operational monitors	1. Mechanical interlock jammed. 2. Local repair. 3. Replace with better quality contactors. Weekly inspection to be performed.
57	1. Transmissions and Drive Shafts/Rod Actuator Brake Shoe 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor/control rod No. 18 3. 350 to 945°F 4. Monthly operating report No. 21	MI 31Z	MI A5	MI 550	8320	Operational monitors	1. Evidence of grease on brake shoes, causing slow release and sluggish drive. 2. Part replaced. 3. None.
58	1. Transmissions and Drive Shafts/Shaft Seal 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod CR-19 3. 350 to 945°F 4. Monthly operating report No. 20	MI 12Z	MI 5Z	MI 530	7754	Direct observation	1. Oil observed on brake disk caused by leaking shaft seal. 2. Part replaced. 3. None.
59	1. Transmission and Drive Shafts/Pull Tubes 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod SN-20 3. 350 to 945°F 4. Monthly operating report No. 25	MI 178	MI 5Z	MI 550	9420	Direct observation	1. Pull tubes elongated due to unsnubbed drops. 2. Unknown. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-50

FAILURE DATA FOR TRANSMISSIONS AND DRIVE SHAFTS

(Sheet 13 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
60	1. Transmissions and Drive Shafts/Snubbers 2. Reactor Equipment/ Reactivity Control and Safety Shutdown 3. 12 212300	1. HNPF 2. Reactor core/control rod SN-20 3. 350 to 945°F 4. Monthly operating report No. 24	MI 321	MI 54	MI 550	4450	Direct observation	1. Assembly error, no snubbers were installed in control rod. 2. Snubbers added. 3. None.

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TABLE 1-51

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TRANSMISSIONS AND DRIVE SHAFTS

COMPONENT SUBTYPE TRANSMISSIONS AND DRIVE SHAFTS

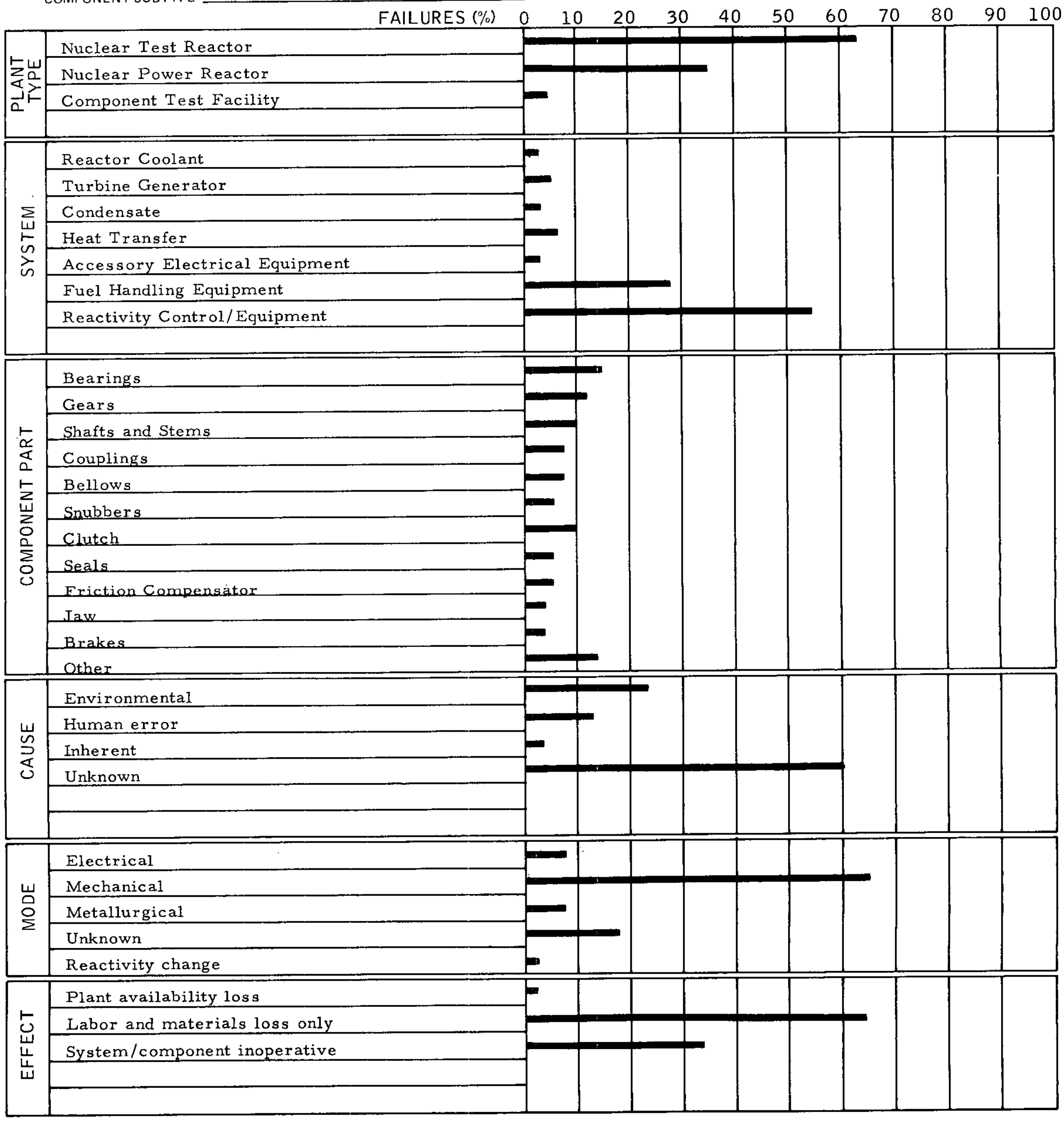
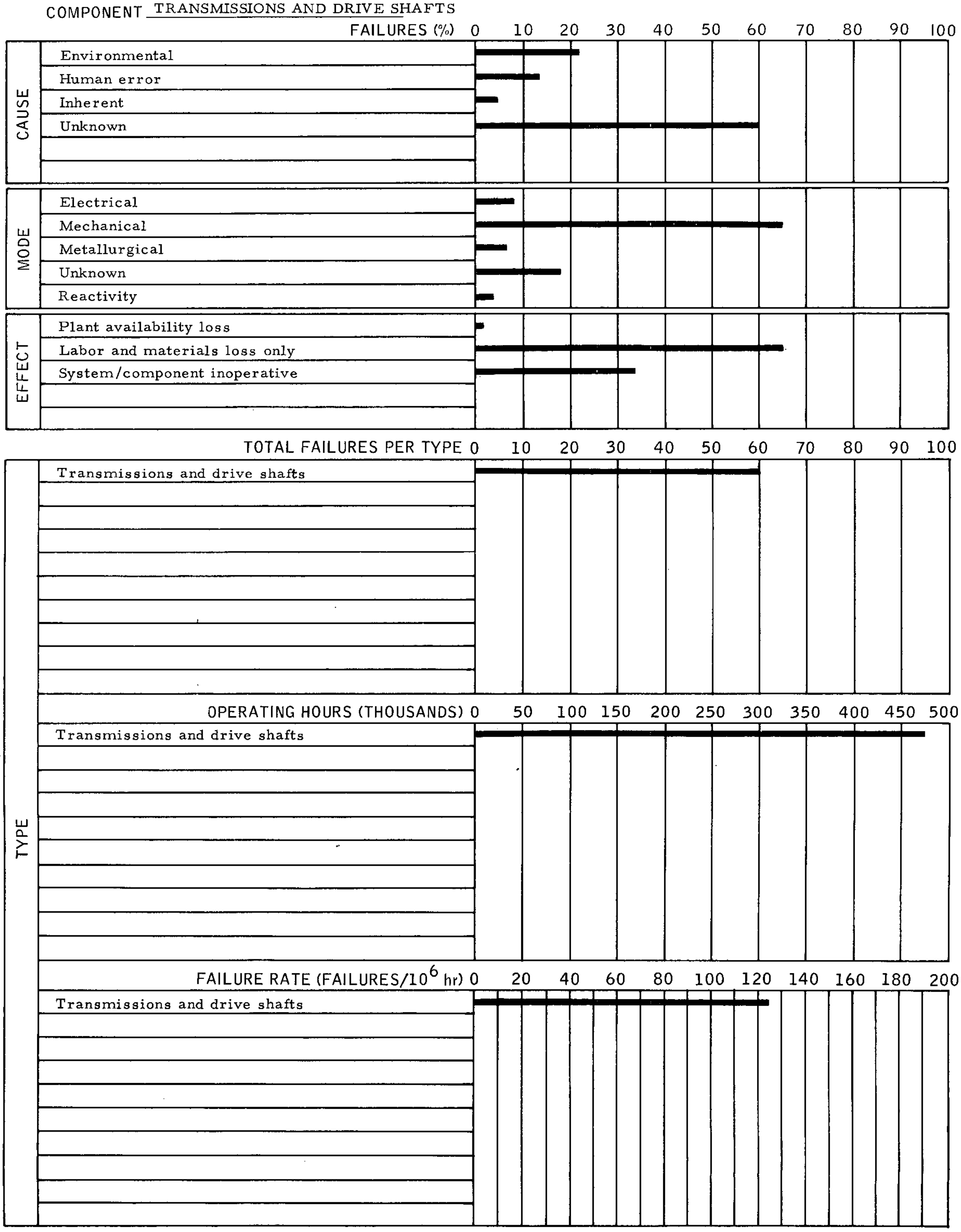


TABLE 1-52

GENERAL SUMMARY

COMPONENT TRANSMISSIONS AND DRIVE SHAFTS



4. Turbine Generators (turbine side)

Failure data for turbine generators (turbine side) are presented in Tables 1-53 through 1-55.

a. Reliability Information

Design Features:

Large rotating machinery normally designed for long-term trouble-free operation.

Critical Characteristics:

Multi-stage turbine, long thin blading, close running clearances.

Mode of Failure:

1) Steam flange leaks
2) Seal ring
3) Blade damage
4) Control malfunctions.

Description of Failures:

1) Leakage at steam turbine flange with cause undescribed.
2) Section of broken seal ring caused blade damage.
3) Pressure governor malfunctioned apparently due to misalignment developing and resulting in control problems.

Control Methods:

1) Preventive maintenance - check and retorque flange bolts, particularly after failures which may cause increased system vibration.
2) Maintain accelerometer surveillance of large equipment to detect failures.
3) Ensure running clearances are in accordance with supplier recommendations.

4) Perform analysis to establish metallurgical cause of failure.

5) Maintain adequate servicing of controls to prevent corrosion, inadequate lubrication, and contamination.

b. Discussion and Recommendations

A total of three failure events were reviewed. The failures fell into three categories: (1) leakage, (2) mechanical, and (3) control malfunction.

A steam leak on the vertical flange of the main turbine was reported. The report did not indicate whether the leakage was at the flange joint or in the flange parent metal. It is assumed that the leakage occurred at the joint. Leakage at the flange joint could be caused by (1) thermal cycling and differential expansion which would reduce the flange loading and allow leakage, or by (2) vibration causing loosening of the flange bolts. This particular leakage did occur after a reported turbine blade failure. There is good possibility that the increased vibration coupled with thermal stress could have resulted in the flange leakage. After turbine difficulties it would be in order to torque check all bolted flange connections.

A mechanical failure of the seal ring was reported. A piece of the seal ring broke from the turbine casing causing extensive blade damage. However, it is possible that a blade failure caused the seal ring damage. Assuming the seal ring to be at fault, the failure probably occurred as a result of excessive rubbing between the ring and rotating assembly. The rubbing may have occurred at startup, damaging the ring, so that subsequent vibration and pressure loading and even light rubbing eventually resulted in the failure. There is no indication as to when the failure occurred, only when it was observed. In any case, it appears as though a design change is in order to prevent future problems. Opening the running clearances is one possible remedy for this type of problem. There is also the possibility of faulty material which would indicate a quality control problem.

The use of a vibration meter with a recorded output and surveillance of the records might have indicated the time of failure and possibly given indications of an impending failure, depending upon how the failure progressed.

A control malfunction was reported. The governor pressure control apparently experienced a performance shift which caused difficulties in controlling the header pressure. The problem was solved by readjusting and realigning the governor.

The performance shift could have been caused by (1) vibration loosening the adjustment mechanism, (2) improper or inadequate lubrication, (3) mechanical stress, and (4) improper maintenance and lack of cleaning.

Since it is not known what was accomplished during the readjustment and realignment, it is difficult to make a recommendation.

TABLE 1-53

FAILURE DATA FOR TURBINE GENERATORS (TURBINE SIDE)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Turbine-Generator/ Flange 2. Turbine-Generator Units/Turbine Side 3. 55 310000	1. EBR-II 2. Main turbine/vertical flange 3. 20,000 kw, 3,600 rpm 4. PMMR-91	MI 500	MI BZ	MI 550	8,732	Direct observation	1. Steam leak on main turbine flange 2. Local repair to be attempted – apparently successful because turbine put back in service. 3. Following any turbine problems of increasing vibration recheck turbine flange connections – tighten bolts.
2	1. Turbine-Generator/ Spill Strip Casing 2. Turbine-Generator Units/Turbine Side 3. 55 310000	1. EBR-II 2. Main turbine 3. 20,000 kw, 3,600 rpm 4. ANL7255, PMMR-85	MA 500	MA 53	MA 520	7,800	Routine inspection	1. Portion of seal ring broke from turbine causing extensive blade damage. 2. The supplier representative (GE) replaced or repaired all questionable blading. 3. Increase running clearance of seal ring if possible – clean steam system – incorporate vibration meter with visual read out chart or electronic alarm red line – determine blade fatigue not problem – determine ring material is sound.
3	1. Turbine-Generator/ Governor 2. Turbine-Generator Units/Turbine Side 3. 55 310000	1. EBR-II 2. Main turbine 3. 20,000 kw, 3,600 rpm 4. PMMR-113	MI 500	MI 43	MI 550	12,390	Operational monitors	1. Pressure governor malfunction causing difficulties in controlling steam header pressure. 2. Governor was realigned and reset at facility. 3. Improve maintenance procedures – check for cleanliness of mechanism, corrosion, lubrication – check to ensure vibration is not loosening adjustment mechanism.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-54

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TURBINE GENERATOR (TURBINE SIDE)

COMPONENT SUBTYPE TURBINE GENERATOR (TURBINE SIDE)

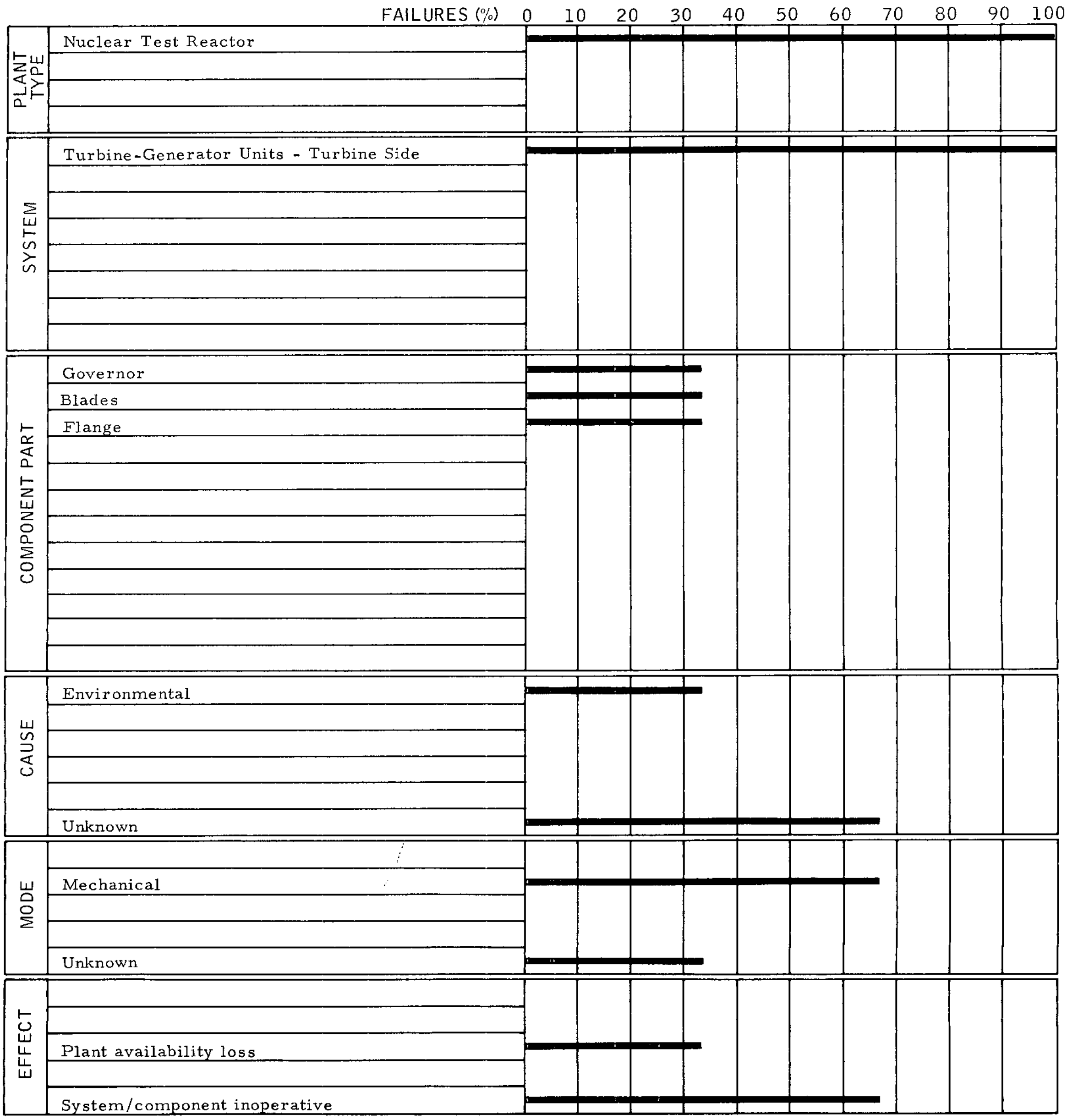
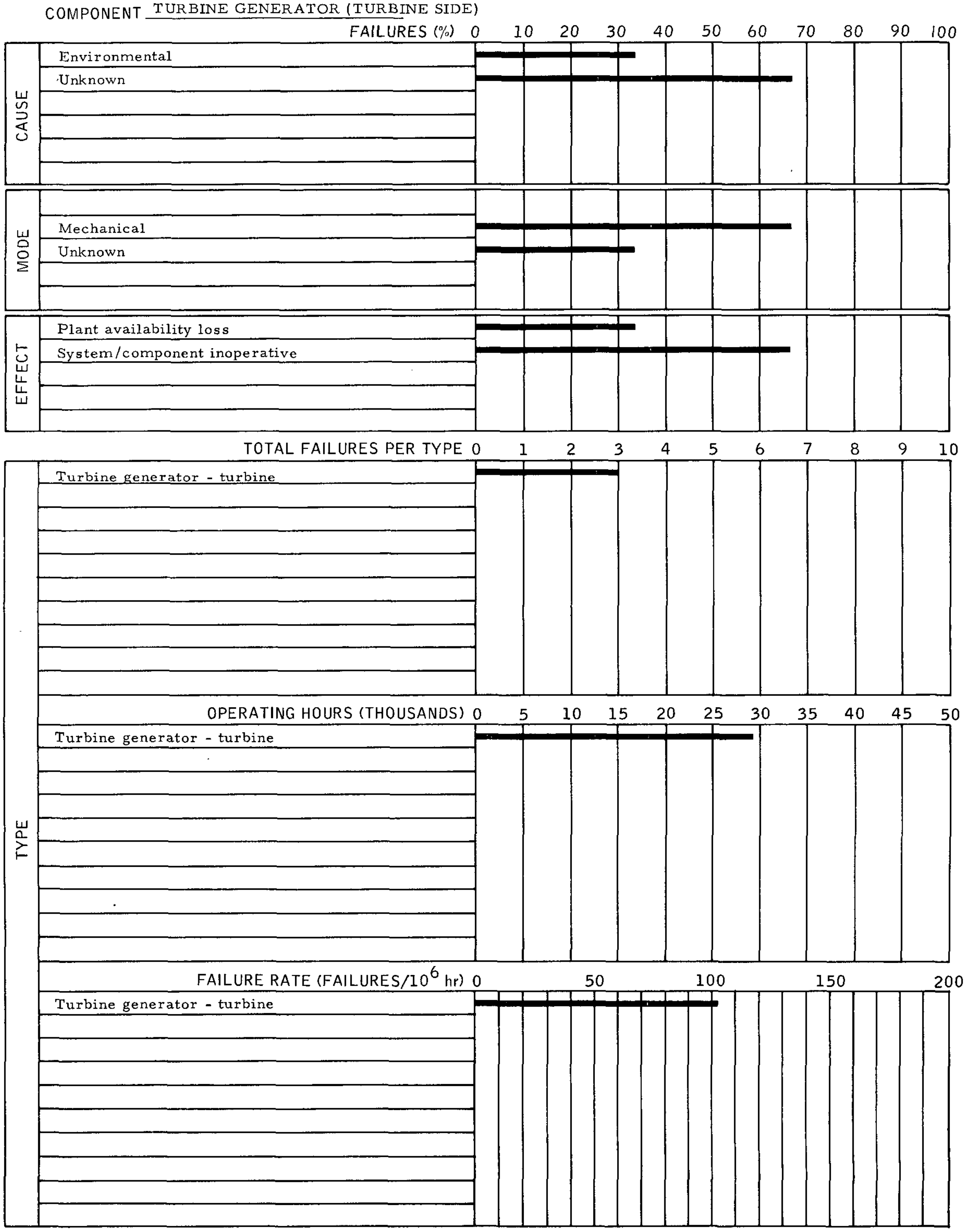


TABLE 1-55

GENERAL SUMMARY

COMPONENT TURBINE GENERATOR (TURBINE SIDE)



5. Valve Operators (See Figures 1-4 and 1-5)

Failure data for valve operators are presented in Tables 1-56 through 1-58.

a. Reliability Information

Design Features:

Pneumatic cyclinder is used to open and close valves.

Critical Characteristics:

1) Cylinder seals
2) Packing gland and valve stem assembly
3) Coupling between actuator and valve.

Failure Description:

1) Dirt or paint on stem
2) Stem bent
3) Improper packing techniques
4) Wrong type of packing
5) Actuator moving too fast
6) Improper repair and/or assembly and/or installation
7) Water in cylinders.

Control Methods:

1) Clean actuator stems.
2) Break packing joint alignment.
3) Install packing rings with care.
4) Tighten up packing evenly.
5) Verify that packing is of right size and material.
6) Install orifices in actuation system to control timing.
7) Write repair, assembly, and installation checklists and detailed procedures if necessary.
8) Install water traps and filters in air system.

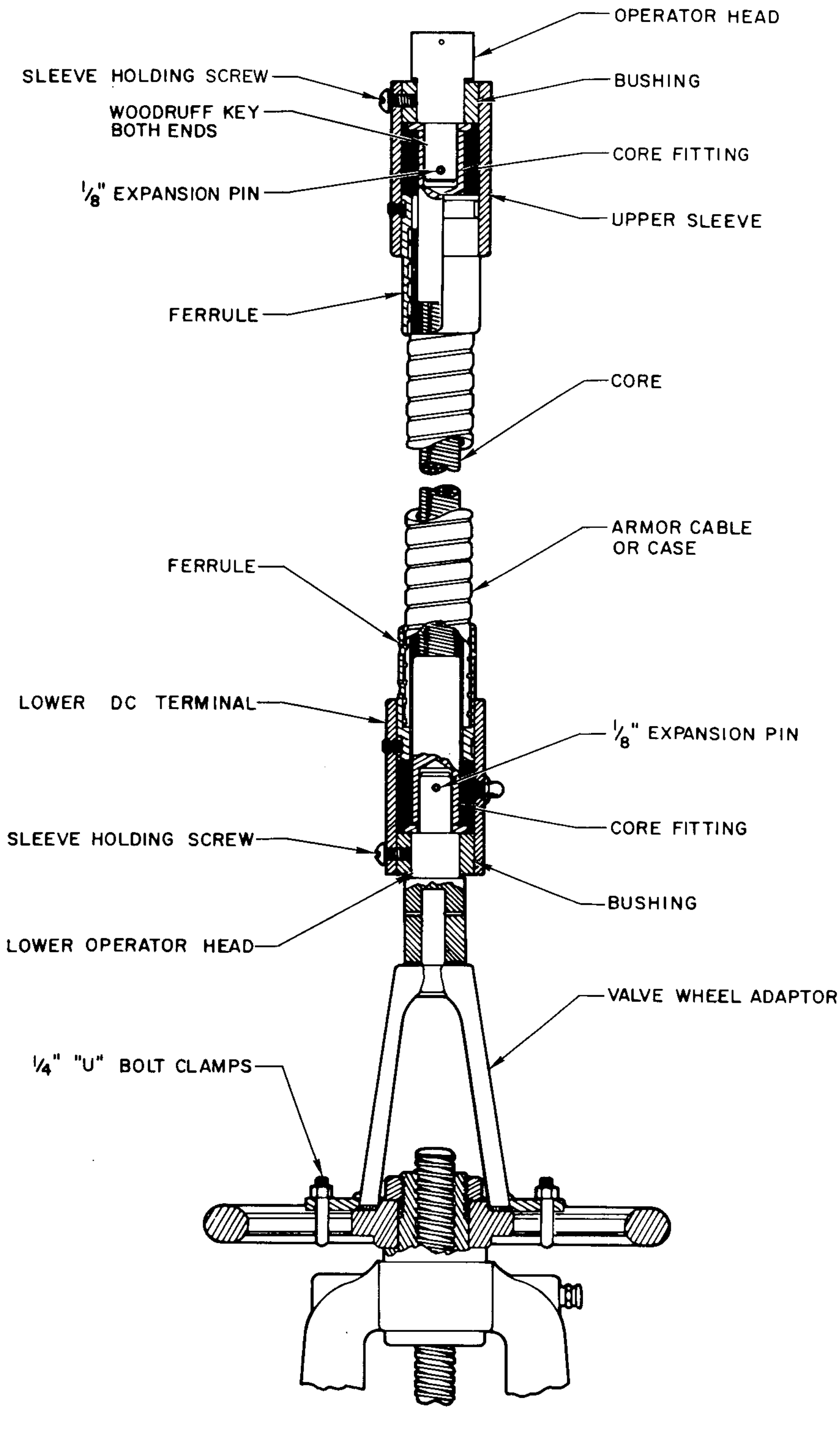


Figure 1-4. Remote Valve Operator

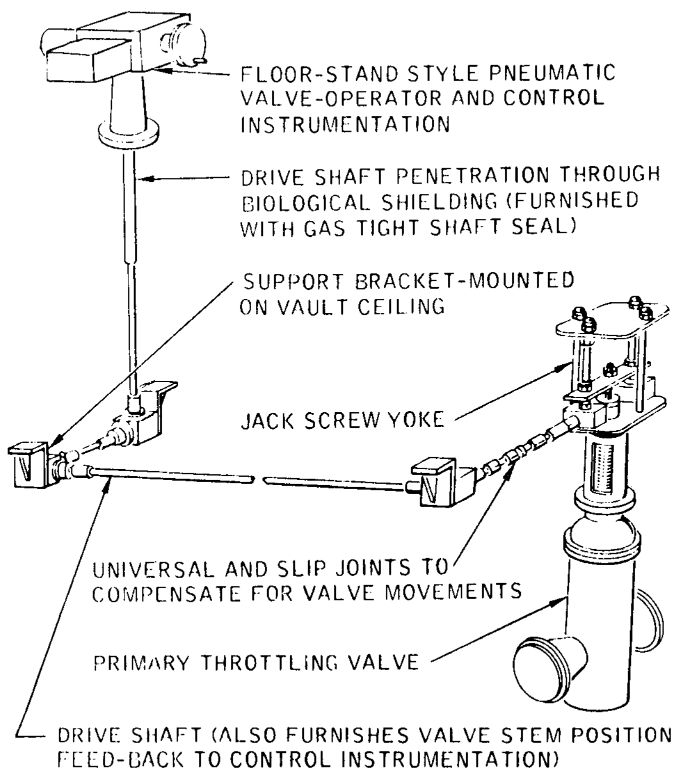


Figure 1-5. Typical Remote Valve Operator and Drive Shaft

b. Discussion and Recommendations

Remote valve operators (see Figure 1-5) are generally required in sodium systems for reasons of accessibility limitations. The nuclear radiation field in which the valve operator may function must be considered to ensure that lubricants and electrical insulation will not suffer deterioration. Stem force must be controlled in order not to exceed any structural limitations to the valve. Frictional losses associated with either flexible drive shafts or solid mechanical drive trains interconnected to gear boxes, universal joints and couplings must be allowed for, when establishing power actuating requirements. Allowances should also be made for pipe deflections and valve motion relative to the drive shafts. Where closing or opening speed is high, the valve design must have adequate provision for reducing the transient forces by the use of energy-absorption devices.

Failures to either the coupling or universal joint were high. It was concluded that the original design did not adequately consider the forces involved and did not provide for thermal growth. The timing of the actuator was off, and orifices installed in the system would have provided more positive control. Water was found in the cylinders. This could have been prevented if the system were designed with traps to prevent the collection of moisture in areas that harm the system.

There were many failures during installation or while personnel were working in the area. These included the disengaging of shafts from their couplings, the shearing of pins, breaking of keys, bent stems, repair and replacement of gears and clutches, and improper choice of packing and its installation. This situation could be improved with better design, more training for personnel, and more complete installation and maintenance procedures.

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 1 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Valve Operator/ Shaft 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (block valve) V-101 3. Gas cooled freeze seal gate, 14 in., ambient temperature 4. HNPF, work request No. 1742	MA 110	MA 53	MA 530	2784	Direct observation (unscheduled)	1. Shaft rising and disengaging from coupling. 2. Local repair, tack welded shaft to coupling. 3. None.
2	1. Valve Operator/ Shaft 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (block valve) V-201 3. Gas cooled freeze seal gate, 14 in., ambient temperature 4. HNPF, work request No. 1742	MA 110	MA 53	MA 530	2784	Direct observation (unscheduled)	1. Shaft rising and disengaging from coupling. 2. Local repair, tack welded shaft to coupling. 3. None.
3	1. Valve Operator/ Shaft 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (block valve) V-301 3. Gas cooled freeze seal gate, 14 in., ambient temperature 4. HNPF, work request No. 1742	MA 110	MA 53	MA 530	2784	Direct observation (unscheduled)	1. Shaft rising and disengaging from coupling. 2. Local repair, tack welded shaft to coupling. 3. None.
4	1. Valve Operator/ Key 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-203 3. Ambient temperature 4. S. Berger, et al, HNPF, Reactor Operations Analysis Program Semi-Annual Progress Report No. 4, Feb. 29, 1964-Sept. 30, 1964, NAA-SR-10743	MI 126	MI 59	MI 530	14,208	Operational monitors	1. Part broken. 2. Part replaced. 3. None.
5	1. Valve Operator/ Key 2. Heat Transfer/Intermediate Coolant Piping and Valves 3. 21 222230	1. HNPF 2. Secondary (throttle) V-102 3. Ambient temperature 4. HNPF, work request No. 2490	MA 126	MA 55	MA 520	5836	Operational monitors	1. Park broken. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 2 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
6	1. Valve Operator/ Clutch and Gear Box 2. Heat Transfer/Intermediate Coolant Piping and Valves 3. 21 222230	1. HNPF 2. Secondary (throttle) V-102 3. Ambient temperature 4. HNPF, work request No. 2526	MA 126	MA 55	MA 520	5932	Alarm	1. Dogs on both clutch and gears were sheared off. 2. Part replaced. 3. None.
7	1. Valve Operator/ Gear Box 2. Heat Transfer/Intermediate Coolant Piping and Valves 3. 21 222230	1. HNPF 2. Secondary (throttle) V-302 3. Ambient temperature 4. HNPF, work request No. 1932	MI 126	MI 52	MI 530	2640	During preventive maintenance	1. Broken part. 2. Local repair, replaced with new gear and gaskets. 3. None.
8	1. Valve Operator/ Gear Box 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (fill and drain) V-461 3. Ambient temperature 4. HNPF, work request No. 949	MI 110	MI 55	MI 530	24	Direct observation (unscheduled)	1. Would not open or close. 2. Local repair, repaired gear box. 3. None.
9	1. Valve Operator/ Gear Box 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (fill and drain) V-462 3. Ambient temperature 4. HNPF, work request No. 949	MI 110	MI 55	MI 530	24	Direct observation (unscheduled)	1. Would not open or close. 2. Local repair, repaired gear box. 3. None.
10	1. Valve Operator/ Gear Box 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (reactor inlet) V-002 3. Ambient temperature 4. HNPF, work request No. 2397	MI 126	MI 52	MI 530	6790	During preventative maintenance	1. Would not open or close. 2. Local repair, repaired gear box. 3. None.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 3 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
11	1. Valve Operator/ Clutch Assembly Gears 2. Heat Transfer/Intermediate Coolant Piping and Valves 3. 21 222230	1. HNPF 2. Secondary (throttle) V-302 3. Ambient temperature 4. HNPF, work request No. 814	MI 126	MI 59	MI 530	24	During actuation	1. Clutch assembly broken. 2. Local repair, replaced damaged clutch assembly with assembly from No. 3 primary valve. 3. None.
12	1. Valve Operator/ Gears 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-303 3. Ambient temperature 4. HNPF, work request No. 959	MI 321	MI 59	MI 530	48	During actuation	1. Gears and shaft jammed. 2. Local repair, replaced damaged parts. 3. None.
13	1. Valve Operator/ Jack Screw 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-103 3. Ambient temperature 4. HNPF, work request No. 2852	MI 110	MI 55	MI 530	7200	During preventive maintenance	1. Movement obstruction (working stress). 2. Local repair, increased size of jack screw penetration. 3. Redesign of drive mechanism of valve.
14	1. Valve Operator/ Jack Screw 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-203 3. Ambient temperature 4. HNPF, work request No. 2857	MI 110	MI 55	MI 530	7440	During preventive maintenance	1. Movement obstruction (working stress). 2. Local repair, increased size of jack screw penetration. 3. Redesign of drive mechanism of valve.
15	1. Valve Operator/ Jack Screw 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-303 3. Ambient temperature 4. HNPF, work request No. 2857	MI 110	MI 55	MI 530	7992	During preventive maintenance	1. Movement obstruction (working stress). 2. Local repair, increased size of jack screw penetration. 3. Redesign of drive mechanism of valve.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 4 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
16	1. Valve Operator/ Jack Spindle 2. Heat Transfer/Intermediate Coolant Piping and Valves 3. 21 222230	1. HNPF 2. Secondary (throttle) V-202 3. Ambient temperature 4. HNPF, shift leader's log book, 2/23/63	MA 126	MA 59	MA 520	5880	Direct observation (unscheduled)	1. Keys in gear to jack spindle sheared. 2. Jack spindle sent to vendor for rework. 3. Redesign of drive mechanism of valve.
17	1. Valve Operator/ Roll Pins 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (block valve) V-201 3. Ambient temperature 4. HNPF, work request No. 3446	MA 416	MA 59	MA 520	4320	Direct observation (unscheduled)	1. A dowel pin in the valve operator gear train sheared. 2. Local repair, replaced pin. 3. Increase pin diameter.
18	1. Valve Operator/ Key 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-103 3. Ambient temperature 4. HNPF, monthly operating report, No. 10098	MI 126	MI 59	MI 530	13,536	Operational monitors	1. Key broke (improper differential motion). 2. Park replaced. 3. None.
19	1. Valve Operator/ Drive Shaft 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (throttle) V-103 3. Ambient temperature 4. HNPF, monthly operating report, No. 10098	MI 149	MI 68	MI 530	13,536	Operatinal monitors	1. Shaft scored (improper differential motion). 2. Part replaced. 3. None.
20	1. Valve Operator/ Universal Joint 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (block) V-457 3. Ambient temperature 4. HNPF, work request No. 1915	MI 475	MI 59	MI 530	3600	During actuation	1. Broken during actuation. 2. Local repair. 3. Change to stainless steel type.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 5 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
21	1. Valve Operator/ Universal Joint 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221200	1. HNPF 2. Primary (drain) V-464 3. Ambient temperature 4. HNPF, work request No. 963	MI 110	MI 59	MI 530	48	Direct observation	1. Broken universal joint. 2. Local repair. 3. Change to stainless steel type.
22	1. Valve Operator/ Universal Joint 2. Heat Transfer/Liquid Metals Purification 3. 21 224235	1. HNPF 2. Primary (plugging meter inlet) V-443 3. Ambient temperature 4. HNPF, work request No. 2665	MI 410	MI 59	MI 530	7656	During actuation	1. Broken universal joint. 2. Part replaced with stainless steel type. 3. None.
23	1. Valve Operator/ Universal Joint 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (drain tank outlet) V-482 3. Ambient temperature 4. HNPF, work request No. 1799	MI 410	MI 59	MI 530	3624	During actuation	1. Broken universal joint. 2. Part replaced. 3. Change to stainless steel type.
24	1. Valve Operator/ Universal Joint 2. Heat Transfer/Liquid Metals Purification 3. 21 224233	1. HNPF 2. Primary (cold trap inlet) V-447 3. Ambient temperature 4. HNPF, work request No. 1913	MI 410	MI 59	MI 530	3750	Direct observation	1. Broken universal joint. 2. Part replaced. 3. Change to stainless steel type.
25	1. Valve Operator/ Universal Joint 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (balancing drain leg) V-308 3. Ambient temperature 4. HNPF, work request No. 2825	MI 117	MI 53	MI 530	9432	Direct observation	1. Disconnection or loose universal joint. 2. Local repair (welded U-joints to shaft). 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 6 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
26	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (fill line) V-475 3. Ambient temperature 4. HNPF, work request No. 1984	MI 410	MI 59	MI 530	4416	During actuation	1. Broken universal joint. 2. Part replaced. 3. Change to stainless steel type.
27	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (sodium fill tank vent) V-419 3. Ambient temperature 4. HNPF, work request No. 2006	MI 410	MI 59	MI 530	4056	During actuation	1. Broken universal joint. 2. Part replaced. 3. Change to stainless steel type.
28	1. Valve Operator/ Universal Joint 2. Heat Transfer/Liquid Metals Purification 3. 21 224235	1. HNPF 2. Primary (plugging meter inlet) V-441 3. Ambient temperature 4. HNPF, work request No. 2048	MI 410	MI 59	MI 530	5064	During actuation	1. Broken universal joint. 2. Part replaced. 3. Replace with stainless steel type.
29	1. Valve Operator/ Universal Joint 2. Heat Transfer/Liquid Metals Purification 3. 21 224235	1. HNPF 2. Primary (cold trap inlet) V-449 3. Ambient temperature 4. HNPF, work request No. 2058	MI 126	MI 59	MI 530	5136	During actuation	1. Broken universal joint. 2. Part replaced with stainless steel type. 3. None.
30	1. Valve Operator/ Universal Joint 2. Heat Transfer/Primary Coolant Piping and Valves 3. 21 221230	1. HNPF 2. Primary (fill tank vent) V-425 3. Ambient temperature 4. HNPF, work request No. 2326	MI 410	MI 59	MI 530	5688	During actuation	1. Broken universal joint. 2. Part replaced with stainless steel type. 3. None.
31	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Liquid Metals Purification 3. 21 224235	1. HNPF 2. Primary (cold trap inlet) V-449 3. Ambient temperature 4. HNPF, work request No. 1322	MI 126	MI 59	MI 530	2160	During actuation	1. Broken universal joint. 2. Part replaced. 3. Replace with stainless steel type.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 7 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
32	1. Valve Operator/ Universal Joint 2. Heat Transfer/Liquid Metals Purification 3. 21 224235	1. HNPF 2. Primary (plugging meter outlet) V-444 3. Ambient temperature 4. HNPF, work request No. 1797	MI 410	MI 59	MI 530	3600	During actuation	1. Broken universal joint. 2. Part replaced. 3. Replace with stainless steel type.
33	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/fill and drain V-465 3. Ambient temperature 4. Work request No. 1510	MI 475	MI 59	MI 530	1872	During actuation	1. Broken universal joint. 2. Local repair, replaced U-joint and shear pins. 3. Replace with stainless steel type.
34	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/block V-457 3. Ambient temperature 4. Work request No. 1912	MI 475	MI 59	MI 530	3600	During actuation	1. Broken universal joint. 2. Local repair, replaced with stainless steel joint. 3. None.
35	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/block V-458 3. Ambient temperature 4. Work request No. 1914	MI 475	MI 59	MI 530	3600	During actuation	1. Broken universal joint. 2. Local repair, replaced with stainless steel joint. 3. None.
36	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/block V-456 3. Ambient temperature 4. Work request No. 1915	MI 475	MI 59	MI 530	3572	During actuation	1. Broken universal joint. 2. Local repair, replaced with stainless steel joint. 3. None.
37	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/drain V-463 3. Ambient temperature 4. Work request No. 1916	MI 475	MI 59	MI 530	3572	During actuation	1. Broken universal joint. 2. Local repair, replaced with stainless steel type. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 8 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
38	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/drain V-464 3. Ambient temperature 4. Work request No. 1922	MI 475	MI 59	MI 530	3572	During actuation	1. Broken universal joint. 2. Local repair, replaced with stainless steel type. 3. None.
39	1. Valve Operator/ Universal Joint 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. HNPF 2. Primary/drain V-464 3. Ambient temperature 4. Work request No. 1472	MI 110	MI 59	MI 530	1800	Direct observation	1. Broken universal joint. 2. Local repair, replaced universal joint. 3. Replace with stainless steel type.
40	1. Valve Operator/ Air Line 2. Heat Transfer/ Intermediate Coolant 3. 21 222230	1. SCTI 2. Secondary sodium system 3. - 4. Incident report No. 77	MI 479	MI 51	MI 110	115	Direct observation	1. Foreign object blocking air line, jammed operator. 2. Instrument air lines were cleaned. 3. All air lines between compressors and operators should be blown free prior to installation.
41	1. Valve Operator/ Coupling 2. Heat Transfer/ Liquid Metals Purification 3. 21 224230	1. SRE 2. Main primary/sodium service 3. Ambient temperature 4. Operations log book No. 6, p 70	MI 120	MI 59	MI 530	3600	Direct observation	1. Weak solder joint broken. 2. Part replaced. 3. Use welded steel parts.
42	1. Valve Operator/ Gear 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. SRE 2. Auxiliary primary/sodium 3. Ambient temperature 4. Operations log book No. 13, p 106	MI 120	MI 51	MI 530	17,300	Direct observation	1. Gear broken. 2. Part replaced. 3. None.
43	1. Valve Operator/ Shear Pin 2. Heat Transfer/ Liquid Metals Purification 3. 21 224230	1. SRE 2. Main primary/sodium service 3. Ambient temperature 4. Operations log book No. 39, p 75	MI 120	MI 51	MI 530	12,250	Direct observation	1. Shear pin broke three times. 2. Corrective modification (welded). 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-56

FAILURE DATA FOR VALVE OPERATORS

(Sheet 9 of 9)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
44	1. Valve Operator/ Threaded Spindle 2. Heat Transfer/ Primary Coolant 3. 21 221230	1. SRE 2. Main primary 3. Ambient temperature 4. Operations log book No. 36, p 183	MI 126	MI 50	MI 530	9700	Direct observation	1. Stripped threads. 2. Part replaced. 3. None.
45	1. Valve Operator/ Operator 2. Steam, Condensate and Feedwater Piping and Equipment/Steam 3. 21 282000	1. EBR-II 2. Auxiliary steam supply valve (P3-VC-627B) 3. 1250 to 1265 psig 4. ANL-6965	MI 500	MI 55	MI 550	1200	Operational monitors	1. Valve tended to open fully when stem position reached half open and seemed to stick in full open position. 2. Part replaced with a larger operator. 3. None.
46	1. Valve Operator/ Position Control Rod 2. Steam, Condensate and Feedwater Piping and Equipment/Valves 3. 21 283300	1. EBR-II 2. Condensate storage tank (P3-UC-615B) 3. 840°F, 1500 psig 4. PMMR-58	MI 500	MI 59	MI 530	4544	Direct observation	1. Position control rod broken. 2. Part replaced. 3. None.
47	1. Valve Operator/ Coupling 2. Nuclear Fuel Handling and Storage Equip-ment/Cooling 3. 21 235140	1. EBR-II 2. Fuel unloading machine cooling system (V-"A") 3. - 4. PMMR-56, 12/65	MI 500	MI 59	MI 530	4400	Operational monitors	1. Coupling broken. 2. Part replaced. 3. None.
48	1. Valve Operator/ Cylinder 2. Steam, Condensate and Feedwater Piping and Equipment/Valve 3. 21 284300	1. EBR-II 2. Feedwater/motor driven feed pump (P5-VC-596) 3. 364°F, 1500 psig 4. PMMR-107	MI 500	MI 52	MI 59	1500	Operational monitors	1. An air leak in the valve operator cylinder caused the valve malfunction. 2. Local repair. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-57

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVE OPERATORS

COMPONENT SUBTYPE VALVE OPERATORS

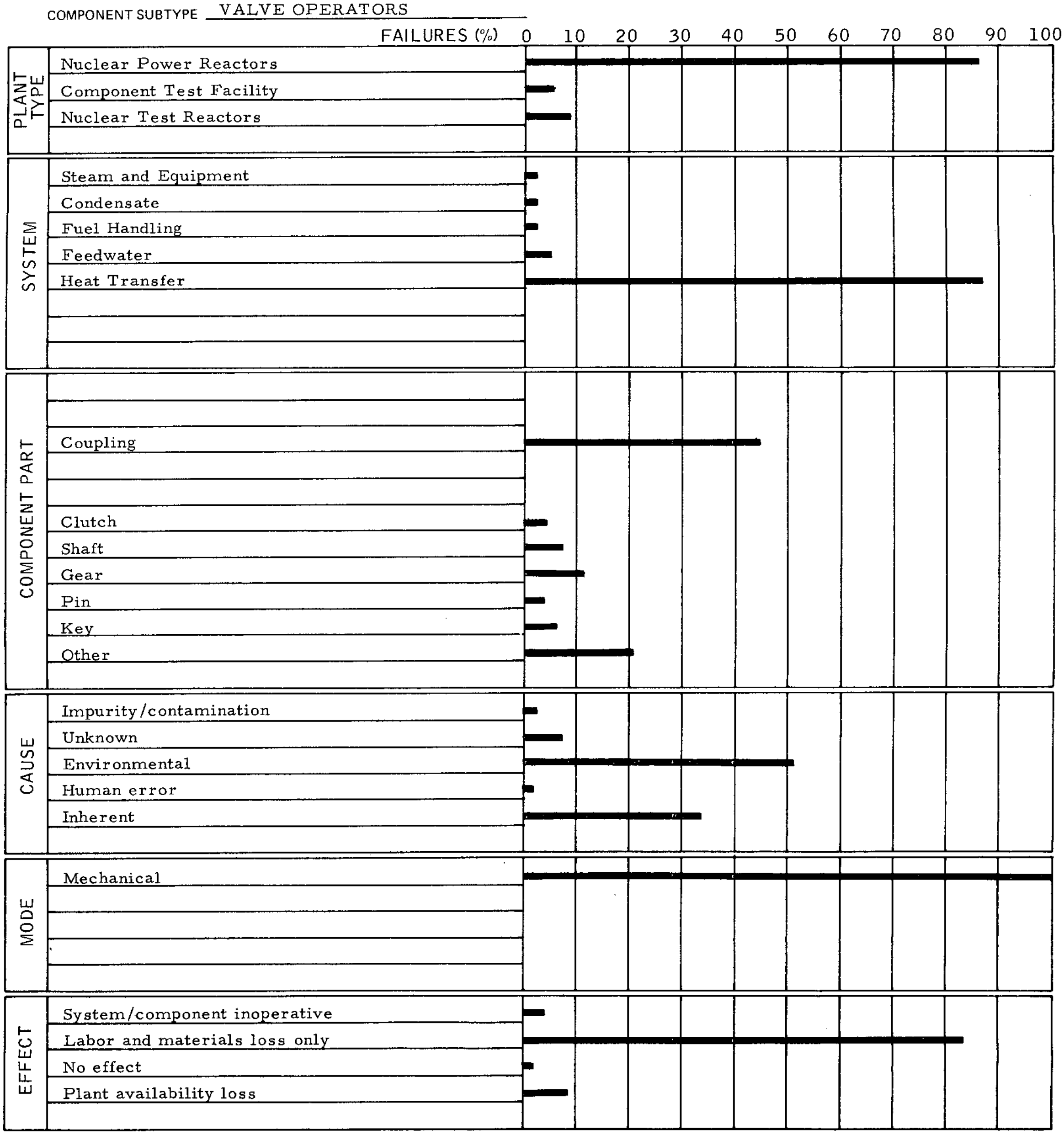
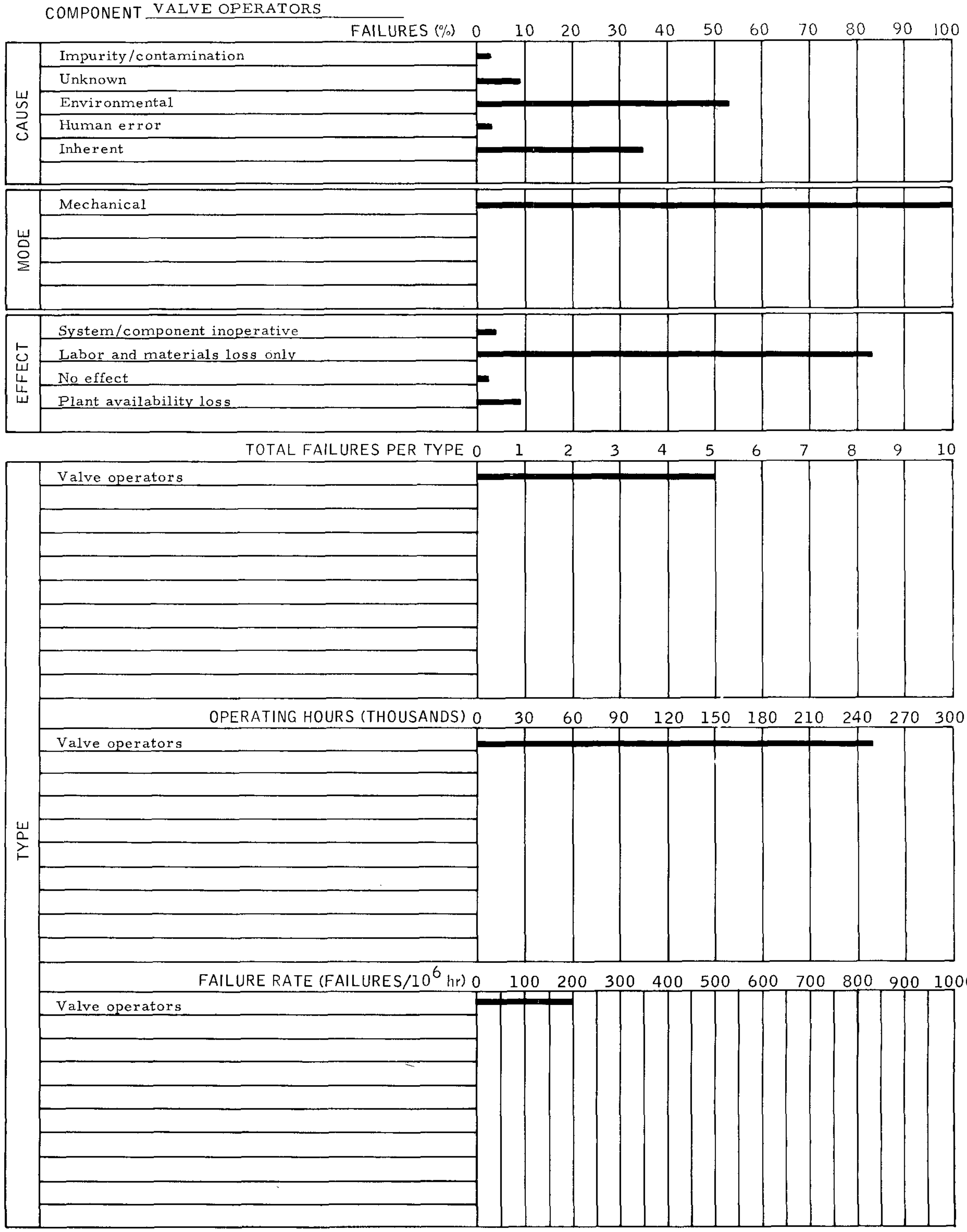


TABLE 1-58

GENERAL SUMMARY

COMPONENT VALVE OPERATORS



E. FUEL HANDLING AND CORE COMPONENTS

1. Fuel and Breeder Elements

Failure data for fuel and breeder elements are presented in Tables 1-59 through 1-61.

a. Reliability Information

Design Features:

Fuel elements are designed to prevent fuel, breeder, and fission product material from contaminating the primary coolant.

Critical Characteristics:

Heat transfer and burn-up limitations.

Mode of Failure:

1) Pin holes developed releasing fission products.
2) Fuel swelling due to excess burn-up.
3) Fabrication defects in cladding undetected until insertion in reactor core.
4) Cladding scratched due to improper handling.
5) Fuel melting.
6) Thermocouple shorted.
7) Orifice drive cables stuck or broken.

Failure Description:

1) Inadequate quality control permits faulty elements to be used.
2) Improper handling procedures result in damage to elements during loading or unloading.
3) Plugging of fuel channels by loose foreign material causes fuel melting.
4) Thermocouple failure due to improper attachment method or excessive vibration.
5) Adjustable fuel bundle orifices in sodium have not yet been proven practical.

Control Methods:

1) Thermocouples, fission product monitors, and other devices which give warning of overheated fuel should be fast responding and readily visible to the console operator.

2) Quality control inspection and test procedures should be as explicit as cost trade-off will permit.

3) Loading and unloading proceeds should be carefully developed and take into consideration such problems as soaking time, dripping time, alignment, cover gas purity, and cooling adequacy.

b. Discussion and Recommendations

None.

TABLE 1-59

FAILURE DATA FOR FUEL AND BREEDER ELEMENTS

(Sheet 1 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Fuel Subassembly/Rod 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. Fermi 2. Reactor Core/M-098 3. Reactor Environment 4. PRDC-EF-47	MA 111	MA A3	MA 520	14,941	Operational monitors	1. Fuel melting in subassembly. 2. Part replaced. 3. None.
2	1. Fuel Subassembly/ Exterior Can Wall 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. Fermi 2. Reactor Core/M-122 3. Reactor Environment 4. EF-50	MA 111	MA A1	MA 520	14,941	Direct observation	1. A large part of the exterior can wall surface was found to be covered with uranium which had alloyed with the steel. 2. Part replaced. 3. None.
3	1. Fuel Subassembly/Rod 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. Fermi 2. Reactor Core/M-127 3. 550°F to 800°F 4. PRDC-EF-47	MA 111	MA A3	MA 520	14,941	Operational monitors	1. Fuel melting in subassembly. 2. Part replaced. 3. None.
4	1. Fuel Subassembly/ Wrapper 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. Fermi 2. Reactor Core/M-140 3. 550°F to 800°F 4. EF-38 and EF-46	MA 176	MA A1	MA 520	14,941	Operational monitors	1. Wrapper can distorted. 2. Part replaced. 3. None
5	1. Fuel Element/Orifice Drive Cable 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. Reactor core/element MF-81 3. Reactor Environment 4. Monthly operating report No. 28	MA 172	MA 59	MA 550	10,130	Director observation	1. Orifice drive cable assembly broke at coupling. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-59

FAILURE DATA FOR FUEL AND BREEDER ELEMENTS

(Sheet 2 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Fuel Assembly/ Thermocouple 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. Element C-29/T/C 49-2 3. Reactor environment 4. Monthly operating report No. 21	MA 15Z	MA 13	MA 520	10,130	Operational monitors	1. Thermocouple shorted to ground, causing scram. 2. Corrective modification. 3. None.
7	1. Fuel Element/Orifice Control 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. Reactor core/orifice MF-81 3. 350 to 945°F - sodium 4. Monthly operating report No. 30	MA 195	MA 55	MA 550	10,130	Direct observation	1. Seven orifice drive cables stuck. 2. Component corrective modification. 3. None.
8	1. Fuel Element/Orifice 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. Orifice adjusting mechanism, C-164 3. Reactor environment 4. WR 2783	MA 148	MA 55	MA 550	Unknown	Operational monitors	1. Orifice could not be adjusted properly. 2. Removed rod, replaced orifice rod seals, tightened packing nut. 3. None.
9	1. Fuel Element/Orifice 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. Reactor core/C-81 3. Reactor environment 4. WR 2814	MI 14Z	MI 55	MI 550	Unknown	Operational monitors	1. Orifice drive assembly broke during operation. 2. Replaced. 3. None.
10	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core subassembly X028 3. 300 to 800°F 4. ANL-7445	MA 500	MA 59	MA 520	Unknown	Operational monitors	1. Subassembly X028, fission product release to approx. 30 times the normal level. Reactor bldg. was evacuated. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-59

FAILURE DATA FOR FUEL AND BREEDER ELEMENTS

(Sheet 3 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
11	1. Fuel Element/Fuel Pins 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core 3. 300 to 800°F 4. ANL 7082	MA 500	MA 54	MA 530	2590	During routine inspection	1. Swelling due to excessive burnout. 2. Part replaced. 3. None.
12	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core 3. 300 to 800°F 4. ANL 7403	MA 500	MA 59	MA 520	13,340	Operational monitors	1. Small defect in cladding which released bond sodium slowly. 2. Component part replaced. 3. Revise Quality Assurance procedures for acceptance of fuel cladding material.
13	1. Fuel Element/Cladding Flat 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core subassembly C-2039 3. 300 to 800°F 4. ANL 7419	MA 500	MA 54	MA 520	13,380	Inspection of associated systems	1. Subassembly was wedged against control rod L-446 and caused the rod to be scratched when it was removed. 2. Component replaced. 3. None.
14	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core subassembly XG05 3. 300 to 800°F 4. ANL 7438	MA 500	MA BZ	MA 520	13,800	Operational monitors	1. Fission gas release into primary systems, very slight. 2. Component part replaced. 3. None.
15	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core subassembly XA08 3. 300 to 800°F 4. ANL 7438	MA 500	MA BZ	MA 520	13,850	Operational monitors	1. Fission gas release into primary systems, very slight. 2. Component part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-59

FAILURE DATA FOR FUEL AND BREEDER ELEMENTS

(Sheet 4 of 4)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
16	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core subassembly XO11 3. 300 to 800°F 4. ANL 7342	MA 500	MA 59	MA 550	10,270	Operational monitor	1. FGM monitor indicated greater than 10 times the normal reading on a portable instrument. 2. Reactor power was reduced for investigation. 3. None.
17	1. Fuel Element/Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. EBR-II 2. Primary/reactor core C-2111 and C-2113 3. 300 to 800°F 4. ANL 7403	MA 500	MA BZ	MA 520	12,425	Operational monitor	1. Fission gas release was from newly inserted "fresh" fuel assembly. 2. Component replaced. 3. Upgrade Quality Assurance procedure for fuel element inspection.
18	1. Fuel Element/Orifice 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. HNPF 2. C-178 3. Reactor environment 4. WR 2819	MI 9ZZ	MI 59	MI 530	-	Operational monitor	1. Orifice housing broke. 2. Replaced. 3. None.
19	1. Fuel Elements/ Fuel Meat and Cladding 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	1. SRE (Core I) 2. Reactor core 3. 950°F sodium 4. NAA-SR-4488 and NAA-SR-4488 Supplement	I 111	I 66	I 520	16,200	Operational monitor	1. Fuel channel clogging caused by tetralin decomposition products results in fuel and cladding melting. 2. Sodium pump tetralin freeze seals replaced with NaK freeze seals thereby eliminating the potential source of contaminant. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-60

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FUEL AND BREEDER ELEMENTS

COMPONENT SUBTYPE FUEL ELEMENTS

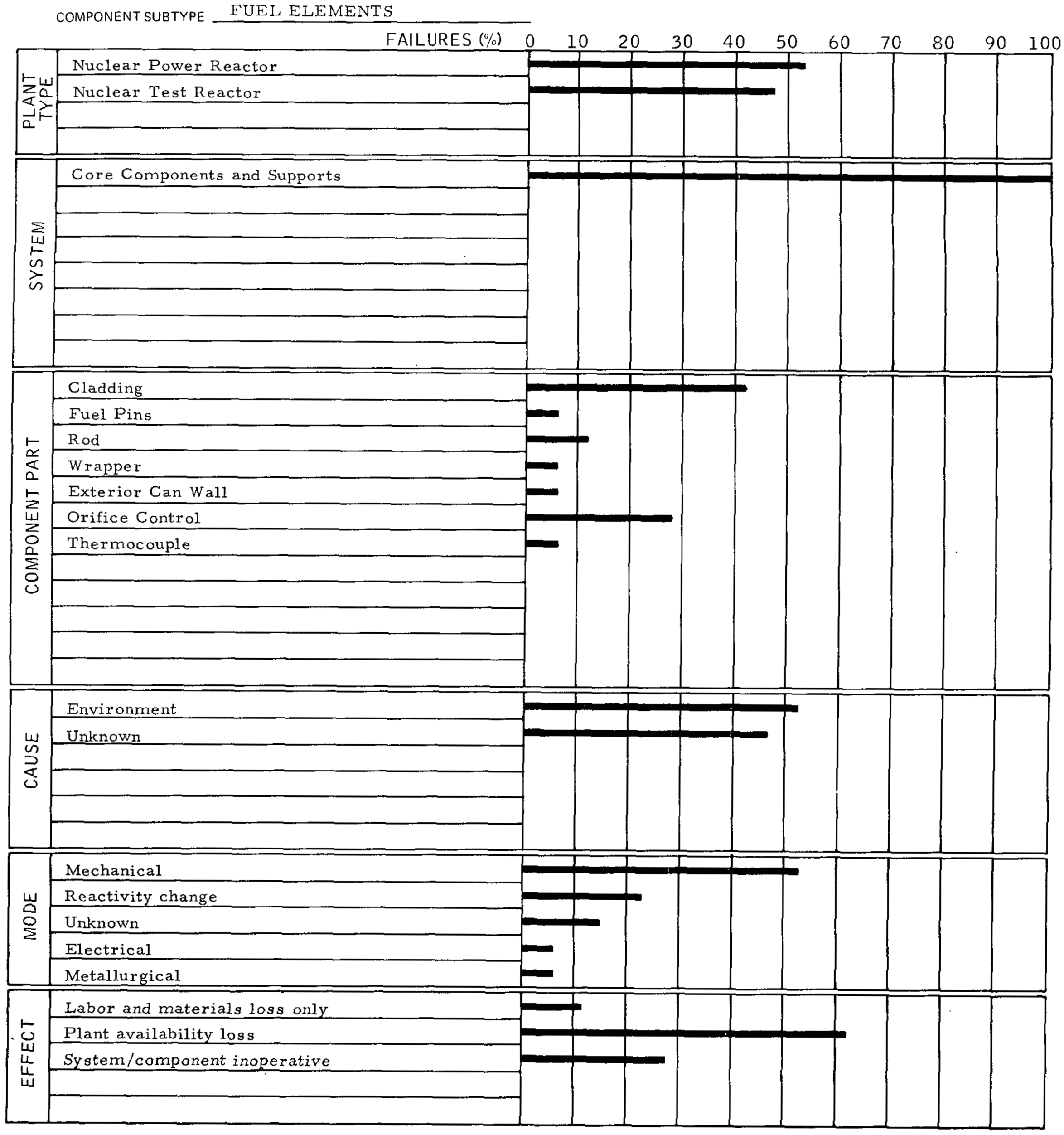
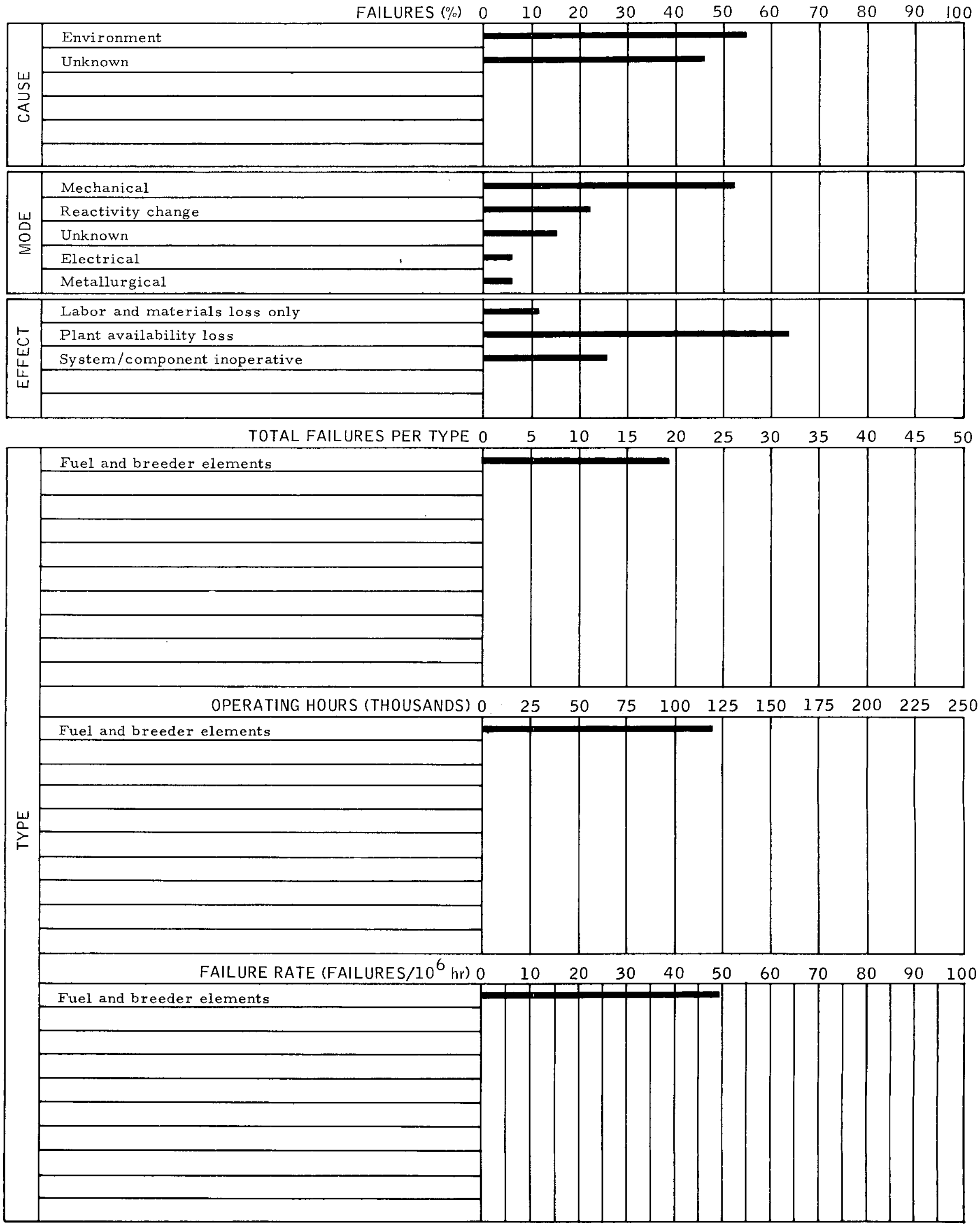


TABLE 1-61

GENERAL SUMMARY

COMPONENT FUEL AND BREEDER ELEMENTS



2. Fuel Handling Equipment (liquid metal, internal) (see Figure 1-6)

Failure data for fuel handling equipment (liquid metal, internal) are presented in Tables 1-62 through 1-64.

a. Reliability Information

Design Feature:

In-core handling mechanisms are designed to provide motion interlocks for all system operations minimizing damage to equipment. Gripper design utilizes positive actuation for opening and closing to reduce the risk of accidental droppage or unintentional removal of core subassemblies. Operation in sodium minimizes crudding and contamination resulting from frequent insertions and removal from the sodium pool.

Critical Characteristic:

Equipment parts have to survive in liquid sodium and sodium vapor environments.

Mode of Failure:

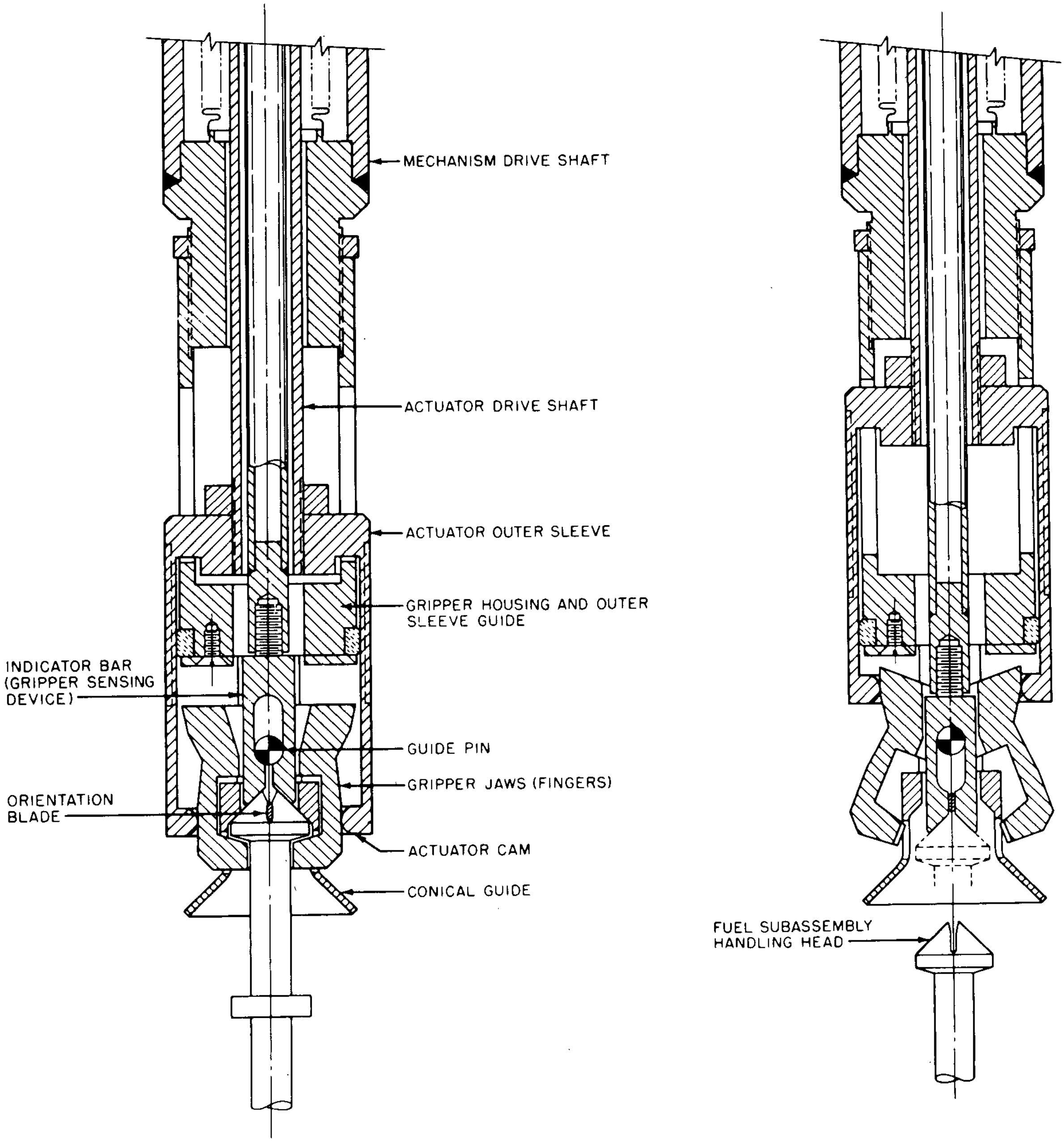
1) Misalignment
2) Seal leak
3) Wear.

Failure Description:

1) Bearing failed due to misalignment.
2) O-ring seal leaked.
3) Revolving lock in a holddown mechanism wore out.

Control Methods:

1) Proper installation and maintenance procedures are required.
2) Materials must be selected for their particular use.
3) Special parts must be carefully designed with complete knowledge of their requirements.



7-7694-215-70

Figure 1-6. EBR-II Gripper Mechanism

b. Discussion and Recommendations

Bearing failures occurring before the normal projected lifetime are the result of overloading some portion of the race or rolling element. This overload comes from misalignments, direct overloads, too high preloads, foreign objects in the bearings, or changes in stress on bearing due to temperature changes which shift the mounting. In design, select a bearing suitable for the job. Also, design so that the bearing will not loose its lubrication and is properly protected from the entrance of foreign materials. Determine what the logical limit to bearing life should be under the conditions of operation.

Bearings under low speed operation will generally show signs of breakdown before complete failure by binding and making scrapping and clicking sounds. An improperly mounted bearing is usually misaligned and will show this misalignment by binding and freeing as it is rotated.

O-ring failures are due to improper installation, improper compression, or incorrect material for the environment. Make certain that the seal is not damaged during installation. In design, select correct materials and design for correct pressure.

Little can be done to determine incipient failure in an O-ring seal. If the seal is a linear seal, some evidence of the O-ring material might be seen rubbing on the moving element.

Incipient failure in mechanisms is manifested by changes in operating characteristics such as the force to operate, roughness, etc. Some visual evidence, such as metal chips or dust, may indicate future failure.

TABLE 1-62

FAILURE DATA FOR FUEL HANDLING EQUIPMENT (LIQUID METAL, INTERNAL)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Fuel Handling Equipment/Bearing 2. Nuclear Fuel Handling and Storage Equipment/ Liquid Metal Internal 3. 47 236100	1. Fermi 2. Offset handling mechanism 3. - 4. EF-22	MI 322	MI 56	MI 530	11,740	During actuation	1. Bearing misaligned. 2. Operating limits changed to correct erratic latching of subassemblies. 3. Provide adequate assembly procedures.
2	1. Fuel Handling Equipment/O-ring Seal 2. Nuclear Fuel Handling and Storage Equipment/ Liquid Metal Internal 3. 47 236100	1. Fermi 2. Offset handling mechanism 3. - 4. EF-42	MI 417	MI 52	MI 530	14941	Operational monitors	1. O-ring seal leak. 2. Component design change; the O-ring material was replaced. A "silastic" seal to stop a leak rate of 2 cfh was installed. 3. Improve engineering material evaluation.
3	1. Fuel Handling Internal/Revolving Lock 2. Nuclear Fuel Handling and Storage Equipment/ Liquid Metal Internal 3. 47 236100	1. EBR-II 2. Holddown mechanism 3. - 4. Operation weekly report, 1/10/68	MI 500	MI 52	MI 530	13,380	Preventive maintenance	1. Revolving lock worn out. 2. Part replaced. 3. Revise preventive maintenance inspection interval to permit replacement before total failure.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-63

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FUEL HANDLING EQUIPMENT

COMPONENT SUBTYPE

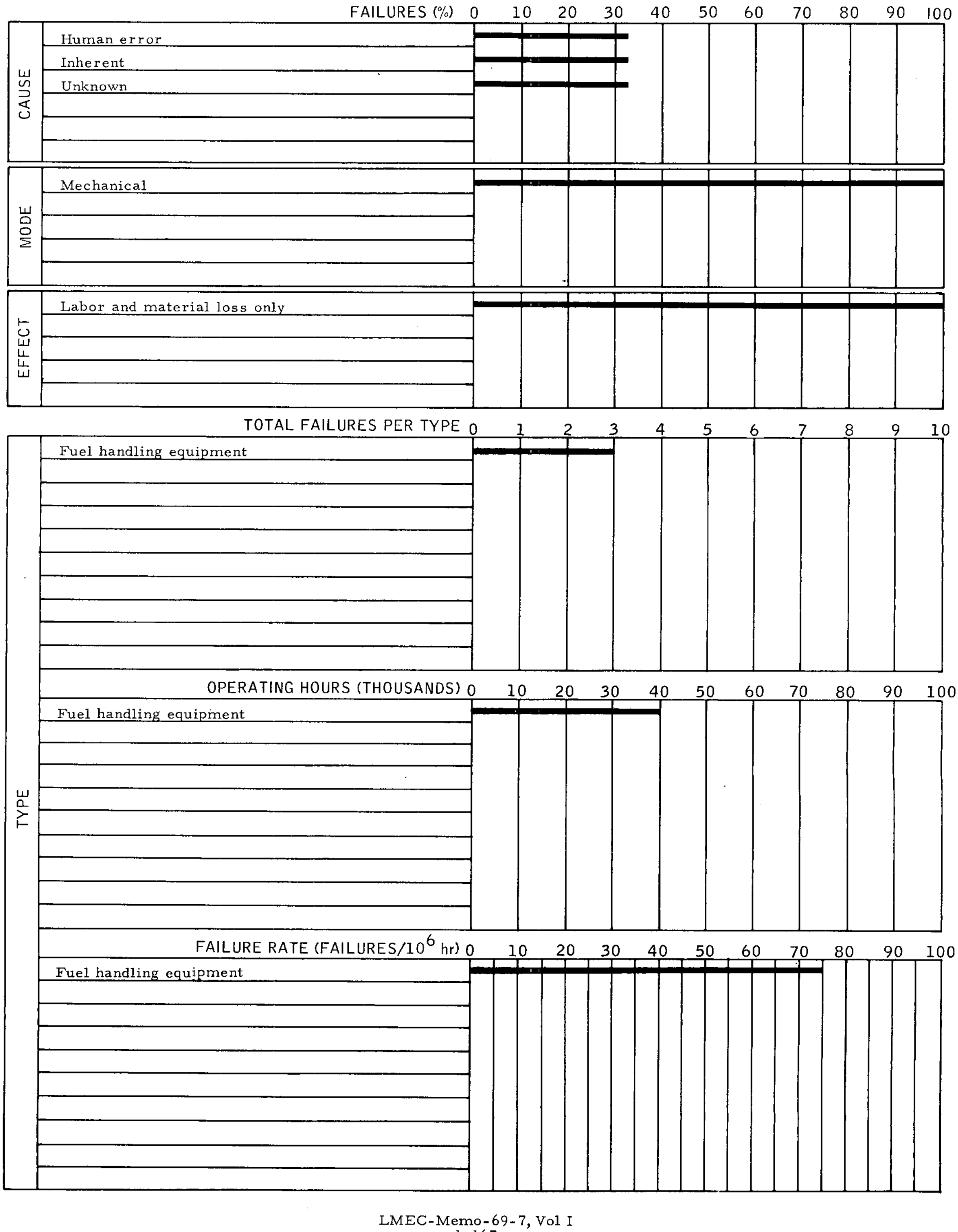
FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactor
	Nuclear Test Reactor
SYSTEM	Nuclear Fuel Handling and Storage Equipment
COMPONENT PART	Bearing
	"O" Ring Seal
	Revolving Lock
CAUSE	Human error
	Inherent
	Unknown
MODE	Mechanical
EFFECT	Labor and materials loss only

TABLE 1-64

GENERAL SUMMARY

COMPONENT FUEL HANDLING EQUIPMENT



F. HEAT TRANSFER SYSTEM COMPONENTS

1. Blowers and Fans

Failure data for blowers and fans are presented in Tables 1-65 through 1-68.

a. Reliability Information

Design Features:

Provide air flow at specified rates for various applications.

Modes of Failure:

1) Bearings noisy or races broken
2) Gear broken
3) Fan blades cracked.

Failure Experience:

Causes have been poorly described, if at all. However, there were several indications of inadequate inspection and incipient failure detection methods. Bearings were the high-frequency failure item, with some indication on inadequate lubrication and possible misalignment.

Control Methods:

1) The bearing problem is common to all types of rotating equipment. A concentrated effort should be made to adapt existing methods of incipient failure detection to early awareness of potential bearing failure in order to prevent major damage to other parts of the fan or blower.
2) Establish reliable inspection and maintenance procedures including checks on alignment and loading.

b. Discussion and Recommendations

None.

TABLE 1-65

FAILURE DATA FOR BLOWERS AND FANS

(Sheet 1 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Fan/Shaft Bearing (inboard) 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 28 330000	1. EBR-II 2. Cooling tower 3. 70 to 83°F 4. PMMR-82	MI 500	MI 59	MI 530	7400	Operational monitors	1. Bearing broken. 2. Part replaced. 3. Investigate cause for broken bearing and modify accordingly.
2	1. Fan/Gear 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 28 330000	1. EBR-II 2. Cooling tower 3. 70 to 83°F 4. PMMR-82	MI 500	MI 59	MI 530	7400	Operational monitors	1. Gear broken. 2. Part replaced. 3. None.
3	1. Fan/Shaft Bearing 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 28 330000	1. EBR-II 2. Cooling tower 3. 70 to 83°F 4. PMMR-82	MI 500	MI 59	MI 530	7400	Operational monitors	1. Bearing broken. 2. Part replaced. 3. Investigate cause of bearing breakage. Check balance of blower, load on bearing, etc.
4	1. Fan/Bearings 2. Heat Transfer/Conventional Fossil Fuel Fired Superheaters or Boilers 3. 28 227300	1. SCTI 2. Primary sodium system/heater (H-1) 3. 1160 rpm, 53,400 cfm 4. Incident report No. 320	MA 126	MA 59	MA 550	19,222	Direct observation	1. Bearings noisy as both races had broken surfaces and indentations in the outer races caused knocking. 2. Defective parts replaced. 3. Improve maintenance.
5	1. Blowers and Fans/ Cooler Fan 2. Heat Transfer/Reactor Coolant System 3. 28 221120	1. SCTI 2. Primary, sodium cooler fan, E-8 3. 75,000 cfm, 526 rpm, 450 hp 4. Incident report No. 85	MI 9ZZ	MI 53	MI 530	103	Routine area watch	1. Grease seal ring of bearing became loose because of loose setscrew. 2. Flat plate ring and gasket substituted for grease seal ring. 3. None.
6	1. Blower/Fan Blade 2. Other Plant Equipment/ Cover Gas Cooling 3. 28 290000	1. EBR-II 2. Fuel element rupture detector 3. - 4. PMMR-48	MI 500	MI 73	MI 530	3410	Operational monitors	1. Fan blade cracked. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-65

FAILURE DATA FOR BLOWERS AND FANS

(Sheet 2 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Blower/Fan Blades 2. Other Plant Equipment/Cover Gas Cooling 3. 28 290000	1. EBR-II 2. Fuel element rupture detector 3. - 4. PMMR-34	MI 500	MI 54	MI 530	2590	Direct observation	1. Fan blades bent. 2. Part replaced. 3. None.
8	1. Blower/Bearings 2. Fuel Handling/Fuel Handling Machines (cooling) 3. 28 235140	1. Fermi 2. No. 1 argon cask car 3. Min. 350°F, argon, 1000 rpm 4. EFAPP MR No. 59	MI 128	MI 68	MI 530	7930	Direct observation	1. Bearings worn out. 2. Part replaced, remachined galled motor shaft. 3. The use of high-temperature lubricant (melting point 528°F) might help.
9	1. Blower/Bearings 2. Fuel Handling/Fuel Handling Machines 3. 28 235140	1. Fermi 2. No. 2 argon cask car 3. Min. 350°F, argon, 1000 rpm 4. PRDC-EF-14	MI 128	MI 54	MI 530	7930	Audio noise	1. Bad bearings. 2. Local repair. 3. None.
10	1. Blower/Bearing 2. Other Reactor Plant Equipment/Auxiliary Cooling 3. 28 290000	1. EBR-II 2. Pump M-1 cooling air 3. - 4. PMMR-22	MI 127	MI 58	MI 530	1200	Audio noise	1. Noisy bearing. 2. Part replaced. 3. None.
11	1. Blower/Bearing 2. Other Reactor Plant Equipment/Auxiliary Cooling 3. 28 290000	1. EBR-II 2. Primary sodium pump (M-2) 3. - 4. PMMR-22	MI 127	MI 58	MI 530	1200	Audible noise	1. Noisy bearing. 2. Part replaced. 3. Revise preventive maintenance inspections interval on blower bearings to provide adequate lubrication.
12	1. Blower/Bearing 2. Other Reactor Plant Equipment/Auxiliary Cooling 3. 28 290000	1. EBR-II 2. Primary auxiliary EM pump 3. - 4. Operations weekly report, 2-21-68	MI 148	MI 52	MI 530	13,500	Direct observation	1. Outer race of bearings turning in bearing housing. 2. Bearings replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-65

FAILURE DATA FOR BLOWERS AND FANS

(Sheet 3 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
13	1. Blower/Bearing 2. Other Reactor Plant Equipment/Auxiliary Cooling 3. 28 290000	1. EBR-II 2. Primary auxiliary EM pump 3. - 4. PMMR-95	MI 500	MI 52	MI 530	9345	During preventive maintenance	1. Bearing worn out. 2. Part replaced. 3. None.
14	1. Blower/Bearings 2. Heat Transfer/Inert Gas Supply and Monitoring 3. 28 224600	1. EBR-II 2. Primary argon purification No.2 blower 3. 10 hp, 440 volts, 150 cfm 4. PMMR-96	MI 500	MI 52	MI 530	9345	During preventive maintenance	1. Bad bearings. 2. Replaced bearings. 3. None.
15	1. Blower/Bearings 2. Other Plant Equipment/Cover Gas Cooling 3. 28 290000	1. EBR-II 2. Fuel element rupture detector 3. - 4. PMMR-92	MI 500	MI 52	MI 530	8960	Direct observation	1. Bearings failed. 2. Bearings replaced. 3. None.
16	1. Blower/Gears 2. Other Plant Equipment/Cover Gas Cooling 3. 28 290000	1. EBR-II 2. Fuel element rupture detector 3. - 4. PMMR-92	MI 500	MI 52	MI 530	8960	Direct observation	1. Gears failed. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-66

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT BLOWERS AND FANS

COMPONENT SUBTYPE BLOWERS

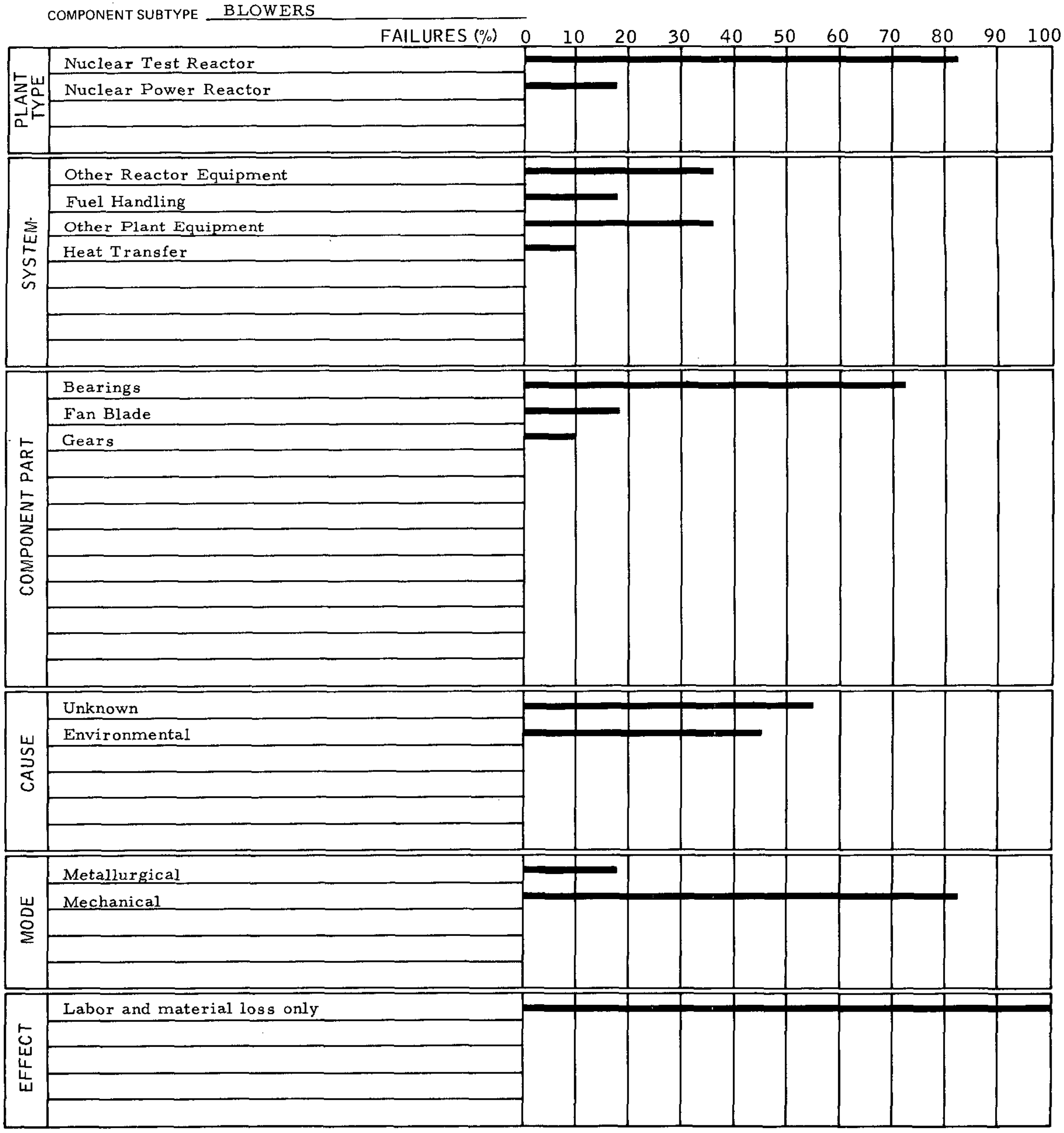


TABLE 1-67

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT BLOWERS AND FANS

COMPONENT SUBTYPE FANS

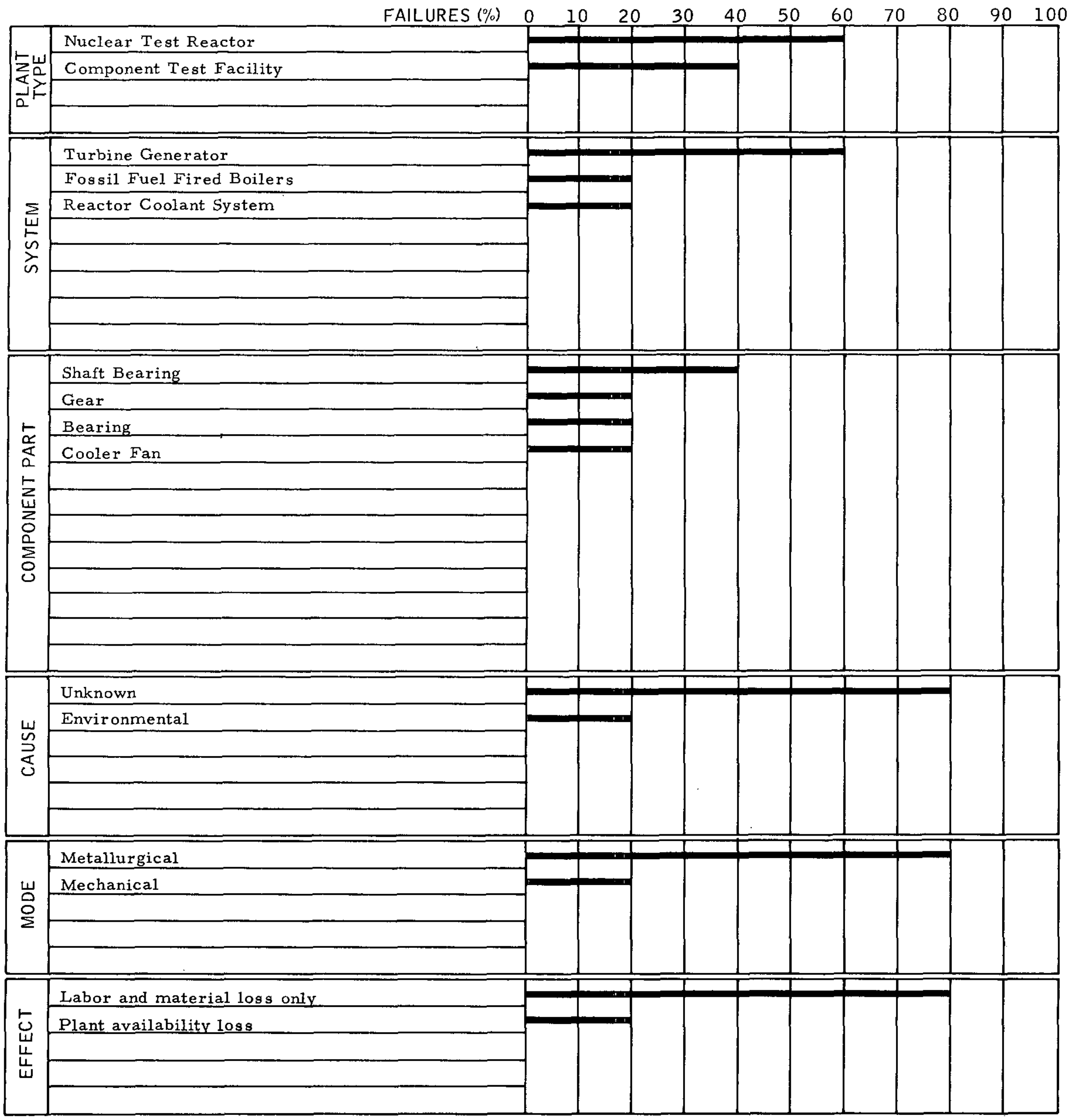
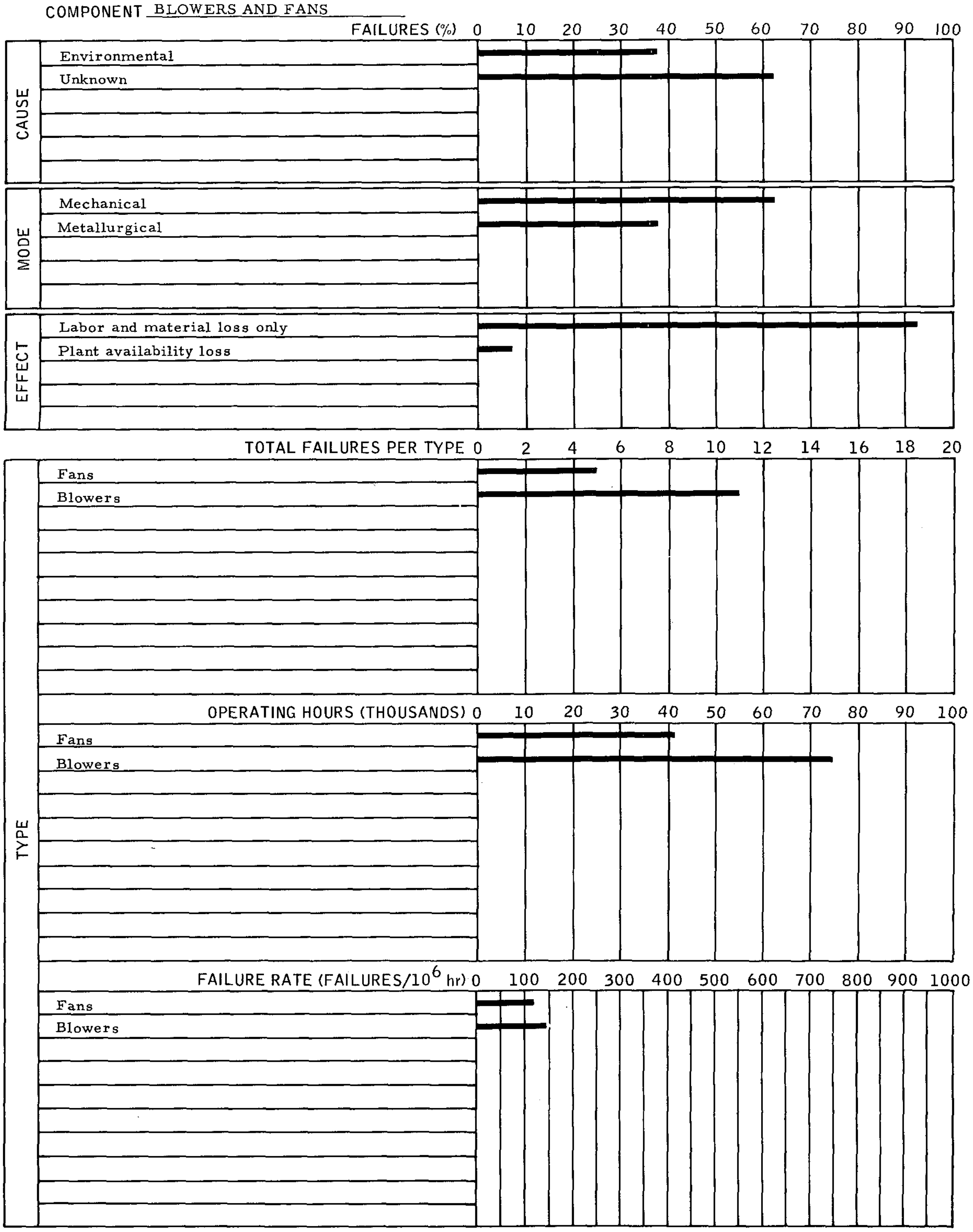


TABLE 1-68

GENERAL SUMMARY

COMPONENT BLOWERS AND FANS



2. Cold Traps/Hot Traps (See Figure 1-7)

Failure data for cold traps/hot traps are presented in Tables 1-69 through 1-72.

a. Reliability Information

Design Features:

Hot traps and cold traps are designed to remove impurities from liquid sodium systems.

Mode of Failure:

1) Chemical reaction

2) Electrical aging or wear

3) Mechanical wear or distortion.

Failure Description:

1) Sodium leakage at flange or other area

2) Plugged trap.

Control Methods:

1) Flanges and O-rings should be clean and bolts tightened in a specified manner.

2) Location of heaters in area are important.

3) Personnel training and proper procedures aid in satisfactory operation of traps.

b. Discussion and Recommendations

None.

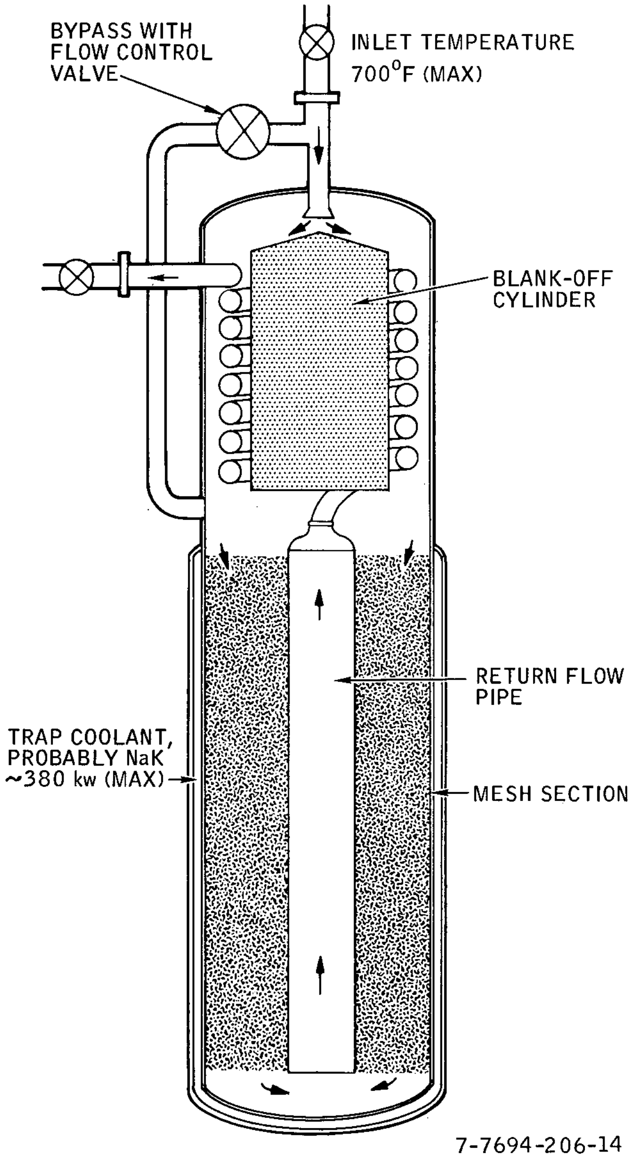


Figure 1-7. Circulating Cold Trap

TABLE 1-69

FAILURE DATA FOR COLD TRAPS/HOT TRAPS

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Cold Trap/Clamp Joint 2. Heat Transfer/ Purification 3. 36 224239	1. Fermi 2. Cold trap room 3. 250 to 1000°F 4. EFAPP-MR-44	MA 136	MA 34	MA 550	5643	Protective system	1. Sodium leaked through union seal ring joint. 2. Local repair. 3. Determine torque requirements for flange bolts at the upper operating temperatures and torque.
2	1. Cold Trap/ - 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Primary system cell No. 2 3. Design - 100 psig, 650°F Operating - 20 psig 4. Monthly operating report No. 6	MA 136	MA 37	MA 550	Unknown	Operational monitors	1. Visual observation through port after alarm annunciation revealed sodium on floor and on nitrogen ducting. 2. Part replaced. 3. None.
3	1. Cold Trap/Flange 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Primary system cell No. 2 3. Design - 100 psig, 650°F Operating - 20 psig, Max. 600°F 4. Monthly operating report No. 7	MA 326	MA 34	MA 550	Unknown	Operational monitors	1. Misalignment of inlet flange caused sodium leak. 2. Local repair. 3. None.
4	1. Cold Trap/Plugged 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Secondary system loop No. 2 3. Sodium flow, 10 gpm Inlet, 602°F; outlet, 295°F 4. Monthly operating report No. 15	MI 195	MI 51	MI 550	4560	Operational monitors	1. Cold trap plugged, sent to AI for cleaning and service. 2. Part replaced. 3. None.
5	1. Cold Trap/Coupling 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Primary system 3. Sodium flow, 1700 cfm/trap flow, 10 gpm; inlet, 350°F; outlet, 295°F 4. Monthly operating report No. 4	MI 321	MI 53	MI 530	Unknown	Operational monitors	1. Spacer piece and internal coupling were not installed. 2. Local repair. 3. None.
6	1. Cold Traps/ - 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Primary system cell No. 2 3. - 4. AI monthly operating report, 2/14/63	MI 191	MI 19Z	MI 550	768	Operational monitors	1. Cold trap filled. 2. Replaced with cold trap from primary cell No. 1. 3. None.
7	1. Cold Traps/ - 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Primary system cell No. 1 3. - 4. Monthly operating report No. 9	MI 191	MI 19Z	MI 550	3528	Operational monitors	1. Original trap moved to No. 2 primary location. 2. Installed new trap. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-69

FAILURE DATA FOR COLD TRAPS/HOT TRAPS

(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
8	1. Cold Traps/ - 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Secondary system 3. - 4. Monthly operating report No. 9	MI 191	MI 19Z	MI 550	9360	Operational monitors	1. Cold trap filled. 2. Part replaced. 3. None.
9	1. Hot Trap (carbon)/ Sampler 2. Heat Transfer/ Purification 3. 36 224239	1. HNPF 2. Sodium purification/carbon trap cell 3. Should be removed at less than 200°F 4. Monthly operating report No. 5	I 136	I 34	I 550	2400	Direct observation	1. One man sprayed with sodium while removing a sample, but was not burned due to protective clothing. 2. Operational procedure change. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-70

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT COLD TRAPS/HOT TRAPS

COMPONENT SUBTYPE COLD TRAPS

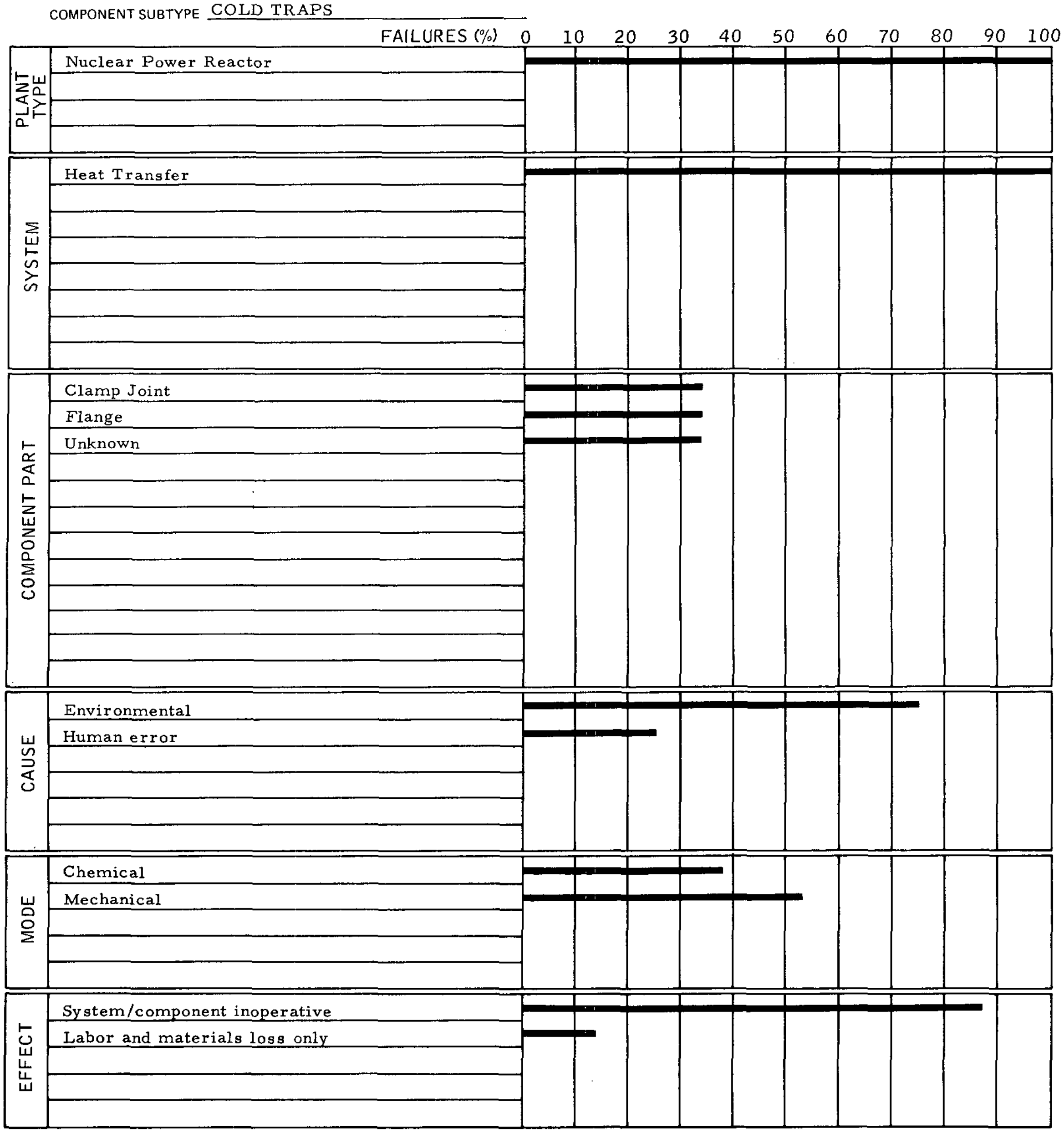


TABLE 1-71

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT COLD TRAPS/HOT TRAPS

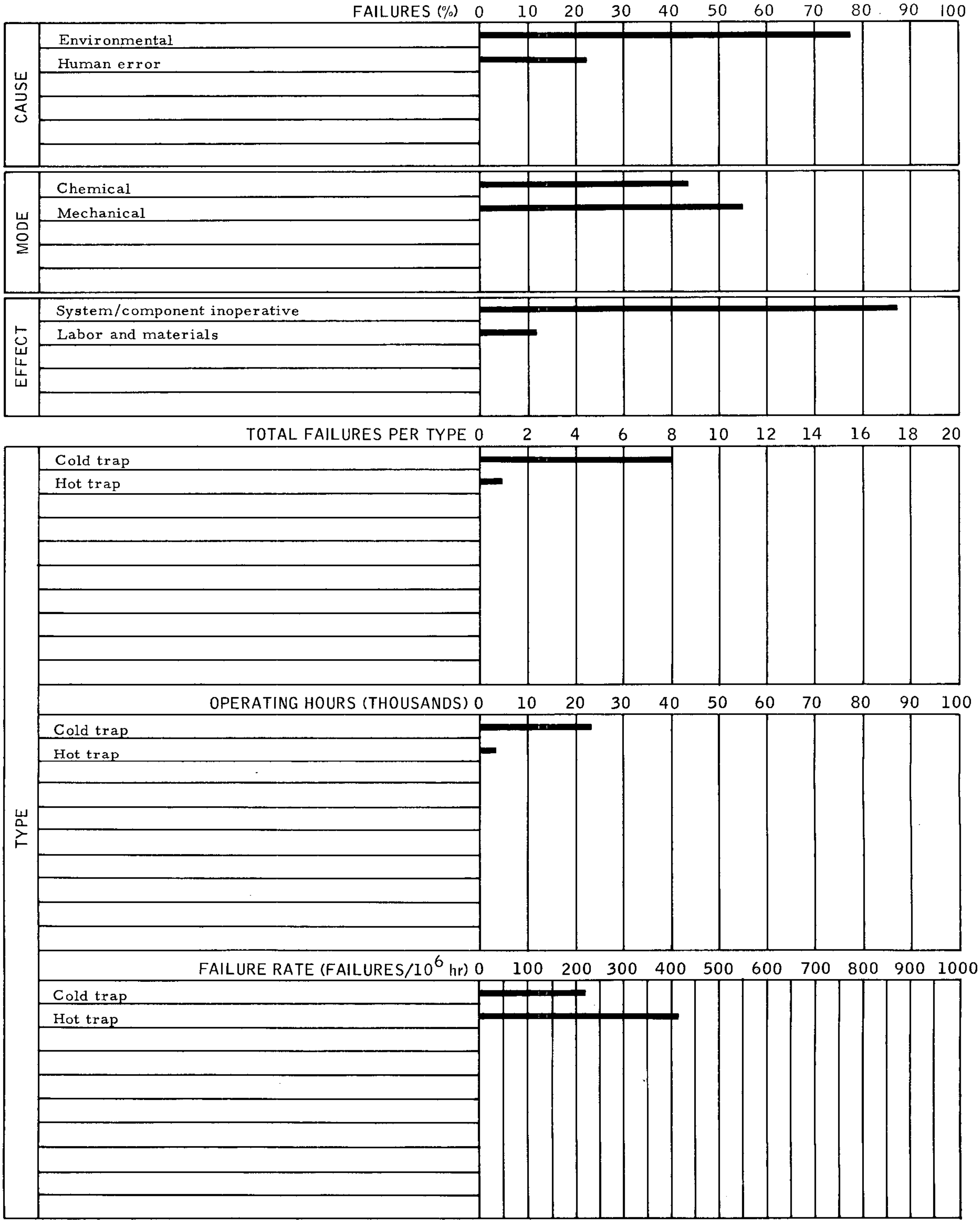
COMPONENT SUBTYPE HOT TRAPS

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Power Reactor	
SYSTEM	Heat Transfer	
COMPONENT PART	Sampler	
CAUSE	Environmental	
MODE	Chemical	
EFFECT	System/component inoperative	

TABLE 1-72

GENERAL SUMMARY

COMPONENT COLD TRAPS/HOT TRAPS



3. Coolers (other than liquid-metal-to-air)

Failure data for coolers (other than liquid-metal-to-air) are presented in Tables 1-73 through 1-75.

a. Reliability Information

Design Features:

An oil cooler used to cool steam turbine lubricating oil.

Mode of Failure:

Deterioration of unit heads.

Failure Description:

The unit heads were deteriorated.

Control Methods

1) To prevent corrosion, chemically treated cooling water can be used.

2) To prevent erosion, baffle plates can be installed so that water impingement is minimized.

Heat Exchangers (coolers, oil coolers) generally use chemically treated cooling water to prevent corrosion. If the problem was erosion, then baffle plates are installed to direct the flow so the water doesn't impinge on areas that may erode. Oil coolers have been used in industry for many years; therefore, nearly any operating condition that may be encountered has been experienced. The system designer should be able to avoid problems of corrosion, erosion, galvanic action, etc., if they are considered during design of the system.

b. Discussion and Recommendations

None.

TABLE 1-73

FAILURE DATA FOR COOLERS (OTHER THAN LIQUID METAL-TO-AIR)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Coolers/Turbine Lube Oil Cooler 2. Turbine-Generator Units and Condenser/ Central Lubricating 3. 35 350000	1. EBR-II 2. Turbine water side 3. 140 to 160°F 4. PMMR-87	MI 200	MI 91	MI 550	7800	Routine inspection	1. Head of one unit deteriorated badly. Head of other unit slightly deteriorated. 2. Flow baffles built in and flange surfaces remachined. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-74

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT COOLERS (OTHER THAN LIQUID METAL TO AIR)

COMPONENT SUBTYPE COOLERS

	FAILURES (%)
PLANT TYPE	Nuclear Test Reactor
SYSTEM	Turbine Generator Unit
COMPONENT PART	Turbine Lube Oil Cooler
CAUSE	Impurity/contamination
MODE	Metal corrosion
EFFECT	System/component inoperative

TABLE 1-75

GENERAL SUMMARY

COMPONENT COOLERS (OTHER THAN LIQUID METAL TO AIR)

	FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
CAUSE	Impurity/contamination
MODE	Metal corrosion
EFFECT	System/component inoperative

	TOTAL FAILURES PER TYPE 0 1 2 3 4 5 6 7 8 9 10
TYPE	Coolers

	OPERATING HOURS (THOUSANDS) 0 2,000 4,000 6,000 8,000 10,000
TYPE	Coolers

	FAILURE RATE (FAILURES/10^6 hr) 0 100 200 300 400 500 600 700 800 900 1000
TYPE	Coolers

4. Desuperheaters

Failure data for desuperheaters are presented in Tables 1-76 through 1-78.

a. Reliability Information

Design Features:

Desuperheaters are used in the main steam system to reduce the temperature of the steam.

Mode of Failure:

1) Flange bolts

2) Flow vanes.

Failure Description:

1) Flange bolts were improperly torqued.

2) Flow straightening vanes were plugged.

Control Methods:

1) The bolts should be tightened in a predetermined sequence.

2) Inspect inlet lines whenever work is done on the system.

b. Discussion and Recommendations

Desuperheaters are standard equipment in high-temperature steam systems; therefore, the problems associated with maintaining them are well known. In view of this fact, the rash of flange leaks reported may be attributed to improper techniques in making up flanges. The bolts should be tightened in a predetermined sequence; that is, tighten one bolt just snug, then move 180 degrees around the flange and another bolt. Continue this sequence until all the flange bolts are snug. Then start torquing the bolts in increments using the sequence described above.

TABLE 1-76

FAILURE DATA FOR DESUPERHEATERS

(Sheet 1 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Desuperheater No. 1/ Straightening Vanes 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. SCTI 2. Feedwater system/line 211 3. - 4. Incident report No. 113	MI 259	MI 51	MI 520	Unknown	Operational monitors	1. Flow straightening vanes at flowmeter inlet plugged. 2. Local repair, flow transmitter FR-203 isolated; straightening vane disassembled and cleaned. 3. Keep line section ends sealed during construction; inspect lines before welding sections.
2	1. Desuperheater No. 1/ Flange Studs 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. SCTI 2. Steam and feedwater system 3. 17,000 lb/hr 4. Incident report No. 121	MI 148	MI 53	MI 136	5875	Direct observation	1. Flange studs had not been torqued evenly. 2. Local repair, studs retorqued. 3. Specify torque requirements and procedures for flange bolts.
3	1. Desuperheater No. 1/ Flange Joint O-ring 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. SCTI 2. Feedwater system 3. 670 to 1032°F, 1285 to 1825 psig 4. Incident report No. 14	MI 136	MI 56	MI 520	510	Direct observation	1. Bolts improperly torqued and O-ring not seated in groove. 2. Local repair. 3. Piping design should provide gasket change capability without pipe cutting and welding.
4	1. Desuperheater No. 1/ Bolted Flange 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. SCTI 2. Steam and feedwater system 3. 2200 psig, 1050°F 4. Incident report No. 130	MA 144	MA 53	MA 136	6030	Direct observation	1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. Component corrective modification. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket.
5	1. Desuperheater No. 1/ Flanged Joint 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. SCTI 2. Feedwater system 3. - 4. Incident report No. 76	MI 148	MI 53	MI 530	4470	Direct observation	1. Bolts improperly torqued. 2. Bolts retorqued. 3. Improved QA procedures at initial contractor level.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-76

FAILURE DATA FOR DESUPERHEATERS
(Sheet 2 of 2)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Desuperheater/ Thermocouple Well 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. EBR-II 2. Main steam/desuperheater 3. 740 to 840°F, 1250 psig 4. PMMR-82	MA 500	MA BZ	MA 520	7400	Direct observation	1. Thermocouple well body cracked. 2. Local repair, plant shut down to repair leak. 3. Proper well design, good welding and heat treatment procedures will reduce this type of failure.
7	1. Desuperheater/Spray Nozzle 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. EBR-II 2. Main steam/desuperheater 3. 740 to 840°F, 1250 psig 4. PMMR-81	MI 500	MI 53	MI 530	6920	Preventive maintenance	1. Spray nozzle loose. 2. Local repair; nozzles removed, cleaned, and set screws were applied to prevent loosening. 3. None.
8	1. Desuperheater/Bellows 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. EBR-II 2. Main steam/desuperheater 3. 740 to 840°F, 1250 psig 4. PMMR-12	MI 500	MI BZ	MI 530	1200	Direct observation	1. Bellows modified. 2. Part replaced. 3. None.
9	1. Desuperheater/Flange Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	1. EBR-II 2. Main steam/desuperheater nozzle 3. 740 to 840°F, 1250 psig 4. PMMR-83	MI 500	MI BZ	MI 530	7400	Preventive maintenance	1. Gasket worn out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-77

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT DESUPERHEATER

COMPONENT SUBTYPE

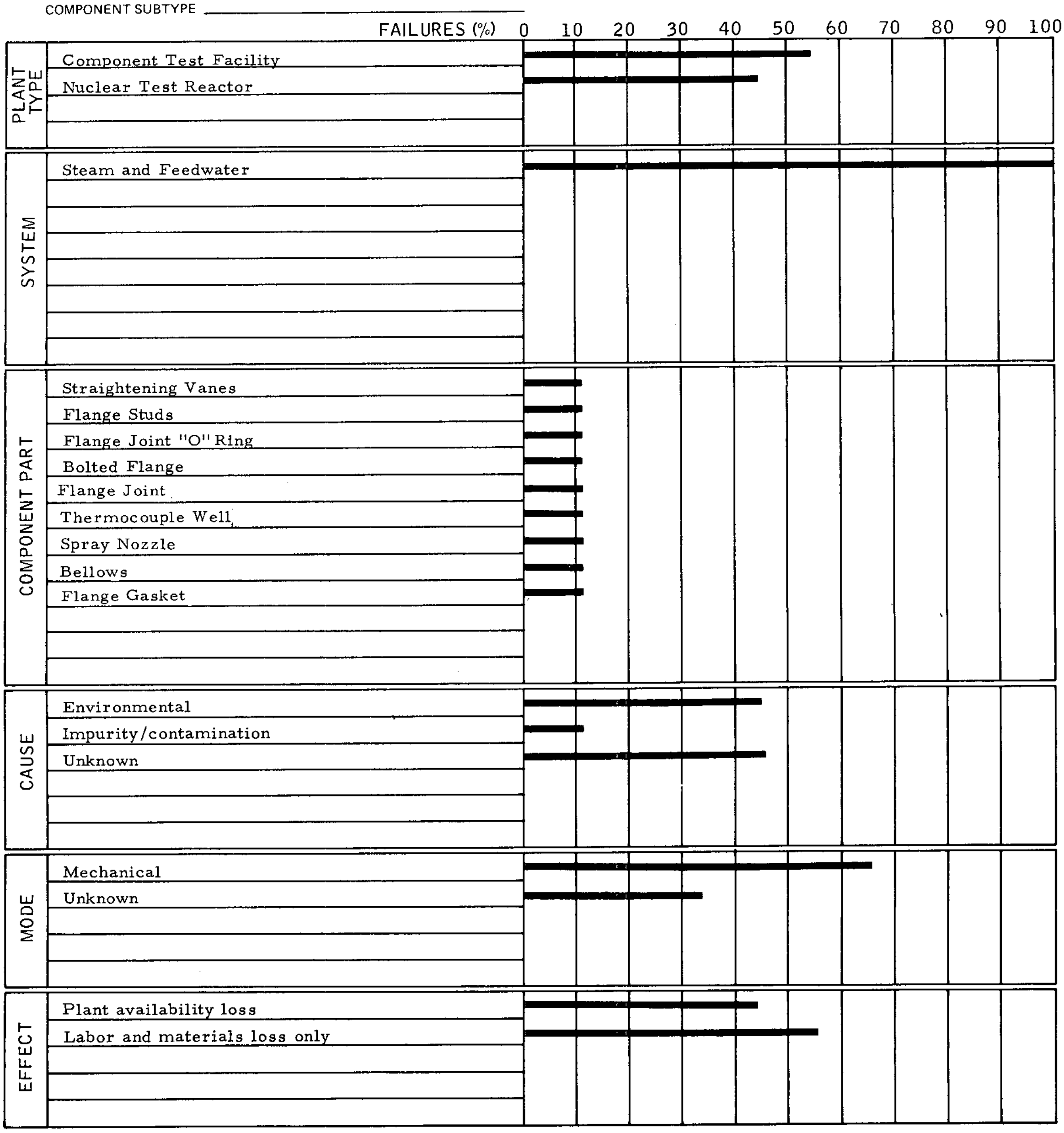
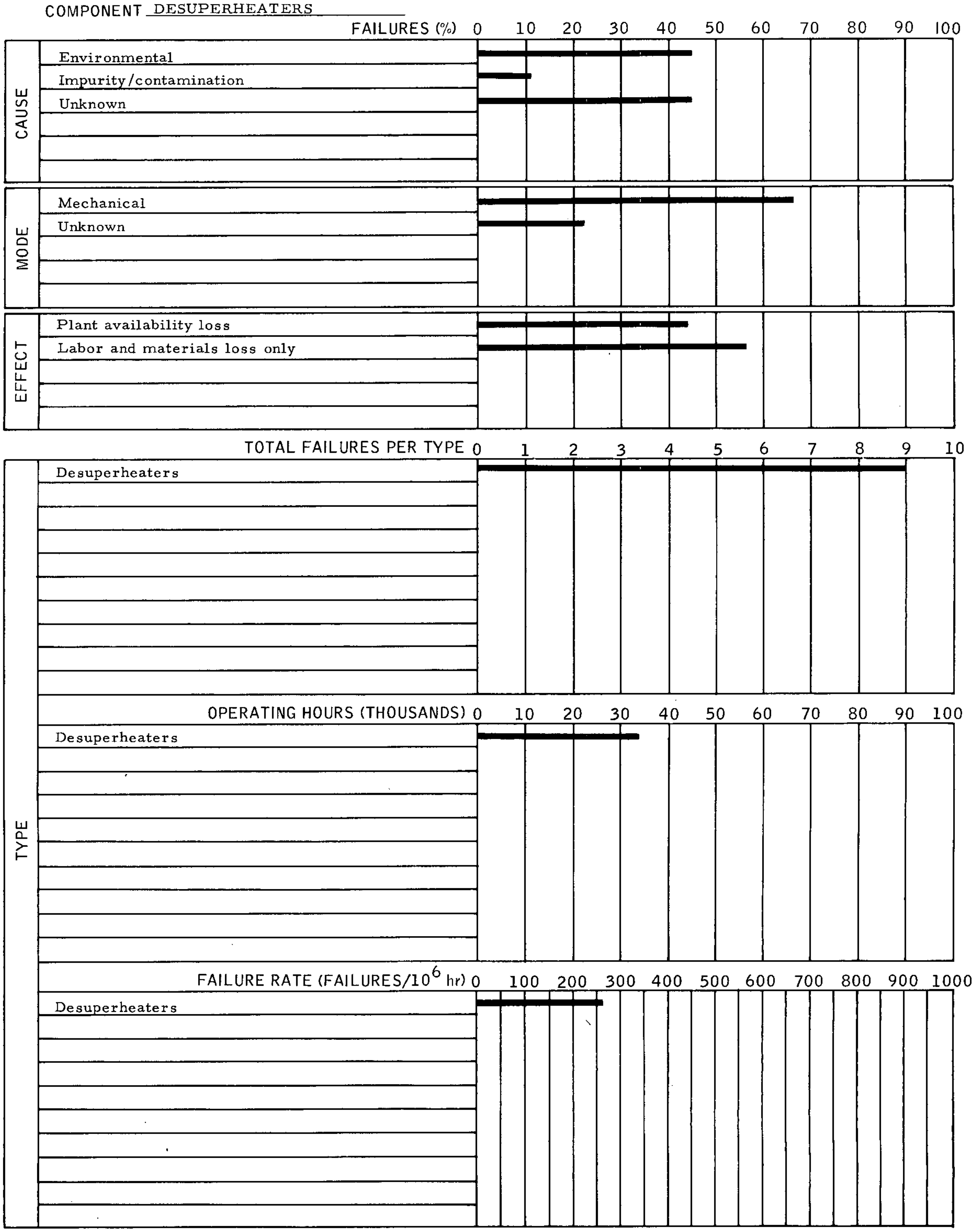


TABLE 1-78

GENERAL SUMMARY

COMPONENT DESUPERHEATERS



5. Feedwater Heaters

Failure data for feedwater heaters are presented in Tables 1-79 through 1-81.

a. Reliability Information

Design Features:

Preheat feedwater to steam generator. Tap off steam from the main steam header to heat incoming feedwater.

Critical Characteristics:

Exchange heat between steam generated in process and feedwater to steam generator.

Mode of Failure:

Gasket leakage

Failure Description:

1) Flange gasket leakage
2) Manhole cover gasket leakage
3) Heater nozzle gasket leakage.

Control Methods:

1) When using spiral wound gaskets, make sure that mating surfaces of flanges are free of nicks, radial scratchs, or grooves from previous installations.
2) Retorque flange bolts after initial installation to account for torque relaxation.

b. Discussion and Recommendations

Gasket failures on feedwater heater connections can generally be attributed to using the wrong gasket material for the application or improper techniques used when the connections were made up; therefore, selecting the proper gaskets and employing the correct installation techniques should eliminate most of the problems.

TABLE 1-79

FAILURE DATA FOR FEEDWATER HEATERS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Feedwater Heater/ Flange Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater Heater 3. 54 284200	1. EBR-II 2. Feedwater heater No. 4 level control 3. 480 to 565°F 4. Operations maintenance report, 5-29-68	MI 500	MI 59	MI 530	14,710	Direct observation	1. Flange leaking, bad gasket. 2. Component corrective modification, flexitallic gasket replaced original asbestos gasket. 3. None.
2	1. Feedwater Heater/ Manhole Cover Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater Heater 3. 54 284200	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F, 200 psig 4. Operations weekly report, 12-20-67	MI 500	MI 52	MI 530	780	Preventive maintenance	1. Manhole cover gasket leaking. 2. Part replaced. 3. None.
3	1. Feedwater Heater/ Nozzle Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater Heater 3. 54 284200	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F, 200 psig 4. PMMR-72 (4-20-66)	MI 500	MI 32	MI 530	1090	Direct observation	1. Heater nozzle gasket leaking. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-80

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FEEDWATER HEATERS

COMPONENT SUBTYPE FEEDWATER HEATERS

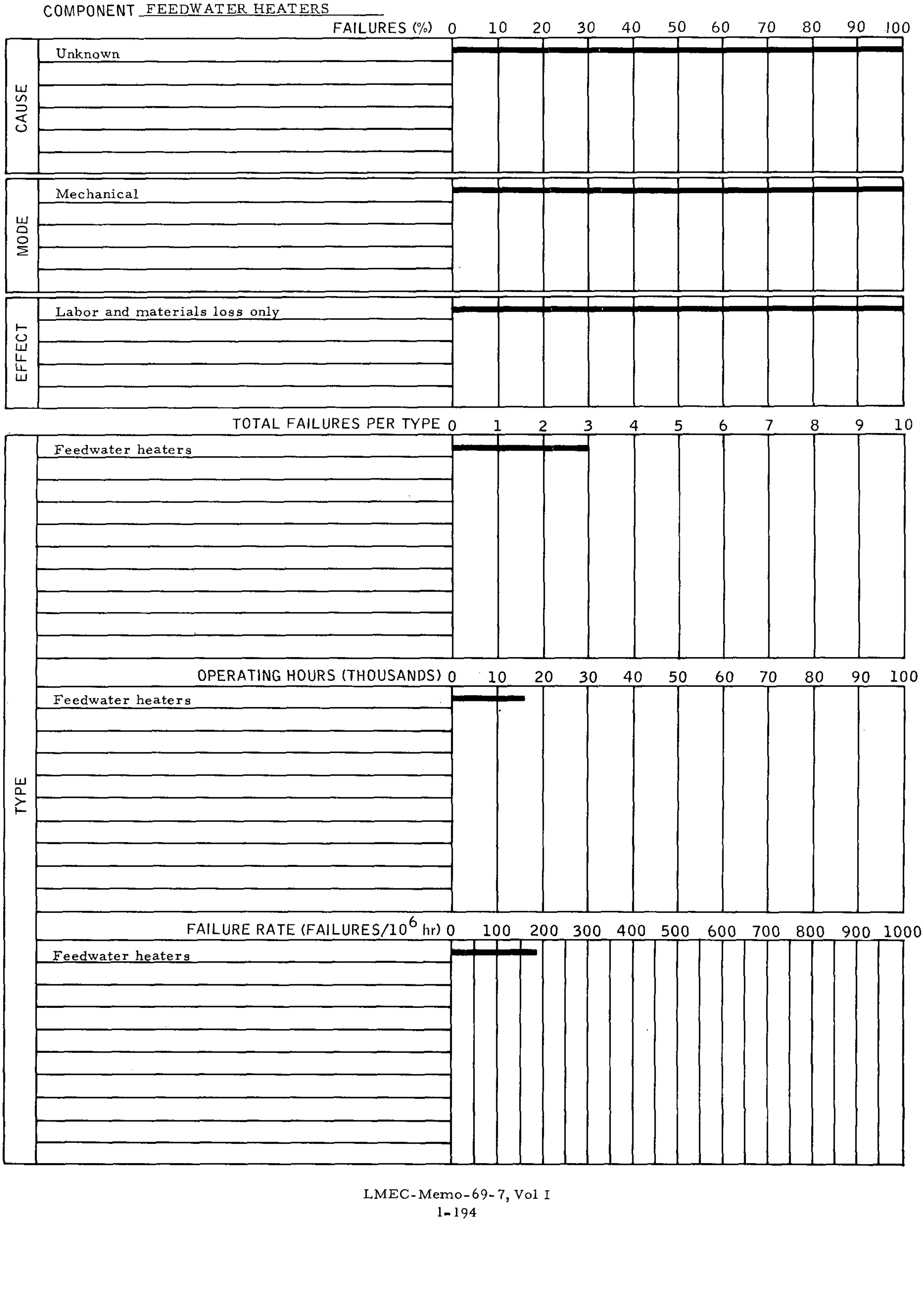
FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactors
SYSTEM	Feedwater
COMPONENT PART	Gasket
CAUSE	Unknown
MODE	Mechanical
EFFECT	Labor and materials loss only

TABLE 1-81

GENERAL SUMMARY

COMPONENT FEEDWATER HEATERS



6. Filters and Strainers (see Figure 1-8)

Failure data for filters and strainers are presented in Tables 1-82 through 1-86.

a. Reliability Information

Design Features:

Strainers and filters are used to remove foreign particles from liquid sodium and water systems.

Mode of Failure:

1) Misalignment

2) Plugging.

Failure Description:

1) The torque bolts were torqued improperly.

2) The strainers were plugged.

Control Methods:

1) Installation procedures should be carefully prepared and adhered to.

2) When plugging of a filter or strainer is critical to plant operation, they should be provided with audible alarms against impending problems.

3) Better quality assurance should be provided during construction to keep the feedwater system clean.

b. Discussion and Recommendations

Micro-metallic filters are generally used in sodium service systems, especially when initially filling the system with sodium. The filter vessel usually has bolted O-ring flanges to facilitate changing the filter element. The operating history of sodium filters has been good. The one reported incident of a flange vessel leaking was an isolated incident and was the result of improper installation.

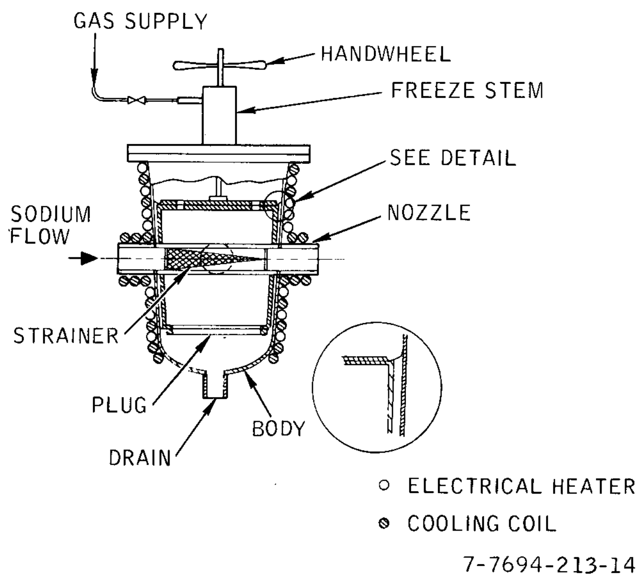


Figure 1-8. Valve-Strainer Device

TABLE 1-82

FAILURE DATA FOR FILTERS AND STRAINERS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Sodium Filter/ Vessel Flange 2. Heat Transfer/ Purification 3. 27 224233	1. SRE 2. Sodium service main primary sodium system 3. 210 to 350°F 4. SRE log book	MI 321	MI 56	MI 530	Unknown	Direct observation	1. Sodium leak, flange bolts not torqued properly. 2. Retorqued bolts. 3. Specify values for torquing flange bolts.
2	1. Filter/Gas Purifier Seal Ring 2. Nuclear Fuel Handling and Storage Equipment/ Cooling 3. 27 235140	1. EBR-II 2. Fuel unloading machine 3. - 4. Operations maintenance, 10-23-68	MI 500	MI 52	MI 530	15,240 as of 7-68	Direct observation	1. Seal ring leaking gas. 2. Part replaced. 3. None.
3	1. Filters/Oil Vapor Extractor Bearings 2. Turbine-Generator Units and Condenser/ Lubricating System 3. 27 350000	1. EBR-II 2. Main Turbine 3. 1250 psig, 3600 rpm 4. Operations weekly report, 12-20-67	MI 500	MI BZ	MI 530	13,380	Preventive maintenance	1. Bad bearings. 2. Part replaced. 3. None.
4	1. Filters/O-Rings 2. Feedwater Supply and Treatment/Filters 3. 27 271100	1. SCTI 2. Feedwater diatomite filters (F-IR&IL) 3. 140 gpm, 20-in. diameter 4. Incident report No. 59 (11-2-65)	P 325	P 52	P 530	1534	Direct observation	1. Filters cleaned, O-rings replaced with wrong size causing water leak. 2. Proper size O-rings installed. 3. Stock proper size components; use proper maintenance procedures.
5	1. Strainer/Screen 2. Other Reactor Plant Equipment/Plant Cooling Water 3. 27 290000	1. EBR-II 2. Primary pump eddy current coupling cooling water system 3. - 4. PMMR-99	MA 273	MA 51	MA 520	11,320	Operational monitor	1. Strainer plugging caused low water pressure in the primary pumps eddy current coupling cooling water system which resulted in reactor scrams. 2. New type strainer installed. 3. Audible pressure differential alarm on strainer to serve as warning of insipient clogging.
6	1. Strainer/Basket 2. Feedwater Supply and Treatment/Boiler Feed Pump 3. 27 284100	1. EBR-II 2. Feedwater/motor-driven feed pump 3. 369°F, 1300 psig 4. PMMR-50	MI 252	MI 51	MI 530	3650	Operational monitors	1. Strainer badly plugged with mud and packing material. 2. Local repair. 3. Maintenance personnel training should include instructions for proper packing installations.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-83

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FILTERS AND STRAINERS

COMPONENT SUBTYPE FILTERS, MISCELLANEOUS

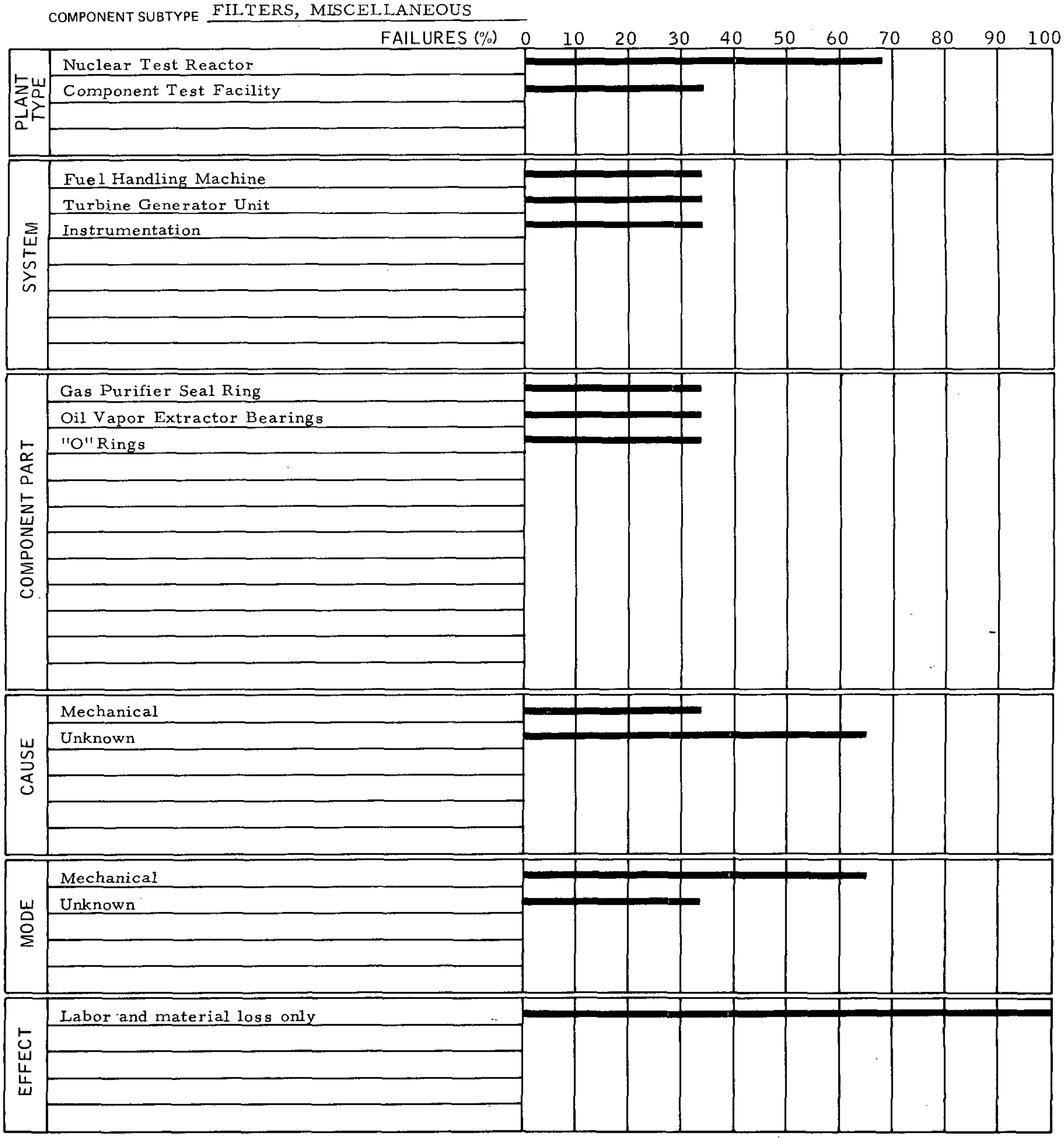


TABLE 1-84

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FILTERS AND STRAINERS

COMPONENT SUBTYPE FILTERS (SODIUM)

	FAILURES (%)	0	10	20	30	40	50	60	70	80	90	100
PLANT TYPE	Nuclear Test Reactor											
SYSTEM	Heat Transfer											
COMPONENT PART	Vessel Flange											
CAUSE	Human error											
MODE	Mechanical											
EFFECT	Labor and material loss only											

TABLE 1-85

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT FILTERS AND STRAINERS

COMPONENT SUBTYPE STRAINERS

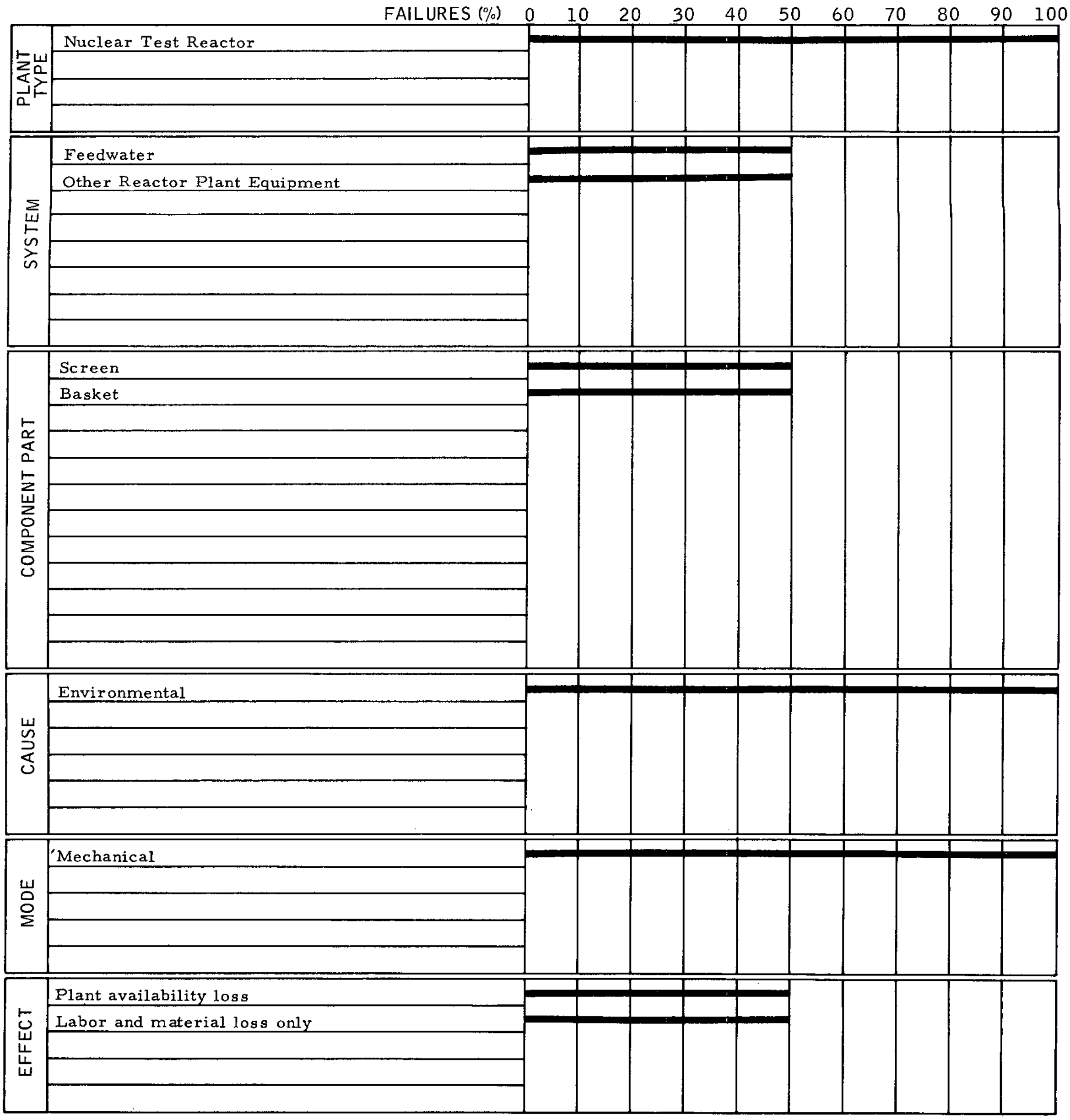
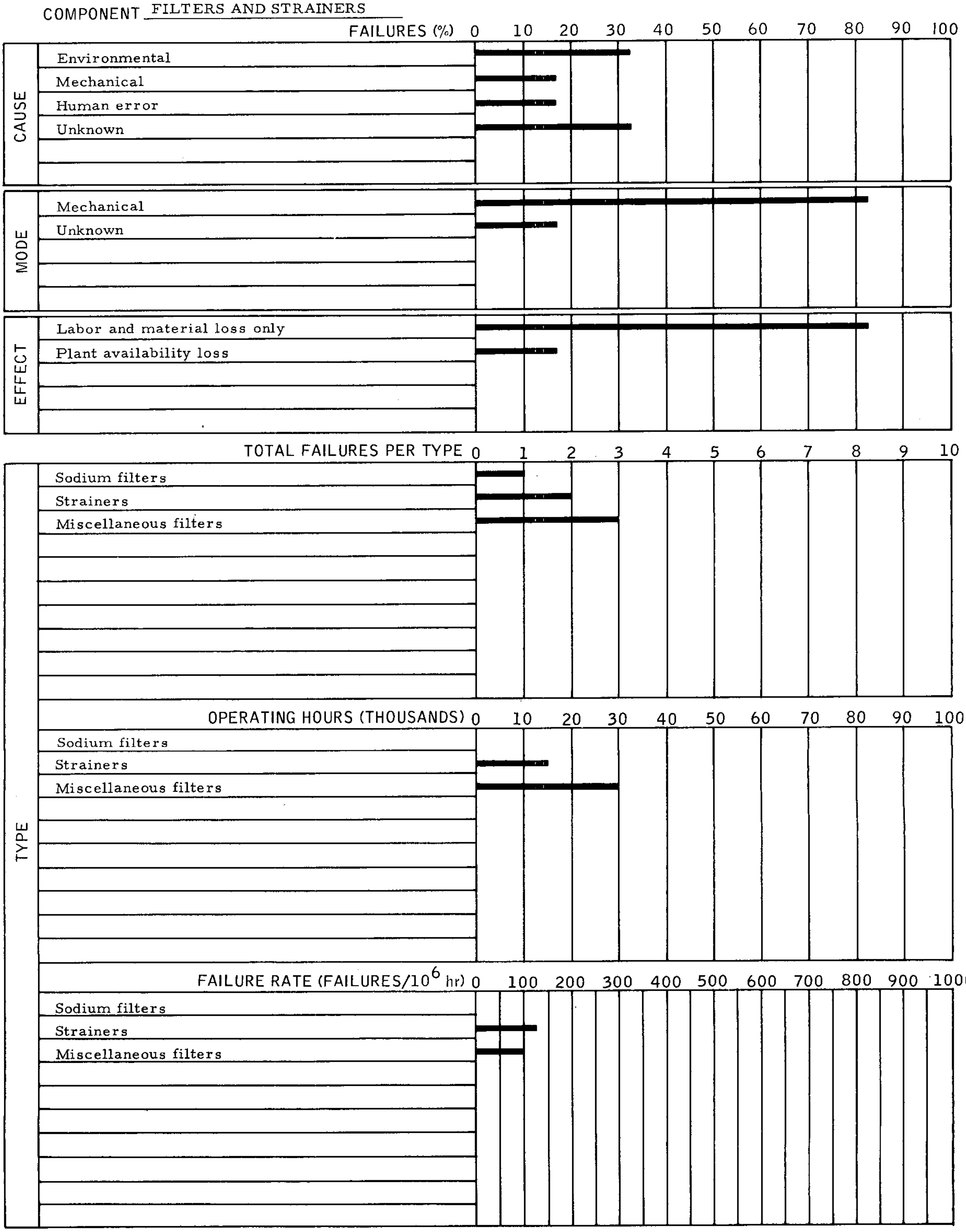


TABLE 1-86

GENERAL SUMMARY

COMPONENT FILTERS AND STRAINERS



7. Intermediate Heat Exchangers (see Figures 1-9 through 1-13)

Failure data for intermediate heat exchangers are presented in Tables 1-87 through 1-89.

a. Reliability Information

Design Features:

Loop-type shell-and-tube heat exchanger for sodium-to-sodium heat transfer.

Critical Characteristics:

Provide efficient transfer of heat from primary source to secondary system.

Provide buffer between radioactive primary side and steam generator.

Mode of Failure:

1) Gas pocket enclosure in the top of intermediate heat exchanger varied its volume driving pressure and temperature changes, generating strong fluctuation in the primary surge tank level.

2) Due to improper matching of tube configuration and liquid metal flow rate, harmonic oscillations produced stress, cracking, and failure of tubes.

Description of Failure:

1) No vent line on top of intermediate heat exchanger where a large volume of cover gas was trapped, resulting in gas entrainment.

2) Liquid metal found leaking through cracked tubing.

Control Methods:

1) Any liquid-carrying loop should be designed for complete filling and drainage. This objective may be accomplished by use of the following:

   a) Utilization of tools and equipment which do not by themselves introduce cover gas (or air) into the liquid metal while the loop is being filled

   b) Installation of appropriate venting fixtures and connections where gas pocket buildup is unavoidable.

c) Adherence to geometric constraints which eliminate low loop fluid pockets during drainage

d) Implementation of special drain lines where stagnant fluid pockets are unavoidable.

2) Any filling or draining procedure should be conducted in accordance with an operational manual which clearly delineates the nature and sequence of steps required for filling and drainage.

3) Any construction of large-scale liquid metal components should be preceded by an adequate and complete design review, entailing, if necessary, application of workable and reliable mathematical models to verify the operability of the component prior to its manufacture.

4) Any significant uncertainties or inadequacy associated with the design analysis techniques shall be resolved by means of the appropriate development project(s) that should be based upon actual experimental results derived from hardware prototype or mockup units.

5) Prior to acceptance and installation of the completed, manufactured unit, an appropriate acceptance test procedure should be devised and utilized to verify satisfactory operation of the component.

b. Discussion and Recommendations

None.

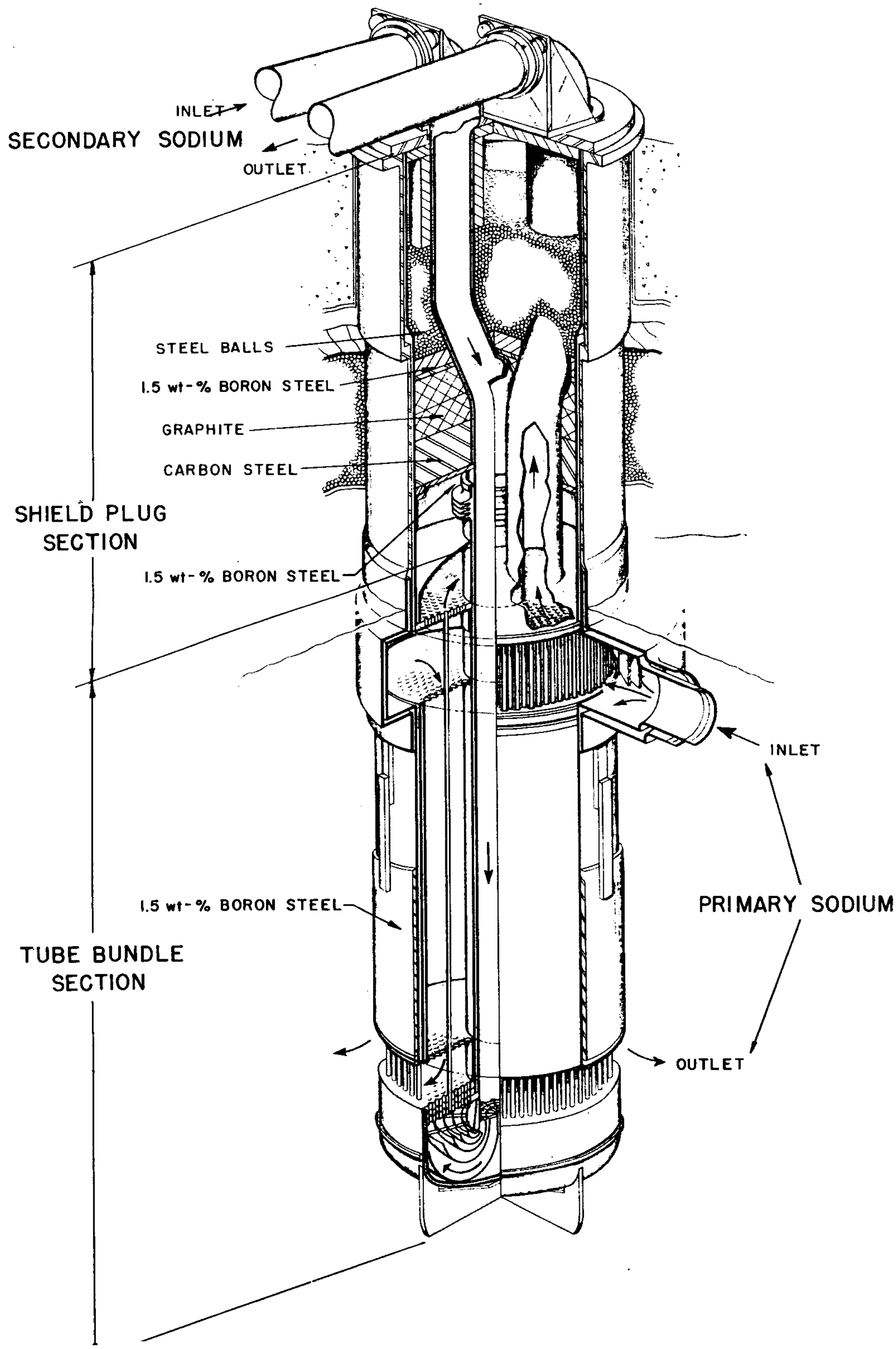
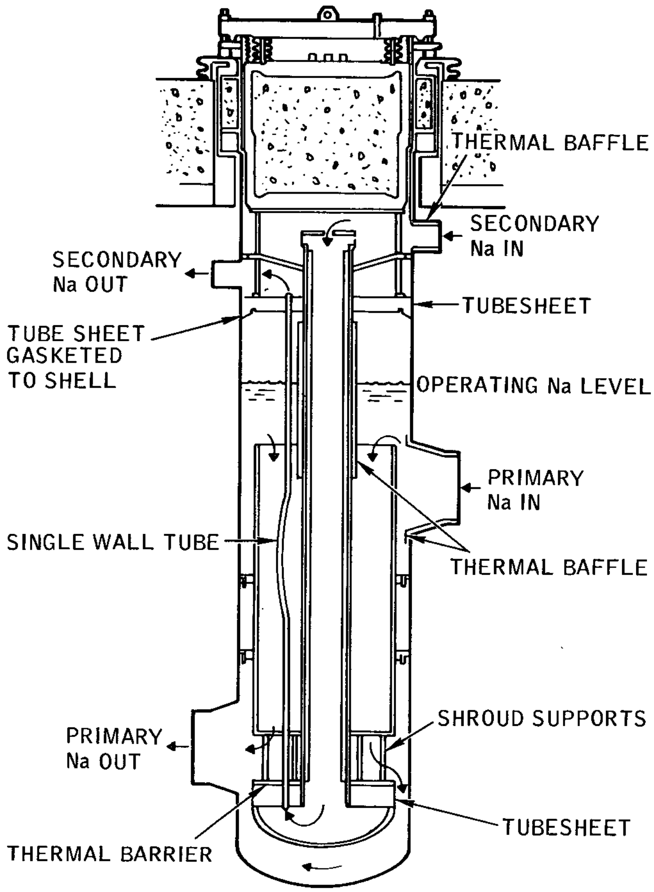


Figure 1-9. EBR-II Intermediate Heat Exchanger



7-7694-208-35

Figure 1-10. EFFR Intermediate Heat Exchanger

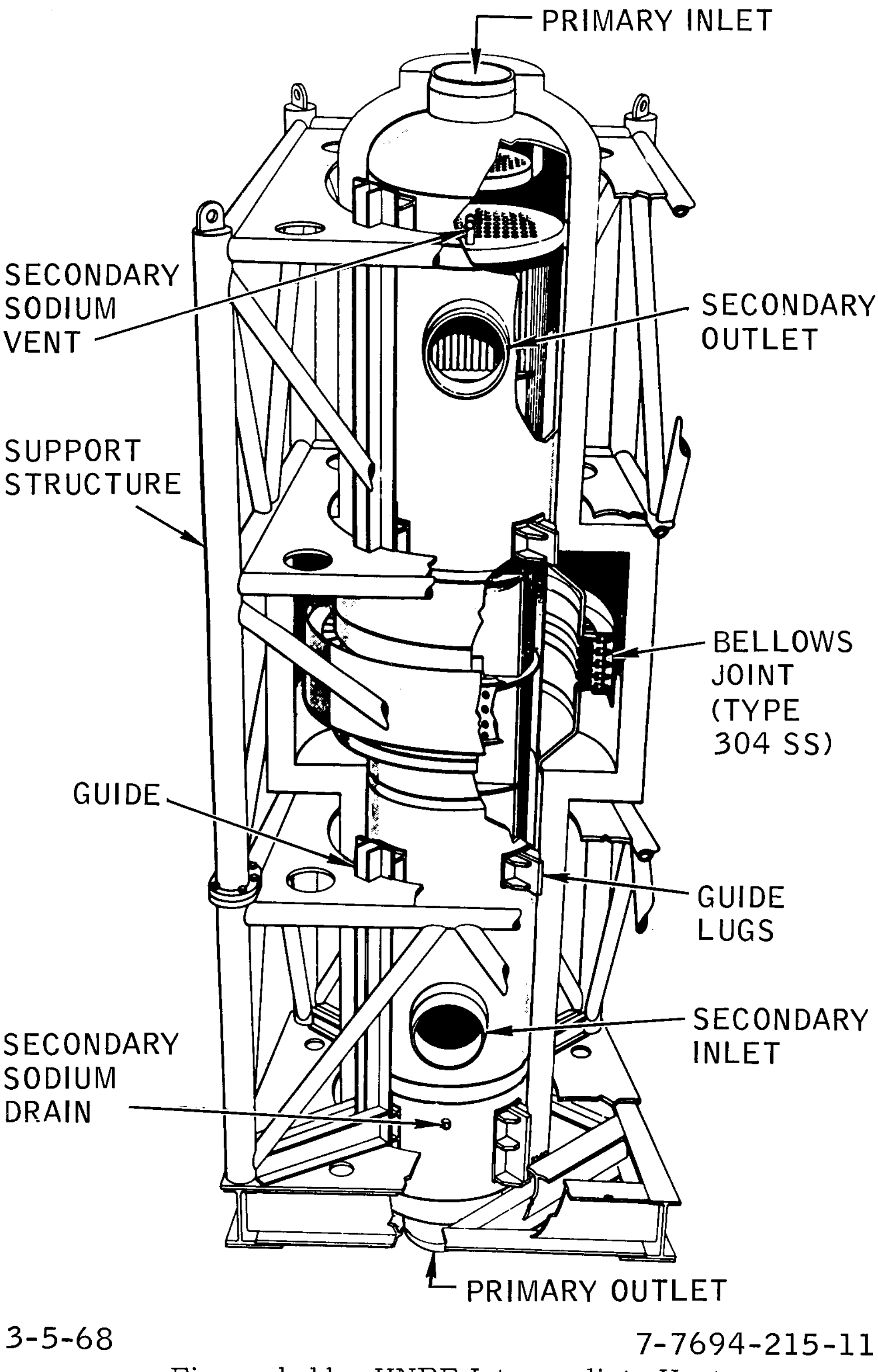


Figure 1-11. HNPF Intermediate Heat Exchanger

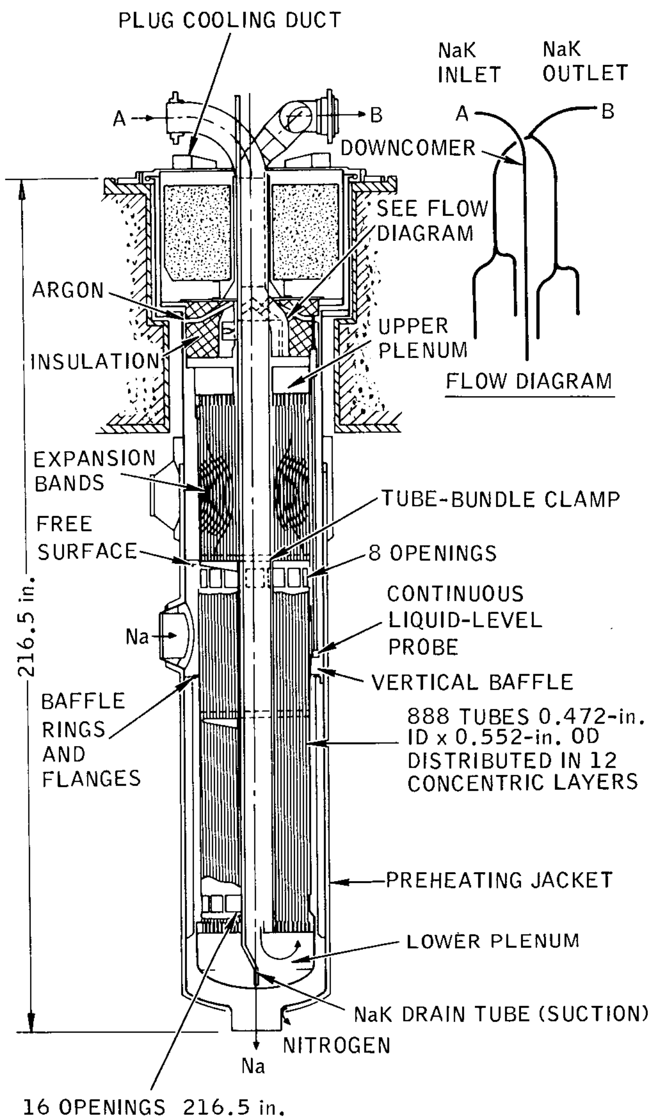


Figure 1-12. Rapsodie Intermediate Heat Exchanger

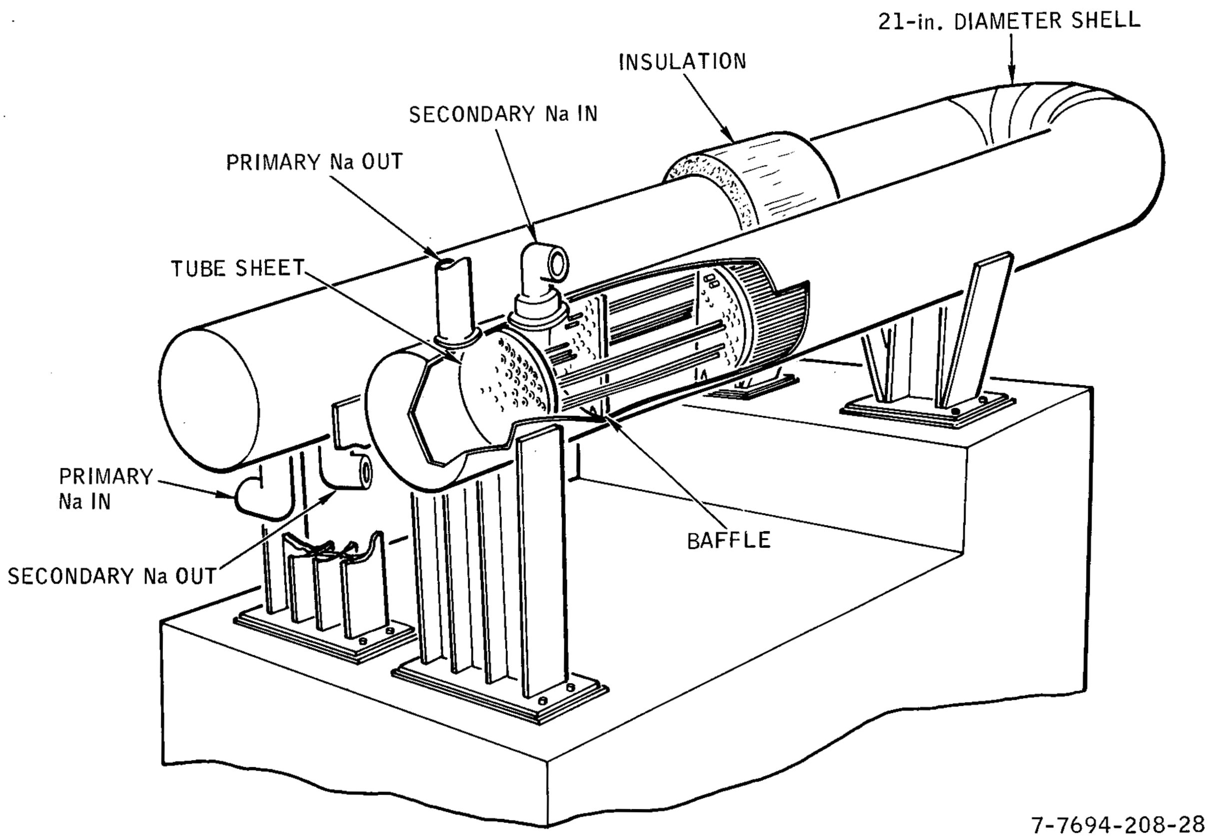


Figure 1-13. SRE Main Intermediate Heat Exchanger

TABLE 1-87

FAILURE DATA FOR INTERMEDIATE HEAT EXCHANGER

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Intermediate Heat Exchanger/Tubesheet 2. Heat Transfer/Intermediate Heat Exchanger 3. 39 222300	1. SCTI 2. Primary sodium 3. Flow 885,000 lb/hr sodium temperature in/out (°F) 775/1175 4. SCTI, incident report No. 46	MI 410	MI 50	MI 530	611	Operational monitor	1. Original piping did not include a cover gas vent from the top of the IHX shell side. Gas was trapped between the sodium inlet nozzle and the upper tubesheet. 2. A vent line and a manually operated valve were installed from the shell side of the IHX to the primary expansion tank. 3. None.
2	1. Intermediate Heat Exchanger/Tubes 2. Heat Transfer/Intermediate Heat Exchanger 3. 39 222300	1. HNPF 2. IHX No. 1A 3. 4. NAA-SR-10743 (11-18-62)	MA 128	MA 59	MA 520	5,640	Operational monitor	1. Tubes cracked and leaked as a result of flow induced vibration. 2. Tube vibration suppressors installed. 3. Provide adequate design analysis and acceptance testing.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-88

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INTERMEDIATE HEAT EXCHANGER

COMPONENT SUBTYPE INTERMEDIATE HEAT EXCHANGER

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Component Test Facility
	Nuclear Power Reactor
SYSTEM	Heat Transfer
COMPONENT PART	Tube Sheet
	Tubes
CAUSE	Environmental
	Inherent
MODE	Mechanical
	Metallurgical
EFFECT	Plant availability loss
	Labor and material loss

TABLE 1-89

GENERAL SUMMARY

COMPONENT INTERMEDIATE HEAT EXCHANGER

	FAILURES (%)	0	10	20	30	40	50	60	70	80	90	100
CAUSE	Environmental											
	Inherent											
MODE	Mechanical											
	Metallurgical											
EFFECT	Labor and material loss only											
	Plant availability loss											

	TOTAL FAILURES PER TYPE	0	1	2	3	4	5	6	7	8	9	10
TYPE	Intermediate Heat Exchangers											

	OPERATING HOURS (THOUSANDS)	0	1	2	3	4	5	6	7	8	9	10
TYPE	Intermediate Heat Exchangers (6,251 hrs)											

	FAILURE RATE (FAILURES/10^6 hr)	0	10	20	30	40	50	60	70	80	90	100
TYPE	Intermediate Heat Exchangers											

8. Piping and Associated Fittings (Figure 1-14)

a. Introduction

The piping and fittings data collected for this section include service in gas, steam, water, and sodium. Some gas systems will include sodium vapor and, for this analysis, are identified as a separate subtype. While a large number of different piping materials are used in nuclear systems, the events collected herein are primarily for the stainless steels and high-strength alloys. The 38 failure events collected to date are itemized in Table 1-90.

Evidence of a pipe failure is a leak or, in a limited number of cases, plugging or high-pressure drop. Approximately three-quarters of the reported failures were detected by direct observation and one-quarter of them by monitors. Monitors are categorized as operations and performance measurements that are monitored by means of leak detectors and protective systems.

b. Summary of Tabulated Data

The detailed data of Table 1-90 are summarized in Tables 1-91 through 1-96. The data are subdivided into piping subtypes: water, steam, sodium, sodium vapor, inert gas, and miscellaneous.

Table 1-96 provides a general summary of the data as to cause, mode, effect, and total number of piping failures. Computation of updated failure rate information has been discontinued until a later date. The number of failures collected for any one of these subsystems is not large. The mode of failure is indicated to be in the class of mechanical failures 57% of the time. The effect of the failure is predominantly a labor and material loss (71%).

The water-piping experience presented in Table 1-95 is primarily associated with nuclear power reactors; the feedwater systems contribute the majority of the failures. The failure distribution function for steam piping shows the flange and flange gasket to be the major contributors of malfunctions. In sodium piping (Table 1-92), the bellows convolutions are shown to be a troublesome area. The failures associated with miscellaneous piping (Table 1-91) occur primarily in the fuel handling system and instrument air supply system.

Piping malfunctions can be reduced by following good design practices. Material quality requirements must be carefully considered, material specifications properly written, and the highest quality workmanship used during fabrication.

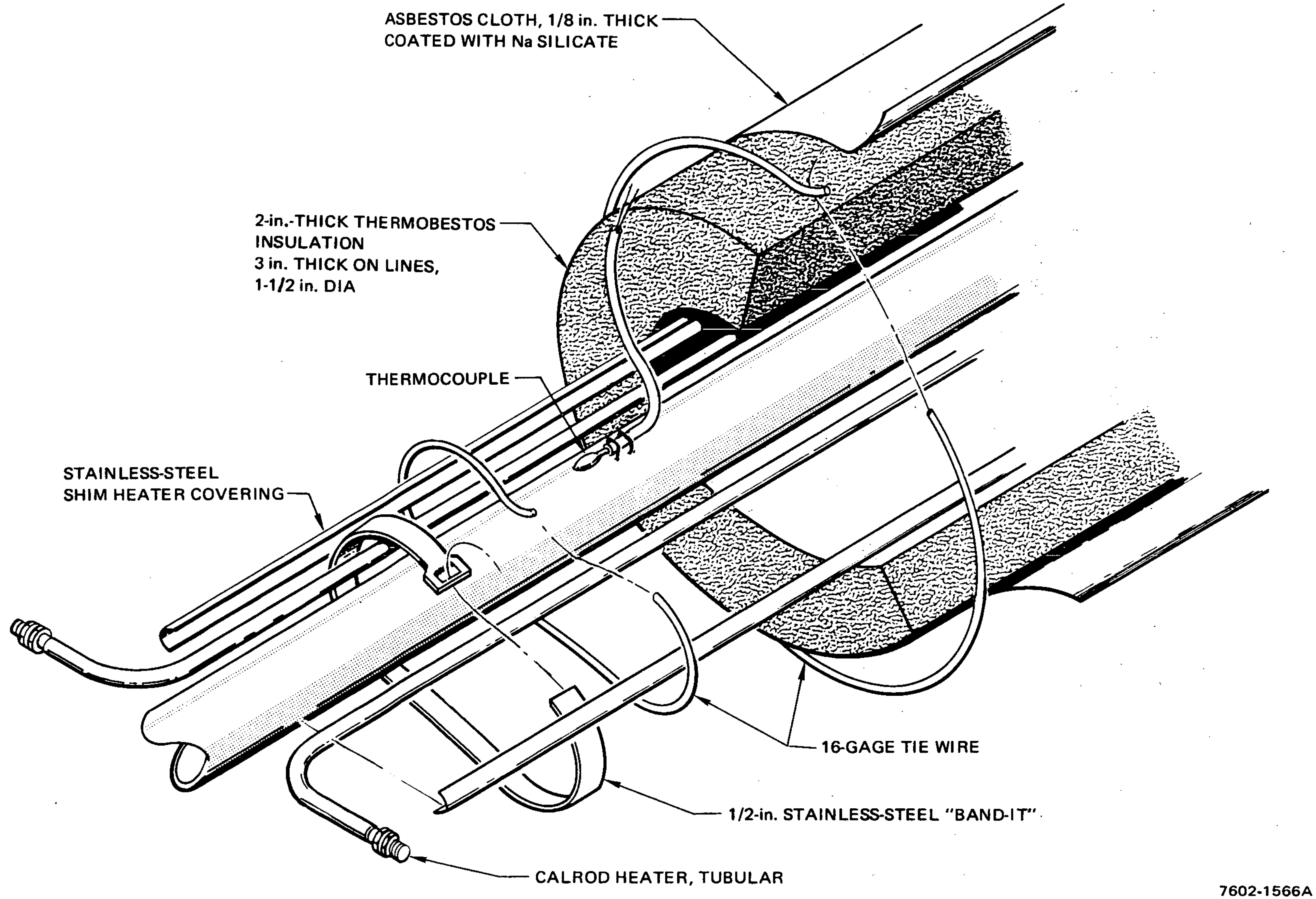


Figure 1-14. Sodium Pipe Section

Welding procedures are very important; post-mortem examinations of pipe stub welds and joint welds have revealed several cases of very poor penetration and of poor weld fitup. Facility operating procedures should be clearly defined, established, and closely followed.

Fatigue problems under thermal and mechanical cycling loading conditions must be considered in the design of the piping system. When notches or stress risers are incorporated in the piping system, the potential for fatigue failures is increased. Piping wall sections that are subjected to large temperature differentials or mechanical vibrations are areas of special concern with respect to cycle fatigue.

Particular care is required to avoid the initiation of stress corrosion in the Type 300 series stainless steels when using chloride cleaning solvents or acid pickling solutions. If the use of such materials is unavoidable, meticulous cleaning precautions must be used. Insulation must be kept dry to prevent leaching of chlorides present in the insulation onto the pipe surface. Special precautions are required for inactivated systems exposed to the elements. Moist sea air is a particular source of chlorides. To minimize the possibility of stress corrosion due to chlorides from the insulation, choose insulating materials which contain inhibitors or which are low in chloride content. Obviously, the insulating material should be protected from moisture.

After a piping system has been exposed to the sensitizing temperature range of 800 to 1300°F (e.g., a welded region), care must be exercised to protect the pipe surface from corrodents. Sensitized stainless steels are highly susceptible to atmospheric or aqueous corrosion on piping exposed to weather. To reduce potential exposure to the weather, a minimum of penetrations should be made through the insulation and protective covering. A preheat on the pipe minimizes the effect of moisture that contacts the pipe surface.

c. Sodium Systems

A sodium pipe section with a typical arrangement of pipe, calrod heater, insulation, and protective covering is shown in Figure 1-14.

The over-pressurization of sodium systems while thawing frozen lines can be avoided by initiating thawing at a free surface and progressing from there to the rest of the system.

Special consideration should be given to the design of mixing tees in sodium to minimize the effects of cyclic thermal stress fatigue.

In actual operating sodium systems, the normal sodium impurities will not be detrimental to piping, except possibly to thin-walled tubing or fuel cladding. The post-operational examination of the SRE[1] substantiates this conclusion regarding the sodium piping in the system. The primary sodium system was exposed for approximately 44,000 hr to sodium at temperatures ranging from 205 to 1030°F, while the secondary sodium system was exposed for approximately 25,000 hr at temperature from 300 to 1000°F.[2] The results of this investigation disclosed no evidence of impending functional failures, cracking, or erosion problems. Some surface layers showed slight evidence of carburization and possible corrosion, but in all cases, materials deterioration was insignificant. The investigators reached a conclusion that "large sodium systems operated under SRE conditions could be expected to have a reliable long life, commensurate with power plant practices."[1]

LMFBR systems will be operating at creep temperatures. Creep stress rupture is caused by the combination of steady stress at a temperature where no appreciable strain hardening occurs. Any excessive deformation may point out a creep problem which indicates that pipe deformation or movement should be monitored.

d. Discussion

(1) General

The causes of piping failures can be classified into five categories as follows:[3]

1) Service (excessively severe service conditions).

2) Materials (selection and handling of base and welding materials).

3) Base metal defects (introduced during manufacture).

4) Design (structural, design notches, joint location, weld configuration).

5) Fabrication (fabrication, welding, heat treatment, or cleaning).

Cyclic loading conditions, whether mechanical or thermal, in piping with inadequate flexibility results in peak stresses of sufficient magnitude to initiate and propagate cracks. These cracks are often initiated at branch connections or anchored supports where motion is restricted.

Incorrect selection of piping materials for exposure conditions has resulted in numerous piping failures. Failures have resulted due to graphitization of carbon and carbon-molybdenum steal piping after service above 800°F. Graphitization has been most commonly found in the weld heat-affected zone when the material has been heated briefly above 1333°F. Specific heat composition as well as heating conditions appear to affect cracking tendencies of Type 347 stainless steel piping in the weld heat-affected zone. This tendency toward hot cracking has been a problem in the past, and has generally been related to a low liquation temperature. High carbon and nitrogen in relation to columbium tend to raise the liquation temperature and increase resistance to cracking.

Between 800 and 1300°F austenitic stainless steels become sensitized. Carbon combines with chromium near the grain boundaries and precipitates out in these grain boundaries as chromium carbides. This precipitation leaves a narrow zone on either side of the grain boundary which has less than the 12% chromium necessary for corrosion resistance. In the presence of a corrosive environment the material is highly susceptible to intergranular attack and possible failure.

Base metal defects such as laps, laminations, seams, porosity, or any significant discontinuities in the microstructure can act as sites for crack nucleation.

Sharp changes in section thickness, hangers, nozzles, branch connections, reinforcement, metallurgical notches (e.g., welds), and built-in residual stresses are all areas for concern under cyclic loading.

Welded piping fabrication is particularly susceptible to careless choice of weld rod, contaminated rod, poor fitup, poor welding technique, lack of penetration, porosity, undercut, cracking, and arc strikes. Austenitic stainless steels are particularly susceptible to stress corrosion especially in the presence of chlorides.

GEAP testing of materials in flowing non-isothermal sodium indicated that corrosion rates:[4]

1) Varied directly with the oxide content of the sodium.

2) For materials tested (316 SS, 2-1/4 Cr - 1 Mo, 5 Cr - 1/2 Mo - 1/2 TC) were all essentially the same.

3) Became linear after an initial period of a few hundred hours.

4) Increased three-fold with an increase in temperature from 1100 to 1200°F.

5) Were affected by sodium saturation. The first material exposed at a given temperature showed the greatest corrosion rate. Material "downstream" showed progressively lower corrosion rates.

(2) Detailed Discussion

In the following discussion, specific examples of the effects of stress corrosion, thermal/mechanical cycling, fabrication deficiencies, and human errors are presented.

Stress-Corrosion (Sensitization/Chloride Induced)

Transgranular stress-corrosion cracks were detected[5] in Type 304 and Type 347 stainless steel components of the homogeneous reactor during tests of remote-maintenance procedures prior to actual startup of the reactor. The cracks were in tubing of the secondary system used for detecting leaks at the flanged joints of the primary system and in the grooves of the flanges in the primary system. Up to 1070 ppm chlorides were found in the fluid drained from the secondary system. Apparently a chlorinated-hydrocarbon lubricating compound was not removed during fabrication and was baked in during subsequent annealing.

During hot-flushing of the piping in the merchant ship, N. S. Savannah, several leaks developed in the primary system which wet the thermal insulation.[6] Since it was known that the thermal insulation applied to the primary system piping contained chlorides, and that the primary system had been thermally cycled several times after the insulation had been wet, an investigation was initiated to determine whether the system had been damaged. The investigation showed that the proper conditions existed for chloride stress-corrosion cracking of the austenitic stainless steel in the primary system. Laboratory investigation of a sample of pipe removed from the primary system indicated that chloride stress-corrosion cracking had begun but that the reaction had been interrupted before serious damage occurred.

A sodium leak was observed in the secondary expansion tank overflow nozzle at the Hallam Nuclear Power Facility. The subsequent investigation indicated that an earlier leak preceded the observed leak. After removal of the insulation, visual inspection revealed severe corrosion on the external surfaces of the tank wall and 8-in. overflow nozzle from the tank to an 8-in. overflow line. A pinhole was discovered 1/2 in. from a butt-weld joining the nozzle with the overflow line. Further examination showed a massive network of cracks in the tank wall, which metallographic examination showed to be transgranular in nature. This was the initial (primary) leak and sodium-insulation-reaction products from this leak appear to have produced the external corrosion that resulted in the pinhole leak. The primary leak is considered to be due to transgranular stress corrosion resulting from the chloride/fluorine contained in the weld flux discovered in a cavity between a welded internal baffle and the tank wall.

Intergranular corrosion cracking was detected in two Type 304 stainless steel outlet nozzles in high-purity heavy-water moderator service at the Savannah River reactor plant.[5] The cracks propagated from general intergranular attack that apparently occurred at sensitized grain boundaries as the result of acid pickling during initial fabrication of the nozzles. Cracking was attributed to chlorides, although the bulk heavy water contained only about 6 ppm chloride. The chloride ions were believed to have concentrated in the intergranular pickling cracks.

A 3-in. line of Type 304 stainless steel at the Large Component Test Loop (LCTL) developed a sodium leak.[7] Metallurgical examination of the failed section revealed the material had been sensitized due to operation over 800°F and that corrosion attack was intergranular. At the point of leakage the thermal insulation had been rain soaked. It was postulated that a corrodent was leached from the insulation and concentrated on the pipe surface. A similar failure occurred in a plugging meter loop at the LCTL.[8] Again it was attributed to intergranular corrosion due to a corrodent leached from wet thermal insulation.

Three Type 304 stainless steel bellows expansion joints installed in the sodium piping at the Sodium Component Test Installation (SCTI) at LMEC failed after relatively short service.[9] Failure analysis revealed the bellows had been sensitized during fabrication due to a baking treatment at 1300°F for 30 min to remove volatile materials. There was a 30-mo period between fabrication and installation of the bellows in the SCTI. It was postulated that during this period the material, sensitized by the baking treatment, was attacked by an unidentified corrodent. It was known that moisture, salt, and chemicals were present in the atmosphere at the fabrication, storage, and installation sites.

Thermal/Mechanical Cycling

Thielsch[3] reports a steam pipe failure where periodic startups and shutdowns of the boiler resulted in expansion and contraction of the line. "With insufficient flexibility in the system to absorb the stresses over the years, cracking was initiated and gradually spread across the wall thickness." GEAP[10] reports 10 cases where expansion/flexibility is listed as the primary cause of failure. In two instances steam header piping (14- and 16-in.-OD seamless carbon steel pipe) failed due to bending over supports. Thermal and mechanical fatigue was responsible for crack initiation and propagation. Cracking of a drain line near the point of attachment to the main piping resulted in leakage of NaK at the Russian BR-5 plant.[11] The cause of this failure was attributed to inadequate provisions for thermal expansion.

A number of service failures resulting from the combination of a stress concentration and cyclic loading are reported.[3,10] Mechanical notches, metallurgical notches, and high residual stresses due to a socket weld were all present in these cases. One such failure was in a socket weld joining a thermometer well to a steam pipe and another in the thermowell of the SCTI secondary sodium system. Another failure[3] occurred at the toe of a fillet weld attaching a hanger lug to a curved pipe section. The failure was attributed to thermal fatigue because of a sharp change in weldment design. Two similar failures resulted from severe design notches. In one case, coupled to thermal fatigue in a 10-in.-OD by 0.690-in.-wall main steam line and a hanger lug. In the other, a sharp notch between a reinforcing rib and a 5-in. schedule 40 17-4 Ph stainless steel was coupled to mechanical fatigue.

A 2-1/2-in. Type 304L stainless steel mixing tee revealed numerous cracks after 9500 hr of operation.[12] Cause of cracking was attributed to thermal-stress fatigue (possibly high cycle) due to mixing of hot (~700°F) and cold (~510°F) sodium. Crack propagation under these conditions is relatively slow, with a large number of cycles required to cause failure.

The GEAP survey[10] lists 41 cases where graphitization embrittlement was reportedly the cause of failure. The location of failure in 38 of these cases was in the weld-heat-affected zone of a welded pipe joint. Essentially all these failures occurred in carbon-molybdenon steam piping, operating between 900 and 960°F, after long exposure times, and resulted in cracking but not complete severance.

Fabrication

One instance of an inadequate inspection requirement of some Croloy (2-1/4 Cr - 1 Mo) steam pipe was reported at the Sodium Component Test Installation (SCTI) at LMEC.[13] This material had been purchased to ASME Pressure Vessel Code, Section II, SA335, requiring only visual inspection for surface flows. One length of pipe previously accepted to the above specification requirement was found, during routine spool fabrication, to contain a longitudinal forging lap. Subsequent ultrasonic inspection of all the Cr-Mo pipe resulted in rejection of several of the pipe spools due to forging laps. Plant startup was delayed 69 days.[14]

A NaK leak in the primary coolant circuit of the British Dounreay Fast Reactor (DFR)[15] illustrates some of the problems that can be caused by defective welds. The primary coolant piping in this case was enclosed in a vault due to the radioactive nature of the primary circuit. The primary piping was also surrounded by a leak jacket. This situation made it difficult to determine the exact leak location and further complicated repair once the leak had been located. Final metallurgical examination of the leak revealed that it had occurred at a weld joint due to the following weld defects: Joint misalignment, straying of the weld from the line of the butt joint, lack of penetration, and a stress riser where the weld had a double start. Total facility down-time due to this incident was about 11 mo, which illustrates the severe consequences of inadequate control of welding procedures. The GEAP survey[10] reported 31 cases where the primary cause of failure was attributed to some type of weld defect.

Human Error

Improper preheating of a line filled with solid sodium can result in melting of sodium between solid sodium plugs and possible overpressure of pipe lines due to expansion of the melted sodium. Failure of this sort was experienced at Rapsodie during preheating of a system fill line which was full of sodium.[16] This same procedure caused many failures of bellows seals in valves at the Sodium Reactor Experiment (SRE) during early operation.

A flanged elbow ruptured instantaneously from the impact of a slug of water accelerated by steam from a valve that had just been opened.[3] This incident resulted in the loss of one life.

Discussion with cognizant personnel revealed a pipe failure in the SRE in a 2-in. pipe leading from the sodium service vault to a primary heat transfer line. An electric arc from a shorted line heater made a hole in the pipe which resulted in a sodium leak. Also, a welder inadvertently touched a pipe in the SCTI primary pump sodium line, leaving an undetected hole until the system was filled.

One case was reported[3] where an incorrectly identified coupling failed during a pressure test. The coupling had been certified and stamped as Type 304 stainless steel. Examination subsequent to the failure revealed the material to be "Monel." Welding of this "Monel" with stainless steel electrodes resulted in a brittle joint which was responsible for the failure.

The principal investigator of this material was R. C. Calkins. If additional information regarding piping/fitting failures is required, contact J. J. Auleta, R. C. Calkins, or E. Ferguson at LMEC.

e. References

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TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS

(Sheet 1 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. IHX Inlet Pipe/ Thermowell 2. Heat Transfer/Hot Leg 3. 18 222211	1. SCTI 2. Secondary sodium system, inlet line to IHX 3. Contains thermocouples to indicate sodium loop temperature 4. Incident report No. 79	MI 474	MI 128	MI 520	1140	Operational monitors	1. Thermowells cracked because of metal fatigue due to vibration. 2. Thermowells removed and replaced with shorter length unit. 3. Deviations from specifications should be routed through a material review board.
2	1. Piping/Bellows Convolution 2. Heat Transfer/Hot Leg 3. 18 221211	1. SCTI 2. Expansion joint No. 5 3. 1000°F at 125 psi 4. Incident report No. 34	MI 457	MI 61	MI 530	612	Direct observation	1. Bellows cracked. 2. Part replaced. 3. Use of bellows expansion joints in sodium loops is not recommended.
3	1. Piping/Suction Line 2. Heat Transfer/Primary Coolant 3. 18 221210	1. SCTI 2. Primary sodium system, sodium pump (P-5) 3. 10 in., schedule 40-304 SS, 1300°F 4. Incident report No. 60	MI 328	MI 34	MI 136	1208	Direct observation sodium fire during loop filling	1. Welder inadvertently touched pipe with welding torch creating a hole which remained undetected by visual inspection. 2. Local repair. 3. Any welding on the sodium line should be checked by dye penetration method prior to filling.
4	1. Piping/Bellows Convolutions 2. Heat Transfer/Hot Leg 3. 18 222211	1. SCTI 2. Expansion joint XJ-10, line No. 552 3. 1000°F at 125 psig 4. Incident report No. 108	I 457	I 61	I 520	612	Operational monitors	1. This bellows failure was the same as previous failures. The stainless steel had sensitized and subsequently corroded. 2. Part replaced. 3. Avoid use of bellows expansion joints in sodium loops.
5	1. Piping/Bellows Convolutions 2. Heat Transfer/Hot Leg 3. 18 222211	1. SCTI 2. Expansion joint No. 8 3. - 4. Incident report No. 114	I 457	I 61	I 520	887	Protective system, leak detector alarm actuated	1. Very small cracks and pin hole leaks developed in the convoluted portion of the bellows due to sensitization of the metal. 2. Part replaced. 3. Avoid use of bellows expansion joints in sodium loops.
6	1. Piping and Fittings/ Gasket 2. Heat Transfer/Coolant Receiving 3. 18 224110	1. HNPF 2. No. 2 drum melt station 3. - 4. AI monthly, 1/11/63	MI 442	MI 5Z	MI 530	Unknown	Direct observation	1. Sodium leak around gasket between piping and drain bung. 2. A new gasket of copper-covered asbestos was installed. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS
(Sheet 2 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Piping and Fittings/ Pipe 2. Heat Transfer/Intermediate Cooling 3. 18 222000	1. HNPF 2. Overflow line pump to secondary expansion tank No. 3 3. - 4. Conference 650620	MI 24Z	MI 94	MI 530	15,000	Direct observation	1. Sodium leak occurred in the 8-in. inlet overflow pipe from sodium pump No. 3 to expansion tank No. 3. Failure of the pipe was due to stress corrosion cracking. 2. The pipe spool was removed from the system and replaced with a new section. 3. None.
8	1. Vent Piping/Pump Vent Line 2. Heat Transfer/ Reactor Coolant Piping 3. 18 221210	1. HNPF 2. Primary sodium system 3. Vent lines are preheated to 338°F 4. Monthly operating report No. 2	MI 116	MI 51	MI 530	890	Direct observation	1. Vent line plugged. 2. Operating limits change. 3. None.
9	1. Piping/Vent Line 2. Heat Transfer/Purification (Cold Trap) 3. 18 224239	1. HNPF 2. Primary cold trap No. 1/freeze trap No. 3 3. 3-10 psi helium when draining sodium 200 to 350°F 4. Work request No. 2629	MI 187	MI 51	MI 550	Unknown	During actuation	1. Vent piping plugged with sodium. 2. Local repair; (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity ground the cam shaft housing to ensure solidification of any sodium that may flow past the float. Change in operating procedure should be made whereby a slight positive sodium pressure is maintained on freeze trap at all times.
10	1. Piping/Line to Chromatograph 2. Heat Transfer/Inert Gas Monitor 3. 18 224600	1. EBR-II 2. Fission Gas Monitor 3. Ambient Temperature 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	Routine inspection	1. Gas leak from primary system. 2. Local repair. 3. None.
11	1. Piping/Joint 2. Heat Transfer/Inert Gas Monitoring 3. 18 224630	1. EBR-II 2. Primary/argon system 3. Ambient temperature 4. Operations maintenance report, 5/29/68	MI 500	MI 43	MI 530	14,710	Operational monitors	1. Leaking joint in argon system to chromatograph. 2. Temporary repair. Joint was sealed with RTV. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS

(Sheet 3 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
12	1. Piping/Piping Plugged 2. Fuel Handling Machine/ Cooling System 3. 18 235140	1. EBR-II 2. Fuel Handling Machine 3. - 4. ANL-6808, 9/63	MI 218	MI 51	MI 530	Unknown	Operational monitor	1. Liquid metal condensation clogged piping. 2. Local repair. 3. None.
13	1. Piping/Argon Seal 2. Fuel Handling/Fuel Handling Machine Cooling 3. 18 235140	1. Fermi 2. Cask car 3. - 4. EFAPP-47	MI 136	MI 54	MI 530	6470	Direct observation	1. Seal leaking. 2. Part replaced. 3. None.
14	1. Piping/Flange 2. Steam-Feedwater/ Piping 3. 18 281300	1. SCTI 2. Steam and Feedwater System 3. - 4. Incident report No. 129	MA 144	MA 53	MA 136	6030	Direct observation	1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. Component corrective modification. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket.
15	1. Level Sensing Pipe/ Flange 2. Steam-Feedwater/ Feedwater Heater 3. 18 284200	1. SCTI 2. High pressure feedwater heater (E-1) 3. 600°F, 2000 to 2400 psig steam 4. Incident report No. 96	MI 326	MI 53	MI 530	4935	Direct observation	1. Flange bolts unevenly torqued, flange leaking steam. 2. Local repair, bolts properly torqued. 3. Quality control for gasket material and torque of flange connections should be specified.
16	1. Piping/Flange 2. Steam-Feedwater/ Piping 3. 18 281300	1. SCTI 2. Flow nozzle - FRC-200E 3. 0-1200 H_2O, 0-146,000 lb/hr 4. Incident report No. 127	MA 136	MA 53	MA 550	6030	Direct observation	1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. Component corrective modification. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket.
17	1. Piping/Flange Gasket 2. Steam-Feedwater/ Piping 3. 18 281300	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-62	MI 500	MI BZ	MI 530	4955	Direct observation	1. Gasket worn out. 2. Part replaced. Original gasket changed to Flexatallic type. 3. Gasket materials should be selected for temperature and pressure conditions. Proper installation is essential for long lasting operation.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS

(Sheet 4 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
18	1. Piping/Elbow 2. Steam-Feedwater/ Piping 3. 18 281300	1. EBR-II 2. Steam system/between the high pressure and low pressure flash tanks 3. - 4. Operating maintenance W/E, 8/21/68	MI 126	MI 65	MI 530	15,240	Direct observation	1. Elbow eroded. 2. Local repair, elbow replaced because of erosion. 3. Heavier wall thickness should be required for elbows than for straight pipes because of high level turbulences.
19	1. Piping/Line 2. Steam-Feedwater/ Piping 3. 18 281300	1. SCTI 2. Steam and feedwater system line 100 PSV-208 3. 600 psig, 580°F, 16,900 lb/hr 4. Incident report No. 316A	I 121	I 94	I 136	2160	Direct observation	1. Steam leakage between two safety valves due to chloride stress corrosion of 347 SS. Four cracks developed, 4 to 6 in. long. 2. Replacement with ASTM-A335-P22, 2-1/4 Cr and 1% Mo. 3. None.
20	1. Piping/Pipe Nipple 2. Steam-Feedwater/ Condensate 3. 18 283400	1. SCTI 2. Feedwater system 3. 121°F, 30 psia, 89,510 lb/hr flow 4. Incident report No. 73	MI 470	MI 54	MI 530	3570	Direct observation	1. Pipe nipple cracked at threads when bent to align during installation. 2. Nipple replaced. Sight glass correctly aligned. 3. Use proper Quality Assurance procedures during construction.
21	1. Piping/Orifice 2. Steam-Feedwater/ Piping 3. 18 284400	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 1300 psig 4. PMMR-55	MI 500	MI 54	MI 530	4100	Preventive maintenance	1. Orifice plate badly bowed out of shape. 2. Part replaced. A thicker plate with a larger hole was installed. 3. None.
22	1. Piping/Gland Cooling Discharge Pipe 2. Steam-Feedwater/ Piping 3. 18 284400	1. EBR-II 2. Feedwater/startup boiler feed pump No. 1 cylinder 3. 364°F, 1500 psig 4. Operating weekly report, 11/29/67	MI 417	MI 51	MI 550	Unknown	Operational monitors	1. Pipe diameter too small, pressure drop too high. 2. Part replaced. 3. None.
23	1. Piping/Orifice Spool Flange 2. Steam-Feedwater/ Piping 3. 18 284400	1. EBR-II 2. Feedwater/recirculating line 3. 364°F, 1500 psig 4. PMMR-78	MI 456	MI 73	MI 530	6700	Direct observation	1. Flange had cracks and porosity holes. 2. Temporary repair. 3. Proper quality control could eliminate this type of malfunction.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS

(Sheet 5 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
24	1. Fitting/Bellows (2 units) 2. Steam-Feedwater/Piping 3. 18 283400	1. EBR-II 2. Condenser/steam bypass 3. - 4. ANL-6965	MI 500	MI 59	MI 550	1200	Direct observation	1. Bellows ruptured, leaked. 2. Part replaced. 3. Determine cause of failure before replacing bellows to prevent recurrence.
25	1. Piping and Fittings/Actuator 2. Fuel Handling/Fuel Handling Machine 3. 18 235130	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. EFAPP No. 1	MI 151	MI 12	MI 530	3650	Operational monitors	1. Actuator failed. 2. Vendor repair of component. 3. None.
26	1. Piping and Fittings/Actuator 2. Fuel Handling/Fuel Handling Machine 3. 18 235130	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. EFAPP No. 47	MI 110	MI 55	MI 530	2820	Direct observation	1. Uneven operation caused actuators to join sealing flange. 2. Vendor repair of component. 3. None.
27	1. Piping and Fittings/Actuator 2. Fuel Handling/Fuel Handling Machine 3. 18 235130	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. EFAPP No. 59	MI 172	MI 59	MI 530	1460	Direct observation	1. Cotter key sheared in the actuator drive. 2. Local repair. 3. None.
28	1. Piping/Air Line 2. Miscellaneous Equipment/Instrument Air Supply 3. 18 540000	1. SCTI 2. Instrument air line/instrument air system 3. - 4. Incident report No. 133	MI 331	MI 59	MI 530	10,250	Direct observation	1. Instrument air line stepped on and broken. 2. Broken section replaced. 3. Install protective device to prevent recurrence.
29	1. Piping/Nipple 2. Miscellaneous Equipment/Instrument Air Supply 3. 18 540000	1. SCTI 2. Instrument air system 3. Ambient temperature 4. Incident report No. 345	MI 127	MI 59	MI 530	21,970	Routine area watch	1. Cooling water line cracked at pipe nipple threaded area. 2. Replaced broken component. 3. Flex connection should be installed to minimize vibration effects.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS
(Sheet 6 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
30	1. Piping/Pipe 2. Heat Transfer/Piping 3. 18 221210	1. ETR 2. Primary system piping 3. Steady full power (175 Mw) 4. INC-69-124	I 121	I 61	I 520	Unknown	Direct observation (unscheduled)	1. Crack developed in weld near inlet of C-7 primary heat exchanger. 2. Installed new section of piping. 3. None.
31	1. Piping/Insulation 2. Heat Transfer/Intermediate Cooling 3. 18 222210	1. EBR-II 2. Secondary sodium piping 3. Happened over several years 4. EBR-II No. 4	MA 477	MA 99	MA 580	Unknown	Direct observation (unscheduled)	1. Insulation cracked due to thermal expansion over several years' time. 2. Repaired waterproof lagging cover. 3. Provide adequate preventive maintenance to maintain protection from moisture.
32	1. Piping/Pipe 2. Steam, Condensate and Feedwater/Main Steam Piping 3. 18 281300	1. SCTI 2. Main steam system 3. Down (unscheduled repair) 4. SCTI-338	I 452	I 6Z	I 520	Unknown	Direct observation (unscheduled)	1. During preheat a separation in pipe wall was observed to "open up." 2. All new spools were ultrasonically tested and defective sections rejected. Acceptable sections were welded into the system. 3. Improved Quality Assurance procedures.
33	1. Piping/Pipe 2. Heat Transfer/Coolant Piping 3. 18 221210	1. LCTL 2. 3-in. sodium loop, Line No. 303 3. Down (unscheduled maintenance) 4. IMPR No. 012	I 200	I 90	I 550	Unknown	Routine inspection	1. Sodium leak discovered in 2-by-3-in. pump discharge line. Failure due to intergranular corrosion. 2. Pipe removed from system and replaced with new spool. 3. Maintain loop in preheat condition (~250°F) when system is in standby. When in operation, protect loop from elements.
34	1. Piping/Finned Tube 2. Heat Transfer/Purification 3. 18 224235	1. LCTL 2. 1-in. plugging loop 3. Startup 4. IMPR No. 021	I 200	I 90	I 550	Unknown	Direct observation	1. Sodium leak discovered in 1-in. plugging loop finned tube section. Failure due to intergranular corrosion. 2. Finned tubing removed and replaced with new section. 3. Provide moisture protection for loop when system is is in shutdown condition, maintaining loop in preheat condition when practical.
35	1. Piping/Flange 2. Instrumentation and Control/ Fuel Element Failure Detection 3. 18 26114	1. ANL 2. Fuel failure detection loop 3. Unknown 4. FFDL No. 1	MA 500	MA 53	MA 550	Unknown	Alarm	1. Sodium leak at flange located at base of riser. 2. Unknown. 3. None. Report lacking in sufficient information for complete analysis.
36	1. Piping/Pipe 2. Heat Transfer/Piping 3. 18 221210	1. BNW Bldg. 324 2. Test loop 3. Test in progress, 1240°F 4. 324-3-69	I 15Z	I 59	I 550	Unknown	Direct observation (unscheduled)	1. Sodium leak occurred causing sodium fire. 2. Operational procedure changed. 3. System redesign.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-90

FAILURE DATA FOR PIPING AND ASSOCIATED FITTINGS
(Sheet 7 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
37	1. Piping/Flange 2. Reactor Equipment/ In-core Capsules and Test Loops 3. 18 218000	1. ETR 2. Test loop 3. Down (unscheduled repair) 4. INC-69-120	MI 500	MI 5Z	MI 530	Unknown	Direct observation (unscheduled)	1. Flange seal had failed. 2. New flange seal inserted. 3. Additional research and development.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-91

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING AND ASSOCIATED FITTINGS

COMPONENT SUBTYPE MISCELLANEOUS PIPING

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Power Reactor
	Nuclear Test Reactor
SYSTEM	Fuel Handling
	Instrument Air Supply
	Miscellaneous Equipment
COMPONENT PART	Actuator
	Air Line
	Nipple
CAUSE	Environment
	Human error
MODE	Mechanical
	Electrical
EFFECT	Labor and material loss only

TABLE 1-92

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING AND ASSOCIATED FITTINGS

COMPONENT SUBTYPE SODIUM PIPING

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Component Test Facility	
	Nuclear Power Reactor	
SYSTEM	Intermediate Cooling	
	Primary Cooling	
	Heat Transfer	
	Instrumentation and Control	
COMPONENT PART	Bellows	
	Thermowell	
	Pipe	
	Gasket	
	Insulation	
	Flange	
CAUSE	Inherent	
	Human error	
	Impurity/contamination	
	Environmental	
	Unknown	
MODE	Metallurgical	
	Mechanical	
	Chemical	
	Metal corrosion	
	Other	
EFFECT	Plant availability loss	
	Labor and material loss only	
	System/component inoperative	
	Potential damage to equipment	

TABLE I-93

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING AND ASSOCIATED FITTINGS

COMPONENT SUBTYPE SODIUM VAPOR AND INERT GAS PIPING

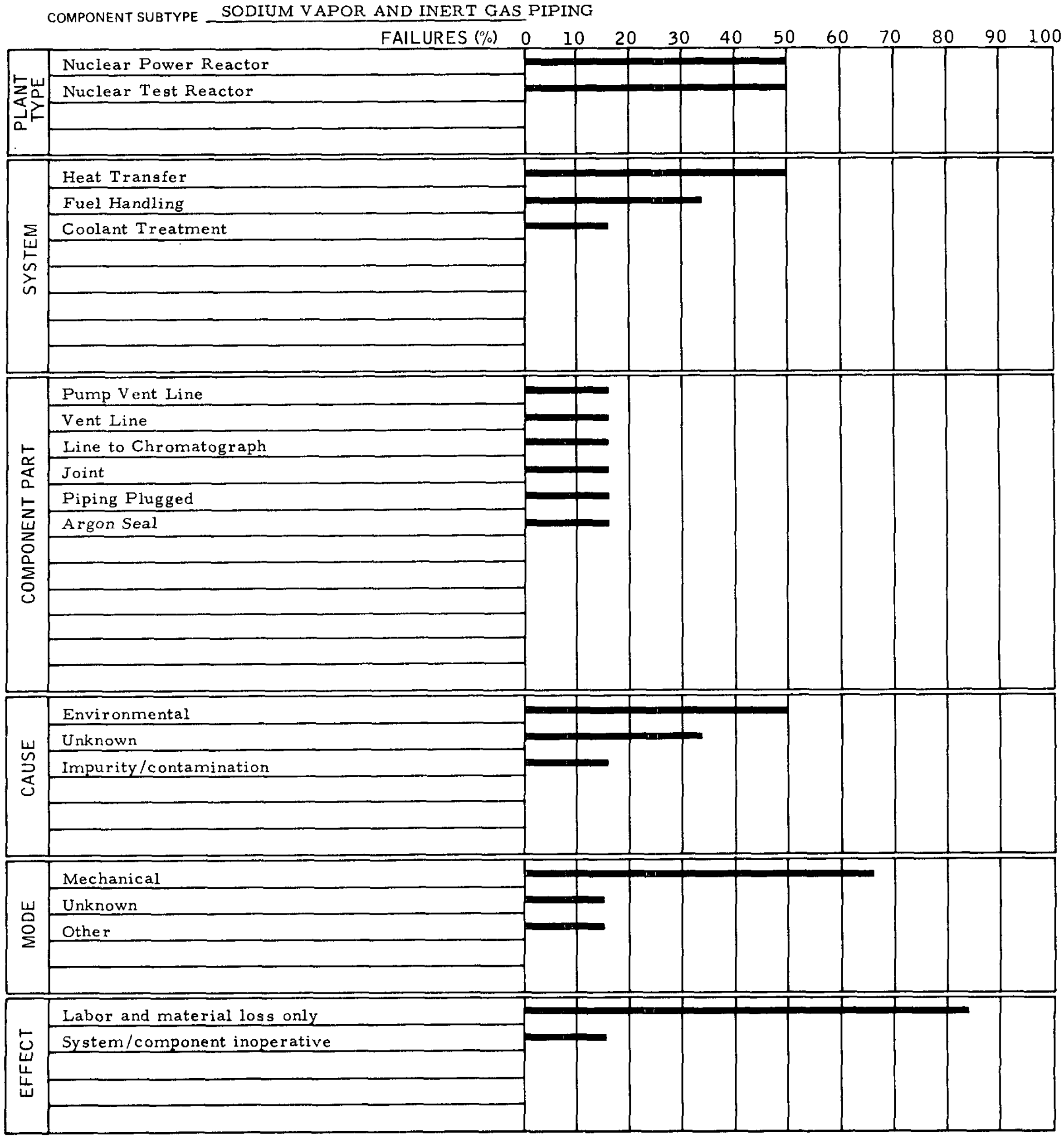


TABLE 1-94

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING AND ASSOCIATED FITTINGS

COMPONENT SUBTYPE STEAM PIPING

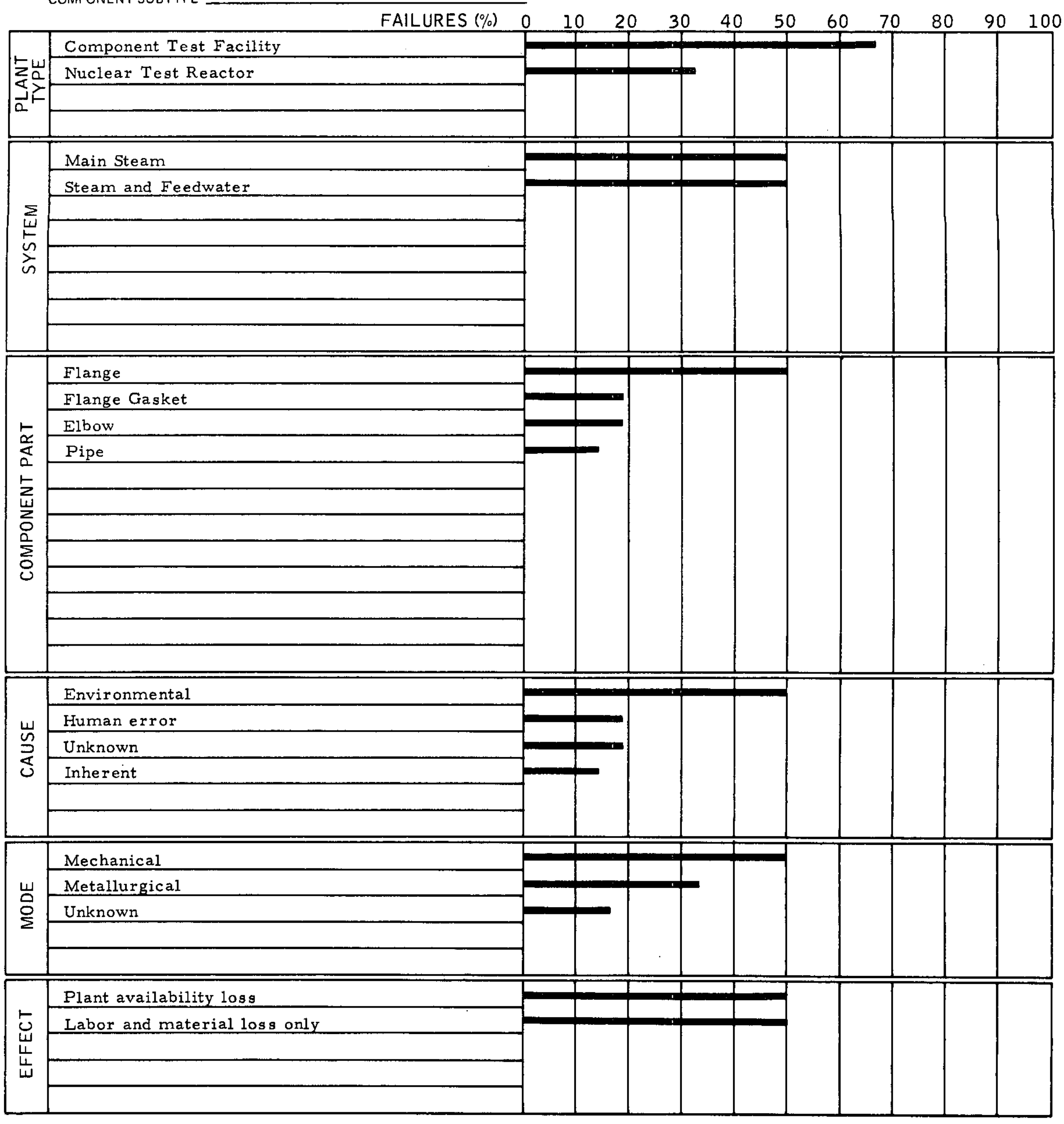


TABLE 1-95

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING AND ASSOCIATED FITTINGS

COMPONENT SUBTYPE WATER PIPING

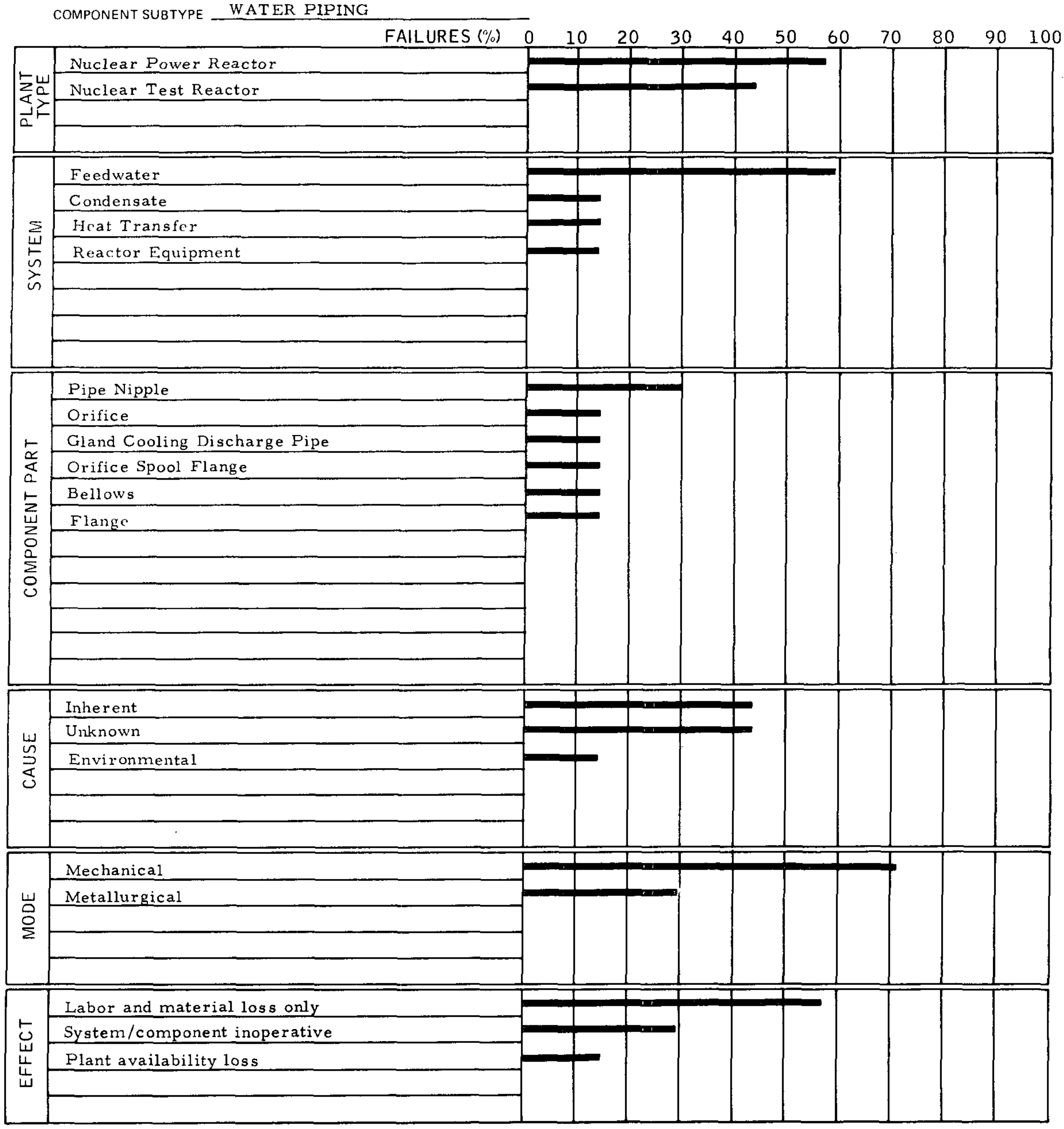
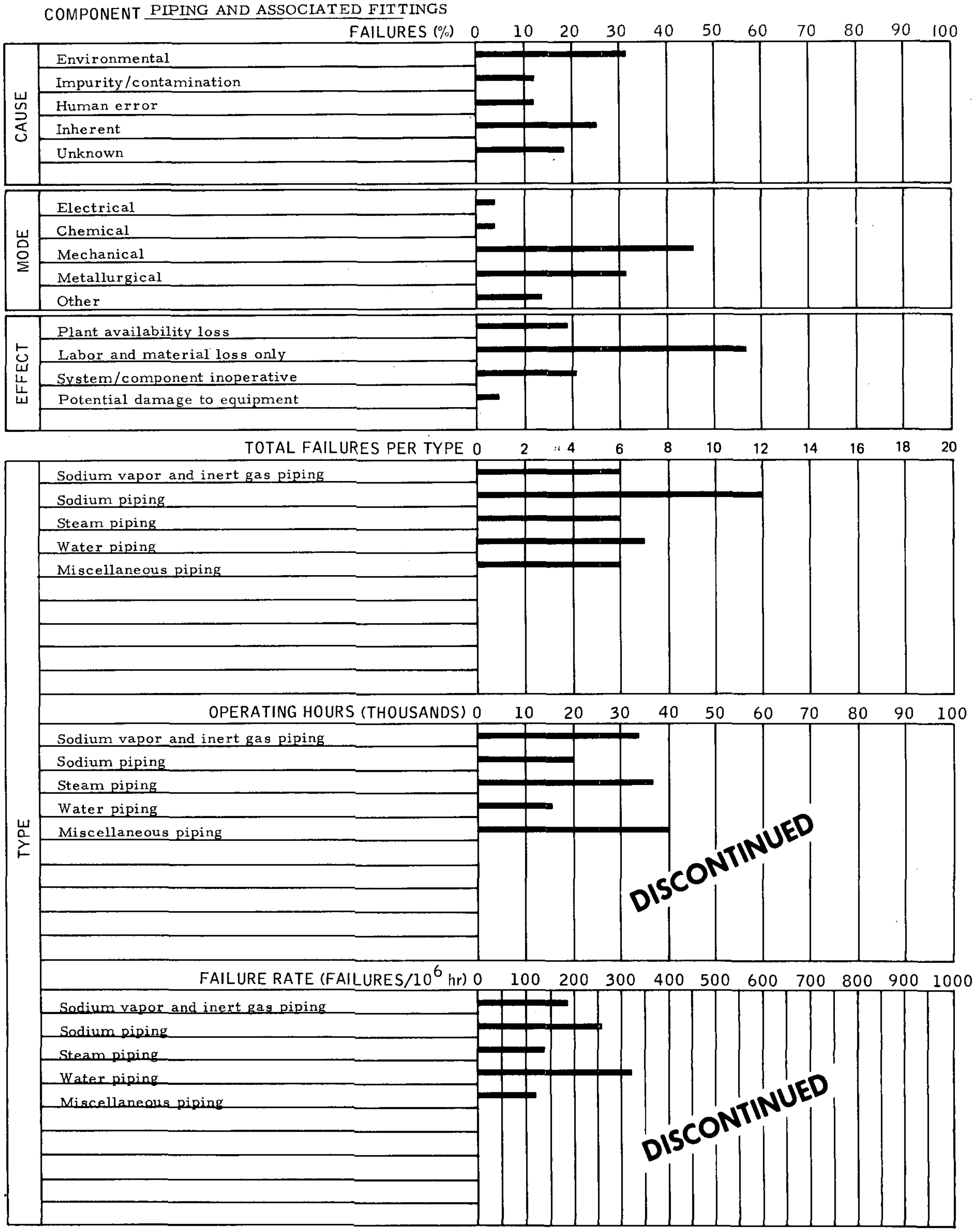


TABLE 1-96

GENERAL SUMMARY

COMPONENT PIPING AND ASSOCIATED FITTINGS



9. Piping Supports

Failure data for piping supports are presented in Tables 1-97 through 1-99.

a. Reliability Information

Design Features:

Supports sodium piping under all thermal and hydraulic design conditions.

Critical Characteristics:

1) Support pipe if adjoining supports fail

2) Allow for thermal expansion.

Mode of Failure:

1) Misalignment

2) Sway braces failed

3) Weld failures

4) Excessive loads.

Failure Description:

1) Pipe hangers misaligned

2) Weldment of bracket to vessel wall failed

3) Imposed loads exceeded design limits resulting in support failure.

Control Methods:

None.

Alternate Concepts:

The problem of how to support large-diameter, relatively thin-walled hot pipes has not been solved. Pipe hangers as now used are of questionable value. Circumferential stiffeners for local strengthening in support areas may be a possibility, but present additional problems of thermal stresses. Problems relating to pipe support may lead to revising traditional concepts of connecting fluid systems. Short sections of connecting piping might be reasonable. These sections might be similar flexible hoses, with reinforcing rings at the base of the convolutions for added strength.

TABLE 1-97

FAILURE DATA FOR PIPING SUPPORTS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Piping Supports/Turbine Exhaust Pipe Hangers 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater 3. 19 284400	1. EBR-II 2. Condensate system 3. 4. Operations weekly report, 11-29-67	MA 416	MA 56	MA 550	12,600	During repair of associated system	1. Pipe hangers misaligned. 2. Local repair, pipe hangers were modified. 3. Install thermal expansion joint in turbine exhaust line to prevent loading turbine case.
2	1. Piping Supports/ Balance Line Sway Braces 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater 3. 19 284400	1. EBR-II 2. Feedwater system 3. - 4. PMMR-107	MI 500	MI 54	MI 550	~11,320	Direct observation	1. Sway braces failed. 2. Part replaced. 3. None.
3	1. Piping Supports/ Hanger 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater 3. 19 284400	1. EBR-II 2. Feedwater system 3. - 4. PMMR-95	MI 500	MI BZ	MI 530	~541	Direct observation	1. Hanger failed. Cause unknown. 2. Part replaced. 3. None.
4	1. Piping Support/Header Support 2. Feedwater Supply and Treatment System/ Chemical Treatment Facilities 3. 19 273300	1. SCTI 2. Treated water and chemical feed system makeup demineralizer D-1 3. - 4. Incident report No. 328	MI 416	MI 59	MI 117	4066	Direct observation	1. Weld holding bracket to vessel wall failed. 2. Local repair. 3. None.
5	1. Piping Support/ Manifold Support 2. Feedwater Supply and Treatment System/ Chemical Treatment Facilities 3. 19 273300	1. SCTI 2. Treated water and chemical feed system demineralizer D-2 3. - 4. Incident report No. 315	MI 120	MI 54	MI 530	19,380	Direct observation	1. Excessive stress on manifold caused support to break. 2. New interface manifold fabricated with the tee socket welded at all three openings. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-98

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PIPING SUPPORTS

COMPONENT SUBTYPE PIPING SUPPORTS

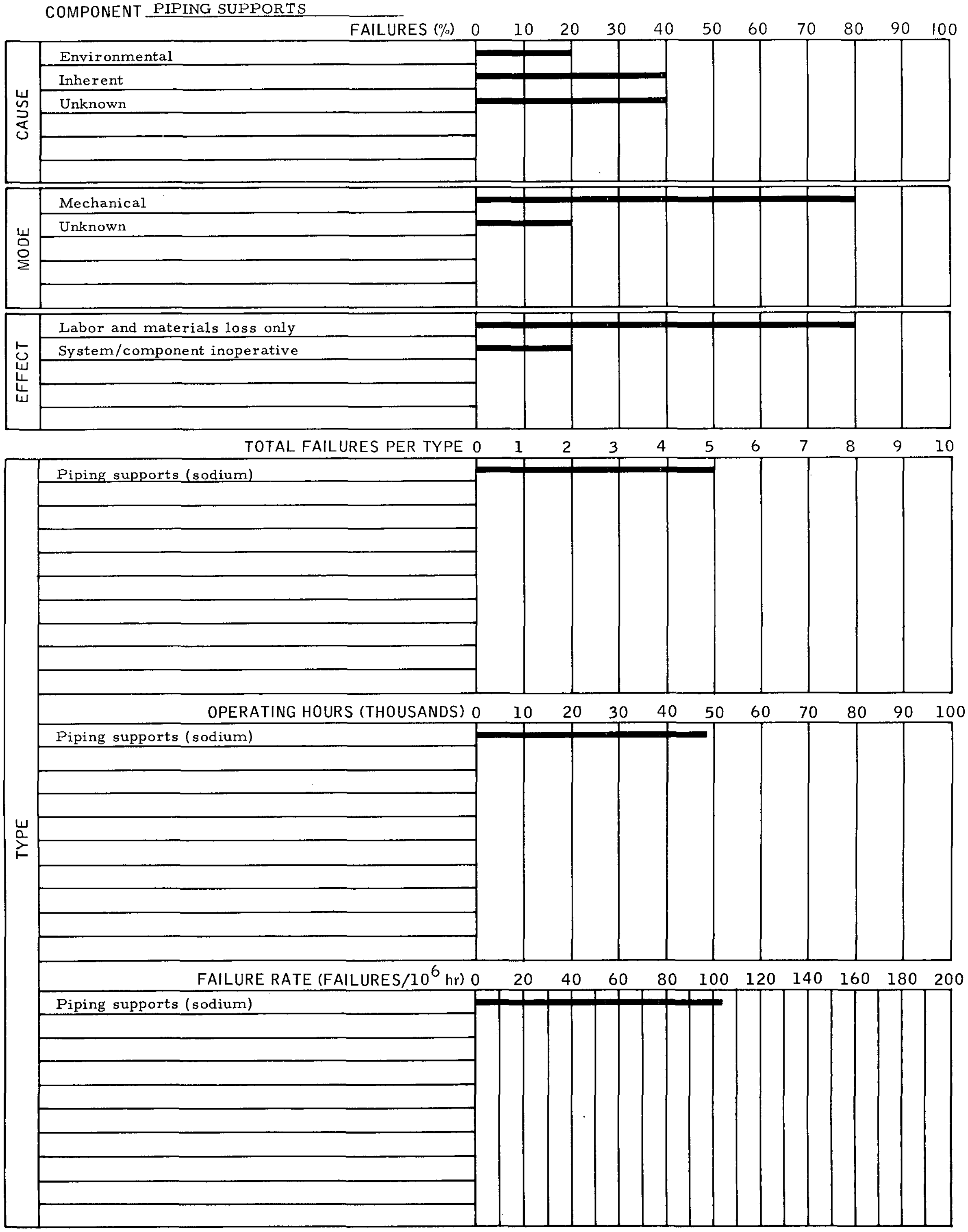
FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Test Reactors
	Components Test Facility
SYSTEM	Condensate
	Feedwater
	Feedwater Supply and Treatment
COMPONENT PART	Hanger
	Turbine Exhaust Pipe Hangers
	Balance Line Sway Braces
	Header Support
	Manifold Support
CAUSE	Environmental
	Inherent
	Unknown
MODE	Mechanical
	Unknown
EFFECT	Labor and materials loss only
	System/component inoperative

TABLE 1-99

GENERAL SUMMARY

COMPONENT PIPING SUPPORTS



10. Pumps and Supports

Failure data for pumps and supports are presented in Tables 1-100 through 1-107.

a. Feedwater

(1) Reliability Information

Design Features:

1) Rotary centrifugal
2) Constant speed or variable speed
3) Single impeller, double impeller, or scoop tube
4) Reciprocating startup pumps.

Critical Characteristics:

1) Low-flow operation limit
2) Flow control sensitivity vs head
3) Pump drive reliability and characteristics are especially critical between different types of drives.

Mode of Failure:

1) Wear, score, or break of rotating components or seal elements
2) Wiped or scored bearings
3) Lubrication control inadequate.

Failure Description:

1) Pump cylinder packing worn out
2) Pump cylinder packing ruptured
3) Pump cylinder O-ring worn out
4) Too much packing installed
5) Thrust bearing wiped
6) Bearing damaged
7) Impeller scored

8) Discharge flange gasket worn out

9) Improper oil in oil reservior

10) Too much oil in oil reservoir

11) Rubber bushing of control shaft deteriorated on the turbine-driven pump

12) Strainer dirty

13) Shaft labyrinth seal leaked oil

14) Unloader spring malfunctioned on the turbine-driven pump.

Control Methods:

1) There should be more frequent maintenance inspections.

2) The maintenance procedures should be improved.

3) The installation procedures should be available.

4) There should be more personnel training.

5) In some cases, parts should be better designed.

(2) Discussion and Recommendations

Reciprocating Type Startup Pump:

A large number of malfunctions caused by piston-rod packing failures could be reduced: (1) by using prefabricated packing elements made from proper material, (2) by determining and applying measured torque, (3) by request of manufacturer's suggestions, and (4) by training all maintenance personnel who should perform this type of work.

General:

Maintenance personnel should be equipped and trained to check bearing wear and bearing lubrication; and to follow manufacturer's instructions for lubrication oil selection and oil level check of turbine-driven pumps. An individual preventive maintenance schedule should be determined for each important component, and check points should be detailed.

There are several methods to reduce the possibility that a valve is left closed in a pump discharge line:

1) Important changes in the operational conditions should be transmitted in written form to the succeeding shift operators.

2) Motor start can be prevented by the installation of an interlock between all valves in the pump discharge line and the motor starter.

3) Plant layout schematic board can supply visual inspection about the positions of all important loop components.

4) Thermal switch in the pump recirculation line can actuate alarm in case of sudden restriction in the pump discharge line.

It is recommended that a periodic course be introduced for the operational personnel, where the dangerous and important sections of the operational manual can be refreshed and discussed. During these occasions the participants can exchange their experiences for the benefit of plant safety and plant availability. A similar periodical course could improve preventive maintenance performance.

b. Miscellaneous

(1) Reliability Information

Design Features:

Generally centrifugal or positive displacement gear or lobe types.

Critical Characteristics:

Proper installation, choice of type, and maintenance are important to pump bearings.

Mode of Failure:

1) Clogging of system or filters

2) Worn, broken, or ruptured component

3) Vibration

4) Misalignment

Failure Description:

1) Bearing worn out

2) Bearing wiped

3) Bearing broken, seized

4) Shaft seal rings worn

5) Impeller and casing vibration

6) Belt drive broken

7) Air lock supply pump malfunction

8) Acid system pump clogged

9) Vacuum pump diaphragm ruptured.

(2) Discussion and Recommendations

Worn and misaligned or broken bearings can be detected early using thermocouples, thermoswitches, and vibration detectors. Each sensor could be connected to an alarm.

An interlock between the discharge line valve and motor starter can prevent pump damage. The use of settling tank level switches and flow indicators that are inspected frequently can signal clogging or malfunction of water treatment systems.

Other suggestions are:

1) Maintenance personnel should be equipped and trained for checking bearing wear and lubrication.

2) Factory-sealed bearings, and proper installation procedure, should be used.

3) Pump failure caused by closed discharge line valve can be eliminated by interlock between valve position sensor and pump starter.

4) Corrosion and possible chemical reactions shall be considered in selecting pumps and piping materials for chemicals in a feedwater treatment loop. Manufacturer's proposal for maintenance should be requested and followed.

c. Free-Surface (see Figures 1-15 through 1-18)

(1) Reliability Information

Design Features:

This type of pump maintains a safe sodium level in the pump housing through an intricate balance of wear ring, weep hole, cover gas pressure and sodium return line design characteristics.

Critical Characteristics:

1) The alignment and life of bearings, seals, and shafts are important.
2) Adequate case cooling is required to prevent thermal distortion during startup or transient.
3) Good sodium level control is vital.

Mode of Failure:

1) Restricting flow in system
2) Wear
3) Misalignment
4) Seizure through thermal distortion
5) Vibration
6) Maintenance deficiency.

Failure Description:

1) Bearing worn out
2) Bearing noisy
3) Bearing vibrating
4) Weep holes sucking sodium into pump casing
5) Shaft seal worn out
6) Shaft seal misaligned
7) Carbon face seal rings chipped
8) Foreign material in rotating seal
9) O-ring worn out

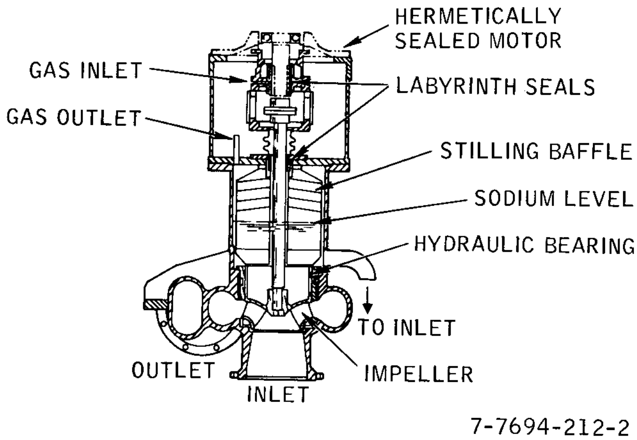


Figure 1-15. A 5000-gpm Mechanical Sodium Pump

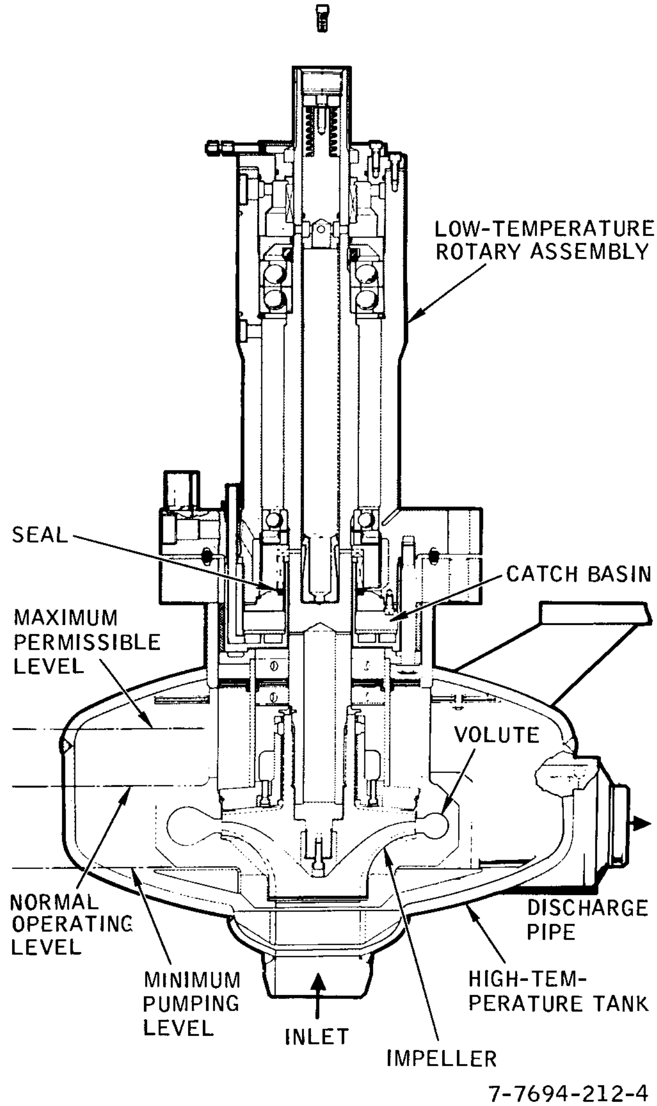


Figure 1-16. High-Temperature Centrifugal Pump

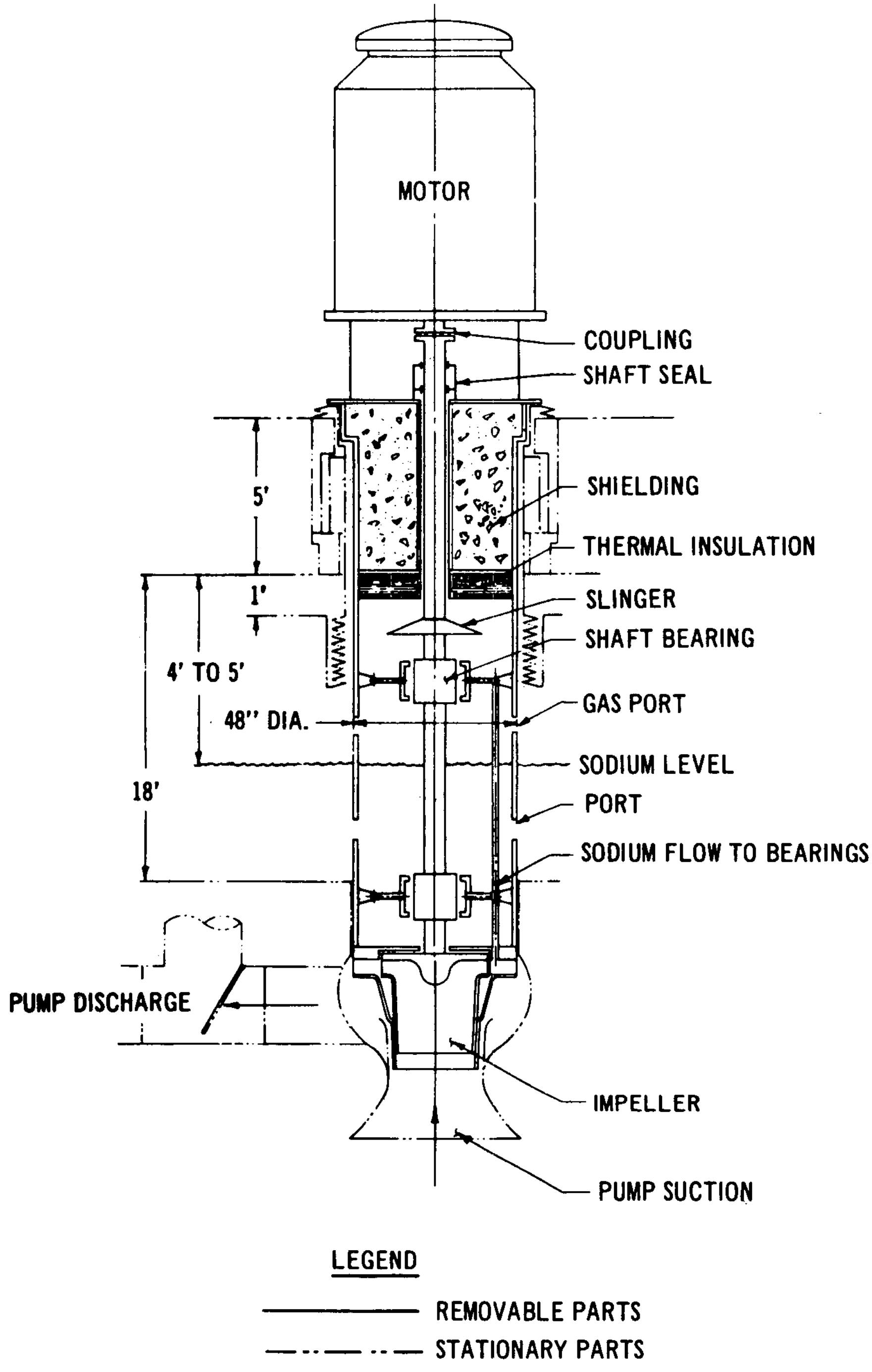


Figure 1-17. GE 1000-Mwe LMFBR Primary Pump

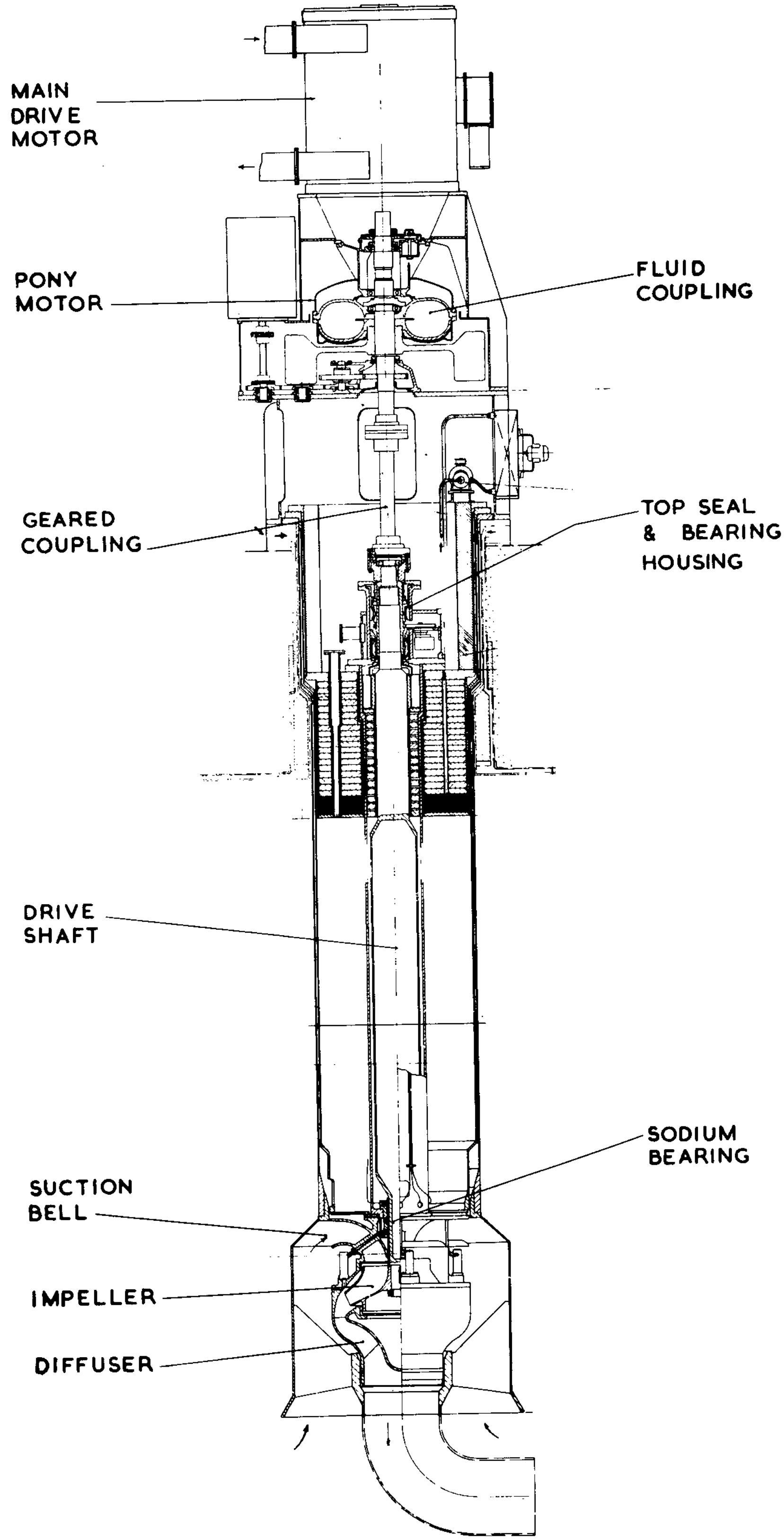


Figure 1-18. PFR Primary Sodium Pump

10) Shaft seizure from foreign material in bearings

11) Shaft distorted from thermal gradients causing binding

12) Shaft deflected

13) Sodium frozen to pump shaft and leaked into oil reservior

14) Pump squealing

15) Piston cups worn out

16) Oil leaks into sodium from oil seal.

(2) Discussion and Recommendations

Description:

The free-surface sodium pump is one of the early concepts.

The pump has no internal seals or internal lubricated bearings. The bearings and seals are located on top of the pump floor plate. An unlubricated hydrodynamic guide bearing, located inside the pump, guides the impeller shaft.

These pumps require no internal instrumentation except for sodium level indicators located in thimbles. The sodium level indicators may be located on the exterior surface of the pump case. In either case they are accessible and the pump need not be disturbed to perform maintenance work on the instrumentation.

The sodium level in the free-surface pump is controlled by locating the pump at the high point in the system or the pump case can be fitted with an overflow line that returns excess sodium to a balancing leg which in turn is connected to the pump suction line.

Problems:

The following are some of the more serious problems encountered with free-surface pumps:

1) Preheating the system prior to filling with sodium has caused warpage that resulted in binding the impeller shaft.

2) Foreign matter (metal cuttings) have deposited in the hydrodynamic bearing and caused seizure of the impeller shaft.

3) An impeller shaft was bent during the installation of the bearing seal assembly on the pump floor plate resulting in loss of plant availability.

4) Mechanical oil seals located in the bearing seal assembly (top of pump floor plate) have failed resulting in downtime.

5) Mechanical oil seals have failed resulting in oil leakage into the sodium system. This is an unacceptable incident and the bearing seal assembly must be designed to make it impossible to leak oil into the sodium system.

6) Magnetic clutches used for driving some free-surface pumps have operated at higher-than-specified temperatures. This was the result of inadequate air circulation inside buildings.

7) Problems with belt-driven tachometers have resulted in unnecessary shutdowns.

8) Permitting pump drive motors to be exposed to the elements (rain) has caused motor failure resulting in downtime.

9) The lack of adequate operator training has resulted in downtime, including getting oil into the sodium system.

10) The impeller shaft guide bearing journal has been scored in some pumps; however, this has not caused pump failure.

11) Bearings have failed in the bearing seal assembly on some pumps; however, other pumps have operated for thousands of hours without bearing problems.

12) Pumps equipped with balancing legs have been flooded by improper operation of inert cover gas systems, resulting in downtime and and plugged vent systems.

13) Carbon (oil in sodium system) has deposited in bellows, actuated level indicators on the pump cases, and rendered them inoperative, resulting in pump downtime.

14) Pump downtime has resulted because of pump instrument thimbles vibrating. The thimbles were attached on the upper end only.

Summary:

Free surface pumps have been used quite extensively in the industry. There have been many problems encountered with the pumps; however, the operating history of these pumps is relatively good. After about one year of debugging the SRE, free-surface pumps were considered very reliable.

Recommendations:

The free-surface concept of sodium pumps should be further developed. The pump floor plate should be designed to make it nearly impossible to leak oil into the pump case. The bearing seal assembly leak-off chambers should be sized to hold the entire quantity of oil in the bearing housing.

Mechanical seals that are presently used in the bearing seal assemblies inherently leak oil; therefore, a method of knowing precisely how much oil is leaking across the seal should be designed into the assembly. Knowing the quantity of oil leaked and the amount of makeup is necessary for a free surface pump.

Pumps that can be flooded for any reason should be equipped with protective devices to detect the incipient stage of such an occurrence.

Other recommendations are:

1) Better designed bearings

2) Adequate preventive maintenance schedule

3) Sensors to detect bearing malfunctions

4) Provision for tolerance checking of bearings

5) Provisions for aligning bearings and seals during maintenance operations

6) Selection of proper materials for parts

7) Improvement of cover gas oil seals

8) Designing for uniform pump casing cooling.

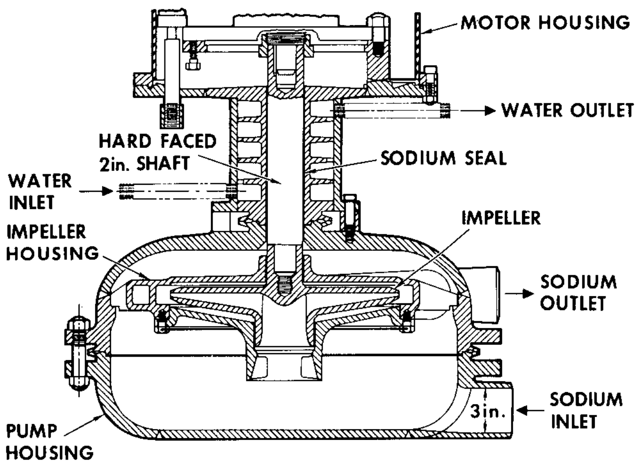


Figure 1-19. Duriron Pump and Seal

d. Freeze Seal (see Figure 1-19)

(1) Reliability Information

Design Features:

Impeller region is sealed from the pump bearing case by a frozen column of sodium between the case and the shaft. Freezing is maintained by a cooling system.

Critical Characteristics:

The freeze seals have small operating tolerances and require frequent inspection.

Mode of Failure:

1) Seizure of shaft

2) Misalignment

3) Broken

4) Cracked.

Failure Description:

1) Pump shaft seizure by freeze seal or wear-ring area

2) Loss of freeze seal

3) Bearing alignment was performed improperly during maintenance

4) Crack in thermowell welding, an organic material deposit

5) Magnetic seal leakage.

Control Methods:

1) Procedure which set controls at proper limits.

2) Better maintenance schedules and procedures.

3) Design wide clearance between wear-rings.

4) Determine proper ratio between wear-ring and weep-hole areas; maintain same ratio for all subsequent modifications.

(2) Discussion and Recommendations

The freeze seal sodium pump is one of the first concepts that was developed. Sodium is frozen around the periphery of the pump bucket and the impeller shaft to act as seals. The pump case seal can be easily maintained and is quite reliable. The pump impeller shaft seal is a problem because it is affected by several variables.

The impeller shaft seal requires almost constant surveillance and then on occasion the seal appears to operate unpredictably.

Loss of a freeze seal renders the pump inoperative. A complicated maintenance activity is required to return the pump to an operable status. If the pump is used to circulate radioactive sodium, then the time required to overhaul the pump after losing a freeze seal will increase because the radioactive sodium must be permitted to decay.

The sodium in the seal regions is kept frozen by an auxiliary cooling system. The coolant in this auxiliary system may present a hazard if a leak should develop permitting the coolant to come in contact with the sodium. (Note: SRE fuel badly damaged by leaking shaft seal; coolant - tetralin.)

Losing a freeze seal requires stem cleaning the pump, replacing the pump bearings, cutting, and welding freeze seal coolant lines, and generally involves extensive thermocouple work.

Extensive experiments in water loops and subsequent experience on the SRE, indicated that, for the SRE pumps, a two-to-one area ratio between the wear-ring annulus and the impeller weep-holes would give an approximately constant pressure at the base of the freeze seal for all pump speeds, thus reducing the problem of blowing one of the seals either by too much sodium pressure at the base of the seal or too much cover gas pressure above the seal. This could differ for another system.

Summary:

Freeze seal sodium pumps have a poor reliability record, they are difficult to operate, require almost constant operator attention, are costly to maintain, and require support systems that are not required by other pumps.

Plant or system availability has been greatly reduced where these pumps were used, due to their failure history.

Recommendations:

Freeze seals should be kept under close surveillance, supported by frequent inspection of pump functional indicators or recorders. Preventive maintenance shall keep close check on the temperature control system of the freeze seal.

Freeze seal can prevent sodium leakage at the pump shaft if the sodium is kept at certain low viscosity level in the seal area. Since the required low viscosity exists only in a very narrow temperature range, a close temperature control is required for the freeze seal. Varying pump loads vary the pump speeds, changing friction heat generation, which requires elaborate heating-cooling sodium control.

At the present the free-surface pump shaft seals are in an advanced development stage compared with the freeze seal; therefore, free-surface pumps are more highly recommended.

e. Electromagnetic (see Figure 1-20)

(1) Reliability Information

Design Features:

Electromagnetic pumps are widely varied in design, each having specific advantages and disadvantages which are described in the text. Four fundamental types are AC conduction, DC conduction, rotary, and stationary magnet.

Critical Characteristics:

Thin-walled pump duct, delicate electrical equipment, overtemperature of liquid metal.

Mode of Failure:

1) Clogged

2) Cracks

3) Electrical.

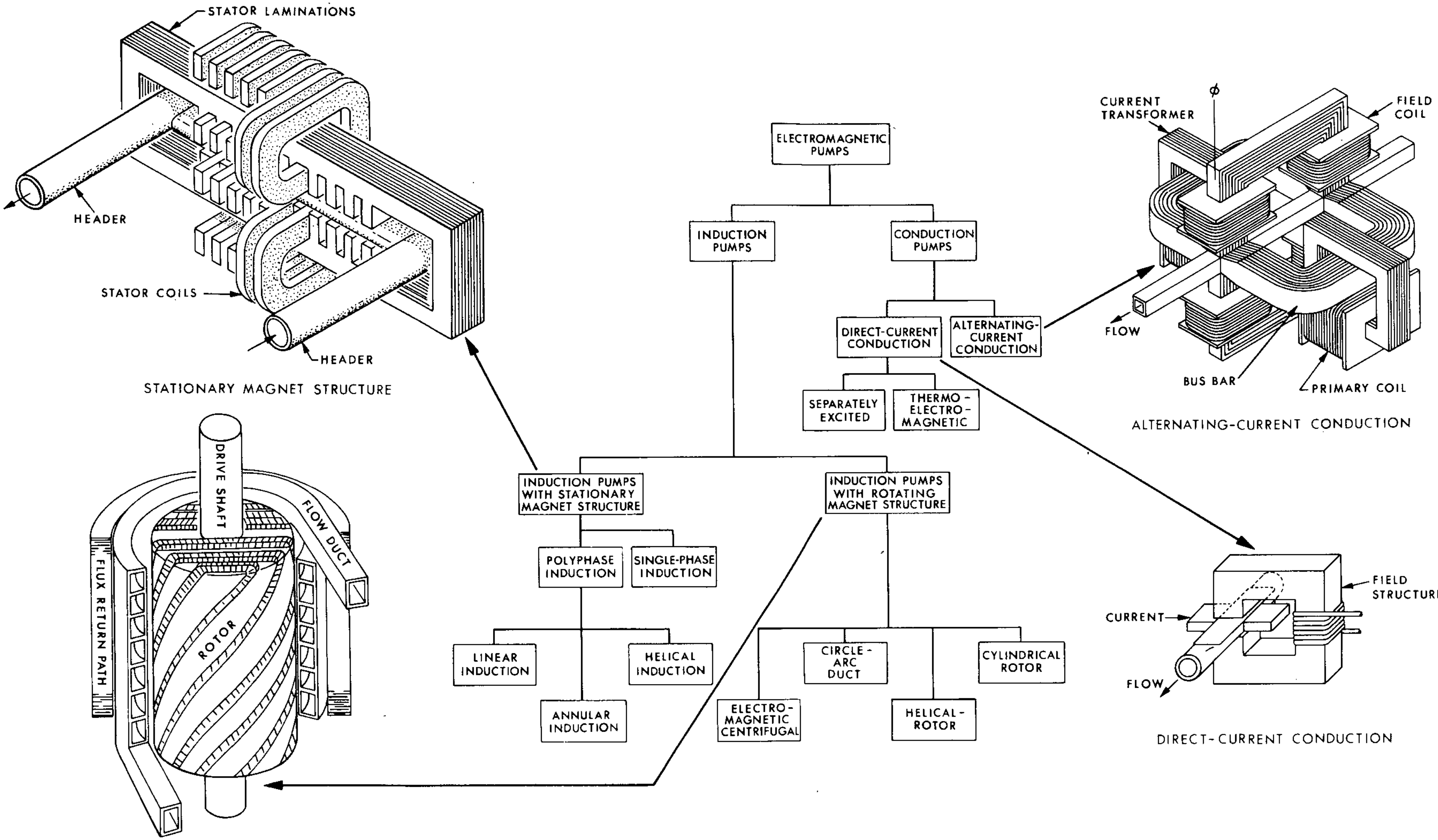


Figure 1-20. Principal Subclassification of Electromagnetic Pumps

Failure Description:

1) Clogged cooling lines

2) Cooling jacket clogged

3) Coolant void.

Control Methods:

1) Establish a preventive maintenance schedule.

2) Install a differential pressure gage to indicate filter congestion.

(2) Discussion and Recommendations:

General:

Experience with electromagnetic pumps has shown that reliability and efficiency are adversely affected by the following:

1) Coolant void formation in the pump duct, accompanied by inadvertant electrical energizing of the pump circuit will damage conduction-type pumps due to the high current density in high ohmic resistance joints, such as the duct-to-bus bar connection.

2) Pressure fluctuations will fatigue the thin-walled pump duct.

3) Overtemperature in the liquid metal. This can reduce the performance and life of all types of electromagnetic pumps.

4) Loss of pump cooling. This adversely affects any of the various types of electromagnetic pumps by increasing coil resistivities, reducing magnetic material performance, and deteriorating electrical insulation.

5) The pump duct is a thin-walled member requiring extreme care in design and fabrication and possibly a hermetically sealed secondary enclosure.

6) Electrical insulation breakdown may result if exposed to gamma or neutron radiation.

7) Fabrication techniques are not as conventional as for centrifugal pumps and require special inspection and test techniques.

8) Delicate electrical equipment including field windings and bus bars are frequently damaged during installation and maintenance if not adquately protected by cages or covers.

Only four of the major subtypes of pumps shown in Figure 1-20 are discussed due to the limited availability of failure data. As an example, one failed annular induction pump is the only data on this pump subtype.

<u>Alternating-Current Conduction Pumps:</u>

Alternating-current pulsations can produce mechanical vibrations of the pump components. High temperature (1000 to 1200°F) fatigue and stress concentration problems occur where the magnet poles and electrodes are attached to the duct. A detailed and careful piping stress analysis is required for the connected loops. If the required EM pump output temperature is below the maximum design allowable for copper, copper bus bars are recommended since copper is not susceptible to magnetostriction and would not vibrate under the influence of the magnetic field. For higher temperature application, nickel bus bars are acceptable. When operating below the curie point of nickel (676.4°F), the pump power level should be maintained below the point where forces generate unacceptable vibration.

Electrical components exposed to mechanical vibration should have their coils periodically inspected and, if necessary, reimpregnated with insulating compounds before turn-to-turn shorts develop.

Operation is limited to temperatures that exceed the sodium plugging temperature by several hundred degrees fahrenheit. The oxides of sodium having poor electrical conductivity tend to preferentially deposit at the poles.

Alternating-current conduction pumps should not be operated under conditions where the pump duct is empty, or that allow gas bubbles to pass into the pumps, since either will cause the current passing through the sodium liquid to decrease. This, due to magnetic coupling with the secondary, results in increased current passing through the duct walls. Overheating and failure of the bond connecting the electrode or bus bar to the duct walls may result.

To eliminate the possibility of energizing an ac conduction pump when there is no liquid metal in the pump duct, it is recommended that the pump startup circuit be interlocked with a liquid sensor (spark-plug type).

<u>Direct-Current Conduction Pumps:</u>

Direct-current conduction pumps are suitable for flow rates up to 200 gpm, but the maximum liquid metal temperature is limited to approximately 500°F due to:

1) Oxidation of the bus bar conductor which is bonded to the pump duct.
2) Deterioration of the direct-current source (rectifiers or generators) due to heat conducted into the source by the bus bars from the pump duct.

The pressure rise that can be produced by a dc conduction pump can be increased by multiple-staging; that is, by exposing the liquid metal to the magnetic field at several places within the pump where current from the bus bars passes through the liquid. However, this introduces problems due to the multiplicity of bonded joints that become necessary.

Designers should consider the magnetostrictive forces acting on the duct wall in attempting to eliminate failures due to self-induced vibration.

To eliminate the possibility of mass transfer, material compatibility should be investigated before final design of any components that are in direct contact with the liquid metal.

Where cooling fans are used for cooling of the pump coils, it is recommended that the unit be provided with factory-sealed bearings.

As with the ac conduction-type pumps, in order to eliminate the possibility of energizing a dc conduction pump when there is no liquid metal in the pump duct, the existing pump startup circuit should be interlocked with a liquid sensor (spark-plug type). New designs should also provide this same protective feature.

Improper bonding of the bus bar to the pump duct permits oxide corrosion, and eventual reduction in pump performance will occur.

Induction Pumps:

Mechanical vibration and metal fatigue that result from magnetostrictive forces should be considered in linear induction electromagnetic pump design.

Curves showing the fatigue strengths of EM pump duct materials are included in the AC Conduction Pump Standard being prepared by the LMEC. Vibration limits have been established in this standard which will also apply to linear induction pumps.

Where environmental conditions, such as temperature, humidity, fumes, etc., can adversely affect the electrical controls for ac induction pumps (i. e., circuit breakers, relays, variacs, etc.), designers should recommend sealed, instead of open contacts.

Component and system designers should consider the high startup in-rush currents whenever electrical ac components are used.

AC magnetic coil design should include the special insulation requirements in connection with laminated magnetic cores.

Designers should follow the design standard recommendations developed for proper bolting of laminated ac magnet cores. Standards for 1/4 to 20 NC stud bolts are 35 to 105 in.-lb, and for 5/16 to 18 NC are 80 to 260 in.-lb. Torque all bolts to minimum standards of 35 in.-lb for 1/4-in. bolts and 80 in.-lb for 5/16 in. bolts.

Linear induction pumps are suitable for much higher flow rates than conduction pumps but practical problems such as increase in weight, size, cost of flow control equipment, and power conditioning apparatus limit the pressure rise.

Cooling water systems used to control the pump temperature should offer the same degree of purification control as used for feedwater purity to the steam generators. Obstruction to coolant flow in cooling jackets can adversely affect pump life.

The annular induction pump was designed to provide easy installation of the excitation magnet and the central iron core around the pump duct.

Mechanical vibration and metal fatigue that result from magnetostrictive forces should be considered for all types of induction pump designs.

Annular induction pumps are suitable for the same flows and pressures as linear induction pumps but are temperature limited because the stator winding cannot be cooled as effectively as in a linear induction pump.

This is a "one-of-a-kind" pump and was considered developmental. Difficulties experienced with this particular pump may not be applicable to other concepts based on the annular duct induction principle.

EM Pump Water Cooling System:

1) Apply differential pressure gages to indicate the state of the filters for the maintenance personnel.

2) Install sight glasses to inspect sediments in settling pockets if they cannot be eliminated.

3) Change filters to finer mesh if larger-size particles cause clogging.

4) Build settling tanks in the loop if the piping slope is not adequate.

5) Preventive maintenance schedules should be established to check the above-mentioned gages and sight glasses if they are not connected to an automatic alarm system.

For New Loops or Loops Which Must be Rebuilt:

1) Water source purity check, cooling loop orifice size, and available slope should determine the application of filter and settling tank dimensions.

2) Use redundant filtering and settling equipment where uninterrupted service is at premium.

3) If backwash is considered for filter and settling tank cleaning, provide adequate drain and sewer pipe sizes for mud and dirt removal.

4) Apply temporary pipe end caps during loop construction to avoid entrance of foreign material into the loop.

5) After the loop construction is completed, wash it out with pressurized water to secure as clean a loop as possible.

6) Provide penalty and/or premium for the construction company if such accident may or may not occur.

TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 1 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Pump/Shaft Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. EBR-II 2. Condensate/turbine drive condensate pump 3. 9700 RPM, 150 psig 4. Operations weekly report, 11-21-67	MA 125	MA 52	MA 530	12,425	Operational monitors	1. Bad bearing. 2. Bearing replaced. 3. Correct installation and sufficient lubricating procedures should be maintained.
2	1. Pump/Journal Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Booster Pump 3. 17 283200	1. EBR-II 2. Condensate/motor driven condensate pump 3. 364°F, 1500 psig, 3580 RPM 4. PMMR-35	MI 500	MI 52	MI 530	2590	Preventive Maintenance	1. Bearing worn out. 2. Part replaced. 3. None.
3	1. Pump/Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. EBR-II 2. Condensate system/turbine driven condensate pump 3. 9700 RPM, 150 psig 4. Operations weekly report, 11-29-67	MA 146	MA 52	MA 550	12,600	Operational monitors, bearing temperature high	1. Bearing worn. 2. Part replaced. 3. None.
4	1. Pump/Shaft Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. EBR-II 2. Condensate system/turbine driven condensate pump 3. 9700 RPM, 150 psig 4. Operations weekly report, 12-13-67	MA 500	MA 52	MA 530	12,390	Operational monitors	1. Bearings were completely worn. 2. Part replaced. 3. Check alignment of pump and drive turbine.
5	1. Pump/Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. EBR-II 2. Condensate/turbine driven condensate pump 3. 9700 RPM, 150 psig 4. PMMR-113	MA 136	MA 59	MA 550	12,390	Operational monitors	1. Bearing broken. 2. Part replaced. 3. Request factory assistance.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 2 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
6	1. Pump/Shaft Sleeve 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Booster Pump 3. 17 283200	1. EBR-II 2. Condensate/motor driven condensate pump 3. 364°F, 1500 psig, 3580 RPM 4. PMMR-35	MI 500	MI 52	MI 530	Unknown	Preventive maintenance	1. Unknown. 2. Unknown. 3. None.
7	1. Pump/Carbon Sealing Rings 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. EBR-II 2. Condensate/turbine driven condensate pump 3. - 4. Operations maintenance report 6-19-68	MI 500	MI BZ	MI 530	Unknown	During routine inspection	1. Seal rings worn out. 2. Part replaced. 3. None.
8	1. Condensate Pump (P-4)/Mechanical Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. SCTI 2. Feedwater system (condensate) 3. 350 GPM, 225°F 4. Incident report No. 103	MI 126	MI 52	MI 530	2700	Routine area watch	1. Mechanical shaft seal leaked. 2. Part replaced. 3. Maintenance schedule should be revised.
9	1. Pump/Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. SCTI 2. Condensate Pump (P-4) 3. 3550 RPM 4. Incident report No. 326	MI 500	MI 57	MI 530	5200	Direct observation	1. Outboard bearing seized — inspection revealed water in bearing. 2. Replaced component part. 3. Provide equipment for the environment.
10	1. Pumps and Supports 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	1. SCTI 2. Steam and feedwater 3. 350 GPM, 225°F 4. Incident report No. 134	MA 500	MA BZ	MA 520	4427	Operational monitors	1. Loss of feedwater flow required manual scram which froze off sodium on the primary expansion tank vapor trap. 2. Thermal insulation was placed on the primary expansion tank vapor trap to eliminate sodium solidification in similar future cases. As no trouble could be found, pumps restarted. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 3 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
11	1. Pump/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup 3. 364°F, 1300 psig 4. PMMR-69	MI 328	MI 59	MI 530	1137	Direct observation	1. Too much packing installed, caused failure. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
12	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup 3. 364°F, 1300 psig 4. PMMR-80	MI 500	MI BZ	MI 530	1945	Preventive maintenance	1. Packing work out. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
13	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup 3. 364°F, 1300 psig 4. PMMR-82	MI 126	MI 52	MI 530	500	Direct observation	1. Packing worn out. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
14	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup 3. 364°F, 1300 psig 4. PMMR-87	MI 126	MI 59	MI 530	400	Routine area watch	1. Packing leaking. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
15	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup 3. 364°F, 1300 psig 4. PMMR-93	MI 500	MI BZ	MI 530	1404	Preventive maintenance	1. Packing work out. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 4 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
16	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup, Cylinder 1 3. 364°F, 1300 psig 4. PMMR-96	MI 500	MI BZ	MI 530	141	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
17	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Startup, Cylinder 2 3. 364°F, 1300 psig 4. PMMR-96	MI 500	MI BZ	MI 530	141	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Request packing manufacturer to provide assistance with failure problem.
18	1. Pump/Bearings (Inner Thrust) 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 1500 psig 4. Operating monthly report 11/67	MI 500	MI 52	MI 530	Unknown	Operational monitors High oil temperature	1. Bearing was found to be worn. 2. Part replaced. 3. None.
19	1. Pump/Oil 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump 3. 364°F, 1500 psig, 3580 RPM 4. Operating weekly report, 12-20-67	MI 500	MI BZ	MI 530	Unknown	Preventive maintenance	1. Chemical analysis indicated high viscosity. 2. Local repair. 3. None.
20	1. Pump/Oil Reservoir 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump 3. 364°F, 1500 psig, 3580 RPM 4. PMMR-52	MI 310	MI 33	MI 530	Unknown	Direct observation	1. Too much oil in pump caused smoke. 2. Local repair, oil was removed. 3. Follow manufacturer's recommendations on quantity of oil to be used.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 5 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
21	1. Pump/Shaft Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump governor control 3. - 4. PMMR-78	MI 187	MI 52	MI 530	Unknown	Preventive maintenance	1. Shaft bushing (rubber) deteriorated due to excessive heat. 2. Part replaced with bronze bushing. 3. None.
22	1. Pump/Bearings 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 670 to 90 GPM, 1500 psig, 3580 RPM 4. ANL-6808	MI 122	MI 54	MI 530	Unknown	Operational monitors	1. Bearings damaged due to overloading caused by a closed valve. 2. Part replaced. 3. Upgrade operator training on pump.
23	1. Pump/Impeller 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 670 to 90 GPM, 1500 psig 3580 RPM 4. ANL-6808	MI 122	MI 54	MI 530	Unknown	Operational monitors	1. Impeller scored, was remachined. 2. Part replaced. 3. None.
24	1. Pump/Strainer 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump 3. 900 HP, 9700 RPM, 150 psig 4. PMMR-24	MI 500	MI BZ	MI 530	Unknown	Preventive maintenance	1. Strainer dirty. 2. Cleaned and replaced strainer. 3. None.
25	1. Pump/Labyrinth Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump 3. 900 HP, 9700 RPM, 150 psig 4. PMMR-35	MI 500	MI BZ	MI 530	Unknown	Direct observation	1. Labyrinth seal leaking oil. 2. Local repair. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 6 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
26	1. Pump/Manual Trip Plunger 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/turbine driven feed pump 3. 900 HP, 9700 RPM, 150 psig 4. Weekly report, 5-15-68	MA 500	MA 53	MA 520	14,480	Direct observation	1. Spring malfunctioning. 2. Spring and spring retainer were modified by installing a roll pin. 3. None.
27	1. Pump/Cylinder No. 3 Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feedpump 3. 364°F, 1300 psig 4. PMMR-96	MI 500	MI BZ	MI 530	141	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Schedule preventive maintenance inspections as required to prevent leakage.
28	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-102	MI 500	MI 59	MI 550	496	Operational monitors	1. Packing ruptured. 2. Part replaced. 3. Uneven repacking periods show that maintenance personnel should be trained for proper repacking procedures.
29	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-104	MI 500	MI 52	MI 530	680	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.
30	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-105	MI 500	MI 59	MI 530	200	Direct observation	1. Packing ruptured. 2. Part replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 7 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
31	1. Pump/Cylinder No. 2 Plunger Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. Operations maintenance report 5-22-68	MI 500	MI 52	MI 530	4020	Routine area watch, direct observation	1. Packing worn out. 2. Local repair, repacked cylinder. 3. With improved maintenance procedure, even this record (10 days operation) could be improved.
32	1. Pump/Cylinder No. 3 Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. Operations maintenance report 8-14-68	MI 500	MI 52	MI 530	640	During preventive maintenance	1. Packing worn out. 2. Local repair, cylinder repacked. 3. None.
33	1. Pump/Packing and Plungers 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. ANL-6749	MI 270	MI 52	MI 530	Unknown	Unknown	1. Coolant deficiency caused damage to plungers and packing. 2. Modifications were made to improve the gland-cooling system, using condensate rather than raw water. 3. None.
34	1. Pump/Cylinder No. 2 O-rings 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-3	MI 500	MI 52	MI 530	Unknown	Direct observation	1. O-rings worn out. 2. Parts replaced. 3. None.
35	1. Pump/Cylinder O-rings 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-8	MI 187	MI 59	MI 530	Unknown	Routine inspection	1. O-rings worn out. 2. Part replaced. Removed Neoprene O-rings and installed high temperature Viton O-rings on cylinders. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 8 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
36	1. Pump/Discharge Flange Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 1300 psig 4. PMMR-36	MI 500	MI BZ	MI 530	2190	Preventive maintenance	1. Gasket worn out. 2. Part replaced. 3. Apply predetermined torques to flange bolts and gasket materials.
37	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-4	MI 126	MI 52	MI 530	1200	Operational monitors	1. Packing worn out. 2. Part replaced. 3. None.
38	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-21	MI 126	MI 52	MI 530	1200	Operational monitors	1. Packing worn out. 2. Part replaced. 3. None.
39	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-23	MI 126	MI 52	MI 530	84	Operational monitors	1. Packing worn out. 2. Part replaced. 3. Factory representative will guarantee pump if he oversees the pump modifications.
40	1. Pump/Cylinder No. 1 Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-33	MI 500	MI BZ	MI 530	1016	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 9 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
41	1. Pump/Cylinder No. 2 Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-33	MI 500	MI BZ	MI 530	1016	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.
42	1. Pump/Cylinder No. 3 Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-33	MI 500	MI BZ	MI 530	1016	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.
43	1. Pump/Cylinder Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-51	MI 500	MI BZ	MI 530	2534	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.
44	1. Pump/No. 2 Unloader Plunger Rod 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. EBR-II 2. Feedwater/startup boiler feed pump 3. 364°F, 1500 psig 4. Operations maintenance report 7-3-68	MI 172	MI 54	MI 530	Unknown	Direct observation	1. Pump not functioning properly - disassembled and found plunger rod bent. 2. Part replaced; spare unloader was installed. 3. None.
45	1. Pump/Bearing 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Feedwater system 3. 345 GPM, 7450 RPM 4. Incident report No. 19 (7-28-65)	P 33Z	P 5Z	P 590	1580	Direct observation	1. Inboard bearing threw oil when drive motor was started. 2. Motor pump combination shut down and restarted o.k. 3. Assure sufficient operation personnel experience or training.

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FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 10 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
46	1. Pump/Shaft Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Feedwater system 3. 345 GPM, 7450 RPM 4. Incident report No. 102 (2-7-66)	MI 126	MI 52	MI 550	5183	Direct observation	1. Feedwater leaking at pump shaft seal. 2. Shaft seal replaced. 3. Improve maintenance schedule. Consider all pump drive components in accord with manufacturers' schedules.
47	1. Pump/Shaft Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Feedwater system 3. 345 GPM, 7450 RPM 4. Incident report No. 105 (2-10-66)	MI 126	MI 52	MI 550	5225	Direct observation	1. Feedwater leaking at pump shaft seal due to lack of adequate cooling to inboard mechanical seal. 2. Installed new source of water to provide greater pressure head. 3. Improve maintenance schedule.
48	1. Pump/Shaft 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Feedwater system 3. 345 GPM, 7450 RPM 4. Incident report No. 303 (6-6-66)	MI 192	MI 55	MI 520	6075	Operational monitors	1. Pump cavitation following scram. Pump drive shaft seized. 2. Seal replaced, and a modified boiler feed reservoir tank and a condensate booster pump system (with a 40-second time delay for shutoff in case of scram) were installed. 3. Design should specify precautions to prevent pump from running dry.
49	1. Boiler (P-1) Feed Pump/Outboard Mechanical Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Feedwater system 3. 900 HP, 7450 RPM, 165 psig 4. Incident report No. 102	MI 126	MI 52	MI 530	5183	Direct observation, feedwater leakage at pump shaft seal	1. Fragments of the worn seal ring rims destroyed the sealing effect between shaft and seal. 2. Part replaced. 3. Improved maintenance schedule shall be established considering all pump and drive components in accordance with pump manufacturer.
50	1. Pump Rotating Element/Wear Rings 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Boiler Feed Pump (P-1) 3. 7450 RPM, 165 psi, 345 GPM 4. Incident report No. 303	I 111	I 57	I 45	6075	During activation	1. Pump cavitation following scram. Three casing wear rings seized to impeller wear rings. 2. Vendor repair; seal replaced, then modified boiler feed reservoir tank and condensate booster pump system. 3. Include design precautions to prevent pump from running dry.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 11 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
51	1. Pump Boiler Feed/ Inboard Mechanical Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	1. SCTI 2. Steam and feedwater system 3. - 4. Incident report No. 105	MA 275	MA 51	MA 136	5225	Direct observation	1. Feedwater leakage at pump shaft seal. 2. Part replaced. 3. None.
52	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EFAPP No. 82	MI 125	MI 52	MI 530	2920	Direct observation	1. Shaft seal worn out. 2. Part replaced. 3. Determine operating life of seal from operating experience and schedule replacement accordingly.
53	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EFAPP-MR No. 82	MI 321	MI 53	MI 530	168	During actuation	1. Shaft seal loose, leaking. 2. Part replaced. 3. None.
54	1. Pump/Upper Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14, 941	Direct observation	1. Carbon face seal rings chipped. 2. Part replaced. 3. None.
55	1. Pump/Piston Cups 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14, 941	Direct observation	1. Piston cups worn out. 2. Part replaced. 3. None.
56	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14, 941	Direct observation	1. O-rings worn out. 2. Part replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 12 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
57	1. Pump/Lower Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14,941	Direct observation	1. Carbon face seal rings chipped. 2. Parts replaced. 3. Follow manufacturer's instructions on installation and operation of the seals.
58	1. Pump/Piston Cups 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14,941	Direct observation	1. Piston cups worn out. 2. Parts replaced. 3. None.
59	1. Pump/Oil Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary sodium system pump No. 2 3. 7200 GPM 4. WR 927	MI 126	MI 52	MI 530	Unknown	Direct observation	1. Oil seal failed resulting in oil leakage. 2. Seals changed, oil replaced. 3. None.
60	1. Pump 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary sodium system pump No. 1 3. 7200 GPM 4. ROAP Report (AI) 11-18-62	MI 183	MI 57	MI 530	5000	Direct observation	1. Pump case flooded with sodium as a result of IHX tube failure, preventing pump startup. 2. Pump removed and cleaned. Pump modified by plugging 4 of 8 impeller weep holes to maintain proper case sodium level. 3. None.
61	1. Pump/Impeller 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary sodium system pump No. 2 3. 7200 GPM 4. WR 2671	MI 113	MI 5Z	MI 530	7623	Operational monitors	1. Low sodium level in pump case suspected as resulting in gas entrainment. 2. Pump removed and 4 weep holes in impeller plugged to maintain proper case sodium level. 3. None.
62	1. Pump/Impeller 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary sodium system pump No. 3 3. 7200 GPM 4. WR 2672	MI 113	MI 5Z	MI 530	7591	Operational monitors	1. Low sodium level in pump case suspected of resulting in gas entrainment. 2. Pump removed and 4 weep holes in impeller plugged to maintain proper case sodium level. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 13 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
63	1. Pump/Piston Cups 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 126	MI 68	MI 530	14,941	Direct observation	1. Piston cups worn out. 2. Part replaced. 3. None.
64	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 126	MI 52	MI 530	14,941	Direct observation	1. O-rings worn out. 2. Part replaced. 3. None.
65	1. Pump/Lower Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 146	MI 56	MI 530	14,941	Direct observation	1. Inadequate spring pressure on face seals. 2. Part replaced. 3. None.
66	1. Pump/Piston Cups 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 146	MI 56	MI 530	14,941	Direct observation	1. Piston cups worn out. 2. Part replaced. 3. None.
67	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 146	MI 56	MI 530	14,941	Direct observation	1. O-rings worn. 2. Part replaced. 3. None.
68	1. Pump/Pump Shaft Argon Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-61	MI 125	MI 52	MI 530	14,941	Direct observation	1. Seal worn out. 2. Part replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 14 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
69	1. Pump/Elastomer Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow expansion tank No. 2 pump 3. 100 GPM, 75 ft discharge head 4. EF-61	MI 18Z	MI 52	MI 530	14, 941	Direct observation	1. Elastomer seals leaking, worn out. 2. Part replaced. 3. Request manufacturer's assistance on seals.
70	1. Pump/Shaft 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. EBR-II 2. Primary sodium pump No. 1 3. 5500 GPM, 350 HP 4. ANL-7082 7/65	MI 218	MI 55	MI 550	2590	During activation	1. Pump failed to rotate when activated. 2. Impeller drive shaft freed by vertical movement of drive shaft. 3. None.
71	1. Pump/Shaft 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. EBR-II 2. Primary sodium pump No. 1 3. 5500 GPM, 350 HP 4. ANL 7082, 7/65	MI 218	MI 55	MI 550	2590	During activation	1. Pump failed to rotate when activated. 2. Impeller drive shaft freed by vertical movement of drive shaft. 3. None.
72	1. Pump/Shaft 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. EBR-II 2. Primary Sodium pump No. 2 3. 5500 GPM, 350 HP 4. ANL-6780, 8/63	MI 412	MI 57	MI 550	Unknown	Audio noise	1. Impeller drive shaft seized as a result of shaft bowing. 2. Part replaced. 3. None.
73	1. Pump/Shaft 2. Gas Seal Heat Transfer/Reactor Coolant 3. 17 221110	1. SCTI 2. Primary sodium pump P-5 3. 200°F 4. Incident report No. 346, 1/15/69	MI 344	MI 54	MI 520	8530	Routine area watch	1. Excessive amounts of oil observed leaking from the seal vent line due to seal of the rotating face separated from the stationary face by carborized oil preventing faces from repositioning against each other. 2. Replaced part. 3. Procedure changed to reduce probability of carburization.
74	1. Sodium Pump P-5/ Cover Plate 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SCTI 2. Primary sodium system 3. 1750 RPM, 840°F 4. Incident report No. 29, 8/17/65	MA 145	MA 59	MA 136	586	Direct observation	1. Cover plate was not secured to the pump casing. 2. Part replaced. 3. Upgrade maintenance procedures on sodium pumps.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 15 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
75	1. Pump/Shaft Bearings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary/expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EFAPP No. 55	MI 348	MI 52	MI 530	1628	Direct observation	1. Bearings worn out. 2. Part replaced. 3. None.
76	1. Pump/Thrust Bearing 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. PRDC-EF-17	MI 125	MI 52	MI 530	9390	Direct observation	1. Thrust bearing worn out. 2. Part replaced. 3. Upgrade maintenance procedures.
77	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EFAPP No. 74	MI 126	MI 52	MI 530	10,120	Direct observation	1. Shaft seal worn out. 2. Part replaced. 3. Upgrade maintenance procedure.
78	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. PRCD-EF-19	MI 126	MI 68	MI 530	72	Direct observation	1. Shaft seal scored and galled. 2. Parts replaced. 3. Upgrade maintenance procedures.
79	1. Pump/Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium pump No. 3 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-22	MI 125	MI 52	MI 530	235	Direct observation	1. Seals leaking. 2. Part replaced. 3. Upgrade maintenance procedures.
80	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-22	MI 125	MI 52	MI 530	235	Direct observation	1. O-rings worn out. 2. Parts replaced. 3. Upgrade maintenance procedures.
81	1. Pump/ U-Cup Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-22	MI 125	MI 52	MI 530	11,740	Direct observation	1. U-cup seals leaking. 2. Parts replaced. 3. Upgrade maintenance procedures.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 16 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
82	1. Pump/Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-27	MI 125	MI 52	MI 530	13,200	Direct observation	1. Face seals worn out. 2. Parts replaced. 3. Upgrade maintenance procedures.
83	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium system/ expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EFAPP No. 20	MI 135	MI 56	MI 530	3650	Direct observation	1. Shaft seal leak due to misalignment. 2. Part replaced. 3. None.
84	1. Pump/Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium system/ expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. PRDC-EF-6	MI 125	MI 52	MI 530	4015	Direct observation	1. Seal worn out. 2. Part replaced. 3. None.
85	1. Pump/Gears and Bearing 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium system/ expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. PRDC-EF-10	MI 126	MI 52	MI 530	11,740	Direct observation	1. Gears and bearing worn out. 2. Part replaced. 3. None.
86	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium system/ expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. PRDC-EF-12	MI 136	MI 56	MI 530	3550	Direct observation	1. Pump shaft seal, backing spring improperly fit. 2. Local repair, collar was relieved and the seal reassembled. 3. Upgrade maintenance procedures.
87	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary/expansion tank No. 1 pump 3. 100 GPM, 75 ft discharge head 4. EFAPP No. 55	MI 348	MI 52	MI 530	3550	Direct observation	1. Shaft seal worn out. 2. Part replaced. 3. None.
88	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. No. 3 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-27	MI 125	MI 52	MI 530	13,200	Direct observation	1. O-rings worn out. 2. Parts replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 17 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
89	1. Pump/Shaft Seal (Upper) 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 2 3. 100 GPM, 75 ft discharge head 4. EFAPP No. 42	MI 110	MI 87	MI 530	5643	Direct observation	1. Black foreign material on shaft sleeve beneath the upper rotating face seal. 2. Part replaced. 3. None.
90	1. Pump/Pump Shaft 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 2 3. 100 GPM, 75 ft discharge head 4. PRDC-EF No. 17	MI 110	MI 57	MI 530	9390	During activation	1. Shaft seized at the upper labyrinth seal. 2. Local repair. 3. None.
91	1. Pump/Face Seals (Upper) 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 2 3. 100 GPM, 75 ft discharge head 4. EF-43	MI 126	MI 68	MI 530	14,941	Direct observation	1. Seals scored. 2. Parts replaced. 3. None.
92	1. Pump/All Argon Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 1 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-61	MI 120	MI 52	MI 530	14,941	Operational monitors	1. Seals worn out. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
93	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, seal oil pump No. 2 3. 4. PRDC-EF-1	MI 120	MI 52	MI 530	2190	Direct observation	1. Drive gear failure. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
94	1. Pump/Bearings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 2 3. 350 HP, 11,800 GPM, 900 RPM 4. PRDC-EF-25	MI 120	MI 58	MI 530	13,368	Audio noise	1. Bearings noisy. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 18 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
95	1. Pump/Bearings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 2 3. 350 HP, 11,800 GPM, 900 RPM 4. PRDC-EF-29	MI 120	MI 58	MI 530	992	Audio noise	1. Bearings noisy. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
96	1. Pump/Thrust Bearing 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 3 3. 350 HP, 11,800 GPM, 900 RPM 4. PRDC-EF-6	MI 120	MI 58	MI 530	4245	Direct Observation	1. Bearings vibrating. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
97	1. Pump/Shaft Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 3 3. 350 HP, 11,800 GPM, 900 RPM 4. EFAPP No. 68	MI 120	MI 52	MI 530	4245	During preventive maintenance	1. Shaft seal worn out. 2. Part replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
98	1. Pump/Bearings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium, No. 3 3. 350 HP, 11,800 GPM, 900 RPM 4. EFAPP No. 68	MI 120	MI 52	MI 530	4245	During preventive maintenance	1. Bearings worn out. 2. Parts replaced. 3. Revise preventive maintenance inspection intervals on pumps to detect problems before unscheduled outage occurs. Inspections to be made during reactor shutdown.
99	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 1 3. 100 GPM, 75 ft discharge head 4. EF-42	MI 125	MI 52	MI 530	14,941	Direct observation	1. O-rings worn out. 2. Parts replaced. 3. None.
100	1. Pump/Argon Seal (Upper) 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 1 3. 100 GPM, 75 ft discharge head 4. EF-61	MI 125	MI 52	MI 530	14,941	Direct observation	1. Seal worn out. 2. Parts replaced. 3. None.

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FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 19 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
101	1. Pump/Elastomer Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary system/overflow pump No. 1 3. 100 GPM, 75 ft discharge head 4. EF-61	MI 18Z	MI 52	MI 530	14, 941	Direct observation	1. Constriction of elastomer seals caused leaking. 2. Part replaced. 3. None.
102	1. Pump/Shaft 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 1 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. PRDC-EF-9	MI 110	MI 54	MI 530	5643	Direct observation	1. Shaft distorted and rubbing. 2. Part replaced. 3. None.
103	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-30	MI 321	MI 5Z	MI 530	1328	Direct observation	1. O-rings worn out. 2. Parts replaced. 3. None.
104	1. Pump/Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 3 pump 3. 350 HP, 11,800 GPM, 900 RPM 4. EF-30	MI 321	MI 5Z	MI 530	1328	Direct observation	1. Face seals leaking. 2. Part replaced. 3. None.
105	1. Pump/Face Seals 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 1 pump 3. - 4. EF-33	MI 125	MI 52	MI 530	14, 702	Direct observation	1. Face seals worn out. 2. Part replaced. 3. None.
106	1. Pump/O-Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 1 pump 3. - 4. EF-33	MI 125	MI 52	MI 530	14, 702	Direct observation	1. O-rings worn out. 2. Part replaced. 3. None.

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FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 20 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
107	1. Pump/Slip Rings 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. FERMI 2. Primary sodium No. 1 pump 3. - 4. EF-33	MI 125	MI 68	MI 530	14,702	During repair	1. Slip rings scored. 2. Local repair. 3. Upgrade preventive maintenance procedure to include inspection of slip rings. Check brush tension, cleanliness, etc. Follow manufacturer's recommendations on care of slip rings.
108	1. Pump/Thrust Bearings 2. Heat Transfer/Reactor Coolant 3. 17 221100	1. FERMI 2. Primary sodium No. 1 pump 3. - 4. EF-33	MI 125	MI 58	MI 530	14,702	Audio noise	1. Bearings vibrating. 2. Part replaced. 3. Dynamically balance pump.
109	1. Pump/Bearings 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. HNPF, monthly operating report No. 11, 6/8/63	MI 200	MI 55	MI 550	Shake-down	Direct observation	1. Bearings jammed. 2. Local repair. 3. None.
110	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. HNPF, monthly operating report No. 15, 10/63	MI 137	MI 51	MI 550	4560	Direct observation	1. Pump shaft plug (internal leak). 2. Local repair. 3. None.
111	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. Weekly hilites, 1/4/64	MI 137	MI 55	MI 550	10,487	Direct observation	1. Pump shaft plug. Sodium deposition on shaft between shaft and case caused obstruction. 2. Temporary repair. 3. None.
112	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. Weekly site report, 10/9/63	MA 187	MA 54	MA 530	9173	Audio noise	1. Shaft distorted, poor case temperature distribution. 2. Component corrective modification. 3. None.
113	1. Sodium Pump/Bearing 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. Work request No. 2601, CPPD 1/30/64	MA 414	MA 52	MA 530	10,592	Audio noise	1. Lack of lubrication to bearing - bearing worn out. 2. Component corrective modification. 3. None.

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FAILURE DATA FOR PUMPS AND SUPPORTS

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
114	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. CPPD monthly, 4/30/64	MA 9ZZ	MA BZ	MA 550	16,286	Audio noise, squealing	1. Pump shaft squealing. 2. None; 6 hours inspection time only. 3. None.
115	1. Sodium Pump/Oil Reservoirs 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 950°F, 7200 GPM, 160 to 170 ft head, 0-850 RMP 4. Monthly operating report No. 15, 10/13/63	MA 137	MA 51	MA 550	4560	Direct observation	1. Sodium froze on pump shaft and leaked into secondary oil reservoir. 2. Local repair. 3. Upgrade operator training on filling loop.
116	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 950°F, 7200 GPM, 350 HP 4. Weekly hilites, 12/15/63	MA 413	MA 55	MA 530	10,851	Audio noise	1. Shaft expansion or clearance provision incorrect. 2. Component corrective modification. 3. None.
117	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 22210	1. HNPF 2. Secondary/sodium 3. 350 to 950°F, 7200 GPM, 350 HP 4. NAA-SR-TDR-11485, 3/6/64	MA 413	MA 55	MA 530	12,804	Direct observation	1. Shaft stuck, persuader bar used to rotate the shaft. 2. Component corrective modification. 3. None.
118	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 950°F, 7200 GPM, 350 HP 4. CPPD monthly NAA-SR-TDR-1485, 4/20/64	MA 413	MA 55	MA 530	14,112	Direct observation	1. Shaft stuck, persuader bar used to rotate the shaft. 2. Component corrective modification. 3. None.
119	1. Pumps/Impeller Weep Holes 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Main primary sodium 3. 350 to 945°F, 850 RPM, 7200 GPM 4. Monthly operating report No. 9, 3/63	MI 137	MI A7	MI 550	3490	During preventive maintenance	1. Weep holes sucking sodium into pump casings. 2. Corrective modification - four of the eight holes welded closed. 3. None.

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FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 22 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
120	1. Pumps/Impeller Weep Holes 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary/sodium 3. 350 to 945°F, 350 HP, 7200 GPM 4. AI Monthly ROAP Report, 8/29/63	MA 137	MA 55	MA 530	4450	Direct observation	1. Shaft leaking. 2. Corrective modification - four of eight weep holes welded closed. 3. None.
121	1. Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 7200 GPM, 350 HP 4. NAA-SR-TDR-11485, 6/8/63	MI 413	MI 55	MI 530	7711	Direct observation	1. Pump shaft binding. 2. Component corrective modification. 3. None.
122	1. Sodium Pump/P-202 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. Work request No. 909, 4/6/62	MI 136	MI 53	MI 530	Pre-Op Testing	Direct observation	1. Loose bolts caused leak. 2. Local repair. 3. None.
123	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. Daily site wire, 2/4/63	MI 413	MI 55	MI 530	3250	Audio noise	1. Sound of metal-to-metal interference. 2. Component corrective modification; shaft machined, internal parts cleaned and inspected. 3. None.
124	1. Sodium Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium 3. 350 to 925°F, 350 HP, 7200 GPM 4. ANS No. 101, Daily Wire, 6/8/63	MI 413	MI 55	MI 530	1200	Direct observation	1. Pump shaft deflected with slight changes in temperature distribution. 2. Unknown. 3. None.
125	1. Pump/Bearing 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. Internal letter, 1/11/64	MA 187	MA 54	MA 530	10,592	Direct observation	1. Bearing noise due to poor case temperature distribution distorting pump barrel. 2. Component corrective modification. 3. None.
126	1. Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. CPPD monthly, 2/16/64	MA 137	MA 55	MA 550	11,309	Direct observation	1. Shaft would not rotate by hand. 2. Component corrective modification. 3. None.

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FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 23 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
127	1. Pump/Unknown 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary/sodium pump P102 3. 350 to 945°F, 350 HP, 7200 GPM 4. CPPD Monthly, 4/30/64	MA 9ZZ	MA BZ	MA 550	12,685	Audio noise	1. Pump squealing. 2. None; 6 hours inspection only. 3. None.
128	1. Pump/Barrel 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary sodium system pump No. 3 3. 7200 GPM 4. Weekly site report, 10/9/63	MI 111	MI 58	MI 530	9173	Audible noise	1. Rubbing noise noted within pump. 2. Increased rpm and changed cooling distribution to barrel. 3. None.
129	1. Pump/Bearing 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary sodium system pump No. 1 3. 7200 GPM 4. Internal letter, 1/11/64	MI 111	MI 58	MI 530	10,592	Audible noise	1. Rubbing noise from upper bearing. 2. Altered cooling distribution on barrel. 3. None.
130	1. Pump/Oil Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. HNPF 2. Primary sodium system pump No. 1 upper oil seal 3. 7200 GPM 4. MOR 10102, 2/10/64	MI 126	MI 52	MI 530	14,076	Direct observation	1. Oil seal leaked. 2. Seal and gaskets replaced. 3. None.
131	1. Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary sodium system No. 1 3. 7200 GPM 4. CPPD monthly, 3/6/64	MI 11Z	MI 57	MI 530	11,725	During startup	1. Pump failed to rotate. 2. Persuader bar used to initiate shaft rotation. 3. None.
132	1. Pump/Shaft 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. HNPF 2. Secondary sodium system No. 2 3. 7200 GPM 4. CPPD monthly, 3/6/64	MI 11Z	MI 57	MI 530	12,804	During startup	1. Pump failed to rotate. 2. Persuader bar used to initiate shaft rotation. 3. None.
133	1. Pump/Cooling Coils 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 2 sodium pump 3. 30 GPM, water 4. ANL-6944-9-64	MI 274	MI 51	MI 530	790	Direct observation	1. Cooling lines plugged with debris. 2. Local repair. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.

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FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 24 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
134	1. Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 2 sodium pump 3. 30 GPM, water 4. PMMR 17-2-19	MI 273	MI 51	MI 550	1200	Operational monitors	1. Cooling jacket plugged with debris. 2. Local repair. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
135	1. Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 2 sodium pump 3. 30 GPM, water 4. PMMR-26-4-22	MI 273	MI 51	MI 550	1610	Operational monitors	1. Cooling jacket plugged with debris. 2. Local repair, unit was back-flushed. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
136	1. Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 2 sodium pump 3. 30 GPM, water 4. PMMR-29-5-12-65	MI 273	MI 51	MI 550	1850	Operational monitors	1. Cooling jacket plugged with debris 2. Local repair, unit was back-flushed. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
137	1. Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 1 sodium pump 3. 30 GPM, water 4. PMMR 29-5-12-65	MI 273	MI 51	MI 550	1850	Operational monitors	1. Cooling jacket plugged with debris. 2. Local repair, unit was back-flushed. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
138	1. Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222000	1. EBR-II 2. Secondary No. 2 sodium pump 3. 30 GPM, water 4. Operation weekly report 1/3/68	MI 273	MI 51	MI 530	13,380	Operational monitors	1. System plugged. 2. Local repair, unit was back-flushed. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
139	1. AC Conduction Pump/ Pumping Duct 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. Aerojet-General Corp., Von Karman Center 2. AGN loop No. 3, S/N 607 3. 8 KW, 240 V, 1 phase, 60 cycle, 1500°F, 1 in. OD duct 4. AGC TM 9436:66-393, MSA EP-3	I 339	I 61	I 136	1	Direct observation (unscheduled)	1. Pump duct overheated and ruptured due to lack of liquid metal in duct when pump was started. Leak external. 2. Component part replaced. 3. Equip the pump duct with a temperature controlling sensor, including audible alarm.

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FAILURE DATA FOR PUMPS AND SUPPORTS
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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
140	1. AC Conduction Pump/ Pumping Duct 2. Heat Transfer/ Intermediate Cooling 3. 17 221110	1. Aerojet-General Corp., Von Karman Center 2. RPL-2 primary NaK loop (RPL-2 floating mount) S/N 651 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr 4. AGC TM 9436:66-393, MSA EP-3	I 339	I 61	I 136	287	Direct observation (unscheduled)	1. No liquid metal in pumping duct - pump duct damaged (duct overheated and melted) where bus bar attached to duct. 2. Replaced pump with spare EM pump S/N 564 from RPL-1. 3. Equip pumping duct with a temperature controlling sensor, including audible alarm.
141	1. AC Conduction Pump/ Connection Duct 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. Aerojet-General Corp., Von Karman Center 2. RPL-2 heat rejection loop (RPL-2 floating mount) 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr, 1-1/2 in. OD duct 4. AGC TM 9436:66-393, MSA EP-3	I 128	I 61	I 136	1943	Direct observation (unscheduled)	1. Vibration caused pump tube to crack at suction end where bus bar attached. NaK leak, external. 2. Part replaced. 3. EM pumps operated below the curie point of Ni (676.4°F) power level should be reduced to a value where the pump vibration caused by magnetostrictive forces is acceptable.
142	1. AC Conduction Pump/ Pump Duct 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. Aerojet-General Corp., Von Karman Center 2. SL-1 primary NaK test loop (SL-1 solid anchoring-heater circuit) S/N540 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr = 210 GPM, 1-1/2 in. OD duct 4. AGC TM 9436:66-393 MSA EP-3	I 339	I 61	I 136	551	Direct observation (unscheduled)	1. Pump duct overheated and ruptured due to the lack of liquid metal in the duct when the pump was started. Leak external. 2. Component part replaced. 3. Equip pumping duct with temperature controlling sensor, including audible alarm.
143	1. AC Conduction Pump/ Field Stator Coils 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. Aerojet-General Corp., Von Karman Center 2. SL-1 heat rejection loop (SL-1 solid anchoring) S/N 651 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr 4. AGC internal letter 4931-65-0066	MA 454	MA 15	MA 151	1302	Protective system	1. Vibrations damaged electrical insulation field coil "C." Resultant short on circuit caused power cables to melt. 2. Component part replaced. 3. Pump should be checked for excessive vibration as part of acceptance procedures after completion of installation.
144	1. AC Conduction Pump/ Pumping Duct 2. Heat Transfer/ Primary Cooling 3. 17 221110	1. Aerojet-General Corp., Von Karman Center 2. PCS-1 primary NaK loop S/N 564 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr 4. Snap 8-D. of A.G.C. F.C. MSA EM P.F.	MI 195	MI 51	MI 116	669	Routine instrument reading (direct observation)	1. Pump duct partially plugged with oxide deposits at poles - pumping capability dropped to 40,000 lb/hr. 2. Pump duct replaced. 3. Pump should not be operated at more than 600°F if the NaK plugging temperature is >300°F.

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FAILURE DATA FOR PUMPS AND SUPPORTS

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
145	1. AC Conduction Pump/ Supporting Structure 2. Heat Transfer/Intermediate Cooling 3. 17 222110	1. Aerojet-General Corp., Von Karman Center 2. RPL-2 heat rejection loop 3. 55 KW, 480 V, 1 phase, 60 cycle, 1500°F, 52,000 lb/hr., 1-1/2 in. OD duct 4. AGC TM 9436:66-393, MSA EP-3	MI 127	MI 24	MI 148	Unknown	Direct observation (unscheduled)	1. Excessive magnetostrictive vibration of the heavy nickel bus bar caused bus bar to work loose. 2. Operating limits changed. 3. Nickel bus bars should not be used where temperature of bar will be below curie temperature of nickel (676.4°F).
146	1. AC Annular Induction Pump/Stator 2. Heat transfer/Primary Cooling 3. 17 221100	1. APDA, quarry test facility 2. NaK system 3. - 4. NASA C.R. CR-380 APDA AECU-3700	I 137	I 15	I 111	Unknown	Operational monitors	1. Shield can surrounding iron core in center of pump failed, allowing NaK to leak into and around poles — short circuit resulted. 2. Component part replaced. 3. Pump development work incomplete, therefore problems are to be expected. (Einstein-Szilard reversed flow type.)
147	1. AC Conduction Pump/ Electrode 2. Heat Transfer/ Purification 3. 17 224233	1. KAPL, ALPLAUS site 2. MARK "A" cold trap 3. 700°F, 260 V 4. NASA C.R. No. CR-380 KAPL-M-JJM-1	MI 127	MI 21	MI 156	36	Direct observation (unscheduled)	1. Vibrations produced by pulsating frequency resulted in broken electrode. 2. Redesigned component to prevent recurrence. 3. Design specifications should consider vibrations produced by pulsating frequencies.
148	1. AC Conduction Pump/ Electrode 2. Heat Transfer/ Emergency Cooling 3. 17 224233	1. KAPL, ALPLAUS site (No. 60500) 2. MARK "A" cold trap 3. 700°F 4. NASA C.R. No. CR-380 KAPL-M-JJM-1	I 127	I 61	I 134	78	Direct observation (unscheduled)	1. Vibrations produced by pulsating frequency resulted in broken electrode. 2. Redesigned component to prevent recurrence. 3. Design specifications should consider vibrations produced by pulsating frequency.
149	1. AC Conduction Pump/ Electrode 2. Heat Transfer/ Purification 3. 17 224233	1. KAPL, ALPLAUS site (No. 60500) 2. MARK "A" cold trap 3. 700°F, 190 V 4. KAPL-M-JJM-1	MI 127	MI 127	MI 156	83	Direct observation (unscheduled)	1. Vibrations caused by frequency pulsation resulted in broken electrode. 2. Modify design to prevent recurrence. 3. Design specifications should consider vibrations caused by pulsating frequencies.

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FAILURE DATA FOR PUMPS AND SUPPORTS
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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
150	1. AC Conduction Pump/ Electrode 2. Heat Transfer/ Purification 17 224233	1. KAPL, ALPLAUS site (No. 60500) 2. MARK "A" cold trap 3. 700°F, 200 V 4. KAPL-M-JJM-1	MI 127	MI 21	MI 134	400	Direct observation (unscheduled)	1. Vibrations in piping caused by pulsation of frequency from zero to peak resulted in broken electrode. 2. Modify design to prevent recurrence. 3. Design specifications should consider vibrations caused by pulsating frequencies.
151	1. AC Conduction Pump/ Pump Duct 2. Heat Transfer/ Emergency Cooling 3. 17 214400	1. KAPL, ALPLAUS site (No. 60500) 2. Emergency cooling loop 3. 700°F 4. KAPL-M-JJM-1	I 127	I 61	I 134	400	Direct observation (unscheduled)	1. Crack generation, sodium leak, and fire. 2. Analyzed and redesigned duct to prevent recurrence. 3. Pulsating frequency from zero to peak produced vibration in piping, therefore, this phenomena should be considered during design of pump.
152	1. AC Conduction Pump/ Pump Duct 2. Heat Transfer/ Purification 3. 17 224233	1. KAPL, ALPLAUS site (No. 60500) 2. Cold trap 3. 515°F, 150 V 4. NASA C.R. No. CR-380, KAPL-M-JJM-1	I 127	I 61	I 134	42	Direct observation (unscheduled)	1. Crack generation, sodium leak, and fire. 2. Revised design to prevent recurrence. 3. Pulsation frequency from zero to peak produced vibrations in piping resulting in damage; therefore, designer should consider these criteria.
153	1. AC Conduction Pump/ Pump Duct 2. Heat Transfer/Main Cooling 3. 17 221110	1. KAPL, ALPLAUS site (No. 60500) 2. Main system 3. 600°F, 270 V, zero flow at time of failure 4. KAPL-M-JJM-1	MI 127	MI 21	MI 156	528	Direct observation (unscheduled)	1. Pulsating frequencies produced vibrations that resulted in broken electrode. 2. Modified design to prevent recurrence. 3. Design specifications should consider vibrations produced by pulsating frequencies.
154	1. AC Conduction Pump/ Electrode 2. Heat Transfer/Main Cooling 3. 17 221110	1. KAPL, ALPLAUS site (No. 60500) 2. Main system 3. 600°F, 270 V 4. KAPL-M-JJM-1	MI 127	MI 21	MI 156	1754	Direct observation (unscheduled)	1. Electrode broken by vibrations caused by pulsating frequencies. 2. Modified design to prevent recurrence. 3. Design specifications should consider vibrations produced by pulsating frequencies.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 28 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
155	1. DC Conduction Pump/ Pump Duct 2. Heat Transfer/Main Cooling 3. 17 221110	1. ANL, Lemont facility 2. Pump No. 1 3. 150 gpm, 75 psig head, 1000°F 4. LMEC, NAA-SR-12585	I 339	I 66	I 530	1000	Direct observation (routine instrument reading)	1. Pump duct overheated and ruptured due to lack of sodium in duct when pump was started. 2. Component part replaced. 3. Suggest pump duct be equipped with temperature controlling sensor, including audible alarm.
156	1. DC Conduction Pump/ Pump Duct 2. Heat Transfer/Main Cooling 3. 17 221110	1. ANL, Lemont facility 2. Pump No. 2 3. 100 gpm, 75 psig head, 1000°F 4. NASA C.R. No. 380, LMEC, NAA-SR-12585	I 339	I 66	I 530	50,000	Direct observation (routine instrument reading) shakedown test	1. Pump duct overheated and damaged due to lack of sodium in duct when pump was started. 2. Component part replaced. 3. Suggest pump duct be equipped with temperature controlling sensor, including audible alarm.
157	1. DC Conduction Pump/ Copper Electrodes 2. Heat Transfer/Main Cooling 3. 17 221110	1. ANL, Lemont facility 2. Pump No. 3 3. 500 gpm, 700°F 4. NASA C.R. No. 380, LMEC, NAA-SR-12585	MA 445	MA 87	MA 630	30,000	Direct observation (routine instrument reading) shakedown test	1. Metallurgical – surface deposition (mass transfer) copper transferred from pump electrodes to plugging meter valve. 2. Redesigned electrodes to prevent recurrence. 3. Copper and sodium are incompatible; therefore, design accordingly.
158	1. DC Conduction Pump/ Bus Bar 2. Heat Transfer/Main Cooling 3. 17 221110	1. ANL, Lemont facility 2. Pump No. 4 3. 250 gpm, 75 psig head, 1000°F 4. NASA C.R. No. CR-380, LMEC, NAA-SR-12585	MI 162	MI 86	MI 530	40,000	Protective system	1. Air initiated corrosive attack on copper conductors. 2. Component design modified. 3. Modify design to prevent air entrainment.
159	1. AC Linear Induction Pump/Pump Duct 2. Heat Transfer/Main Cooling 3. 17 221110	1. ANL, Lemont facility 2. Pump No. 1 3. 5000 gpm 4. LMEC, NAA-SR-12585	MI 124	MI 61	MI 136	6600	Direct observation (routine area watch)	1. Fatigue cracks around top of spacers. 2. Round holes cut and discs welded in to close holes. 3. Designers should consider the magneto-motive and magneto-strictive forces acting on the duct material.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 29 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
160	1. DC Conduction Pump/ Pump Duct 2. Heat Transfer/ Purification 3. 17 224232	1. ANL, EBR-II 2. Sodium purification system (temporary) 3. 350°F 4. ANL-6739	MA 500	MA 61	MA 136	Unknown	Direct observation (unscheduled)	1. Pump duct leaked sodium. 2. Pump duct removed. 3. None.
161	1. AC Conduction Pump/ Copper Bus Bar 2. Heat Transfer/ Purification 3. 17 224233	1. ANL, EBR-II 2. Sodium purification system/cold trap 3. 275 - 700°F, 60 gpm 4. ANL-6885, EBR-II S. T. P. Vol. C-9	MI 456	MI 14	MI 550	550	Unknown	1. Poor electrical contact at bus bar terminal. 2. Repaired. 3. None.
162	1. AC Linear Induction Pump/Pump Duct 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. ANL, EBR-II 2. Main secondary 3. 6500 gpm, 700°F Pressure head 53 psi, 480 V, 3 phase, 60 cycle, required KW-450 4. ANL-6885, ANL-6904, EBR-II S. T. P. Vol. C-9, ANS-100	MI 500	MI 61	MI 136	Unknown	Operational monitors	1. Cracks resulted from a combination of very low inlet pressure to the duct at a high flow rate. 2. Repaired in field by cutting circular disks containing the cracks from the duct and welding in new disks. Flow rate was limited to 75% after repair. 3. Revise pump operating procedure to prevent recurrence of incident.
163	1. DC Conduction Pump/ Electrodes 2. Heat Transfer/ Primary Cooling 3. 17 221110	1. ANL, EBR-II 2. Primary/auxiliary 3. Operating voltage-1.4 V, 500 gpm, 0.15 psi, 900°F sodium 4. ANL-7317, ANL-7329, EBR-II PMMR No. 99, ANL-Idaho Div. - Operations report 1-1-67	MI 445	MI 87	MI 250	Unknown	Operational monitors	1. Copper dissolved in sodium. Approximately 10 lb eroded away from copper electrodes. 2. Dissolved copper was removed from primary sodium by cold trapping. 3. Copper and sodium are incompatible; therefore, design accordingly.
164	1. AC Linear Induction Pump/Cooling Water Jacket 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. ANL, EBR-II 2. No. 2 secondary coolant 3. 6500 gpm at 53 psi, 700°F, 3 phase, 60 cycle required at 450 KW, water requirement 30 gpm 4. NASA CR No. 380, EBR-II Operations weekly report 2-21-68	MI 127	MI 61	MI 136	1200	Operational monitors	1. Obstruction of coolant passage by impurities in plant cooling water. 2. Coolant passage back flushed. 3. Install filters for removing particulate matter from cooling system.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 30 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
165	1. AC Linear Polyphase Induction Pump/Coils 2. Heat Transfer/ Intermediate Cooling 3. 17 221110	1. HNPF 2. Secondary/sodium service 3. 480 V, 3 phase, 60 cycle, 40 psi, 900°F, 30 amp, 100 gpm, 3 in. diameter piping 4. HNPF W.R. No. 273, HNPF Const. Log Book No. 6, P. 32, TWX to R. S. Baker "HNPF EM Pumps."	MA 151	MA 13	MA 151	80	Protective system	1. Full line voltage applied at startup caused excessive heat to develop in magnetic field coils thereby deteriorating the insulation and allowing the coils to short circuit the system. 2. Installed Powerstat in line. 3. Component and system design should consider the startup in-rush currents, whenever electrical AC components are installed. AC magnetic coil design should observe the special insulation requirements in connection with laminated magnetic cores.
166	1. AC Linear Poly-phase Induction Pump/Coils 2. Heat Transfer/ Main Cooling 3. 17 221110	1. HNPF 2. Primary/sodium service No. 2 Pump 3. 480 V, 30 amp, 100 gpm, 950°F, 60 cycle, 40 psi, 3 phase, 3 in. diameter piping 4. AI letter No. 63AT33, 4, HNPF monthly report No. 8, AI letter No. 63AT4480, HNPF work request No. 2764, HNPF work request No. 2135	MA 151	MA 13	MA 550	Unknown	Protective system	1. Full line voltage at startup caused excessive heat to develop in magnetic field coils, thereby deteriorating the insulation and allowing coils to short circuit. 2. New coils were fitted into the old pump frame. 3. Revise startup procedure to prevent recurrence of incident. Install temperature alarms on coils and voltage control devices on power supply.
167	1. AC Linear Poly-phase Induction Pump/Coils 2. Heat Transfer/Main Cooling 3. 17 221110	1. HNPF 2. Primary/sodium service No. 1 and No. 2 pumps 3. 480 V, 3 phase, 60 cycle, 30 amp, 100 gpm, 40 psi, 950°F, 3 in. diameter piping 4. AI letter No. 63AT334, HNPF work request No. 2135	MI 329	MI 54	MI 530	Unknown	Direct observation	1. Cage over 480 V bus bar bent out of shape by personnel using it for a working platform. 2. Installed angle iron supports. 3. Work platform should be part of original installation.
168	1. AC Linear Poly-phase Induction Pump/ Jumpers 2. Heat Transfer/Main Cooling 3. 17 221110	1. HNPF 2. Primary/sodium service No. 1 and No. 2 pumps 3. 480 V, 3 phase, 60 cycle, 30 amp, 100 gpm, 40 psi, 950°F, 3 in. diameter piping 4. HNPF Construction log No. 6	MI 410	MI 13	MI 580	Unknown	Direct observation	1. Electrical insulation deteriorated on jumper wires. 2. All jumper wires insulated with glass tape. 3. Component and system design should consider the effects of the in-rush currents during startup whenever electrical AC components are installed.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 31 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
169	1. AC Linear Polyphase Induction Pump/Stator Bolts 2. Heat Transfer/Main Cooling 3. 17 221110	1. HNPF 2. Primary/sodium service No. 1 and No. 2 pumps 3. 480 V, 3 phase, 60 cycle, 30 amp, 100 gpm, 40 psi, 950°F, 3 in. diameter piping 4. HNPF Construction log No. 6, AI letter No. 63AT334	MI 473	MI 52	MI 590	Unknown	Audio noise	1. AC hum from laminated magnet cores. 2. Torque bolts to 80 in.-lb. 3. Follow design specifications for assembly laminated AC magnet cores.
170	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Primary Decay Heat Removal 3. 17 214210	1. SRE 2. Auxiliary primary sodium system pump 3. 1000°F, 70 gpm 4. Operations log No. 47, 10-15-62	MA 185	MA 66	MA 550	Unknown	Operational monitors	1. Loss of shaft freeze seal due to excessive temperature. 2. Removed, cleaned, and replaced seal. 3. Operate seal within specified limits.
171	1. Pump/Radial Bearing 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. SRE 2. Main secondary sodium system pump 3. 600°F, 1500 gpm 4. Incident report, 9-17-63	MI 110	MI 57	MI 520	Unknown	During actuation	1. Radial bearing failure because of improper installation of bearing on shaft. 2. Removed and replaced. 3. Position bearings on shaft with a press.
172	1. Pump/Case Freeze Seal 2. Reactor Equipment/ Secondary Decay Heat Removal 3. 17 214220	1. SRE 2. Auxiliary secondary sodium system pump 3. 600°F, 70 gpm 4. Operations log No. 41	MA 338	MA 66	MA 550	Unknown	Operational monitors	1. Case freeze seal failure due to inadequate cooling. 2. Removed, cleaned, and replaced pump. 3. Upgrade operator training for pump operation.
173	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Secondary Decay Heat Removal 3. 17 214220	1. SRE 2. Auxiliary secondary sodium system pump 3. 600°F, 70 gpm 4. Operations log No. 36	MI 113	MI 51	MI 550	Unknown	Alarm	1. Loss of shaft freeze seal due to excessive temperature. 2. Pressurized, and blew sodium back into the system. 3. Upgrade operator training program for pump operation.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS
(Sheet 32 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
174	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. 1000°F, 1500 gpm 4. Incident report, 11-20-63	MI 157	MI 57	MI 520	Unknown	Operational monitors	1. Pump shaft seizure due to low shaft freeze seal temperatures. 2. Reheated shaft seal. 3. Upgrade operator training program for pump operation.
175	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. 1000°F, 70 gpm 4. Incident report, 10-19-61	MI 110	MI 57	MI 550	Unknown	During actuation	1. Pump shaft seizure because of low freeze seal temperature. 2. Reheated shaft seal. 3. Upgrade operator training program for pump operation.
176	1. Pump/Shaft Gas Seal 2. Reactor Equipment/ Primary Decay Heat Removal 3. 17 214210	1. SRE 2. Auxiliary primary sodium system 3. 1000°F, 70 gpm 4. Operations log, 2-2-59	MI 114	MI 68	MI 530	Unknown	Operational monitors	1. Loss of lubrication in bearing. 2. Removed and replaced galled bearing. 3. None.
177	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. SRE 2. Main secondary sodium system 3. 1000°F - 1500 gpm 4. Incident report 1-17-59	MI 110	MI 17	MI 520	Unknown	Protective system	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.
178	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. SRE 2. Main secondary sodium system 3. 1000°F, 1500 gpm 4. Incident report, 11-25-62	MI 110	MI 57	MI 520	Unknown	Protective system	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 33 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
179	1. Pump/Shaft Bearing 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. SRE 2. Main secondary sodium system 3. 600°F, 1800 gpm 4. Incident report 9-17-63	MA 321	MA 56	MA 520	Unknown	Direct observation	1. Pump shaft misaligned during reassembly. 2. Removed and repaired. 3. Upgrade maintenance procedure for installing pump shaft bearings.
180	1. Pump/Shaft Freeze Seal Thermowell 2. Heat Transfer/ Intermediate Cooling 3. 17 222110	1. SRE 2. Main secondary sodium pump 3. 600°F, 1800 gpm 4. Incident report 9-25-58	I 256	I 61	I 530	Unknown	Operational monitors	1. Organic leaked into sodium system through crack in shaft seal thermowell. 2. Seal removed, modified, and replaced. 3. None.
181	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Primary Decay Heat Removal 3. 17 214210	1. SRE 2. Auxiliary primary sodium pump 3. 600°F, 70 gpm 4. Incident report 10-4-62	MI 110	MI 57	MI 520	Unknown	Protective system	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.
182	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Primary Decay Heat Removal 3. 17 214210	1. SRE 2. Auxiliary primary sodium pump 3. 600°F, 70 gpm 4. Incident report 10-5-62	MI 110	MI 57	MI 520	Unknown	Direct observation	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.
183	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Primary Decay Heat Removal 3. 17 214210	1. SRE 2. Auxiliary primary sodium pump 3. 600°F, 70 gpm 4. Incident report 11-15-63	MI 110	MI 57	MI 520	Unknown	Protective system	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 34 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
184	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system 3. 1000°F, 1500 gpm 4. Incident report 3-6-63	MI 110	MI 57	MI 520	Unknown	Operational monitors	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.
185	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. - 4. Operations log No. 3, 4-27-57	I 331	I 66	I 550	Unknown	Operational monitors	1. Loss of shaft freeze seal and seizure of shaft. 2. Removed pump and cleaned. 3. Operate seal within specified limits.
186	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. - 4. Operations log No. 13, 4-19-59	I 331	I 66	I 550	Unknown	Operational monitors	1. Loss of shaft freeze seal and seizure of shaft. 2. Removed pump and cleaned. 3. Operate seal within specified limits.
187	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. - 4. Operations log No. 45, 6-15-62	I 331	I 66	I 550	Unknown	Operational monitors	1. Loss of shaft freeze seal and seizure of shaft. 2. Removed pump and cleaned. 3. Operate seal within specified limits.
188	1. Pump/Shaft Freeze Seal 2. Heat Transfer/ Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system pump 3. - 4. Operations log No. 51, 2-14-63	MI 153	MI 57	MI 550	Unknown	Operational monitors	1. Pump shaft seizure. 2. Reheated shaft freeze seal. 3. Operate seal within specified limits.
189	1. Pump/Shaft Freeze Seal 2. Reactor Equipment/ Secondary Decay Heat Removal 3. 17 214220	1. SRE 2. Auxiliary primary sodium system pump 3. - 4. Incident report 5-10-62	MI 113	MI 66	MI 550	Unknown	During actuation	1. Loss of shaft freeze seal. 2. Reheated shaft freeze seal. 3. Operate seal with specified limits.

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FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 35 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
190	1. Pump/Shaft Freeze Seal 2. Heat Transfer/Reactor Coolant 3. 17 221110	1. SRE 2. Main primary sodium system 3. 1000°F, 1500 gpm 4. Incident report 5-27-63	MI 110	MI 57	MI 520	Unknown	Operational monitors	1. Pump shaft seized due to low shaft seal temperature. 2. Reheated shaft freeze seal. 3. Operate pump shaft freeze seal at design temperature to prevent seizure.
191	1. Pump/Gas Seal 2. Heat Transfer/Reactor Coolant 3. 17 221110	1. LCTL 2. LCTL/6 x 8 sodium loop pump 3. 310 gpm, 550°F 4. LCTL log book, 9-29-60	MI 128	MI 52	MI 530	Unknown	Operational monitors	1. Seal vibrating, faces worn out. 2. Part replaced. 3. Upgrade preventive maintenance inspections of seals to prevent unscheduled outage.
192	1. Pump/Magnetic Seal 2. Heat Transfer/Reactor Coolant 3. 17 221110	1. LCTL 2. LCTL/sodium system 2 x 3 3. 4. LCTL log book, 10-16-59	MI 125	MI 52	MI 530	Unknown	Direct observation	1. Magnetic seal leaking. 2. Part replaced. 3. None.
193	1. Vacuum Pump/Casing 2. Nuclear Fuel Handling and Equipment/Fuel Handling Machine 3. 17 235000	1. SRE 2. Fuel handling machine contaminated vent system 3. - 4. Operating log No. 16, 1-25-60	MA 316	MA 59	MA 550	Unknown	Direct observation	1. Pump placed in service without opening discharge valve — pump ruptured. 2. Component replaced. 3. Install rupture disc or relief valve on pump discharge line.
194	1. Pump/Drive Belt 2. Heat Transfer/Inert Gas Supply and Monitoring System 3. 17 224650	1. EBR-II 2. No. 2 silicone pump 3. 75 gpm, 75 psig 4. PMMR-35	MI 500	MI BZ	MI 530	Unknown	Preventive maintenance	1. Drive belt broken. 2. Part replaced. 3. None.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 36 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
195	1. Pump 2. Reactor Containment Structure and Building/ Air Lock 3. 17 194220	1. EBR-II 2. Personnel air lock No. 2 locking pin drive 3. 40 psig on inflatable seal, ambient temperature 4. PMMR-81	MI 500	MI 52	MI 530	6920	Preventive maintenance	1. Pump malfunction. 2. Part replaced. 3. None.
196	1. Pump/Discharge Valve 2. Turbine-Generator Units and Condenser/ Circulating water Systems 3. 17 330000	1. SCTI 2. Sulphuric acid system pump, cooling tower water treatment 3. 600 lb rating 4. Incident report No. 62	MI 445	MI 51	MI 278	5020	Operational monitors	1. Valve was plugged with ferrous sulphate and iron oxide, and corroded. 2. Part replaced. 3. Consider material compatibility in component selection for chemical process loops.
197	1. Pump/Diaphragm 2. Heat Transfer/Inert Gas Monitoring 3. 17 224600	1. EBR-II 2. Loop B fission gas monitor loop 3. - 4. Weekly report 2-21-68	MI 126	MI 59	MI 530	13,500	Operational monitors	1. Diaphragm ruptured. 2. Part replaced. 3. None.
198	1. Pump/Rotor Bearings 2. Turbine-Generator Units and Condenser/ Turbine Side 3. 17 310000	1. EBR-II 2. Turbine generator/nash pump 3. 75 gpm, 100 psi 4. PMMR-95	MI 500	MI 52	MI 530	Unknown	Preventive maintenance	1. Bearings worn out. 2. Part replaced. 3. None.
199 •	1. Pump/Casing 2. Turbine-Generator Units and Condenser/ Circulating Water System 3. 17 330000	1. EBR-II 2. Turbine Generator/nash pump 3. 75 gpm, 100 psi 4. PMMR-95	MI 500	MI BZ	MI 530	Unknown	Preventive maintenance	1. Oscillation caused scoring of rotor and casing. 2. Local repair. 3. Perform engineering study of problem and institute remedy before returning machine to service.

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TABLE 1-100

FAILURE DATA FOR PUMPS AND SUPPORTS

(Sheet 37 of 37)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
200	1. Pump/Rotor 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 17 330000	1. EBR-II 2. Turbine generator/nash pump 3. 75 gpm, 100 psi 4. PMMR-95	MI 500	MI BZ	MI 530	Unknown	Preventive maintenance	1. Oscillation caused scoring of rotor and casing. 2. Local repair. 3. Perform engineering study of problem and institute remedy before returning machine to service.
201	1. Pump/Bearing 2. Generator Units and Condenser/Circulating Water System 3. 17 330000	1. SCTI 2. Circulating water system (P-2) 3. 9000 gpm, 200 hp, 4160 V 4. Incident report No. 21	MI 500	MI 52	MI 530	2790	Direct observation	1. Bearing worn out. 2. Part replaced. 3. Stock of factory sealed bearings is recommended.
202	1. Pump/Case 2. Heat Transfer/Pump 3. 17 221110	1. Sodium pump tower 2. Pump test loop 3. 300 to 1200°F 4. Personal communication C.W. Griffin	MA	MA	MA	2677	Direct observation	1. Erosion/corrosion of suction side of pump case. 2. 410 series stainless steel pump was replaced with a 304 series. 3. None.

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TABLE 1-101

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, CONDENSATE

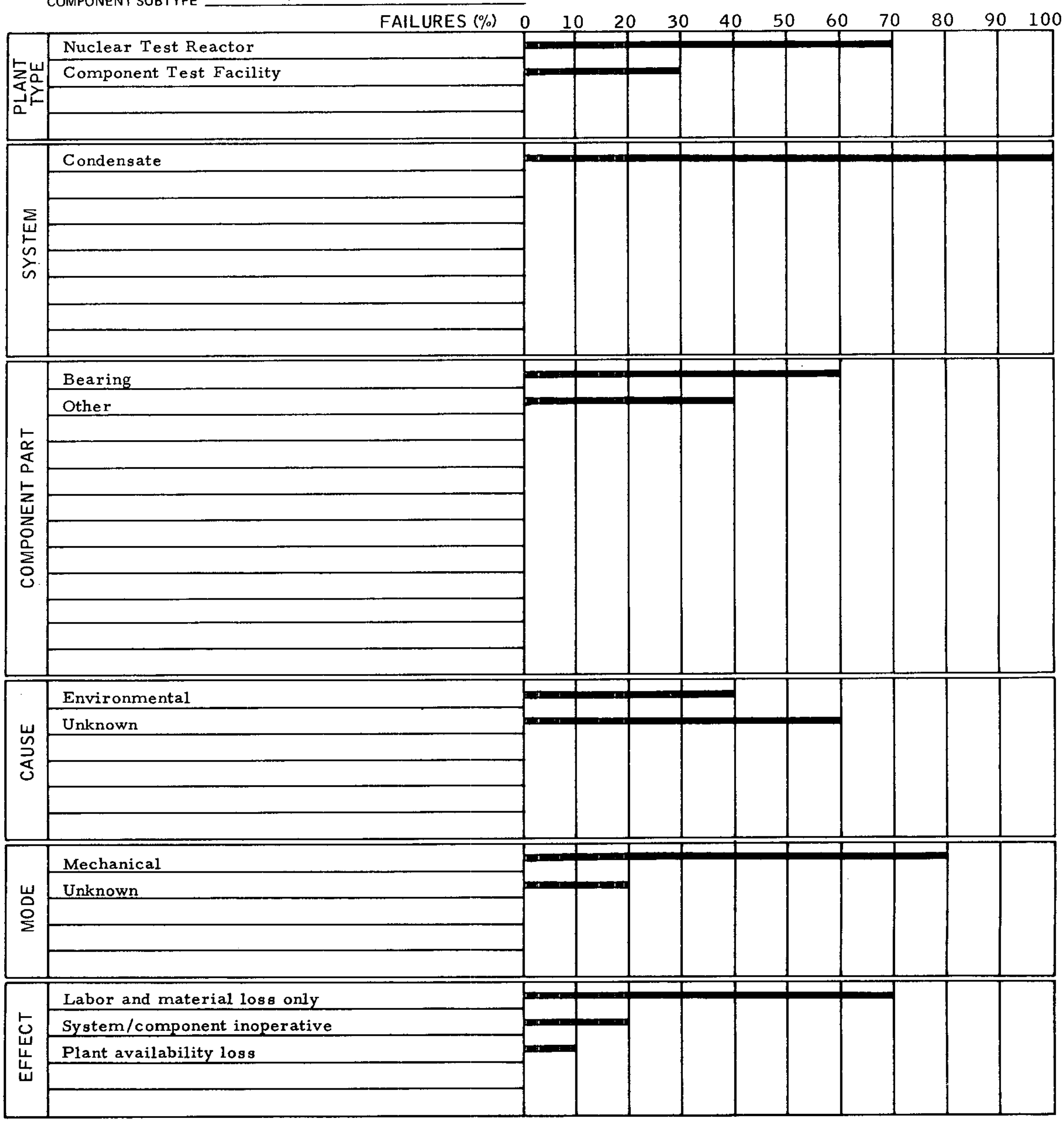


TABLE 1-102

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, FEEDWATER

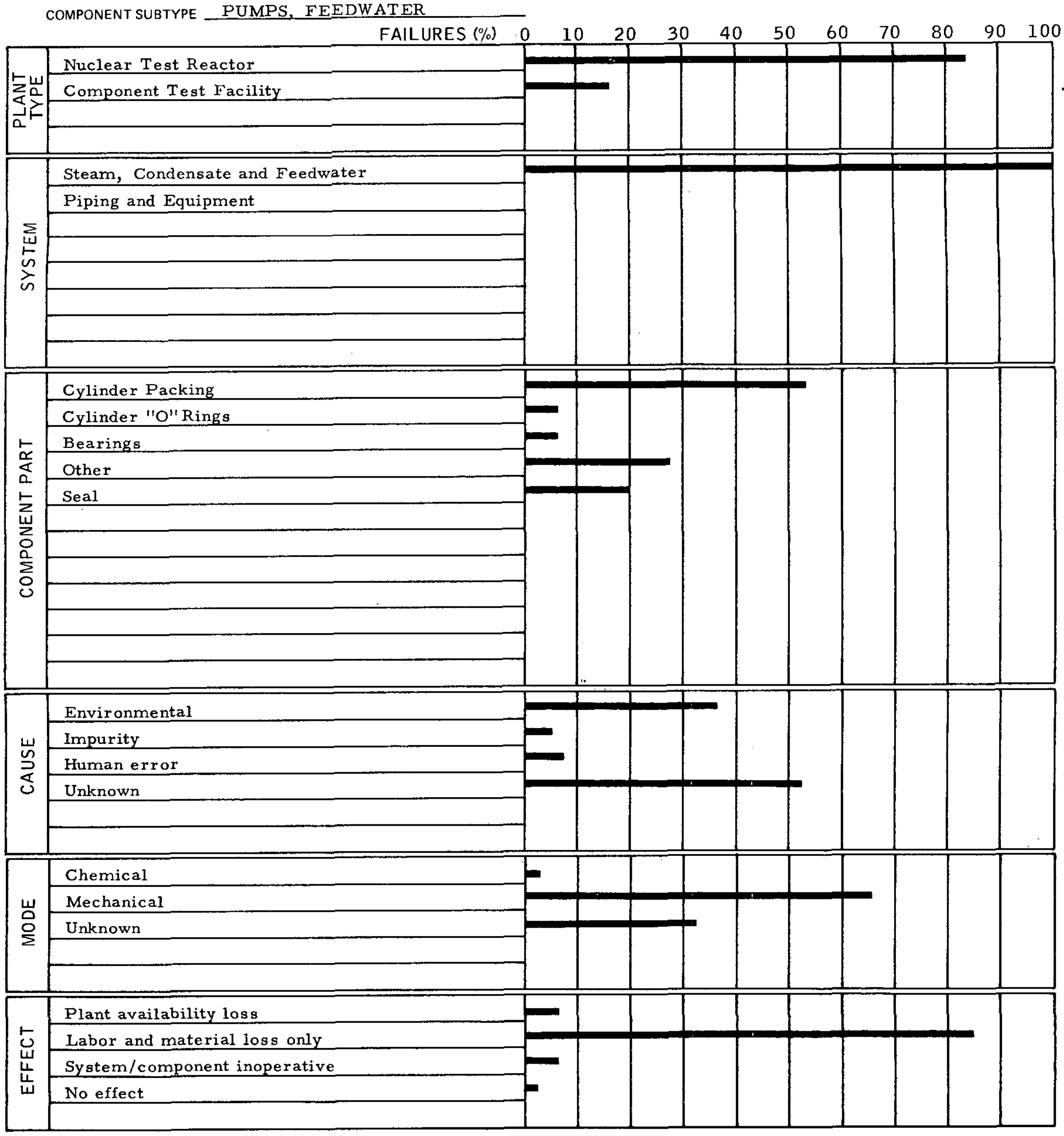


TABLE 1-103

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, SODIUM FREE SURFACE

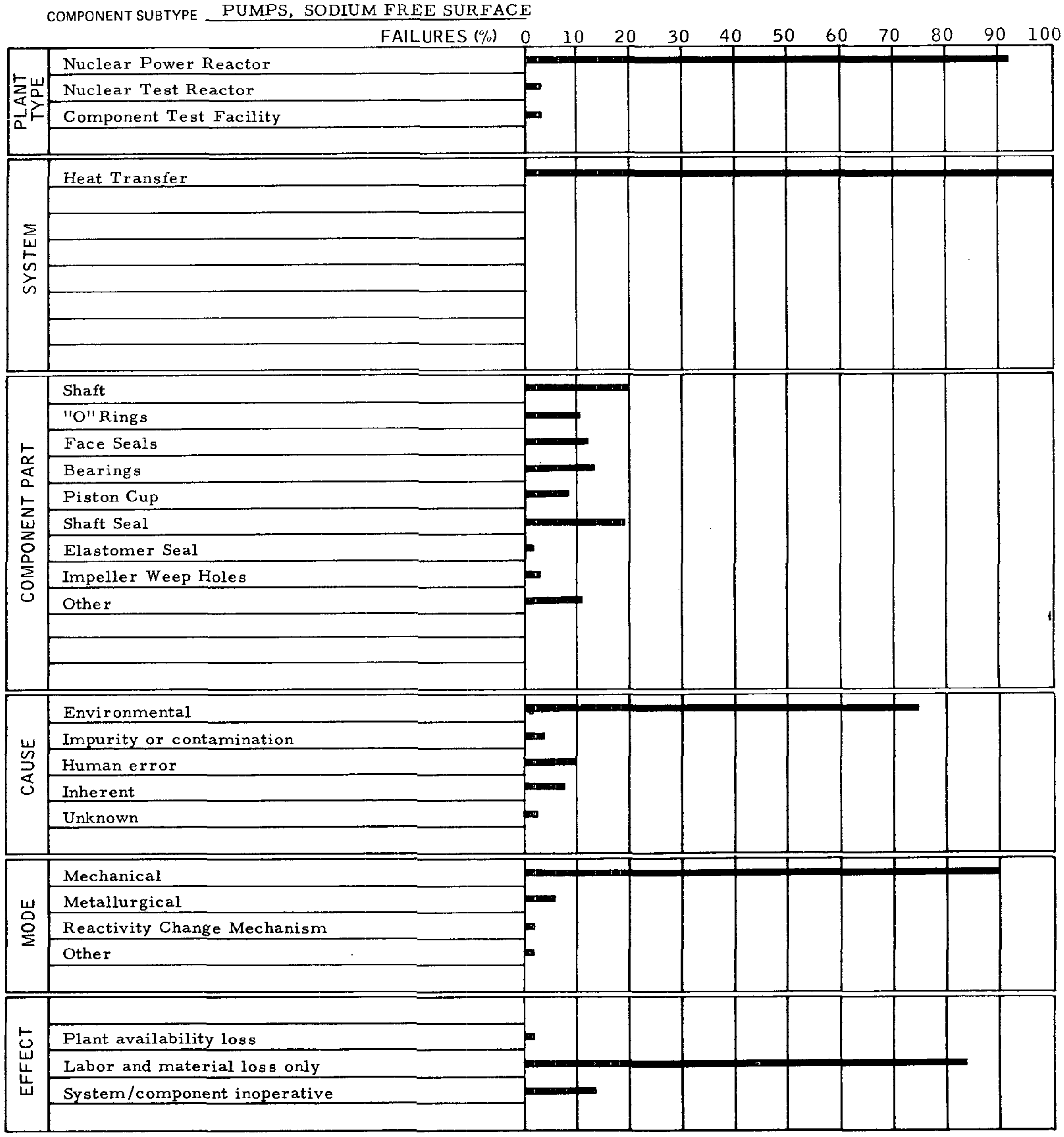


TABLE 1-104

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, ELECTROMAGNETIC

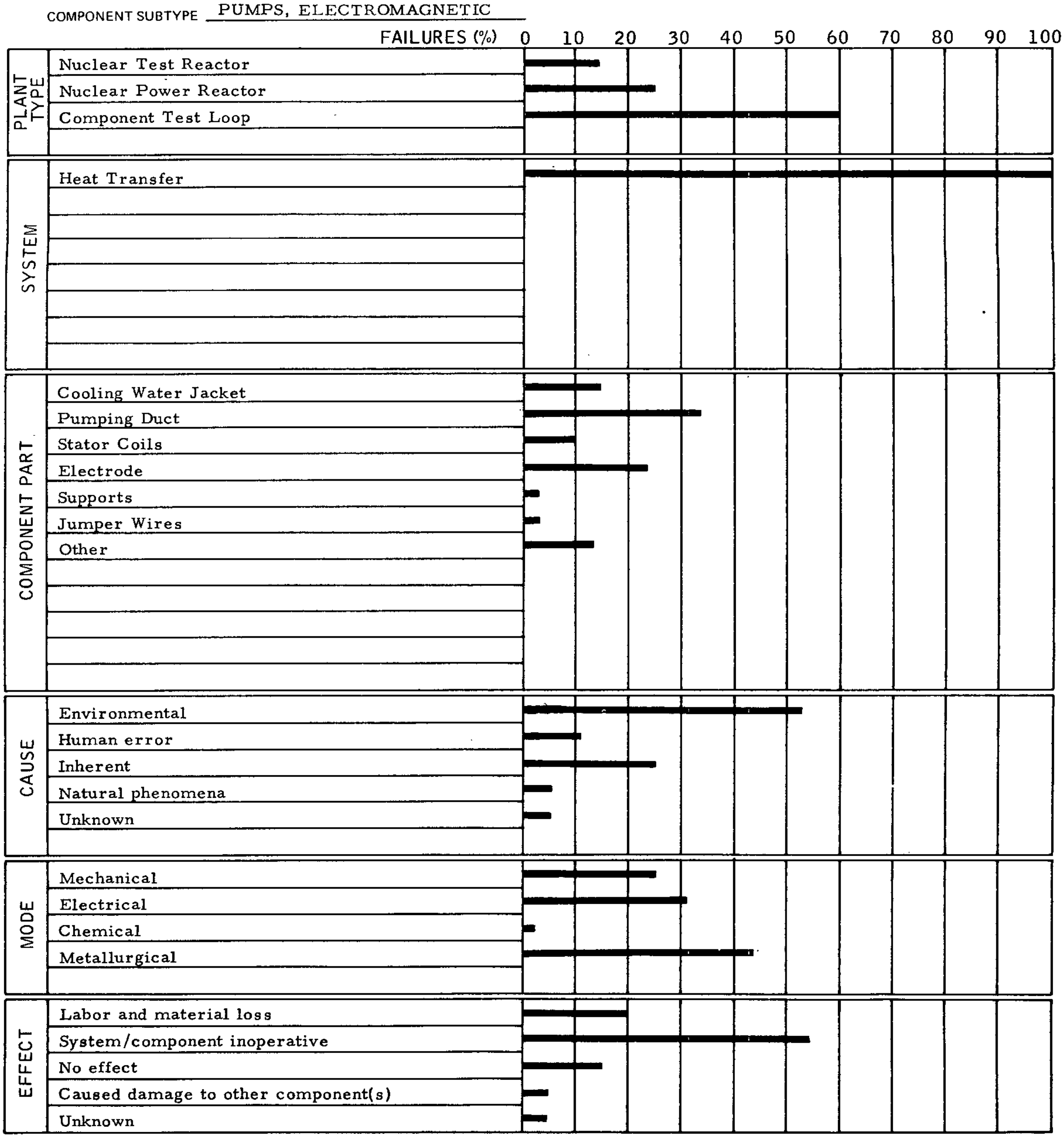


TABLE 1-105

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, SODIUM FREEZE SEAL

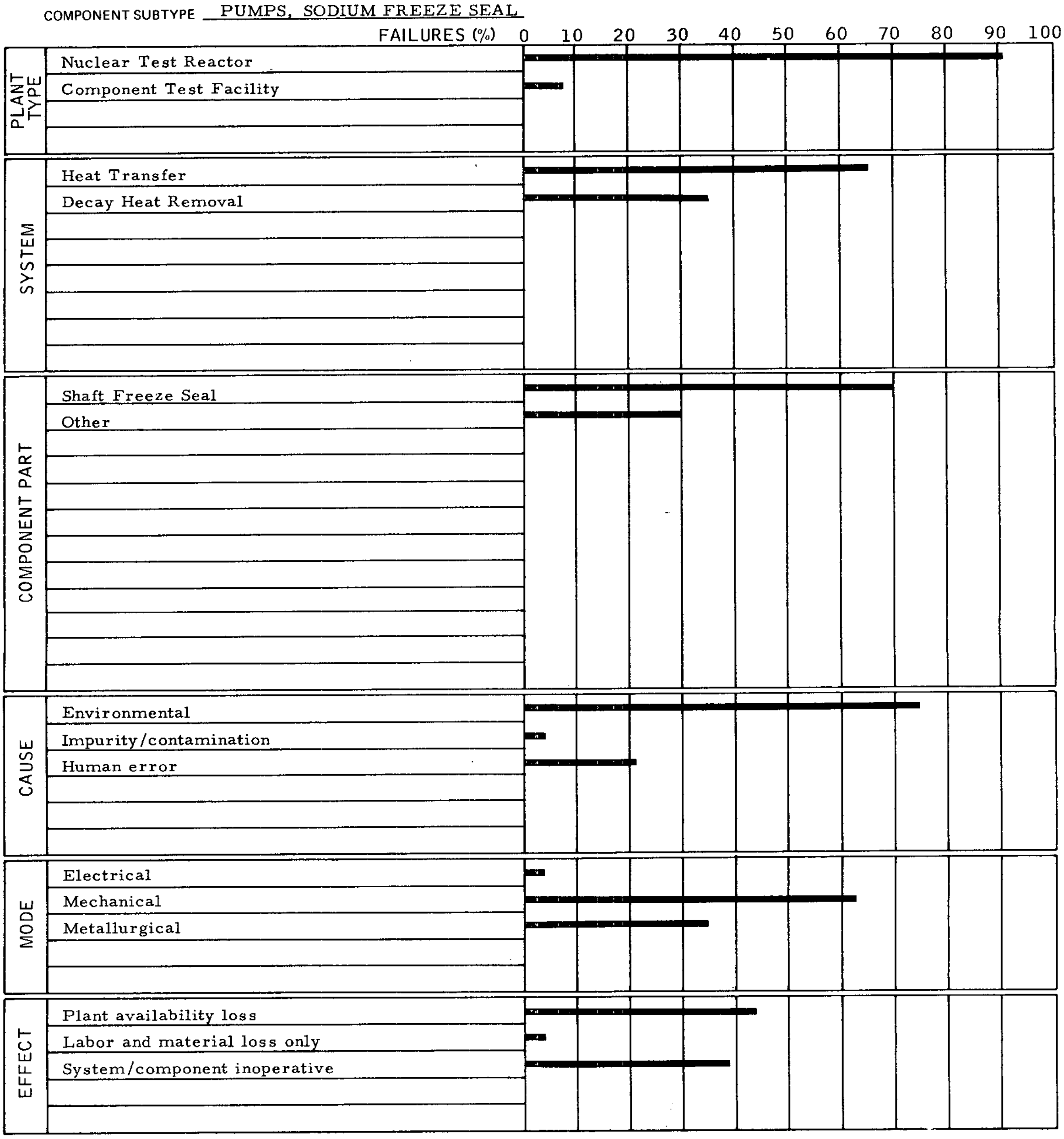


TABLE 1-106

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT PUMPS AND SUPPORTS

COMPONENT SUBTYPE PUMPS, MISCELLANEOUS

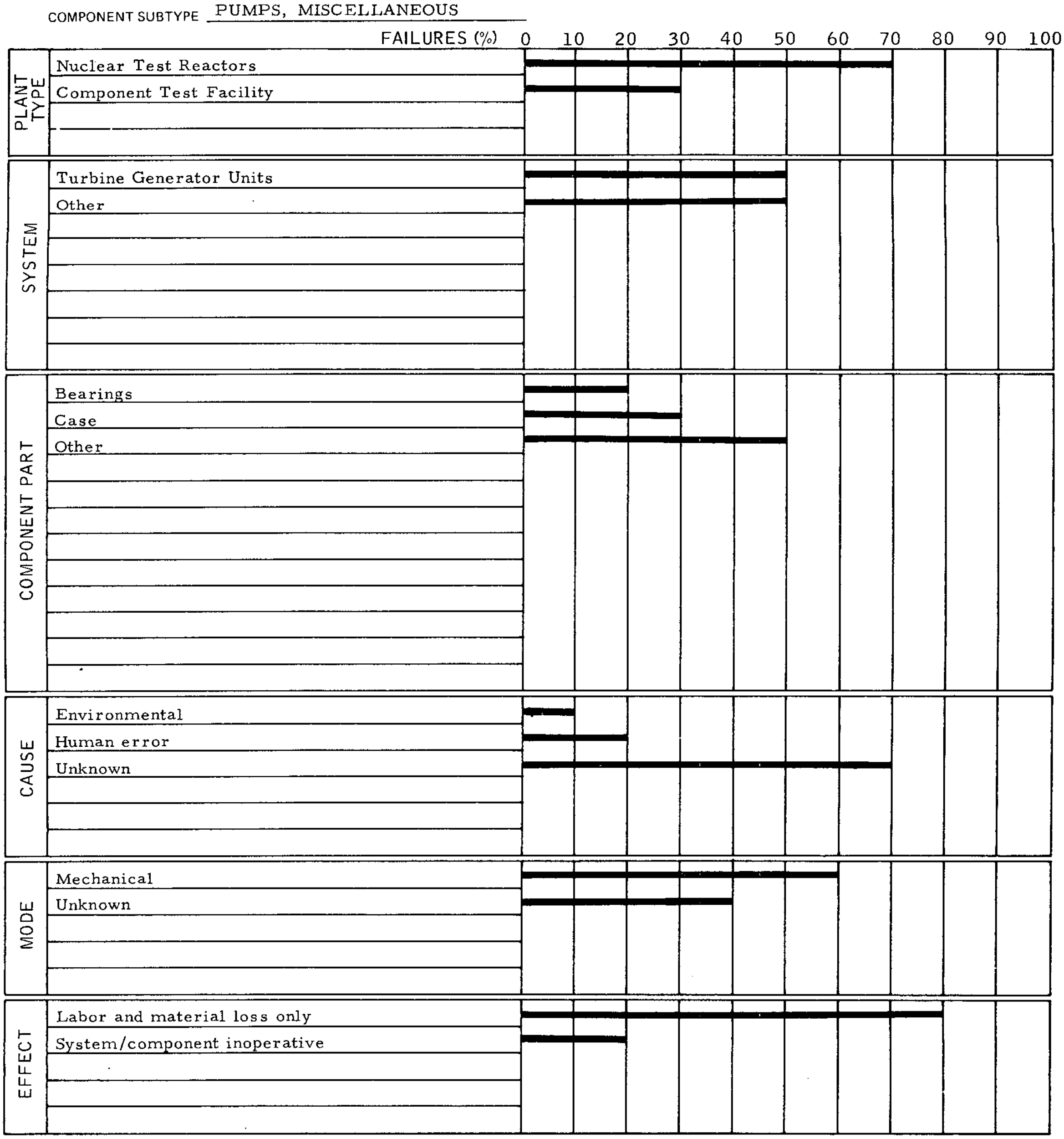
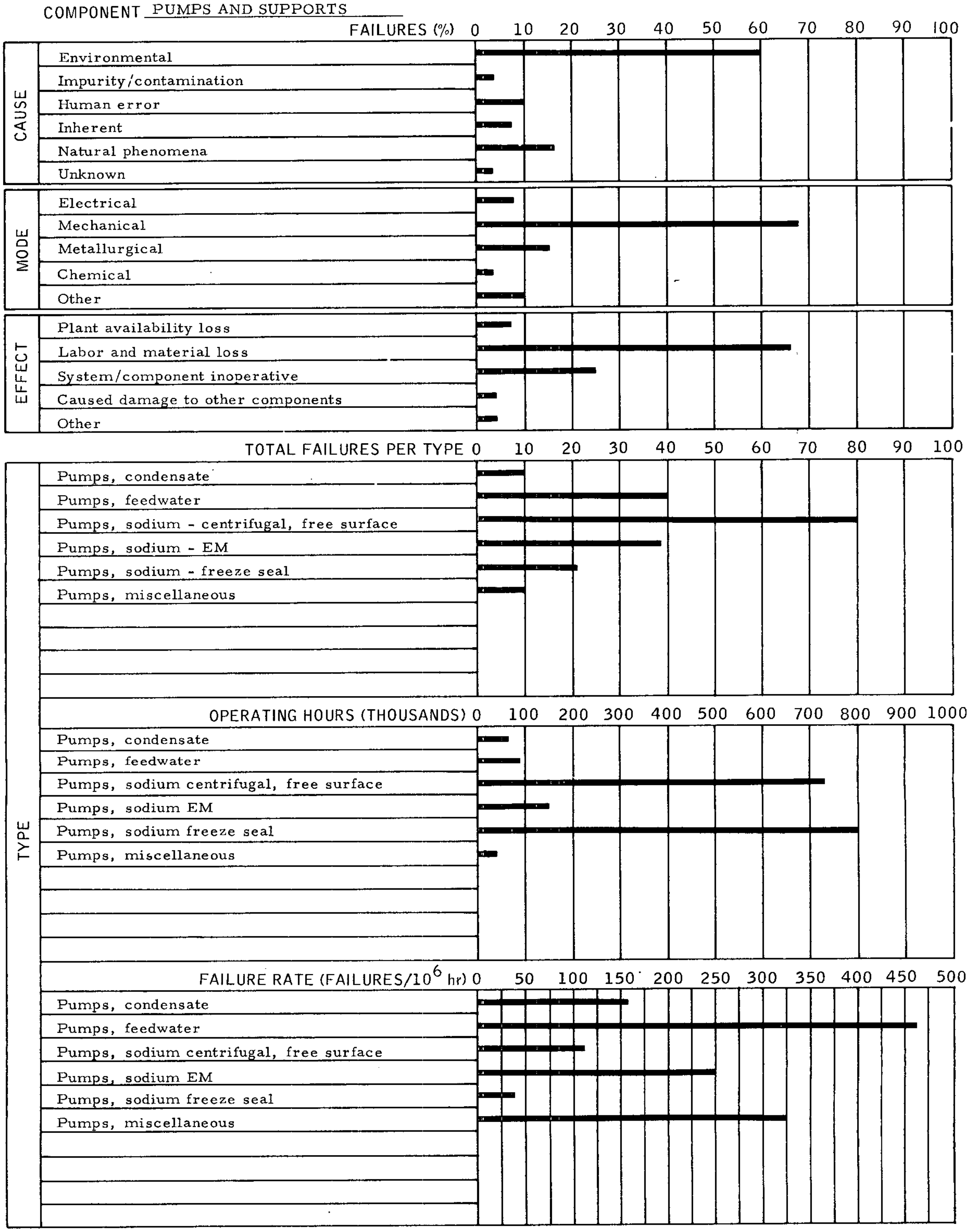


TABLE 1-107

GENERAL SUMMARY

COMPONENT PUMPS AND SUPPORTS



11. Rupture Discs

Failure data for rupture discs are presented in Tables 1-108 through 1-110.

a. Reliability Information

Design Feature:

Rupture disc for protection of steam generator sodium side from overpressure.

Critical Characteristics:

1) Controlled burst pressure after prolonged exposure to high-temperature sodium
2) Fatigue of assembly due to pressure and temperature cycling.

Mode of Failure:

1) Fatigue crack resulted from pressure or temperature cycling.
2) Sodium impurities migrated to crevices and corroded disc.
3) Long-term corrosion, decarburization, or other constituents attacked by sodium.
4) Long-term creep rupture.
5) Intergranular corrosion reduces strength.
6) Stress corrosion reduces strength.

Failure Description:

1) Leakage through fatigue crack
2) Leakage from excessive corrosion in crevices
3) Premature burst from reductions in ultimate strength or stress rupture life
4) Sodium spill from rupture.

Control Methods:

1) Design to eliminate fatigue failure.
2) Design to avoid crevices for collection of sodium impurities.

3) Maintain proper sodium purity level.

4) Protect from exterior contamination.

5) Replace rupture discs used in creep range at periodic intervals of equipment life.

Alternate Concepts:

Use cover gas in vessel and place rupture disc in gas area instead of sodium system.

b. Discussion and Recommendations

The particular rupture disc seal weld failure was typical of failures that occur in interim or hurried fixes. The original rupture disc installed did not incorporate a seal weld and consequently would not contain the sodium. An interim fix was initiated by making a seal weld at the flange joint. After about 5000 hours of operation time a leak was discovered during a routine inspection. The leak was described as a "pin-hole leak." No post-failure metallurgical evaluation was performed to definitely characterize this failure as to fatigue or poor weld quality. A pin hole would be characteristic of inclusions or porosity whereas a fatigue failure would be identified by a crack. Possibly a combination of both was the cause of the leak where a weld defect, resulting in a stress riser, initiated a low-cycle fatigue failure.

A heavier weld joint design was incorporated and has operated without incident for over three years. More weld metal in a seal weld will not necessarily correct a design problem and the later joint configuration may also fail in time due to temperature and pressure cycling.

Any motion of the retaining ring relative to the flange caused by pressure or thermal conditions must be resisted by the seal weld. An examination of joint component movements in any design must be made to verify that a non-structural member such as a seal weld is not subjected to high cyclic stresses induced by relative motion of stiffer structural members.

TABLE 1-108

FAILURE DATA FOR RUPTURE DISCS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Rupture Disc/Seal Weld 2. Heat Transfer/Reactor Coolant Piping 3. 23 221240	1. SCTI 2. Secondary sodium system/steam generator 3. 4. Incident report No. 93	MI 121	MI 67	MI 137	5,302	During routine inspection	1. A leak developed in a seal weld where the rupture disc and its support ring were welded to the face of of the support flange. 2. Part replaced. 3. Follow new quality control requirements.
2	1. Rupture Disc/Disc 2. Heat Transfer/Steam Generators 3. 23 223000	1. SCTI 2. Steam and feedwater rupture disc RD-2 3. 12 in., 125 psi ± 5 at 950°F 4. Incident report No. 98	I 500	I 61	I 520	1,150	Direct observation	1. A crack developed from the rupture disc into the support flange. 2. A double rupture disc assembly of all welded construction was designed, fabricated and installed. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-109

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT RUPTURE DISC

COMPONENT SUBTYPE RUPTURE DISC

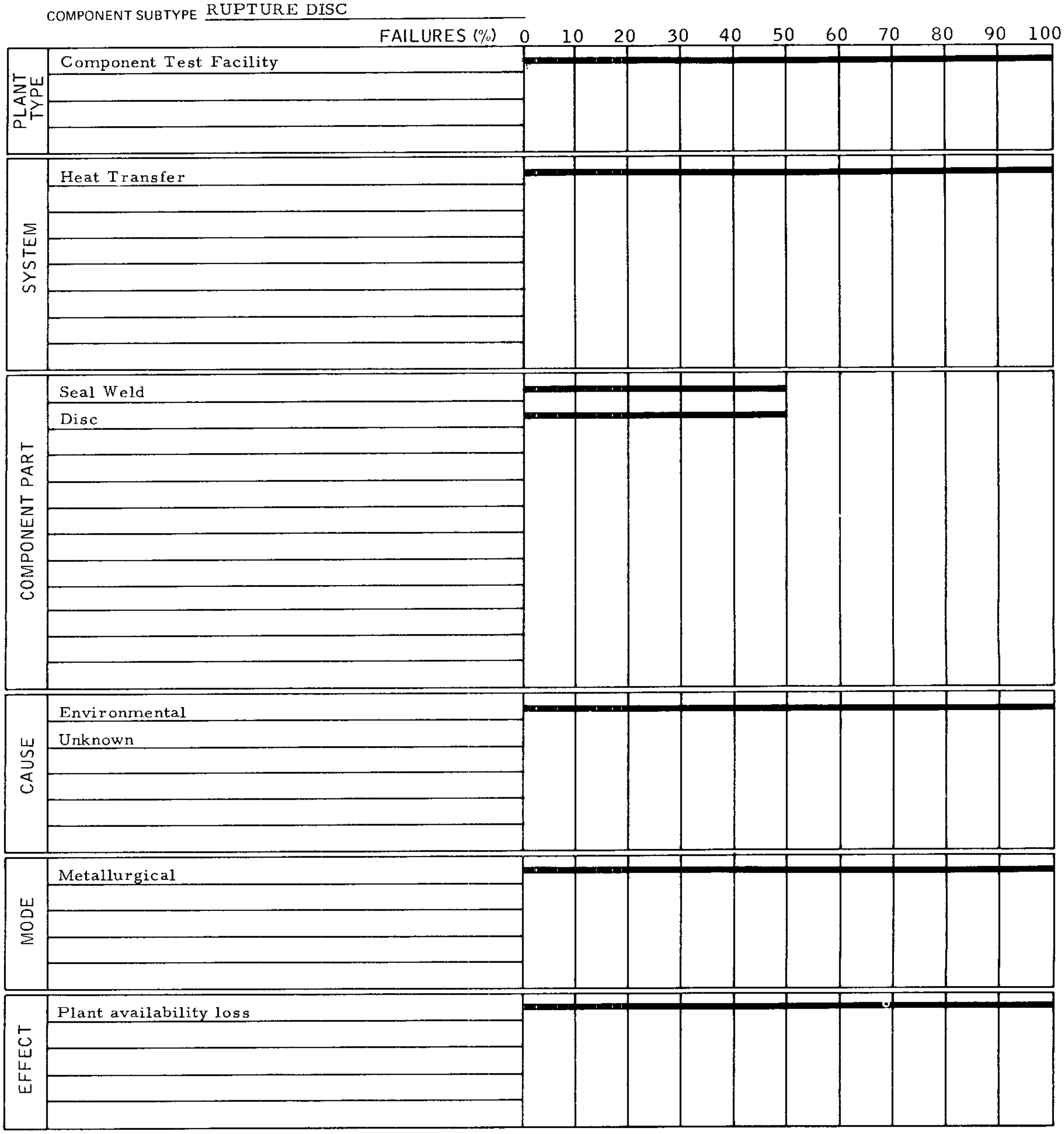
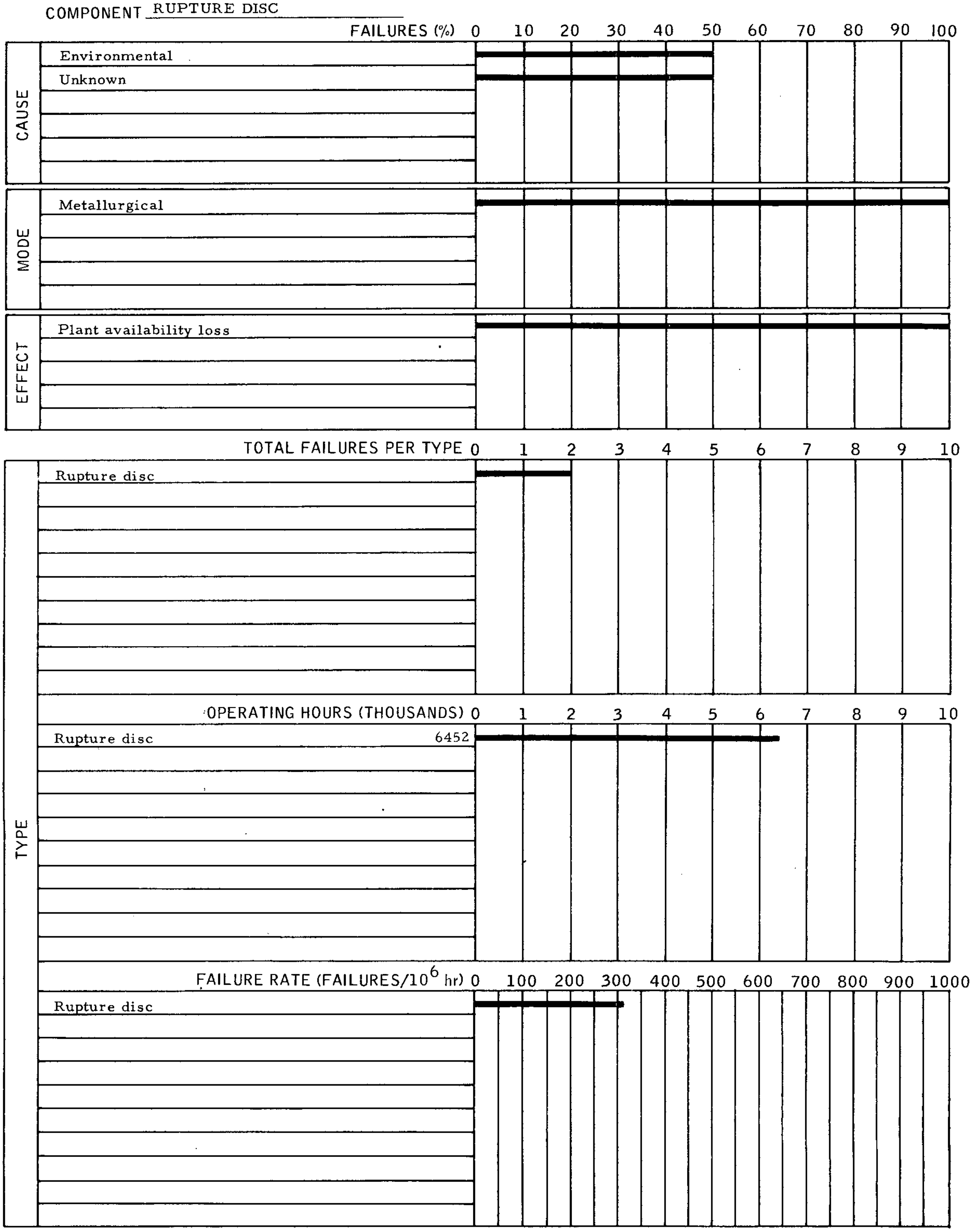


TABLE 1-110

GENERAL SUMMARY

COMPONENT RUPTURE DISC



12. Steam Generators

a. Introduction

The steam generator types for which failure data are considered in this section include four sodium-water designs and three water-water designs. A total of 40 incidents (49 failures) were collected and listed in Table 1-111.

The failures were evaluated with respect to failure cause, mode, and effect. The results of this evaluation are summarized in Tables 1-112 and 1-113.

b. Summary of Tabulated Data

The "Plant Type" section of Table 1-112 shows that approximately 80% of the steam generator incidents collected occurred in liquid metal facilities; the remainder (20%) occurred in water facilities. This distribution is a result of information availability and should not be used for a reliability comparison between liquid metal - water steam generators and water-water steam generators.

The "Component Part" section of Table 1-112 shows that tubes, tube-sheet welds, and manifold gaskets account for 88% of the steam generator failures. Individually, tubes, tube-sheet welds, and manifold gaskets accounted for 37%, 29%, and 22% of the failures, respectively. Pressure drop devices, manway flanges, shells, and steam generator instability accounted for the remainder (12%). From this failure distribution it is apparent that any upgrading of tube or tube-sheet weld reliability would significantly improve steam generator reliability. Although the manifold gasket failures were numerous, these failures were associated with only one facility, and therefore are not as generally important as tube or tube-sheet weld failures.

The "Cause" section of Table 1-112 shows the proportion of failures associated with each cause. As can be observed, the most frequent cause (71%) is "Unknown." This is unfortunate since, if the cause of the failure is unknown, the chance of a repair being truly successful is doubtful.

Of the failures with known causes, about 50% were "Environmental," 14% were "Impurity/Contamination," and 36% were "Inherent." All tube failures were considered to be failures from environmental causes, including damage from hydraulically induced vibrations, erosion from high coolant velocities, and operational instability from boiling in the feedwater downcomer tubes. These problems were corrected by installing flow baffles and pressure drop devices to modify unfavorable flow characteristics and installing tube supports to prevent damaging tube vibrations.

Tubes and pressure drop devices accounted for all the failures caused by impurities or contamination. Tube failures resulted from caustic stress corrosion due to improper water chemistry, and pressure drop device failure resulted from unsatisfactory operation due to small-scale particle contamination. The tube problem was corrected by improving the water treatment to eliminate boiler water alkalinity, and the pressure drop device problem was corrected by cleaning the devices.

Tubes and manway flange accounted for all the inherent failure causes. Tube failures were caused by stress corrosion from residual alkaline cleaning solution, poor workmanship during tube fabrication, improper stress relief, and an installation accident. Improved cleaning procedures were developed to preclude stress corrosion failures from residual cleaning agents. The manway flange failure was caused by inadequate flange design. The flange was reworked and modified to prevent this failure from happening again.

The "Mode" section of Table 1-112 shows the proportion of failures associated with each failure mode. Of the modes observed, 59.2% were "Metallurgical-Physical," 28.5% were "Other," 6.2% were "Mechanical," and 6.1% were "Metal Corrosion." All of the failures which failed by the metallurgical-physical mode were either tubes or tube-sheet welds; the manway flange was the only exception.

The manifold gaskets and the feedwater downcomer tubes accounted for all of the failures listed under the "Other" classification. The manifold gasket failures were undiagnosed and the exact modes of failure are not known. The feedwater downcomer tubes failed by exceeding temperature operating limits.

Tubes and pressure drop devices accounted for all mechanical mode failures. Tubes failed by breaking and fragmentation when they sustained hydraulically induced vibrations, and by distortion when the steam generator was accidently dropped. The pressure drop devices failed by movement obstruction when satisfactory seating could not be achieved due to small-scale particle interference.

Tubes and shell accounted for all metal corrosion mode failures. Tubes failed by stress corrosion and the shell failed by corrosion undiagnosed as to type.

The "Effect" section of Table 1-112 shows the proportion of failures associated with each plant effect. Of the effects observed, 81.6% resulted in a plant availability loss, 12.3% resulted in acceptable incipient damage, 4.1% resulted in potential damage to equipment, and 2.0% resulted in a labor and material loss only. From these figures it is apparent that the great majority of steam generator failures result in significant plant availability loss.

c. Discussion

The following section describes steam generator designs and discusses their failures.

Fermi

The Fermi steam generators (Figure 1-21) are vertical, combination cross and counterflow, single-wall-tube, shell-and-tube, once-through-type heat exchangers, with water and steam inside the tubes and sodium on the shell side.

In the event of a tube failure, a sodium-water reaction will take place. A relief system and an isolation system are provided to minimize possible damage from this reaction. The large quantities of hydrogen gas evolved from a reaction would increase the cover gas pressure over the sodium inside the steam generator. At 60 psig a 24-in.-diameter rupture disk will open up and the gas and reaction products will be relieved through a 30-in. vent pipe to the atmosphere. The isolation system is designed to isolate the steam generator from the feedwater and steam systems and open dump valves to permit the steam and water inside the tubes to vent to the atmosphere. The relief system opens a cover gas vent valve to the atmosphere. This system is actuated by high cover gas pressure, one of two detectors attached to the rupture disk, or by a manually operated switch in the control room. The argon cover gas over the sodium is analyzed by a gas chromatograph and by a thermal conductivity instrument. Both are recorded in the control room.

Three cases of steam generator tube failure occurred at Fermi. Tube cracks resulted in leakage during a hydrotest. Metallographic examination of the cracked tubes disclosed that the tubes failed as a result of stress corrosion cracking. The cause of stress corrosion was attributed to the omission of stress relief after tube bending during fabrication, and to the incomplete removal of the alkaline agent used to clean the tubes. The unit was completely retubed, stress-relieved, and then returned to service.

A failure due to tube wear resulted in a sodium-water reaction. Examination of the damaged tubes showed that the failures had been caused by wear due to vibration and attendant impacting of the tubes in the support bars. The vibration was induced in the tubes by the sodium flow. The tube damage was limited to the steam risers and the uppermost bend sections where the tubes make the first horizontal pass through the inner support bars. The support bar clearances were

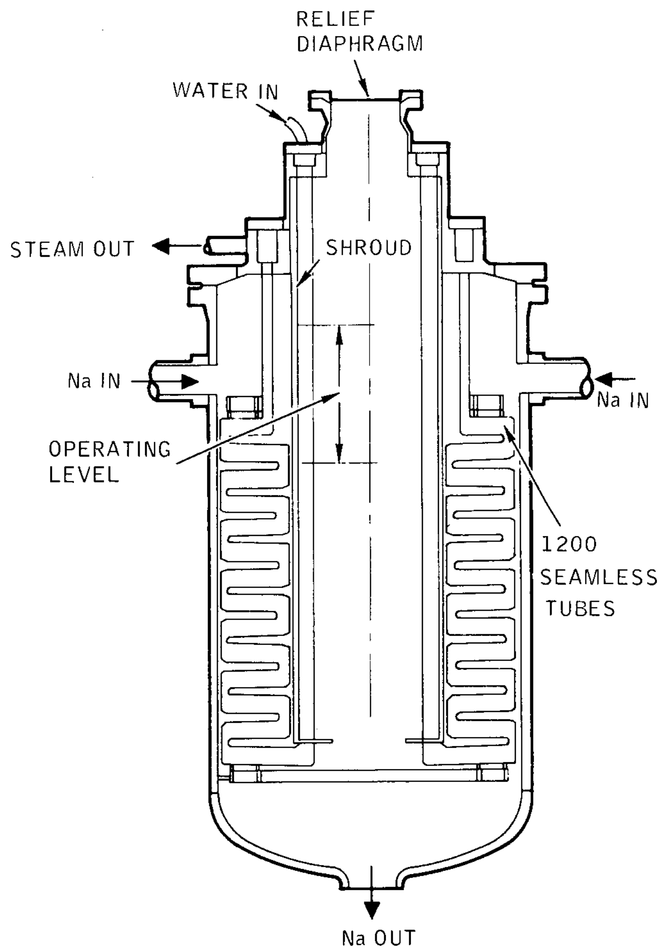


Figure 1-21. Fermi Steam Generator

relatively large and the tubes apparently were worn thin due to vibration-induced impacting and rubbing of the tubes against the support bars. Several tubes were severed completely. These tubes caused considerable rubbing damage to adjacent tubes. The unit was repaired and flow impingement baffles and tube lacing clips were installed on all units to preclude similar failures.

In another failure event, tube leaks resulted in a sodium-water reaction. The cause of the failure is unknown. The tubes were repaired and the unit was returned to service.

Fourteen water and steam tube-to-tube-sheet weld failure incidents occurred, some of which resulted in sodium-water reactions. The nature of the leaks at the seal welds was generally found to be that of pinholes, probably caused by oil or dirt deposits in the tube-to-tube-sheet joints. A weld procedure was devised to repair the tube-to-tube-sheet welds. The process appears to yield satisfactory results based on a borescope inspection of the welds.

Only the failure due to hydraulically induced tube vibration (of approximately nine incidents) had an attendant sodium-water reaction which was serious enough to actuate the relief and isolation systems. The systems functioned properly to limit the reaction.

During this incident the hydrogen recorder measured increasing amounts of hydrogen in the cover gas for at least 20 min prior to the bursting of the rupture disk. Almost simultaneously with action taken to dump water from the steam generator tubes, the rupture disk burst, releasing hydrogen and other reaction products to the atmosphere. Rupture of the disk indicated a cover gas pressure of 64 psig; normal cover gas pressure is 4 psig.

The sodium-water reactions which accompanied the remainder of the incidents were discovered with cover gas hydrogen gas concentration detectors and terminated while the reactions were still at a low level.

Nine water and steam manifold gasket failures occurred. The causes of these failures are unknown; however, hardness tests of several gaskets showed values higher than expected for soft annealed iron. The steam generators were repaired by replacing the leaking gaskets with annealed gaskets.

Three cases of steam generator operational instability occurred. These instabilities have been attributed to boiling in the downcomer tubes. Restriction of the operating parameters to limit the preheat area reduced this problem. In addition, poppet-type orifices were installed in the inlets of the water downcomer tubes to increase the pressure drop, provide more even water distribution to all tubes, and, hopefully, eliminate the instability altogether. Considerable tuning of the control system was necessary before efficient operation was achieved.

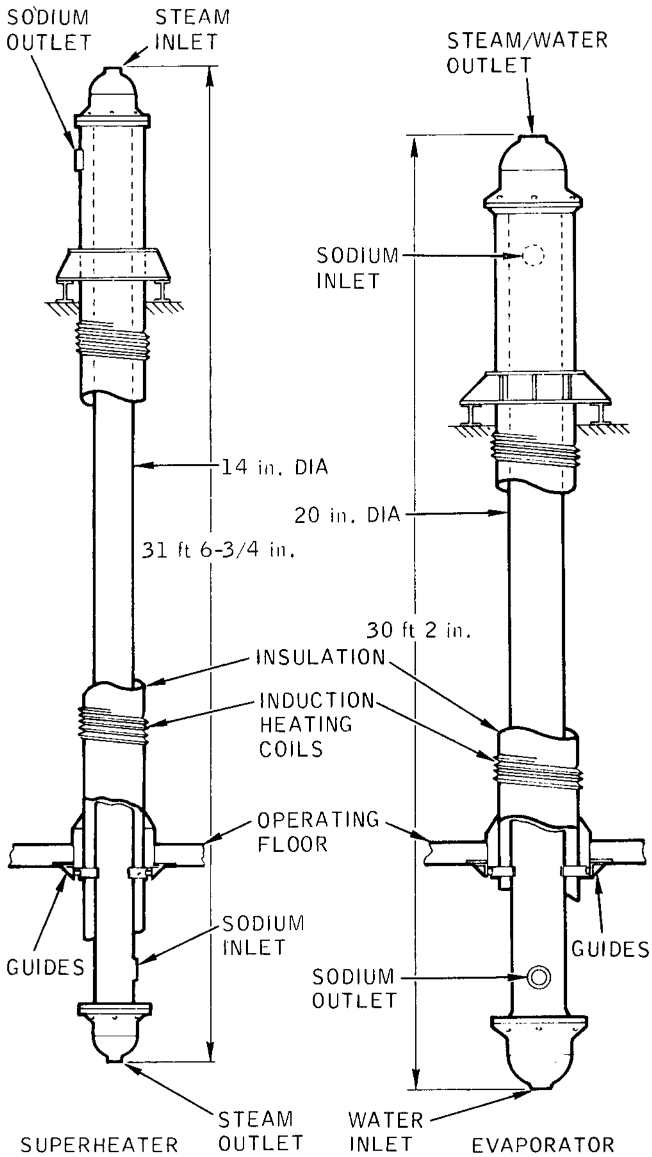
One case of a pressure drop device (poppet-type orifices) failure was encountered. Inspection of the devices showed that several were held off the valve seats by small-scale particles.

EBR-II

The EBR-II steam generator system consists of a natural-circulation evaporating section, a conventional steam drum, and a once-through superheating section. The evaporating section is comprised of eight identical shell-and-tube heat exchangers connected in parallel on the tube side to a horizontal steam drum with internal moisture separation. Dry saturated steam leaves the top of the steam drum and flows downward to what, in the original design, were four identical shell-and-tube superheater units in parallel. However, the superheaters were not completed and two evaporators were modified and substituted.

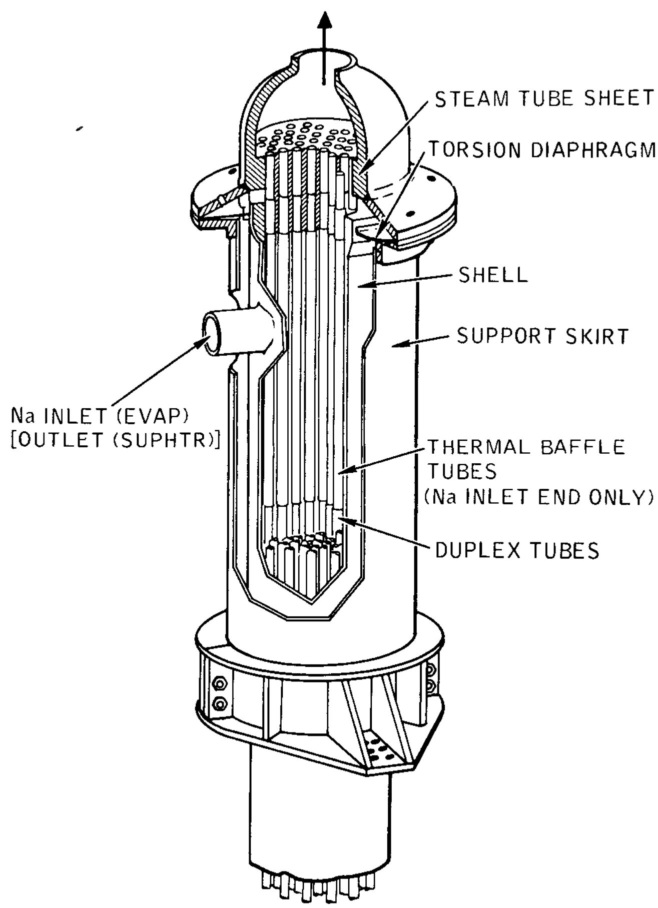
The external design of the evaporators and superheaters is shown in Figure 1-22. The internal details are shown in Figure 1-23. Both evaporator and superheater shells are constructed of 2-1/4 Cr - 1 Mo steel.

A routine inspection of the steam generators while the plant was shut down in October 1964 for control rod repairs disclosed the presence of water in the space between the sodium and water upper tube sheets in evaporator No. 702. Subsequent testing confirmed that a leak existed in the water-side tube sheet of one of its contained tubes. The interconnecting pipe between the evaporator and the steam drum was removed, giving access to the water side of the tube sheet. The air side of the tube sheet was pressurized and bubble-testing pinpointed the location of the leak. A pinhole in a weld crater of a machine-made tube-to-tube-sheet weld was discovered. Since it was accessible, the weld was partially ground out and manually rewelded without having to remove the evaporator. A subsequent helium mass spectrometer leak test showed the repair to be successful. The riser pipe was then rewelded into the system, and the plant was prepared for further operation.



7-7694-209-7

Figure 1-22. EBR-II Steam Generator Components



7-7694-209-8

Figure 1-23. EBR-II Superheater Evaporator Details

SCTI Alco/BLH

The Alco/BLH steam generator (Figure 1-24) is of the vertical once-through type. The unit is 45 ft long and 32 in. in diameter. The sodium enters the shell at the top of the unit, passes through 54 disk-and-doughnut baffles in the shell, and leaves at the bottom shell nozzle. The nozzle courses of the shell are thicker (1-1/8 in.) than the main body (7/16 in.) to accommodate the thrusts and moments applied by the piping to the shell nozzles.

The shell side is designed to operate with a free sodium surface in the region just above the weir baffle. The relatively large gas space between the sodium surface and upper tube sheet is provided to ensure that the upper tube sheet is not subjected to rapid temperature fluctuations resulting from the severe transients that occur in the sodium. The lower tube sheet is protected from such temperature changes by a thermal baffle which consists of ten 1/4 in. stainless-steel plates spaced 1/8 in. apart. Both tube sheets are 6-5/8 in. thick.

Inconel cladding is provided for all steam generator surfaces contacted by water or steam to minimize the effects of chloride stress corrosion on austenitic stainless steel. The shell heads and tube sheets are clad using Inconel weld metal in multiple layers. The tubes are bimetallic; i.e., Type 316 stainless steel on the sodium (shell) side and Inconel on the steam side. The two materials are metallurgically bonded by coextrusion to act as a single-wall tube.

Great care was required during assembly of the steam generator to maintain the integrity of the cladding. Differential thermal expansion between shell and tubes is accomplished by the sine-wave bends incorporated in the upper end of the tubes. There are 360 tubes, 1/2 in. OD by 0.104-in. wall, in the unit.

To protect the shell in the event of a steam tube rupture with accompanying sodium-steam-water reaction, a separate nozzle equipped with a double rupture disk has been provided in the gas space of the unit. A separate disk assembly is also incorporated in the first tee at the sodium outlet. The rupture disks are connected to tanks maintained under inert atmosphere which serve to contain the reaction products that are ejected from the steam generator.

Two cases of tube failure, one case of tube-to-tube-sheet weld failure, a manway flange failure, and a shell failure were observed. After each failure except the last, the steam generator was repaired and returned to test. The causes of all the failures, except the manway flange, are unknown. The manway flange failed because of inadequate flange design.

During both cases of tube failure the resultant sodium-water reaction was of such low level that the relief and isolation systems were not required. The failures were detected by sensing (1) hydrogen gas concentration and (2) humidity in the cover gas. Upon detection of these conditions, manual shutdowns were effected and the steam generator was secured in each case.

Hallam

The Hallam steam generators are natural-circulation, horizontally mounted units composed of an evaporator, a steam drum, and a superheater (Figure 1-25). Sodium in the evaporators and superheaters is contained in reentrant thimbles. Hot sodium enters down a thermally insulated central tube, reverses flow at the end of the tube by impinging on an end cap on the outer tube, and flows back toward the inlet in an annulus between inner and outer tubes. Heat is lost by evaporating and superheating steam in contact with the outside of the outer tubes. The outer double-wall tube contains helium passages between the inner and outer portions, and inner and outer sections are swaged together for maximum heat transfer. Leaks in inner or outer sections produce a change in helium pressure. The use of double-walled bayonet tubes reduces thermal stresses.

Two unusual fabrication techniques are automatic butt welding of tube sheets and tube caps and two-way ultrasonic testing of tubes. It is estimated that double-wall construction and the leak-monitoring system triple the cost.

Volatile chemicals are used to aid in maintaining low boiler solids. The use of high solids concentration in boiler water comparable to conventional boiler practice would result in plugging of the orifice-type baffles in the superheater.

Three cases of steam generator tube failure occurred. A weld crack in the superheater center tube end cap resulted in an increase in third fluid pressure. A radiograph of the weld region showed a mechanical interference between the inner tube end cap and the outer tube cap weld. The tube was rewelded, stress-relieved, and the unit returned to service.

A crack in the evaporator tube 18 end cap weld was visually detected when the tube bundle was removed from the natural circulation shell so that it could be installed in the kettle-type evaporator shell. The tube was rewelded and stress-relieved and the tube bundle installed in the kettle-type evaporation shell. The cause of this failure is unknown.

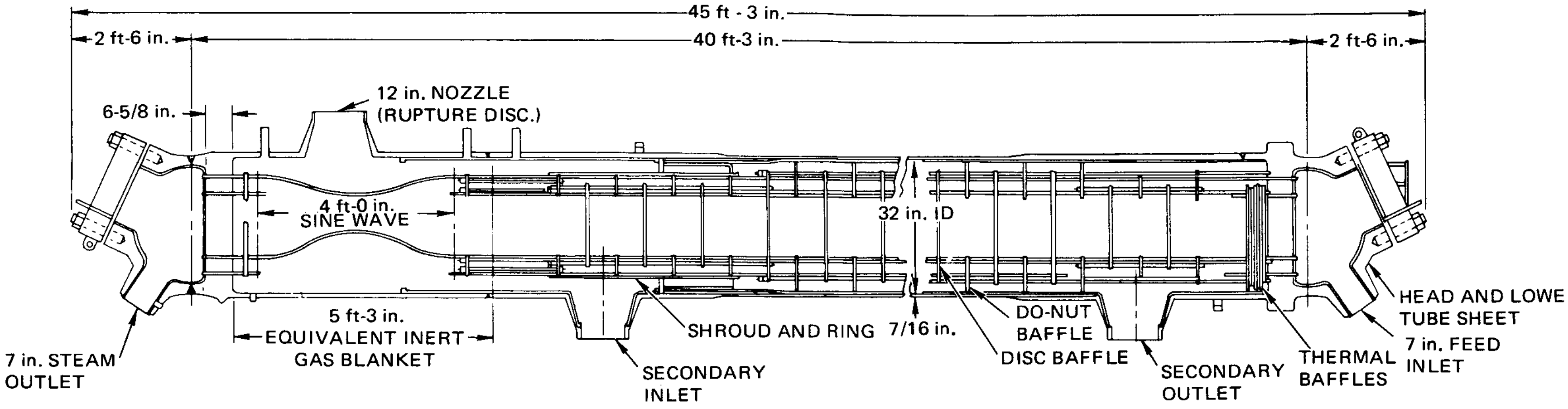


Figure 1-24. Alco-BLH Model Steam Generator

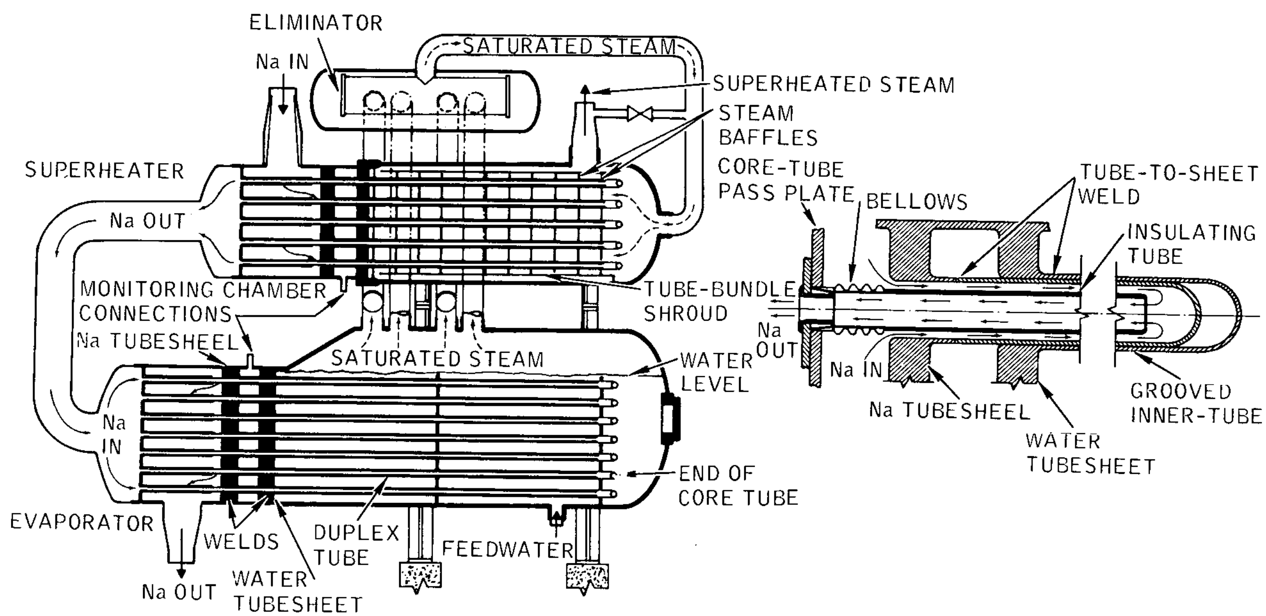


Figure 1-25. Hallam (SGR) Steam Generator

Cracks in four evaporator core tube welds were detected when sodium was found in the annulus of one bellows-type core tube during a destructive examination. All of the cracks observed were attributed to the additive effects of metallurgical, mechanical, and thermal factors. Metallurgical factors include the existence of a weld metal quite different from the parent metal and the lack of heat treatment before and after welding. Mechanical factors involve stress concentrations imposed by laps in the weld head and the drastic change in the cross-section of the material at the weld. Thermal considerations concern the stresses imposed by heating and cooling during welding, differential thermal expansion of the different weld and base materials, and the operating thermal gradients and temperature cycling during the transient testing.

Dresden

Four cases of steam generator tube failure have occurred at the Dresden facility. All of the failures were in the secondary steam generators.

San Onofre

Two cases of steam generator tube failure have occurred at the San Onofre facility. Tube deformation was the result of an accident; the unit was dropped during installation and sustained some minor damage. The unit was subsequently put into service without any repairs. Tube leaks were detected in this same unit during operation; however, it has operated for some time without tube problems.

Shippingport

The steam generators are shell- and tube-type units in which reactor coolant inside the tubes heats secondary water in the shell. Both straight and U-bend generators were used.

The two straight-tube heat exchangers each contain 2096 stainless steel tubes, 31 ft long with 1/2-in. outside diameter. These tubes are rolled and welded into a stainless steel tube sheet and are enclosed by a stainless steel shell 43 in. in diameter. The ends of the heat exchanger portion of the unit have hemispherical heads of stainless steel with 18-in. pipe connections.

The two U-bend heat exchangers each contain 921 stainless steel tubes having a length of 50 ft and an outside diameter of 3/4 in. Rolled and welded into stainless-clad carbon-steel tube sheets, these are enclosed by a U-shaped shell 38 in. in diameter. The ends of the heat-exchanger portion of the unit have hemispherical

carbon-steel heads. Internal surfaces of these heads, as well as the face of the tube sheet in contact with coolant water, are clad with stainless steel.

Four cases of steam generator tube failure have occurred at the Shippingport facility. The causes of these failures were attributed to steam blanketing, caustic stress corrosion, wall thinning, and thermal expansion heading to tube wear. These conditions were corrected by adding two steam risers to the heat exchangers, improving the water chemistry, and installing a flow blocking plate.

The principal investigator of this subject was J. M. Blanco. If additional information regarding steam generator failure experience is required, contact J. M. Blanco, E. Ferguson, or G. S. Budney at LMEC.

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 1 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Steam Generator/Tube-to-Tube Sheet Joint 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 277	MA 92	MA 136	13,000	Dye penetrant and bubble tests	1. Possible chemical attack, with thermal cycling due to flow instability as a contributing factor, resulted in tube damage and leakage of water into sodium. 2. Nicrobraze No. 180 overlay deposited over original welds. 3. None.
2	1. Steam Generator/Tube-to-Tube Sheet Joint 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 277	MA 92	MA 136	13,000	Dye penetrant and bubble tests	1. Possible chemical attack due to foreign material, with thermal cycling as a contributing factor, resulted in water-to-sodium leakage in seal weld area. 2. Internal bore weld through tube wall. Field repair. 3. None.
3	1. Steam Generator/ - 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 197	MA 58	MA 123	13,000	Sodium outlet temperature oscillations on monitors	1. Boiling in a large number of downcomer tubes. 2. Installed feedwater flow orifices to increase pressure drop between water and steam manifolds. 3. None.
4	1. Steam Generator/ - 2. Heat Transfer/Steam Generator 3. 40 223100	1. HNPF 2. Secondary sodium system 3. Water (shell) side: 550°F, 1000 psig Sodium (tube) side: 950°F, 100 psig 4. NAA-SR-12534	P 253	P 51	P 133	13,000	Plugging meter	1. Sodium plugging temperature increase gave rise to the hypothesis that hydrogen being generated by an iron-water reaction was diffusing through the tubes and into the sodium. 2. None. 3. None.
5	1. Steam Generator/Tube-to-Tube Sheet Weld 2. Heat Transfer/Steam Generator 3. 40 223100	1. EBR-II 2. Secondary sodium system 3. 800°F and 1500 psig on water side 4. NAA-SR-12534 PMMR-16	MA 454	MA 59	MA 136	1200	Routine inspection	1. Faulty tube-to-tubesheet machine weld resulted in water leakage into air space between sodium and water tubesheets. 2. Weld partially ground out, then manually rewelded and helium leak checked. 3. None.
6	1. Steam Generator/Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 479	MA 94	MA 136	Unknown	Pressure test	1. Stress corrosion cracking, attributed to residual cleaning solution containing sodium hydroxide, resulted in water leakage into sodium. 2. Units retubed and partially stress relieved. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

6

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 2 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Steam Generator/Tube-to-Tube Sheet Joint 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 197	MA 59	MA 136	350	Gas chromatograph	1. Hydraulically induced tube vibration caused tube cracking and resultant water leakage into sodium. 2. Baffle placed in front of sodium inlet nozzle and tubes laced at two elevations on the outer vertical section. 3. None.
8	1. Steam Generator/Tube-to-Tube Sheet Welds 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Sodium (shell) side: 1000°F, 175 psig Water (tube) side: 900°F, 1000 psig 4. NAA-SR-12534	MA 277	MA 92	MA 136	8760	Dye penetrant inspection	1. Oil and dirt deposits on joints reacted to form pits. 2. Pits and flaws were ground out and rewelded. 3. None.
9	1. Steam Generator No. 2/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Preoperational pressure test 4. NAA-SR-12534, 11/1/67 TI-095-14-009, 8/29/69	I 479	I 94	I 520	None	Pressure test	1. During preoperational testing extensive stress corrosion cracking was discovered in the tubes of one of the steam generators. This was caused by salts remaining in the tubes after a cleaning operation at the manufacturer's facilities. In addition, several manufacturing defects were discovered: (1) One tube was carbon steel instead of Croloy, (2) one tube had a defect that penetrated the tube wall, and (3) one tube had a lap defect. 2. The corroded generator was retubed and all three generators were stress relieved by circulating hot argon through the shell. 3. Upgrade chemical process control.
10	1. Steam Generator No. 1 Tubes 2. Heat Transfer/Steam generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Isothermal operation at 470°F 4. NAA-SR-12534, 11/1/67 EF-8, 4/64	I 127	I 59	I 520	350	Cover gas hydrogen detector	1. A sodium-water reaction occurred during initial operation of the unit in 1962. The leak detection, reaction relief, and isolation and dump systems operated satisfactorily to contain and terminate the reaction. The failure resulted from tube vibration opposite one of the sodium inlets. Subsequent water tests on a tube bundle confirmed that installing impingement baffles and tube lacing clips would be adequate to reduce vibration to an acceptable level. In addition to the vibration damage, four of the tubes in the reaction area exhibited pressure failures (resulting from corrosion and thinning caused by the reaction products). 2. The tube bundle was removed and cleaned in ethyl alcohol. This was the first removal of sodium and sodium-water reaction products from such a large piece of equipment. The damaged area was retubed. 3. Upgrade chemical process control.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 3 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
11	1. Steam Generator No. 2 a. Water Manifold Tube Sheet b. Steam Manifold Tube Sheet Welds 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Unit was being cut into the maintenance cooling loop 4. EF-16, 12/64	I 500	I 61	I 520	Unknown	Cover gas hydrogen detector	1. Unit was manually isolated when the cover gas hydrogen concentration increased rapidly to 400 ppm. The rate of increase was 21 ppm/min. 2. Bubble and dye penetrant tests were used to locate defects. A total of 28 seal welds joining the tubes and tube sheets were repaired. 3. Additional research and development required.
12	1. Steam Generator No. 3/ Water Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Out of service for inspection 4. EF-30, 2/66	I 500	I 61	I 520	Unknown	Bubble Test	1. Tests conducted on the tube bundle indicated a leak rate increase to 335 cc/day compared to an earlier leak rate of 65 cc/day. 2. The tube sheet was cleaned with aluminum oxide and the tube sheet welds were dye-penetrant tested. Nine small cracks and 276 flaws were found in the welds. The cracks were ground out and repaired with 2 1/4 Cr - 1 Mo filler metal, using inert arc. The flaws were repaired by nicrobrazing. 3. Additional research and development required.
13	1. Steam Generator No. 1/ Water Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-30, 2/66	I 500	I BZ	I 520	Unknown	Unknown	1. Water manifold gasket leaked. 2. Gasket was replaced. 3. Materials: select for the enviroment.
14	1. Steam Generator No. 3/ a. Water Manifold Tube Sheet b. Steam Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-32 , 4/66	I 500	I 61	I 520	Unknown	Cover gas hydrogen detector	1. An increase in the hydrogen concentration of the cover gas was detected. Mass spectrometer and bubble testing revealed two ligament cracks in the water manifold tube sheet and one suspected leaking tube in the steam manifold tube sheet. 2. The ligament cracks were ground out and welded and the two tubes bridged by the crack were plugged. The suspected tube in the steam manifold was also plugged. Both tube sheets were also completely dye-penetrant checked. Additional cracks in the seal welds of the inner row of the water manifold were found. All inner row tubes in the water manifold will be counterbored to remove the old seal welds and will be rewelded. The ligaments between these tubes were reinforced by additional weld material. The pitted welds found by the dye-penetrant check were overlayed with Nicrobraze. This amounted to several hundred tubes. 3. Additional research and development required.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 4 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
15	1. Steam Generator No. 1/ a. Water Manifold Tube Sheet b. Steam Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-33 , 5/66	I 500	I 61	I 520	Unknown	Cover gas hydrogen	1. An increase in cover gas hydrogen concentration was detected. Tests conducted on the unit revealed increased leakage compared to previous results. 2. A total of 898 tube end repairs were made to the unit which consisted of the following: (a) 567 tube welds overlayed with Nicobraze, (b) 331 tube ends were repaired with 2-1/4 CR - 1 Mo filler material, (c) 4 tubes plugged. The pitted welds found by dye-penetrant check were overlayed with Nicobraze. The remaining defective welds were repaired using 2-1/4 Cr - 1 Mo filler material and the tungsten inert gas technique. All inner row tubes in the water inlet tube sheet were counterbored and rewelded adding 2-1/4 Cr - 1 Mo filler rod. 3. Additional research and development required.
16	1. Steam Generator No. 2/ Water Manifold Tube 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-33, 5/66	I 500	I 61	I 520	Unknown	Cover gas hydrogen	1. A steady increase of hydrogen leakage into the cover gas was observed over a period of time. Consequently it was decided to remove the manifold covers for investigation and necessary repairs. Bubble testing revealed two tube weld leaks in the water manifold tube sheet. Dye penetrant checking showed an additional 164 questionable welds of which 11 appeared to have flaws. 2. A total of 179 tube end welds were repaired by counterboring out the welds and rewelding with 2-1/4 Cr - 1 Mo filler rod. Bubble testing after repairs was satisfactory. 3. Additional research and development required.
17	1. Steam Generator No. 3/ Steam Manifold cover gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-34 , 6/66 EF-35 , 7/66	I 500	I BZ	I 520	Unknown	Unknown	1. Steam manifold cover gasket leaked. 2. Steam manifold cover gasket was replaced. 3. Materials: select for the enviroment.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 5 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
18	1. Steam Generator No. 1/ Water Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF-36, 8/66	I 500	I 61	I 520	Unknown	Unknown	1. The unit was taken out of service for tube-to-shell-side leakage. A pressure test revealed a nitrogen leak rate of 430 cc/day. 2. Three leaks were found in the water manifold tube sheet by means of bubble testing. Two were tube weld leaks which were repaired by removing the defect area and refilling with 2-1/4 Cr - 1 Mo welding rod using the inert arc technique. One of the leaks appeared just below the weld in the tube roll. This tube was plugged. Both tube sheets were completely dye-penetrant checked. This revealed a number of weld defects in the water manifold most of which were in nicobraze overlays that were applied during the last repair period. Repairs were made by removing the nicobraze and rewelding with 2-1/4 Cr - Mo filler rod. 3. Additional research and development required.
19	1. Steam Generator No. 2/ Water Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF - 37, 9/66 EF - 38, 10/66	I 500	I 61	I 520	Unknown	Unknown	1. Water manifold tube sheet leak. 2. Tube welds in the water side manifold were repaired. Bubble testing and nitrogen pressure testing showed the unit to be leak tight. 3. Additional research and development required.
20	1. Steam Generator No. 3/ Water Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. In service 4. EF - 37, 9/66	I 500	I BZ	I 520	Unknown	Unknown	1. Water manifold gasket leak. 2. Water manifold gasket was replaced. 3. Materials: select for the environment.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 6 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
21	1. Steam Generator No. 1/ a. Water Manifold Tubes Sheet b. Steam Manifold Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 22310	1. Fermi 2. Secondary sodium system 3. In service 4. EF - 42, 2/67 EF - 43, 3/67 EF - 44, 4/67 EF - 45, 5/67 EF - 47, 7/67	I 500	I 61	I 520	Unknown	Unknown	1. Both water and steam manifold tube sheets have been tested for leaks. Two leaking tube end welds were found in the water manifold in the inner tube row. The water side manifold was also dye-penetrant checked. Seven additional tube end welds were found to have questionable defects. Four tube end welds were trepanned as part of a metallographic study to determine the nature of the weld failures. 2. A welding technique developed by Foster-Wheeler Corporation was used on this unit in an effort to eliminate the problem of leaking tube joints. This method employs a special welding head which is inserted into a steam generator tube, and using the tungsten inert gas method, fusion welds the tube to the tube-sheet. Internal bore welding of the tube-to-tube-sheet joints in the water side tube sheet of the unit was completed. A total of 1184 tube welds were made. The remaining 16 tubes in the unit were plugged. Leak testing of the unit after repairs were completed was satisfactory. The water manifold tube ends on steam generators 2 and 3 will be welded using the internal bore welding technique. 3. Additional research and development required.
22	1. Steam Generator No.1/ a. Water Manifold Gasket b. Steam Namifold Gasket c. Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Inservice 4. EF - 61, 9/68 EF - 62, 10/68	I 500	I BZ 61	I 520	Unknown	Cover gas hydrogen detector	1. An increase in hydrogen concentration in the shell side cover gas on steam generator No. 1 indicated tube-to-shell-side leakage. The unit was dismantled as a result of water and steam manifold gasket leaks as well as tube leaks. Subsequently, three tube leaks were found. Two tubes (No. 112-3 and No. 150-1) were leaking at the internal bore weld area in the water manifold tube sheet and the third tube (No. 76-1) was leaking approximately 10 to 10-1/2 ft below the top of the steam manifold tube sheet. The distance was determined by installing a plastic hose with a valve over the defective steam tube. The shell of the steam generator was pressurized with nitrogen to 38 psig which passed through the valve at an ultrasonic velocity. The ultrasonic frequency changed while the water level was maintained either above or below the leak. 2. The unit was repaired. 3. None.

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FAILURE DATA FOR STEAM GENERATORS

(Sheet 7 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
23	1. Steam Generator No. 2/ a. Water Manifold Gasket b. Steam Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Pressure test of steam side with water 4. EF - 61, 9/68	I 500	I BZ	I 520	Unknown	Visual	1. Water and steam manifold gasket leaks were experienced on the unit. Hardness tests of the gaskets showed values higher than expected for soft annealed iron. 2. Water and steam manifold gaskets were replaced with annealed gaskets. 3. None.
24	1. Steam Generator No. 1/ a. Water Manifold Gasket b. Steam Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Pressure test of steam side with water 4. EF - 61, 9/68	I 500	I BZ	I 520	Unknown	Visual	1. Water and steam manifold gasket leaks were experienced on the unit. Hardness tests of the gaskets showed values higher than expected for soft annealed iron. 2. Water and steam manifold gaskets were replaced with annealed gaskets. 3. None.
25	1. Steam Generator No. 3/ Water Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Pressure test of steam side with water 4. EF - 61, 9/68	I 500	I BZ	I 520	Unknown	Visual	1. Water manifold gasket leak was experienced on the unit. Hardness test of the gasket showed values higher than expected for soft annealed iron. 2. Water manifold gasket was replaced with annealed gasket. 3. Materials: select for the environment.
26	1. Steam Generator No. 1/ Pressure Drop Devices 2. Heat Transfer/Steam Generator 3. 40	1. Fermi 2. Secondary sodium system 3. Feedwater flow testing 4. EF - 69, 5/69 EF - 70, 6/69	I 27Z	I 51	I 520	Unknown	Test instrumentation	1. Feedwater flow tests were conducted on the unit after a series of isolation checks. Results of the flow tests indicate that some of the pressure drop devices did not reseat after the isolation checks. Inspection of the pressure drop orifices showed that all had reseated after isolation tests except for several that were held off their seats because of small-scale particles. 2. The orifices were cleaned and returned to service. 3. Upgrade chemical process control.
27	1. Steam Generator No. 3/ Steam Manifold Gasket 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi 2. Secondary sodium system 3. Unit was water filled to run feedwater flow test 4. EF-69, 5/69 EF-70, 6/69	I 500	I BZ	I 520	Unknown	Visual	1. The unit was water filled in preparation for running a feedwater flow test but a leak developed at the steam manifold cover plate. 2. The tube side was water filled following retorquing of the steam manifold cover. Retorquing failed to eliminate the gasket leak; therefore, the leak was repaired by replacing the steam manifold gasket. 3. Materials: select for the environment.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 8 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
28	1. Steam Generator No. 1/ Downcomer Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi (LMFBR) 2. Secondary sodium system 3. Steam pressure: 750 psia Sodium temp: 510°F 4. NAA-SR-12534, 11/1/87 TI-095-14-009	I 197	I BA	I 520	Unknown	Sodium outlet temperature oscillations on monitors	1. During a 67-Mwt, two-loop run, instability occurred as the steam pressure was being ramped from 900 psi down to 600 psi. When the steam pressure reached approximately 750 psia and the sodium outlet temperature 510°F, large oscillations with a maximum amplitude of 100°F were observed in the sodium outlet temperature of one steam generator. The high temperature initiated a single-circuit shutdown which, in turn, resulted in a multicircuit shutdown and scram. 2. Restriction of the operating parameters to limit the preheat area reduced this problem. In addition, poppet-type orifices were installed in the inlets of the water downcomer tubes to increase the pressure drop, provide more even water distribution to all the tubes, and, hopefully, eliminate the instability altogether. Considerable tuning of the control system was necessary before efficient operation was achieved. 3. Additional research and development required.
29	1. Steam Generator No. 1/ Downcomer Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi (LMFBR) 2. Secondary sodium system 3. Steam pressure: 950 psi Sodium temp: 540°F 4. NAA-SR-12534, 11/1/67 TI-095-14-009	I 197	I BA	I 520	Unknown	Sodium outlet temperature oscillations on monitors	1. During a 100-Mwt, 3-loop run, large oscillations with a maximum amplitude of 100°F were observed on loop No. 2 after the sodium outlet temperature drifted from 517°F to approximately 540°F when operating at a steam pressure of 950 psia. Approximately 5 min after operation of this loop was terminated by a single-circuit shutdown from the oscillations, loop No. 1 exhibited the same behavior, thereby terminating the run with a multicircuit shutdown scram. The outlet steam temperature during both these runs was approximately 600°F. Both instabilities developed when the steam generator sodium outlet temperature coincided with the saturation temperature of the feedwater at its operating pressure. 2. Restriction of the operating parameters to limit the preheat area reduced this problem. In addition, poppet-type orifices were installed in the inlets of the water downcomer tubes to increase the pressure drop, provide more even water distribution to all the tubes, and, hopefully, eliminate the instability altogether. Considerable tuning of the control system was necessary before efficient operation was achieved. 3. Additional research and development required.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 9 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
30	1. Steam Generator No. 2/ Downcomer Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Fermi (LMFBR) 2. Secondary sodium system 3. Steam pressure: 950 psia Sodium temp: 540°F 4. NAA-SR-12534, 11/1/67 TI-095-014-009	I 197	I BA	I 520	Unknown	Sodium outlet temperature oscillations on monitors	1. During a 100-Mwt, 3-loop run, large oscillations, with a maximum amplitude of 100°F were observed on loop No. 2 after the sodium outlet temperature drifted from 517°F to approximately 540°F when operating at a steam pressure of 950 psia. Approximately 5 min after operation of this loop was terminated by a single-circuit shutdown from the oscillations, loop No. 1 exhibited the same behavior, thereby terminating the run with a multicircuit shutdown scram. The outlet steam temperature during both these runs was approximately 600°F. Both instabilities developed when the steam generator sodium outlet temperature coincided with the saturation of the feedwater at its operating pressure. 2. Restriction of the operating parameters to limit the preheat area reduced this problem. In addition, poppet-type orifices were installed in the inlets of the water downcomer tubes to increase the pressure drop, provide more even water distribution to all the tubes, and, hopefully, eliminate the instability altogether. Considerable tuning of the control system was necessary before efficient operation was achieved. 3. Additional research and development required.
31	1. Steam Generator/ Water-Side Tube Sheet 2. Heat Transfer/Steam Generator 3. 40 223100	1. EBR-II (LMFBR) 2. Secondary sodium system 3. Plant was shut down for control rod repairs 4. NAA-SR-12534, 11/1/67	MA 500	MA 6Z	MA 580	1200	Routine inspection	1. A routine inspection of the steam generators while the plant was shut down in October 1964 for control rod repairs disclosed the presence of water in the space between the sodium and water upper tube sheets in evaporator No. 702. Subsequent testing confirmed that a leak existed in the water side tube sheet of one of its contained tubes. The interconnecting pipe between the evaporator and the steam drum was removed, giving access to the water side of the tube sheet. The air side of the tube sheet was pressurized and bubble-testing pinpointed the location of the leak. It was a pinhole in a weld crater of a machine-made tube-to-tube-sheet weld. 2. Since it was accessible, the weld was partially ground out and manually rewelded without having to remove the evaporator. A subsequent helium mass spectrometer leak test showed the repair to be successful. The riser pipe was then rewelded into the system, and the plant was prepared for further operation. 3. None.

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FAILURE DATA FOR STEAM GENERATORS
(Sheet 10 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
32	1. Steam Generator / Tubes 2. Heat Transfer / Steam Generator 3. 40 223100	1. SCTI (non-nuclear test facility) 2. Secondary sodium system 3. Startup 4. IMPR-370, 6/22/70	I 500	I 6Z	I 520	2300	Hydrogen recorder	1. Steam generator hydrogen recorder showed H_2 presence in excess of 200 ppm. Temperatures increased. Peak steam temperature was 550°F, as compared with a sodium inlet temperature of 410°F. Feedwater inlet temperature was 370°F. This temperature response was indicative of a sodium-water reaction on the steam side of the steam generator. 2. Tubes 2-47 and 4-27 were plugged and seal welded using a special weld procedure. Dye-penetrant examination and helium leak test verified weld integrity. A hydrostatic test also served to assure the soundness of the bundle at operating pressure. 3. Additional research and development required.
33	1. Steam Generator / Manway Flange 2. Heat Transfer / Steam Generator 3. 40 223100	1. SCTI (non-nuclear test facility) 2. Secondary sodium system 3. Steam generator undergoing repair for tube leak 4. IMPR-374, 8/6/69	I 413	I 61	I 530	3380	Visual	1. Following removal of ring seal from upper steam generator manway flange, cracks were observed at the bottom of the groove around the entire periphery. The cracks are believed to be structural failures due to high radial loading on the relatively small area within the ring diameter. Plastic deformation of the lip, internal to the O-ring groove, is evidenced by the fact that ID measurements at the top of the manway opening indicate a 50-mil deflection. Similar deformation is also evident at the lower manway flange but no cracks exist in this latter region. 2. Upon completion of crack removal, the machined areas in the groove were overlaid with Inconel to reestablish a protective surface. Diaphragms fabricated from Incoloy 800 were installed over the manway opening. 3. Additional research and development required.
34	1. Steam Generator / a. Tubes b. Steam Side Tube Sheet 2. Heat Transfer / Steam Generator 3. 40 223100	1. SCTI (non-nuclear test facility) 2. Secondary sodium system 3. Startup operation 4. LMEC Monthly Progress Reports for 3/69 and 4/69	I 500	I 6Z	I 520	3410	Instrumentation and visual	1. Steaming operation was terminated when evidence of water vapor was found in the cover gas over the sodium. Leakage was confirmed and the water side of the steam generator was opened to permit detailed inspection and isolation of defects. Five defective tubes were found. Liquid penetrant inspections of the upper tube sheet fillet welds revealed a number of porosity and crack indications. 2. The five defective tubes were plugged and tube sheet discrepancies were repaired. 3. Additional research and development required.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 11 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
35	1. Steam Generator/ Shell 2. Heat Transfer/ Steam Generator 3. 40 223100	1. SCTI (non-nuclear test facility) 2. Secondary sodium system 3. Steam generator hydrostatic test 4. IMPR - 383, 5-20-70	I 500	I 99	I 520	3410	Visual	1. Feedwater flow was established through the Alco test steam generator in preparation for hydrostatic test per Special Procedure No. 123. This hydrostatic test was to be conducted at 2300 psig and 350°F. A preliminary inspection of the diaphragm and manway cover areas was being conducted in preparation for heating the steam generator to 350°F and increasing feedwater pressure to 2300 psig. The feedwater pressure in the steam generator was 580 psig and 90°F. The inspection indicated that there was a series of cracks in the steam generator feedwater chest in the vicinity of the lower channel head and tube sheet area. The presence of sodium oxide deposits on the tube sheet edge and undersurface, and of rust-colored stains beneath several of the visible cracks, indicate that cracking and leakage occurred prior to the end of the last operating interval. 2. Pending (under investigation). 3. Additional research and development required.
36	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. HNPF (LMFBR) 2. Secondary sodium system 3. Reactor in shutdown condition 4. NAA-SR-12534, 11-1-67	I 456	I 61	I 520	4926	Third fluid pressure buildup	1. A gradual third fluid pressure buildup indicated the probability of a leak in the superheater between the third fluid and steam. The third fluid pressure was bled to 300 psig. After a short time, the pressure steadily increased to 400 psig. At this time, it was felt that the leak was definite. Further proof of the leak was made by venting the third fluid pressure to 345 psig and again allowing its pressure to approach the steam pressure. 2. The tube bundle was removed from the shell, and the leak was located in the center tube of the tube bundle. A radiograph of the defective tube showed the inner tube cap pushed ahead and rubbing the weld of the outer tube cap. The inner tube was extruded into the outer tube during the roller expansion and caused this interference fit, which could have caused the failure by setting up residual stresses in this area which were not stress relieved after fabrication. The combination of this residual stress and the thermal stress during operation probably caused the weld to crack. The leaking tube was welded, stress relieved, and the tube bundle reinstalled. The shell was rewelded, stress relieved, and hydrostatically tested at 900 psig for 1 hr, steaming operations were resumed. 3. Additional research and development required.

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TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 12 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
37	1. Steam Generator/ Tube 2. Heat Transfer/ Steam Generator 3. 40 223100	1. HNPF (LMFBR) 2. Secondary sodium system 3. Steam generator out of service for modifications 4. NAA-SR-12534, 11-1-67	MA 500	MA 61	MA 520	4926	Visual	1. While preparing to stress relieve the end cap welds of the heat transfer tube bundle, a crack was found in the end cap weld of Tube No. 18. 2. This crack was repaired and all other end caps were radiographed to check for cracks and interference fits between the cap welds of the inner and outer tubes. Seven tubes which had not been stress relieved during fabrication were stress relieved. These tubes (No's. 3, 6, 8, 9, 10, 13, and 20) were wrapped with a heating coil, heated at a controlled rate to 1200°F, and then cooled at a controlled rate to stress-relieve them. The stress-relieved tubes were then checked with penetrant dye and mass spectrometer, then leak tested and radiographed. No defects were found and the tube bundle was installed in the kettle-type evaporator shell. 3. Additional research and development required.
38	1. Steam Generator/ Tube 2. Heat Transfer/ Steam Generator 3. 40 223100	1. HNPF (LMFBR) 2. Secondary sodium system 3. Destructive examination of steam generator 4. NAA-SR-12534	MA 452	MA 61	MA 580	8541	Visual	1. Sodium was found in the annulus of one bellows-type core tube while attempting to cut it apart. The annulus was almost completely filled with solidified sodium, which prevented separation of the inner and outer tubes. No sodium was found in the annulus of any of the other core tubes. Four core tubes were found in which numerous cracks were observed in the weld between the inner and outer tubes on the bellows end of the tube. Although the cracks found in these tube end pieces penetrated through both tube walls and the weld, the annulus space peculiarly enough, was absent of sodium. After all of the bellows-type core tubes had been disassembled, each piece, including the bellows, was individually helium leak-tested. The bellows and all of the welds on the core tube were dye-checked. No leaks were found in any of the length of tubing nor in the bellows. The only leaks found were those in the end pieces in which the welds were cracked. 2. None (destructive examination of steam generator only). 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 13 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
39	1. Steam Generator/ Tubes 2. Heat Transfer/ Steam Generator 3. 40 223100	1. Dresden (BWR) 2. Secondary water loop 3. Full power operation 4. TI-095-14-010, 11-15-69	MA 500	MA 6Z	MA 510	Unknown	Unknown	1. Dresden I has five steam generators: one primary and four secondary. As steam producers, there is no record of any operating difficulty with them except for tube leaks in the secondary generators. 2. Unknown. 3. Additional research and development required.
40	1. Steam Generator/ Tubes 2. Heat Transfer/ Steam Generator 3. 40 223100	1. Dresden (BWR) 2. Secondary water loop 3. Full power operation 4. TI-095-14-010, 11-15-69	MA 500	MA 6Z	MA 510	Unknown	Unknown	1. Dresden I has five steam generators: one primary and four secondary. As steam producers, there is no record of any operating difficulty with them except for tube leaks in the secondary generators. 2. Unknown 3. Additional research and development required.
41	1. Steam Generator/ Tubes 2. Heat Transfer/ Steam Generator 3. 40 223100	1. Dresden (BWR) 2. Secondary water loop 3. Full power operation 4. TI-095-14-010, 11-15-69	MA 500	MA 6Z	MA 510	Unknown	Unknown	1. Dresden I has five steam generators: one primary and four secondary. As steam producers, there is no record of any operating difficulty with them except for tube leaks in the secondary generators. 2. Unknown. 3. Additional research and development required.
42	1 Steam Generator/ Tubes 2. Heat Transfer/ Steam Generator 3. 40 223100	1. Dresden (BWR) 2. Secondary water loop 3. Full power operation 4. TI-095-14-010, 11-15-69	MA 500	MA 6Z	MA 510	Unknown	Unknown	1. Dresden I has five steam generators: one primary and four secondary. As steam producers, there is no record of any operating difficulty with them except for tube leaks in the secondary generators. 2. Unknown. 3. Additional research and development required.
43	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. San Onofre (PWR) 2. Primary coolant loop 3. Steam generator installation during plant construction 4. TI-095-14-007, 6-25-69	MI 47Z	MI 54	MI 510	None	Visual	1. On November 16, 1965, during construction, the rigging contractor dropped the No. 3 steam generator as it was being lifted into the vapor container. The lifting gear in the special portable bridge crane failed and the generator (which was horizontal at the time) dropped 12 in. onto wooden blocking. No nozzles were damaged; however, some tubes in the upper support structure were deformed from a nominal of 0.640 to a deformed value of 0.340 in. Collapse test, metallurgical investigations, velocity measurements, and other tests were performed on similarly deformed tubes. 2. Westinghouse and Bechtel's recommendation was that the unit be operated as-is without tube replacement or plugging. 3. Improve handling technique of large components.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 14 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
44	1. Steam Generator/ Tubes 2. Heat Transfer/ Steam Generator 3. 40 223100	1. San Onofre (PWR) 2. Primary coolant loop 3. Full power operation 4. TI-095-14-007, Change No. 1, 3-70	MI 500	MI 6Z	MI 510	Unknown	Unknown	1. The steam generator, dropped during construction, developed a 2 gal/day leak (determined by the measured tritium concentration in the feedwater). 2. Unknown. 3. Additional research and development required.
45	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Shippingport (PWR) 2. Primary coolant loop 3. Unknown 4. TI-095-14-006, 7-7-69	MA 278	MA 94	MA 520	Unknown	Unknown	1. In 1958 a leak was discovered between the primary and secondary sides of a heat exchanger. Testing revealed that 2 tubes were leaking, 15 had significant wall thickness defects, and there were defects between the secondary face of the inlet-end tube sheet and the first tube baffle. Examinations revealed that the failures were caused by a combination of steam blanketing and caustic stress corrosion as a result of operations out of boiler water chemistry specifications (during initial plant operations when excessive blowdown was required). There were also quite a few other occasions in which the plant experienced heat exchanger leak problems. 2. To correct the condition, two additional steam risers were added to the heat exchangers, and the water chemistry was improved to assure the complete absence of "free" alkalinity in the boiler water. All four Core 1 steam generators were replaced for the operation of Core 2. 3. Continued upgrading of chemical process control.
46	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Shippingport (PWR) 2. Primary coolant loop 3. Unknown 4. TI-095-14-006, 7-7-69	MA 194	MA 65	MA 520	Unknown	Unknown	1. Tube failures have occurred on at least three occasions during Core 2, Seed 1 operations. Severe wall thinning was found and eventually a flow blocking plate was installed. The following novel method was used to pinpoint the failures. A long plastic tube was affixed to an ordinary aspirator at one end and a rubber balloon at the other. The balloon was moved along the tube in increments, inflated and deflated in turn. With the other end of a tube plugged, inflating the balloon over a hole stopped leakage and thus gave proof of failure. Some of the failures were caused by thermal expansion leading to wear of certain tube banks on a stiffener brace. 2. The steam generator deficiencies were repaired. 3. Additional research and development required.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-111

FAILURE DATA FOR STEAM GENERATORS

(Sheet 15 of 15)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
47	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Shippingport (PWR) 2. Primary coolant system 3. Unknown 4. TI-095-14-006, 7-7-69	MA 194	MA 65	MA 520	Unknown	Unknown	1. Tube failures have occurred on at least three occasions during Core 2, Seed 1 operations. Severe wall thinning was found and eventually a flow blocking plate was installed. The following novel method was used to pinpoint the failures. A long plastic tube was affixed to an ordinary aspirator at one end and a rubber balloon at the other. The balloon was moved along the tube in increments, inflated and deflated in turn. With the other end of a tube plugged, inflating the balloon over a hole stopped leakage and thus gave proof of failure. Some of the failures were caused by thermal expansion leading to wear of certain tube banks on a stiffener brace. 2. The steam generator deficiencies were repaired. 3. Additional research and development required.
48	1. Steam Generator/ Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	1. Shippingport (PWR) 2. Primary coolant system 3. Unknown 4. TI-095-14-006, 7-7-69	MA 194	MA 65	MA 520	Unknown	Unknown	1. Tube failures have occurred on at least three occasions during Core 2, Seed 1 operations. Severe wall thinning was found and eventually a flow blocking plate was installed. The following novel method was used to pinpoint the failures. A long plastic tube was affixed to an ordinary aspirator at one end and a rubber balloon at the other. The balloon was moved along the tube in increments, inflated and deflated in turn. With the other end of a tube plugged, inflating the balloon over a hole stopped leakage and thus gave proof of failure. Some of the failures were caused by thermal expansion leading to wear of certain tube banks on a stiffener brace. 2. The steam generator deficiencies were repaired. 3. Additional research and development required.

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TABLE 1-112

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT STEAM GENERATORS

COMPONENT SUBTYPE STEAM GENERATORS

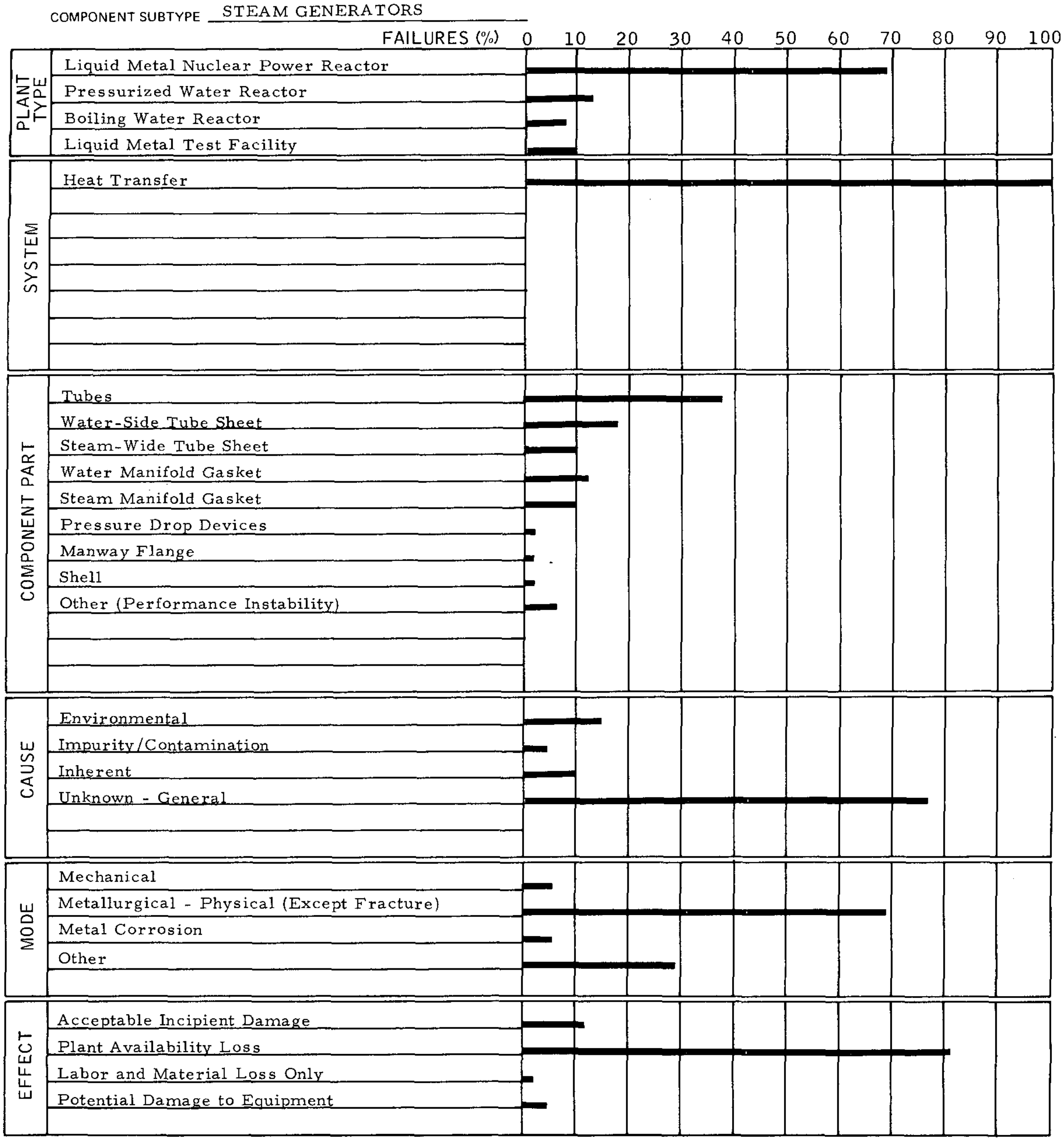
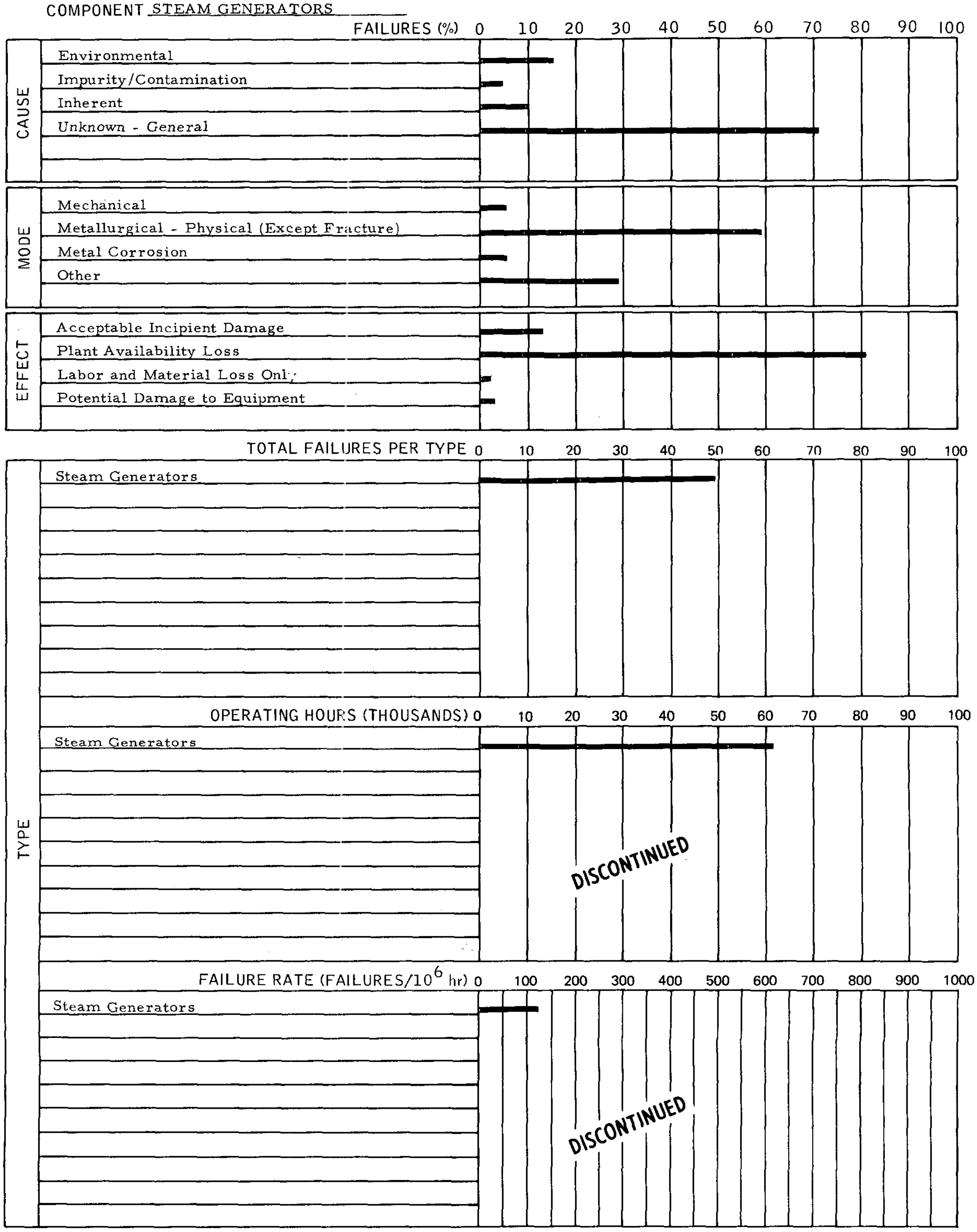


TABLE 1-113

GENERAL SUMMARY

COMPONENT STEAM GENERATORS



13. Traps (General) (see Figures 1-27 through 1-30)

Failure data for traps (general) are presented in Tables 1-114 through 1-118.

a. Reliability Information

Critical Characteristics:

The proper installation and operation of traps is important to their use. They should not be any more complex than necessary.

Mode of Failure:

1) Instrumentation error

2) Clogging

3) Wear

4) Disconnection

5) Distortion

6) Movement obstructed

7) Broken

8) Erosion.

Failure Description:

1) Overheating

2) Packing worn out

3) Springs stuck

4) Plugging of vapor traps

5) Parts broken (shaft, steel balls).

Control Methods

1) Redesign of traps that are not adequate to do the job.

2) Further investigation of failures within a trap.

3) Do not over-design a part.

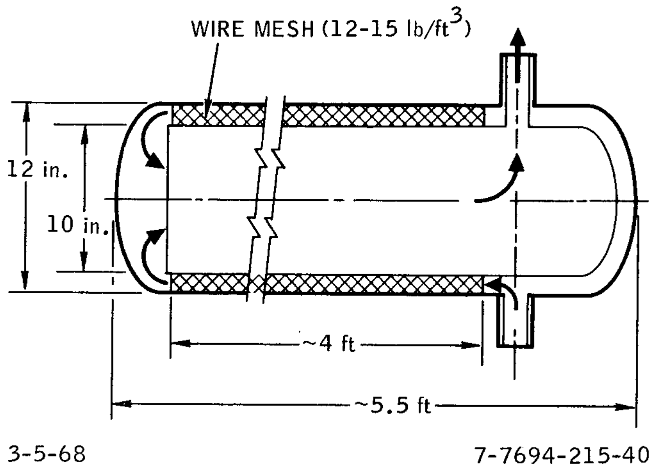


Figure 1-27. HNPF Vapor Trap

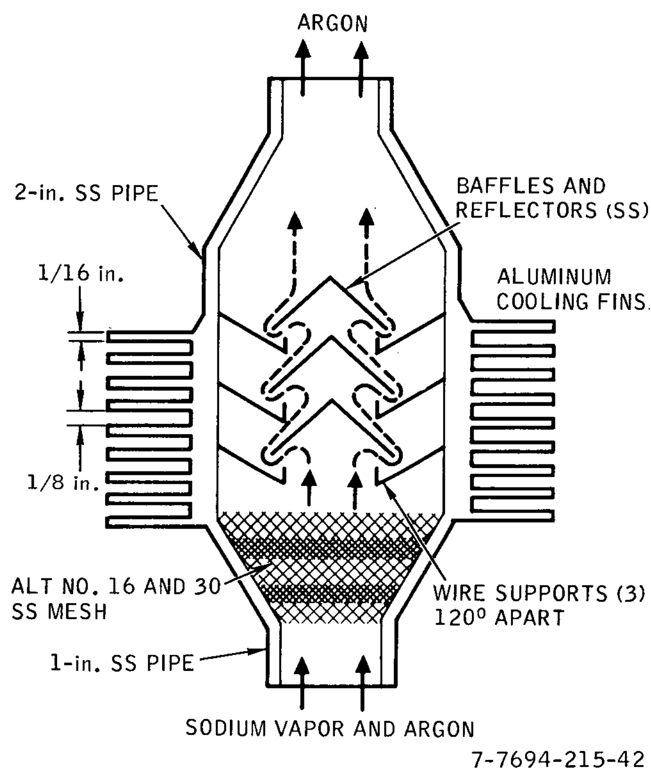


Figure 1-28. ANL Refluxing Type Trap

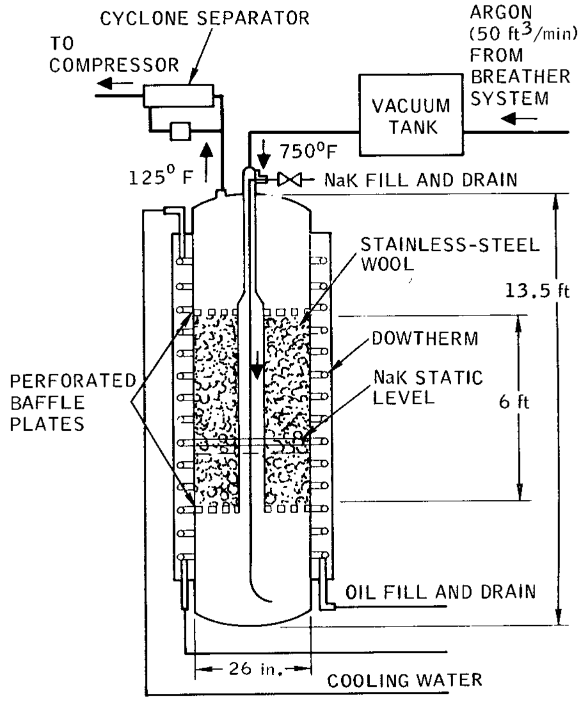


Figure 1-29. Fermi Vapor Trap

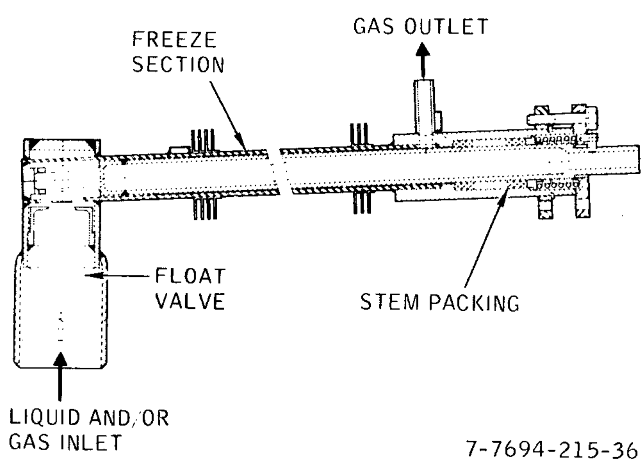


Figure 1-30. Freeze Trap

4) Improve training of personnel.

5) Electrical heaters used with freeze traps should be designed to prevent overheating (spring-loaded circuit breaker, etc.).

b. Discussion and Recommendations

None.

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 1 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Freeze Trap No. 1/ Float 2. Heat Transfer/Coolant Storage 3. 33 224400	1. HNPF 2. Primary sodium service/drain tank 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1682	MI 144	MI 5Z	MI 550	Unknown	Operational monitors	1. Float not seated properly. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap to melt sodium around shaft in housing, (c) pressurized housing with helium to clean out sodium. 3. Install another cooling device and/or allow sufficient air flow and clearance around freeze trap housing in order to minimizethe chance of overheating housing. Thus, molten sodium can flow through rather than solidifying around the cool shaft, as designed.
2	1. Freeze Trap No. 1/ Housing 2. Heat Transfer/Coolant Storage 3. No. 33 224400	1. HNPF 2. Primary sodium service/drain tank 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1682	MI 137	MI 44	MI 550	Unknown	Operational monitors	1. Housing overheated. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap to melt sodium around shaft in housing, (c) pressurized housing with helium to clean out sodium. 3. Install another cooling device and/or allow sufficient air flow and clearance around freeze trap housing in order to minimize the chance of overheating housing. Thus, molten helium can flow through rather than solidifying around the cool shaft, as designed.
3	1. Freeze Trap No. 1/ Vent 2. Heat Transfer/Coolant Storage 3. 33 224400	1. HNPF 2. Primary sodium service/drain tank 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1682	MI 187	MI 51	MI 550	Unknown	Operational monitors	1. Vent piping plugged with sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap to melt sodium around shaft in housing, (c) pressurized housing with helium to clean out sodium. 3. Install another cooling device and/or allow sufficient air flow and clearance around freeze trap housing in order to minimize the chance of overheating housing. Thus, molten sodium can flow through rather than solidifying around the cool shaft, as designed.
4	1. Freeze Trap No. 1/ Shaft Stop 2. Heat Transfer/Coolant Storage 3. 33 224400	1. HNPF 2. Primary sodium service/drain tank 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2134	MI 331	MI 59	MI 550	Unknown	During actuation	1. Shaft stop broken. 2. Local repair, welded stop for cam actuator. 3. Procedures should be written cautioning against rotating the cam shaft control with excessive force or speed to save the stops.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)
(Sheet 2 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
5	1. Freeze Trap No. 2/ Housing 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2252	MI 137	MI 44	MI 550	Unknown	Operational monitors	1. Warmed housing did not solidify sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
6	1. Freeze Trap No. 2/ Vent 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2252	MI 187	MI 51	MI 550	Unknown	Operational monitors	1. Vent piping plugged with sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
7	1. Freeze Trap No. 3/ Cam Actuator 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary cold trap No. 1/actuator 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 925	MI 47Z	MI 53	MI 550	Unknown	During actuation	1. Reach rod that actuates valve cam on freeze trap was disengaged. Tapered pins missing. 2. Part replaced. 3. None.
8	1. Freeze Trap No. 3/ Float 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary cold trap No. 3 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2187	MI 144	MI 5Z	MI 550	Unknown	Operational monitors	1. Float not seated properly. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
9	1. Freeze Trap/Cam Shaft Housing 2. Heat Transfer/ Intermediate Heat Exchanger 3. 33 222300	1. HNPF 2. IHX-1/freeze trap No. 11 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2331	MI 137	MI 51	MI 550	Unknown	During actuation	1. Cam shaft housing full of sodium. 2. Local repairs: (a) removed freeze trap, (b) removed cam shaft, (c) steam cleaned cam shaft housing of sodium obstruction. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 3 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
10	1. Freeze Trap No. 12/ Spring 2. Heat Transfer/Intermediate Heat Exchanger 3. 33 222300	1. HNPF 2. IHX-2 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1003	MI 410	MI 55	MI 530	Unknown	During actuation	1. Spring stuck. 2. Component corrective modification; retainer spring replaced with a solid follower (steel spacer). 3. None.
11	1. Freeze Trap No. 10/ Packing 2. Heat Transfer/Intermediate Coolant Piping 3. 33 222210	1. HNPF 2. Secondary sodium service 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 73	MI 454	MI 5Z	MI 550	Unknown	Direct observation	1. Helium leak through packing. 2. Component corrective modification; added two rings of packing. 3. None.
12	1. Freeze Trap No. 10/ Spring 2. Heat Transfer/Intermediate Coolant Piping 3. 33 222210	1. HNPF 2. Secondary sodium service 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 275	MI 410	MI 53	MI 550	Unknown	Direct observation	1. Spring loose, helium leak through packing. 2. Component corrective modification; retainer springs replaced with steel spacers. 3. Use steel spacers as integral design component and spring of sufficient tension and made of a suitable material for this type of atmosphere in order to improve reliability.
13	1. Freeze Trap No. 7/ Cam Drive Shaft 2. Heat Transfer/Intermediate Coolant Piping 3. 33 222210	1. HNPF 2. Secondary cold trap (outlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 115	MI 339	MI 54	MI 550	Unknown	Operational monitors	1. Cam drive shaft bent at packing. 2. Local repairs: (a) cam shaft straightened, (b) removed rough spots inside cam shaft housing. 3. None.
14	1. Freeze Trap No. 7/ Packing 2. Heat Transfer/Intermediate Coolant Piping 3. 33 222210	1. HNPF 2. Secondary cold trap (outlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 115	MI 115	MI 54	MI 550	Unknown	Operational monitors	1. Gap at packing allowed helium to leak out of system. 2. Local repair, replaced two rings of Jones packing. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 4 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
15	1. Freeze Trap No. 7/ Spring 2. Heat Transfer/Intermediate Coolant Piping 3. 33 222210	1. HNPF 2. Secondary cold trap (outlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 275	MI	MI	MI	Unknown	Operational monitors	1. Helium leak, through packing. 2. Component corrective modification. 3. None.
16	1. Freeze Trap No. 11/ Spring 2. Heat Transfer/Intermediate Heat Exchanger 3. 33 222300	1. HNPF 2. IHX-1 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1003	MI 410	MI 55	MI 530	3495	During actuation	1. Spring stuck. 2. Component corrective modification, retainer springs replaced with a solid follower (steel spacers). 3. None.
17	1. Freeze Trap No. 2/ Float 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary/sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2252	MI 144	MI 5Z	MI 550	2320	Operational monitors	1. Float not seated properly. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear out sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
18	1. Freeze Trap No. 2/ Float 2. Heat Transfer/ Reactor Cooling Piping 3. 33 221210	1. HNPF 2. Primary/sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2629	MI 144	MI 5Z	MI 550	3250	During actuation	1. Float not properly seated. 2. Local repairs: (a) cut helium lines, cleaned out sodium, replaced lines, (b) heated freeze trap housing to clear out sodium. 3. Allow sufficient cooling. Change in operating procedures should be made whereby a slight positive pressure is maintained on freeze trap at all times. Also a good look at a replacement component is in order.
19	1. Freeze Trap No. 2/ Housing 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary/sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2629	MI 137	MI 44	MI 550	3250	During actuation	1. Thermocouple on housing failed to indicate rise in temperature. 2. Local repairs: (a) cut helium lines, cleaned out sodium, replaced lines, (b) heated freeze trap housing to melt sodium in housing, (c) pressurized housing to clear out sodium. 3. Allow sufficient cooling. Change in operating procedures should be made whereby a slight positive pressure is maintained on the freeze trap at all times. Also a good look at a replacement component is in order.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 5 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
20	1. Freeze Trap No. 2/ Vent 2. Heat Transfer/ Reactor Coolant Piping 3. 33 221210	1. HNPF 2. Primary/sodium 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2629	MI 187	MI 51	MI 550	3250	During actuation	1. Vent clogged with sodium blocking helium flow. 2. Local repair: (a) cut helium lines, cleaned out sodium, replaced lines, (b) heated freeze trap housing to melt sodium in housing, (c) pressurized housing to clear out sodium. 3. Allow sufficient cooling. Change in operating procedures should be made whereby a slight positive pressure is maintained on the freeze trap at all times. Also a good look at a replacement component is in order.
21	1. Freeze Trap No. 4/ Packing 2. Heat Transfer/Purification (Cold Trap) 3. 33 224234	1. HNPF 2. Primary cold trap No. 2 (inlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1054	MI 115	MI 52	MI 530	Unknown	Operational monitors	1. Packing worn out. 2. Local repair; added 11 rings of packing. 3. Packing rings should be insulated from heat and hot sodium vapors which evidently contribute to wear and degradation of the packing ring.
22	1. Freeze Trap No. 5/ Packing 2. Heat Transfer/Purification (Cold Trap) 3. 33 224234	1. HNPF 2. Primary cold trap No. 2 (outlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1054	MI 115	MI 52	MI 530	Unknown	Operational monitors	1. Packing worn out. 2. Local repair; added 11 rings of packing. 3. Packing rings should be insulated from heat and hot sodium vapors which evidently contribute to wear and degradation of the packing ring.
23	1. Freeze Trap No. 3/ Housing 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2187	MI 137	MI 44	MI 550	Unknown	Operational monitors	1. Warmed housing did not solidify sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
24	1. Freeze Trap No. 3/ Vent 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2187	MI 187	MI 51	MI 550	Unknown	Operational monitors	1. Vent piping plugged with sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 6 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
25	1. Freeze Trap No. 3/ Float 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2252	MI 144	MI 5Z	MI 550	Unknown	Operational monitors	1. Float not seated properly. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
26	1. Freeze Trap No. 3/ Housing 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium, 200 to 350°F 4. Work request No. 2252	MI 137	MI 44	MI 550	Unknown	Operational monitors	1. Warmed housing did not solidify sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
27	1. Freeze Trap No. 3/ Vent 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium, 200 to 350°F 4. Work request No. 2252	MI 187	MI 51	MI 550	Unknown	Operational monitors	1. Vent piping plugged with sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
28	1. Freeze Trap No. 3/ Float 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium, 200 to 350°F 4. Work request No. 2629	MI 144	MI 5Z	MI 550	Unknown	During actuation	1. Float not seated properly. 2. Local repairs: (a) replaced plugged section of vent piping,(b) heated freeze trap housing to melt sodium in shaft housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.
29	1. Freeze Trap No. 3/ Housing 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 1 3. 3-10 psi helium, 200 to 350°F 4. Work request No. 2629	MI 137	MI 44	MI 550	Unknown	During actuation	1. Warmed housing did not solidify sodium. 2. Local repairs: (a) replaced plugged section of vent piping, (b) heated freeze trap housing to melt sodium in shaft housing, (c) pressurized housing to clear sodium. 3. Allow sufficient cooling capacity around the cam shaft housing to ensure solidification of any sodium that may flow past the float.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 7 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
30	1. Freeze Trap No. 10/ Packing 2. Heat Transfer/ Coolant Storage 3. 33 224400	1. HNPF 2. Secondary drain tank 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 2447	MI 115	MI 52	MI 530	3250	Operational monitors	1. Packing worn out. 2. Part replaced. 3. Packing rings should be insulated from heat and hot sodium vapors which evidently contribute to wear and degradation of the packing rings.
31	1. Freeze Trap No. 5/ Shaft Stop 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Primary cold trap No. 2 (outlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1079	MI 321	MI 5Z	MI 550	Unknown	During actuation	1. Shaft stop missing. 2. Local repair, installed shaft stop in shaft assembly. 3. Tighter quality control and inspection on components that have been overhauled.
32	1. Freeze Trap/Cam Drive 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Secondary cold trap (inlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 115	MI 339	MI 54	MI 550	Unknown	Operational monitors	1. Cam drive shaft sagged and bent at packing. 2. Local repair; cam shaft straightened. 3. Post instructions that cal rod heaters are not to be used to heat freeze trap assemblies. Possible shortening of drive shaft may help to prevent this type of failure.
33	1. Freeze Trap No. 6/ Packing 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Secondary cold trap (inlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 115	MI 115	MI 52	MI 550	Unknown	Operational monitors	1. Gap at packing allowed helium to leak out of system. 2. Local repair; removed rough spots inside cam shaft housing. 3. Post instructions that cal rod heaters are not to be used to heat freeze trap assemblies. Possible shortening of drive shaft may help to prevent this type of failure.
34	1. Freeze Trap/Spring 2. Heat Transfer/Purification 3. 33 224234	1. HNPF 2. Secondary cold trap (inlet) 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 275	MI 410	MI 53	MI 550	Unknown	Operational monitors	1. Spring loose. 2. Component corrective modification; retainer springs replaced with steel spacers. 3. Either use steel spacers as integral design component or a spring of sufficient tension and material compatible with this type of atmosphere.
35	1. Freeze Trap/Spring 2. Heat Transfer/Intermediate Heat Exchanger 3. 33 222300	1. HNPF 2. IHX-3/freeze trap No. 13 3. 3-10 psi helium when draining sodium, 200 to 350°F 4. Work request No. 1003	MI 410	MI 55	MI 530	Unknown	During actuation	1. Spring stuck. 2. Component corrective modification; retainer spring replaced with a solid follower (steel spacer). 3. None.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 8 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
36	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-57	MI 218	MI 51	MI 530	330	Operational monitors	1. Vapor trap plugged. 2. Part replaced. 3. None.
37	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-85	MI 218	MI 51	MI 530	400	During inspection of system associated to failure component	1. Vapor trap plugged. 2. Part replaced. 3. None.
38	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-88	MI 218	MI 51	MI 530	1100	Operational monitors	1. Vapor trap plugged. 2. Part replaced. 3. None.
39	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-92	MI 500	MI BZ	MI 530	960	Operational monitors	1. Vapor trap plugged. 2. Trap replaced. 3. Perform engineering analysis of problem and redesign.
40	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-97	MI 500	MI BZ	MI 530	576	Operational monitors	1. Vapor trap plugged. 2. Trap replaced. 3. Recurring problem. Analyze and redesign.
41	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-99	MI 500	MI BZ	MI 530	720	Operational monitors	1. Vapor trap plugged. 2. Trap replaced. 3. None.

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TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 9 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
42	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operations weekly report, 1/68	MI 500	MI BZ	MI 530	954	During preventive maintenance	1. Vapor trap plugged. 2. Trap replaced. 3. None.
43	1. Traps/Argon Line 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operations weekly report, 2/68	MI 218	MI 51	MI 530	13,380	During preventive maintenance	1. Vapor trap plugged. 2. Part replaced. 3. None.
44	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-40, 8/65	MI 218	MI 51	MI 530	2670	Operational monitors	1. Vapor trap plugged with liquid metal condensation. 2. Part replaced. 3. Perhaps a longer drip time of fuel assembly in transfer port plus a slower rate of removal from molten sodium.
45	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-43, 9/65	MI 218	MI 51	MI 530	400	Operational monitors	1. Vapor trap plugged. 2. Part replaced. 3. None.
46	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operation maintenance report, 6/68	MI 500	MI BZ	MI 530	1860	During actuation	1. Vapor trap plugged. 2. Trap replaced. 3. None.
47	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operation maintenance report, 8/68	MI 218	MI 51	MI 530	1440	During routine inspection	1. Vapor trap plugged. 2. Part replaced. 3. None.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 10 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
48	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operation maintenance report, 9/68	MI 218	MI 51	MI 530	720	Routine instrument reading, direct observation	1. Vapor trap plugged. 2. Part replaced. 3. None.
49	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operation maintenance report, 10/68	MI 500	MI BZ	MI 530	720	During preventive maintenance	1. Vapor trap plugged. 2. Trap replaced. 3. Perform engineering analysis of problem and recommend change in design.
50	1. Traps/Wire Mesh 2. Heat Transfer/Driers and Traps 3. 33 224640	1. EBR-II 2. Primary/argon system 3. - 4. Operations weekly report, 7-31-68	MI 218	MI 51	MI 550	15,240	Operational monitors	1. Vapor trap plugged. 2. Local repair; trap was removed, cleaned, and reinstalled. 3. Install heaters on trap to permit blowing down without removal of trap.
51	1. Traps/Wire Mesh 2. Heat Transfer/Inert Gas Supply and Monitors 3. 33 224600	1. EBR-II 2. Secondary/gas bleed off 3. - 4. Operation maintenance report, 6-5-68	MI 118	MI 51	MI 550	14,880	During actuation	1. Vapor trap plugged. 2. Temporary repair. 3. Closely monitor vapor trap level indicator when filling vessel. Periodically test and operate vapor trap.
52	1. Traps/Vent Pipe 2. Heat Transfer/ Purification 3. 33 224233	1. EBR-II 2. Primary/temporary cold trap loop 3. - 4. ANL-6705	I 500	I BZ	I 530	1000	Protective systems	1. Vent pipe developed a small hole in its wall. Damage was under $25, but one person slightly burned by sodium. 2. Unknown. 3. Requires more stringent quality assurance on pipe inspections before installation.
53	1. Traps/Heater 2. Heat Transfer/Driers and Traps 3. 33 224640	1. EBR-II 2. Primary/fission gas monitor 3. - 4. PMMR-31	MI 500	MI 12	MI 530	2190	Direct observation	1. Heater burned out. 2. Part replaced. 3. None.

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TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 11 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
54	1. Traps/Wire Mesh 2. Heat Transfer/Driers and Traps 3. 33 224640	1. EBR-II 2. Primary/fission gas monitor 3. - 4. PMMR-57	MI 218	MI 51	MI 530	4400	Operational monitors	1. Vapor trap plugged with sodium. 2. Local repair; unit was heated and sodium drained. 3. If space permits, increase size of trap for longer service.
55	1. Traps/Wire Mesh 2. Heat Transfer/Driers and Traps 3. 33 224640	1. EBR-II 2. Primary/argon purification 3. - 4. PMMR-108	MI 218	MI 51	MI 530	11,320	Operational monitors	1. Wire mesh plugged. 2. Part replaced. 3. None.
56	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. PMMR-102	MI 218	MI 51	MI 530	475	Operational monitors	1. Vapor trap plugged. 2. Part replaced. 3. None.
57	1. Traps/Wire Mesh 2. Nuclear Fuel Handling and Storage Equipment /Cooling 3. 33 235140	1. EBR-II 2. Fuel handling machine 3. - 4. Operation weekly report, 11/67	MI 500	MI BZ	MI 530	2156	Operational monitors	1. Vapor trap plugged. 2. Trap replaced. 3. None.
58	1. Traps/Adjusting Shaft 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 33 281000	1. EBR-II 2. Main steam (trap PVT-5) 3. - 4. PMMR-4	MI 500	MI 59	MI 530	1200	Repair of primary failure	1. Adjusting shaft broken. 2. Part replaced. 3. Determine cause of failure and confer with manufacturer before replacing part. Redesign of part may be necessary.
59	1. Traps/Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 33 281000	1. EBR-II 2. Main steam (trap PVT-5) 3. - 4. PMMR-4	MI 500	MI BZ	MI 530	1200	Direct observation	1. Gasket worn out. 2. Part replaced. 3. Determine cause of failure and confer with manufacturer before replacing part. Redesign of part may be necessary.

* I = INCIDENT MI = MINOR MALFUNCTION
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TABLE 1-114

FAILURE DATA FOR TRAPS (GENERAL)

(Sheet 12 of 12)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
60	1. Traps/Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 33 281000	1. EBR-II 2. Main steam (trap PVT-2) 3. - 4. PMMR-75	MI 500	MI BZ	MI 530	5990	Preventive maintenance	1. Gasket worn out. 2. Part replaced. 3. Determine cause of failure and confer with manufacturer before replacing part. Redesign of part may be necessary.
61	1. Traps/Steel Ball 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 33 281000	1. EBR-II 2. Main steam (trap PVT-5) 3. - 4. PMMR-4	MI 500	MI BZ	MI 530	1200	Repair of primary failure	1. Steel ball lost. 2. Part replaced. 3. Determine cause of failure and confer with manufacturer before replacing part. Redesign of part may be necessary.
62	1. Traps/Drain 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 33 283000	1. EBR-II 2. Condensate system/air ejector 3. 92°F at 230 psig 4. PMMR-39	MI 500	MI 65	MI 530	2670	Routine inspection	1. Failure of drain trap occurred twice in three months - chemical or electrochemical reaction. 2. Local repair. 3. Faulty casting - replace trap.

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TABLE 1-115

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TRAPS (GENERAL)

COMPONENT SUBTYPE SODIUM FREEZE TRAPS

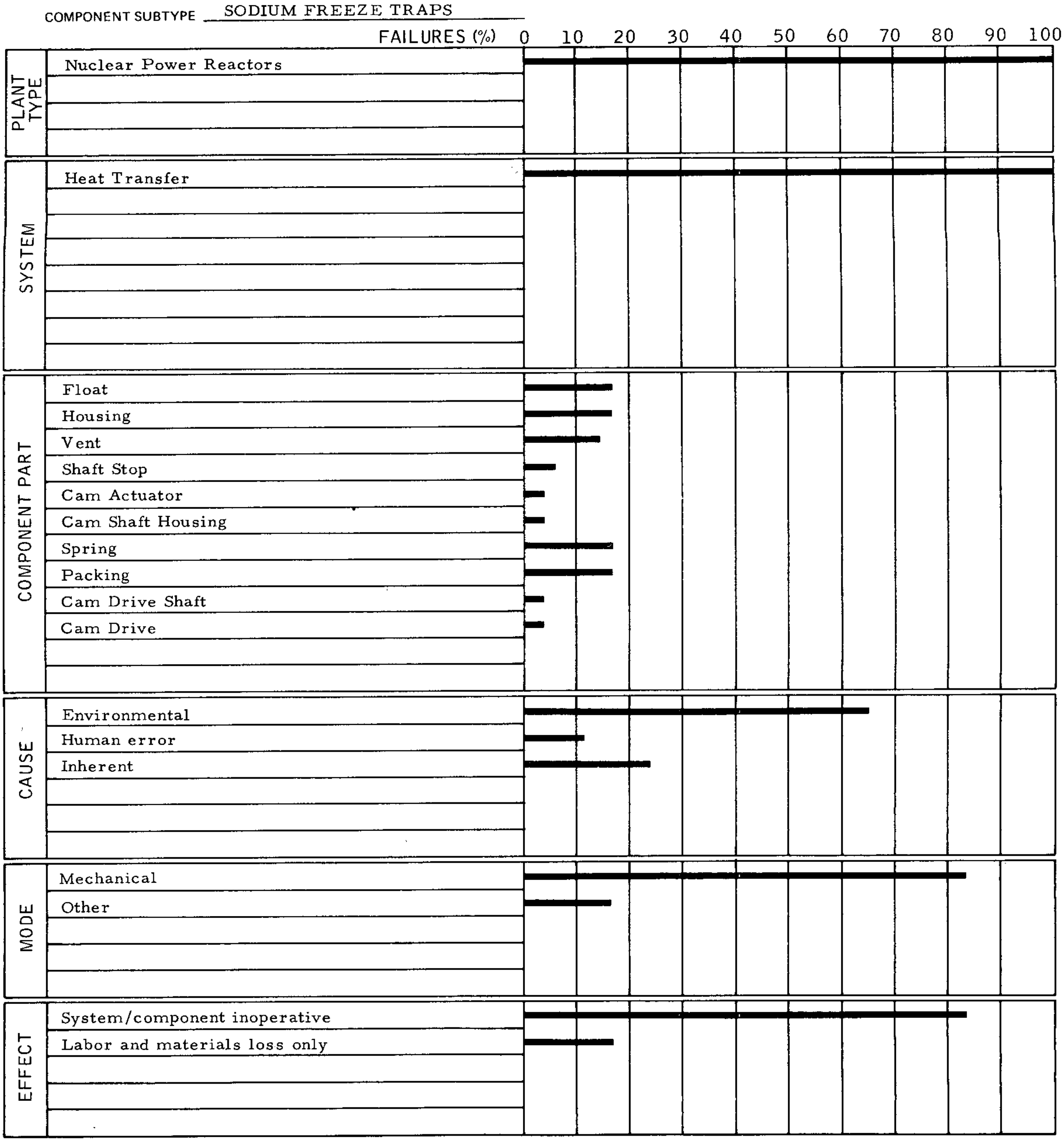


TABLE 1-116

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TRAPS (GENERAL)

COMPONENT SUBTYPE SODIUM VAPOR TRAPS

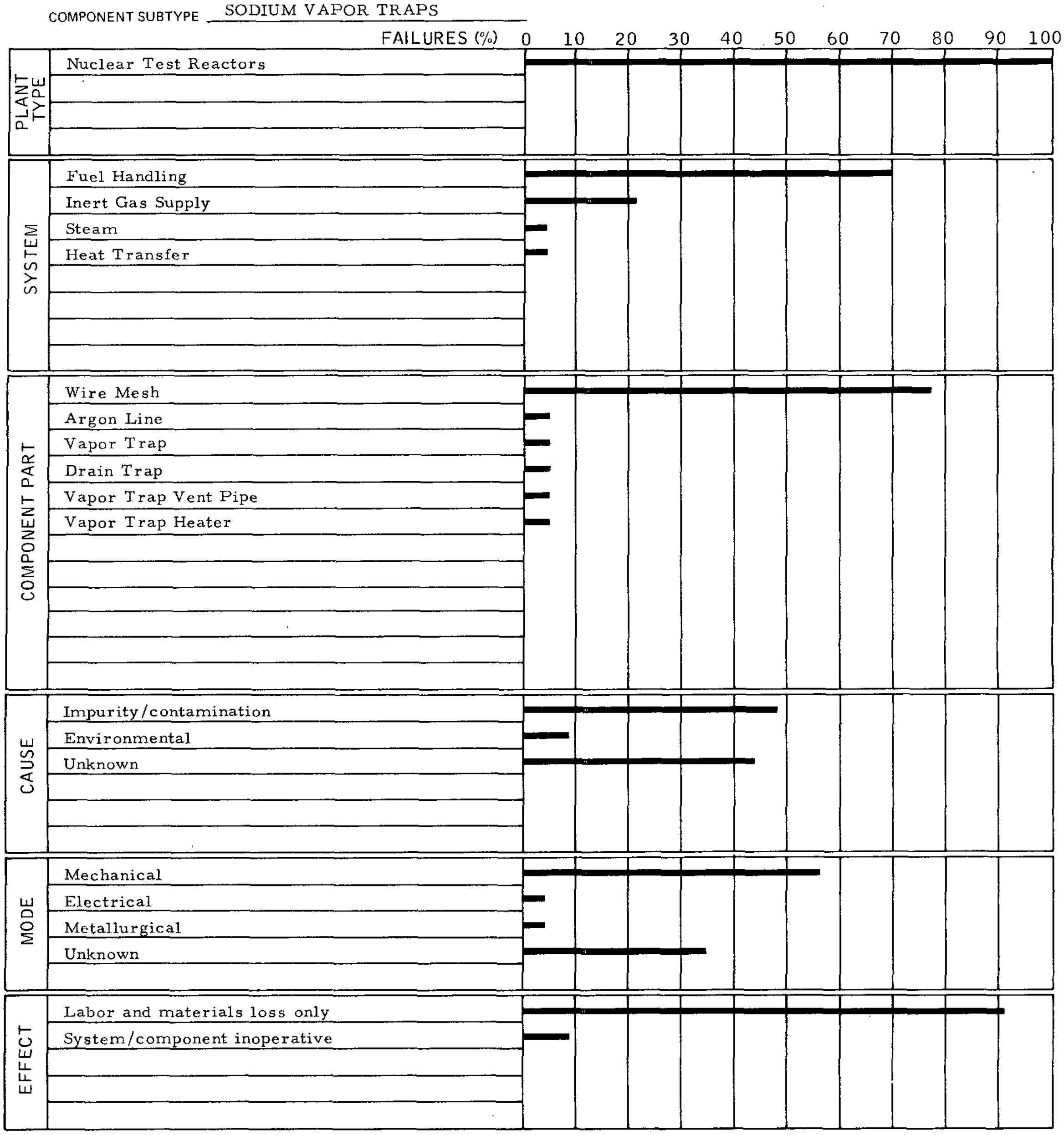


TABLE 1-117

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT TRAPS (GENERAL)

COMPONENT SUBTYPE STEAM TRAPS

PLANT TYPE	Nuclear Test Reactors
SYSTEM	Steam, Condensate, Feedwater
COMPONENT PART	Gasket
	Adjusting Shaft
	Steel Ball
CAUSE	Unknown
MODE	Mechanical
	Unknown
EFFECT	Labor and materials loss only

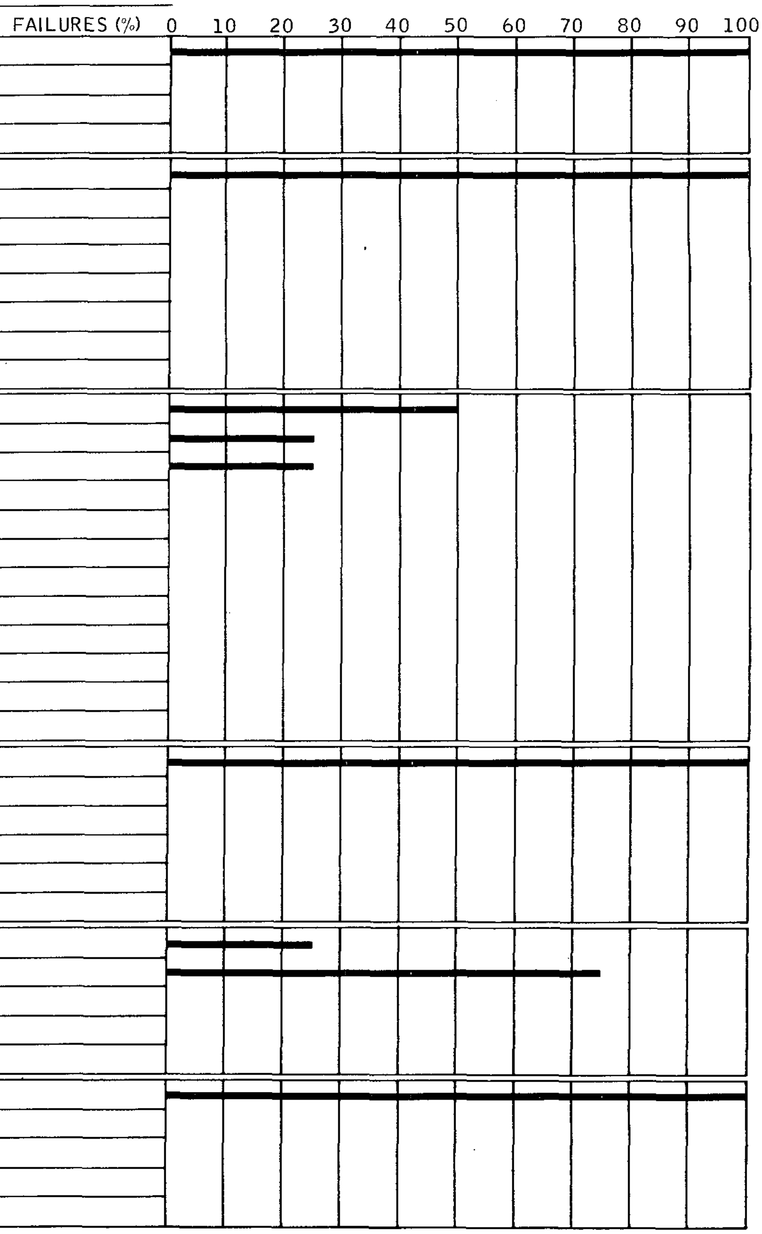
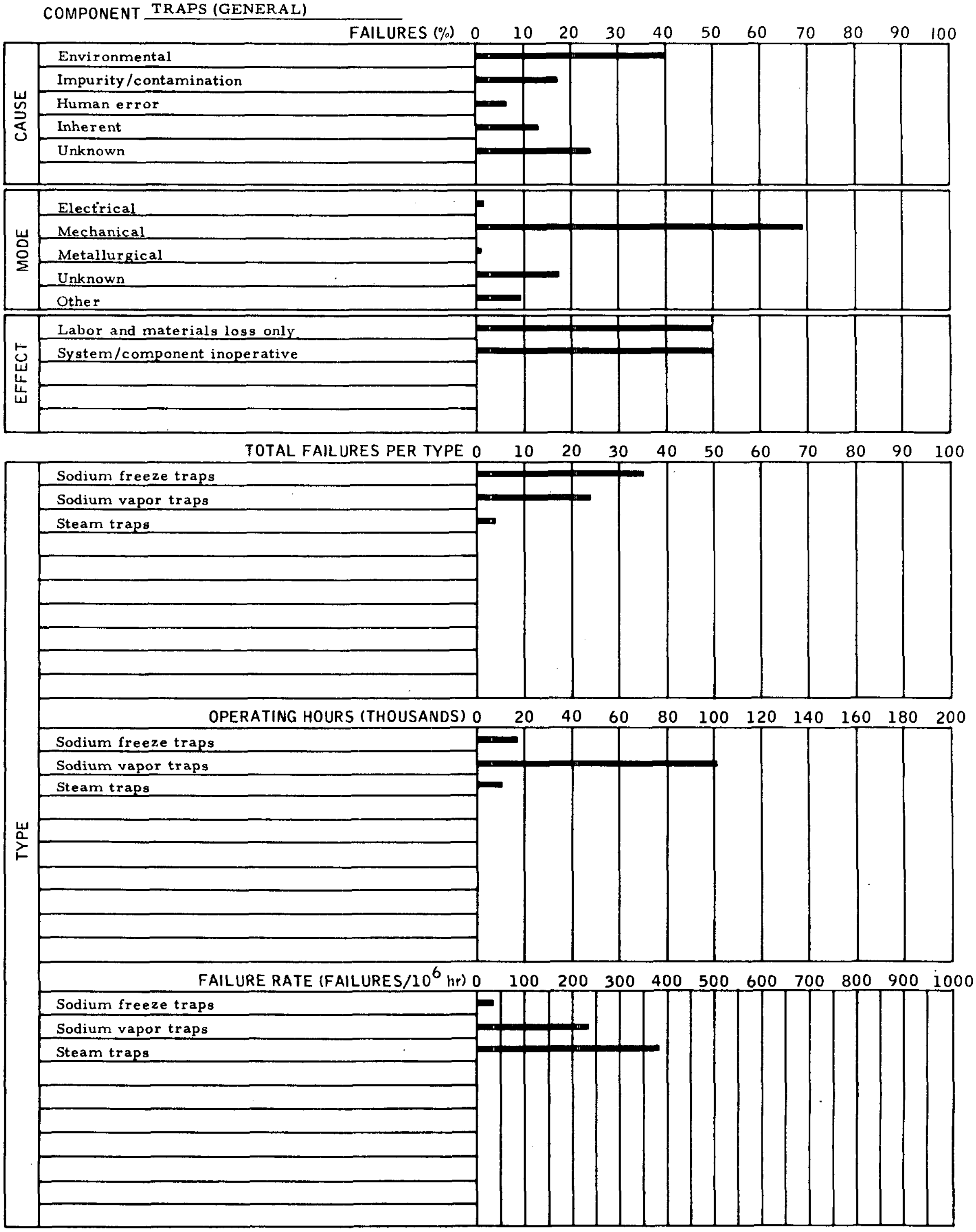


TABLE 1-118

GENERAL SUMMARY

COMPONENT TRAPS (GENERAL)



14. Valves

a. Introduction

The valve types for which malfunction data are considered in this section include: gate, globe, butterfly, check, and safety valves. The failure experience includes service in gases, steam, water, and sodium. A total of 287 failure reports collected from plants, facilities, and loops in connection with nuclear reactors are included in this section. The collected information is itemized in Table 1-119.

Typical valve failure experience includes: (1) external leaks, internal leaks, mechanical damage to component parts, and non-operation. Approximately three-quarters of these reported failures were detected by direct observation and one-quarter by monitors. Of the failures discovered by observation, about one-third were found during preventive maintenance.

b. Summary of Tabulated Data

The data in Table 1-119 are summarized in Tables 1-120 to 1-126. The data are subdivided into water loops: circulating, condensate, and feedwater; then into steam, miscellaneous, and sodium loops.

Under the above headings, the data are further grouped into:

1) Type of plants where the information came from.

2) Systems where the valves actually operated.

3) Valve components which failed.

4) Failure cause.

5) Failure mode.

6) Failure effect.

The majority of information, as indicated in the Failure Distribution Tables 1-120 to 1-125, comes from experience collected from nuclear test reactors and component test facilities, where valve operating environments and requirements are perhaps more severe than in regular power generating plants. The tables give failure occurrence percentages for the main valve components for each group of fluids. As would be expected, the circulating water table shows no valve body failures, since low pressure and temperature requirements can be easily fulfilled with high reliability. Low temperature and somewhat higher pressures of condensate water shows some failures, including flange gasket failures. Feedwater with medium temperatures but high pressures show an increase in failures with the accent again on the flanges. Valve body failures in the high temperature and pressure steam lines show the occurrence of compatibility problems between seldom-used housing materials and water contaminants (chlorides). The miscellaneous valve body failures are the result of experiments for material compatibilities. Sodium valve body problems are mainly grouped around the reinforcements after replacing bellows seals with freeze seals. The subject experience on sodium service valves is probably not representative of future service, because so many of the valves have been reworked.

Valve seat problems for valves in water account for a much larger percent of the problems compared to the valves in steam and sodium service.

The explanation for the large ratio of stem failures in the circulating water systems is probably due to the fact that the water is not chemically treated and that the valves are more frequently used than those in other loops.

Actuator and linkage data are presented in Section D.5, Valve Operators.

Table 1-126 provides a general summary of the data as to cause, mode, effect, and the total number of valve failures. Computation of updated failure rate information has been discontinued until a later date.

c. Discussion

To aid in understanding the following discussion, characteristics of the various valve types are given in the following discussion.

(1) General

Components in the primary loop of a nuclear reactor must have a high degree of reliability since accessibility for repair is limited and depends in part on the radioactive decay time of the primary loop fluid. Valve redundancy tends to generate rather than solve problems. Valves with internal components removable from the reactor containment without too much disturbance to the loop are under test now to facilitate maintenance of seldom-used valves.

Compatibility of valve component materials with the fluid carried in the piping is important to reduce maintenance problems. This requirement is sometimes neglected during repairs if proper spare parts are not stocked, and substitutions made.

Improperly performed quality assurance and quality control lead to startup troubles and malfunctions. Some of these problems become evident only after a long period of operation.

Even the best designed and manufactured valves will perhaps malfunction if servicing and shipping instructions are not followed, foreign material is left in the loop, or valve actuators are improperly installed.

Plant operators' manual should instruct operators that valves are not to be torqued beyond values given by the manufacturer for each extreme position.

Each valve in the loop shall be marked in accordance with the plant operators' manual to reduce the likelihood of actuating a wrong valve, particularly during emergencies. The marking should include the normal and the special valve positions as an aid in emergency applications.

Valves can be connected to the piping by flanges, by screw connections or by welding.

Flanged Connections

Use of flanged connections shall be reduced to a minimum in sodium systems or systems with high bending stresses and thermal transients.

Manufacturer recommendations with respect to gasket material and specifications, for bolts and nuts material (heat-treated state), and for applicable maximum torques in cold and in hot conditions should be used or References 1, 2, and 3 should be consulted. Good practice dictates the replacement of gaskets whenever the joints are loosened.

Bolts exposed to high temperature (600°F and above) are subject to creep; therefore, after each major temperature cycle the flange bolts should be checked for tightness.

A series of steam and water leaks reported at flange connections previously reported in this handbook were corrected by using improved gasket materials.

Threaded Connections

Threaded connections are mainly for small-sized valves in low temperature (300°F and below) and pressure (150 psig) applications. Seal ring and torquing instructions supplied by the manufacturer should be followed. Do not overtorque sizes of 1 in. and below, since cracking of the material at the root of the thread is the usual consequence. Crack propagation is sometimes so slow that the leak appears only after a few weeks or even months.

Welded Connections

Two types of welded connections are used. For small pipe sizes (3 in. and below) socket welds are acceptable and for larger sizes butt-welded connections are typical.

Welding instructions are given in codes, usually listed in the procurement specifications of the valves. Welding quality tests should be performed even for small surface welds applied during maintenance repairs.

(2) Detailed Discussion

For the detailed discussion below, the valves will be grouped in accordance with the fluids carried: gas, steam, water, and liquid sodium.

Failures of valve components are discussed in the following groups: body, including bonnets and yokes; seat, considering also discs, plugs, and diaphragms; and steam, including stem extensions, bushings, packings, and glands. At the end of each discussion, recommendations are given based on the analyzed failures.

Gas Valves

The following gaseous fluids are considered: air for instrumentation signal transfer and for valve actuator systems and inert gases (e.g., nitrogen, argon, and helium) used as cover gases above the free surface of liquid sodium. Air is usually at environmental temperatures of 50 to 90°F and pressures not higher than 200 psig. Cover gas temperatures approximate 900°F and the pressure is seldom above 300 psig.

Body — Valves carrying high-temperature cover gases required bonnet and stem reinforcement.

Seat — A valve supplying air for a control valve actuator leaked enough to actuate the control valve intermittently, causing serious plant disturbances.

Such seat leakage problems were the results of foreign particles carried to and partially impressed into the valve seats. Corrosive vapors in gas/air lines have developed sufficient corrosion to leak through the valve seats. In one case, corrosion caused the valve plug to stick in the valve seat. Valve component damage occurred due to a fast-acting, high-force actuator.

In a special valve, the spring load was so high that the ball type plug stuck in the seat. A new spring with a reduced coefficient solved the problem.

Stem — One case of bushing and stem galling and one case of worn packing is reported in the listing. Shafts and bushings of air dampers became stuck in a venting system.

Other — O-rings wore out in some valves causing frequent maintenance. The valves were redesigned.

Recommendations — As was earlier suggested, gaskets should be replaced whenever the seal is loosened. Keep spare seal rings in stock and follow bolt torquing instructions.

Use upstream filters and desiccants to maintain clean, smooth valve seats and eliminate leakage.

Keep valve stems clean and free from paints or corrosive lubricants.

The use of extreme force in closing valves should be avoided. Back off manually operated valves slightly from the end positions.

Apply packing materials and torquing procedures as suggested by the manufacturer. Accurate maintenance records will help to determine the time intervals for packing changes.

Selection of proper valve types (Figures 1-31 through 1-35), sizes, and materials compatibility is stressed.

Steam Valves

Since industrial and electrical power generating plants have used the basic types of these valves for a long period of time, the following discussions refer to types built more specifically for nuclear fueled plants.

Body — Where flanged connections are still in use, new-type gaskets and bolts have improved the leakage problems.

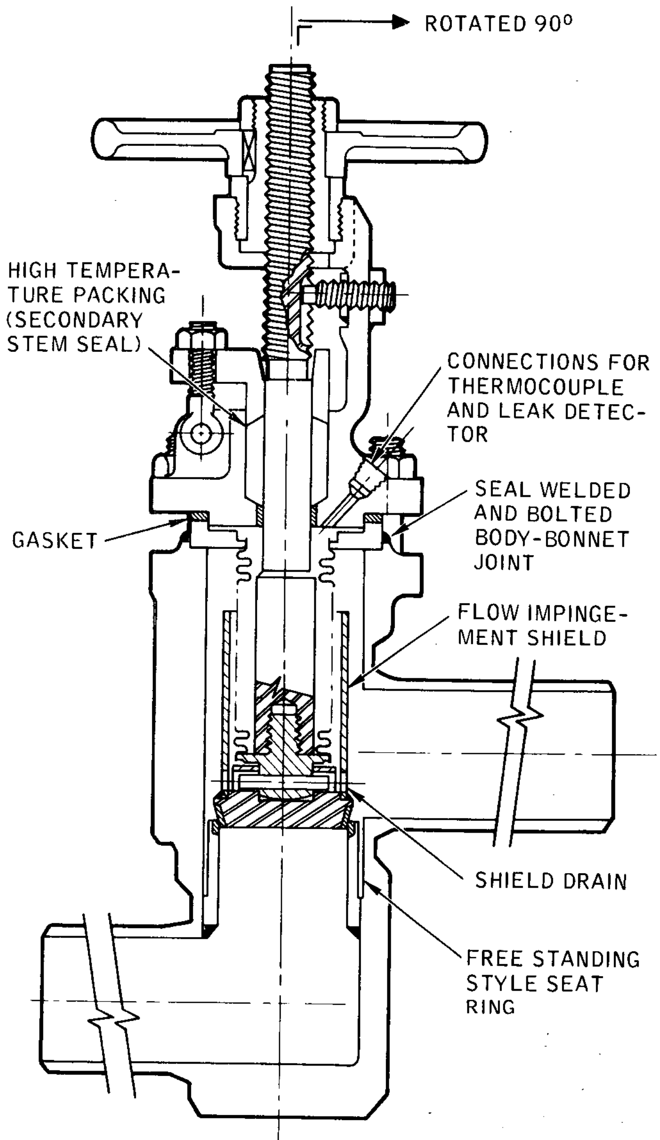


Figure 1-31. Blocking and Diverting Valve (Bellows Stem Seal)

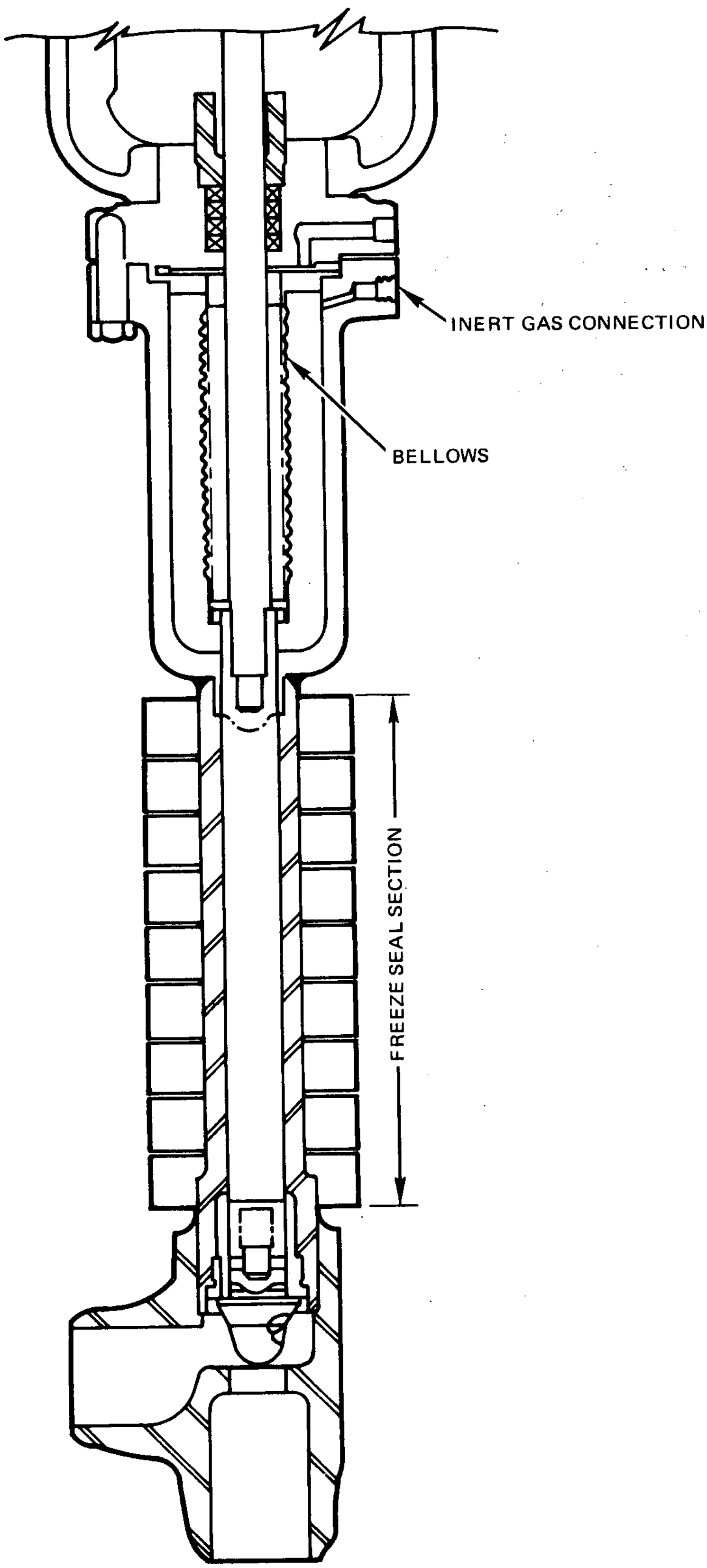


Figure 1-32. Combination Freeze-Stem Bellows Seal Valve

7693-5466

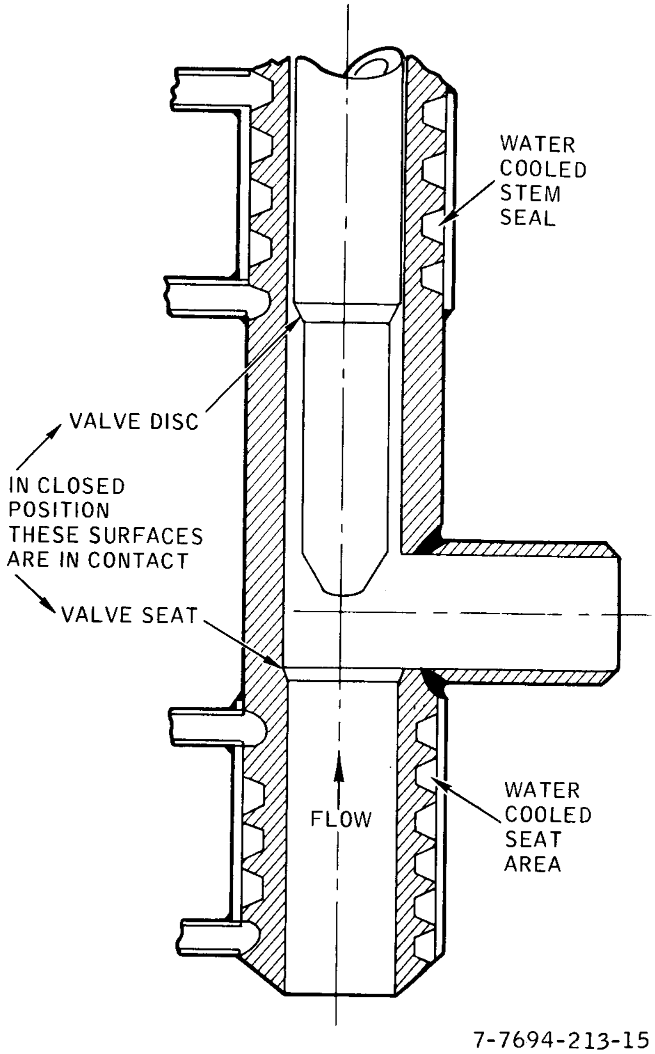


Figure 1-33. Freeze-Seat-Type Valve

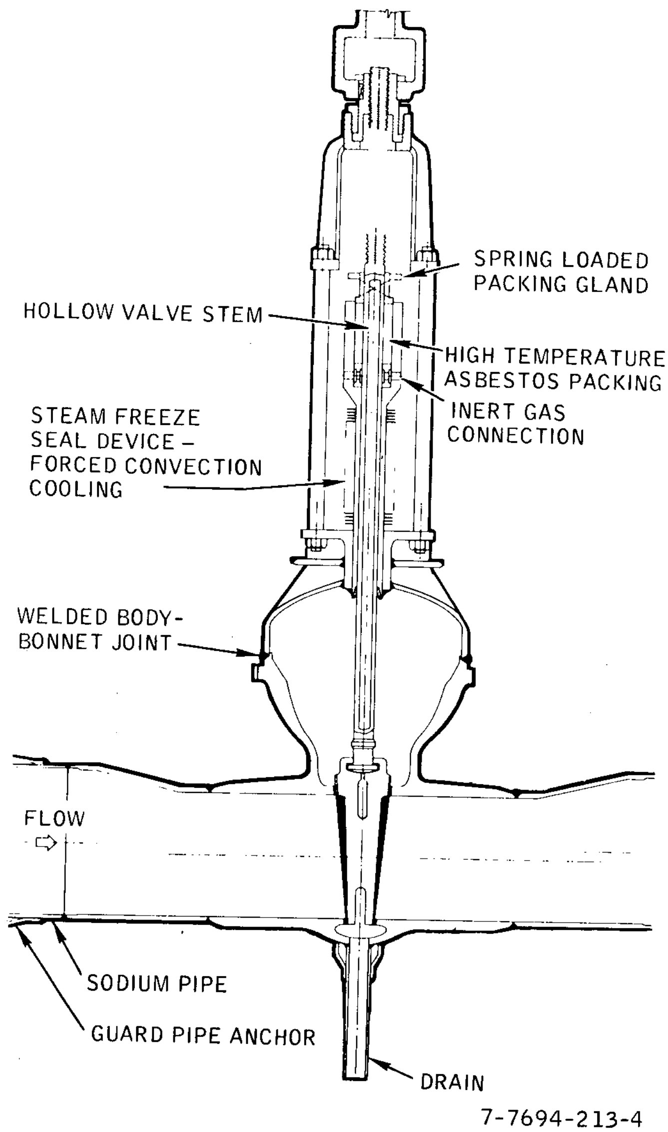


Figure 1-34. Sodium Blocking Valve

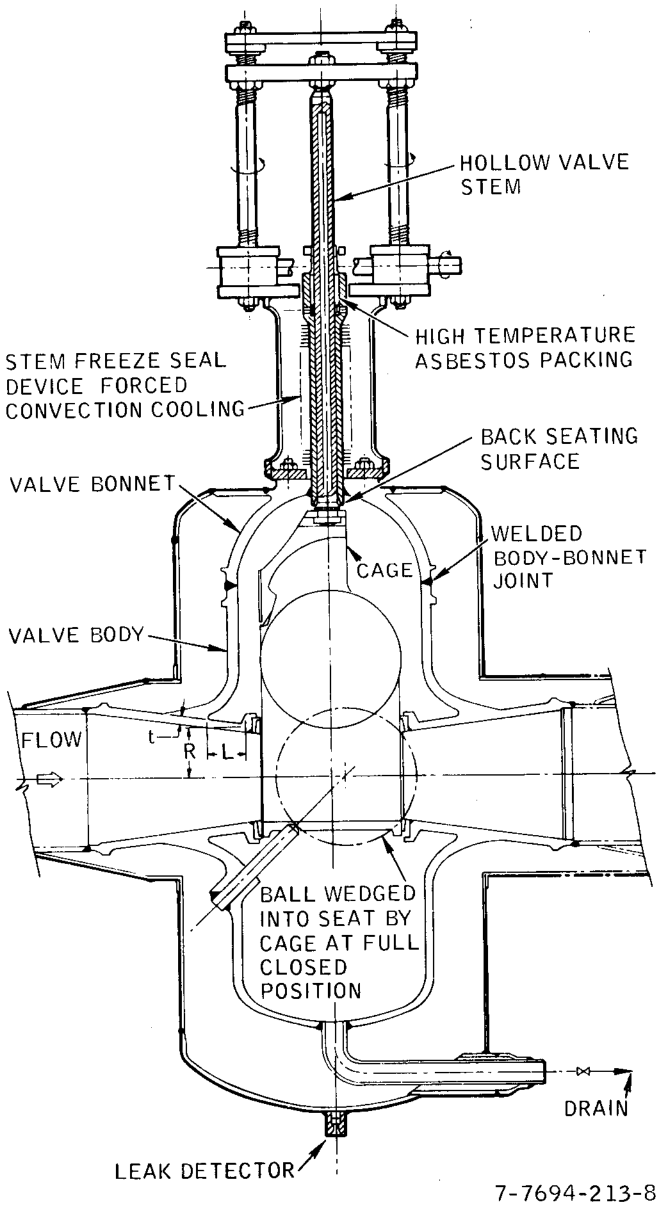


Figure 1-35. Sodium Throttling Valve

Valve bodies of Type 347 SS material developed strong chloride stress corrosion cracks, which can result in long plant operational delays. Type 347 SS valves were replaced by valves of 2-1/4 Cr - 1 Mo type material.

High-velocity, low-quality steam generates erosion damage on the internal surface of a valve body. This damage may be restored by fill-in welding.

Seat — The majority of internal valve leakage is the result of seat or plug erosion at high steam velocities.

Steam also leaks through cracked seats, which frequently is the consequence of extreme closing force applied.

Valve seat cracks are occasionally developed by thermal stresses following steep thermal gradients in high-temperature plant operations.

Stem — Frequently used valves naturally wear faster. Wear is accelerated by tight tolerances between stem and guides at high temperatures. Noncompatible packing material can also reduce the service life of a stem and improperly installed packing will leak earlier.

Recommendations —

Body — The danger of chloride stress corrosion exists in high-temperature (over 1000°F), high-pressure pipe loops fabricated from Type 300 stainless steels. If hydrostatic testing with water rather than some other fluid is necessary, use highly purified water with chloride content below 0.1 ppm.

Select system conditions so as to reduce the probability of flashing inside the valve body since this will cause erosion, or corrosion, thereby reducing valve life expectancy. If a valve in a near-saturated steam loop may experience high-flow velocity of degrading steam quality, placing a condensate separator upstream will improve valve function and life span by reducing erosion.

Seat — The seat at plug surfaces contact point should be properly lapped with hard materials (usually Stellite) to provide longer service life.

Valve operators' manual should contain instruction to avoid application of excessive forces (by wrench or cheaters) in either of the extreme valve positions, which may result in either seat welding or seat cracking.

In high-temperature, high-pressure steam lines, valve seat cracking caused by thermal transients can be greatly reduced by requesting a uniform wall thickness. Some flexibility in the seat carrying section assures less leakage through the equalizing of small distortions.

Stem — A major percent of valve stem leaks are the result of improper packing methods. The valve maintenance manual must include proper instructions for valve stem packing procedures. The valve maintenance schedule must consider the frequency of operation of each valve in the plant.

Water Valves

Valves built for water show a great variety in type and size. Usually the temperature ratings are below the steam saturation point; pressure rating may reach the critical pressure. Since water valve development is well advanced, problems are mainly associated with the high-pressure, fast-acting type valves.

Body — The problems with flanged steam valves are also valid for high-temperature and high-pressure water applications. For low pressures and temperatures, carbon or ferritic steels are used; however, near critical pressures, alloy steels should be used. Bronze valves are used only in low-pressure and low-temperature pipe lines.

Flanged or even screw type connections may be justified at lower pressure in order to facilitate maintenance of frequently actuated valves. Facility design should minimize load input to the valve and the higher corrosion sensitivity of the threaded connections should be considered in the maintenance requirements.

Lack of proper quality control has resulted in: body leakage and even rupture, while smaller failures have required early valve repairs. Improper material selection and the resulting incompatibility yielded failures of plastic valves.

Seat — Valve plug and seat cracking probably resulted from the use of closing forces above the safe limit. Similar damage can be the consequence of maladjusted valve actuators, or spring loading mechanism for safety valves. A loose valve seat was perhaps the result of poor workmanship and quality control.

Relapping of closing seat surfaces have eliminated seat leakages in safety and control valves. The same applies to seldom-used valves such as sight glass valves or cooling-water-spray shut-off valves.

If possible plant control malfunctions are not considered in selecting valve sizes, unstable subsystem operations may result.

Solenoid valve diaphragm cracking can be the result of high closing force, or fluid incompatibility with the diaphragm.

Stem — Problems with these valve components are similar to those for steam valves. Force applied to the stem above the buckling limit caused permanent bending or worn stem threads. Packing and consequent gland galling resulted either in rough control operation or the stem jamming in the open position. Improper thermal expansion tolerances between stem and gland can make a valve inoperative. Good packing material should have enough resiliency to seal slightly above design pressure for a short period of time. Dried out and worn packings will leak. Instability of valve spring constants or improper adjustment may have caused the early opening of a safety valve or the poor closing characteristics.

Recommendations — Many of the recommendations given for steam valves also apply to valves for water service:

1) Select valves with material compatibility or protect the valves from water impurities like chlorides, boron, hydrogen, etc. Type 300 SS material may be sensitive to each in the few-ppb range.

2) Since nuclear reactor scrams reduce heat generation at a faster rate than fossil-fuel-operated plants, thermal stresses will tend to be more severe in the valve body and seat area. Increased attention must be given to the design and selection of valves for this service.

3) Fast-acting control valve actuation is needed to meet reactor scram requirements.

4) High pressure drops in control valves can excite vibration and cavitation problems.

5) Materials should be selected so as to have compatibility between body, seat, plug disc, and lapping materials.

6) Maintenance followup programs should be introduced in each plant to establish maintenance schedules for: seat-plug lapping periods, stem wear checking, changing dried out or worn out packing, and operator linkage-wear inspection.

7) Manufacturers' instructions should be requested or plant maintenance experiences collected for packing material selection, packing procedures, and torquing values for high pressure valves in each plant.

8) Valve identification marking methods should be defined and tags attached to the valves showing normal and emergency positionings. Plant operators' manual should require checking of the position of manually operated valves after maintenance and repair periods.

Liquid Sodium Valves

Functions of the liquid sodium valves are similar to water types; however, differences are: in the material selection because of sodium compatibility problems, in the in-leakage limitations because of the high chemical affinity of sodium for oxygen (in air), in the stress analysis because of the higher heat transfer and conductivity coefficients of sodium as compared to water, and in the sizes. Some variations in conventional valve designs that have performed satisfactorily in sodium systems are illustrated in Figures 1-31 through 1-35.

Basic valve materials for liquid sodium service are alloy steels (Cr-Mo types) and stainless steels (Type 300 or Type 400 series). Welded connections are used almost exclusively. The welding of these dissimilar materials may represent a problem area.

Presently the valve stem seal types depend on the valve size. Small valves tend to use bellows seals, with the maximum deflection and allowable fatigue stresses vs operating cycles as the limiting parameters. Larger-size valves are built with freeze seal stems to reduce extreme valve dimensions. Exotic types of seals are under consideration with some in the testing stage.

Body — When flanged connections are in the loop, loose bolt connections would be expected after thermal transients and the resulting leak may develop into sodium fire. A similar situation could be the consequence of O-ring deformation after expansions and contractions.

A number of bellows-sealed valves were modified to freeze-seal stems, with the result that the bonnets and actuator linkages had to be reinforced to handle the increased actuating force required to shear residual oxides.

Seat — If in high-temperature sodium (at and over 1000°F) the seat surface pressures are sufficiently high to bring the disc-seat materials within molecular distance of each other, seat welding may occur, rendering the valve inoperative. As indicated in References 5 and 9, harder seat lapping materials (e.g., Stellite) resist seat welding even at high surface pressures.

Sodium leakage may develop at the back seat of a fully open valve if the primary (and secondary) seals fail and the contacting surfaces are not maintained in good condition. Seat and plug relapping restores valve seat seals.

Improper quality assurance and control can lead to early malfunctions of valves with inherent design errors or manufacturing misalignment between seat and plug/disc.

Forcing a plug into the seat may distort the seat so that leakage develops. This is possible in either the fully open or fully closed position. Under certain circumstances this extreme force can cause seat-self-welding (References 4 and 5).

Stem — Different configurations of bellows-type stem seals have been used. As seen in Figure 1-31, the bellows are welded at the bottom part of the stem and at the bonnet flange at the top. This gives a complete mechanical seal with a moving flexibility for the plug. Incomplete empirical design of the bellows and the increasing valve sizes resulted in such a high frequency of bellows failures that many of the sodium valves have been converted into frozen seal types, as shown in Figure 1-32. The freeze seal can be cooled by environmental air using fins around the bonnet, or by other fluids with temperature control within the bonnet. Safety requirements suggest a combination of the presently used seals. Forced air freeze seal and graphite asbestos gland packing is used for the gate valve in Figure 1-33. A series of freeze bellows-packing gland seals are depicted in Figure 1-34. Freeze seal and backup seat combination can be seen in Figure 1-35 for ball-type flow-control valve.

The failure reports list bellows cracks as a result of intergranular attack in the heat-affected zone of the weld and fatigue cracks in the welding. Fatigue stress cracks followed by sodium leaks can be blamed for the great majority of failures in bellows-sealed sodium valves.

Some failures were caused by sodium solidification in the bellows convolutions as a consequence of relatively high oxygen content. During the line thawing period, the valve was actuated before complete melting, thereby breaking the bellows.

In a solidified sodium line section, operation of the valve actuator was attempted, consequently rupturing the bellows. A frozen piping loop was heated in the middle section which contained a bellows-sealed valve, with the result that thermal expansion overpressure ruptured the bellows.

Bellows failures introduced by valve components are listed as follows: (1) uneven expansion of convolutions because of lack of guidance resulted in local overstresses which accelerated cracking, (2) bend valve stem rubbed the bellows wall and produced leaking hole failures, (3) vibration transmitted to a valve abbreviated the fatigue life of the bellows, (4) flow fluctuations which generated vibration, led to reduced bellows fatigue life, and (5) direct impingement of sodium stream on a bellows resulted in early fatigue failure.

The increased use of freeze seals in valves has identified several problem areas. When the stem is removed from the sodium seal area, a thin sodium layer clings to the surface of the stem. This thin layer forms an oxide, which is considerably harder than the pure sodium. After several strokes of the valve stem, sodium oxide may fill the seal gap, thereby substantially increasing the break-away torque required. The higher actuating torque leads to a malfunction which requires valve top work (bonnet) and stem reinforcements. Small gap tolerances aggravate the problem. Valves which are seldom actuated require additional heating because of the higher melting temperature of the oxidized material in the seal area.

Related failures, but independent of the seal type, resulted in three cases of non-concentricity of the stem and bushing.

A unique valve malfunction occurred due to interference between the moving stem and the electrical wires of the sodium leak detectors in the valve bonnet.

A discussion of freeze seal problem areas and proposed techniques for improving freeze seal design are given in References 7 and 8.

Recommendations — For valve bodies, body shapes which are adaptable to reliable stress analyses should be selected. Abrupt body cross section changes are to be avoided in order to reduce stress concentrations, thermal stresses, and seat distortions. However, slightly flexible seat supports tend to give a tighter seal.

Minimizing flow directional changes tends to improve valve operation by reducing flow-induced vibrations, and tends to provide lower pressure loss across the valve.

The high chemical affinity of sodium excludes the use of organic materials (e.g., Teflon) in valves even in such applications as in the presence of sodium vapor at low pressures and temperatures (e.g., in cover-gas exhaust line valves).

Check valve leak problems are less likely if the disc is closing in the vertical position. Horizontally seated check valves are spring loaded; however, springs with stable characteristics over a long period of time in a high-temperature environment are yet to be developed.

In general, safety valves are not necessary in liquid sodium loops. Overpressures due to fluid hammer effects can be controlled by properly selecting valve closing times in consideration of pump-motor inertias. Pressures generated by release of chemical energy can be safely controlled by rupture discs.

The use of bellows seals is satisfactory for valve sizes up to 4 in., if the physical dimensions are acceptable and the fatigue life of the bellows is compatible with the expected actuation cycles. New bellows are being designed using theoretical methods and incorporating materials tested for long fatigue life at high temperatures (Reference 6).

Important design considerations are as follows:

1) Bellows stresses are greatly reduced if the inert gas pressure applied outside the bellows is equal to that of sodium.

2) Elimination of vibrations enhances fatigue life expectancy.

3) Limit seating force to avoid seat distortion.

4) Provide for complete sodium drainage in any valve position.

5) Install some type of sodium leak detector in the valve bonnet area.

6) Plant operators' manual should contain filling, drainage, and thawing instructions emphasizing that thawing be started at that end of the line where adequate space is available for sodium expansion without pressure rise.

The freeze seal is a relatively thin layer of sodium between the stem and guide at a temperature which can maintain the seal but with a shear stress low enough to allow valve stem movement with reasonable torque loads.

The main design and operation considerations are:

1) Use of cover gas with low oxygen content to reduce the oxidization process.

2) Actuating force can be reduced with only rotating motion in the seal area.

3) Seal reliability is improved with the addition of other types of seals and the inclusion of backup valve seats.

4) The valve actuator must be able to apply the break-away force as well as properly position the valve and supply a sufficient but not excessive seat closing force.

5) Fast valve stroking action may also be required.

6) Heaters in the seal area of seldom-used valves may be required to melt the seal material with high sodium oxide content.

The selection of an actuator requires careful consideration of material compatibility, not only of liquid and vapors of sodium, but also with the different cover gases. The effect on the electrical insulation of electrical motors or the solenoid actuator must be included.

The principal investigator of this material was K. A. Bonyhady. If additional information regarding valve failure experience is required, contact K. A. Bonyhady, E. Ferguson, or B. S. Pilling at LMEC.

Pages 1-349 through 1-352 deleted.

d. References

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 1 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Valve/Float 2. Feedwater Supply and Treatment System/ Chemical Treatment Facility 3. 20 273300	1. SCTI 2. Treated water system valve to precoat filter and demineralizer 3. - 4. Incident report No. 314 (11-3-66)	MI 182	MI 17	MI 550	4015	Direct observation	1. Circuit breaker to pump P-7 tripped as demand for water from P-7 was excessive, causing overload to pump. Thermal overload burned out. 2. Valve throttled to reduce flow and pump P-7 restarted. 3. Keep flow demand at system design limits.
2	1. Valve/Float 2. Feedwater Supply and Treatment System/ Chemical Treatment Facility 3. 20 273300	1. SCTI 2. Treated water system deaerator valve 3. - 4. Incident report No. 313 (11-2-66)	MI 182	MI 17	MI 550	3568	Direct observation	1. Circuit breaker to pump P-9 tripped due to excessive demand. Deaerator float valve stuck open. 2. Pump P-7 started to continue operation. System to P-9 returned to normal. 3. Keep flow demand at system design limits so that pump motors are not overloaded.
3	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump 3. - 4. Operations weekly report (2-28-68)	MI 500	MI BZ	MI 530	13,620	Direct observation	1. Seal ring surface was worn out. 2. Local repair, surface was remachined. 3. None.
4	1. Valve/Lower Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. 1250°F, 1265 psig 4. PMMR-27	MI 500	MI 52	MI 530	72	Operational monitors	1. Valve leaking. 2. Local repair. 3. Irregular control characteristics and noise during valve operation should be observed earlier. Plant operators' training should be improved.
5	1. Valve/Upper Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor drived feed pump (P5-VC-596) 3. - 4. PMMR-27	MI 500	MI 52	MI 530	72	Operational monitors	1. Valve leaking. 2. Local repair. 3. Irregular control characteristics and noise during valve operation should be observed earlier. Plant operators' training should be improved.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 2 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Valve/Lower Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-27	MI 500	MI 53	MI 530	72	Operational monitors	1. Valve leaking. 2. Local repair. 3. Irregular control characteristics and noise during valve operation should be observed earlier. Plant operators' training should be improved.
7	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-36	MI 500	MI 53	MI 530	908	Routine inspection	1. Valve seat worked loose. 2. Local repair, seat was retightened and spot welded into place. 3. Since the seats were welded in place not too long before, better workmanship could avoid this failure. Improve quality control over repairs. Assembly procedure needed.
8	1. Valve/Stem Connector 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-42	MI 500	MI 59	MI 530	480	Preventive maintenance	1. Valve thread connecting stem to operator was stripped. 2. Part replaced. 3. Assembly procedure needed.
9	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-72	MI 456	MI 55	MI 530	1610	Operational monitors	1. This was reported as a failure in a new valve. 2. Local repair. 3. Better receiving inspection or Quality Assurance before installation can prevent such malfunctions.
10	1. Valve/Nipple 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-25	MI 475	MI 73	MI 550	1610	Direct observation	1. Nipple cracked. 2. Part replaced. 3. Welding of 1-1/4 Cr-1/2 Mo steel to carbon steel shall conform to code requirement. Improper welding can result in cracks at small thermal expansion differences. With proper construction supervision such errors could be avoided. Use proper specification and procedures.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 3 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
11	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-44	MA 122	MA 59	MA 520	144	Direct observation	1. Plant shutdown due to packing blowout. 2. Part replaced. 3. Pressure control valves should be able to resist certain over-pressures. Using higher rated lubricants is advisable in case of valve lubricator rupture. Review procedures to assure proper assembly of parts and use of materials.
12	1. Valve/Stop (For Air Piston) 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-91	MI 172	MI 59	MI 550	3314	Operational monitors	1. Broken stop. 2. Local repair. 3. None.
13	1. Valve/Upper Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. PMMR-27	MI 500	MI 53	MI 530	72	Operational monitors	1. Valve leaking. 2. Local repair. 3. Irregular control characteristics and noise during valve operation should be observed earlier. Plant operators' training should be improved. Review procedure to assure proper assembly.
14	1. Valve/Lower Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (P5-VC-596) 3. - 4. ANL-7122, PMMR-52	MA 500	MA 59	MA 520	508	Operational monitors	1. Valve failed and is not repairable. 2. Temporary jury rig - an orifice was installed in the discharge line from the pump and pressure drop was controlled with 2 valves downstream. 3. Previous repair time seemed to be too short for the described work. Closer quality control should be exercised for such critical repair.
15	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater heater No. 4 (P5-VC-609) 3. - 4. PMMR-75	MI 500	MI BZ	MI 530	3400	Preventive maintenance	1. Packing deteriorated and leaking. 2. Part replaced. 3. None.
16	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater heater No. 4 (P5-VC-609) 3. - 4. PMMR-36	MI 500	MI BZ	MI 530	770	Routine inspection	1. Packing deteriorated and leaking. 2. Part replaced. 3. None.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 4 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
17	1. Valve/Flange Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater heater No. 3 (P3-VC-508) 3. - 4. PMMR-51	MI 500	MI BZ	MI 530	3850	Preventive maintenance	1. Flange gasket leaking. 2. Part replaced. 3. None.
18	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater heater No. 3 (P3-VC-508) 3. - 4. PMMR-75	MI 500	MI BZ	MI 530	2140	Preventive maintenance	1. Gasket leaking. 2. Part replaced. 3. None.
19	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater heater No. 3 (P3-VC-508) 3. - 4. PMMR-92	MI 454	MI BZ	MI 530	2910	Direct observation	1. Leakage through porous valve body. 2. Repair was performed by internal grinding and welding the affected area. 3. Proper quality assurance test could detect this fault of the valve body.
20	1. Valve/Solenoid 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump 3. 364°F - 1300 psig 4. PMMR-49	MI 500	MI 12	MI 530	Unknown	Operational monitors	1. Solenoid coil burned out. Loading valve on No. 3 cylinder. 2. Part replaced. 3. None.
21	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (governor valve) 3. - 4. PMMR-52	MI 500	MI 54	MI 550	3890	Direct observation	1. Stem was bent. 2. Local repair, stem was straightened. 3. None.
22	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (relief valve) 3. - 4. PMMR-42	MI 500	MI BZ	MI 530	3722	Direct observation	1. Valve would not seat, stuck open. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

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FAILURE DATA FOR VALVES

(Sheet 5 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
23	1. Valve/Disk 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (warmup line) PF-13 3. - 4. PMMR-58	MI 122	MI 59	MI 530	3460	Preventive maintenance	1. Valve received considerable punishment due to excessive pressure drop across the seat. 2. Part replaced. 3. If the life period of a valve repair is less than the plant preventive maintenance cycle, it should be replaced with a better design.
24	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump (warmup line) PF-13 3. - 4. -	MI 500	MI BZ	MI 530	1200	Direct observation	1. Packing worn out. 2. Part replaced and tie rod installed to limit vibration. 3. Since vibration aggravates the wear of the valve packing, installation of a tie rod is only a temporary solution. Longer, reliable service requires elimination or reduction of piping vibration.
25	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater - motor driven feed pump warmup line (PF-13) 3. - 4. PMMR-69	MI 500	MI BZ	MI 530	540	Preventive maintenance	1. Valve plug and stem failure due to severe working conditions. 2. Parts replaced. 3. None.
26	1. Valve/Plug 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater - motor driven feed pump warmup line (PF-13) 3. - 4. PMMR-69	MI 500	MI 59	MI 530	540	Preventive maintenance	1. Valve plug and stem failure due to severe working conditions. 2. Parts replaced. 3. None.
27	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Motor driven feed pump 3. - 4. PMMR-5	MI 500	MI BZ	MI 550	1200	Direct observation	1. Valve relieved at lower than set pressure. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 6 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
28	1. Valve/Seat (Locked Open) 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater/motor driven feed pump 3. 364°F, 670 to 90 gpm, 1500 psig, 3580 RPM 4. ANL 6808	MI 333	MI 51	MI 530	Start up	Operational monitors	1. Valve locked in open position. 2. Vendor repair of component. 3. Operating procedures should be more closely followed: (a) A signoff system should be used on the preventive maintenance work when completed, (b) step-by-step checkoff sheet system should be used for plant operation, (c) back off valve one-half turn when fully opening valve.
29	1. Valve/Plug 2. Feedwater Supply and Treatment/Feedwater Purification 3. 20 273100	1. SCTI 2. Steam and feedwater system valve (FR-201V) 3. 375°F 4. IMPR No. 344	MA 122	MA 59	MA 520	1500	Direct observation	1. Valve rework, revealed cracked and broken valve plug. 2. Replaced part. 3. None.
30	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. motor driven feed pump (PS-VC-596) 3. - 4. PMMR-102	MI 456	MI 55	MI 530	1016	Operational monitors	1. Valve stem stuck. 2. Local repair, out of tolerance part was remachined. 3. Quality control could eliminate improperly manufactured parts.
31	1. Valve/Body 2. Feedwater Supply and Treatment/Storage Facilities 3. 20 272400	1. SCTI 2. Treated motor system 3. 100 psi at 130°F 4. *Incident report No. 36*	MI 417	MI 59	MI 35	1668	Direct observation	1. PVC (plastic) material split open in the body section. 2. Component corrective modification, plastic valve and associated plactic system replaced with metal valve and piping. 3. More careful selection if used under special conditions.
32	1. Valve/Body 2. Feedwater Supply and Treatment/Storage Facilities 3. 20 272400	1. SCTI 2. Treated water system 3. *2 in., 150 psi, 100°F* 4. Incident report No. 42	MI 417	MI 59	MI 35	2397	Direct observation	1. Body of valve cracked. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 7 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
33	1. Valve/O-Rings 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater (No. 1 and 3 suction valves) 3. - 4. Operation weekly report, 5/1/68	MI 500	MI BZ	MI 530	13,620	Preventive maintenance	1. O-rings worn out. 2. Part replaced. 3. Possibly select O-ring of different material.
34	1. Valve/Nipple 2. Steam, Condensate, and Feedwater Piping and Equipment/Valve 3. 20 284300	1. EBR-II 2. Feedwater 3. 364°F, 1500 psig 4. PMMR-27	MI 452	MI 59	MI 530	1682	Direct observation	1. Nipple ruptured. 2. Part replaced. 3. Properly managed quality control could eliminate this failure.
35	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Feedwater 3. 364°F, 1500 psig 4. PMMR-27	MI 452	MI 59	MI 530	1682	Direct observation	1. Valve ruptured. 2. Part replaced. 3. Properly managed quality control could eliminate this failure.
36	1. Solenoid Valve/ Diaphragm 2. Feedwater Supply and Treatment/ Demineralizers 3. 20 272200	1. SCTI 2. Treated water system valve SV-D. Demineralizer D-1 3. 35 gpm at 30-100 psig 4. Incident report No. 342	MI 131	MI 59	MI 530	4210	Routine area watch	1. Valve diaphragm cracked. 2. Replaced part. 3. Determine, from analysis, compatibility of materials.
37	1. Relief Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump relief 3. - 4. Operating maintenance report, 6/26/68	MI 500	MI BZ	MI 530	15,168	Operational monitors	1. Seat worn out. 2. Local repair. 3. Relief valves should be checked periodically as a part of a preventive maintenance schedule.
38	1. Valve/Spring 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump 3. 364°F, 1300 psig 4. PMMR-42	MI 500	MI 55	MI 530	3722	Operational monitor	1. Safety valve opened and would not reseat. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 8 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
39	1. Valve/O-Ring 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump No. 2 suction valve 3. - 4. PMMR-96	MI 500	MI 52	MI 530	Unknown	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. Investigate use of different O-ring material.
40	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump 3. - 4. PMMR-42	MI 500	MI 59	MI 530	3722	Operational monitor	1. Gasket blew out. 2. Part replaced. 3. None.
41	1. Valve/O-Ring 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump (No. 3 suction valve) 3. - 4. PMMR-96	MI 500	MI 52	MI 530	Unknown	Preventive maintenance	1. O- ring worn out. 2. Part replaced. 3. Investigate use of different O-ring material.
42	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump (pressure relief valve) 3. - 4. Operations monthly report, 11/67	MI 500	MI 65	MI 530	12,594	During repair of associated system	1. Valve seat erosion. 2. Local repair. 3. None.
43	1. Valve/Nipple 2. Steam, Condensate, and Feedwater Piping and Equipment/Valves 3. 20 284300	1. EBR-II 2. Startup boiler feed pump (pressure relief valve) 3. - 4. Operations monthly report, 11/67	MI 122	MI 59	MI 530	12,594	Direct observation	1. Nipple broken. 2. Part replaced. 3. None.
44	Deleted							

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FAILURE DATA FOR VALVES

(Sheet 9 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
45	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 4 3. Shell side - 480°F, 1200 psig Tube side - 565°F, 1500 psig 4. PMMR-72	MI 500	MI BZ	MI 530	1840	Direct observation	1. Packing worn out. 2. Packing replaced. 3. None.
46	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 3 sightglass 3. - 4. PMMR-76	MI 500	MI 52	MI 530	144	Direct observation	1. Valve leaking past seat. 2. Local repair, repaired valve seat. 3. No requirement needed.
47	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 4 3. - 4. PMMR-29	MI 500	MI 59	MI 530	1850	Operational monitors	1. Gasket ruptured. 2. Part replaced. 3. None.
48	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 4 3. - 4. PMMR-30	MA 126	MA 52	MA 520	2000	Direct observation	1. Packing ruptured, valve leaking. 2. Part replaced. 3. Ensure that the valve packing material be installed properly and that the valve is not subjected to excessive pressures.
49	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 4 3. - 4. Weekly maintenance report, 5/21/68	MI 500	MI BZ	MI 530	14, 500	Routine area watch, direct observation	1. Valve leaked. 2. Local repair, was reconditioned. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 10 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
50	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/ Feedwater Heater 3. 20 284200	1. EBR-II 2. Feedwater heater No. 2 3. - 4. PMMR-46	MI 500	MI BZ	MI 530	3410	Operational monitors	1. Valve leaked. 2. Local repair, seat and disc cleaned, lapped, checked, new packing and lubricator nipple installed. 3. Preventive maintenance repair should be performed periodically before leak develops.
51	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. High pressure flash tank 3. 578°F, 700 psig 4. PMMR-80	MI 500	MI BZ	MI 530	6900	Preventive maintenance	1. Stem worn. 2. Local repair, valve removed and stem remachined. 3. Better sightglass material would reduce the frequency of the valve operation, saving valve and stem wear. Investigate use of different material.
52	1. Valves/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate valve (P5-VC-620) 3. 150 psig 4. PMMR-25	MI 500	MI 59	MI 530	1610	Operational monitor	1. Valve seat broken. 2. Temporarily reassembled for continued operation (no parts). 3. As the state-of-the-art advances with larger FBR's, adequate storage of spare parts should be more closely planned. Do not close valve as tight as possible, especially when valve is cold.
53	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate valve (P5-VC-620) 3. 150 psig 4. Operations maintenance report, 6/26/68	MI 500	MI BZ	MI 530	13,630	Direct observation	1. Valve repairs completed (only information available). 2. Parts replaced. 3. Periodical checking should be a part of the preventive maintenance schedule.
54	1. Valve/Bushing (Upper) 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate valve (P5-VC-620) 3. 150 psig 4. PMMR-25	MI 500	MI 68	MI 530	1610	During repair of primary component	1. Valve bushings were galled. 2. Temporarily reassembled for continued operation (no parts). 3. As the state-of-the-art advances with larger FBR's, adequate storing of spare parts should be more closely planned.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 11 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
55	1. Valve/Bushing (Lower) 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate valve (P5-VC-620) 3. 150 psig 4. PMMR-25	MI 500	MI 68	MI 530	1610	During repair of primary component	1. Valve bushings were galled. 2. Temporarily reassembled for continued operation (no parts). 3. As the state-of-the-art advances with larger FBR's, adequate storing of spare parts should be more closely planned.
56	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate valve (P5-VC-620) 3. 150 psig 4. PMMR-25	MI 500	MI 68	MI 530	1610	During repair of primary component	1. Valve stem was galled. 2. Temporarily reassembled for continued operation (no parts). 3. As the state-of-the-art advances with larger FBR's, adequate storing of spare parts should be more closely planned.
57	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate high pressure flash tank 3. 700 psig, 578 °F 4. Operations maintenance report, week ending 8/14/68	MI 500	MI BZ	MI 530	15, 240	During preventive maintenance	1. Valve seat worn. 2. Local repair, valve disassembled and the seat was repaired. 3. Possibly different seat material might improve duration.
58	1. Valve/Flange Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condenser bypass valve (P3-VC-544D) 3. 150 psig 4. PMMR-80	MI 500	MI BZ	MI 530	6900	Preventive maintenance	1. Leak at gasket. 2. Part replaced. 3. None.
59	1. Valve/Support Valves 2. Steam, Condensate, and Feedwater Piping and Equipment/ Condensate Valves 3. 20 283300	1. SCTI 2. Valves HIC 209 and HIC 210 controlling flow through condensate pump P-4 3. Open valves 4. Incident report No. 330	MI 346	MI 5Z	MI 111	6215	Routine instrument reading, direct observation	1. Zero flow on indicators F1-201 and F1-202 indicating valves were closed or clogged - valves HIC 209 and 210 closed - standard operating procedures not followed. 2. Opened valves. 3. Standard operating procedure should be followed and a system instituted to provide verification of concurrence.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 12 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
60	1. Valve/Valve Seat 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 20 330000	1. SCTI 2. Cooling water system/cooling tower E-5 3. 150 lb WOG 4. Incident report No. 300	MI 144	MI 52	MI 530	Unknown	Direct observation	1. Cooling tower dump valve opened, leaking valve seat on air control valve. 2. Valve replaced. 3. Upgrade preventive maintenance on items.
61	1. Valve/Shaft 2. Turbine-Generator Units and Condenser/ Circulating Water System 3. 20 330000	1. EBR-II 2. Cooling tower (by pass valve) 3. 84°F 4. PMMR-97	MI 172	MI 54	MI 550	9345	Operational monitors	1. Shaft was bent. 2. Part replaced. 3. Protect valve handle, verify proper operating procedures.
62	1. Valve/Bushing 2. Turbine-Generator Units and Condenser/ Circulating Water System 3. 20 330000	1. EBR-II 2. Cooling tower (YW-10) 3. 84°F 4. PMMR-101	MI 500	MI 55	MI 530	9345	Direct observation	1. Bushings jammed. 2. Part replaced. 3. Revise preventive maintenance procedure to require more frequent valve operation, stem lubrication to prevent sticking.
63	1. Valve/Rubber Seat 2. Turbine-Generator Units and Condenser/ Circulating Water System 3. 20 330000	1. EBR-II 2. Cooling tower (north riser) (YW-10) 3. 84°F 4. PMMR-107	MI 500	MI 59	MI 530	1975	Operational monitors	1. Seat worn out. 2. Part replaced. 3. None.
64	1. Valve/Stem 2. Turbine-Generator Units and Condenser/ Circulating Water System 3. 20 330000	1. EBR-II 2. Cooling tower riser 3. 84°F 4. PMMR-109	MI 500	MI BZ	MI 530	11,420	Direct observation	1. Valve stuck. 2. Local repair. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 13 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
65	1. Valve/Stem 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 20 330000	1. EBR-II 2. Cooling tower/spraywater 3. 84°F 4. Oper. maint. 8/14/68	MI 500	MI BZ	MI 530	11,320	During preventive maintenance	1. Valves binding. 2. Local repair. 3. None.
66	1. Valve/Opening 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 20 330000	1. SCTI 2. Cooling tower basin dump valve (CR-300V) 3. 3 in., 300 psig, 316 SS 4. Incident report No. 97	MI 410	MI 5Z	MI 590	Unknown	Operational monitors	1. Conductivity alarm from cooling water system opened dump valve. Raw water add valve opened dumping cooling water and adding raw water lowers conductivity to acceptable limits. Dump rate exceeds makeup rate so available water level drops. 2. Control air to CR-300V shut off closing dump valve allowing water level to build up. Outlet of dump valve fitted with reducers to reduce flow. 3. Design of valve sizes should take possibility of problems like above into account.
67	1. Valves/Valve 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 20 330000	1. SCTI 2. Valve 334F, water inlet valve 3. 300 psig, 3 in. 4. SCTI, Incident report No. 61	MI 410	MI 55	MI 520	4995	Operational monitors	1. Flowrate of the dump valve exceeded that of makeup valve in automatic operation and the valve stuck in closed position. 2. Water dump discharge line size reduced to match the makeup valve flowrate. 3. New design considerations were initiated to on-off type makeup/drawn controls.
68	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system/Shutoff valve PF-20 between power plant and sodium building 3. - 4. PMMR-29	MI 500	MI BZ	MI 530	2110	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Use proper packing for service.
69	1. Valve/Seal Ring 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valve 3. 20 281200	1. EBR-II 2. Steam system/Shutoff valve PF-20 between power plant and sodium building 3. - 4. PMMR-80	MI 500	MI BZ	MI 530	4810	Preventive maintenance	1. Seal ring leaking. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 14 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
70	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system/Valve PT-25 3. - 4. PMMR-50	MI 175	MI 52	MI 530	4660	Operational monitors	1. Valve leaked as a result of plug and seat deterioration. 2. Temporarily reassembled. 3. Preventive periodic maintenance could avoid such deterioration.
71	1. Valve/Plug 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system/Valve PT-25 3. - 4. PMMR-50	MI 175	MI 52	MI 530	4660	Operational monitors	1. Valve leaked as a result of plug and seat deterioration. 2. Part replaced. 3. Preventive periodic maintenance could avoid such deterioration.
72	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-29	MI 500	MI 59	MI 530	2110	Direct observation	1. Bad packing leak developed. 2. Part replaced. 3. Prefabricated packing elements and prescribed bolt torques could eliminate these failures.
73	1. Valve/Stem 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-105	MI 500	MI 52	MI 530	1975	Direct observation	1. Stem worn out. 2. Part replaced. 3. None.
74	1. Valve/Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-105	MI 500	MI 52	MI 530	1975	Direct observation	1. Bushing worn out. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 15 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
75	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-72	MI 500	MI BZ	MI 530	830	Direct observation	1. Valve leaking. 2. Local repair; stem was cleaned, gasket and packing replaced. 3. Replace valve either with a better made or with a higher rated one.
76	1. Valve/Disk 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-94	MI 500	MI 52	MI 530	1945	Preventive maintenance	1. Disk worn out. 2. Part replaced. 3. Investigate new disk material for longer service.
77	1. Valve/Bushing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Main steam/bypass valve (P3-VC-501B) 3. 840°F, 1250 psig 4. PMMR-94	MI 500	MI 52	MI 530	1945	Preventive maintenance	1. Bushing worn out. 2. Part replaced. 3. None.
78	1. Valve V-3129/ Adapter Nipple 2. Turbine-Generator Units and Condenser/ Circulating Water 3. 20 330000	1. SCTI 2. Cooling tower acid system 3. - 4. Incident report No. 80	MI 277	MI 91	MI 530	5925	Operational monitors	1. Nipple corroded through causing acid leak. 2. Removed and replaced with stainless steel item. 3. Improve design requirements of chemical feed components.
79	1. Valve/Flange Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system/P3-VC-530 3. 160 psig normal set point 4. PMMR-75	MI 500	MI BZ	MI 530	5990	Preventive maintenance	1. Old type gaskets were exchanged to flexitallic gasket to improve flange seal. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 16 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	 MODE	 EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
80	1. Valve/Bonnet 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. PS-614/Safety relief system 3. 1250 to 1265 psig 4. PMMR-77	MA 500	MA 52	MA 520	6444	Direct observation	1. Bonnet worn out. 2. Local repair. 3. None.
81	1. Valve/Seal Ring 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. PS-614/Safety relief system 3. 1250 to 1265 psig 4. PMMR-77	MA 500	MA 52	MA 520	6444	Direct observation	1. Seal ring worn out. 2. Local repair. 3. None.
82	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Isolation Valve PS-309 3. 150 psig 4. PMMR-75	MI 500	MI BZ	MI 530	5990	Preventive maintenance	1. Gasket leaking. 2. Part replaced, new Flexatallic gaskets were installed. 3. Use of new gaskets is not enough. Apply controlled (calculated) bolt torques for long lasting seals.
83	1. Valve/Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Isolation valve PS-301 3. 1250 to 1265 psig 4. PMMR-81	MI 500	MI BZ	MI 530	6920	Preventive maintenance	1. Seal leaking. 2. Part replaced. 3. None.
84	1. Valve/Seat and Disc 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system P3-VC-676 3. - 4. Weekly maintenance report (5-21-68)	MI 500	MI BZ	MI 530	14,576	Routine instrument reading	1. Valve was reconditioned. 2. Local repair. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 17 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
85	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system/PS-611 3. 1250 to 1265°F 4. PMMR-4	MI 125	MI 52	MI 530	1200	Direct observation	1. Packing worn out. 2. Part replaced. 3. Since isolation valves are usually used in case of emergencies, their maintenance should be scheduled for plant down times when other major periodic repairs are planned. Select packing materials which will last for one maintenance period without deterioration.
86	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. PS-311/Low pressure line 3. 150 psig 4. PMMR-72	MI 500	MI BZ	MI 530	6940	Direct observation	1. Gasket leaking. 2. Part replaced. 3. Determine the necessary bolt torques for each flange size and gasket type and require their application during any maintenance work.
87	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system (V-PF-18) 3. - 4. PMMR-51	MI 500	MI 52	MI 530	3850	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Select packing material which will last for one maintenance period without deterioration.
88	1. Valve/Connector 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-58	MI 500	MI 53	MI 530	1010	Preventive maintenance	1. Connector worked loose. 2. Local repair. 3. Avoid use of valves having split nut stem-plug connectors. Replace them with a better type.
89	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-42	MI 126	MI 52	MI 530	960	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Provide better maintenance procedures.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 18 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
90	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-42	MI 500	MI 68	MI 530	960	Preventive maintenance	1. Stem galled. 2. Part replaced. 3. Provide better maintenance procedures.
91	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-49	MI 500	MI 52	MI 530	580	Preventive maintenance	1. Packing and gaskets were replaced due to excessive steam leakage. 2. Part replaced. 3. To reduce packing failures, use prefabricated packing rings and apply predetermined packing bolt torques.
92	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-94	MI 500	MI 52	MI 530	1945	Preventive maintenance	1. Valve stem worn. 2. Part replaced. 3. Recurring failure. Revise preventive maintenance inspection interval to prevent unscheduled failure, or purchase better quality valve.
93	1. Valve/Packing Retainer 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-42	MI 500	MI 68	MI 530	960	Preventive maintenance	1. Retainer worn out. 2. Part replaced. 3. Repair should provide improved operation conditions. Supervision should control repeatedly repaired failures.
94	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. Operation weekly report 3-27-68	MI 500	MI 52	MI 530	2530	Preventive maintenance	1. Valve stem worn out. 2. Part replaced, sent to vendor for inspection. Recommended changing cage material from stainless steel to stellite. 3. To provide high pressure drop (1200 psig) in a single valve is critical. The loop design needs better basic study of the high pressure drop.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 19 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
95	1. Valve/Cage Assembly 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. Operation weekly report 3-27-68	MI 500	MI 52	MI 530	2530	Preventive maintenance	1. Valve cage assembly worn out. 2. Part replaced. 3. To provide high pressure drop (1200 psig) in a single valve is critical. The loop design needs better basic study of the high pressure drop.
96	1. Valve/Stem 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-80	MI 500	MI 52	MI 530	1430	Preventive maintenance	1. Stem was remachined. 2. Local repair. 3. None.
97	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-501B/bypass 3. 840°F, 1250 psig 4. PMMR-82	MI 500	MI BZ	MI 530	480	Preventive maintenance	1. Stem badly worn, no packing would last for a normal period. 2. Part replaced. 3. Better quality valve was ordered as replacement for damaged valve.
98	1. Valve/Packing 2. Turbine-Generator Units and Condenser/ Turbine Side 3. 20 310000	1. EBR-II 2. Main turbine/steam regulator 3. No information 4. PMMR-29	MI 500	MI 52	MI 530	2590	Preventive maintenance	1. Valve leak around packing. 2. Part replaced. 3. None.
99	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281200	1. EBR-II 2. Line to desuperheater control valve P3-VC-616 3. 1250 to 1265 psig 4. PMMR-80	MI 500	MI BZ	MI 530	6920	Preventive maintenance	1. Valve packing worn out. 2. Part replaced. 3. Use proper packing and installation procedures.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 20 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
100	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 282000	1. EBR-II 2. Auxiliary steam supply valve P3-VC-664 3. 150 psig 4. PMMR-61	MI 500	MI BZ	MI 530	4708	Operational monitors	1. Valve seat worn. 2. Local repair, seat and disc were lapped. 3. Preventive maintenance program shall be established to avoid valve through (internal) leaks.
101	1. Pressure Reducing Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281200	1. SCTI 2. Steam-generator second stage/valve body 3. To 2500 lb, 110,800 lb/hr 4. Incident report No. 306	I 450	I 61	I 550	600	Direct observation	1. Cracks in valve body allowing steam leakage. Chloride stress corrosion and poor quality casting (347SS). 2. Replace valve. 3. Improve QA on procurement.
102	1. Valve/Flange 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281200	1. SCTI 2. Steam and feed outlet nozzle on first stage pressure reducing valve (PRC-200-VB) 3. 600 psig, 520°F 4. Incident report 317A	MA 121	MA 94	MA 136	88	Direct observation	1. Investigation of all 347 SS revealed cracks below center line of outlet nozzle were due to chloride stress corrosion. 2. Replacement with 2-1/4 Cr and 1% Mo. 3. None.
103	1. Valve/Ring Gaskets 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281300	1. SCTI 2. Steam and feedwater system, (TRC-201V) 3. Steam - 1400 psig, 800°F, 15% flow 4. Incident report No. 126	MA 122	MA 53	MA 136	6030	Direct observation	1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. New gaskets and high strength alloy bolts were installed. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket.
104	1. Valve/Line Outlet Flange 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281200	1. SCTI 2. Steam and feedwater system (PRC-200V) 3. 1100°F, 2500 psig 4. Incident report No. 128	MA 122	MA 53	MA 136	6030	Direct observation	1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. New gaskets and high strength alloy bolts were installed. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 21 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
105	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam 3. 20 281200	1. SCTI 2. Second stage pressure reducing valve (PRC-201V) 3. - 4. Incident report No. 306 (10-1-66)	MA 121	MA 94	MA 520	600	Direct observation	1. Cracks in valve body (chloride stress corrosion of 347SS and poor quality of valve casting). 2. Valve removed (metallurgical examination) and replaced with 2-1/4 Cr 1/2 Mo body composition type. 3. Improve quality control requirements for valve purchase and design specifications.
106	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Steam system (PS-603A) 3. -' 4. PMMR-61	MI 500	MI BZ	MI 530	4700	Direct observation	1. Packing worn out. 2. Part replaced. 3. Possibly need different type of packing.
107	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. PS-VC-552, isolating valve PF-8 3. - 4. PMMR-51	MI 500	MI BZ	MI 530	3850	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. None.
108	1. Valve/Seal Ring 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Blocking valve PS-609 3. 1250 to 1265 psig 4. PMMR-29	MI 500	MI BZ	MI 530	1820	Direct observation	1. Leak developed at the seal ring. 2. Part replaced. 3. Prevention of leakage can be achieved with periodically planned maintenance and not waiting until leak develops.
109	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Turbine generator line valve PS-605 3. 1250 to 1265 psig 4. PMMR-29	MI 500	MI 52	MI 530	1860	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Possibly need different type of packing.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 22 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
110	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. P3-VC-544B bypass valve PS-607 3. 1250 to 1265 psig 4. PMMR-51	MI 500	MI BZ	MI 530	3890	Preventive maintenance	1. Packing worn out. 2. Part replaced. 3. Possibly different type of packing.
111	1. Valve/Packing 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Steam Valves 3. 20 281200	1. EBR-II 2. Lube oil pump block valve PS-607A 3. 1250 to 1265 psig 4. PMMR-61	MI 500	MI BZ	MI 530	4660	Direct observation	1. Difficulty in valve operation made the repacking necessary. 2. Part replaced. 3. Revise preventive maintenance inspections of valves to prevent outage from packing failure.
112	1. Valve/Body 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/condensate high pressure flash tank valve P3-VC-553 3. 700 psig, 578°F 4. PMMR-95	MI 500	MI 64	MI 530	9345	During repair of primary component	1. Valve body damaged. Erosion from steam. 2. Local repair; erosion marks were weld-filled and valve was reassembled. 3. In such a serious erosion/corrosion case, investigation should be initiated to define and correct it.
113	1. Valve/Gasket 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Valves 3. 20 283300	1. EBR-II 2. Condensate pump turbine/low pressure line, valve PS-308 3. 150 psig 4. PMMR-75	MI 126	MI 52	MI 530	5490	Preventive maintenance	1. Gasket leaking. 2. Part replaced. New Flexitallic gaskets installed. 3. Use of new gasket is not enough. Apply controlled (calculated) bolt torques for long lasting seals.
114	1. Valve/Seat 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Valves 3. 20 283300	1. EBR-II 2. Main steam/turbine driven condensate pump steam stop, valve SS-602 3. - 4. PMMR-94	MI 122	MI 64	MI 530	9345	Preventive maintenance	1. Seat was steam cut. 2. Local repair. 3. Reduce velocity of fluid across seat.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 23 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
115	1. Valve/Spring 2. Station Service Equipment/Air Starting 3. 20 462400	1. EBR-II 2. Valve P3-X724 on emergency air compressor 3. 90 to 100 psi 4. PMMR-82	MI 500	MI 52	MI 530	7400	Routine inspection	1. Valve internals binding. 2. Part replaced. 3. None.
116	1. Valve/Disk 2. Turbine Generator Units and Condenser/Central Lubricating 3. 20 350000	1. EBR-II 2. Main turbine/control valve to auxiliary pump (P063) 3. 135 lb hydraulic pressure 4. PMMR-63	MI 500	MI 73	MI 530	4660	Preventive maintenance	1. Valve leaked across seat. 2. Part replaced. 3. A regular plant maintenance schedule should be set up for all valves in the system. Valves in locations with high failure rates should be redesigned or replaced.
117	1. Valve/Plug 2. Turbine Generator Units and Condenser/Central Lubrication 3. 20 350000	1. EBR-II 2. Main turbine/lubricating system 3. 1250 psig 4. PMMR-45	MI 500	MI 61	MI 550	3410	Operational monitors	1. Valve sticking and leaking steam. Stellite was cracked on valve plug. 2. Temporarily reassembled for continued operation. 3. Perform metallurgical study of cracked metal to determine cause of failure and make recommendations if necessary.
118	1. Valve/Fuel Supply Line 2. Instrumentation and Control/Fire Control System 3. 20 267100	1. SCTI 2. Primary sodium system supervisory valve 1 3. Open 4. Incident report No. 125	MI 330	MI 51	MI 520	8362	During activation	1. Valve closed on fuel supply line pressure gage indicator. 2. Open valve. 3. Improve operations procedure.
119	1. Valve/Throat 2. Heat Transfer/Purification System (Vacuum Line) 3. 20 224239	1. EBR-II 2. Primary purification vacuum system 3. - 4. PMMR-15	MI 218	MI 51	MI 550	1200	Operational monitors	1. Valve throat plugged with sodium condensate. 2. Part replaced. 3. None.

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TABLE I-119

FAILURE DATA FOR VALVES

(Sheet 24 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
120	1. Isolation Valve/Seat Ring 2. Reactor Containment Structure and Building/ Ventilation 3. 20 196300	1. EBR-II 2. Reactor building/exhaust air system 3. - 4. ANL 7082	MI 500	MI BZ	MI 530	6920	Routine inspection	1. Did not seat properly. 2. Part replaced. 3. None.
121	1. Valve/Rubber Seal 2. Reactor Containment Structure and Building/ Ventilation 3. 20 196300	1. EBR-II 2. Reactor building/exhaust air system (VR-306) 3. - 4. PMMR-107	MI 500	MI BZ	MI 530	11,320	Operational monitors	1. Rubber seal replaced. 2. Part replaced. 3. None.
122	1. Valve, Isolation/ Discharge Port 2. Reactor Containment Structure and Building/ Ventilation 3. 20 196300	1. EBR-II 2. R 13VR-318/air exhaust system 3. - 4. PMMR-47	MI 122	MI 55	MI 550	8160	Operational monitors	1. Valve slammed shut and jammed. 2. Local repair, discharge port on air cylinder was orificed, valve normally open, and thermostatically actuated. 3. Incorporate valve timing into installation and operational procedures.
123	1. Valve, Damper/ Bearings 2. Reactor Containment Structure and Building/ Ventilation 3. 20 196300	1. EBR-II 2. R8-DM-726/air exhaust system 3. - 4. PMMR-113	MI 500	MI BZ	MI 530	12,390	Preventive maintenance	1. Damper sticking on switch over. 2. New bearings and seals installed. 3. None.
124	1. Damper Valve/Seals 2. Reactor Containment Structure and Building/ Ventilation 3. 20 196300	1. EBR-II 2. Reactor building/air exhaust system 3. - 4. PMMR-113	MI 500	MI BZ	MI 530	12,390	Preventive maintenance	1. Damper sticking on switch over. 2. New bearings and seals installed. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 25 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
125	1. Valve/Body 2. Heat Transfer/Inert Gas Supply and Monitor 3. 20 224600	1. EBR-II 2. Fission gas monitor (loop B) 3. - 4. PMMR-109	MI 218	MI 51	MI 530	11,420	Preventive maintenance	1. Valve clogged with sodium. 2. Local repair. 3. If needle valve, remove from vapor environment.
126	1. Valve/Body 2. Turbine-Generator Units and Condensers/Central Lubricating 3. 20 350000	1. EBR-II 2. Turbine/oil cooler 3. No information 4. PMMR-25	MI 500	MI 59	MI 530	1610	Direct observation	1. Valve broken. 2. Part replaced. 3. If valve must have excessive force applied to open or close: check packing gland, replace valve.
127	1. Valve/Body 2. Heat Transfer/Inert Gas Supply and Monitor 3. 20 224600	1. EBR-II 2. Fission gas monitor (loop A) 3. - 4. Operation maintenance report 8-21-68	MI 500	MI 51	MI 530	15,240	Direct observation	1. Valve clogged with sodium. 2. Local repair. 3. None.
128	1. Valve/Body 2. Nuclear Fuel Handling and Storage Equipment/Containers and Racks 3. 20 232500	1. EBR-II 2. Source coffin 3. - 4. PMMR-72	MI 500	MI 59	MI 530	5490	Direct observation	1. Valve was broken when coffin was set upright after coffin repairs. 2. Part replaced. 3. If valve is an important part of unit, install a protector so as not to repeat incident. Revise appropriate procedures.
129	1. Valve/Valve Seat 2. Compressed Air and Vacuum Cleaning Equipment/Air Control Valve 3. 20 520000	1. SCTI 2. Control valve for cooling tower dump valve 3. - 4. Incident report No. 300 6-2-66	MA 125	MA 52	MA 520	Unknown	Direct observation	1. Valve seat of air control valve leaked causing dump valve to open. 2. Remove line (air) from valve taking it out of system. 3. Establish maintenance procedure for all critical control components (executed).

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 26 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
130	1. Valve/Bushing 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve G) 3. 210°F 4. PMMR-27	MI 500	MI 68	MI 530	1610	Operational monitors	1. Valve bushing galled. 2. Local repair. 3. None.
131	1. Valve/Stem 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve G) 3. Remote operated valves 4. PMMR-27	MI 500	MI 55	MI 530	4400	During actuation	1. Valve stem stuck. 2. Local repair. 3. None.
132	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve A) 3. 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Valve modified. 2. Part replaced. 3. None.
133	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve B) 3. 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Valve modified. 2. Part replaced. 3. None.
134	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve F) 3. 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Valve modified. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 27 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
135	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve G) 3. 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Valve modified. 2. Part replaced. 3. None.
136	1. Valve/Seats 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (ball valves) 3. 450°F 4. ANL-6912	MI 500	MI 52	MI 530	1000	Operational monitors	1. Valve seats worn out. 2. Part replaced. 3. None.
137	1. Valve/Seat 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve Z) 3. 450°F 4. PMMR-22	MI 500	MI BZ	MI 530	1200	Operational monitors	1. Valve seat worn out. 2. Part replaced. 3. None.
138	1. Valve/Bonnet Gasket 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve Z) 3. 450°F 4. PMMR-22	MI 500	MI BZ	MI 530	1200	Operational monitors	1. Gasket worn out. 2. Part replaced. 2. None.
139	1. Valve/Packing 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve F) 3. 450°F 4. PMMR-76, 5/66	MI 456	MI 55	MI 530	6300	Operational monitors	1. Packing worn out. 2. Part replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 28 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
140	1. Valve/Seats 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve L) 3. 450°F 4. PMMR-77, 6/66	MI 21Z	MI 51	MI 530	6500	Operational monitors	1. Small metal particles were found imbedded in the Teflon seats. 2. Local repair. 3. Ensure system is free of foreign matter initially. Where additional fluids are added to system, a filter should be installed downstream of entry point.
141	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve J) 3. Remote operated, 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Reinforced supports and bonnets installed. 2. Part replaced. 3. None.
142	1. Valve/Bonnet 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve W) 3. Remote operated, 450°F 4. PMMR-104	MI 500	MI BZ	MI 530	10,380	During preventive maintenance	1. Reinforced supports and bonnets installed. 2. Part replaced. 3. None.
143	1. Valve/Seat 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve D) 3. Remote operated, outlet valve 4. Operation weekly report, 2-21-68	MI 500	MI 55	MI 530	13,500	Operational monitors	1. Valve stuck. 2. Part replaced. 3. Replace seat material if necessary – test cycle the 5 hp DC turbine on regular schedule.
144	1. Valve/Spring 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve G) 3. No information 4. PMMR-82, 8-66	MI 500	MI 55	MI 530	7400	During actuation	1. Spring which forces ball onto seat was removed. This has corrected binding difficulties. 2. Local repair. 3. Use weaker or smaller diameter spring, if necessary to valve closing.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 29 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
145	1. Valve/Spring 2. Nuclear Fuel Handling and Storage Equipment/Fuel Handling Machine 3. 20 235140	1. EBR-II 2. FUM/argon cooling system (valve W) 3. No information 4. PMMR-82, 8/66	MI 500	MI 55	MI 530	7400	During actuation	1. Spring which forces ball onto seat was removed. This has corrected binding difficulties. 2. Local repair. 3. Use weaker or smaller diameter spring, if necessary to valve closing.
146	1. Valve/Solenoid 2. Heat Transfer/Inert Gas Supply and Monitor 3. 20 224650	1. EBR-II 2. Primary shield/cooling blower No. 1 exhaust damper 3. - 4. Operation weekly report, 2-7-68	MI 500	MI BZ	MI 530	13,400	Operational monitors	1. Valve did not operate properly. 2. Part replaced. 3. None.
147	1. Valve/Pneumatic Damper 2. Heat Transfer/Inert Gas Supply and Monitor 3. 20 224650	1. EBR-II 2. Reactor top shield cooling exhaust valve DM-726 3. - 4. PMMR-109	MI 500	MI 55	MI 550	11,420	Operational monitors	1. Damper stuck. 2. Local repair. 3. None.
148	1. Valve/Transfer Port Locator Pins 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing 3. 20 213000	1. EBR-II 2. Reactor exit port shield plug 3. 150°F 4. Operation maintenance report, 3-6-68	MI 312	MI 52	MI 530	15,240	Direct observation	1. Location pins misaligned. 2. Local repair, pin realigned to alleviate binding. 3. None.
149	1. Valve/Fuel Transfer Port Drip Catcher 2. Nuclear Fuel Handling and Storage Equipment/Shielding 3. 20 235150	1. EBR-II 2. Primary/fuel handling machine 3. Argon heated 4. Operation weekly report, 7-10-68	MI 218	MI 55	MI 550	1000	Direct observation	1. The drip catcher had been completely filled with sodium each time the port was cleaned. 2. Temporary repair. 3. Permit element to drain more thoroughly over core.

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TABLE 1-119

FAILURE DATA FOR VALVES

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
150	1. Valve/Transfer Port Tube 2. Nuclear Fuel Handling and Storage Equipment/Shielding 3. 20 232100	1. EBR-II 2. Primary/Reactor shield cover port 3. ANL 6912, 6-64	MI 500	MI 59	M 530	1000	Direct observation	1. Transfer port tube restricted gripper movement. 2. Part replaced. 3. None.
151	1. Valve/Transfer Port Bevel Gear 2. Nuclear Fuel Handling and Storage Equipment/Shielding 3. 20 235150	1. EBR-II 2. Primary/fuel handling machine 3. Ambient temperature 4. ANL 6912, 6-64	MI 500	MI 59	M 530	1000	Direct observation	1. Transfer port tube restricted gripper movement. 2. Part replaced. 3. None.
152	1. Valve/Rotating Port Gasket 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing Equipment 3. 20 232100	1. EBR-II 2. Reactor shield cover port 3. Ambient temperature 4. PMMR-43, 9-65	MI 500	MI 52	MI 530	3070	Preventive maintenance	1. Gasket worn out. 2. Part replaced. 3. None.
153	1. Valve/Rotating O-Ring 2. Nuclear Fuel Handling and Storage Equipment/Shielding 3. 20 235150	1. EBR-II 2. Fuel unloading machine cover port 3. Ambient temperature 4. PMMR-44, 9-65	MI 500	M 52	M 530	3070	During repair of primary failure component	1. O-ring worn out. 2. Part replaced. 3. None.
154	1. Valve/Transfer Port O-Ring 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing 3. 20 232100	1. EBR-II 2. Reactor shield cover port 3. - 4. Operation weekly report, 4-10-68	MI 500	MI 52	MI 530	14, 024	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. Replacement of O-rings and other seals is desirable whenever parts are disassembled for repair or maintenance.

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FAILURE DATA FOR VALVES

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
155	1. Valve/Transfer Port O-Ring 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing 3. 20 232100	1. EBR-II 2. Reactor shield cover port 3. - 4. Operation weekly report, 12-27-67	MI 500	MI 52	MI 530	13,380	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. None.
156	1. Valve/Transfer Port O-Ring 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing 3. 20 232100	1. EBR-II 2. Reactor shield cover port 3. - 4. Operation weekly report, 3-27-68	MI 500	MI 52	MI 530	13,800	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. None.
157	1. Valve/Transfer Port O-Ring 2. Nuclear Fuel Handling and Storage Equipment/Reactor Vessel Servicing 3. 20 232100	1. EBR-II 2. Reactor shield cover port 3. - 4. Operation weekly report, 2-7-68	MI 500	MI 52	MI 530	13,400	Preventive maintenance	1. O-ring worn out. 2. Part replaced. 3. None.
158	1. Valve/Stem 2. Heat Transfer/Liquid Metal Purification 3. 20 224233	1. SCTI 2. Secondary/purification cold trap V-510 3. 900°F, approximately 100 psig 4. SCTI, incident report No. 48	MI 471	MI 55	MI 550	115	Operational monitor	1. Improperly placed stem stop prevented valve closing. 2. Local repair. 3. Preoperational acceptance procedures should include test to assure valve closure.
159	1. Valve/Bellows 2. Heat Transfer/Primary Coolant 3. 20 221220	1. FERMI 2. Primary/sodium service V-516 3. 210 to 700°F 4. APDA, CFE-21, Page 42	MI 136	MI 61	MI 530	15,000	Operational monitors	1. Local intergranular attack in weld heat affected zone. 2. Part replaced. 3. Investigate alternate material of construction.

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FAILURE DATA FOR VALVES

(Sheet 32 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
160	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. Fermi 2. Primary/sodium service 3. 3 in. motorized value FCV-505 4. APDA, CFE-11, page 22	MA 137	MA 61	MA 550	15,000	Operational monitors	1. Bellows leaked. 2. Vendor repair. 3. None.
161	1. Valve/Bellows 2. Heat Transfer/ Coolant Treatment 3. 20 224235	1. Fermi 2. Plugging indicator/NaK loop TCV-509 3. 210 to 700°F 4. EFAPP, maintenance report No. 129	MI 136	MI 59	MI 530	3000	Direct observation	1. Defective bellows. 2. Bellows replaced. 3. None.
162	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. Fermi 2. Primary/sodium service V-502-1 3. 210 to 700°F 4. APDA, CFE-21, page 39	MI 136	MI 61	MI 530	15,000	Operational monitors	1. Defective bellows. 2. Bellows replaced. 3. None.
163	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. Fermi 2. Primary/sodium service FCV-506 3. 550 to 800°F 4. APDA, CFE-11, page 22	MI 124	MI 61	MI 530	1632	Operational monitors	1. Bellows leaked. 2. Vendor repair. 3. Source acceptance standards should be reviewed to ensure satisfactory performance of future purchased parts.
164	1. Valve/Bellows 2. Heat Transfer/ Coolant Treatment 3. 20 224235	1. Fermi 2. Secondary sodium/plugging indicator (FCV-829) 3. 765°F 4. EF-26, page 5	MI 136	MI 61	MI 530	13,400	Operational monitors	1. Bellows leaked. 2. Bellows replaced. 3. None.
165	1. Valve/Disk 2. Heat Transfer/ Intermediate Coolant 3. 20 222220	1. Fermi 2. IHX/drain line 3. Ambient to 300°F, V-521 4. EFAPP, maintenance report No. 71	MI 456	MI 61	MI 530	9400	Operational monitors	1. Not seating properly. 2. Vendor repair of part. 3. None.
166	1. Valve/Seat 2. Heat Transfer/ Intermediate Coolant 3. 20 222220	1. Fermi 2. IHX/drain line 3. Ambient to 300°F, V-521 4. EFAPP, maintenance report No. 71	MI 137	MI 56	MI 530	9400	Operational monitors	1. Not seating properly. 2. Vendor repair of part. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 33 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
167	1. Valve/Disk 2. Heat Transfer/Liquid Metals Purification 3. 20 224239	1. FERMI 2. Transfer tank/cold trap 3. Approx. 700°F 4. EF-26, page 3	MI 417	MI 56	MI 530	13, 400	Operational monitors	1. Valve strokes had been found incompatible with the intended design control pressure signals. 2. Vendor design modification, new discs were installed to provide better flow characteristics. 3. Preoperational acceptance procedures should be established to ensure proper operation of the valve.
168	1. Valve/Disk 2. Heat Transfer/Liquid Metal Purification 3. 20 224239	1. FERMI 2. Transfer tank/cold trap 3. Approx. 700°F 4. EF-26, page 3	MI 417	MI 55	MI 530	13, 400	Operational monitors	1. Valve strokes had been found incompatible with the intended design control pressure signals. 2. Vendor design modification, new discs were installed to provide better flow characteristics. 3. Preoperational acceptance procedures should be established to ensure proper operation of the valve.
169	1. Valve/Disk and Seat 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. FERMI 2. IHX/drain line/shut off 3. Approx. 765°F 4. EF-18, page 3	MI 136	MI 52	MI 530	10, 100	Operational monitors	1. Leak across valve seat. 2. Component corrective modification, rework of the disk and seat (relapped). 3. None.
170	1. Valve/Leak Detector Leads 2. Heat Transfer/Intermediate Heat Exchanger 3. 20 222300	1. FERMI 2. IHX/drain line/shut off 3. Approx. 765°F 4. EF-18, page 3	MI 156	MI 21	MI 530	10, 100	Operational monitors	1. Operation of the valve caused damage to three of the four leak detector leads. 2. Leads were repaired and relocated to avoid interference with valve stem. 3. Leads should be secured so as not to interfere with valve operation.
171	1. Valve/Disk 2. Heat Transfer/Primary Coolant 3. 20 221220	1. FERMI 2. Primary/No. 1 sodium pump 3. 360 to 1000°F 4. EFAPP, maintenance report No. 15	MA 174	MA 58	MA 417	7588	Protective system	1. Check valve caused sodium hammer during pump startup. 2. Component design change; the original check valve was replaced with a new check valve incorporating an integral dash pot. 3. The design of check valves should consider rate decay and valve closure rate to minimize sodium hammer.
172	1. Valve/Disk 2. Heat Transfer/Primary Coolant 3. 20 221220	1. FERMI 2. Primary/No. 2 sodium pump 3. 360 to 1999°F 4. EFAPP, maintenance report No. 33	MA 174	MA 58	MA 417	7840	Protective system	1. Check valve caused sodium hammer during pump startup. 2. Component design change; the original check valve was replaced with a new check valve incorporating an integral dash pot. 3. The design of check valves should consider rate decay and valve closure rate to minimize sodium hammer.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 34 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
173	1. Valve/Disk 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. FERMI 2. Primary/No. 3 sodium pump 3. 360 to 1000°F 4. EFAPP, maintenance report No. 27	MA 174	MA 58	MA 417	7840	Protective system	1. Check valve caused sodium hammer during pump startup. 2. Component design change; the original check valve was replaced with a new check valve incorporating an integral dash pot. 3. The design of check valves should consider rate decay and valve closure rate to minimize sodium hammer.
174	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224239	1. FERMI 2. Secondary/cold trap V-836 3. 515°F 4. EF-21	MI 136	MI 59	MI 530	11,010	Direct observation	1. Bellows ruptured. 2. Bellows replaced. 3. None.
175	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224239	1. FERMI 2. Transfer tank/cold trap FCV-401 3. 515°F 4. EF-52	MI 136	MI 61	MI 530	15,000	Leak detector system	1. Bellows leaked. 2. Defective component returned to manufacturer. 3. None.
176	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. FERMI 2. Primary sodium 3. - 4. APDA, CFE-11	MI 136	MI 61	MI 530	15,000	Operational monitors	1. Bellows leaked. 2. Vendor repair of component. 3. None.
177	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. FERMI 2. Primary sodium service building 3. 550 to 800°F 4. EF-26, page 3	MI 454	MI 61	MI 136	13,400	Operational monitors	1. Bellows leaked. 2. Component part replaced by vendor. 3. Source acceptance standards should be reviewed to ensure satisfactory performance of future purchased parts.
178	1. Valve/Bellows 2. Heat Transfer/Liquid Metal Purification 3. 20 224230	1. EBR-II 2. Primary (cold trap bypass) 3. 250 to 700°F 4. ANL 6810, December 1963	MI 172	MI 59	MI 136	100	Direct observation	1. Bellows leaked. 2. Part replaced. 3. None.

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FAILURE DATA FOR VALVES
(Sheet 35 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
179	1. Valve/Bellows 2. Heat Transfer/Liquid Metal Purification 3. 20 224233	1. EBR-II 2. Primary system/plugging loop 3. 250 to 700°F 4. PMMR-86	MI 172	MI 59	MI 530	8800	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. None.
180	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224233	1. EBR-II 2. Primary system/plugging loop 3. 250 to 700°F 4. PMMR-86	MI 172	MI 59	MI 530	8800	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. None.
181	1. Valve/Gate 2. Heat Transfer/Liquid Metals Purification 3. 20 224233	1. EBR-II 2. Primary/plugging loop plug RIVC-677 3. 300°F at 60 gpm 4. PMMR-101	MI 172	MI 55	MI 530	10,400	Direct observation	1. Gate jammed, forced open. 2. Local repair, valve gate was stuck into the seat. The valve was freed manually. 3. Valve operated satisfactorily following corrective action.
182	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 221220	1. EBR-II 2. Primary/throttle 3. 300°F 4. PMMR-101	MI 260	MI 52	MI 580	10,400	Preventive maintenance	1. Possible copper deposition on bellows. 2. Part replaced. 3. Components containing copper should not be used in sodium systems.
183	1. Valve/Bellows 2. Heat Transfer/ Primary Coolant 3. 20 221220	1. EBR-II 2. Primary/throttle 3. 300°F 4. PMMR-101	MI 260	MI 52	MI 580	10,400	Preventive maintenance	1. Possible copper deposition on bellows. 2. Part replaced. 3. Components containing copper should not be used in sodium systems.
184	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224239	1. EBR-II 2. Primary 3. 250 to 700°F 4. Operations weekly report, week ending April 10, 1968	MI 126	MI 61	MI 530	15,000	Direct observation	1. Bellows ruptured. 2. Valve replaced. 3. None.
185	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 222220	1. EBR-II 2. Secondary/plugging meter 3. 250 to 700°F 4. ANL 6965, October 1964	MI 172	MI 59	MI 136	2608	Operational monitors	1. Bellows ruptured. 2. Part replaced. 3. None.

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FAILURE DATA FOR VALVES

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
186	1. Valve/Bellows 2. Heat Transfer/Intermediate Cooling 3. 20 222220	1. EBR-II 2. Secondary/surge tank vent, S2-VC-1589 3. 300°F 4. PMMR-25	MI 172	MI 59	MI 530	2608	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. None.
187	1. Valve/Bellows 2. Heat Transfer/Intermediate Cooling 3. 20 224236	1. EBR-II 2. Secondary/surge tank vent, S2-VC-1589 3. 250 to 700°F 4. PMMR-33	MI 172	MI 59	MI 530	3208	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. None.
188	1. Valve/Unknown 2. Heat Transfer/Liquid Metal Purification 3. 20 224235	1. EBR-II 2. Secondary/plugging 3. 250 to 700°F 4. PMMR-57	MI 125	MI 52	MI 530	2415	During actuation	1. Valve not operating properly. 2. Local repair. 3. None.
189	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224235	1. EBR-II 2. Secondary/plugging loop 3. 250 to 700°F 4. PMMR-77	MI 126	MI 59	MI 530	7290	Direct observation	1. Bellows leaked. 2. Part replaced. 3. None.
190	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224235	1. EBR-II 2. Secondary/plugging loop 3. 250 to 700°F 4. PMMR-92	MI 172	MI 59	MI 530	10, 100	Direct observation	1. Bellows leaked. 2. Part replaced. 3. None.
191	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224235	1. EBR-II 2. Secondary/plugging loop 3. 250 to 700°F 4. PMMR-102	MI 172	MI 59	MI 530	10, 800	Direct observation	1. Bellows leaked. 2. Part replaced. 3. None.

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ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
192	1. Valve/Bellows 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. EBR-II 2. Secondary/sodium 3. 250 to 700°F 4. Operations weekly report, week ending 2-14-68	MI 172	MI 59	MI 530	14,500	Direct observation	1. Bellows leaked. 2. Part replaced. 3. None.
193	1. Valve/Bellows 2. Heat Transfer/Primary Coolant 3. 20 221213	1. ANL 2. Sodium quality test loop 3. 1200°F 4. NAA-SR-12585	MA 120	MA 69	MA 136	6100	Direct observation	1. Bellows leaked, fatigue failure at the weld joint. 2. Part replaced. 3. None.
194	1. Valve/Plug 2. Heat Transfer/Test Section 3. 20 221213	1. ANL 2. Mechanical pump test loop 3. 1000°F 4. NAA-SR-12585	MA 455	MA 55	MA 550	6750	Direct observation	1. Failed to open or close — handwheel that secures valve position was closed at the same time operator was attempting to operate valve. 2. Local repair; replaced with new parts. 3. Redesign of system to prevent operation in the locked position.
195	1. Y-Valve/Stem and Bushing 2. Heat Transfer/Test Section 3. 20 222213	1. ANL 2. Mechanical pump test loop 3. 800°F 4. NAA-SR-12585	MI 413	MI 55	MI 111	21,500	Direct observation	1. Valve stem and bushing not fabricated to specified dimensions, resulting in flow variance through valve. 2. Local repair; stem and bushing machined to correct dimensions. 3. Revise quality assurance procedures to include inspecting stem and bushing.
196	1. Ball Valve/Ball 2. Heat Transfer/Test Section 3. 20 222213	1. ANL 2. Mechanical pump test loop 3. 750°F 4. NAA-SR-12585	MI 126	MI 83	MI 590	11,400	Direct observation	1. Stellite-coated ball worn. Valve operated 11,400 hours before being resurfaced. Normal wearout. 2. Vendor repaired component — resurfaced ball. 3. None.
197	1. Y-Valve/Bushing and Stem 2. Heat Transfer/Test Section 3. 20 222213	1. ANL 2. AC linear induction sodium pump test loop 3. 850°F 4. NAA-SR-12585	MI 413	MI 55	MI 111	6600	Direct observation	1. Valve stem and guide bushing not fabricated to specified dimensions, resulted in unstable flow through valve. 2. Local repair; stem and bushings were machined to specified dimensions. 3. Upgrade quality assurance inspections for acceptance of valves.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 38 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
198	1. Y-Valve/Stem and Bushing 2. Heat Transfer/Test Section 3. 20 222213	1. ANL 2. Electromagnetic pump test loop 3. 850°F 4. NAA-SR-12585	MI 413	MI 55	MI 111	5000	Direct observation	1. Valve stem and guide bushing not fabricated to specified dimensions, resulting in unstable flow through valve. 2. Local repair; stem and bushings were machined to specified dimensions. 3. Upgrade quality assurance inspections for acceptance of valves.
199	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. HNPF 2. Primary/cold trap inlet (V-449) 3. 300 to 700°F 4. HNPF monthly hilites, 10-12-62	MA 172	MA 59	MA 136	5280	During actuation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows sealed valve with stem freeze seal type.
200	1. Valves/Bellows 2. Heat Transfer/Primary Coolant 3. 20 224230	1. HNPF 2. Primary/fill and drain line (V-466) 3. 300 to 700°F 4. HNPF, work request No. 2092	MA 172	MA 59	MA 136	4320	During actuation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows sealed valve with stem freeze seal type.
201	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. HNPF 2. Primary/hot trap (V-471) 3. 300 to 700°F 4. HNPF, initial malfunction report-MOR 10081	MA 332	MA 59	MA 136	15,744	During actuation	1. Bellows leaked; valve operated before it was properly preheated. 2. Part replaced. 3. Replaces bellows sealed valve with stem freeze seal type.
202	1. Valve/Packing 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-103) 3. 300 to 900°F 4. HNPF, work request No. 1869	MI 125	MI 52	MI 530	730	During preventive maintenance	1. Packing worn out. 2. Local repair; packing replaced. 3. None.
203	1. Valve/Packing 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-203) 3. Ambient temperature 4. HNPF, work request No. 1869	MI 125	MI 52	MI 530	730	During preventive maintenance	1. Packing worn out. 2. Local repair; packing replaced. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES
(Sheet 39 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
204	1. Valve/Packing 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-303) 3. Ambient temperature 4. HNPF, work request No. 1869	MI 125	MI 52	MI 530	730	During preventive maintenance	1. Packing worn out. 2. Local repair; packing replaced. 3. None.
205	1. Valve/Packing 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-102, V-202, V-302) 3. - 4. Work request No. 1869	MI 125	MI 52	MI 530	2130	During preventive maintenance	1. Packing worn out (three secondary throttle valves). 2. Local repair, packing replaced. 3. None.
206	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-103) 3. - 4. Work request No. 2749	MI 124	MI 54	MI 530	7000	Direct observation	1. Distortion. 2. Local repair, rebuilt yoke mechanism. 3. None.
207	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-203) 3. - 4. Work request No. 2749	MI 124	MI 54	MI 530	7000	Direct observation	1. Distortion. 2. Local repair, rebuilt yoke mechanism. 3. None.
208	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-303) 3. - 4. Work request No. 1440	MA 122	MA 54	MA 550	1656	Operational monitors	1. Distortion, yoke and stem were bent at 75% open position. 2. Vendor repair of component. 3. Redesign yoke mechanism to eliminate bending stress in stem.
209	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-103) 3. - 4. AI monthly hilites, 8-15-62	MI 416	MI 52	MI 530	3000	During routine inspection	1. Distortion. 2. Local repair, stiffeners added to cross-arm. 3. Redesign yoke mechanism to eliminate bending stress in stem.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 40 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
210	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-103) 3. - 4. Work request No. 2867	MI 126	MI 59	MI 530	7392	Operational monitors	1. Cross-arm cracked. 2. Local repair, repaired cross-arm and straightened stem. 3. Redesign yoke mechanism to eliminate bending stress in stem.
211	1. Valve/Yoke Mechanism 2. Heat Transfer/Intermediate Coolant 3. 20 222200	1. HNPF 2. Secondary/throttle (V-202) 3. - 4. Work request No. 2939	MI 331	MI 54	MI 530	7180	Operational monitors	1. Yoke distorted because of misuse. 2. Local repair, straightened stem and jack screw. 3. Review operator training manual.
212	1. Valve/Yoke Mechanism 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-303) 3. - 4. Work request No. 2749	MI 416	MI 54	MI 530	7000	Direct observation	1. Yoke distorted. 2. Local repair, rebuilt yoke mechanism. 3. Redesign yoke mechanism to eliminate bending stress in stem.
213	1. Valve/Stem 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/throttle (V-303) 3. - 4. Work request No. 1440	MA 321	MA 55	MA 122	1656	Operational monitors	1. Stem shield plug over valve installed wrong, prevented valve operating over full range. 2. Vendor repair of component. 3. Redesign shield plug to prevent interference with valve operation.
214	1. Valve/Stem 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/drain (V-459) 3. - 4. A.I. Monthly Hilites, 3-20-63	MI 172	MI 68	MI 530	8928	Direct observation	1. Valve stem was bent and scored. 2. Component part replaced. 3. None.
215	1. Valve/Stem Guide Bushing 2. Heat Transfer/Liquid Metals Purification 3. 20 224233	1. HNPF 2. Secondary/cold trap fill and drain (V-4109) 3. - 4. Work request No. 3364	MI 126	MI 68	MI 530	5800	Direct observation	1. Scored/galled. 2. Component part replaced. 3. None.
216	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224236	1. HNPF 2. Secondary/fill tank outlet (V-491) 3. 100 - 300°F 4. IMR - MOR 10089	MA 172	MA 61	MA 136	18840	Routine area watch	1. Bellows leaked. 2. Part replaced. 3. Replace bellows with freeze stem seal.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 41 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
217	1. Valve/Bellows 2. Heat Transfer/Primary Coolant 3. 20 221220	1. HNPF 2. Primary/block (V-476) 3. 100 to 300°F 4. IMR - MOR 10113	MA 172	MA 61	MA 136	21,000	Protective system	1. Bellows leaked. 2. Part replaced. 3. Replace bellows with freeze stem seal.
218	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. HNPF 2. Primary/plugging meter (V-443) 3. 100 to 300°F 4. Work request No. 1432	MA 172	MA 59	MA 136	1440	During actuation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows with freeze stem seal.
219	1. Valve/Bellows 2. Heat Transfer/Primary Coolant 3. 20 224230	1. HNPF 2. Primary/hot trap carbon (V-471) 3. 100 to 300°F 4. Work request No. 1772	MA 172	MA 59	MA 136	3600	During actuation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows with freeze stem seal.
220	1. Valve/Yoke Mechanism 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-102) 3. - 4. Work request No. 2749	MI 416	MI 54	MI 530	7000	Direct observation	1. Yoke distorted. 2. Local repair; rebuilt yoke. 3. Redesign yoke mechanism to eliminate bending stress in stem.
221	1. Valve/Yoke Mechanism 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-202) 3. - 4. Work request No. 2749	MI 416	MI 54	MI 530	7000	Direct observation	1. Yoke distorted. 2. Local repair; rebuilt yoke. 3. Redesign yoke mechanism to eliminate bending stress in stem.
222	1. Valve/Yoke Mechanism 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-302) 3. - 4. Work request No. 2749	MI 416	MI 54	MI 530	7000	Direct observation	1. Yoke distorted. 2. Local repair; rebuilt yoke. 3. Redesign yoke mechanism to eliminate bending stress in stem.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 42 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
223	1. Valve/Packing 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-202) 3. - 4. Work request No. 1869	MI 125	MI 52	MI 530	730	During preventive maintenance	1. Packing worn out. 2. Local repair; packing replaced. 3. None.
224	1. Valve/Packing 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. HNPF 2. Secondary/throttle (V-302) 3. - 4. Work request No. 1869	MI 125	MI 52	MI 530	730	During preventive maintenance	1. Packing worn out. 2. Local repair; packing replaced. 3. None.
225	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (PMV) 3. 250 to 950°F 4. Operation log book, 1-29-63	MI 126	MI 59	MI 530	5760	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
226	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-124) 3. 250 to 950°F 4. Operation log book No. 51, 2-24-63	MI 125	MI 59	MI 530	16,400	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
227	1. Valve/Bellows 2. Heat Transfer/Intermediate Coolant 3. 20 222220	1. SRE 2. Main secondary/sodium (V-124) 3. 250 to 950°F 4. Operation log book No. 51, 3-6-63	MI 321	MI 59	MI 530	336	Direct observation	1. Bellows leaked due to assembly error. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
228	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-644) 3. 250 to 950°F 4. Maintenance log book, 7-10-63	MI 126	MI 59	MI 530	18,100	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.

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TABLE 1-119

FAILURE DATA FOR VALVES
(Sheet 43 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
229	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224235	1. SRE 2. Main secondary/plugging meter (PMV) 3. 250 to 950°F 4. Operation log book No. 9	MI 126	MI 59	MI 530	3600	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
230	1. Valve/Bellows 2. Heat Transfer/Coolant Receiving, Makeup, and Treatment 3. 20 224230	1. SRE 2. Main secondary/fill and drain (V-166) 3. 250 to 950°F 4. Operation log book No. 11, 11-25-58	MI 126	MI 59	MI 530	15, 100	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
231	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (PMV) 3. 250 to 950°F 4. Operation log book No. 13, 6-23-59	MI 126	MI 59	MI 530	18, 720	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
232	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-105) 3. 250 to 950°F 4. Operation log book No. 6, 1-4-58	MI 120	MI 54	MI 530	7200	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
233	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Primary/freeze trap (V-624) 3. 250 to 950°F 4. Operation log book No. 7, 6-1-58	MI 126	MI 59	MI 530	9360	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
234	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-126) 3. 250 to 950°F 4. Operation log book No. 7, 6-16-69	MI 126	MI 59	MI 530	9360	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 44 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
235	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (PMV) 3. 250 to 950°F 4. Operation log book No. 7, 6-24-69	MI 126	MI 59	MI 530	4080	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
236	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (PMV) 3. 250 to 950°F 4. Operation log book, 8-12-60	MI 126	MI 59	MI 530	4200	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
237	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-634) 3. 250 to 950°F 4. Operation log book, 3-10-60	MI 126	MI 59	MI 530	9720	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
238	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-617) 3. 250 to 950°F 4. Operation log book No. 24, 9-30-60	MI 126	MI 59	MI 530	9720	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows valve with freeze stem seal.
239	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-125) 3. 250 to 950°F 4. Operation log book No. 25, 12-28-60	MI 126	MI 59	MI 530	13,600	Direct observation	1. Bellows leaked. 2. Part replaced. 3. Replace bellows with freeze stem seal.
240	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-620) 3. 250 to 950°F 4. Operation log book No. 26, 1-13-61	MI 126	MI 59	MI 530	12,100	Direct observation	1. Bellows ruptured. 2. Part replaced. 3. Replace bellows with freeze stem seal.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 45 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
241	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-616) 3. 250 to 950°F 4. Operation log book No. 26, 1-28-61	MI 126	MI 59	MI 530	12, 100	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.
242	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (V-618) 3. 250 to 950°F 4. Operation log book No. 26, 3-30-61	MI 126	MI 59	MI 530	13, 000	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.
243	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/plugging meter (PMV) 3. 250 to 950°F 4. Operation log book No. 35, 11-8-61	MI 327	MI 59	MI 530	11, 000	Direct observation	1. Bellows failed; valve was closed when cold. 2. Part replaced. 3. Replace bellows with freeze stem seal.
244	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium (V-635) 3. 250 to 950°F 4. Operation log book No. 35, 2-6-62	MI 120	MI 59	MI 530	12, 000	Direct observation	1. Bellows failed. 2. Part replaced with freeze stem seal. 3. None.
245	1. Valve/O-Ring 2. Heat Transfer/Liquid Metals Purification 3. 20 224235	1. SRE 2. Main secondary/plugging meter (PMV) 3. 250 to 950°F 4. Operation log book No. 11, 11-30-58	MI 321	MI 56	MI 136	14, 400	Direct observation	1. O-ring not seated ontop flange. 2. Stainless steel O-ring replaced. 3. None.
246	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main primary/sodium service (PMV) 3. 250 to 950°F 4. Operation log book No. 8, 6-24-58	MI 126	MI 59	MI 530	3600	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.
247	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-124) 3. 250 to 950°F 4. Operation log book No. 8, 7-2-58	MI 126	MI 59	MI 530	4560	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 46 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
248	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-127) 3. 250 to 950°F 4. Operation log book No. 8, 7-13-68	MI 126	MI 59	MI 530	10, 800	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.
249	1. Valve/Bellows 2. Heat Transfer/Liquid Metals Purification 3. 20 224230	1. SRE 2. Main secondary/sodium service (V-124) 3. 250 to 950°F 4. Operation log book No. 8, 8-16-58	MI 126	MI 59	MI 530	10,800	Direct observation	1. Bellows failed. 2. Part replaced. 3. Replace bellows with freeze stem seal.
250	1. Valve/Solenoid 2. Heat Transfer/ Electrical 3. 20 221121	1. LCTL 2. LCTL/core tank drain (V-33) 3. 1200°F 4. Lab notebook A-086301, 9-28-59	MI 236	MI 13	MI 550	Unknown	Direct observation	1. Coil of solenoid failed. 2. Replaced part. 3. Cover coil with a sealant to protect against moisture.
251	1. Valve/Solenoid 2. Heat Transfer/ Electrical 3. 20 221121	1. LCTL 2. LCTL/core tank inlet (V-303C) 3. 1200°F 4. Lab notebook A-086301, 9-28-59	MI 236	MI 13	MI 550	Unknown	Direct observation	1. Coil of solenoid failed. 2. Replaced part. 3. Cover coil with a sealant to protect against moisture.
252	1. Valve/Bellows 2. Heat Transfer/ Reactor Coolant Piping and Valves 3. 20 221220	1. LCTL 2. LCTL/2 by 3 loop vent (V-23A) 3. 1200°F 4. Lab notebook A-086374, 4-20-60	MI 126	MI 59	MI 550	Unknown	Direct observation	1. Bellows ruptured. 2. Replaced bellows. 3. Replace bellows with freeze stem seal.
253	1. Valve/Solenoid 2. Heat Transfer/ Electrical 3. 20 221121	1. LCTL 2. LCTL/drain tank drain (V-37) 3. 1200°F 4. Log book 21-2, 1-4-65	MI 236	MI 13	MI 550	Unknown	Direct observation	1. Solenoid inoperative. 2. Replaced part. 3. None.

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TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 47 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
254	1. Valve/Flange 2. Heat Transfer/Cold Trap 3. 20 224230	1. LCTL 2. LCTL/inlet to cold trap 3. 1200°F 4. Lab notebook B-041182, 10-11-61	MI 148	MI 34	MI 530	Unknown	Direct observation	1. Flange bolts worked loose which caused a sodium leak. Valves not originally designed for sodium service. 2. Flange was welded. 3. Initial maintenance procedures on correct installation of flanges.
255	1. Valve/Flange 2. Heat Transfer/Reactor Coolant Piping and Valves 3. 20 221220	1. LCTL 2. LCTL/3 in. thermal shock drain line (V-31A) 3. 1200°F 4. Lab notebook B-041183, 10-17-61	MI 148	MI 53	MI 530	Unknown	Direct observation	1. Flange bolts worked loose which caused a sodium leak. Valves not originally designed for sodium service. 2. Flange was welded. 3. Initiate maintenance procedure on correct installation of flanges.
256	1. Valve/Stem 2. Heat Transfer/Primary Coolant 3. 20 221220	1. LCTL 2. LCTL/6 in. thermal shock loop (V-HIC-62) 3. 1000°F 4. Lab notebook B-104302, 1-15-62	MI 120	MI 55	MI 550	Unknown	Direct observation	1. Valve stem jammed. 2. Disassembled, cleaned, and placed back in system. 3. None.
257	1. Valve/Flange 2. Heat Transfer/Primary Coolant 3. 20 221220	1. LCTL 2. LCTL/3 in. magnetic trap 3. 1200°F 4. Lab notebook A-086329	MI 148	MI 34	MI 550	Unknown	Direct observation	1. Flange bolts worked loose which caused a sodium leak. 2. Tightened flange bolts. 3. Initiate maintenance procedure on correct installation of flanges.
258	1. Valve/Solenoid 2. Heat Transfer/Primary Coolant 3. 20 221121	1. LCTL 2. LCTL/core tank inlet (V-HIC-63) 3. 1000°F 4. Log book No. 2, 2-20-68	MI 236	MI 13	MI 550	Unknown	Direct observation	1. Solenoid inoperative. 2. Replaced part. 3. None.
259	1. Valve/Bellows 2. Heat Transfer/Intermediate Coolant Test Section 3. 20 222213	1. LCTL 2. LCTL/6 by 8 test section (V-67) 3. 1000°F 4. Lab notebook A-086360	MI 120	MI 34	MI 550	Unknown	Direct observation	1. Bellows ruptured. 2. Replaced bellows. 3. Replace bellows with freeze stem seal.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 48 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
260	1. Valve/Freeze Stem 2. Heat Transfer/Primary Coolant 3. 20 221220	1. LCTL 2. Supply tank/drain (V-HIC-305A) 3. Maximum operating temperature 1200°F 4. Incident, malfunction, and problem report No. 002	MA 195	MA 55	MA 550	Unknown	Direct observation	1. Valve inoperative — oxide deposit in stem region. 2. Jury rig, freeze stem heated with GE heater cable until valve stem free to move. Valve is in the scram circuit of the system and therefore not usually operated. 3. None.
261	1. Valve 2. Heat Transfer System/Gas Supply and Monitoring System 3. 20 224600	1. Fermi 2. No. 2 recirculating gas compressor room climate changer (TCV-1904-2) 3. Unknown 4. EF-51, page 4	MI 479	MI 51	MI 550	Unknown	During actuation	1. Valve would not close upon demand. 2. Valve disassembled, revealing a foreign object in valve housing. 3. Quality assurance needs improvement.
262	1. Valve 2. Heat Transfer/Inert Gas Supply and Monitoring System 3. 20 224610	1. Fermi 2. No. 1 recirculating gas compressor (Valve FCV-471) 3. Unknown 4. EF-51, page 4	MI 479	MI 51	MI 550	Unknown	During actuation	1. Valve would not close upon demand. 2. Valve disassembled, revealing a foreign object in valve housing. 3. Quality assurance needs improvement.
263	1. Valve/Assembly 2. Nuclear Fuel Handling and Storage Equipment /Fuel Handling Equipment 3. 20 236000	1. Fermi 2. Cask car 3. 450 to 550°F sodium temperature 4. EF-16 and EFAPP-MR-85	MI 410	MI 55	MI 550	Unknown	During actuation	1. Sodium froze valve shut. 2. Assembly cleaned, and thrust bearings and O-ring seal replaced. 3. Additional research and development required.
264	1. Valve 2. Nuclear Fuel Handling and Storage Equipment /Fuel Handling Equipment 3. 20 236000	1. Fermi 2. Cask car 3. Unknown 4. EFAPP-MR-59	MI 218	MI 51	MI 550	Unknown	Operation monitors	1. Ball valve operation difficult due to accumulation of sodium in the valve cavity. 2. Valve cleaned, and all O-ring seals replaced. 3. Additional research and development required.
265	1. Valve/Bellows 2. Heat Transfer/Coolant Piping and Valves 3. 20 221220	1. Fermi 2. Cold trap room primary sodium service piping (V-516) 3. Unknown 4. EF-53, EF-56, and EF-57	MI 124	MI 59	MI 530	Unknown	During preventive maintenance	1. Bellows leaked. 2. Bellows replaced. 3. Additional research and development required.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 49 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
266	1. Valve/Bellows 2. Heat Transfer/Coolant Piping and Valve 3. 20 221220	1. Fermi 2. Cold trap room primary sodium service piping (V502-1) 3. Unknown 4. EF-52, EF-56, and EF-57	MI 124	MI 59	MI 530	Unknown	Routine area watch - direct observation	1. Bellows leaked. 2. Bellows replaced. 3. Additional research and development required.
267	1. Valve 2. Heat Transfer/Pump 3. 20 221110	1. Fermi 2. No. 1 primary pump liquid rheostat general service water bypass valve 3. 450 to 525°F sodium temperature 4. EF-37, page 4	MI 110	MI 51	MI 550	Unknown	Operation monitor	1. Valve plugged and inoperative. 2. Valve removed and cleaned. 3. None.
268	1. Valve/Drain Plug 2. Heat Transfer/Steam Generators 3. 20 223000	1. Fermi 2. No. 1 steam generator drain plug on isolation valve (FSV-604) 3. 450 to 525°F sodium temperature 4. EF-34, page 8	MI 125	MI 96	MI 530	Unknown	Direct observation	1. Leaking drain plug. 2. While generator vented off, plug repaired. 3. None.
269	1. Valve/Solenoid 2. Instrumentation and Coltrol/Argon Supply 3. 20 269000	1. Fermi 2. Cleaning machine (FSV-202) 3. 475 to 650°F sodium temperature 4. EF-33, page 5	MI 124	MI 52	MI 530	Unknown	Operational monitors	1. Erratic argon supply valve operation to the cleaning machine. 2. Solenoid armature for FSV-202 replaced. 3. None.
270	1. Valve/Solenoid 2. Instrumentation and Control/Shield 3. 20 261200	1. Fermi 2. Primary shield tank sensing line 3. Unknown 4. EFAPP-MR-125	MI 16Z	MI 13	MI 550	Unknown	During actuation	1. Malfunction of the solenoid valve caused a fuse to blow in the electrical circuit, which prevented switch-over to the alternate sensing line. The overall result was a loss of control with positive pressure swings. 2. The alternate sensing line was switched into service, and FCV-1370-4 was energized by replacing blown fuse. 3. Design modification to part or circuit.
271	1. Valve 2. Nuclear Fuel Handling and Storage Equipment /Cooling and Cleaning 3. 20 233100	1. Fermi 2. Steam cleaning machine valve 3. Unknown 4. EF-41 and EFAPP-MR-119	MI 127	MI 57	MI 550	Unknown	Direct observation (unscheduled)	1. Valve froze in a partially open position, resulting in a low load cut-out. 2. Galled valve stem, bushing, and valve carrier were replaced with new parts of harder material. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES
(Sheet 50 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
272	1. Valve/Bushing 2. Nuclear Fuel Handling and Storage Equipment /Cooling and Cleaning 3. 20 233100	1. Fermi 2. Steam cleaning machine valve 3. Unknown 4. EF-42, page 5	MI 127	MI 57	MI 550	Unknown	During actuation	1. Recently installed parts galled, resulting in valve siezure. 2. Galled valve stem bushing, and valve carrier replaced with parts hardened to Rockwell C 50/55. 3. None.
273	1. Valve/Gasket 2. Reactor Equipment/ In-core Capsules and Test Loops 3. 20 218000	1. CCTL 2. Cold trap loop 3. Unknown 4. CCTL-1	MA 500	MA 96	MA 580	Unknown	Direct observation (unscheduled)	1. Sodium leakage through gasket caused a fire and damage to a 2-in. control valve. Severe corrosion was noted on the outer surfaces of the valve body and piping. 2. Fire extinguished and valve replaced. 3. Provide valves with short-circuit type leak detection.
274	1. Valve/Packing 2. Heat Transfer System /Test Facility Coolant System and Valves 3. 20 221220	1. SCTI 2. Primary sodium system 3. 850°F 4. IMPR-359	MI 124	MI 52	MI 580	Unknown	Protective system	1. Sodium extruded past gland packing, causing a small fire and loss of ≈3 lb sodium. 2. Replaced valve packing. 3. Periodic maintenance checks.
275	1. Valve/Seat 2. Heat Transfer System /Steam and Feedwater /Piping and Valves 3. 20 281200	1. SCTI 2. Steam and water system 3. 2200 psig, 1050°F, 6 Mwt 4. IMPR-357	I 137	I 65	I 530	Unknown	Direct observation (routine watch)	1. Pressure safety valve was observed to be weeping across valve seat with steam generator operating at 2200 psig. Leakage slight, plant not shut down. 2. Valve seat lapped to repair eroded area. 3. Continued R&D for high pressure steam safety relief valves.
276	1. Valve/Stem 2. Heat Transfer System /Coolant System and Valves 3. 20 221220	1. LCTL 2. Supply tank 3. Down (scheduled maintenance) 4. LCTL IMPR-008	P 195	P 55	P 520	Unknown	Direct observation (unscheduled)	1. Valve failed to close when cycled closed. Sodium and sodium oxide held valve open. 2. Sodium melted with heater until valve was free. 3. Bellows enclosure should be added to freeze stem area of valve.
277	1. Valve 2. Reactor Equipment/ In-core Capsules and Test Loops 3. 20 218000	1. ETR 2. Reactor surge tank 3. 700°F 4. INC-69-81	MI 33Z	MI 43	MI 520	Unknown	Operational monitors	1. Surge tank partially drained because of incorrect tank level reading. Three surge tank liquid level fill line valves were found to be open, causing the false indication. 2. Valves closed, normal operation reestablished. 3. Modify procedure for filling and venting.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 51 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
278	1. Valve/Stem 2. Heat Transfer System /Reactor Coolant Piping and Valves 3. 20 221200	1. ATR 2. Primary pressure system 3. Shut down 4. INC-69-183	P 448	P 68	P 530	Unknown	Direct observation (unscheduled)	1. During disassembly of primary system pressure control valve an examination of the shaft was made. Galling was discovered in the upper guide bushing. Damage was probably caused by improper materials and inadequate heat treatment. 2. Replaced shaft and bushings. Machined galled area in valve body. 3. Review materials available for this application and fabricate new components with most suitable material.
279	1. Valve/Stem 2. Heat Transfer/Reactor Coolant System 3. 20 221200	1. ATR 2. Primary coolant system 3. Down (scheduled maintenance) 4. INC-69-50	I 448	I 68	I 520	Unknown	Direct observation (unscheduled)	1. Air operated diaphragm valve opened with pulsating motion, causing vibration of the valve and associated piping. Examination of valve showed erosion of the stem, apparently due to cavitation.
280	1. Valve 2. Feedwater Supply and Treatment/Makeup Water Treatment 3. 20 272000	1. ETR 2. Deoxygenation system 3. Steady full power (175 Mw) 4. INC-69-102	I 33Z	I 3Z	I 580	Unknown	Direct observation (unscheduled)	1. Operator error caused low level in makeup water tank by incorrect valve operation. 2. System returned to normal operation. 3. Improve operations procedure and training.
281	1. Valve/Seat 2. Heat Transfer System /Reactor Coolant System 3. 20 221200	1. ATR 2. Primary coolant system 3. Test in progress 4. INC-69-102	MI 41Z	MI 85	MI 520	Unknown	Routine instrument reading	1. Thermal and radiation measurements indicated leakage from primary system to water supply lines. 2. Valve seat relapped. 3. Additional R&D.
282	1. Valve/ 2. Heat Transfer/Reactor Coolant System 3. 20 218000	1. ATR 2. Primary coolant system 3. Steady full power (250 Mw) 4. INC-69-162	I 344	I BA	I 520	Unknown	Protective system	1. Reactor scrammed when valves were operated in wrong sequence. 2. System returned to normal operation. 3. Review operating procedures thoroughly.
283	1. Valve/Stem 2. Heat Transfer System /Coolant System and Valves 3. 20 221220	1. LCTL 2. Supply tank 3. Startup 4. LCTL IMPR-002	P 195	P 55	P 520	Unknown	Direct observation (unscheduled)	1. Valve failed to close when cycled closed. Sodium and sodium oxide in freeze stem held valve open. 2. Valve heated until operation was normal. 3. Bellows enclosure should be added to freeze stem area.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-119

FAILURE DATA FOR VALVES

(Sheet 52 of 52)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
284	1. Valve/Plug 2. Steam, Condensate, and Feedwater/ Feedwater 3. 20 284300	1. SCTI 2. Feedwater bypass line 3. Down (scheduled maintenance) 4. IMPR 344	M 149	M 59	M 530	1440	During preventive maintenance	1. Valve plug was broken. 2. The valve plug and stem were replaced. Valve modified by incorporating a hydraulic snubber to reduce the impact during operation. 3. Snubbers should be provided when valve plug is fabricated of Type 440C Martensitic stainless steel.
285	1. Valve/Stem 2. Heat Transfer/ Coolant Piping and Valves 3. 20 221200	1. ATR 2. Primary coolant system 3. Down (scheduled maintenance) 4. INC-69-105	I 192	I 64	I 550	Unknown	Direct observation (unscheduled)	1. Inspection of previously repaired valve (INC-69-50) revealed stem erosion and galling. 2. Valve stem replaced. 3. Additional research and development.
286	1. Valve 2. Reactor Equipment/ In-core Capsules and Test Loops 3. 20 218000	1. ETR 2. Primary coolant system 3. Down (scheduled maintenance) 4. INC-69-135	MI 33Z	MI 59	MI 530	Unknown	Direct observation (unscheduled)	1. Steam leak discovered. Valve closed to eliminate possible source. Rotometer blew out due to loop over-pressure caused by cracked open drain valves in surge tank. 2. Valves closed to stop excessive water makeup rate. Rotometer replaced. 3. Procedure revision required.
287	1. Valve 2. Reactor Equipment/ In-core Capsules and Test Loops 3. 20 218000	1. ETR 2. Primary reactor pressurization system 3. Down (scheduled maintenance) 4. INC-69-109	MI 33Z	MI 5Z	MI 550	Unknown	Operational monitors	1. Lack of gas-tightness in nitrogen pressurization valve caused flow fluctuations and thermal "spikes" in primary coolant system. Incorrect closing of valve also cited. 2. Valve repaired — procedures changed. 3. Operator training needs review.
288	1. Valve 2. Reactor Equipment/ Capsules and Test Equipment 3. 20 218000	1. ATR 2. Primary reactor pressurization system 3. Down (scheduled maintenance) 4. INC-69-104	I 33Z	I 5Z	I 590	Unknown	Direct observation (unscheduled)	1. During experimental sample removal, an operator closed a vent valve on the loop high point vent. 2. Operator closed valve after realizing his error. 3. Improve operating training.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-120

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVES

COMPONENT SUBTYPE CIRCULATING WATER VALVES

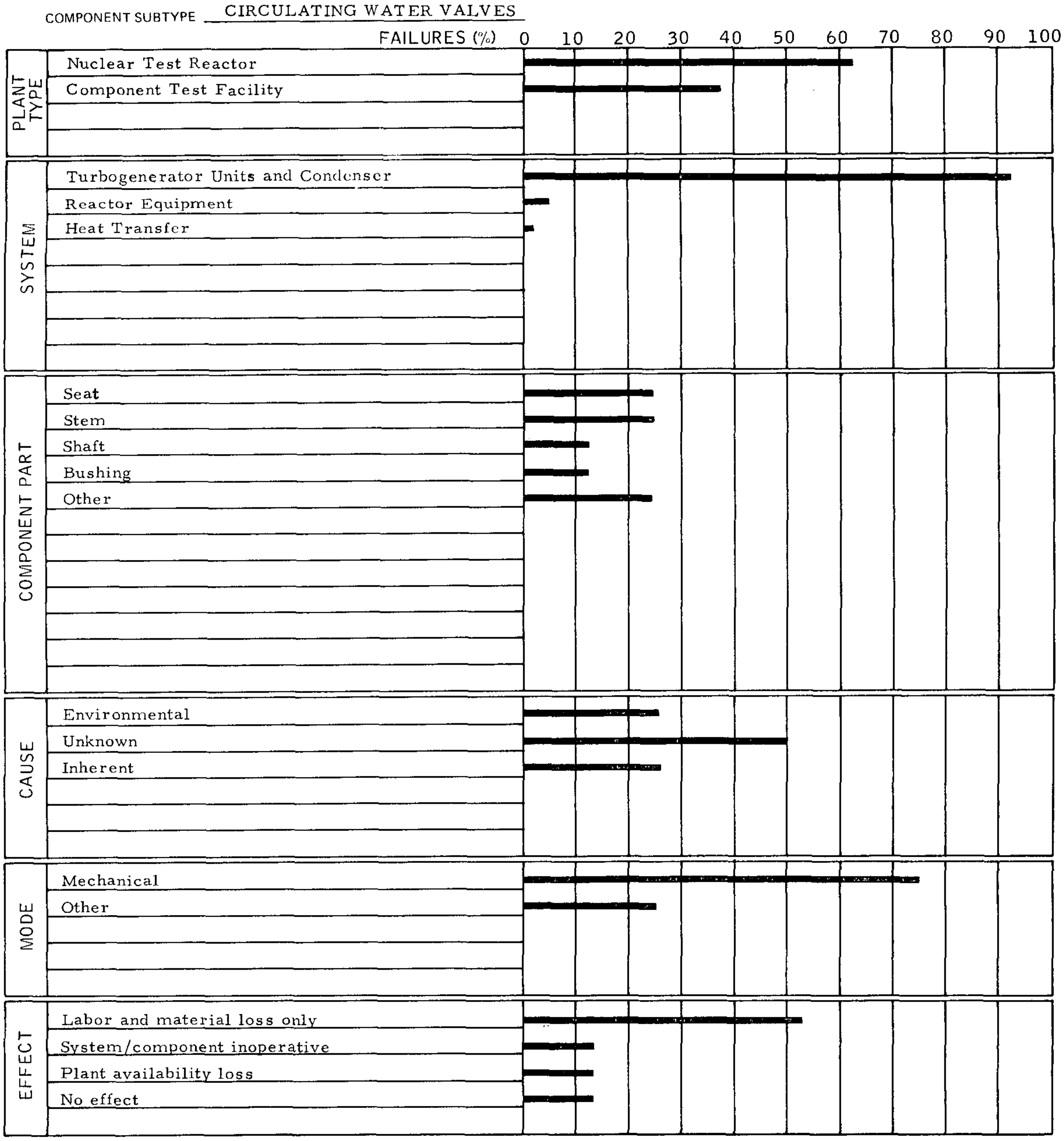


TABLE 1-121

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVES

COMPONENT SUBTYPE CONDENSATE VALVES

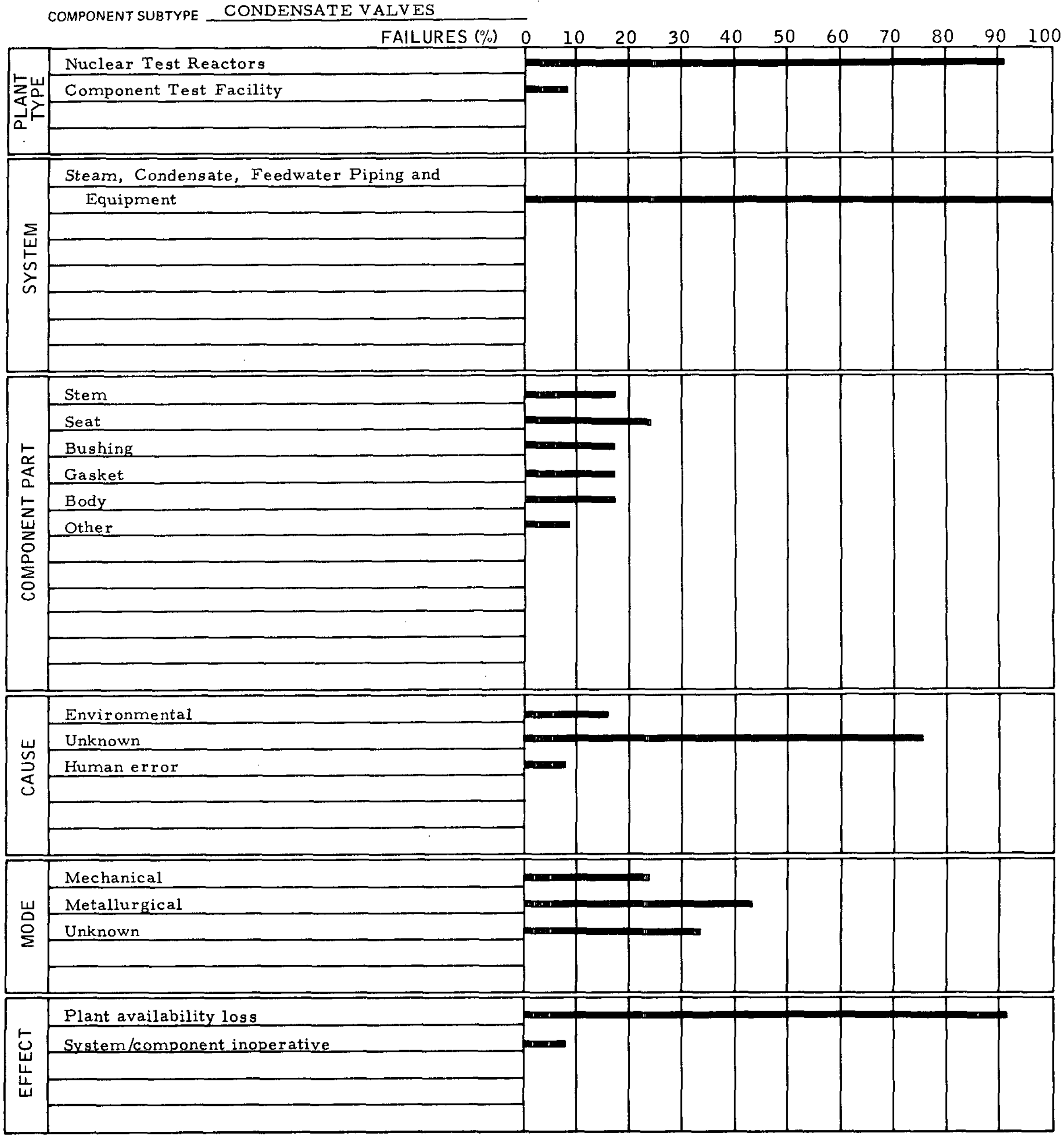


TABLE 1-122

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVES

COMPONENT SUBTYPE FEEDWATER VALVES

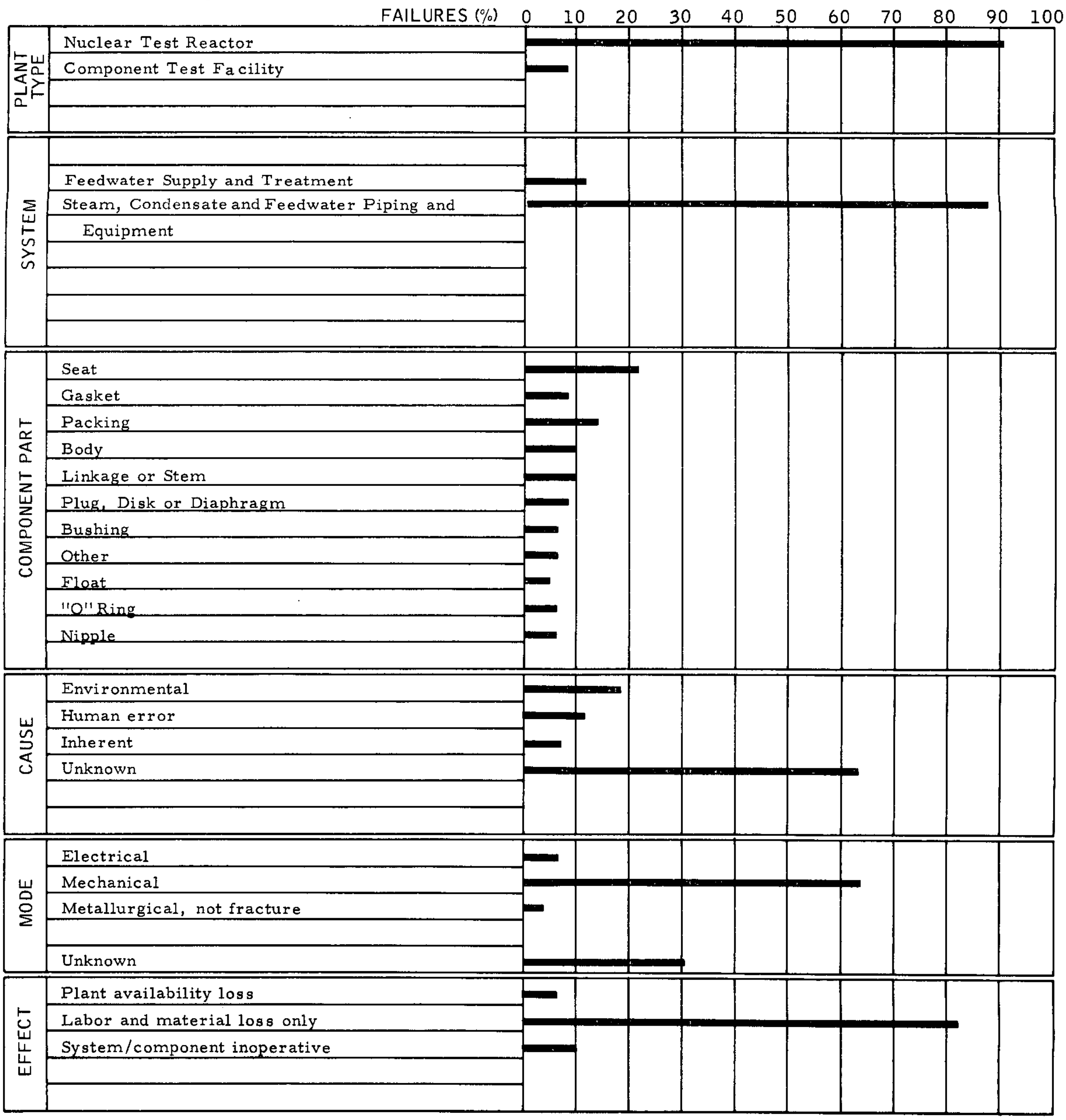


TABLE 1-123

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVES

COMPONENT SUBTYPE MISCELLANEOUS VALVES

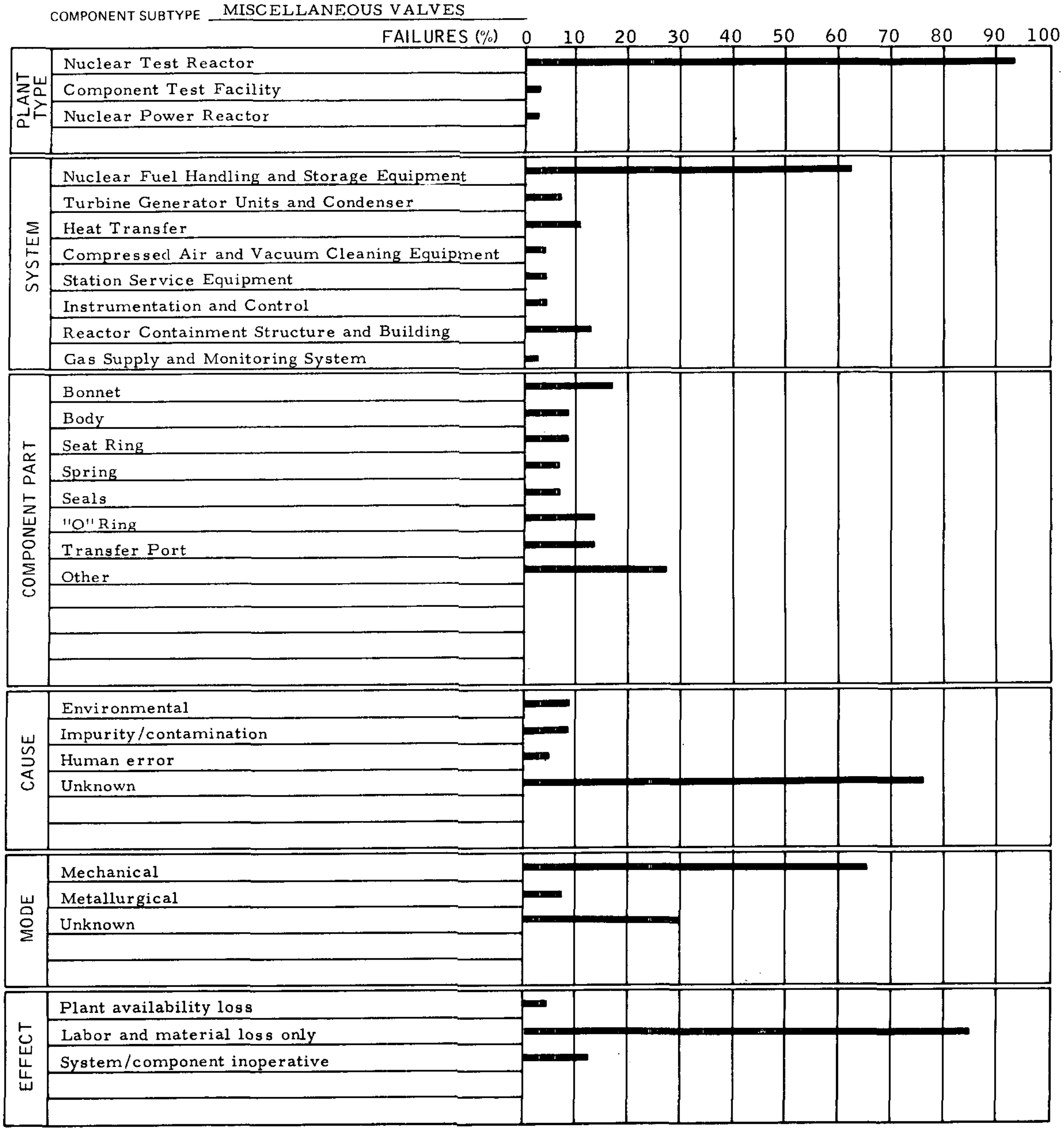


TABLE 1-124

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVE

COMPONENT SUBTYPE SODIUM VALVES

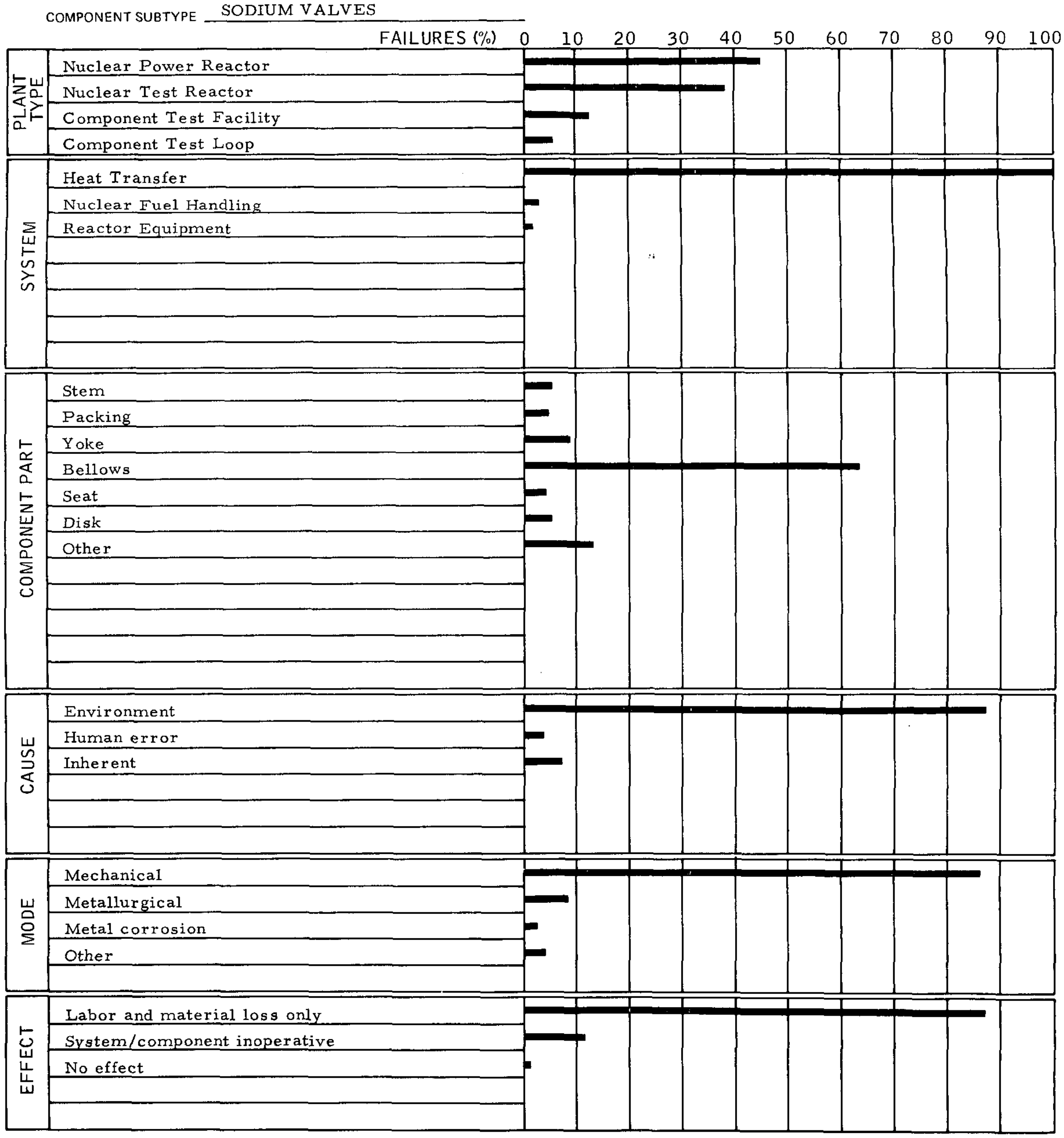


TABLE 1-125

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT VALVES

COMPONENT SUBTYPE STEAM VALVES

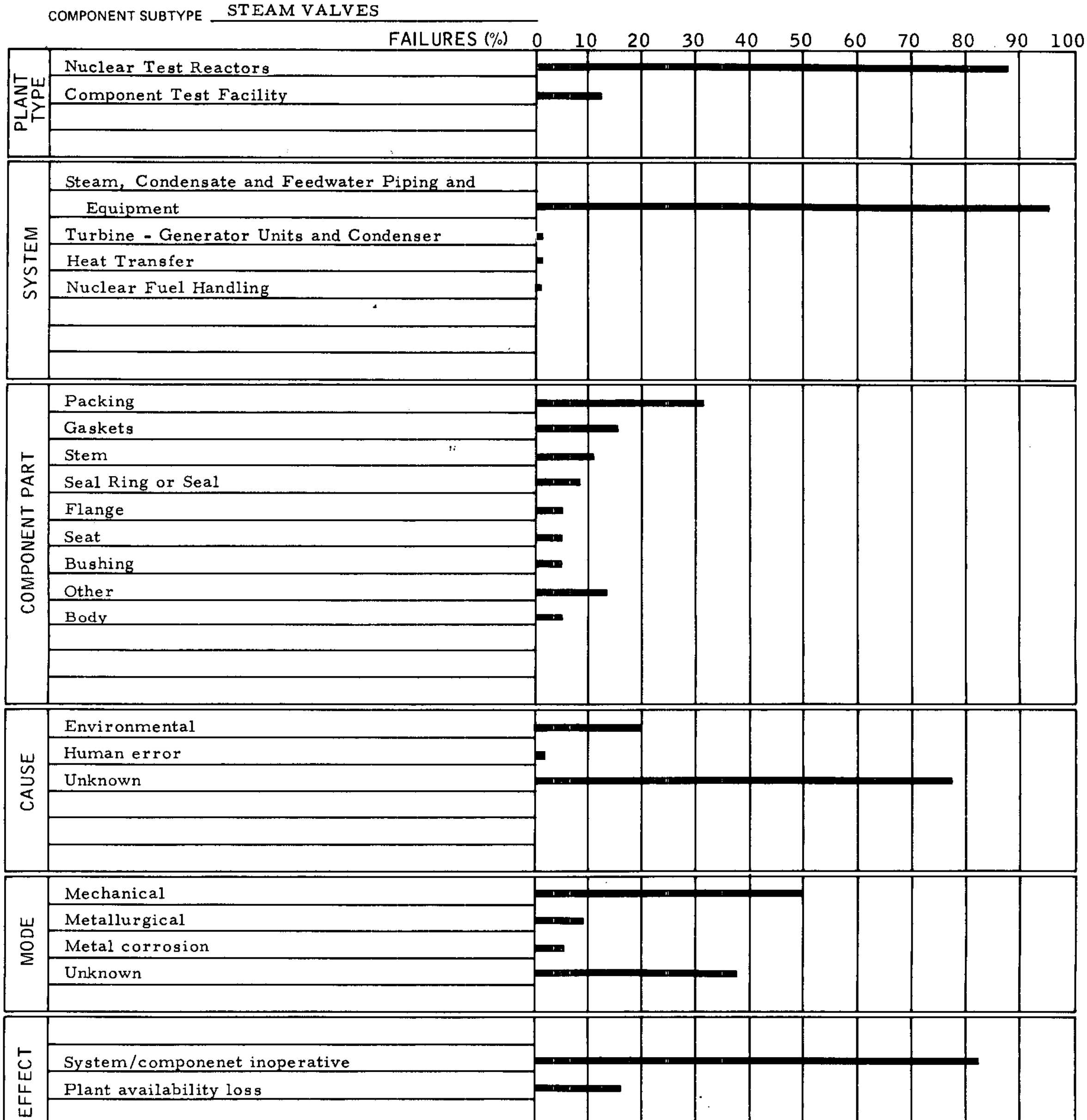
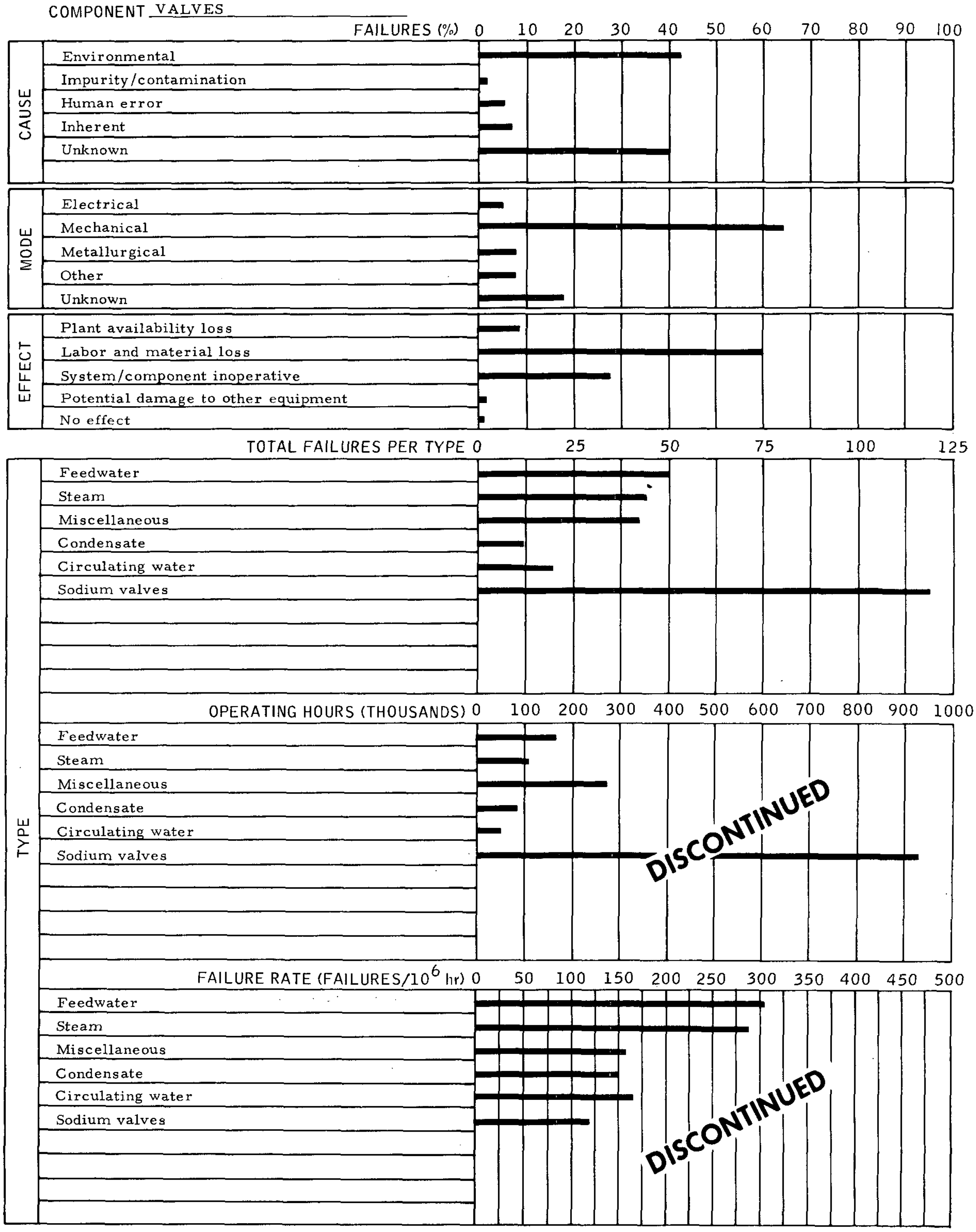


TABLE 1-126

GENERAL SUMMARY

COMPONENT VALVES



G. INSTRUMENTATION AND CONTROL SYSTEM COMPONENTS

1. Air Dryers

Failure data for air dryers are presented in Tables 1-127 through 1-129.

a. Reliability Information

Design Features:

They are used to remove moisture from pneumatic instrumentation systems.

Mode of Failure:

Mechanical.

Failure Description:

Improper material in gaskets.

Control Methods:

Maintenance manual should contain a regular inspection schedule of these parts.

b. Discussion and Recommendations

None.

TABLE 1-127

FAILURE DATA FOR AIR DRYERS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Air Dryer/Gasket 2. Instrument Air Supply/ Air Dryer 3. 26 540000	1. SCTI 2. Instrument Air System 3. 150 psig max., 190 scfm, filter area 99 in.^{2} 4. Incident report No. 94	MI 313	MI 52	MI 137	5320	Direct observation	1. Gasket failure, improper (hard) material did not seal. 2. Part replaced. 3. Periodic inspection of the "Poro-Stone" filters and gaskets should be included in the maintenance manual.
2	1. Air Dryer/Gasket 2. Instrument Air Supply/ Air Dryer 3. 26 540000	1. SCTI 2. Instrument air line desicant filter 3. 190 scfm, 99 in.^{2}, 150 psig max. 4. Incident report No. 94 (1-17-66)	MI 21Z	MI 55	MI 530	4438	Direct observation	1. Bottom gaskets on the "Poro-Stone" filters in both desiccant dryers were too hard to permit sealing; filter or dryer unit leaked particles of poro-stone in air line causing faulty operation of several valve operators. 2. New gaskets installed, instrument air headers cleaned, and valve operators removed, cleaned, and replaced. 3. Add regular inspection of air dryers to maintenance schedule.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE I-128

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT AIR DRYERS

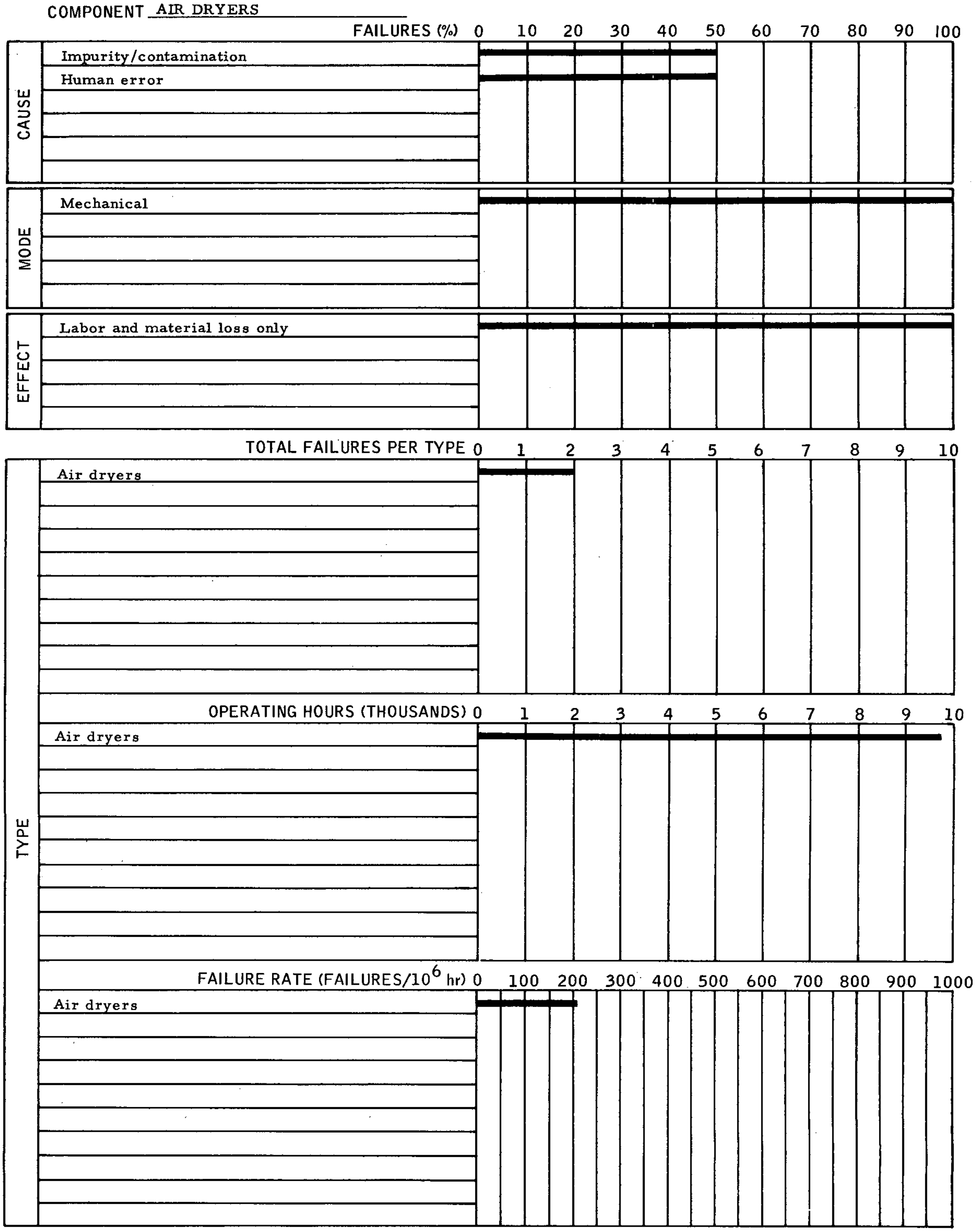
COMPONENT SUBTYPE AIR DRYERS

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Component Test Facility	0–100
SYSTEM	Instrument Air Supply	0–100
COMPONENT PART	Gasket	0–100
CAUSE	Impurity/contamination	0–50
	Human error	0–50
MODE	Mechanical	0–100
EFFECT	Labor and material loss only	0–100

TABLE 1-129

GENERAL SUMMARY

COMPONENT AIR DRYERS



2. Annunciators-Alarms

Failure data for annunciators-alarms are presented in Tables 1-130 through 1-132.

a. Reliability Information

Design Features:

Designed on the inductive principle. Does not require physical contact with the liquid during operation (sodium level).

Critical Characteristics:

Insulation and wire materials.

Mode of Failure:

1) Wire material corrosion

2) Power supply failure.

Failure Description:

1) Overheating during the bake-on of insulation during manufacture results in material decomposition.

2) Capacitor failure in power supply attributed to faulty component.

Control Methods:

1) Improve manufacturing process control.

2) Stringent quality requirements in procurement specifications.

Alternate Concepts:

Resistance level probes or float techniques. Different type of coil insulation that would not require high-temperature installation process.

b. Discussion and Recommendations

It should be noted that the circuit design of these instruments provides for a fail-safe warning. In the event of a power supply failure or a coil open-circuit, the alarm will sound. This feature eliminates any system consequences resulting from the failure of the alarm to operate in a real emergency situation.

This fact should be weighed against the added cost of more stringent quality control. The cost of high reliability is probably not warranted in this case.

The feasibility of backup warning devices could also be considered. In this case, for instance, a second-level device existed which could be visually monitored during the critical operation of filling the loop with sodium, which is about the only conceivable time when an overflow condition could occur.

TABLE 1-130

FAILURE DATA FOR ANNUNCIATORS – ALARMS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Level Alarm/Coil 2. Control and Instrumentation/Intermediate Coolant Vessel 3. 62 262210	1. HNPF 2. Secondary/No. 2 expansion tank level alarm 3. - 4. Monthly operating report No. 12	MI 156	MI 21	MI 530	~4450	Direct observation	1. Coil, open circuit. 2. Component corrective modification. 3. Improve manufacturing process control.
2	1. Level Alarm/Power Supply Capacitor 2. Control and Instrumentation/Intermediate Coolant Loop 3. 62 262210	1. HNPF 2. Secondary/No. 3 expansion tank level alarm 3. - 4. Monthly operating report No. 13	MI 127	MI 19	MI 530	~4450	Direct observation	1. Faulty capacitor. 2. Part replaced. 3. Upgrade quality requirements in procurement specifications.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-131

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT ANNUNCIATORS - ALARMS

COMPONENT SUBTYPE ALARM (SODIUM LEVEL)

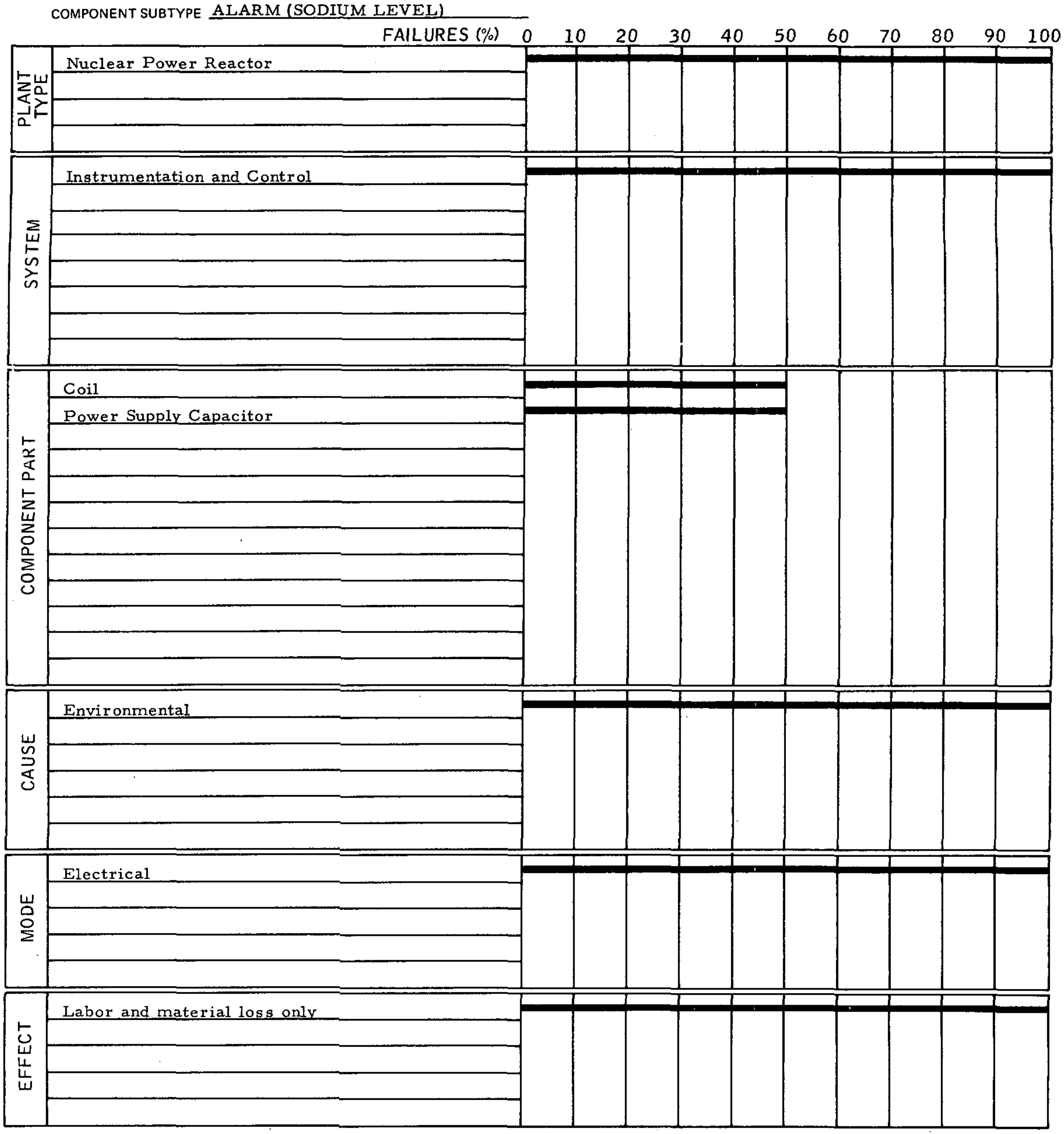


TABLE 1-132

GENERAL SUMMARY

COMPONENT ANNUNCIATORS - ALARMS

	FAILURES (%)	0	10	20	30	40	50	60	70	80	90	100
CAUSE	Environmental											
MODE	Electrical											
EFFECT	Labor and material loss only											

	TOTAL FAILURES PER TYPE	0	1	2	3	4	5	6	7	8	9	10
TYPE	Alarm (sodium level)											

	OPERATING HOURS (THOUSANDS)	0	1	2	3	4	5	6	7	8	9	10
TYPE	Alarm (sodium level)											

	FAILURE RATE (FAILURES/10^6 hr)	0	100	200	300	400	500	600	700	800	900	1000
TYPE	Alarm (sodium level)											

3. Compressors

Failure data for compressors are presented in Tables 1-133 through 1-135.

a. Reliability Information

Design Features:

Auxiliary machinery, providing compressed air for the operation of control instrumentation and associated devices used in reactor installations.

Critical Characteristics:

Environmental conditions (grit, dirt, moisture), seals and gaskets, torquing requirements in flanges, and bearing alignment.

Mode of Failure:

1) Plugging of lines, jamming of valves, etc.
2) Rupture of seals, gaskets, diaphragms
3) Degradation of performance below acceptable limit.

Failure Description:

1) Air leakage, intermittent operation, sticking valves, etc., caused by grit, dirt, moisture.
2) Blowout of head gasket, rod packing wearout, etc., due to inadequate maintenance or extreme operating condition.
3) Shaft seals worn, packing worn, etc., reason unknown.

Control Methods:

1) Ascertain that component has adequate capacity.
2) Review design provisions to cope with environmental conditions.
3) Review, and if necessary revise, preventive maintenance provisions.
4) Review preventive maintenance schedule.

b. Discussion and Recommendations

The compressor failures fall essentially into one of two categories: (1) failures due to lack of preventive maintenance (hence, insufficient or poorly scheduled preventive maintenance) and (2) failures due to inadequacy of design or installation provision (e. g, lack of air intake filter, allowing the admission of dirt, grit, dust, etc.) which causes an important part of the compressor to become inoperative.

It is therefore recommended that:

1) The design selection of the compressors needs to be based on a capacity which provides a generous margin of safety below its rated capability so that it never has to operate near its marginal characteristics.

2) The design selection of the compressors needs to take into consideration the fact that the operation of these compressors will be frequently under outdoor environmental conditions or at least under generally unfavorable environmental conditions such as blowing sand and dust, contaminated air etc., leading to an accumulation of grit, dirt, and moisture in the sensitive parts of the machinery, unless appropriate measures prevent such an accumulation.

3) Maintainability procedures need to be developed which take into consideration the unfavorable environmental conditions as well as the normal wear and tear. Replacement schedule for typical wear-out parts such as gaskets, diaphragms, seals, packings, bearings, etc., should be established realistically, and should take the typical outage schedules of the power generating station into account in order to reduce any unscheduled down-time to an absolute minimum.

4) Operating cycles and down-time periods need to be carefully recorded and provisions need to be planned by Quality and Reliability Assurance to have satisfactory data documented for each of the air compressors installed as part of a nuclear power generating facility.

TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 1 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Compressor/Gaskets 2. Instrument Air Supply 3. 25 540000	1. SCTI 2. Valve plate gaskets on compressor A-1a 3. 122 scfm, 135 psig 4. Incident report No. 35 (8-28-65)	MI 326	MI 53	MI 550	5300	Direct observation	1. Improper torque of valve plate studs allowing air leakage. 2. Bolts retorqued. 3. Review training requirements of personnel for torquing flange connections. Review maintenance procedure for torque requirement.
2	1. Compressor/Cooling Water Flow 2. Instrument Air Supply 3. 25 540000	1. SCTI 2. Cooling water to compressor A-1a 3. 122 scfm, 135 psig 4. Incident report No. 55 (10-14-65)	MI 339	MI 52	MI 580	6258	Operational monitors	1. Hose connect to bib that was on cooling water supply line. Water used reduced cooling water flow. 2. Compressor shut down when outlet cooling water temperature rose. Auxiliary air compressor turned on. 3. Effect of maintenance operation should be considered in design. Systems used for maintenance should be isolated from operations systems.
3	1. Compressor/Pressure Regulator 2. Instrument Air Supply 3. 25 540000	1. SCTI 2. Cooling water to compressor A-1a 3. 122 scfm, 135 psig 4. Incident report No. 56 (10-16-65)	MI 273	MI 55	MI 580	6300	Operational monitors	1. Pressure regulator bound, clogged with grit and head bolts allowing air leakage. 2. Pressure regulator disassembled and cleaned. Bolts retorqued evenly. 3. Revise maintenance procedure by adding torque requirement and cleaning of intake air filter.
4	1. Compressor/Valve 2. Instrument Air Supply 3. 25 520000	1. SCTI 2. Valve plate gasket leak compressor A-1a 3. 122 scfm, 135 psig 4. Incident report No. 72 (11-25-65)	MI 326	MI 53	MI 550	7240	Direct observation	1. Air leakage at upper valve plate gasket. 2. Retorqued head bolts. 3. Maintenance personnel shall be trained in proper torquing procedure of flanged connections. Proper maintenance procedure should be used.
5	1. Compressor/Valve 2. Instrument Air Supply 3. 25 520000	1. SCTI 2. Intake air valve 3. 160 scfm, 130 psig 4. Incident report No. 119 (4-26-66)	MI 500	MI 55	MI 550	2400	Direct observation	1. Intake valve sticking intermittently. 2. Valves inspected, no cause for sticking found. Grit or wear not in evidence. 3. None.
6	1. Compressor/Unloading Valve 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air compressor A-1 3. Ambient, 122 scfm, 135 psig 4. Incident report No. 75	MI 273	MI 51	MI 530	7430	Operational monitors	1. Dirt and moisture clogged valve. 2. Removed, cleaned, reassembled valve. 3. Add a drip leg to trap moisture and dirt.

* I = INCIDENT   MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION   P = PROBLEM

TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 2 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
7	1. Compressor/Valve Plate Gasket 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air compressor A-1 3. 122 cfm, 135 psig 4. Incident report No. 25	MI 136	MI 59	MI 530	4947	Direct observation	1. The replacement gasket failed. This gasket had been handmade and its workmanship was poor. 2. Part replaced. 3. Provide a quality assurance requirement for replacement items and maintenance work.
8	1. Compressor/Head Gasket 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air compressor A-1 3. - 4. Incident report No. 27	MI 320	MI 53	MI 530	4960	Direct observation	1. Head gasket blew due to faulty bolt torquing. 2. Part replaced. 3. Upgrade the maintenance procedure to specify a bolt torquing sequence and torque requirements.
9	1. Compressor/Head Gasket 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air compressor A-1 3. 132 cfm, 135 psig 4. Incident report No. 47	MI 137	MI 59	MI 530	5714	Direct observation	1. Head gasket blew. 2. Part replaced. 3. Upgrade maintenance procedure to specify a bolt torquing sequence and torque requirements.
10	1. Compressor/Unloading Valve 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air compressor A-1 3. 122 scfm, 135 psig 4. Incident report No. 69	MI 273	MI 51	MI 530	7170	Direct observation	1. Dirt or grit in instrument air system caused valve to stick. 2. Remove and clean valve, reassemble. 3. Revise preventive maintenance procedure by adding a requirement to clean intake air filter in order to prevent recurrence.
11	1. Compressor Air/Valve 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 71	MI 273	MI 51	MI 530	7235	Direct observation	1. Dirt and/or moisture caused valve to stick. 2. Remove and clean valve, reassemble. 3. Revise preventive maintenance procedure by adding a requirement to clean intake air filter in order to prevent recurrence.
12	1. Compressor Air/Head Gasket 2. Misc. Equipment/Instrument Air Supply 3. 25/540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 71	MI 322	MI 53	MI 530	7240	Direct observation	1. Insufficient and uneven torque on head bolts caused air leak. 2. Gasket replaced. 3. Upgrade maintenance procedure to specify a bolt torquing sequence and torque requirements.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-133

FAILURE DATA FOR COMPRESSORS
(Sheet 3 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
13	1. Compressor Air/ Valve Guide 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 92	I 110	I 59	I 520	8438	Operational monitors	1. Broken discharge valve guide. 2. Local repair, repaired cylinder wall by metalizing and honing. 3. Before installation of used equipment, a thorough quality control inspection should be required.
14	1. Compressor Air/ Piston Key 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 92	I 148	I 62	I 126	8438	Operational monitors	1. Piston key retaining pin hole became elongated, permitting the key to contact the cylinder wall. 2. Vendor repair of component/part. 3. Before installation of used equipment, a thorough quality control inspection is recommended.
15	1. Compressor Air/Valve 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 57	MI 200	MI 55	MI 116	6350	Direct observation	1. Dirt and/or moisture caused valve to stick. 2. Local repair, valve removed and cleaned. 3. Add intake air filter and/or revise maintenance schedule by adding requirement to clean filter frequently.
16	1. Compressor Air/Valve 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 58	MI 200	MI 55	MI 112	6375	Direct observation	1. Dirt and/or moisture caused valve to stick. 2. Local maintenance, valve was later replaced. 3. Add intake air filter and/or revise maintenance schedule by adding requirement to clean filter frequently.
17	1. Compressor/Head Gaskets 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1 3. 122 cfm, 135 psig 4. Incident report No. 4	MI 111	MI 51	MI 580	-	Direct observation	1. Inadequate cooling water resulted in overheated compressor causing subsequent air leaks in head gaskets. 2. Part replaced. 3. Modify system to provide cooling water with adequate head pressure (SCTI and LMEC-executed).
18	1. Compressor Air/ Unloader Plungers 2. Misc. Equipment/ Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1b 3. 160 acfm, 138 psig 4. Incident report No. 120	MI 110	MI 55	MI 530	2475	Direct observation	1. Unloader plungers bound against valve seats. 2. Local repair, modified by adding teflon sleeve around valve stem. 3. Improved quality control could eliminate this malfunction.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 4 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
19	1. Compressor/Cooling Jacket 2. Miscellaneous Equipment/Instrument Air Supply 3. 25 540000	1. SCTI 2. Instrument air system A-1b 3. - 4. Incident report No. 117	MI 310	MI 51	MI 580	1805	Routine area watch	1. Overheating due to maintenance shutting off raw water supply. 2. None. 3. Install audible temperature alarm on compressor cylinder.
20	1. Compressor/Bearing 2. Misc. Power Equipment /Instrument Cooling Air 3. 25 540000	1. EBR-II 2. No. 1 on instrument thimble 3. Ambient temperature 4. PMMR-33	MI 500	MI BZ	MI 530	2190	Audible noise	1. Noisy bearing. 2. Part replaced. 3. None.
21	1. Turbocompressor/ Bearing 2. Misc. Power Equipment /Instrument Cooling Air 3. 25 540000	1. EBR-II 2. Primary/instrument thimble 3. No information available 4. ANL-6764, 7/63	MI 500	MI 52	MI 550	1000	Unknown	1. None. 2. Unknown. 3. None.
22	1. Turbocompressor/ Impeller 2. Fuel Handling Machine / Cooling System 3. 25 235140	1. EBR-II 2. FUM/ permanent argon system 3. 10 hp, 440 v, 150 cfm 4. ANL-6764, 7/63	MI 100	MI 73	MI 550	During shakedown	Audible noise	1. Casting which forms the hub of impeller cracked. 2. Part ordered. 3. Upgrade the quality assurance and acceptance procedure for this purchased item.
23	1. Compressor/Bearing 2. Misc. Power Equipment /Instrument Air System 3. 25 540000	1. SCTI 2. Preheat air system (ASA) 3. 1750 rpm, 75 hp 4. Incident report No. 341	MI 125	MI 86	MI 530	3140	Routine area watch	1. Noise came from bearing housing, moisture and rust present. 2. New bearings installed utilizing neoprene shield. 3. Upgrade preventive maintenance inspection procedure to detect problem prior to an outage.
24	1. Compressor/Motor Bearings 2. Reactor Equipment/ Preheating System Gas 3. 25 214330	1. SCTI 2. Air preheat compressor A-5a 3. 75 hp, 1175 rpm, 400 to 550°F 4. Incident report No. 15	MI 126	MI 52	MI 110	2618	Direct observation	1. Noisy motor bearings. 2. Old parts were reused. Bearings are still noisy. 3. Maintain an adequate supply of spare parts. Review logistic specifications.

* I = INCIDENT MI = MINOR MALFUNCTION
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TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 5 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
25	1. Compressor/Exhaust Valves 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 1 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 3	MI 328	MI 51	MI 530	1605	Direct observation	1. Slag from welding of snubbers into system found in exhaust valve. 2. Valves (4) removed and fingers reversed. 3. Revise welding procedures.
26	1. Compressor/Rod Packing 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 2 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly Operating Report No. 15	MI 136	MI 52	MI 530	4560	Direct observation	1. Rod packing worn out allowing excessive nitrogen leakage. 2. Part was repacked. 3. Preventive maintenance.
27	1. Compressor/Seals 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 2 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 18	MI 326	MI 52	MI 530	4560	Direct observation	1. Seals worn out, excessive leakage at stuffing box. 2. Local repair. 3. Preventive maintenance.
28	1. Compressor/Packing 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 1 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 4	MI 126	MI 52	MI 530	2500	Direct observation	1. Packing worn out. 2. Part replaced. 3. Preventive maintenance.
29	1. Compressor/Shaft Seal 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 1 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 12	MI 136	MI 52	MI 550	4450	Direct observation	1. Shaft seals worn out, leaking. 2. Part replaced. 3. Preventive maintenance.
30	1. Compressor/Diaphragm 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 1 3. 235 psig nitrogen, 150°F max. temp 4. Monthly operating report No. 15	MI 126	MI 59	MI 530	4560	Direct observation	1. Diaphragm broken. 2. Part replaced. 3. Preventive maintenance.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 6 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
31	1. Compressor/Shaft Seal 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 1 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 21	MI 126	MI 52	MI 530	8320	Direct observation	1. Shaft seals worn, excessive nitrogen leaking. 2. Part replaced. 3. Preventive maintenance.
32	1. Compressor/Shaft Seal 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 2 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 20	MI 126	MI 52	MI 530	7250	Direct observation	1. Seals worn out. 2. Part replaced. 3. Preventive maintenance.
33	1. Compressor/Shaft Seal 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. LFS nitrogen system No. 2 3. 235 psig nitrogen, 150°F max. temp. 4. Monthly operating report No. 25	MI 126	MI 52	MI 530	9420	Direct observation	1. Seals worn out. 2. Part replaced. 3. Preventive maintenance.
34	1. Compressor/Shaft Seals 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 1 compressor 3. 235 psig 4. Monthly operating report No. 24	MI 500	MI 52	MI 530	8700	Direct observation	1. Shaft seals worn out, leaking. 2. Part replaced. 3. Preventive maintenance.
35	1. Compressor/Casting 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 1 compressor 3. 235 psig 4. Monthly operating report No. 15	MI 500	MI 67	MI 530	4560	During routine inspection	1. Recompressor casting porous and leaking. 2. Part replaced. 3. Preventive maintenance.
36	1. Compressor/Valve Plug 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 1 compressor 3. 235 psig 4. Monthly operating report No. 18	MI 500	MI 52	MI 530	7100	Direct observation	1. Valve plug worn out. 2. Part replaced. 3. Preventive maintenance.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-133

FAILURE DATA FOR COMPRESSORS

(Sheet 7 of 7)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
37	1. Compressor/ Diaphragms 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 1 compressor 3. 235 psig 4. Monthly operating report No. 21	MI 124	MI 59	MI 530	8320	During preventive maintenance	1. Diaphragms ruptured. 2. Part replaced. 3. Preventive maintenance.
38	1. Compressor/ Diaphragms 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 1 compressor 3. 235 psig 4. Monthly operating report No. 25	MI 500	MI 52	MI 530	1100	Direct observation	1. Diaphragms worn out. 2. Part replaced. 3. Preventive maintenance.
39	1. Compressor/Stud 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 2 compressor 3. 235 psig 4. Monthly operating report No. 15	MI 120	MI 59	MI 530	4560	Direct observation	1. Flange stud broken. 2. Part replaced. 3. Insufficient data to evaluate this failure. Review torque requirement.
40	1. Compressor/ Diaphragm 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 2 compressor 3. 235 psig 4. Monthly operating report No. 16	MI 500	MI 59	MI 530	5180	Direct observation	1. Diaphragm ruptured. 2. Part replaced. 3. Preventive maintenance.
41	1. Compressor/ Diaphragms 2. Reactor Equipment/ Reactor Shielding Cooling 3. 25 213000	1. HNPF 2. Loading face shield/nitrogen cooling system No. 2 compressor 3. 235 psig 4. Monthly operating report No. 21	MI 124	MI 61	MI 530	3140	During preventive maintenance	1. Each diaphragm had a small crack. 2. Parts replaced. 3. Preventive maintenance.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-134

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT COMPRESSORS

COMPONENT SUBTYPE COMPRESSORS

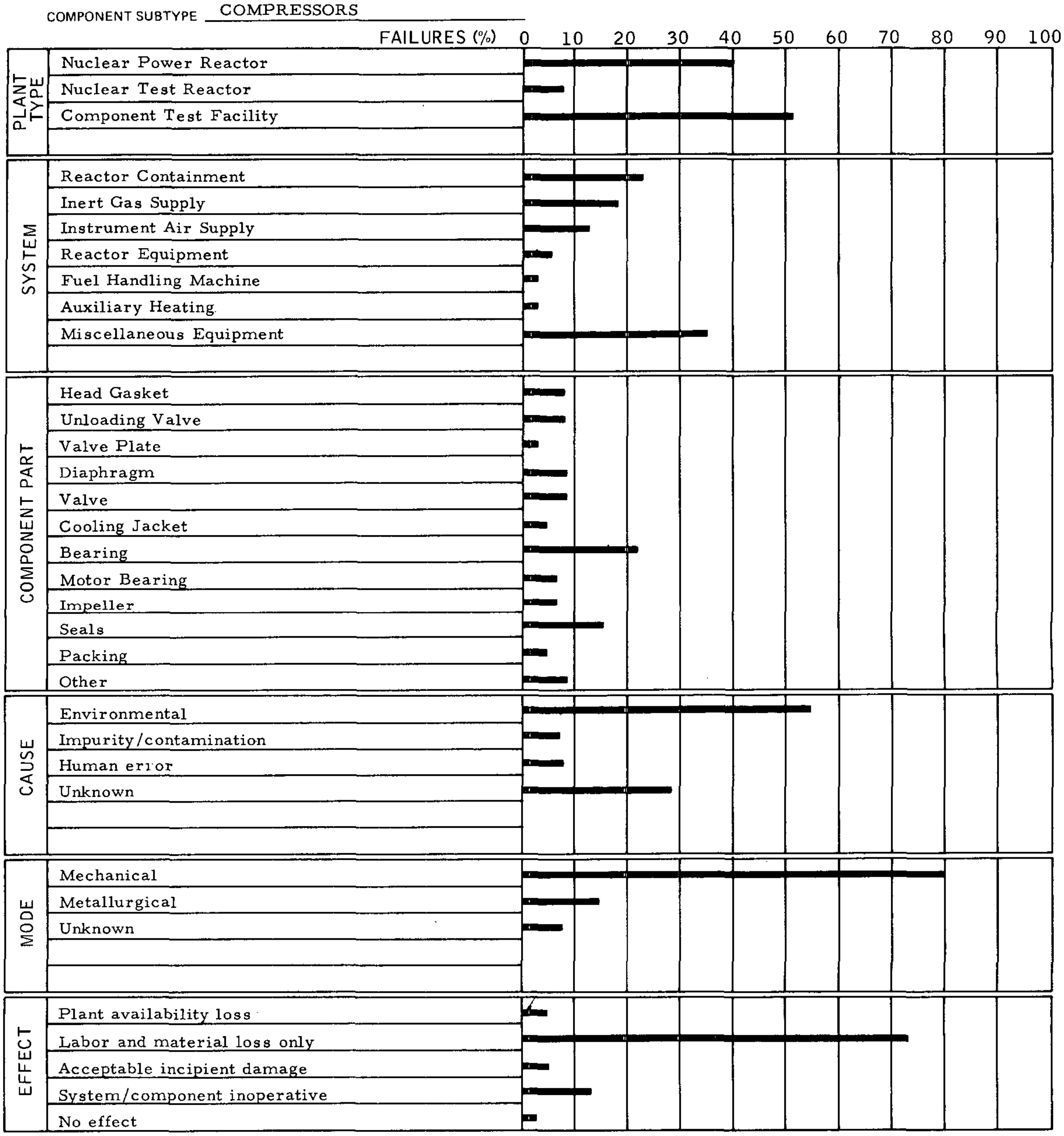
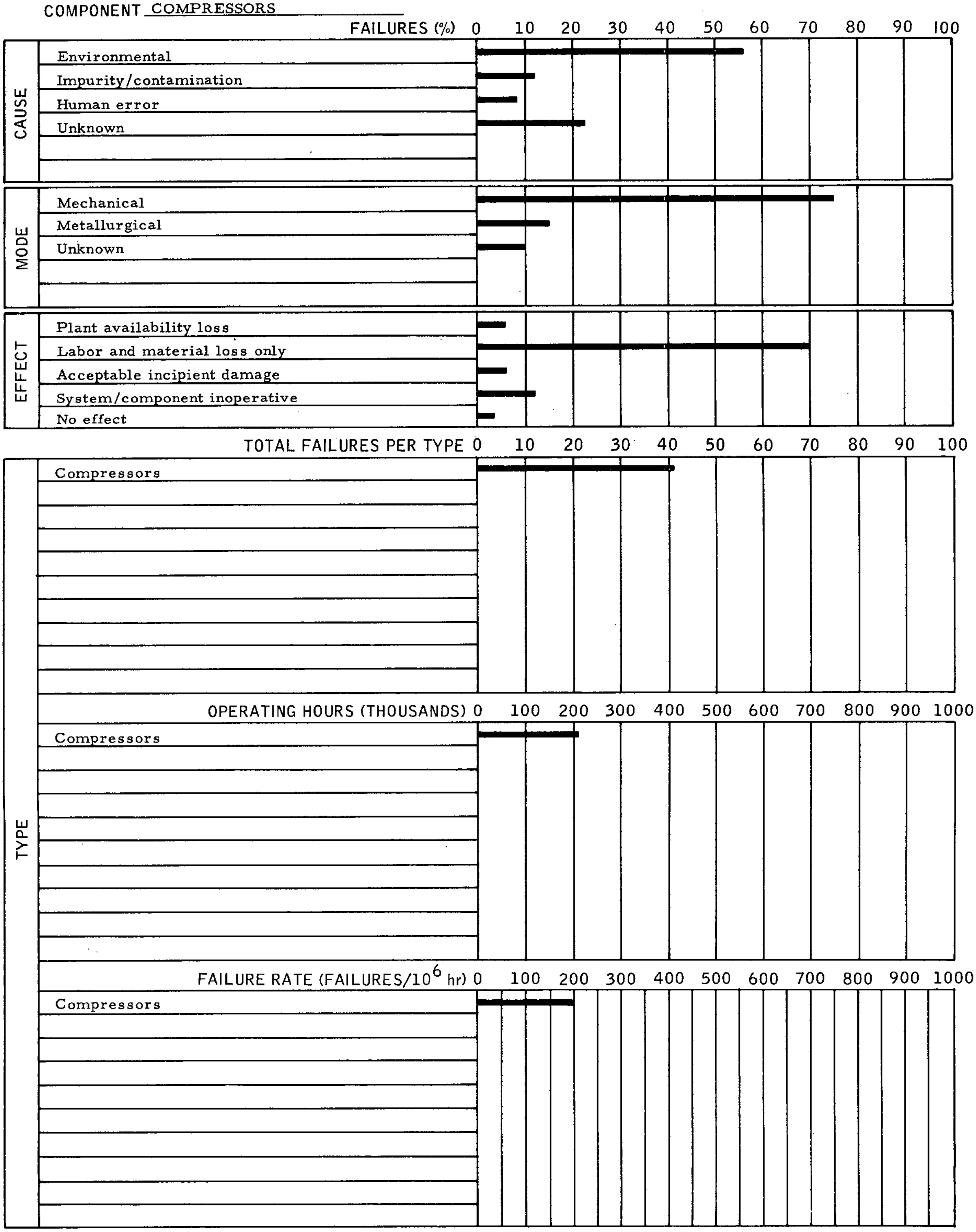


TABLE 1-135

GENERAL SUMMARY

COMPONENT COMPRESSORS



4. Control and Safety Elements

Failure data for control and safety elements are presented in Tables 1-136 through 1-138.

a. Reliability Information

Design Features:

Control and safety mechanisms for controlling reactor devices are designed to be fail-safe.

Critical Characteristics:

Most control rods are long and narrow and their travel is linear over a long distance through close, if not tight, clearances. The majority of control rod mechanisms or assemblies provide the sealing functions with regard to the reactor shield and reactor cover gas.

Mode of Failure:

1) Seal failed
2) Deformation
3) Part failed.

Failure Description:

1) Bellows seal failed allowing sodium and cover gas leakage.
2) A guide tube deformed during steam cleaning from a sodium and water reaction.
3) The purge tube and valve became worn at the sealing point with another component.

Control Methods:

1) The sodium should be removed from parts by mechanical or safe chemical methods before the parts are steam cleaned.
2) Procedures for installation and maintenance are necessary.

b. Discussion and Recommendations

Three events were reviewed on safety and control rods. Each of the events was independent and of a different nature.

One event involved the bellows that is used to seal the linear stroke of the control rod. The bellows was a thin dish-welded nesting type. Failures of this type of bellows are generally due to over-stressing, fatigue, or erosion of the thin material. Bellows over-stressing is due either to a design error which makes the bellows travel too far and exceeds the elastic limits of the material or to stray material which clogs the convolutions making the bellows work in an uneven manner over its effective length.

The second event studied was damage to a control rod guide tube during steam cleaning operations in which water reacted with the sodium. This type of event can be avoided by removing all possible sodium from the items to be cleaned. This should be accomplished by some mechanical means rather than permitting the residue sodium to react with water during steam cleaning.

The third event documented was the wearing of a purge tube and a back flow valve. The early wear-out was probably due to a misfit of parts, a poor adjustment, or lack of lubrication.

Incipient failures in bellows are nearly impossible to detect. The event leading to the sodium-steam reaction which damaged the guide tube was a human error. Generally, the wear or rubbing of parts can be detected in changes in drive power feed, and in the type of event studied might show up as a change in gas purge rate.

TABLE 1-136

FAILURE DATA FOR CONTROL AND SAFETY ELEMENTS

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Control and Safety Element/Bellows 2. Reactor Equipment/ Control and Safety Element 3. 08 212100	1. Fermi 2. Safety rod No. 4 3. Reactor environment, 800°F discharge 4. PRDC EF-1, EF-2, EFAPP No. 45	MI 500	MI 90	MI 550	2190	Direct observation	1. Lower bellows had failed. 2. Part replaced. 3. None.
2	1. Control and Safety Element/Lower Guide Tube 2. Reactor Equipment/ Control and Safety Element 3. 08 212100	1. Fermi 2. Safety rod No. 5 3. Reactor environment 4. EFAPP No. 39	MI 315	MI 54	MI 550	5643	Direct observation	1. During steam cleaning of the guide tube, a sodium reaction occurred inside the tube. The inner tube was found to be distorted in the center at the point of the reaction. 2. Part replaced. 3. Remove the major portion of sodium from the inner area of the tube by oil bath or by chemically reacting sodium prior to steam cleaning.
3	1. Control Rod/Helium Purge Tube and Valve 2. Reactor Equipment/ Control and Safety Element 3. 08 212100	1. HNPF 2. Reactor core/control rod No. 10 3. 350 to 945°F 4. Monthly operating report No. 24	MI 142	MI 56	MI 550	8700	Direct observation	1. Helium purge tube and valve worn out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-137

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT CONTROL AND SAFETY ELEMENTS

COMPONENT SUBTYPE SAFETY ROD

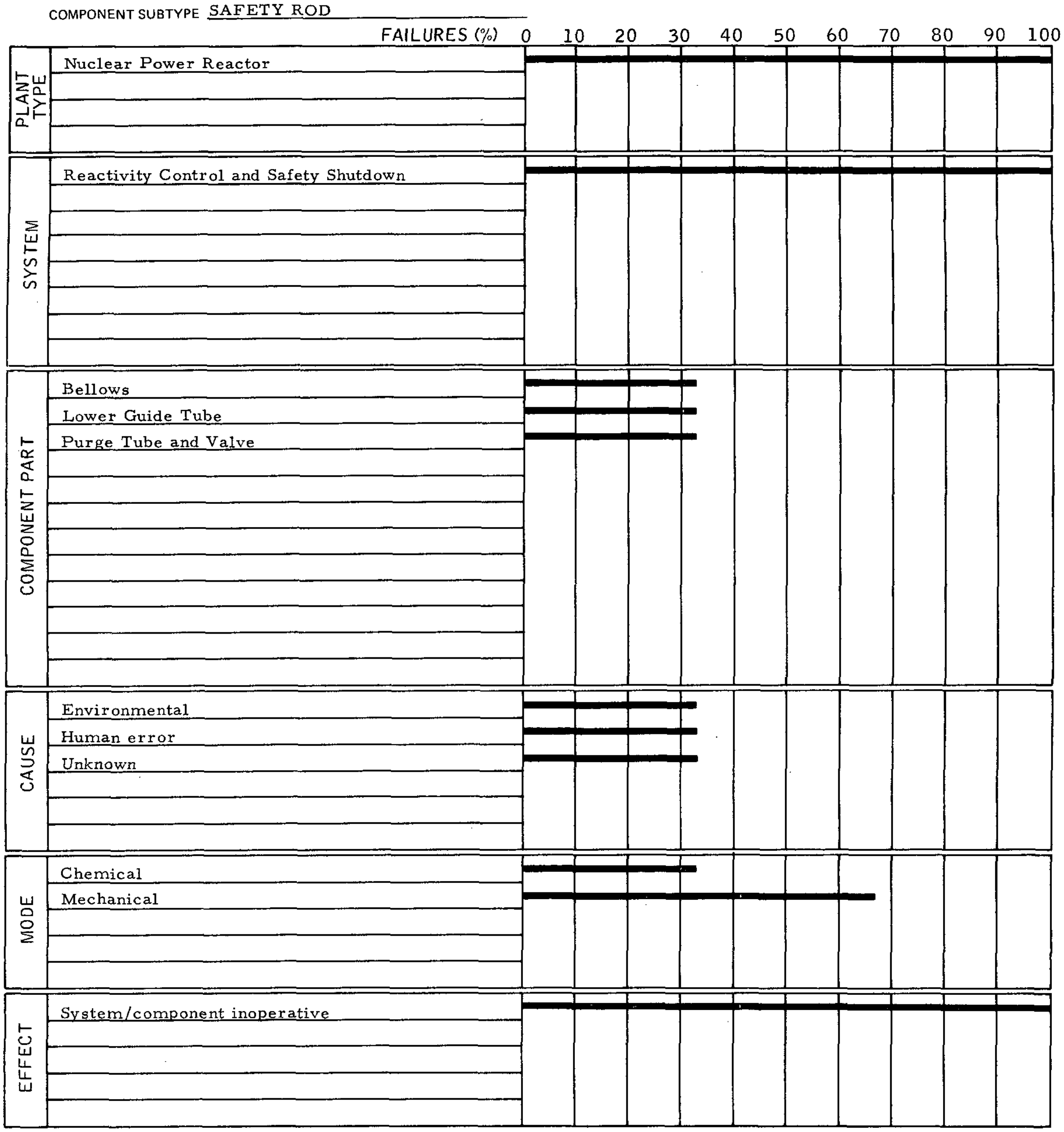
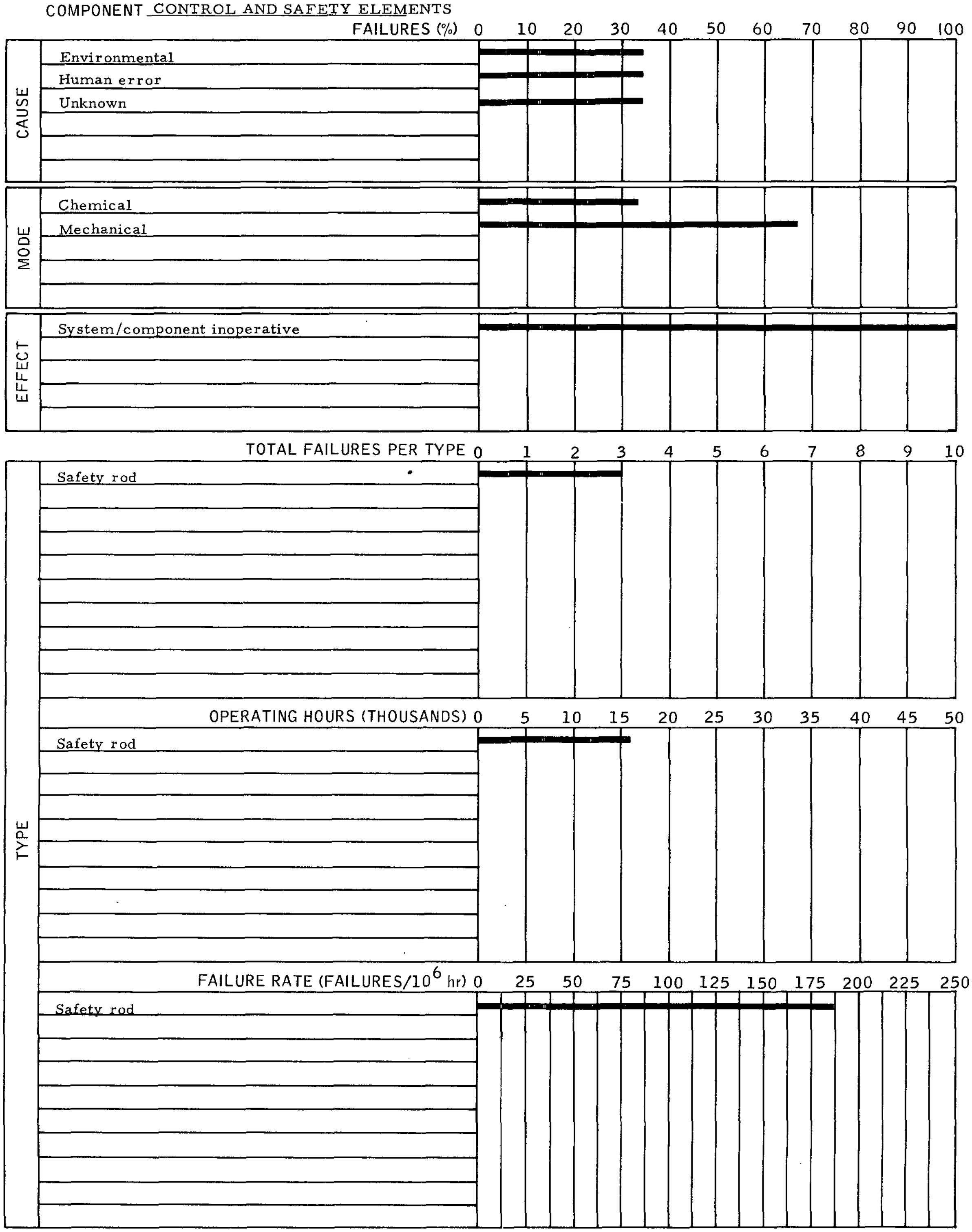


TABLE 1-138

GENERAL SUMMARY

COMPONENT CONTROL AND SAFETY ELEMENTS



5. Controllers

Failure data for controllers are presented in Tables 1-39 through 1-143.

a. Electrical and Electronic Controllers

(1) Reliability Information

Design Feature:

Performs measurement, comparison, and/or correction to hold the output of a given process to some desired value.

Critical Characteristics:

1) Minimal and predictable delay time

2) Predictable behavior throughout a wide range of environmental conditions

3) Capability to compensate for the effects of unwanted disturbances.

Mode of Failure:

1) Amplifier failure

2) Power supply failure

3) Mechanical damage to wiper arm of hand-operated potentiometer

4) Loose connection

5) Relay failure

6) Pressure switch malfunction

7) Flowmeter malfunction caused by bubbles in sodium.

Failure Description:

1) Anomalous failure of amplifier detected when demand temperature increased without adjustment.

2) Reactor scram occurred when wiper on hand-operated flux control potentiometer was broken.

3) Poor electrical connection apparently caused by vibration.

4) Pressure switch caused to malfunction by vibration.

5) Bubbles entrained in liquid sodium flowmeter resulted in low flow indication and reactor trip.

Control Methods:

1) Investigate environmental and operational conditions to which amplifier is exposed, in order to determine whether amplifier design specifications are respected and the extent of the vendor's responsibility.

2) Implement protective device, such as mechanical limit stops, to assure that potentiometers shall not be damaged by manual abuse.

3) Include discussions in operator training curriculum to consider possible effects of abusing potentiometers.

4) Implement preventive maintenance and inspection procedures to minimize potential failures caused by vibration.

5) Establish design requirements to include the installation of vibration isolating devices in order to protect vibration-sensitive components in environments having the possibility of a vibration hazard.

6) Provide for constraints in the selection of components, in the form of an environmental checklist, so that bubbler type level sensors shall not be installed where there is a possibility of bubble entrainment in flowing sodium.

(2) Discussion and Recommendations

None.

b. Mechanical Controllers

(1) Reliability Information

Design Features:

Performs measurements, comparison, and/or correction to hold the output of a given process to some desired value.

Critical Characteristics:

1) Minimal and predictable delay time

2) Predictable behavior throughout a wide range of environmental conditions

3) Capability to compensate for the effects of unwanted disturbances.

Mode of Failure:

1) Sticking of feedwater level controller

2) Anomalous lifting of safety release valve

3) Turbine governor spring broken.

Failure Description:

1) Safety relief valve lifted at pressure well below proper set point due to vibration during changes in plant conditions.

2) Improper assembly and/or fatigue caused turbine governor spring to break.

Control Methods:

1) Implement preventive maintenance procedures to include examination of feedwater level controller for evidence of corrosion, mechanical damage, and fatigue.

2) Implement preventive maintenance procedures to include examination of steam system safety release valve for evidence of corrosion, erosion, and mechanical damage.

3) Implement acceptance test procedure to include verification of steam system safety release valve operation under full spectrum of possible environmental conditions.

(2) Discussion and Recommendations

None.

TABLE 1-139

FAILURE DATA FOR CONTROLLERS

(Sheet 1 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Controller/Amplifier 2. Instrumentation and Control/Reactor Plant Control 3. 65 261160	1. HNPF 2. Reactor control system/outlet temperature set (HCS-10) 3. - 4. Monthly operating report No. 20	MI 15Z	MI 27	MI 550	7754	Operational monitors	1. Faulty amplifier replaced when demand temperature started to increase without adjustment. 2. Part replaced. 3. None.
2	1. Controller/Amplifier 2. Instrumentation and Control/Neutron Monitor System 3. 65 261110	1. HNPF 2. Reactor control system/neutron flux monitor 3. - 4. Monthly operating report No. 12	MI 15Z	MI 47	MI 550	4450	Direct observation	1. Faulty amplifier. 2. Part replaced. 3. None.
3	1. Controller/Transistor 2. Instrumentation and Control/Neutron Monitor System 3. 65 261110	1. HNPF 2. Reactor control system/neutron flux monitor 3. - 4. Monthly operating report No. 12	MI 15Z	MI 47	MI 550	4450	Direct observation	1. Faulty transistor in amplifier booster. 2. Part replaced. 3. None.
4	1. Controller/Transistor 2. Instrumentation and Control/Neutron Monitor System 3. 65 26110	1. HNPF 2. Reactor control system/neutron flux monitor 3. - 4. Monthly operating report No. 12	MI 15Z	MI 47	MI 550	4450	Direct observation	1. Faulty transistor. 2. Part replaced. 3. None.
5	1. Controller/Power Supply 2. Instrumentation and Control/Reactor Plant Control 3. 65 261130	1. HNPF 2. Reactor safety/flow ratio computer 3. - 4. Monthly operating report No. 16	MA 15Z	MA 48	MA 520	5180	Direct observation	1. Faulty power supply in flow-to-flow computer rack C. 2. Part replaced. 3. None.
6	1. Controller/Potentiometer 2. Instrumentation and Control/Reactor Plant Control 3. 65 261160	1. HNPF 2. Reactor control system/flux control set (HCS 11) 3. - 4. Monthly operating report No. 15	MA 500	MA 24	MA 520	4560	Operational monitor	1. Wiper broken on hand-operated flux control potentiometer causing scram. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-139

FAILURE DATA FOR CONTROLLERS

(Sheet 2 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Pump Controller/Variacs 2. Instrumentation and Control/Intermediate Coolant 3. 65 262210	1. EBR-II 2. Secondary system 3. - 4. PMMR-107	MI 500	MI 5Z	MI 530	11,320	During preventive maintenance	1. Variacs replaced, no information as to why. 2. Part replaced. 3. None.
8	1. Controller/Speed Controller 2. Instrumentation and Control/Intermediate Coolant Loop 3. 65 262210	1. SCTI 2. Secondary sodium system/dynamatic coupling 3. Model-ACMV-990, 1135 rpm, 220 vdc 4. Incident report No. 89 and No. 91	MI 157	MI 14	MI 530	1283	Operational monitors	1. Apparent problem was a poor electrical connection. 2. Local repair, a different source of incoming power to the speed control chassis was connected. Permanent repairs were made on 1-18-66. 3. Improve electrical maintenance procedure.
9	1. Controller/Pressure Switch 2. Instrumentation and Control/Heat Transfer 3. 65 262110	1. SCTI 2. Primary sodium system S-704 3. 1600 gpm, 103 psig air pressure 4. Incident report No. 51	MI 141	MI 24	MI 119	745	Protective system	1. Pressure switch malfunction, due to vibration. 2. Part replaced. 3. Provide vibration protection to control instruments when selected location provides vibration exposure.
10	1. Controller/Pressure Switch PS-703 2. Instrumentation and Control/Fire Control 3. 65 267100	1. SCTI 2. Pilot burners 3. 4. Incident report No. 16 and No. 17	MI 157	MI 24	MI 530	Unknown	Operational monitor	1. Pilots tripped on two occasions in the same day. 2. Component part replaced. 3. Upgrade plant preventive maintenance inspections of pressure switches.
11	1. Controller/Switch 2. Instrumentation and Control/Heat Transfer 3. 65 262210	1. SCTI 2. Secondary system (cold trap) 3. 4. Incident report No. 53	MI 327	MI 13	MI 550	115	During routine inspection	1. Operator accidentally grounded electrical wiring on valve actuator switch during inspection. 2. No repair; restarting of burners and primary pump. 3. Improve training of operator personnel.
12	1. Controller/Relay Driver Boards 2. Instrumentation and Control/Preheating System 3. 65 261360	1. EBR-II 2. Sodium trace heating, secondary 3. 4. Maintenance report, 4-18-68	MI 500	MI BZ	MI 530	14,150	Preventive maintenance	1. Faulty transistors. 2. Part replaced. 3. None.

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TABLE 1-139

FAILURE DATA FOR CONTROLLERS

(Sheet 3 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
13	1. Controller/Relay 2. Instrumentation and Control/Intermediate Coolant Loop 3. 65 262210	1. EBR-II 2. Secondary EM pump circuit 3. 4. Maintenance report, 3-14-68	MI 500	MI 52	MI 530	13,850	Operational monitors	1. Relay not operational. 2. Part replaced. 3. None.
14	1. Controller/Relay 2. Instrumentation and Control/Neutron Monitor System 3. 65 261110	1. HNPF 2. Reactor control system/neutron flux monitor 3. 4. Monthly operating report No. 12	MI 15Z	MI 47	MI 550	5,900	Operational monitors	1. Faulty relay. 2. Local repair. 3. None
15	1. Controller/Cylinder No. 1 Control Solenoid 2. Instrumentation and Control/Feedwater 3. 65 268400	1. EBR-II 2. Feedwater/startup boilder feed pump 3. 364°F, 1300 psig 4. PMMR-22	MI 500	MI 15	MI 550	Unknown	Audio noise	1. Solenoid shorted. Loss of No. 1 cylinder caused pump to vibrate excessively. 2. Part replaced. 3. None.
16	1. Controller/High Level Override Relay 2. Instrumentation and Control/Main Coolant Loop 3. 65 262110	1. SCTI 2. Primary sodium pump (P-5)/ sodium level indicator controller LIC-100 3. 4. Incident report No. 109	MI 144	MI 47	MI 520	Unknown	Operational monitor	1. Entrainment of gas bubbles in the sodium, detected by the magnetic flowmeter as low flow. 2. Local repair, system redesign. 3. Avoid bubbler type level controller in EM flowmeter loops.
17	1. Controller/High Level Override Alarm and Relay 2. Instrumentation and Control/Main Coolant Loop 3. 65 262110	1. SCTI 2. Primary sodium pump (P-5)/ sodium level indicator controller LIC-100 3. 4. Incident report No. 112	MA 158	MA 48	MA 520	Unknown	Operational monitors	1. Sodium level lowered causing gas entrainment and plant trip. 2. Local repair, relay readjusted, and primary sodium flow restored. Final correction by installation of a displacement type instead of bubbler. 3. More stable level controller needed to maintain free-surface sodium level.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-139

FAILURE DATA FOR CONTROLLERS

(Sheet 4 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
18	1. Controller/Converter Tube 2. Instrumentation and Control/Reactor Coolant 3. 65 262110	1. EBR-II 2. Primary pump/control system 3. - 4. Maintenance report ANL-7445, 4-18-66	MA 500	MA 15	MA 520	14,100	Protective system	1. Tube shorted. 2. Part replaced. 3. None.
19	1. Controller/Wiring 2. Instrumentation and Control/Reactor Coolant 3. 65 262100	1. SCTI 2. Temperature monitoring 3. - 4. Incident report No. 28, 8-16-65	MI 324	MI 16	MI 550	1475	Low-temperature indications; operational monitors	1. Faulty wiring caused fuses to blow in controller following previous maintenance. 2. Wiring corrected; new fuses installed. 3. Improve maintenance procedures on personnel training.
20	1. Controller/Relay 2. Instrumentation and Control/Steam Generators 3. 65 262311	1. SCTI 2. Sodium heat transfer 3. 120-volt, ac-coil actuated 4. SCTI Incident report No. 78	MA 344	MA 87	MA 520	4050	During actuation	1. Relay caused steam generator inlet and outlet sodium valves to close. 2. Relay was bypassed during cover gas pressurization test to avoid valve closure. 3. The cover gas pressurization procedure was modified to include bypassing a relay.
21	1. Controller/pH 2. Instrumentation and Control/Cooling Water 3. 65 269630	1. SCTI 2. Cooling water acid and control 3. Automatic 4. Incident Report No. 95, 1-21-66	MI 333	MI 31	MI 530	6729	Operational monitor	1. Operator left acid feed pump switch in manual position instead of auto, causing low pH readings on pHr-300 meter. 2. Proper amount of NaOH flakes added to cooling tower basin water. 3. Closer operator vigilance and adequate training required.
22	1. Controller, Level/Torque Tube 2. Instrumentation and Control/Feedwater 3. 65 268400	1. EBR-II 2. Feedwater heater No. 4 3. Shell side - 480°F, 1250 psig Tube side - 565°F, 1500 psig 4. PMMR-76	MI 500	MI 55	MI 530	6300	Operational monitor	1. Level controller stuck. 2. Local repair. 3. Upgrade preventive maintenance on level control.

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TABLE 1-139

FAILURE DATA FOR CONTROLLERS

(Sheet 5 of 5)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
23	1. Controller/(Pressure Setting) 2. Instrumentation and Control/Steam, Condensate and Feedwater Piping and Equipment 3. 65 268100	1. SCTI 2. Steam system, safety valve PSV-202V 3. 1800 psig, 900°F, 2.6×10^4 lb/hr 4. Incident report No. 116	I 144	I 51	I 520	Unknown	Direct observation	1. Safety relief valve lifted at pressure well below proper setpoint during a change in plant conditions. 2. Vendor repair of component. 3. None.
24	1. Controller/(Pressure Setting) 2. Instrumentation and Control/Steam, Condensate and Feedwater Piping and Equipment 3. 65 268100	1. SCTI 2. Steam system, safety valve PSV-208V 3. 1800 psig, 900°F, 2.6×10^4 lb/hr 4. Incident report No. 116	I 144	I 62	I 520	Unknown	Direct observation	1. Safety relief valve lifted at pressure well below proper setpoint during a change in plant conditions. 2. Vendor repair of component. 3. None.
25	1. Controller/Turbine Governor 2. Instrumentation and Control/Condensate 3. 65 268300	1. EBR-II 2. Turbine-driven feed pump 3. - 4. PMMR-105	MI 500	MI 59	MI 530	10,580	Operational monitors	1. Spring broken. 2. Part replaced. 3. None.
26	1. Controller/Air Line 2. Instrument Air Supply/Piping 3. 65 540000	1. SCTI 2. Steam and feedwater system 3. - 4. Incident report No. 123	MI 141	MI 59	MI 550	Unknown	During actuation	1. A plastic air control line to the level controller split, allowing the level control valve to close. 2. Local repair, plastic tubing replaced. 3. Select proper material considering enviromental conditions.

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TABLE 1-140

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT CONTROLLERS

COMPONENT SUBTYPE ELECTRICAL/ELECTRONIC

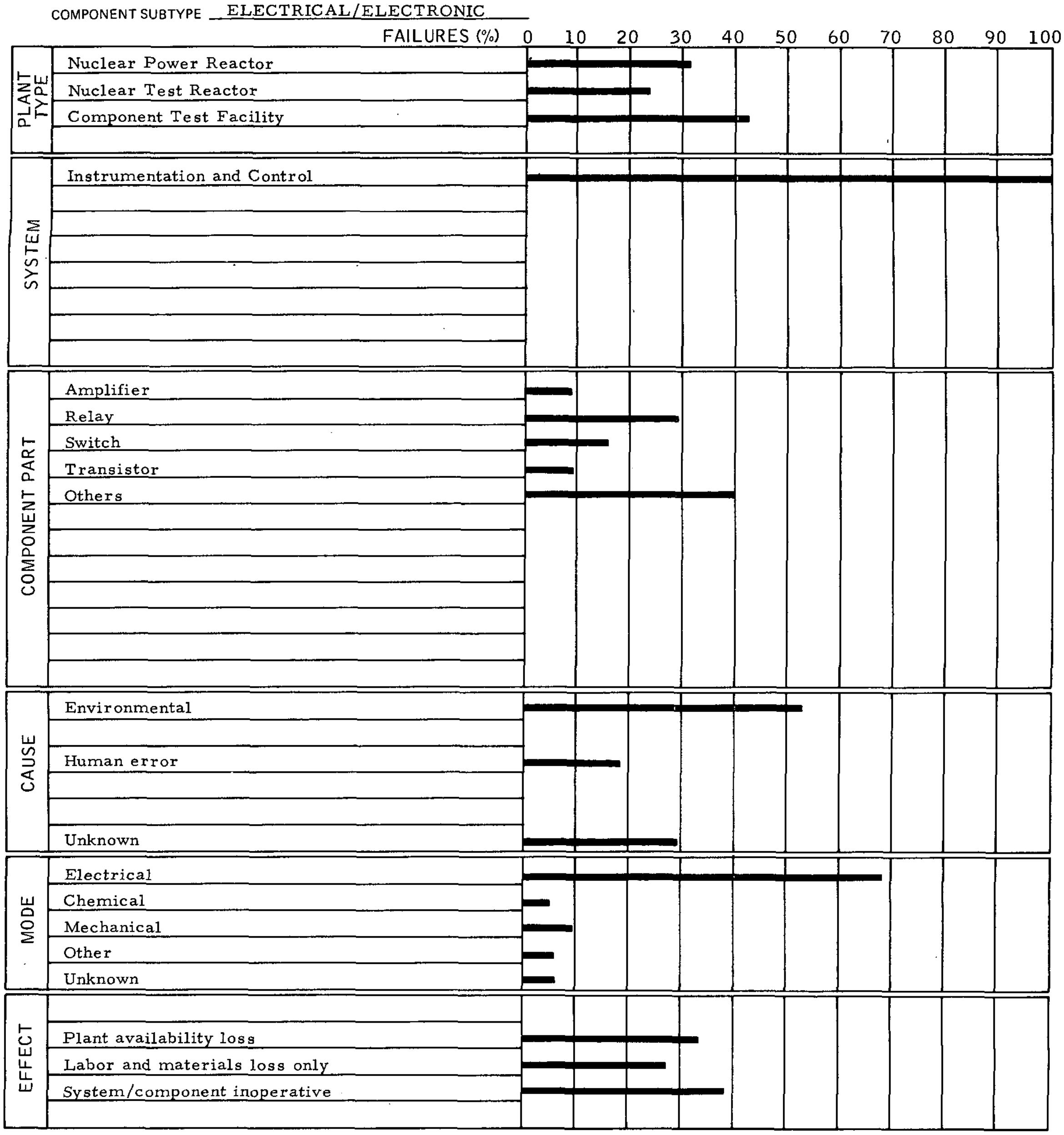


TABLE 1-141

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT CONTROLLERS

COMPONENT SUBTYPE MECHANICAL

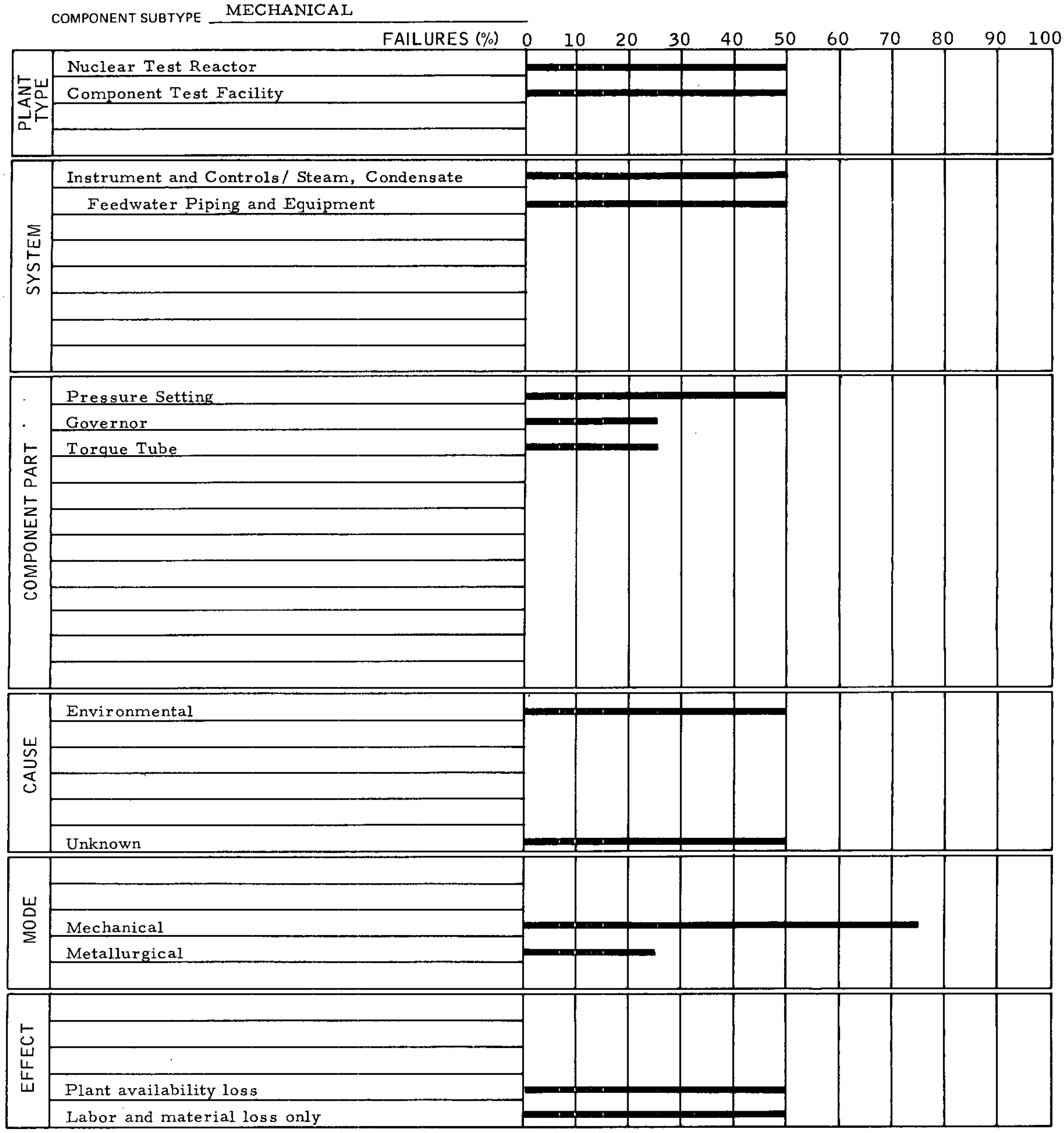


TABLE 1-142

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT CONTROLLERS

COMPONENT SUBTYPE PNEUMATIC

PLANT TYPE	Component Test Facility
SYSTEM	Instrument and Control - Reactor Plant
COMPONENT PART	Air Line (Piping)
CAUSE	Environmental
MODE	Mechanical
EFFECT	System/component inoperative

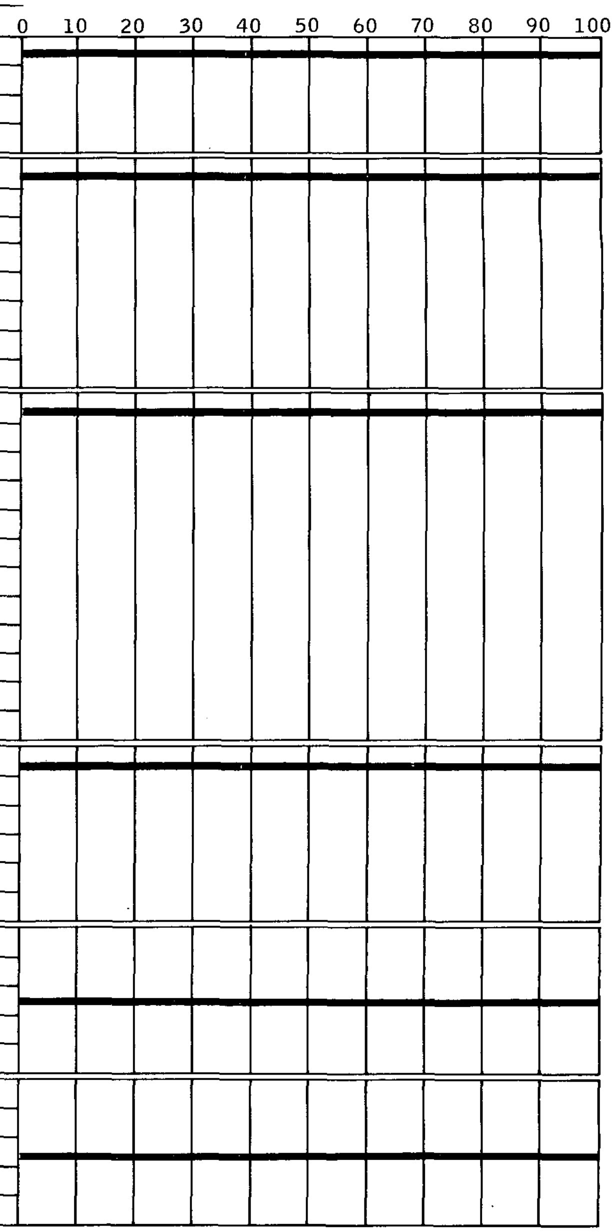
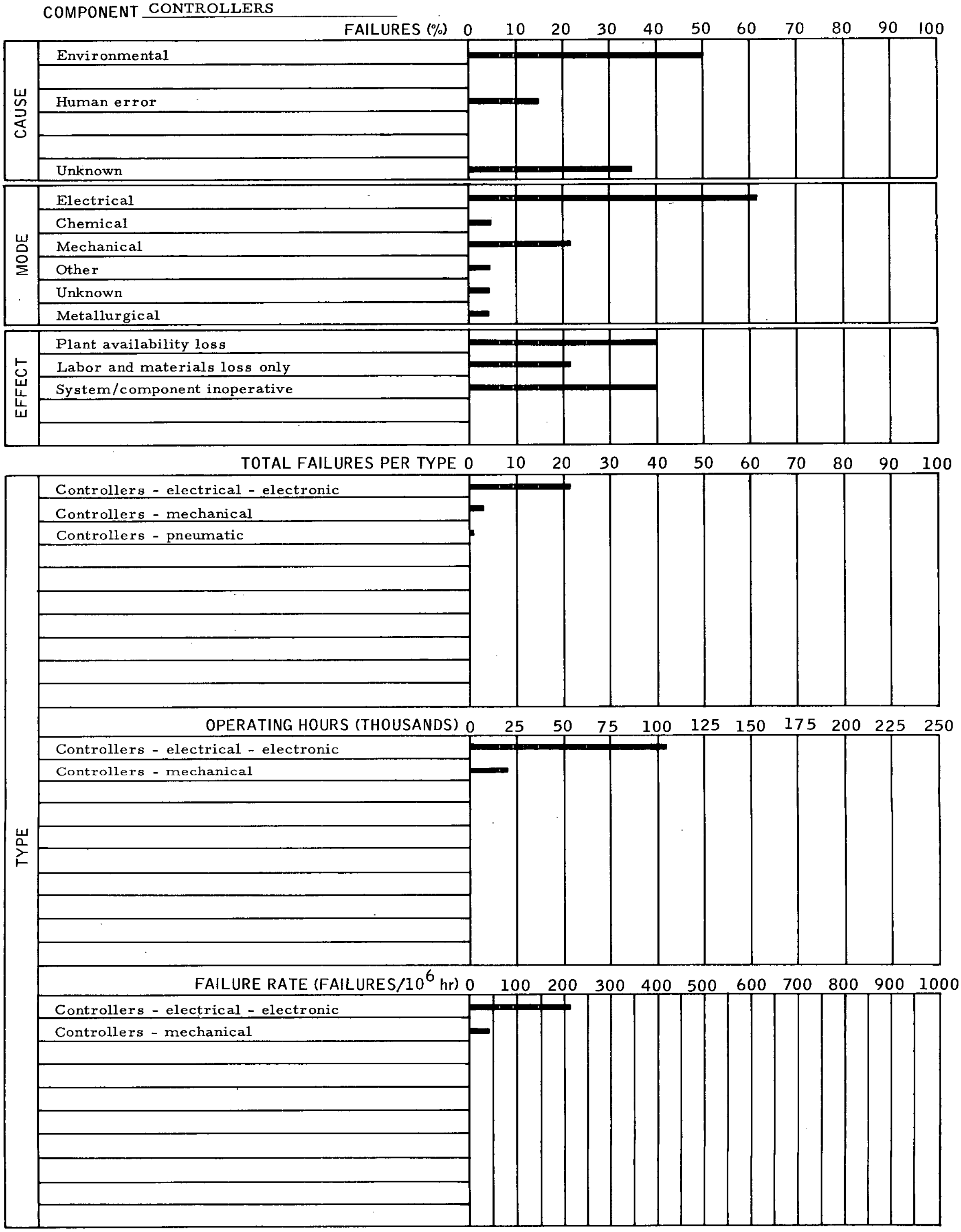


TABLE 1-143

GENERAL SUMMARY

COMPONENT CONTROLLERS



6. Indicators and Recorders

Failure data for indicators and recorders are presented in Tables 1-144 through 1-150.

a. Mechanical

(1) Reliability Information

Design Features:

Direct indicating through mechanical linkage.

Critical Characteristics:

1) Cables
2) Diaphragms and bellows
3) Linkage and bearing surfaces.

Mode of Failure:

1) Glass breakage
2) Cable chafing.

Failure Description:

1) Pressure gage dial face broken accidentally.
2) Cable chafed against seal housing.

Control Methods:

1) Use plexiglass or other plastic facing on gages.
2) Upgrade installation, operating, and preventive maintenance procedures.

Alternate Concepts:

Remote sensing pressure instruments utilizing direct writing records.

(2) Discussion and Recommendations

If parameters being monitored on recorders or indicators are of sufficient importance that a failure would necessitate a system shutdown, then it is recommended that a redundant means of recording or indicating be added to the system. Providing this capability is often cheaper than the cost of excessively high reliability.

Adequate records should be maintained on all component failures so that a failure history record can be accumulated to help establish service intervals. Industry and vendor information of this nature is also usually available.

The units that failed had anywhere from 2000 to 15,000 operating hours. If the operating hours in any particular event did not exceed the design life, then a malfunction analysis should be performed on that unit to determine the exact cause of failure. Information from this analysis would dictate a design change, increased quality control surveillance, or a change in the replacement cycle time.

If the unit did exceed its operating life, then a design change is in order to expand its life or the replacement cycle time must be reduced to minimize the potential of a failure occurring at an inopportune time.

b. Electronic

(1) Reliability Information

Design Feature:

Graphic direct writing analog recorders and direct indicating instruments.

Critical Characteristics:

Recorder drive mechanisms and inking systems and electronic tubes.

Mode of Failure:

1) Drive mechanism binding
2) Cold solder joints
3) Electron tube failures
4) Motor bearing failure
5) Enclosures improperly secured
6) Potentiometer failure
7) Tachometer wearout
8) Plugged sensing tube
9) Voltage surges.

Failure Description:

1) Improper installation of chart paper

2) Failure to clean and lubricate mechanisms

3) Cold solder joints resulting from inadequately trained personnel, inadequate tools, or poor working conditions

4) Exceeding life of components; inadequate cooling

5) Inadequate checkout and operating procedures

6) Detailed checkout and troubleshooting procedures

7) Voltage regulating equipment for power supplies.

Alternate Concepts:

1) Use of solid-state devices in lieu of electron tubes

2) Use of digital data acquisition systems in lieu of direct-writing analog records

3) Immersion type pH meters instead of sampling system

4) Float type or electrical resistance point contact type level gages.

(2) Discussion and Recommendations

Refer to Paragraph 6.a.(2).

c. Pneumatic

(1) Reliability Information

Design Features:

Direct indicating instruments utilizing pneumatics.

Critical Characteristics:

1) Seal leakage

2) Mechanical linkage.

Mode of Failure:

1) N_2 flowmeter failure

2) Sodium freezing.

Failure Description:

1) Probably caused by a leak or sticky ball inductor

2) Sodium frozen in an unheated section of a bubbler tube.

Control Methods:

1) Periodic instrument servicing

2) Application of heat to all sections of bubbler tube.

(2) Discussion and Recommendations

Refer to Paragraph 6.a.(2).

d. Sight Glass

(1) Reliability Information

Design Features:

Float principle with graduated glass tube to allow visual monitoring of the media.

Critical Characteristics:

1) Glass tube sensitive to thermal cycling.

2) Glass tube limits use to low-pressure applications.

3) Sealing depends on careful assembly of components.

Mode of Failure:

1) Glass tube breaks

2) Gasket failure

3) Glass etching

4) Stud threads stripped

5) Bolts not correctly torqued.

Failure Description:

1) Improper installation techniques: gaskets installed improperly, bolts torqued unevenly or over-torqued, etc.

2) Pressure surges

3) Inadequate preventive maintenance

4) Corrosive effects of water and steam on components

5) Stresses on components resulting from thermal cycling.

Control Methods:

1) Use of detailed installation procedures that reflect manufacturer's recommendations

2) Personnel training in the implementation of the procedure

3) Preventive maintenance program

4) Pressure surge control

5) H_2 treatment.

Alternate Concepts:

Other types of level and flow indicators that are not dependent on glass tubes.

(2) Discussion and Recommendations

It is common in sight-glass installations to provide valving on both sides of the indicator so that it may be quickly isolated by the system operator in case of failure and may be replaced or repaired without shutting down the system that it is monitoring. This capability should be considered with respect to the increased cost of a more reliable component.

An engineering study of this device seems to be in order. Its applicability to the service to which it is being subjected is questionable. The availability of new materials and/or design changes to enhance the criticality of assembly should be investigated. The feasibility of system changes to reduce or eliminate thermal cycling and pressure surges should also be investigated.

The etching of the glass tubes in some cases suggests that perhaps additional water treatment is needed to minimize the corrosive effects. Treatable water and steam conditions may be affecting the gasket material.

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 1 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Recorder/Drive Mechanism 2. Instrumentation and Control/Neutron Monitor System 3. 64 261110	1. HNPF 2. Reactor control system/neutron flux monitor channel 1 and 2 3. - 4. Monthly operating report No. 10	MI 12Z	MI 47	MI 550	3710	Operational monitors	1. Drive mechanism binding. 2. Part cleaned and returned to service. 3. Improve preventive maintenance.
2	1. Recorder/Carrier Oscillator 2. Instrumentation and Control/Intermediate Coolant Loop 3. 64 262210	1. Fermi 2. Secondary sodium service 3. - 4. PRDC-EF-13	MI 15Z	MI 43	MI 530	7200	Direct observation	1. Inspection revealed a broken solder joint (cold joint). 2. Local repair. 3. Improve inspection procedures.
3	1. Recorder/Preamplifier Tubes 2. Instrumentation and Control/Fuel Element Failure Detector 3. 64 261140	1. EBR-II 2. Fission gas monitor 3. - 4. Maintenance report, 3/14/68	MI 500	MI BZ	MI 530	13,850	Preventive maintenance	1. Bad tubes. 2. Part replaced. 3. None.
4	1. Indicator/Transmitter 2. Instrumentation and Control/Reactor Coolant 3. 64 262100	1. SCTI 2. Primary sodium fill and drain tank/level indicator LI-500T 3. 250 to 600°F 4. Incident report No. 66	MI 477	MI 13	MI 530	4846	Operational monitors	1. Transmitter shorted to ground during rain. 2. Local repair, plastic cover installed on transmitter and connector. 3. More careful installation of instruments exposed to weather.
5	1. Indicators/Rectifier Shroud 2. Instrumentation and Control/Fuel Element Failure Detection 3. 64 261140	1. EBR-II 2. Primary/fuel element rupture detector 3. - 4. PMMR-34	MI 500	MI 59	MI 530	2590	Direct observation	1. Broken shroud. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 2 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
6	1. Level Indicator/ Potentiometer 2. Instrumentation and Control/Purification 3. 64 262420	1. Fermi 2. FARB/cold trap system 3. - 4. PRDC-EF-52	MI 15Z	MI 13	MI 530	14,941	Direct observation	1. Potentiometer shorted out. 2. Part replaced. 3. None.
7	1. Recorder/Motor 2. Instrumentation and Control/Intermediate Coolant Loop 3. 64 262210	1. EBR-II 2. Secondary sodium system/cold trap 3. - 4. EBR-II maintenance report, 3/14/68	MI 500	MI 52	MI 530	13,850	Preventive maintenance	1. Bearings failed. 2. Part replaced. 3. Upgrade recorder preventive maintenance to detect problem prior to total failure.
8	1. Indicator/Tachometer 2. Instrumentation and Control/M. G. set 3. 64 269000	1. EBR-II 2. Primary pump/M. G. set No. 1 3. - 4. Operation weekly report, 12/20/67	MI 500	MI BZ	MI 530	13,380	Operational monitors	1. Tachometer worn out. 2. Part replaced. 3. Increase inspections to detect problem before failure.
9	1. Indicator/Sampling Tube 2. Instrumentation and Control/Cooling Water 3. 64 269630	1. SCTI 2. Cooling tower water system/pH meter 3. 2-12 pH 4. Incident report, No. 22	MI 312	MI 31	MI 139	1795	Direct observation	1. Sample tubes plugged with silt. 2. Local repair, tubes cleaned and timer installed on H_2SO_4 pump. 3. Operating procedure should include requirement for regular backwash - to be executed.
10	1. Indicators and Recorders/Flowmeter Power Supply 2. Instrumentation and Control/Shield Cooling System 3. 64 261220	1. EBR-II 2. Primary/shield cooling 3. - 4. Maintenance report, 4/18/68	MI 152	MI 12	MI 530	14,150	Operational monitors	1. Voltage surge. 2. Local repair. 3. None.
11	1. Indicator/Light Bulb 2. Instrumentation and Control/Steam, Condensate and Feedwater Piping and Equipment 3. 64 268300	1. SCTI 2. Boiler feed pump "ON" indicator 3. - 4. Incident report No. 49, 9/27/65	MI 152	MI 12	MI 47	6800	Operational monitors	1. Burned out light falsely indicated that the boiler feed pump was shut down. 2. Lamp replaced. 3. Use indicator "push to test" circuits where necessary or long life indicators before executing next procedure. Check bulbs for burn out.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS
(Sheet 3 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
12	1. Indicator/Shorted Leads 2. Instrumentation and Control/Intermediate Coolant System 3. 64 262200	1. SCTI 2. Secondary fill tank level 3. - 4. Incident report No. 43, 9/10/65	MI 339	MI 13	MI 550	4846	Direct observation	1. Operator accidentally grounded level indicator leads actuating pilot gas valve cutout. 2. Ground removed, pilot reignited. 3. Improve training for electrical maintenance personnel on requirements for guards over connections and improve operators training to assure alertness to possible exposed leads.
13	1. Indicator/Potentiometer 2. Instrumentation and Control/Intermediate Coolant Loop 3. 64 262210	1. HNPF 2. Sodium level No. 2 secondary expansion tank 3. - 4. AI monthly, 2/14/63	MI 500	MI 43	MI 550	Unknown	Operational monitor	1. Spurious drops in indication caused by bad potentiometer. 2. Part replaced. 3. None.
14	1. Indicator/Pressure Gage 2. Instrumentation and Control/M. G. set 3. 64 269000	1. EBR-II 2. M. G. set No. 2/cooling water 3. - 4. Operation weekly report, 12/20/67	MI 500	MI BZ	MI 530	13,380	Operational monitors	1. Gage broken. 2. Part replaced. 3. Provide protection for gauge glass.
15	1. Indicator/Cable 2. Instrumentation and Control/Fuel Handling 3. 64 263000	1. Fermi 2. Cask Car 3. Minimum 350°F, argon 4. EF-No. 22	MI 126	MI 59	MI 530	11,740	Operational monitors	1. Cable dragged on seal housing. 2. Part replaced. 3. None.
16	1. Indicator/N_2 Flowmeter 2. Instrumentation and Control/Shield 3. 64 261220	1. EBR-II 2. Reactor shield/small plug 3. 20-40 psig 4. PMMR-76	MI 500	MI 43	MI 530	6300	Operational monitors	1. Operation faulty. 2. Local repair. 3. None.
17	1. Indicator/Bubbler Tube 2. Instrumentation and Control/Heat Transfer 3. 64 262110	1. SCTI 2. Primary sodium system, sodium pump, level control 3. Control section below 300°F 4. Incident report No. 33	MI 118	MI 55	MI 550	611	Protective system	1. Sodium entered an unheated section of the level control bubbler tube and solidified. 2. Component corrective modification. 3. Modified level gage eliminated the need of heater.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 4 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
18	1. Indicator/Sightglass Gaskets 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum east end 3. 580°F, 1300 psig 4. PMMR-113, Item No. 12	MI 500	MI 52	MI 530	3045	Direct observation	1. Gaskets worn out. 2. Parts replaced. 3. None.
19	1. Indicator/Sightglass Studs 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum east end 3. 580°F, 1300 psig 4. PMMR-113, Item No. 12	MI 500	MI 52	MI 530	3045	Direct observation	1. Studs worn. 2. Parts replaced. 3. None.
20	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum east end 3. 580°F, 1300 psig 4. PMMR-113, Item No. 12	MI 500	MI 52	MI 530	3045	Direct observation	1. Mica worn out. 2. Part replaced. 3. None.
21	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum west gage 3. 580°F, 1300 psig 4. Operations weekly report, 12/27/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Sightglass glass worn out. 2. Part replaced. 3. None.
22	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum west gage 3. 580°F, 1300 psig 4. Operations weekly report, 12/27/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Mica worn out. 2. Part replaced. 3. None.
23	1. Indicator/Sightglass Cushions 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum west gage 3. 580°F, 1300 psig 4. Operations weekly report, 12/27/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Cushions worn out. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 5 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
24	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Water side 3. 580°F, 1300 psig 4. PMMR-32	MI 500	MI 52	MI 530	2190	Direct observation	1. Gasket leaking. 2. Part replaced. 3. Installation procedures for sightglasses should be reviewed and/or revised to limit failures of these units through improper installation techniques.
25	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Water side 3. 580°F, 1300 psig 4. PMMR-32	MI 500	MI 52	MI 530	2190	Direct observation	1. Mica worn out. 2. Part replaced. 3. None.
26	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/low pressure flash tank 3. 298°F, 50 psig 4. PMMR-80	MI 500	MI 52	MI 530	5700	Preventive maintenance	1. Sightglass glass worn out. 2. Part replaced. 3. Better glass material would provide longer service life.
27	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/low pressure flash tank 3. 298°F, 50 psig 4. PMMR-80	MI 500	MI 52	MI 530	5700	Preventive maintenance	1. Gasket worn out. 2. Part replaced. 3. None.
28	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-29	MI 500	MI 59	MI 530	30	Direct observation	1. Sightglass glass broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
29	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-31	MI 500	MI 59	MI 530	340	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 6 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
30	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-31	MI 500	MI 59	MI 530	340	Direct Observation	1. Gasket ruptured. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
31	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-31	MI 500	MI 59	MI 530	340	Direct observation	1. Glass broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
32	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-31	MI 500	MI 59	MI 530	340	Direct observation	1. Gasket ruptured on repressurizing. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
33	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-31	MI 500	MI 59	MI 530	340	Direct observation	1. Glass broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
34	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-33	MI 500	MI 59	MI 530	340	Direct observation	1. Glass shattered on repressurizing. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
35	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. Operation monthly report, 11/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS
(Sheet 7 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
36	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-34	MI 500	MI 52	MI 530	170	Direct observation	1. Gasket leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
37	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Steam Drum 3. 64 262312	1. EBR-II 2. Steam drum east end 3. 580°F, 1300 psig 4. PMMR-98	MI 500	MI 52	MI 530	9345	Direct observation	1. Gasket leaking. 2. Part replaced, small leak still exists. Additional work is needed. 3. None.
38	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. PMMR-24, 4/8/65	MI 500	MI 59	MI 530	1490	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
39	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. PMMR-24, 4/8/65	MI 500	MI 59	MI 530	1490	Direct observation	1. Gasket ruptured. 2. Part replaced. 3. Recommend engineering study of problem.
40	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. PMMR-30, 5/18/65	MI 500	MI 59	MI 530	550	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
41	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. PMMR-38, 7/21/65	MI 500	MI 59	MI 530	630	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 8 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
42	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. PMMR-57, 12/15/65	MI 500	MI 59	MI 530	1730	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
43	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-75	MI 500	MI 52	MI 530	3630	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
44	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-75	MI 500	MI 52	MI 530	3630	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
45	1. Indicator/Sightglass Cushion 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-75	MI 500	MI 52	MI 530	3630	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
46	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature - 565°F 4. PMMR-107	MI 500	MI 52	MI 530	5330	Direct observation	1. Sightglass leaking and broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
47	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-107	MI 500	MI 52	MI 530	5330	Direct observation	1. Sightglass leaking and broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 9 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
48	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-75, 5/11/66	MI 500	MI 52	MI 530	6344	Preventive maintenance	1. Glass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
49	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-75, 5/11/66	MI 500	MI 52	MI 530	6344	Preventive maintenance	1. Gasket damaged. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
50	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-75, 5/11/66	MI 500	MI 52	MI 530	6344	Preventive maintenance	1. Mica damaged. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
51	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-75, 5/11/66	MI 500	MI 52	MI 530	6344	Preventive maintenance	1. Cushion worn out. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
52	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-75, 5/11/66	MI 500	MI 92	MI 530	6344	Preventive maintenance	1. Flange pitted. 2. Local repair, flange resurfaced. 3. None.
53	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-80, 6/29/66	MI 500	MI 52	MI 530	140	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
54	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-80, 6/29/66	MI 500	MI 52	MI 530	140	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS
(Sheet 10 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
55	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-80, 6/29/66	MI 500	MI 52	MI 530	140	Preventive maintenance	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
56	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-105, 6/21/67	MI 500	MI BZ	MI 530	3660	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
57	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 3 3. Shellside = 800°F at 700 psig Tubeside = 500°F at 2000 psig 4. PMMR-105, 6/21/67	MI 500	MI BZ	MI 530	3660	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
58	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-3	MI 500	MI 52	MI 530	1200	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
59	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-3	MI 500	MI 52	MI 530	1200	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
60	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-3	MI 500	MI 52	MI 530	1200	Direct observation	1. Gasket leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
61	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-23	MI 500	MI 52	MI 530	120	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.

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MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS
(Sheet 11 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
62	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-23	MI 500	MI 52	MI 530	120	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
63	1. Indicator/Sightglass 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-28	MI 500	MI 52	MI 530	500	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
64	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-29	MI 500	MI 59	MI 530	30	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Manufacturer's recommendations should be followed for installation and operating conditions.
65	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-107	MI 500	MI 52	MI 530	5330	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
66	1. Indicator/Sightglass Cushions 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 4 3. Inlet temperature = 480°F Outlet temperature = 565°F 4. PMMR-107	MI 500	MI 52	MI 530	5330	Direct observation	1. Sightglass leaking. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
67	1. Indicator/Sightglass Mica 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. Operating monthly report, 11/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Mica damaged. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 12 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
68	1. Indicator/Sightglass Gasket 2. Instrumentation and Control/Feedwater 3. 64 268400	1. EBR-II 2. Feedwater/heater No. 2 3. 374°F at 200 psig 4. Operation monthly report, 11/67	MI 500	MI 52	MI 530	7110	Direct observation	1. Gasket damaged. 2. Part replaced. 3. Follow manufacturer's recommendations for installation and operating conditions.
69	1. Indicator/Sightglass 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-28	MI 500	MI 52	MI 530	1820	Direct observation	1. Sightglass severely etched. 2. Part replaced. 3. High pressure sightglasses should operate approximately four months without problems. Thermal cycling of sightglasses tends to shorten their operating lives.
70	1. Indicator/Sightglass 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-30	MI 500	MI 59	MI 530	180	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Installation procedures should be reviewed and/or revised to limit failures of these units through improper installation techniques.
71	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-33	MI 500	MI 52	MI 530	190	Direct observation	1. Glass appeared to be eroding. 2. Part replaced. 3. Use of better sightglass material is suggested.
72	1. Indicator/Water Level Sightglass 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/low pressure flash tank No. 2 3. 298°F, 50 psig 4. PMMR-4	MI 500	MI BZ	MI 530	1200	Operational monitors	1. Sightglass broken. 2. Part replaced. 3. Installation procedures should be reviewed and/or revised to limit failures of these units through improper installation techniques.
73	1. Indicator/Sightglass Glass 2. Instrumentation and Control/Main Steam 3. 64 268100	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-42, 43	MI 500	MI 59	MI 530	880	Direct observation	1. Sightglass broken. 2. Part replaced. 3. Installation procedures should be reviewed and/or revised to limit failures of these units through improper installation techniques.

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TABLE 1-144

FAILURE DATA FOR INDICATORS AND RECORDERS

(Sheet 13 of 13)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
74	1. Flow Indicator/Glass 2. Instrumentation and Control/Raw Water Supply 3. 64 268400	1. SCTI 2. Cooling water supply 3. 125 psig 4. Incident report No. 331	MI 174	MI 59	MI 550	3460	Direct observation	1. Abnormal high pressure surge in raw cooling water supply caused breakage of sightglass. 2. Part replaced. 3. Install pressure regulator.
75	1. Indicator/Flowmeter Flange 2. Instrumentation and Control/Feedwater 3. 64 268400	1. SCTI 2. Main steam/feedwater flowmeter FRC-201 3. 475 to 600°F 4. Incident report No. 104	MI 326	MI 53	MI 136	5225	Direct observation	1. Feedwater leakage at flange, bolts not properly torques. 2. Local repair, bolts retorqued. 3. Maintenance personnel should be trained for torquing flange connections.
76	1. Indicator/Level Control Gasket 2. Instrumentation and Control/Condensate 3. 64 268300	1. EBR-II 2. Steam system/high pressure flash tank 3. 578°F, 700 psig 4. PMMR-107	MI 413	MI 52	MI 530	11,320	Direct observation	1. Gasket worn out, leaking. 2. Part replaced. 3. Revise sightglass overhaul procedure, if required. Thermal cycling sightglasses drastically shortens their operating life.

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TABLE 1-145

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT *INDICATORS AND RECORDERS*

COMPONENT SUBTYPE ELECTRONIC

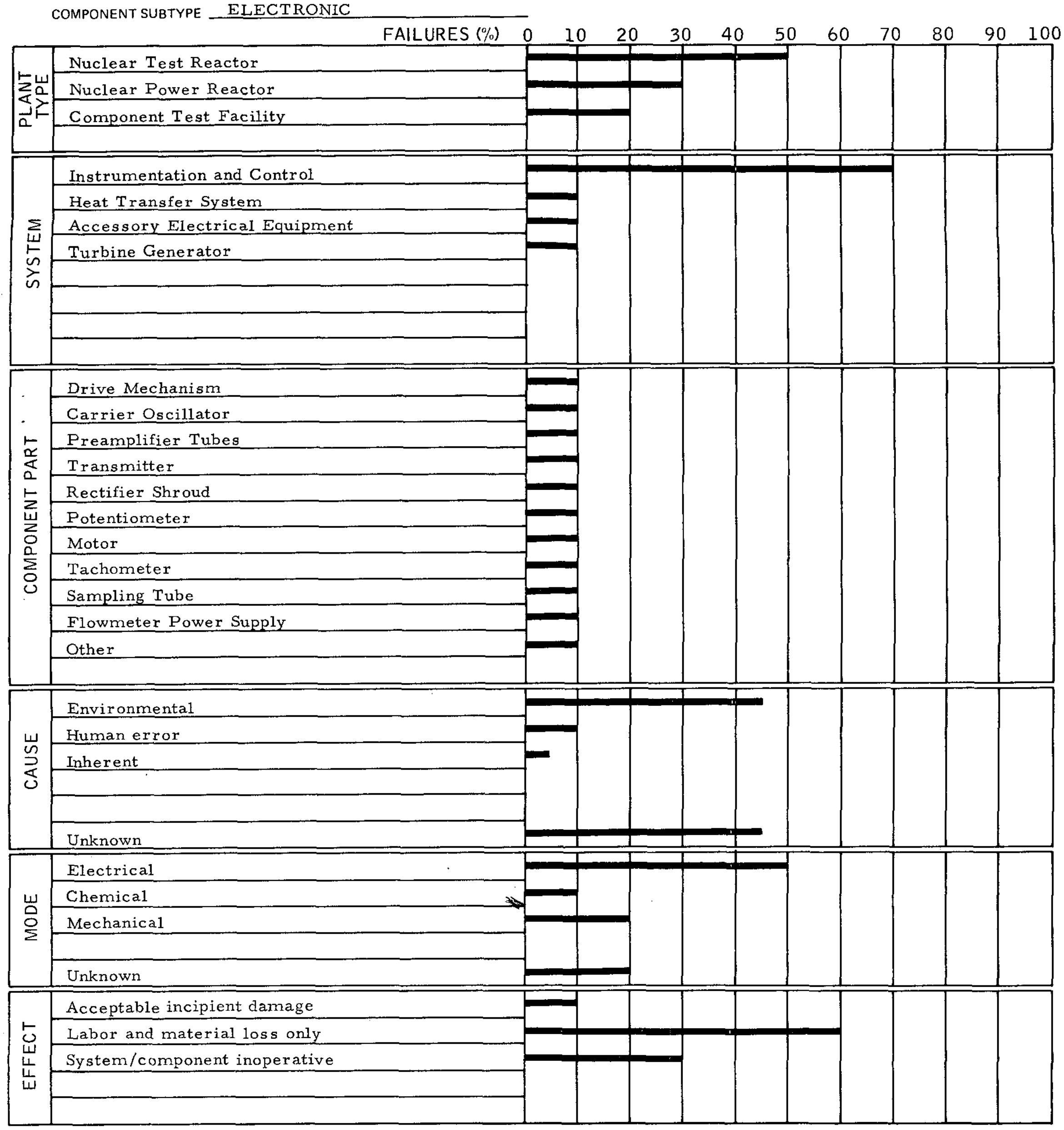


TABLE 1-146

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INDICATORS AND RECORDERS

COMPONENT SUBTYPE MECHANICAL

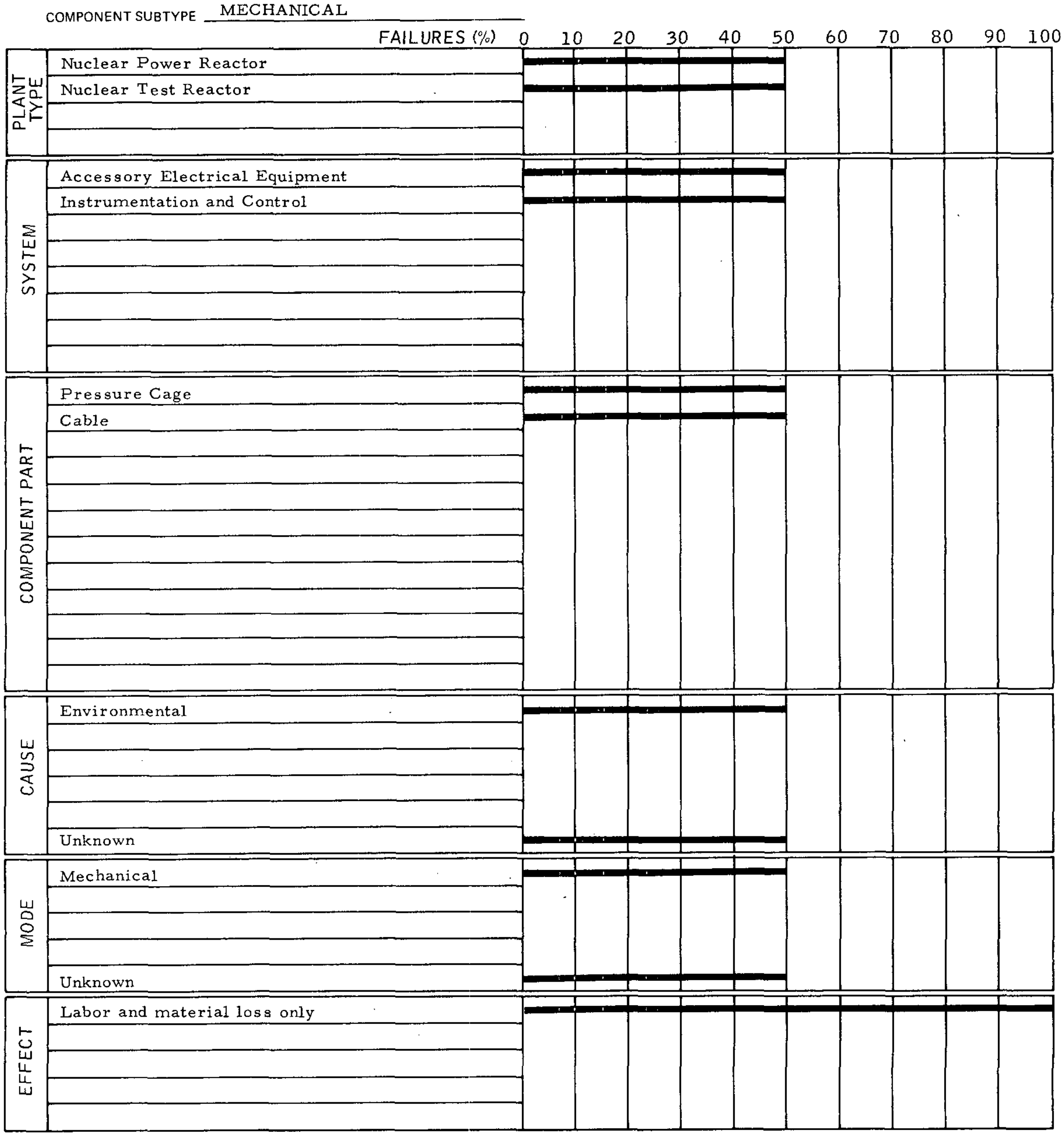


TABLE 1-147

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INDICATORS AND RECORDERS

COMPONENT SUBTYPE PNEUMATIC

PLANT TYPE	Nuclear Test Reactor
	Component Test Facility
SYSTEM	Instrumentation and Control
COMPONENT PART	Sodium Flowmeter
	Bubbler Tube
CAUSE	Environmental
	Unknown
MODE	Mechanical
EFFECT	Labor and material loss only
	System/component inoperative

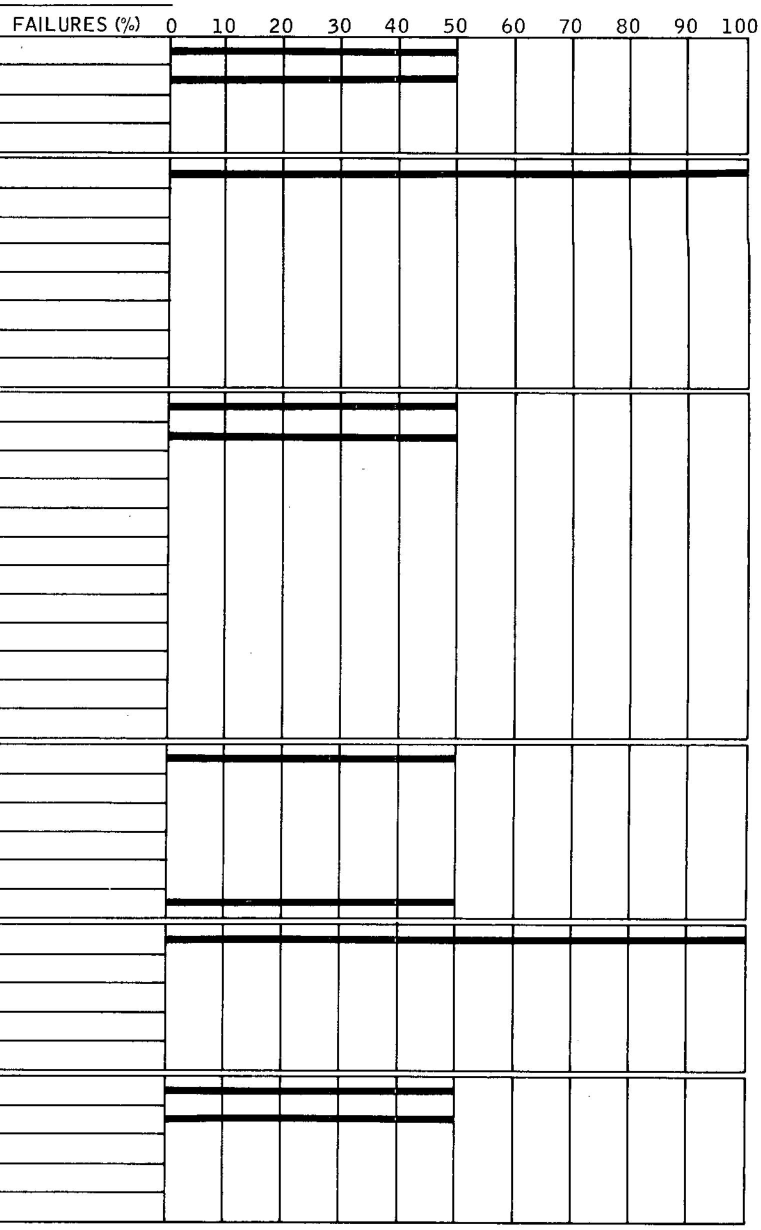


TABLE 1-148

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INDICATORS AND RECORDERS

COMPONENT SUBTYPE SIGHTGLASS

PLANT TYPE	Nuclear Test Reactor
	Component Test Facility
SYSTEM	Instrumentation
	Feedwater Supply and Treatment
COMPONENT PART	Sightglass Gasket
	Sightglass Glass
	Sightglass Mica
	Sightglass Cushion
	Sightglass Studs
	Water Level Sightglass
CAUSE	Environmental
	Unknown
MODE	Mechanical
	Metal corrosion
	Unknown
EFFECT	Labor and material loss only
	System/component inoperative

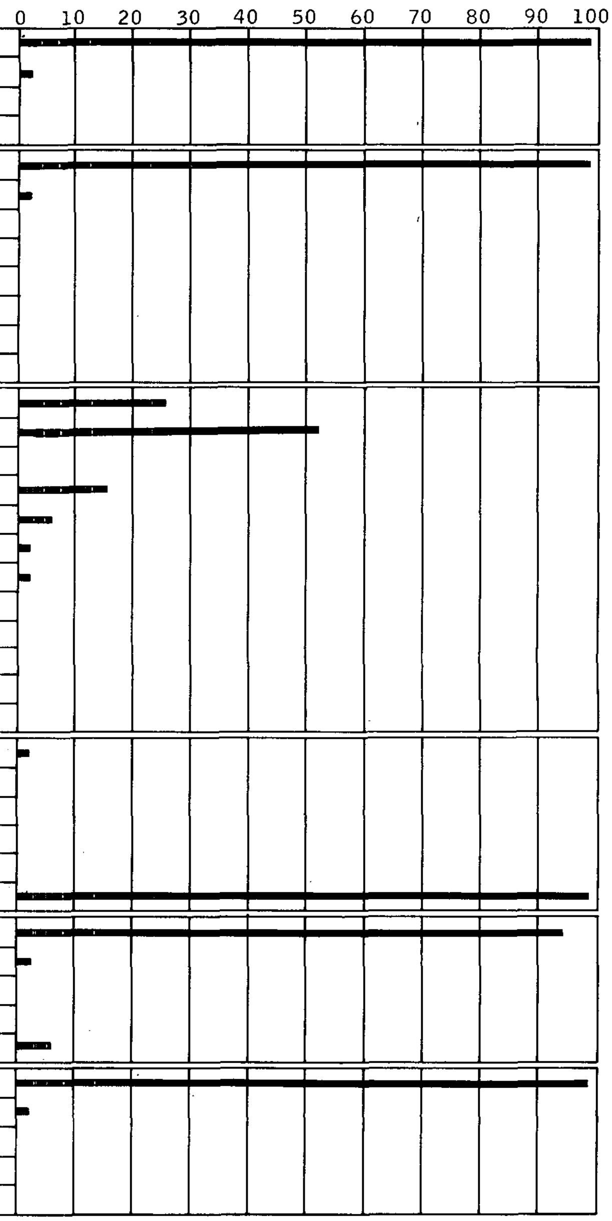


TABLE 1-149

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INDICATORS AND RECORDERS

COMPONENT SUBTYPE STEAM SYSTEM

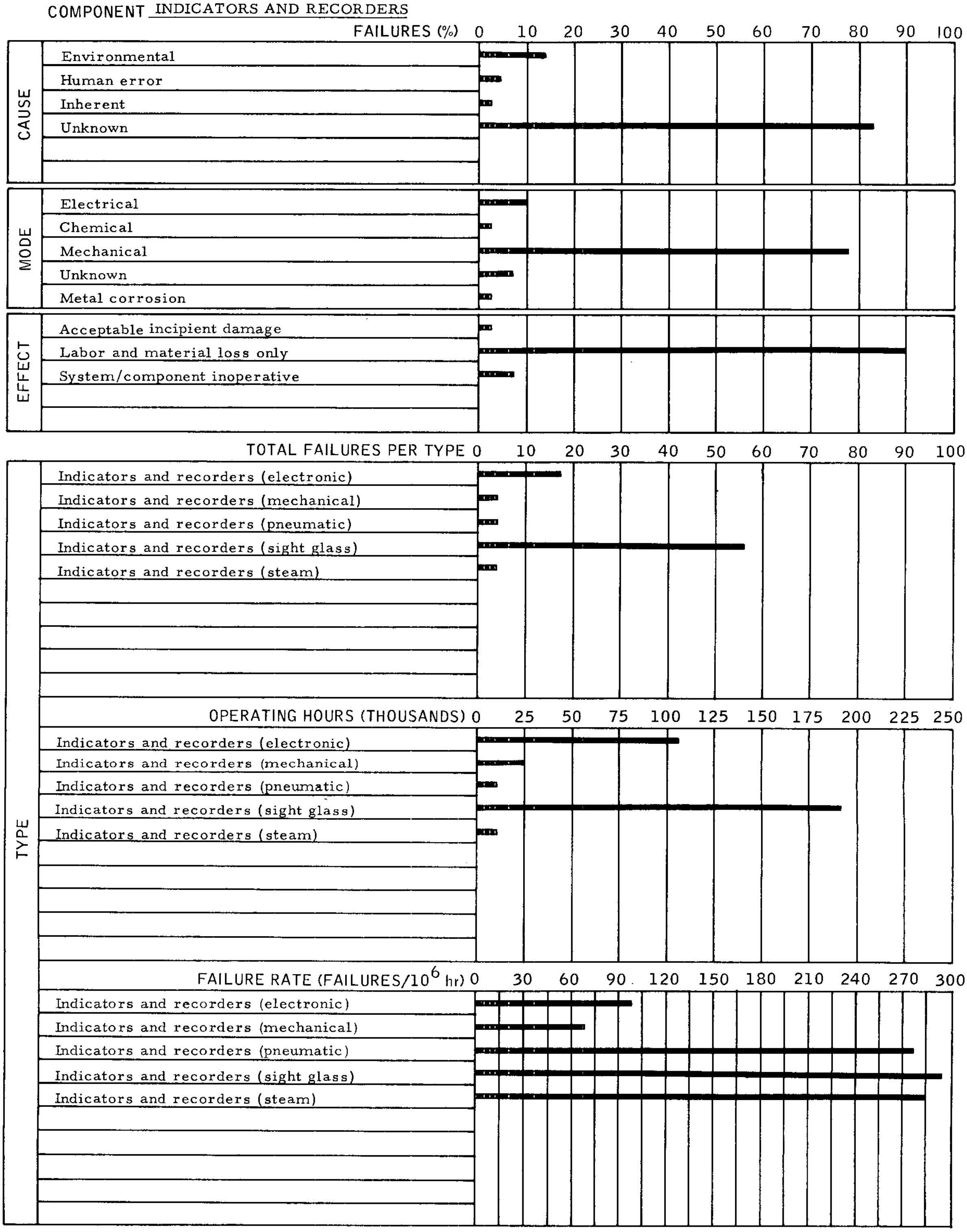
FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Test Reactor
	Component Test Facility
SYSTEM	Steam
	Instrumentation
COMPONENT PART	Flowmeter Flange
	Level Control Gasket
CAUSE	Human error
	Inherent
MODE	Mechanical
EFFECT	Labor and material loss only

TABLE 1-150

GENERAL SUMMARY

COMPONENT INDICATORS AND RECORDERS



7. Instrumentation (terminal boards, patch panels, relays, suppressors)

Failure data for instrumentation (terminal boards, patch panels, relays, suppressors) are presented in Tables 1-151 through 1-153.

a. Reliability Information

Design Features:

Coil-operated contact switches and cam-operated microswitches.

Critical Characteristics:

1) Coil material deterioration due to heat

2) Contact corrosion

3) Physical adjustment of microswitch with respect to operating cam or lever.

Mode of Failure:

1) Relay coil open circuit

2) Contact arm mechanical failure.

Failure Description:

1) Relay coil burned out.

2) Microswitch contact arm folded over the operating cam.

Control Methods:

1) Improve preventive maintenance procedures.

2) Upgrade procurement specifications.

Alternate Concepts:

Utilize voltage monitoring system in conjunction with a computerized digital data acquisition system in lieu of a mechanically operated microswitch for protective systems that could result in a plant scram.

Transistor circuits in place of electro-mechanical relays.

b. Discussion and Recommendations

In a protective circuit that can initiate a plant scram, it is questionable whether a mechanical device, such as the cam-operated microswitch that malfunctioned, could ever be reliable enough. An engineering study is in order to determine if better methods can be applied. An automatic monitoring and control system in conjunction with the new data acquisition system proposed for the SCTI is recommended.

The cost of higher reliability must be pitted against the effects or consequences of an event. In many applications, relays may be used to failure without any significant system effects.

TABLE 1-151

FAILURE DATA FOR INSTRUMENTATION (TERMINAL BOARDS, PATCH PANELS, RELAYS, SUPPRESSORS)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
1	1. Relay/Microswitch Actuator 2. Instrumentation and Control/Protective System 3. 69 267300	1. SCTI 2. Sodium heater (H-1)/temperature recorder TR-101 3. - 4. Incident report No. 110	MI 146	MI 53	MI 110	340	Operational monitors	1. Malfunction of microswitch actuator lever. 2. Part replaced. 3. Cam operators should be carefully examined for this type of failure potential.
2	1. Relay/ Drive Up Relay K-82 2. Instrumentation and Control/Reactor Automatic Control 3. 69 261160	1. HNPF 2. Reactor core/auto control rod 3. Reactor environment 4. Monthly operating report No. 18	MI 16Z	MI BZ	MI 530	7100	Operational monitors	1. Relay coil open. 2. Part replaced. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-152

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT INSTRUMENTATION - TERMINAL BOARDS, PATCH PANELS, RELAYS, SUPPRESSORS

COMPONENT SUBTYPE INSTRUMENTATION RELAYS

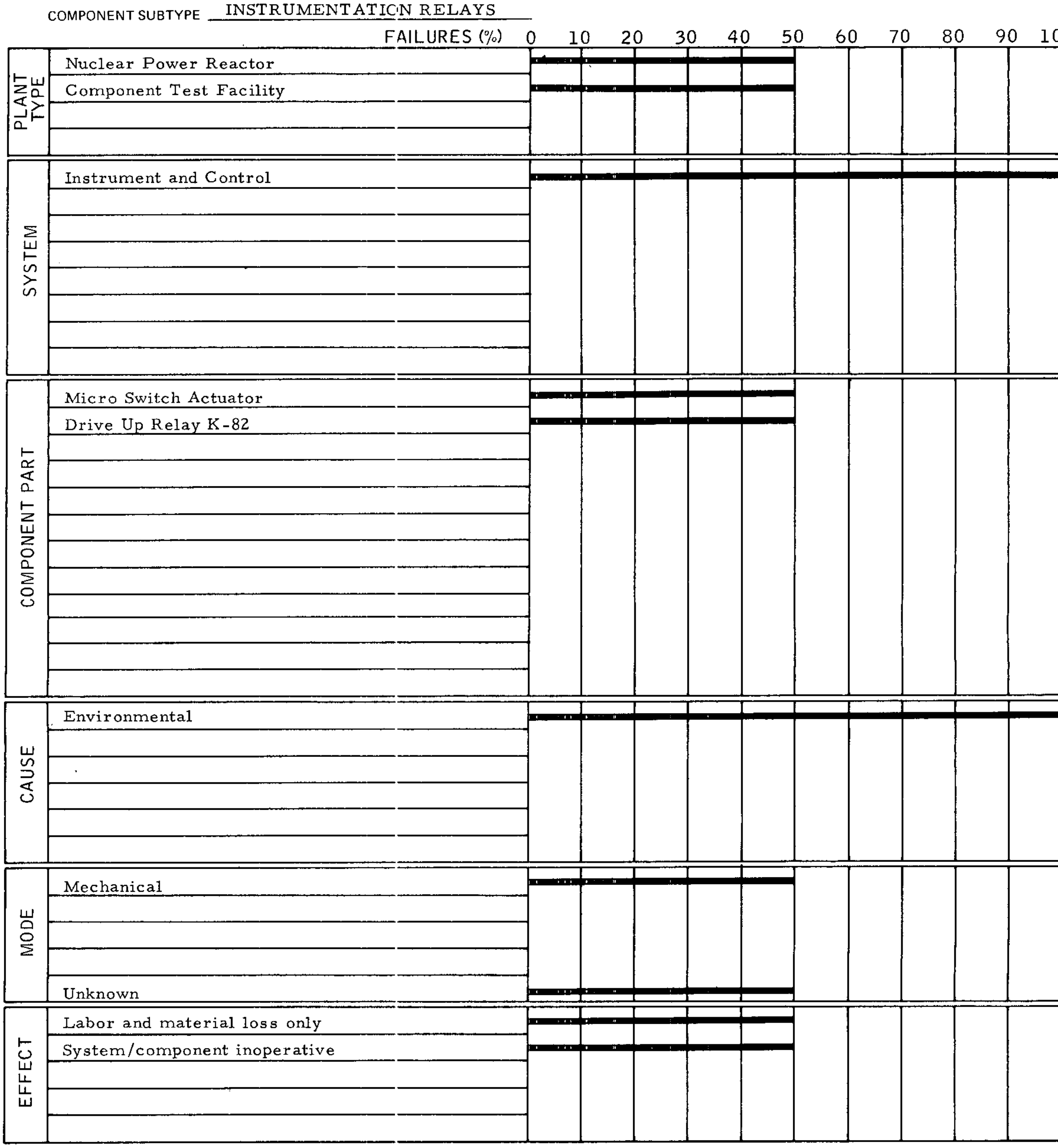
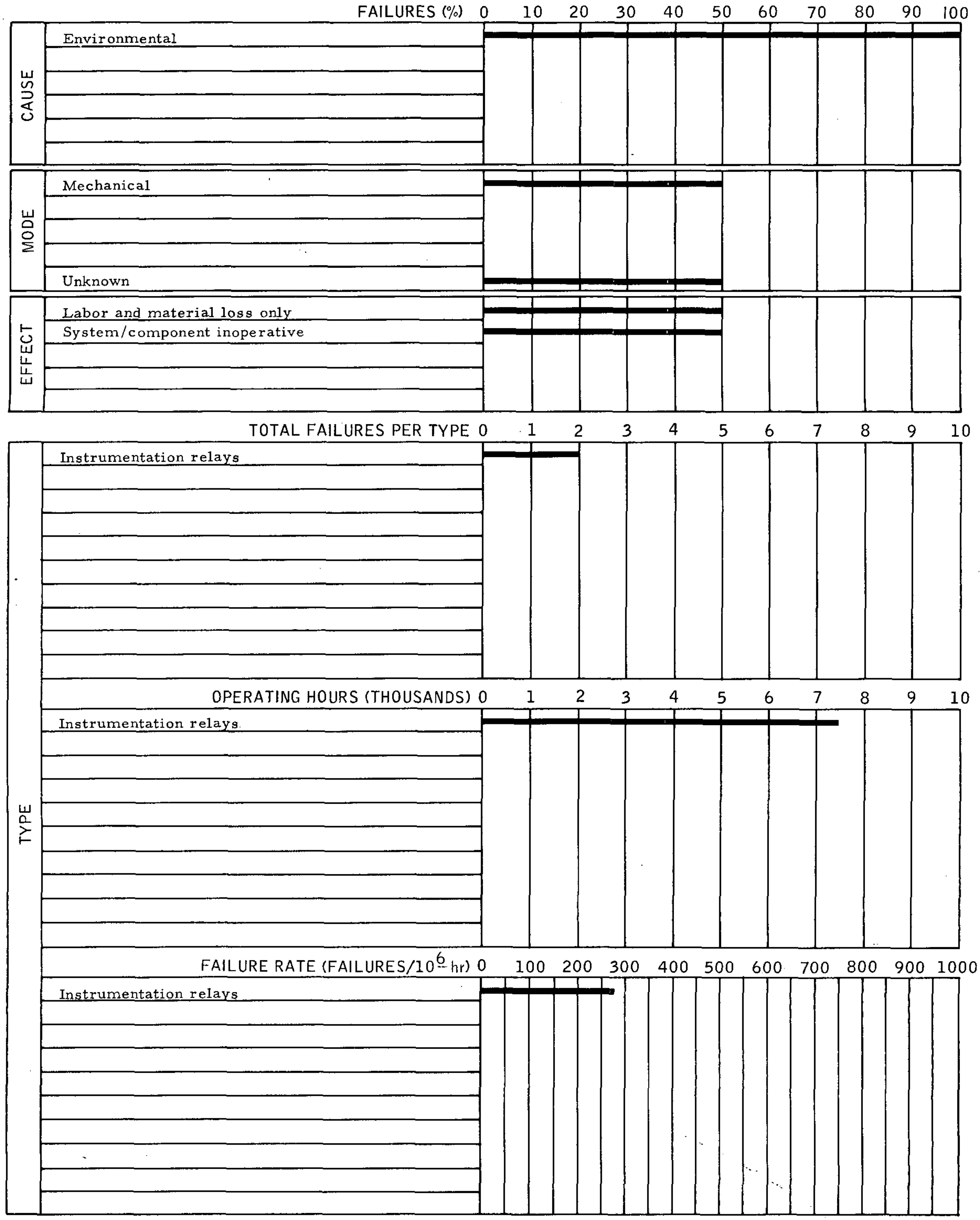


TABLE 1-153

GENERAL SUMMARY

COMPONENT INSTRUMENTATION - TERMINAL BOARDS, PATCH PANELS, RELAYS, SUPPRESSORS



8. Neutron Source

Failure data for neutron source are presented in Talbes 1-154 through 1-156.

a. Reliability Information

None.

b. Discussion and Recommendations

None.

TABLE 1-154

FAILURE DATA FOR NEUTRON SOURCE

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Neutron Source/ Threaded Stud 2. Reactor Equipment/ Neutron Source 3. 14 212400	1. Fermi 2. Neutron source 3. - 4. PRDC-EF-13 and PRDC-EF-14	MI 172	MI 54	MI 530	7930	Direct observation	1. Due to excessive torque while assembling neutron source No. 5, the end studs were damaged. 2. Vendor repair of component. 3. Assembly procedure should specify torque to be applied to studs.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-155

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT NEUTRON SOURCE

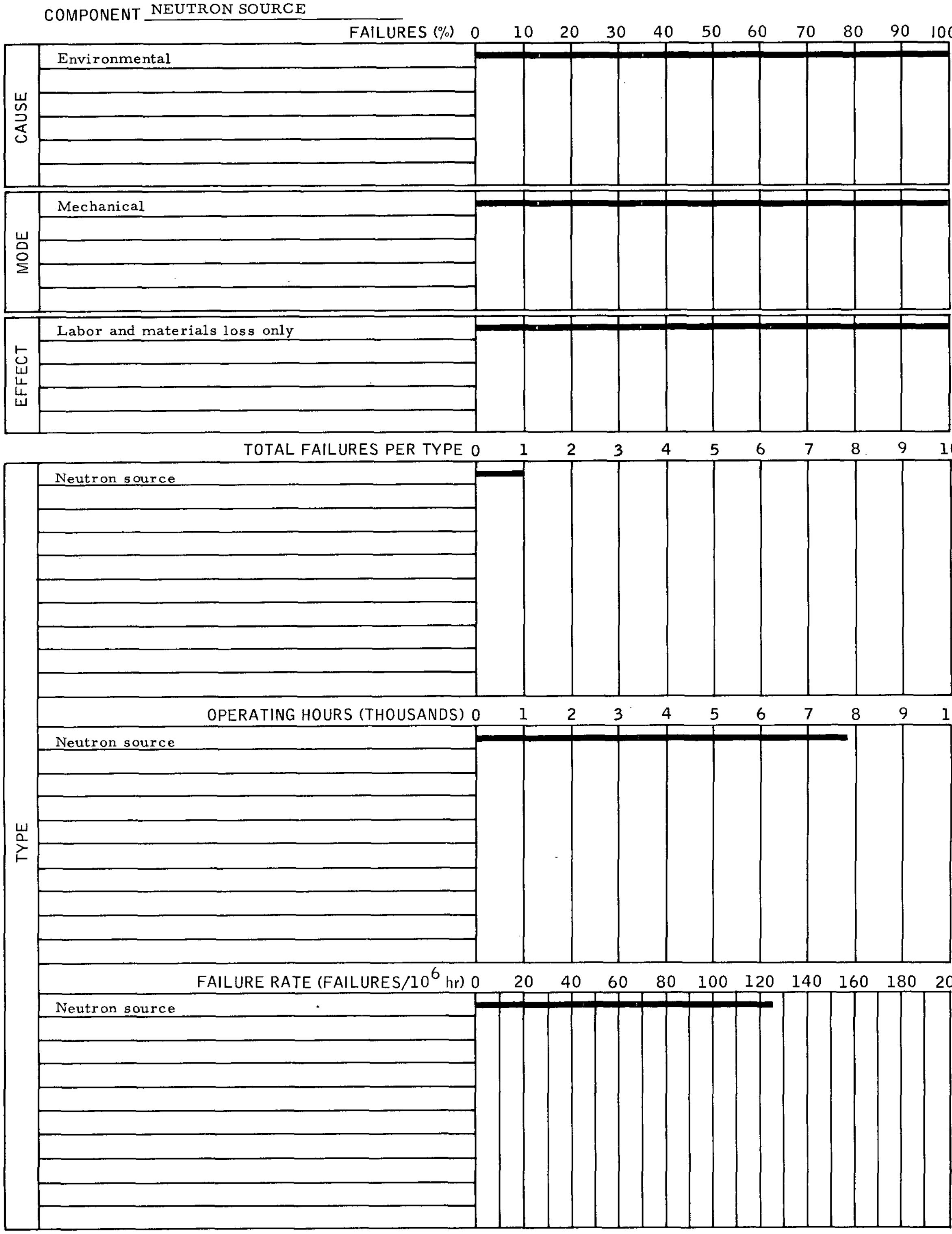
COMPONENT SUBTYPE NEUTRON SOURCE

	FAILURES (%)	0	10	20	30	40	50	60	70	80	90	100
PLANT TYPE	Nuclear Power Reactor											
SYSTEM	Reactor Equipment											
COMPONENT PART	Threaded Stud											
CAUSE	Environmental											
MODE	Mechanical											
EFFECT	Labor and materials loss only											

TABLE 1-156

GENERAL SUMMARY

COMPONENT NEUTRON SOURCE



9. Sensors (Other than Radiation)

Failure data for sensors (other than radiation) are presented in Tables 1-157 through 1-161.

a. Temperature Sensors and Thermocouples

(1) Reliability Information

Design Features:

Two configurations are considered, viz.,

1) Welded thermocouple junctions
2) Platinum wire resistance thermometers.

Critical Characteristics:

1) Purity of thermocouple junction
2) Attachment of thermocouple junction to surface to be measured
3) Durability of resistance thermometer insulation.

Mode of Failure:

1) Separation of thermocouple from surface to be measured
2) Short-circuiting of unprotected thermocouple wiring
3) Decay of insulation resistance.

Failure Description:

1) Improper installation of thermocouple junction caused separation of thermocouple from surface to be measured.
2) Sodium leak near thermocouple resulted in short circuting of leads.
3) Resistance thermometer insulation deteriorated so that a condition of low resistance-to-ground was produced.

Control Methods:

1) Develop and follow process specification for installation of thermocouple wires to steel.
2) Provide protective covering for the thermocouple junctions and wiring in component design.

3) Implement procurement specifications which assure proper mating of insulation material with its operating environment.

4) Implement acceptance test procedures to determine durability of insulation material at high temperature.

5) Implement preventive maintenance procedures to inspect component for degradation before the occurrence of failures.

6) Consider the use of thermocouples, where appropriate, during trade-off studies and design reviews prior to acquisition and fabrication.

(2) Discussion and Recommendations

The proper application of thermocouples to steel surfaces is a precarious task that is best controlled by a detailed process specification if high reliability and accuracy is required. Specification No. 7693-12100-2, "Process Specification for Welding Thermocouple Wires to Steel Using the Electronic Discharge Welding Method," an LMEC document, is suggested.

Protective covers over thermocouple junction and wiring will minimize the probability of failure as a result of a sodium leak.

Most problems associated with insulation resistance decay in resistance thermometers used for high-temperature liquid metal application derive from contamination of the magnesium oxide insulation. Rigid procurement specifications and source inspection can alleviate this problem. Periodic replacement of these instruments will be necessary in any event. Failure history data should be used to establish the proper material.

In pressure switches where vibration from the compressor caused the sensing capillary tube to become fatigued and to eventually split, the failure occurred after approximately 11,000 hours of operation. Subsequent installations should provide for flexibility so that the vibration experienced by the capillary tube will be damped. A flexible section of tube or expansion loops between securing points should be effective.

The location of the switch is also important. It should not be subject to excessive vibration. Ideally, it should not be located on the compressor.

Fabrication and installation procedures should provide detailed information concerning the proper flaring of fittings, installation of seals, and torque values. Personnel must also be thoroughly trained in implementing these procedures.

A preventive maintenance program that called for periodic torque checking or replacement of gaskets could alleviate untimely failures of this nature.

Heating of the entire sensing line length will eliminate the freezing of sodium in the sensing line.

Compliance with RDT F6-1 standard for welding will minimize the probability of sodium leaks occurring at welds.

The added cost of high reliability for many of these components must be compared with the cost and feasibility of other courses of action such as redundant measurement systems. Many of the failures affect only the measurement system or some minor control function. Periodic surveillance will detect potential failures and recently occurring failures. Most of these failures do not cause a plant or system shutdown and can also be repaired without a plant shutdown or even a significant system shutdown.

The establishment and implementation of good operating procedures can also alleviate many of the failures attributed to component malfunctions. In many cases the failure may be due simply to exceeding the component design life.

The incorporation of "press to test" circuits can provide a means for easily checking the integrity of the sodium leak detection circuit. This, coupled with a periodic visual check, should reduce the occurrence of false alarms and failures to detect actual leaks.

Sodium leak detectors have had a poor performance record in the past due to improper design. Short circuits were common because of the manner in which the wiring and sensors were installed; this problem should be considered during system design.

b. Pressure Switches

(1) Reliability Information

Design Features:

Sensors utilizing mechanical tubing with liquid or gaseous media.

Critical Characteristics:

1) Sensor diaphragms

2) Seals

3) Welds

4) Fittings.

Mode of Failure:

1) Fatigue and cracking of capillary tube

2) Leakage of feedwater through sensing line fittings

3) Leakage of feedwater through union gasket

4) Leakage of liquid sodium through ruptured transmitter diaphragm

5) Leakage of liquid sodium through faulty weld on sodium level detector

6) Plugging of sodium flow by solid sodium on level controller.

Failure Description:

1) Capillary tube on high-temperature discharge safety switch cracked, allowing part of sensing bulb fluid to escape and causing compressor shutdown.

2) Sensing line tubing of flowmeter leaked at mechanical fitting.

3) Union gasket on flow sensor for low pressure feedwater leaked.

4) Feedwater leaked through unions and O-rings on both legs of flow transmitter.

5) Transmitter diaphragm in sodium purification system ruptured.

6) Sodium backed up into faulty weld of sodium level indicator, leaked out, and caused fire.

7) Sensing line for sodium level controllers blocked by solidified sodium.

8) Low sodium flow through gas heater resulted from pump bubbler tube being plugged with solid sodium, causing gas bubble in primary sodium system.

Control Methods

1) Provide flexible installation for capillary tube.

2) Relocate high-temperature discharge safety switch.

3) Upgrade fabrication and installation procedures for tubing and fittings.

4) Implement preventive maintenance program to include inspections of regions susceptible to vibration damage, so that deterioration may be identified and corrected prior to the occurrence of failures.

5) Include the study of tubing fabrication and installation techniques in personnel training.

6) Implement more stringent quality control procedures for welds, such as RDT standard RDT-F6-1.

7) Include the consideration of flexible sensing lines in trade-off studies and design reviews.

(2) Discussion and Recommendations

Refer to Paragraph 9.a.(2).

c. Sodium Leak Detectors

(1) Reliability Information

Design Features:

Electrodes are placed in the expected path of leaking sodium such that, when a sufficient quantity accumulates to contact both electrodes, an electric current flows to an indicator.

Critical Characteristics:

1) Tip corrosion

2) Probe location.

Mode of Failure:

Open circuit.

Failure Description:

1) Corrosion of tip causes electrical discontinuity.

2) Accidental mechanical damage breaks electrical contact.

Control Methods:

1) Use corrosion-resistant material for probe tips.

2) Provide protective enclosure for probes, to minimize the probability of inadvertant mechanical damage.

3) Implement preventive maintenance and/or inspection procedures for early detection of failures.

(2) Discussion and Recommendations

Refer to Paragraph 9.a.(2).

TABLE 1-157

FAILURE DATA FOR SENSORS (OTHER THAN RADIATION)
(Sheet 1 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Sensor/Thermocouple 2. Instrumentation and Control/Intermediate Heat Exchanger 3. 66 262220	1. HNPF 2. IHX-3 - Freeze No. 13 3. 3-10 psi helium when draining sodium, 200 to 350°F, 3 in. 4. Work request No. 2621	MI 148	MI 43	MI 530	3250	Operational monitors	1. Thermocouple worked loose. 2. Local repair, reconnected thermocouple. 3. Upgrade Quality Assurance inspections during system construction.
2	1. Sensor/Resistance Thermometer 2. Instrumentation and Control/Reactor Coolant 3. 66 262110	1. EBR-II 2. Primary/pump M-1 3. 208-700°F 4. ANL report No. 2115	MI 154	MI 15	MI 510	3410	Operational monitors	1. Circuit shorted to other circuit. 2. None. 3. None.
3	1. Sensors/Thermocouple 2. Instrumentation and Control/Shield Temperature Monitoring 3. 66 261210	1. EBR-II 2. Reactor vessel cover 3. - 4. ANL report No. 7017	MI 125	MI 52	MI 530	13,400	Preventive maintenance	1. Clutch inoperative. 2. Part replaced. 3. None.
4	1. Sensor/Pressure Switch 2. Instrumentation and Control/Fire Control 3. 66 267100	1. SCTI 2. Air preheat 3. - 4. Incident report No. 5	MI 333	MI 24	MI 112	940	Operational monitors	1. PS-703 correctly sensed forced draft fan failure due to inappropriate adjustment. 2. Local repair pilots relighted. 3. Review heater temperature increase procedure.
5	1. Sensor/Pressure Switch 2. Instrumentation and Control/Fire Control 3. 66 267100	1. SCTI 2. Air preheat 3. - 4. Incident report No. 6	MI 333	MI 24	MI 112	960	Operational monitors	1. PS-703 correctly sensed forced draft fan failure due to inappropriate adjustment. 2. Local repair, pilots relighted. 3. Review heater temperature increase procedure.
6	1. Sensor/Sensing Element 2. Instrumentation and Control/Preheating 3. 66 261360	1. SCTI 2. Preheat air system switch TS-2 to compressor 3. 400-550°F, set at 460°F 4. Incident report No. 339	MI 127	MI 61	MI 530	11,000	Operational monitors	1. Capillary tube on high temperature discharge safety switch cracked, allowing part of sensing bulb fluid to escape, causing compressor shutdown. 2. Temporary repair. 3. Vibration should be considered when any controlling device is installed.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-157

FAILURE DATA FOR SENSORS (OTHER THAN RADIATION)
(Sheet 2 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Sensor/Sensing Element 2. Instrumentation and Control/Preheating 3. 66 261360	1. SCTI 2. Preheat air compressor A-5A 3. 400 to 550°F 4. Incident report No. 8	MI 57	MI 41	MI 112	2030	Operational monitors	1. Sensing element of Mercoid switch failed, possibly due to excess vibration. 2. Local repair. 3. Do not install control instruments where exposed to vibration. Check new equipment for this feature (LMEC executed).
8	1. Sensor, Flowmeter/Sensing Linetube 2. Instrumentation and Control/Feedwater 3. 66 268400	1. EBR-II 2. Feedwater heater No. 4 3. Shellside = 480°F - 1250 psig Tubeside = 565°F - 1500 psig 4. Maintenance report, 4/18/68	MI 326	MI 52	MI 530	14,150	Direct observation	1. Tubing leaked at a mechanical fitting. 2. Part replaced. 3. None.
9	1. Flow Sensor/Pipe Union 2. Instrumentation and Control/Feedwater 3. 66 268400	1. SCTI 2. Steam and feedwater system 3. - 4. Incident report No. 301	MI 136	MI 53	MI 570	6025	Direct observation	1. Union gasket on low pressure side leaked. 2. Isolated flow transmitter to stop leak. New pressure gasket and union installed. 3. None.
10	1. Sensor (Flow)/Flange 2. Instrumentation and Control/Feedwater 3. 66 268400	1. SCTI 2. Feedwater system 3. - 4. Incident report No. 115	MI 326	MI 53	MI 530	5630	Direct observation	1. Unions and flange bolts improperly torqued; feedwater leak at both legs of flow transmitter. 2. Local repair, unions replaced and new O-rings installed. 3. Design and field inspection for gasket material and torque flange connections should be specified.
11	1. Sensor/Transmitter Diaphragm 2. Instrumentaion and Control/Purification 3. 66 262420	1. EBR-II 2. Sodium purification system 3. 300 to 500°F 4. Maintenance report, 4/18/68	MI 500	MI BZ	MI 530	14,150	Operational monitors	1. Diaphragm ruptured. 2. Local repair. 3. None.
12	1. Sensor/Sensing Line 2. Heat Transfer/Main Coolant Loop 3. 66 262110	1. SCTI 2. Primary sodium pump (P-5)/sodium level indicator controller LIC-100 3. 300°F 4. Incident report No. 87	I 348	I 61	I 45	827	Direct observation	1. Sodium backed up into unsuspected faulty weld and leaked out, causing fire. 2. Weld joint repaired. 3. Improve Quality Assurance procedures on welding tubing.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-157

FAILURE DATA FOR SENSORS (OTHER THAN RADIATION)

(Sheet 3 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
13	1. Sensor/Sensing Line 2. Heat Transfer System/ Main Coolant Loop 3. 66 262110	1. SCTI 2. Primary sodium pump (P-5)/ sodium level indicator controller LIC-100 3. - 4. Incident report No. 81	MI 174	MI 51	MI 550	613	Operational monitors	1. Sensing line for level controllers blocked by solidified sodium. 2. Pump casing disassembled and line removed and cleaned. 3. Install heaters on line.
14	1. Sensor/Level Control Tube 2. Instrumentation and Control/Reactor Coolant 3. 66 262110	1. SCTI 2. Primary sodium pump (P-5) 3. - 4. Incident report No. 135	I 500	I 51	I 520	4722	Operational monitors	1. Low sodium flow through gas heater caused by pump bubbler tube being plugged with solid sodium causing gas bubble in primary sodium system. 2. Modified level controller (pump bubbler tube). 3. None.
15	1. Sensor/Level Probe 2. Instrumentation and Control/Intermediate Coolant Vessel 3. 66 262210	1. HNPF 2. Secondary/No. 2 expansion tank level alarm 3. - 4. Monthly operating report No. 13	MI 127	MI 86	MI 530	4450	Direct observation	1. Probe oxidized, faulty. 2. Component corrective modification. 3. Determine cause of oxidiation and determine if replacing part with like part is sufficient.
16	1. Sensor/Leak Detector Probe Tip 2. Instrumentation and Control/Reactor Coolant 3. 66 262110	1. Fermi 2. Containment building LE-250-5 6 in. throttle valve No. 3 loop 3. - 4. EF report No. 33	MI 130	MI 94	MI 530	14,708	Direct observation	1. Probe tip corrosion damage. 2. Design change. 3. Use corrosion resistant material for probe.
17	1. Sensor/Sodium Leak Detector 2. Instrumentation and Control/Purification 3. 66 262420	1. Fermi 2. FARB/cold trap system FSV-101 3. - 4. PRDC-EF report No. 54	MI 161	MI 12	MI 530	14,941	Operational monitors	1. Detector burned out. 2. Local repair. 3. None.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-158

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SENSORS (OTHER THAN RADIATION)

COMPONENT SUBTYPE PRESSURE SENSORS

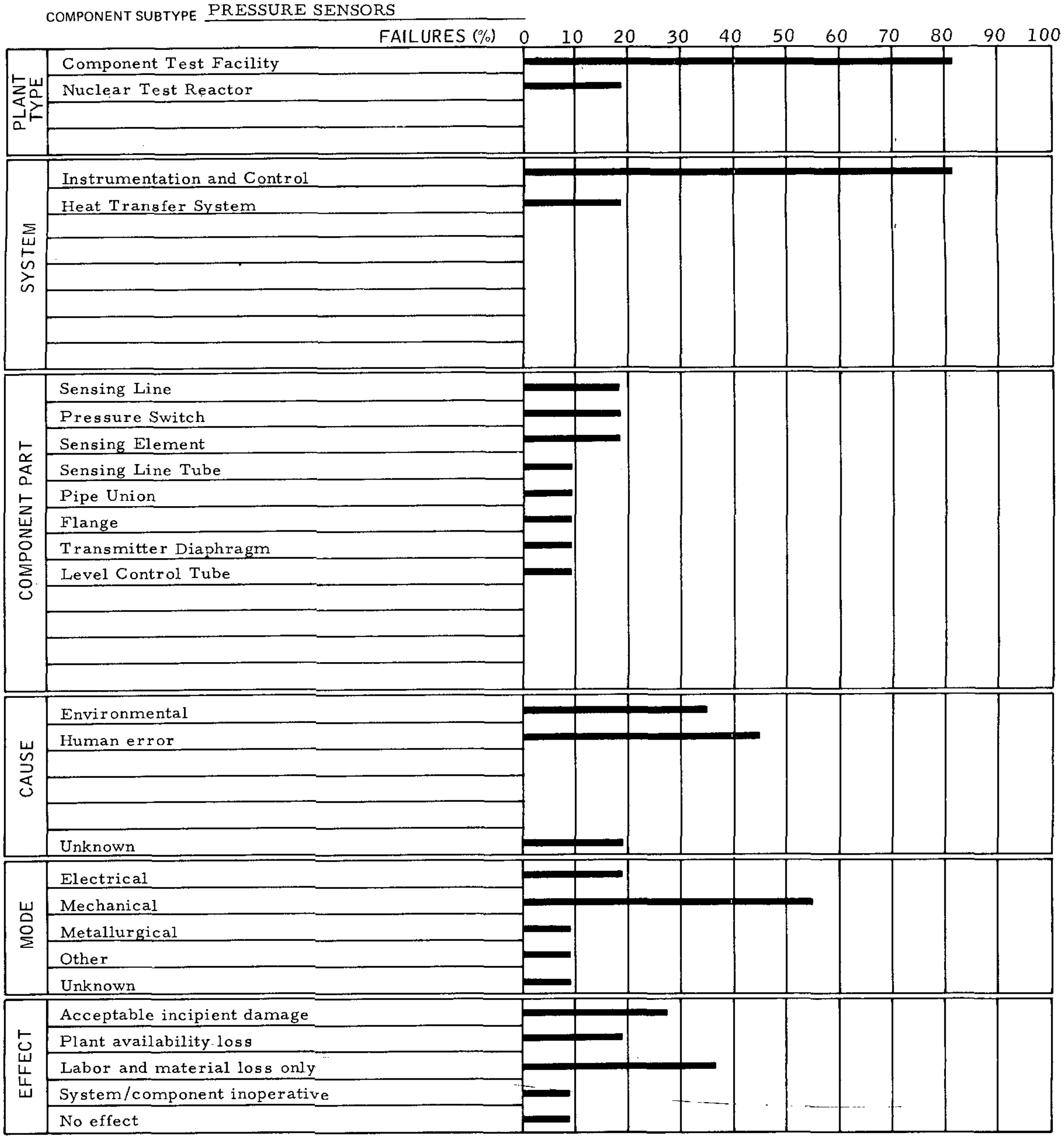


TABLE 1-159

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SENSORS (OTHER THAN RADIATION)

COMPONENT SUBTYPE RELUCTANCE AND CONDUCTIVITY SENSORS

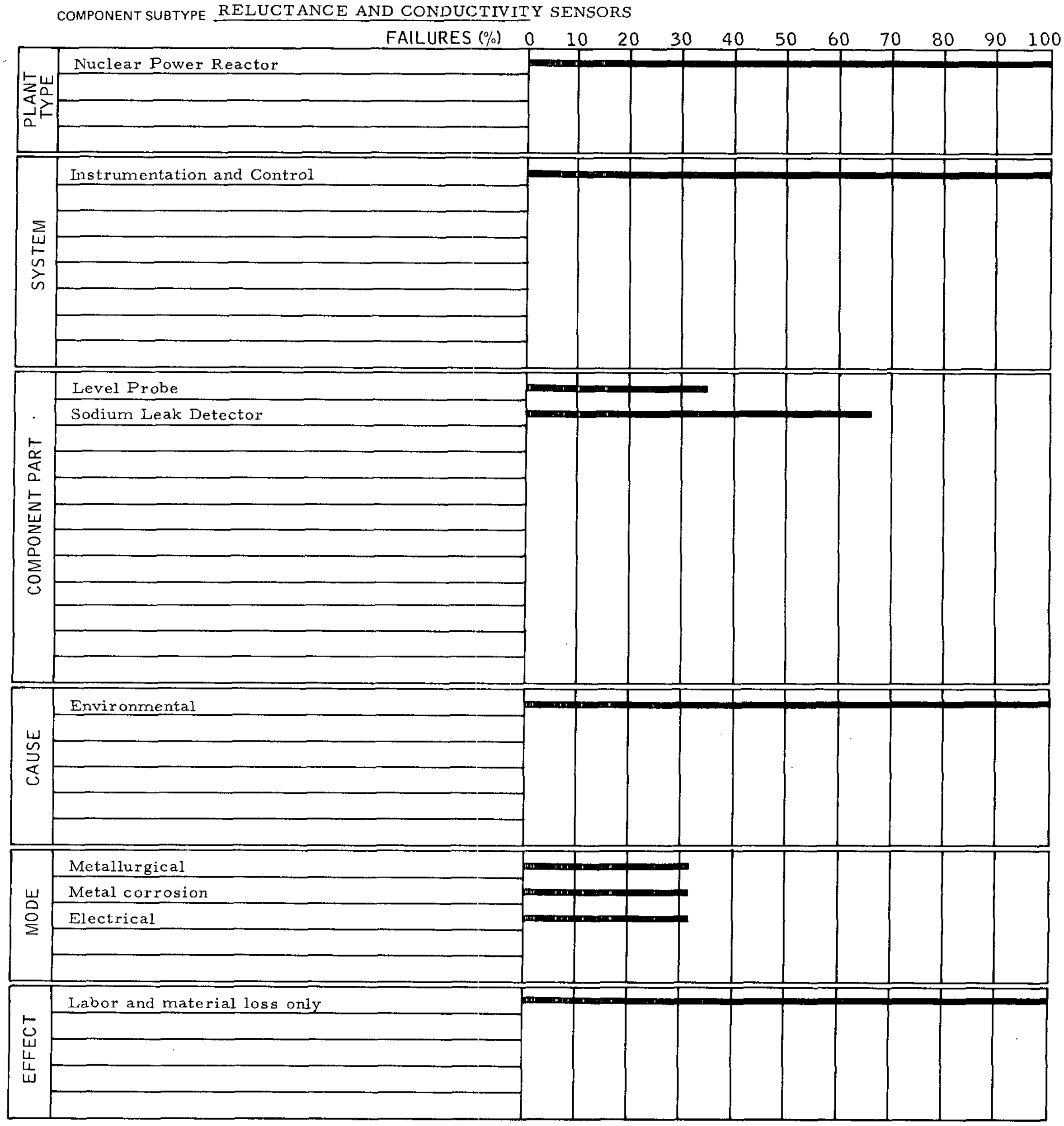


TABLE 1-160

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SENSORS (OTHER THAN RADIATION)

COMPONENT SUBTYPE TEMPERATURE SENSORS

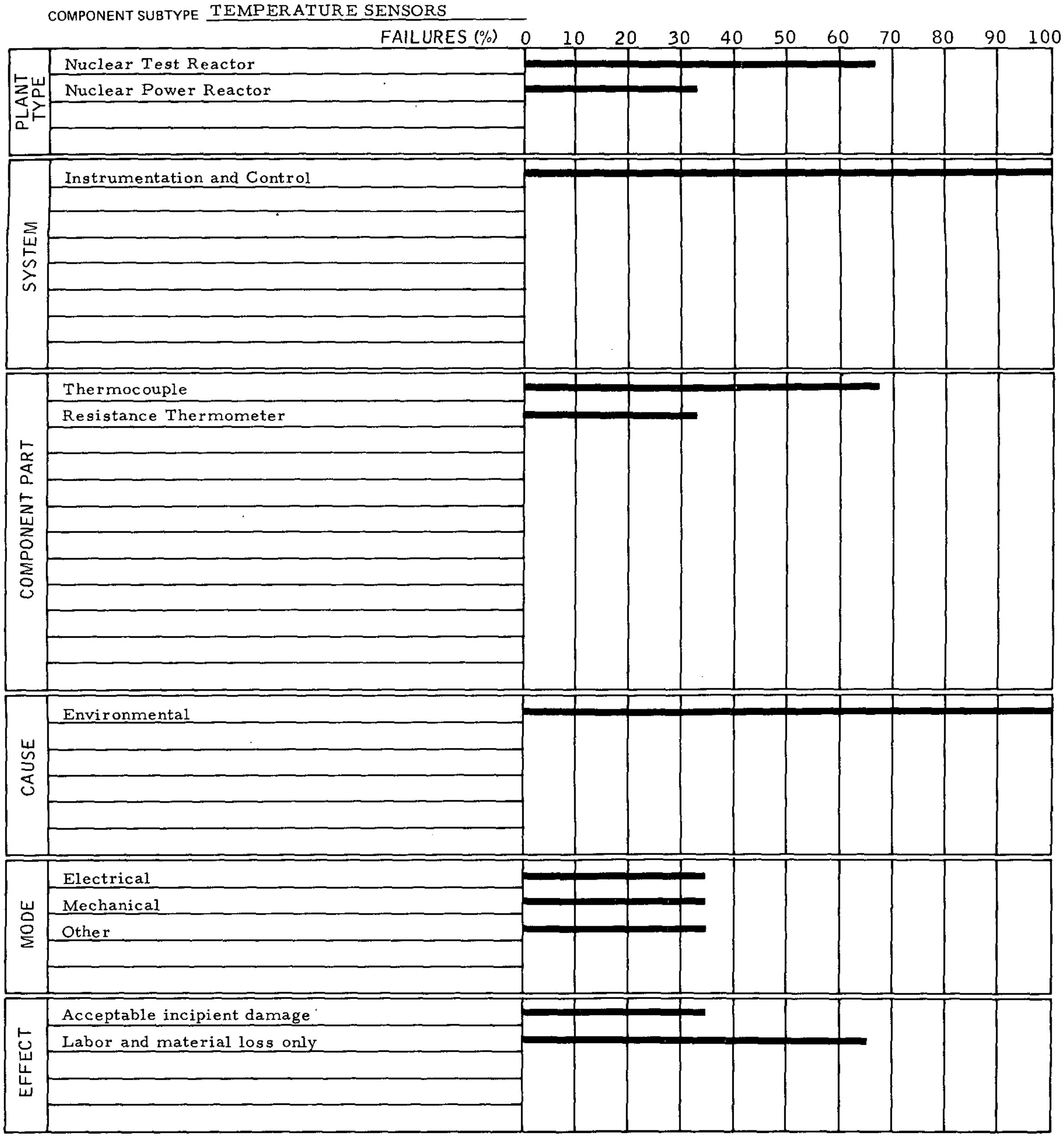
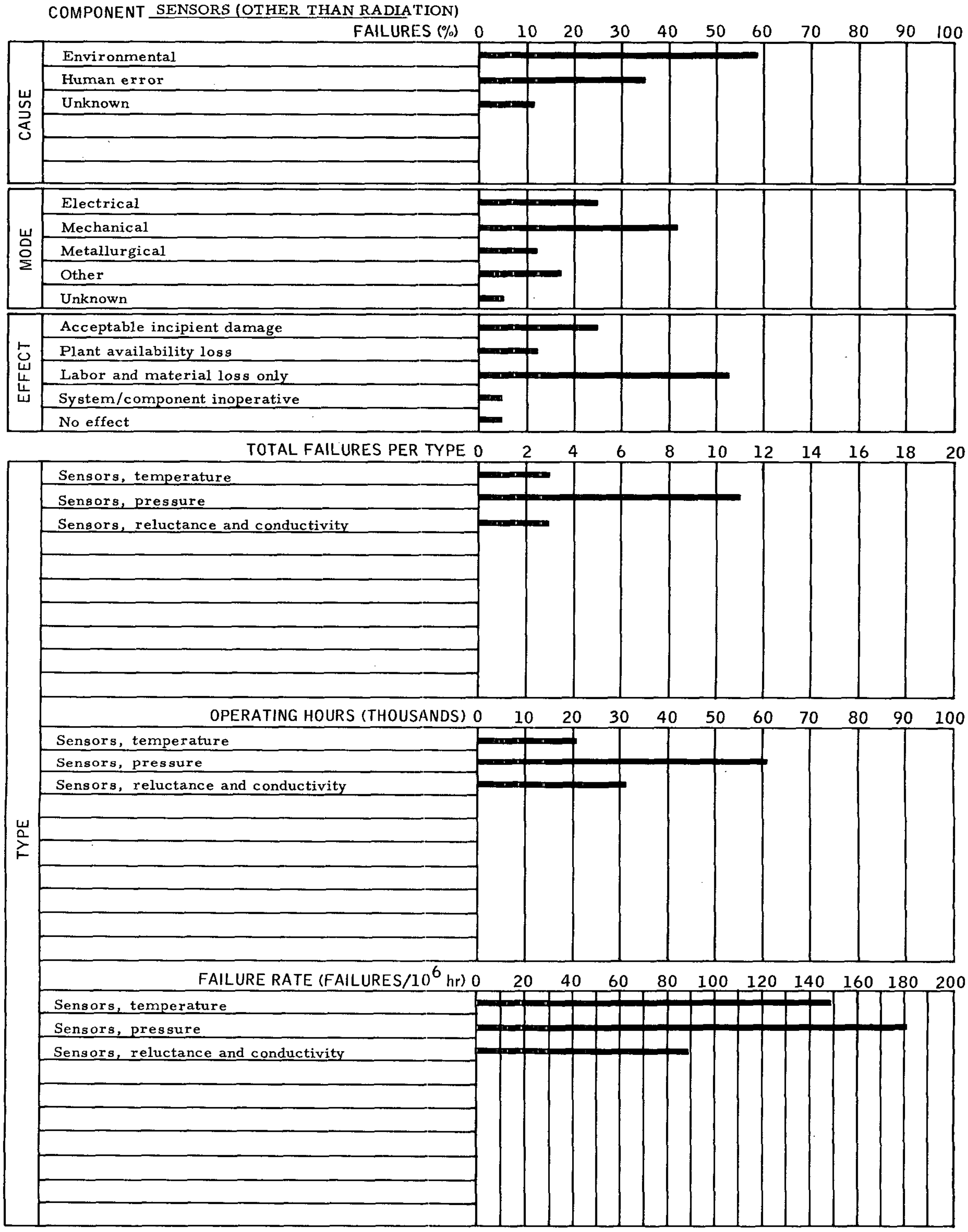


TABLE 1-161

GENERAL SUMMARY

COMPONENT SENSORS (OTHER THAN RADIATION)



10. Sensors (Radiation)

Failure data for sensors (radiation) are presented in Tables 1-162 through 1-165.

a. Neutron Monitor

(1) Reliability Information

Design Features:

Designed to provide a direct current proportional to neutron flux level and independent of gamma flux level.

Mode of Failure:

1) Excessive leakage current due to deterioration of insulation.

2) Loss of sensitivity due to burn-up of neutron sensitive material.

3) Loss of hermetic seal.

Failure Description:

Radiation to electrical insulator.

Control Methods:

1) Conduct development program to identify improved materials and fabrication processes.

2) Prepare specifications to require improved materials, processes, quality control, and testing procedures.

3) Until results of the development program are available, all insulators should be of inorganic type.

4) Use only alumina, beryllia, magnesia, or mica insulators until the results of a development program are known.

(2) Discussion and Recommendations

None.

b. Fission Gas Monitor

(1) Reliability Information

Design Features:

Designed to collect fission fragments found in the cover gas. The radioactivity thus concentrated is monitored to detect the release of fission fragments into the cover gas.

Mode of Failure:

1) Failure of the high-voltage power supply

2) Failure of the particle counter

3) Failure of the mechanical drive mechanism gears

4) Failure of the wire by tangling in take-up assembly.

Failure Description:

1) Wire knotting problem

2) Gears jammed on take-up reel.

Control Methods:

Implement procedure for scheduled inspection and preventive maintenance.

(2) Discussion and Recommendations

None.

TABLE 1-162

FAILURE DATA FOR SENSORS (RADIATION)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Sensor/Compensated Ion Chamber 2. Instrumentation and Control/Neutron Monitor System 3. 67 261110	1. EBR-II 2. Channel No. 4 3. - 4. ANL-7193	MI 500	MI BZ	MI 530	4955	Preventive maintenance	1. Radiation damage to the electrical insulators. 2. Part replaced, with others having mica-alumina insulators which offer protection against radiation damage. 3. Development program should be initiated to obtain a suitable insulator.
2	1. Sensor/Compensated Ion Chamber 2. Instrumentation and Control/Neutron Monitor System 3. 67 261110	1. EBR-II 2. Channel No. 5 3. - 4. ANL-7193	MI 500	MI BZ	MI 530	4955	Preventive maintenance	1. Radiation damage to the electrical insulators. 2. Part replaced, with others having mica-alumina insulators which offer protection against radiation damage. 3. Development program should be initiated to obtain a suitable insulator.
3	1. Sensor/Compensated Ion Chamber 2. Instrumentation and Control/Neutron Monitor System 3. 67 261110	1. EBR-II 2. Channel No. 6 3. - 4. ANL-7193	MI 500	MI BZ	MI 530	4955	Preventive maintenance	1. Radiation damage to the electrical insulators. 2. Part replaced, with others having mica-alumina insulators which offer protection against radiation damage. 3. Development program should be initiated to obtain a suitable insulator.
4	1. Sensor/Compensated Ion Chamber 2. Instrumentation and Control/Neutron Monitor System 3. 67 261110	1. EBR-II 2. Channel No. 7 3. 4. ANL-7193	MI 500	MI BZ	MI 530	4955	Preventive maintenance	1. Radiation damage to the electrical insulators. 2. Part replaced, with others having mica-alumina insulators which offer protection against radiation damage. 3. Development program should be initiated to obtain a suitable insulator.
5	1. Sensor/Takeup Gears 2. Instrumentation and Control/Fuel Element Failure Detection 3. 67 261140	1. EBR-II 2. Primary system/fission gas monitor 3. 4. Weekly report, 5-21-68	MI 500	MI 59	MI 530	14,650	Direct observation	1. Gears jammed on takeup reel. 2. Part replaced. 3. Upgrade preventive maintenance effort.
6	1. Sensor Ext./Wire Reel 2. Instrumentation and Control/Fuel Element Failure Detection 3. 67 261140	1. EBR-II 2. Primary system/fission gas monitor 3. 4. Weekly report, 5-22-68	MI 500	MI 56	MI 550	14,674	Protective system	1. Wire knotting problem. 2. Corrective modification, adjusted travel switches. 3. Upgrade preventive maintenance effort.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-163

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SENSORS (RADIATION)

COMPONENT SUBTYPE FISSION GAS MONITOR

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Nuclear Test Reactor
SYSTEM	Instrumentation and Control
COMPONENT PART	Take Up Gear
	Wire Reel
CAUSE	Unknown
MODE	Mechanical
EFFECT	Labor and material loss only
	System/component inoperative

TABLE 1-164

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT SENSORS (RADIATION)

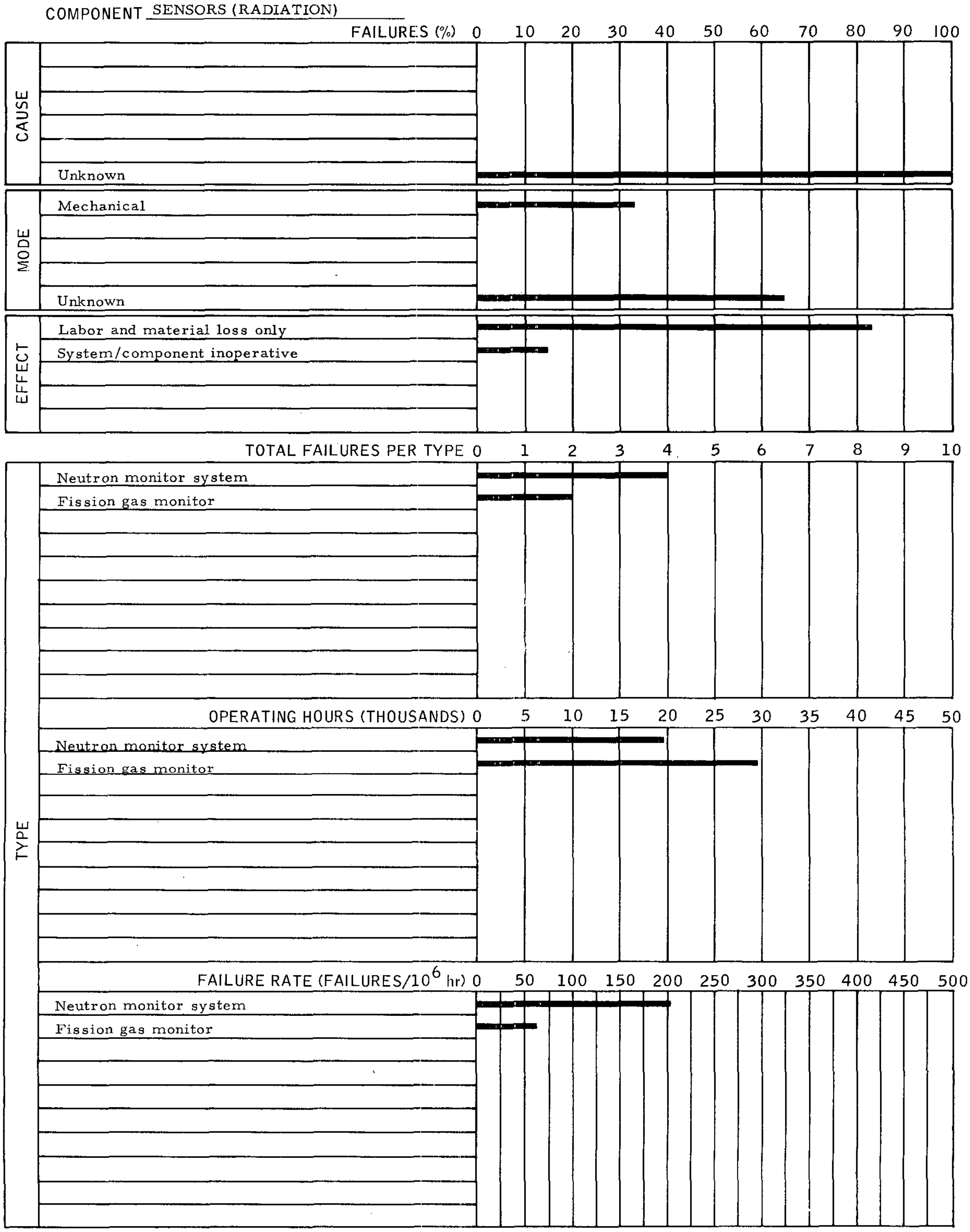
COMPONENT SUBTYPE NEUTRON MONITOR SYSTEM

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Test Reactor	
SYSTEM	Instrumentation and Control	
COMPONENT PART	Compensated Ion Chamber	
CAUSE	Unknown	
MODE	Unknown	
EFFECT	Labor and material loss only	

TABLE 1-165

GENERAL SUMMARY

COMPONENT SENSORS (RADIATION)



11. Wiring and Connectors

Failure data for wiring and connectors are presented in Tables 1-166 through 1-170.

a. Reliability Information

Design Features:

All electrical wiring, both power and control, is dependent on proper installation, adequate current-carrying capacity, mechanical protection, proper insulation, and proper termination. Most of these requirements are met by compliance with the appropriate electrical code.

Mode of Failure:

1) Short between conductors or to ground
2) Insulation failure
3) Improper installation
4) Inadequate wire size.

Failure Experience

1) Six malfunctions due to short circuits
2) Two cases of insulation failure
3) Three malfunctions due to poor workmanship
4) One failure due to inadequate wire size.

Control Methods:

1) All electrical work should be performed by qualified electricians. It should be carefully inspected to assure compliance with code. Many, if not most, electrical wiring malfunctions are due to improper or careless installation.
2) Care should be taken to use the proper type of insulation if environmental conditions are extreme, such as high temperature or high radiation.
3) Wiring changes should be made only with the concurrence of qualified engineering personnel.

b. Discussion and Recommendations

Most of the reported wiring malfunctions cannot be properly evaluated due to lack of detailed information. The nature of most of the malfunctions tends to place them in certain well known failure categories, which emphasizes the need for taking equally well known precautions.

The best way to avoid the bulk of wiring failures is to install all electrical work in accordance with the applicable electrical code. The National Electrical Code should be used in any area which does not have a state or local code which replaces the NEC.

In locations which expose wiring to high temperatures, care must be taken to use the proper insulation. Few insulating materials are approved for more than 200°C. When temperatures greater than this are encountered, MI cable or special cooling must be provided.

Splices and terminations must be properly insulated and protected. Approved connectors and terminals must be used to ensure good, low-resistance contact. Shielded conductors must be used when appropriate in both signal circuits and high-voltage power circuits. The failure to properly terminate a shielded power cable in a pothead or with a stress cone can result in a dangerous flash-over.

Loose wiring connections can cause many malfunctions. In power circuits, loose wiring may be a source of heat which can damage insulation or cause flase tripping. In signal circuits a loose connection can cause a system malfunction. For these reasons, good workmanship and inspection are necessary.

TABLE 1-166

FAILURE DATA FOR WIRING AND CONNECTORS

(Sheet 1 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	FAILURE INDEX CODE* MODE	FAILURE INDEX CODE* EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1	1. Wiring and Connectors/ Control Wire 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. EBR-II 2. Primary/pump No. 2 3. 4. Operations monthly report 4/6/68	MA 500	MA 15	MA 520	14,024	Protective system	1. Wire shorted. 2. Local repair. 3. None.
2	1. Wiring and Connectors/ Rectifier Lead 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. EBR-II 2. Primary pump/control 3. 4. Maintenance report 4/18/68	MI 500	MI 15	MI 520	14,150	Protective system	1. Shorted load. 2. Local repair. 3. None.
3	1. Wiring/Power Cord 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. EBR-II 2. Reactor/subassembly hold-down 3. 4. Operations maintenance report, 9/18/68	MI 500	MI 59	MI 530	15,240	Direct observation	1. The power feed cord was found damaged. 2. Part replaced. 3. None.
4	1. Wiring/Cables 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. Fermi 2. Cask car 3. Ambient to 350°F argon atmosphere 4. EF-29	MI 15Z	MI 13	MI 530	13,368	During actuation	1. Cables shorted. 2. Parts replaced. 3. None.
5	1. Wiring and Connectors/ Leads 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. HNPF 2. Reactor atmosphere monitor pump/ motor 3. 4. Monthly operating report No. 33	MI 324	MI 12	MI 530	10,130	Direct observation	1. Motor leads burned out. 2. Local repair. 3. None.
6	1. Wiring/Insulation 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. SCTI 2. Drain line 607 3. 4. Incident report No. 70	MI 156	MI 13	MI 530	4,100	Loss of drain flow	1. Electrical insulation (plastic) melted because of wire location. 2. Replaced and relocated wires. 3. High-temperature insulation should be installed.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-166

FAILURE DATA FOR WIRING AND CONNECTORS

(Sheet 2 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE* CAUSE	MODE	EFFECT	OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
7	1. Wiring/Connections 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. SCTI 2. Primary sodium system, sodium pump P-5 3. 480 volts 4. Incident report No. 307	MI 148	MI 14	MI 530	Unknown	Protective system	1. Line connections to circuit breaker loose. 2. Connections tightened. 3. Improve training for electrical maintenance personnel.
8	1. Wiring/Conductor and Disconnects 2. Miscellaneous Equipment/Other Power Plant Equipment 3. 68 530000	1. SCTI 2. Substation No. 756 power 3. 4. Incident report No. 310	I 161	I 17	I 520	4,518	Direct observation	1. Starting current caused cable to overheat when boiler feed pump was turned on. Amps required beyond cable capacity. 2. 4160-volt cables to manual disconnect replaced. Larger cables installed. 3. None.
9	1. Wiring/Connector 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	1. SCTI 2. Primary sodium system/heater (H-1) fan motor 3. 4. Incident report No. 319	MI 324	MI 25	MI 550	13,415	During activation	1. Fan motor would not start. Circuit found connected improperly. 2. Circuit wiring corrected. 3. Improved maintenance procedures.
10	1. Wiring and Connectors/ Ion Chamber Signal Cable 2. Instrumentation and Control/Neutron Monitoring 3. 68 261110	1. EBR-II 2. Nuclear channel No. 9 3. 4. Weekly maintenance report 5/21/68	MI 600	MI 13	MI 520	14,650	Protective systems	1. Channel grounded. 2. System design change, RG/149U cable was replaced with an amphenol No. 421-010. 3. None
11	1. Wiring and Connectors/ Ion Chamber Signal Cable 2. Instrumentation and Control/Neutron Monitoring 3. 68 261110	1. EBR-II 2. Thimble No. J2 3. 4. Weekly maintenance report 5/21/68	MA 600	MA 13	MA 520	14,650	Protective systems	1. Channel grounded. 2. System design change, RG/149U cable was replaced with an amphenol No. 421-010. 3. None

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-166

FAILURE DATA FOR WIRING AND CONNECTORS

(Sheet 3 of 3)

ITEM	1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	1. FACILITY 2. COMPONENT LOCATION 3. OPERATING CONDITIONS 4. SOURCE DOCUMENT	FAILURE INDEX CODE*			OPERATING HOURS	METHOD OF FAILURE DETECTION	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
			CAUSE	MODE	EFFECT			
12	1. Wiring/Flowmeter Leads 2. Instrumentation and Control/Intermediate Coolant Loop 3. 68 262210	1. SRE 2. Main secondary sodium system 3. 4. Incident report 9/10/58	MI 128	MI 44	MI 520	Unknown	Operational monitors	1. Flowmeter signal erratic due to intermittent ground of leads. 2. Local repair of flowmeter lead insulation. 3. None.
13	1. Wiring/Junction Box 2. Instrumentation and Control/Heat Transfer 3. 68 262110	1. SCTI 2. Primary sodium system, pump electrical circuitry 3. 4. Incident report No. 64	MI 344	MI 13	MI 157	Unknown	Operational monitors	1. One electrical lead to the primary sodium pump shorted to ground in the motor junction box when start-up of pump was attempted. 2. Local repair, cable isolated from ground. 3. Improve electrical maintenance procedure.
14	1. Wiring and Connectors/ Insulation 2. Accessory Electrical Equipment/Power Wiring and Conduit 3. 68 450000	1. SCTI 2. Air preheat/junction box to compressor A-5A 3. 4. Incident report No. 327	MI 247	MI 18	MI 530	9,925	Periodic circuit check	1. Conduit junction box seal deteriorated permitting moisture to enter box causing insulation to get wet. 2. Local repair. 3. Check weather tight fittings periodically.

* I = INCIDENT MI = MINOR MALFUNCTION
MA = MAJOR MALFUNCTION P = PROBLEM

TABLE 1-167

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT WIRING AND CONNECTORS

COMPONENT SUBTYPE CONNECTORS

FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100

PLANT TYPE	Component Test Facility
SYSTEM	Instrumentation and Control
	Accessory Electrical Equipment
COMPONENT PART	Junction Box
	Insulation
CAUSE	Environmental
	Human error
MODE	Electrical
EFFECT	Labor and material loss only

TABLE 1-168

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT WIRING AND CONNECTORS

COMPONENT SUBTYPE POWER WIRING

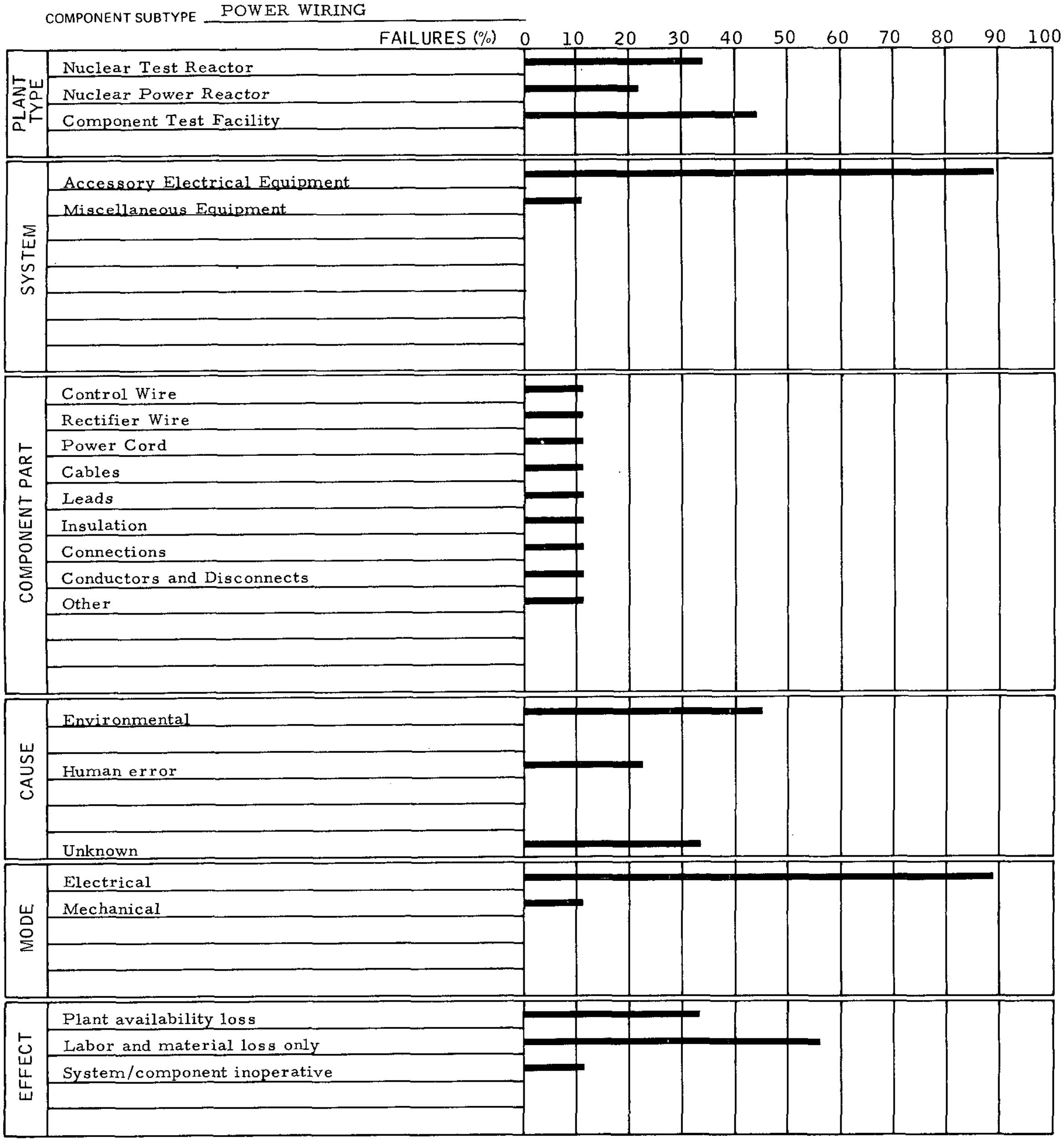


TABLE 1-169

FAILURE DISTRIBUTION FUNCTIONS

COMPONENT WIRING AND CONNECTORS

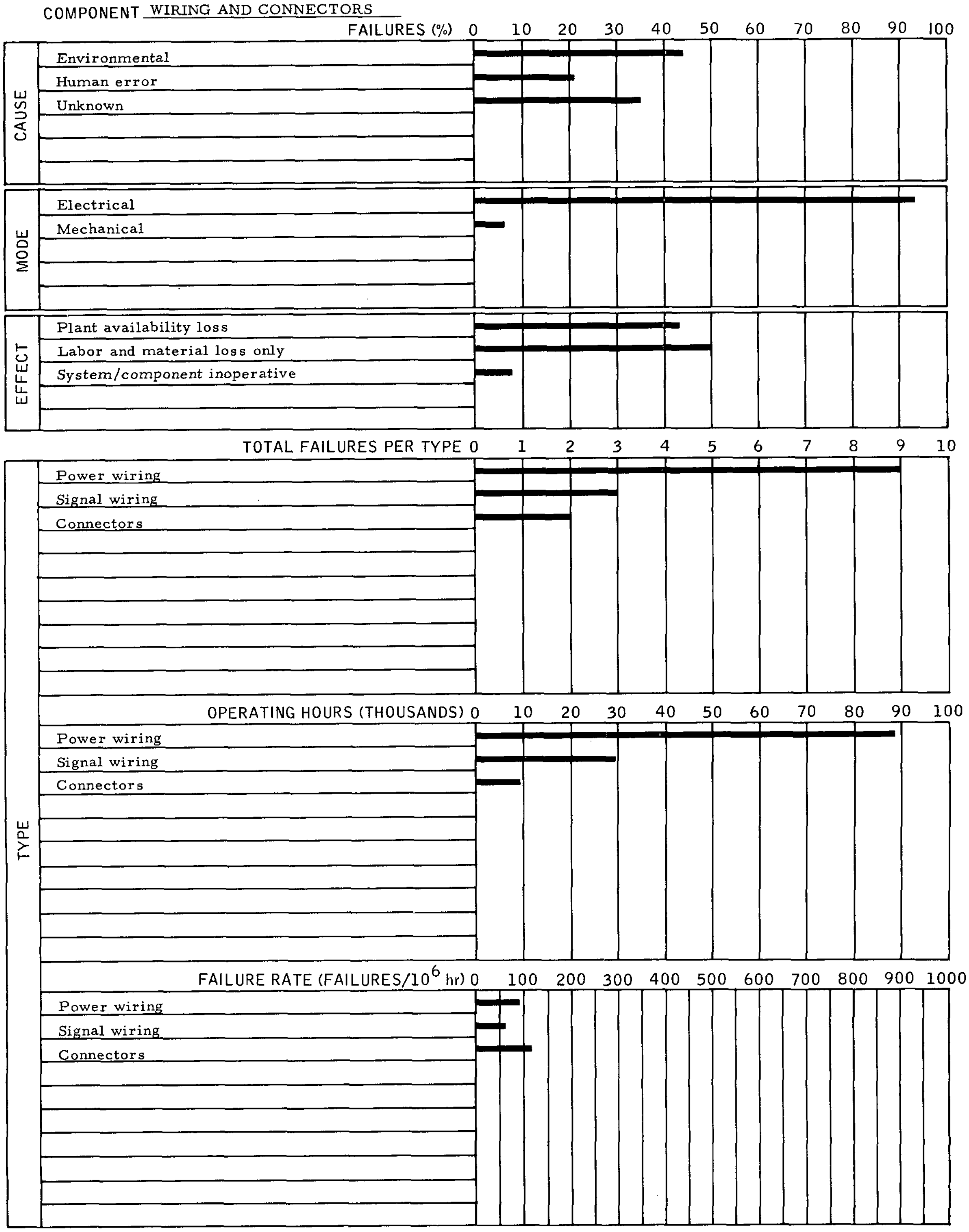
COMPONENT SUBTYPE SIGNAL WIRING

		FAILURES (%) 0 10 20 30 40 50 60 70 80 90 100
PLANT TYPE	Nuclear Test Reactor	
SYSTEM	Instrumentation and Control	
COMPONENT PART	Ion Chamber Signal Cable	
	Flow Meter Leads	
CAUSE	Environmental	
	Unknown	
MODE	Electrical	
EFFECT	Plant availability loss	

TABLE 1-170

GENERAL SUMMARY

COMPONENT WIRING AND CONNECTORS



II. SYSTEM-ORIENTED COMPONENT FAILURES

A. GENERAL

The data presented in this section are also included in Section I. These events have been selected for special attention since the cause of failure is more properly described as a source external to the component. Without this external problem source, no corrective action would be required for the component. The type of corrective action taken singles out this class of failure. These corrective actions are, in general: design modifications to other components or to the system to eliminate the problem source, protective system addition to affected component, monitoring device addition (i. e., vibration detector), and operational procedures modification to avoid the potential of human error.

All existing system-caused failures listed in Section I have been retabulated in this section with respect to the system or subsystem classified in Volume II to which the cause of failure can be traced. All other externally-caused failures attributable to system inadequacy or non-existing protective systems are separately tabulated. The system/subsystem was selected as the primary reference since nearly all of this class of failures can be traced to system design problems. However, equipment failure is sometimes only remotely related to system design and performance, and is attributable to human error. It is assumed that the depth of information in this category is very limited but should improve as an effective event reporting system becomes operative. With respect to system failure rates, few of these early data may be classified as random, and many years of data collection will be required before reliable system failure rate data on liquid metal systems will be available for use with a reasonable level of confidence.

B. FAILURES DUE TO EXISTING SYSTEM ACTION

Typical causes of existing system-oriented failures include human operating errors, incorrect installation of components or failure of other components. The corrective action required for these types of failures would necessitate design changes or modification to systems or components in Tables 1-171 through 1-187.

C. FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

Typical causes of nonexistent system-oriented failures include: (1) improper design of a component that results in the failure of a related component, (2) use of inadequate operating or maintenance procedures, and (3) lack of the necessary protective device or system to assure proper component or system operation. These types of failures are tabulated by components in Tables 1-188 through 1-202.

TABLE 1-171

COMPONENT AIR DRYERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-127	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Air Dryer/Gasket 2. Instrument Air Supply/ Air Dryer 3. 26 540000	1, 2	9758	2		1. Bottom gaskets on the "Poro-Stone" filters in both desiccant dryers were too hard to permit sealing; filter or dryer unit leaked particles of Poro-Stone in air line causing faulty operation of several valve operators. 2. New gaskets installed, instrument air headers cleaned, and valve operators removed, cleaned, and replaced. 3. Add regular inspection of air dryers to maintenance schedule.

TABLE 1-172

COMPONENT COMPRESSORS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-133	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Compressor Air/Head Gasket 2. Miscellaneous Equipment/ Instrument Air Supply 3. 25 540000	8, 9, 12, 17	17914	4		1. Insufficient and uneven torque on head bolts caused air leak. 2. Gasket replaced. 3. Upgrade maintenance procedure to specify a bolt torquing sequence and torque requirements.
1. Compressor Air/Valve 2. Miscellaneous Equipment/ Instrument Air Supply 3. 25 540000	10, 11, 15, 16	27130	4		1. Dirt and/or moisture caused valve to stick. 2. Valves removed, cleaned, replaced. 3. Revise preventive maintenance procedure by adding a requirement to clean intake air filter in order to prevent recurrence.

TABLE 1-173

COMPONENT CONTROLLERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-139	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Controller/Switch 2. Instrumentation and Control/Heat Transfer 3. 65 262210	11	115	1		1. Operator accidentally grounded electrical wiring on valve actuator switch during the inspection. 2. No repair; restarting of burners and primary pump. 3. Improve training of operator personnel.
1. Controller/pH 2. Instrumentation and Control/Cooling Water 3. 65 269630	21	6729	1		1. Operator left acid feed pump switch in manual position instead of auto, causing low pH readings on pHr-300 meter. 2. Proper amount of NaOH flakes added to cooling tower basin water. 3. Closer operator vigilance and adequate training required.

TABLE 1-174

COMPONENT DEMINERALIZERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-1	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Demineralizer/Plastic Pipe 2. Feedwater Supply and Treatment/Condensate Demineralizer 3. 53 273200	3	4175	1		1. Piping manifold inadequately supported. 2. Plastic influent header manifold replaced by stainless steel flange and manifold. 3. Improve quality assurance on original installation.
1. Demineralizer/Acid Inlet Header 2. Feedwater Supply and Treatment/Demineralizer 3. 53 272200	5	6300	1		1. Weld holding acid inlet header support bracket to tank broke allowing header to tear loose from tank. 2. Substituted header (stainless steel flanges) and rewelded bracket of improved design. 3. Improve bracket design - replace plastic flange by stainless steel.

TABLE 1-175

COMPONENT ELECTRICAL GENERATORS (EMERGENCY AND AUXILIARY)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-23	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Electrical Generators/ Wiring 2. Accessory Electrical Equipment/Emergency 3. 57 462100	15	58	1		1. Maintenance personnel hit wires while lowering air filter causing short circuit in wiring. 2. Replaced damaged wiring. 3. None.
1. Generator/Emergency Diesel 2. Accessory Electrical Equipment/Emergency Diesel Generators 3. 57 462100	17, 18	1200	1		1. Human error. Diesel started, loaded normally, stopped, and could not be restarted. The diesel control switch had to be switched to the off position, then to standby. This was not known by the operating personnel. 2. Operational procedure change. 3. Upgrade operator training on diesel engine operation.

TABLE 1-176

COMPONENT FILTERS AND STRAINERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-82	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Sodium Filter/Vessel Flange 2. Heat Transfer/ Purification 3. 27 224233	1		1		1. Sodium leak, flange bolts not torqued properly. 2. Retorqued bolts. 3. Specify values for torquing flange bolts.

TABLE 1-177

COMPONENT FUEL AND BREEDER ELEMENTS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-59	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Fuel Element/Cladding 2. Reactor Equipment/Core Components and Supports 3. 46 216300	10, 12, 14, 15, 16, 17	63685	6		1. Fission gas release was from newly inserted "fresh" fuel assembly. 2. Component replaced. 3. Upgrade Quality Assurance procedure for fuel element inspection.
1. Fuel Elements/Fuel Meat and Cladding 2. Reactor Equipment/Core Components and Supports 3. 46 216300	19	16200	1		1. Fuel channel clogging caused by tetralin decomposition products results in fuel and cladding melting. 2. Sodium pump tetralin freeze seals replaced with NaK freeze seals thereby eliminating the potential source of contaminant. 3. None.
1. Fuel Assembly/Thermocouple 2. Reactor Equipment/Core Components and Supports 3. 46 216300	6	10130	1		1. Thermocouple shorted to ground, causing scram. 2. Corrective modification. 3. None.

TABLE 1-178

COMPONENT INDICATORS AND RECORDERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-144	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Indicator/Shorted Leads 2. Instrumentation and Control/Intermediate Coolant System 3. 64 262200	12	4846	1		1. Operator accidentally grounded level indicator leads actuating pilot gas valve cutout. 2. Ground removed, pilot reignited. 3. Improve training for electrical maintenance personnel on requirements for guards over connections and improve operators training to assure alertness to possible exposed leads.

TABLE 1-179

COMPONENT MOTORS, ENGINES AND TURBINES
(Hydraulic, Pneumatic, Steam)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-47	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Turbine/Turbine Blades 2. Steam, Condensate and Feedwater/Boiler Feed Pump 3. 10 284100	2	Unk	1		1. (a) Overheating and smoking because of too much oil in unit. (b) Failure due to turbine blade damage (minor). 2. Oil drained to proper level and turbine cleaned of metal particles – local repair. 3. Maintain clean steam system – improve maintenance procedures (excess oil human error) – install debris catcher at turbine inlet.
1. Turbine/Turbine Bearing 2. Steam, Condensate and Feedwater/Condensate Pump 3. 10 283100	4	9,345	1		1. Bearing discrepancy – unusual rubbing on top and bottom of bearing. 2. Bearing clearance found too small – bearing rebored and reinstalled with proper clearance. 3. Quality control problem – improve QA procedures.

TABLE 1-180

COMPONENT NEUTRON SOURCE

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-154	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Neutron Source/Threaded Stud 2. Reactor Equipment/ Neutron Source 3. 14 212400	1	7930	1		1. Due to excessive torque while assembling neutron source No. 5, the end studs were damaged. 2. Vendor repair of component. 3. Assembly procedure should specify torque to be applied to studs.

TABLE 1-181

COMPONENT PIPING SUPPORTS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-97	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Piping Support/ Manifold Support 2. Feedwater Supply and Treatment System/ Chemical Treatment Facilities 3. 19 273300	5	19,380			1. Excessive stress on manifold caused support to break. 2. New interface manifold fabricated with the tee socket welded at all three openings. 3. None.

TABLE 1-182

COMPONENT POWER SWITCH GEAR, CIRCUIT BREAKERS, RELAYS, TRANSFORMERS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-35	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Circuit Breaker/Wires 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	22	2205	1		1. Construction men shorted wires while working on control panel (contractor personnel). 2. Vendor repair. 3. None.
1. Breaker/Bus Bars 2. Accessory Electrical Equipment/Circuit Breakers 3. 58 412000	23	0	1		1. Contractor personnel shorted bus bars with electrical fish tape resulting in fire among bus bar cables. 2. Bus bar sections and circuit breaker connections rewired. 3. Improve supervision of construction work.

TABLE 1-183

COMPONENT PUMPS AND SUPPORTS

(Sheet 1 of 2)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-100	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Pump/Bearings 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	22	Unk	1		1. Bearings damaged due to overloading caused by a closed valve. 2. Part replaced. 3. Upgrade operator training on pump.
1. Pump 2. Heat Transfer/Reactor Coolant 3. 17 221110	60	5,000	1		1. Pump case flooded with sodium as a result of tube failure, preventing pump startup. 2. Pump removed and cleaned. 3. None.
1. AC Linear Induction Pump/Cooling Water Jacket 2. Heat Transfer/Intermediate Cooling 3. 17 222110	164	1,200	1		1. Obstruction of coolant passage by impurities in plant cooling water. 2. Coolant passages were backflushed. 3. Protective System: Install filters for sediment collection.

TABLE 1-183

COMPONENT PUMPS AND SUPPORTS
(Sheet 2 of 2)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-100	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Vacuum Pump/Casing 2. Nuclear Fuel Handling and Equipment/Fuel Handling Machine 3. 17 235000	193	Unk	1		1. Pump placed in service without opening discharge valve – pump ruptured. 2. Component replaced. 3. Install rupture disc or relief valve on pump discharge line.

TABLE 1-184

COMPONENT STEAM GENERATOR

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-111	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Steam Generator/Tubes 2. Heat Transfer/Steam Generator 3. 40 223100	2, 6, 8	21,760	3		1. Stress corrosion cracking attributed to residual cleaning solution containing sodium hydroxide resulted in water leakage into sodium or formation of pits due to reaction of foreign material. 2. Pits and flaws ground out and rewelded or units retubed. 3. Adequate procedures should be instituted to insure cleanliness of the components in the system.

TABLE 1-185

COMPONENT VALVES

(Sheet 1 of 3)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-119	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Valve/Float 2. Feedwater Supply and Treatment/Chemical Treatment Facility 3. 20 273300	1, 2	7583	2		1. Circuit breakers to pumps P-7 and P-9 tripped due to overload on pumps, caused by float valve sticking open. Float sticks open when it hits travel limit, open. Cause is excessive flow rate of water from system the float valve operates. 2. Throttle valve to reduce flow and restart pumps. 3. Keep flow demand at system design limits so pump motors are not overloaded, thus not overheated. Thorough operator training on system operation can prevent recurrence.

TABLE 1-185

COMPONENT VALVES

(Sheet 2 of 3)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-119	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Valve/Support Valves 2. Steam, Condensate, and Feedwater Piping and Equipment/Condensate Valves 3. 20 283300	59	6215	1		1. Zero flow on indicators FI-201 and FI-202 indicated valves were clogged or closed. Valves affecting HIC-209 and HIC-210 were found closed. Standard operating procedures were not followed. 2. Opened valves per operating instructions. 3. Standard operating procedures should be followed and a system instituted to provide verification of concurrence.

TABLE 1-185

COMPONENT VALVES

(Sheet 3 of 3)

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-119	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Valve/Valve Seat 2. Compressed Air and Vacuum Cleaning Equipment/Air Control Valve 3. 20 520000	129	Unk	1		1. Valve seat of air control valve leaked causing dump valve for cooling tower to open. 2. Removed air line from valve making it inoperative in the system except manually. 3. Establish maintenance procedure for all critical components. (This was executed.)

TABLE 1-186

COMPONENT VESSEL INTERNALS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-16	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Vessel Internals/Thimble 2. Reactor Equipment/Core Components and Supports 3. 07 216400	7	3710	1		1. Attempt made to place thimble in an occupied maintenance cell engaging the thimble to a plug pickup cup. 2. Operational procedure and/or training change. 3. None.

TABLE 1-187

COMPONENT WIRING AND CONNECTORS

FAILURE DUE TO EXISTING SYSTEM ACTION

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-166	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Wiring/Connector 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	9	13415	1		1. Fan motor would not start. Circuit found connected improperly. 2. Circuit wiring corrected. 3. Improve maintenance and inspection procedures.

TABLE 1-188

COMPONENT COLD TRAPS/HOT TRAPS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-69	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Hot Trap (Carbon)/ Sampler 2. Heat Transfer/ Purification 3. 36 224239	9	2400	1		1. One man sprayed with sodium while removing a sample but was not burned due to protective clothing. 2. Operational procedure change. 3. None.

TABLE 1-189

COMPONENT CONTROLLERS

(Sheet 1 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-139	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Controller/High Level Override Alarm and Relay 2. Instrumentation and Control/Main Coolant Loop 3. 65 262110	16, 17	-	2		1. Sodium level lowered causing gas entrainment and plant trip. 2. Local repair, relay readjusted, and primary sodium flow restored. Final correction by installation of a displacement type instead of bubbler. 3. More stable level controller needed to maintain free-surface sodium level.
1. Controller/Relay 2. Instrumentation and Control/Steam Generators 3. 65 262311	20	4050	1		1. Relay caused steam generator inlet and outlet sodium valves to close. 2. Relay was bypassed during cover gas pressurization test to avoid valve closure. 3. The cover gas pressurization procedure was modified to include bypassing a relay.

TABLE 1-189

COMPONENT CONTROLLERS

(Sheet 2 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-139	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Controller/(Pressure Setting) 2. Instrumentation and Control/Steam, Condensate and Feedwater Piping and Equipment 3. 65 268100	23, 24		2		1. Safety relief valve lifted at pressure well below proper setpoint during a change in plant conditions. 2. Vendor repair of component. 3. Piping loops containing safety or relief valves should be designed for the additional stress and vibration caused by the safety and relief valve actuation.

TABLE 1-190

COMPONENT COOLERS (Other than Liquid-Metal-to-Air)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-173	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Coolers/Turbine Lube Oil Coolers 2. Turbine-Generator Units and Condenser/ Central Lubricating 3. 35 350000	1	7800	1		1. Head of one unit deteriorated badly. Head of other unit slightly deteriorated. 2. Flow baffles built in and flange surfaces remachined. 3. None.

TABLE 1-191

COMPONENT DESUPERHEATERS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-76	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Desuperheater No. 1/ Flanged Joint 2. Steam, Condensate and Feedwater Piping and Equipment/Main Steam 3. 43 281100	2, 3, 4, 5	20475	4		1. Steam leaks developed during an operating period when steam pressure was increased from 1400 to 1850 psig. 2. Component corrective modification. 3. Maintenance manual should include proper flange bolt torquing instructions for each type of flange and gasket. Improved QA procedures at initial contractor level.

TABLE 1-192

COMPONENT FEEDWATER HEATERS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-79	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Feedwater Heater/Flange Gasket 2. Steam, Condensate and Feedwater Piping and Equipment/Feedwater Heater 3. 54 284200	1	14,710	1		1. Flange leaking, bad gasket. 2. Component corrective modification, Flexitallic gasket replaced original asbestos gasket. 3. None.

TABLE 1-193

COMPONENT FILTERS AND STRAINERS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-82	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Strainer/Screen 2. Other Reactor Plant Equipment/Plant Cooling Water 3. 27 290000	5	11320	1		1. Strainer plugging caused low water pressure in the primary pumps eddy current coupling cooling water system which resulted in reactor scrams. 2. New type strainer installed. 3. Audible pressure differential alarm on strainer to serve as warning of insipient clogging.

TABLE 1-194

COMPONENT FUEL AND BREEDER ELEMENTS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-59	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Fuel Element/Orifice Control 2. Reactor Equipment/ Core Components and Supports 3. 46 216300	5, 7, 8, 9	20260	10		1. Seven orifice drive cables stuck. 2. Component corrective modification. 3. None.

TABLE 1-195

COMPONENT INDICATORS AND RECORDERS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-144	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Indicator/Transmitter 2. Instrumentation and Control/Reactor Coolant 3. 64 262100	4	4846	1		1. Transmitter shorted to ground during rain. 2. Local repair, plastic cover installed on transmitter and connector. 3. More careful installation of instruments exposed to weather.
1. Flow Indicator/Glass 2. Instrumentation and Control/Raw Water Supply 3. 64 268400	74	3460	1		1. Abnormal high-pressure surge in raw cooling water supply broke sight glass. 2. Replace. 3. Install pressure regulator.

TABLE 1-196

COMPONENT INTERMEDIATE HEAT EXCHANGER

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-87	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Intermediate Heat Exchanger/Tubesheet 2. Heat Transfer/Intermediate Heat Exchanger 3. 39 222300	1	611	1		1. Original piping did not include a cover gas vent from the top of the IHX shell side. Gas was trapped between the sodium inlet nozzle and the upper tubesheet. 2. A vent line and a manually operated valve were installed from the shell side of the IHX to the primary expansion tank. 3. None.
1. Intermediate Heat Exchanger/Tubes 2. Heat Transfer/Intermediate Heat Exchanger 3. 39 222300	2	5640	1		1. Tubes cracked and leaked as a result of flow induced vibration. 2. Tube vibration suppressors installed. 3. Provide adequate design analysis and acceptance testing.

TABLE 1-197

COMPONENT PUMPS AND SUPPORTS

(Sheet 1 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-100	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Pumps and Supports 2. Steam, Condensate, and Feedwater Piping and Equipment/Main Condensate Pump 3. 17 283100	10	4,427	1		1. Loss of feedwater flow required manual scram which froze off sodium on the primary expansion tank vapor trap. 2. Thermal insulation was placed on the primary expansion tank vapor trap to eliminate sodium solidification in similar future cases. As no trouble could be found pumps restarted. 3. None.
1. Pump/Packing and Plungers 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	33	Ukn	1		1. Coolant deficiency caused damage to plungers and packing. 2. Modifications were made to improve the gland-cooling system, using condensate rather than raw water. 3. None.

TABLE 1-197

COMPONENT PUMPS AND SUPPORTS

(Sheet 2 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-100	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Pump/Shaft Seal 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	47, 51	5,225	2		1. Feedwater leaking at pump shaft seal due to lack of adequate cooling to inboard mechanical seal. 2. Installed new source of water to provide greater pressure head. 3. Improve maintenance schedule.
1. Pump/Shaft 2. Steam, Condensate, and Feedwater Piping and Equipment/Boiler Feed Pump 3. 17 284100	48, 50	6,075	2		1. Pump cavitation following scram. Pump drive shaft seized. 2. Seal replaced, and a modified boiler feed reservoir tank and a condensate booster pump system (with a 40-second time delay for shutoff in case of scram) were installed. 3. Design should specify precautions to prevent pump from running dry.

TABLE 1-197

COMPONENT PUMPS AND SUPPORTS

(Sheet 3 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table ____	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Pump/Cooling Coils 2. Heat Transfer/Intermediate Cooling 3. 17 222000	133, 134, 135 136, 137, 138	15,230	6		1. Cooling lines plugged with debris. System plugged. 2. Local repair. Unit was backflushed. 3. Install parallel filters with differential pressure indicator to indicate filter plugging.
1. AC Conduction Pump/Pump Duct 2. Heat Transfer/Intermediate Cooling 3. 17 222110	139, 140, 142, 155, 156	51,839	5		1. No liquid metal in pumping duct caused rupture in pump duct at bus bar area - leak external. 2. Component part replaced. 3. Protective System: Change operating procedures and/or install a fail safe fluid sensor into pump duct to prevent premature supply of electrical power to EM pumps.
1. AC Linear Polyphase Induction Pump/Coils 2. Heat Transfer/Intermediate Cooling 3. 17 221110	165	80	1		1. Full line voltage applied at start-up caused excessive heat to develop in magnetic field coils thereby deteriorating the insulation and allowing the coils to short circuit the system. 2. System design change - installed powerstat. 3. Control System: Component and system design should consider the start-up in-rush currents whenever electrical ac components are installed.

TABLE 1-198

COMPONENT RUPTURE DISCS

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-108	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Rupture Disc/Disc 2. Heat Transfer/Steam Generators 3. 23 223000	1, 2	6452	2		1. A crack developed from the rupture disc into the support flange. 2. A double rupture disc assembly of all welded construction was designed, fabricated and installed. 3. None.

TABLE 1-199

COMPONENT SENSORS (RADIATION)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-162	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Sensor/Compensated Ion Chamber 2. Instrumentation and Control/Neutron Monitor System 3. 67 261110	1, 2, 3, 4	18820	4		1. Radiation damage to the electrical insulators. 2. Part replaced with others having mica-alumina insulators which offer protection against radiation damage. 3. Development program should be initiated to obtain a suitable insulator.

TABLE 1-200

COMPONENT VALVES

(Sheet 1 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-119	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Valve 2. Turbine-Generator Units and Condenser/Circulating Water System 3. 20 330000	66, 67	4995	2		1. Conductivity alarm from cooling water system opened dump valve. Raw water "add" valve opened. Dumping cooling water and adding raw water lowers conductivity to acceptable limits. Dump rate exceeded makeup rate so the available water level drops. 2. Control air to CR 300V shutoff, closing dump valve, allowing water level to build-up. Outlet of dump valve fitted with reducers to reduce flow. 3. Design of valve system should take into account possibilities of potential problem like above.

TABLE 1-200

COMPONENT VALVES

(Sheet 2 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-119	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Valve/Body 2. Steam Condensate and Feedwater Piping and Equipment/Main Steam 3. 20 281200	101, 102, 105	1288	3		1. Cracks in valve body and nozzle due to chloride stress corrosion of material. 347 SS was used and the casting quality was poor. 2. Valve removed and replaced with 2-1/2% Cr - 1/2% Mo body composition type; metallurgical examination was performed. 3. Improve design requirements for valve material and upgrade quality control requirements on purchased components.

TABLE 1-201

COMPONENT VESSELS AND TANKS

(Sheet 1 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-19	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Vessel/50-gal Drum 2. Other Reactor Plant Equipment/ Maintenance 3. 06 292000	7	2400	1		1. Sodium fire occurred in 50-gal, open-top drum while draining sodium. 2. Operational procedure change; use only drums with covered ends with two bung holes, one for sodium drain and one for purge line. Also insulate between barrel and rack. 3. None.

TABLE 1-201

COMPONENT VESSELS AND TANKS
(Sheet 2 of 2)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-19	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Expansion Tank/ Sodium 2. Heat Transfer/ Intermediate Cooling 3. 06 222000	8	3744	1		1. Velocity of sodium high enough to cause cover gas entrainment. 2. Installed bypass line so 90% of sodium flows around tank. 3. None.

TABLE 1-202

COMPONENT WIRING AND CONNECTORS

(Sheet 1 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-166	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Wiring/Insulation 2. Accessory Electrical Equipment/Power Wiring 3. 68 450000	6	4100	1		1. Electrical insulation (plastic) melted because of wire location. 2. Replaced and relocated wires. 3. High-temperature insulation should be installed.

TABLE 1-202

COMPONENT WIRING AND CONNECTORS
(Sheet 2 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-166	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Wiring/Conductor and Disconnects 2. Miscellaneous Equipment/Other Power Plant Equipment 3. 68 530000	8	4518	1		1. Starting current caused cable to overheat when boiler feed pump was turned on. Amps required beyond cable capability. 2. 4160-volt cables to manual disconnect replaced. Larger cables installed. 3. None.

TABLE 1-202

COMPONENT WIRING AND CONNECTORS

(Sheet 3 of 3)

FAILURES DUE TO NONEXISTENT SYSTEM OR INADEQUACY OF A SYSTEM

1. COMPONENT/PART 2. SYSTEM/SUBSYSTEM 3. CODE: (Component) (System/Subsystem)	ITEM Refer to Table 1-166	OPERATING HOURS	NUMBER OF FAILURES	TOTAL HOURS SYSTEM DOWN	1. FAILURE DESCRIPTION 2. CORRECTIVE ACTION 3. RECOMMENDATIONS
1. Wiring and Connectors/ Ion Chamber Signal Cable 2. Instrumentation and Control/Neutron Monitoring 3. 68 261110	10, 11	29300	2		1. Channel grounded. 2. System design change, RG/149U cable was replaced with an Amphenol No. 421-010. 3. None.

III. SODIUM LEAK EXPERIENCE

This section on sodium leak experience was prepared by the LMEC Technical Staff members listed below:

J. Blanco	G. Clark
W. Carlson	B. Fischer

Any comments or questions concerning the material presented should be directed to J. Blanco or W. Carlson.

A. INTRODUCTION

Data pertinent to sodium leak failures are required for a variety of needs, such as general information, sodium fire analyses, design base accident (DBA) studies, hazards analyses, etc. Generally, such data have been very difficult if not impossible to obtain with any degree of confidence. To meet the need for this type of information, design, operating, and failure data relevant to sodium leaks have been compiled in this section.

These data are based on the sodium experience associated with the following plants: SCTI, LCTL, SRE, Hallam, EBR-II, and Fermi. Data sources include all types of reports, plant design handbooks, training manuals, schematics, piping and installation drawings, and verbal communications. Sincere thanks are extended to Bob Sera of EBR-II and Ted Ross of Fermi for providing much needed design data on their respective plants.

B. DESIGN AND OPERATING DATA

Tables 1-203 through 1-208 contain design and operating data on the six sodium plants considered. Each table contains a list of plant components and their associated systems; i.e., primary coolant, secondary coolant, primary purification, etc. Adjacent to each component listed, design data are given on size and material of construction, environmental conditions and protection, the number of identical components in the system, and the design temperature, pressure, and velocity. The operating data listed consist of operating temperature, pressure, and velocity information, and the hours of exposure to the internal sodium environment. In many cases, pressure and velocity data were not listed because they were unavailable. The last entry in the table indicates the number of leak failures which occurred and where they may be found in the Sodium Leak Incident Summaries (Tables 1-210 through 1-215).

Although considerable effort was made to obtain a complete and accurate compilation of design, operating, and failure data, some items were probably overlooked. However, it is believed that the number of items which may have been overlooked is not significant when compared to the total population of like items.

Table 1-209 is a plant component summary which provides an overall comparison between the sodium plants considered.

C. SODIUM LEAK INCIDENT SUMMARIES

Tables 1-210 through 1-215 present sodium leak incident tabulations for each plant. Each entry identifies a failed component, the line size associated with the component, the leakage incident, the amount of sodium lost during the leak, the hours of component operation prior to failure, the means by which the leak was detected, and the sources from which the information was gathered.

In general, the failures could be classified as nuisance, minor, or major leaks. Nuisance leaks were very small with no attendant fire or damage to adjacent equipment. Minor leaks were moderate in magnitude and accompanied by a small but controllable fire and light-to-moderate damage to adjacent equipment. Major leaks were large spills which resulted in large intense fires and heavy equipment damage. Of the 80 leaks reported, 69 were nuisance types, 9 were minor, and only 2 were major. Of the 2 major leaks, one caused extensive damage and the other only light-to-moderate damage. The major leak which caused light damage did so only because the leak occurred in a region contained by fire brick insulation and isolated from adjacent equipment.

The smallest leaks observed were approximately one pound in magnitude and accounted for 79% of the entire leak population. The major portion (82%) of these leaks resulted from valve failures. The largest leak was approximately 600 lb. It occurred in a pipe section and was caused by human error. The second largest leak was about 400 lb and was the result of tube failure in a gas-fired sodium heater. Table 1-216 shows the type and number of leaks each plant experienced. Table 1-217 shows the type and number of leaks each component type experienced.

Although leak magnitudes were not available for the majority of failures, a careful study of all the failure descriptions allowed reasonable estimates to be made for those magnitudes not available.

D. COMPONENT FAILURE RATES

Table 1-218 is a tabulation of component failure rates obtained from actual plant design, operating, and failure data. These failure rates were calculated by dividing the number of failures by the total component exposure hours.

The number of component failures were acquired from Tables 1-210 through 1-215, and the sum of total component exposure hours was acquired from Tables 1-203 through 1-208.

Analysis of the failure data did not disclose any significant temperature, pressure, or velocity effects; therefore, component failure rates were calculated without any special consideration given to these parameters.

Of the components listed, some require clarification. Sodium heaters refer to gas-fired heaters, not electrical heaters, which are used to increase sodium temperature.

Purification system components include hot traps, cold traps, carbon traps, plugging meters, and oxygen meters. The failure rate for piping is the number of pipe failures per foot - exposure hour. The failure rates for rupture discs and freeze traps are based upon SCTI data only. Data on these items for the other five plants were not available. Human errors are those leak failures which were the result of human action and not a hardware deficiency.

E. APPLICATION OF SODIUM LEAK DATA

The sodium leak data contained herein were used in the safety analysis of the proposed Sodium Pump Test Facility (SPTF) at LMEC.* An analysis of the sodium leak data and acceptable risk levels to the general public resulted in a design base accident and associated design, operations, and maintenance constraints for the SPTF. The design base accident and associated constraints, determined in this manner, are more realistic than those determined by arbitrary assumptions on the type and magnitude of leak failures.

*"SPTF Preliminary Safety Report," LMEC-Memo-70-11 (to be published)

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 1 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Sodium preheater	64 Finned tubes. 3.4-in. fin OD. Finned tubes are ss-clad copper-core fins brazed to tubes. Material: 304 SS.	Stack gas temperature: 1500 to 1283°F. Tubes are inside an air-tight refractory-lined steel casing.	1	Inlet temperature: 900°F Outlet temperature: 940°F Pressure: 100 psi	Cold leg: <400 400-500 500-600 600-700 700-800 800-900 900-1000	Cold leg: 16,154 22,150 1,224 948 740 202 6	None	None
Primary	Sodium main heater	183 parallel multi-U-bend tubes. 1.25-in. OD. 0.095-in. wall thickness. Material: 304 SS.	Tubes are inside an airtight refractory-lined steel casing.	1	Inlet temperature: 940°F Outlet temperature: 1300°F	Hot leg: <400 400-500 500-600 600-700 700-800 800-900 900-1000 1000-1100 1100-1200	Hot leg: 18,184 19,824 1,018 385 809 472 334 246 142	1	Item 7
Primary	Sodium cooler	Finned-tube unit with forced-draft air cooling. 3.4-in. fin OD. Tube material: 304 SS Fin material: 4-6 Chrome-Moly steel.	Gas-fired heater used with fan and louvres.	1	Inlet temperature: 1320°F Outlet temperature: 1050°F Pressure: 100 psia	Hot leg:*	Hot leg:†	None	None
Primary	Main pump	1-1/2-ft OD. 8-ft length. Case and impeller material: 304 SS	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer. Hot air preheat.	1	Inlet temperature: 840°F Inlet pressure: 20 psi Outlet pressure: 117 psi	Cold leg:*	Cold leg:†	1	Item 3

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 2 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	EM pump	3-ft height. 3-ft width. 5-ft length. 3-in. OD line size.	Ambient air. Type I insulation, 1-1/2-in. outer layer. Type II insulation, 1-1/2-in. inner layer.	1	Inlet temperature: 1200°F Inlet pressure: 22 psi Outlet pressure: 91 psi Flowrate: 130 gpm	Cold leg:*	Cold leg:†	None	None
Primary	Expansion tank	5-ft diameter. 10-ft length. 1000-gal capacity. Material: 304 SS	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer. Hot air preheat.	1	Temperature: 1000°F Pressure: 100 psi	Cold leg:*	Cold leg:†	None	None
Primary	Fill and drain tank	10-ft diameter. 16-ft length. 7500-gal capacity. Material: 304 SS.	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer. Hot air preheat.	1	Temperature: 850°F Pressure: (cover gas) 60 psi	Cold leg:*	Cold Leg:†	None	None
Primary	IHX (shell side)	3-ft OD. 28-ft-3 in. length. Material: 304 SS	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer. Hot air preheat.	1	Inlet temperature: 1200°F Outlet temperature: 900°F Pressure: 120 psi at 1200°F Flowrate: 1, 140, 000 lb/hr	Hot leg:*	Hot leg:†	None	None
Primary	Cold trap	2-ft diameter. 9-ft length. 140-gal capacity. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Temperature: 650°F Pressure: 100 psi	Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 3 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperature (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Freeze traps: Ft-1 Ft-2 Ft-3 Ft-5	1-in. OD finned tubing 2-1/2-ft length. Material: 304 SS.	Ambient air. No insulation.	4	–	Hot leg:*	Hot leg:†	1	Item 8
Primary	Freeze traps: Ft-4 Ft-6 Ft-7	1-in. OD finned tubing. 2-1/2-ft length. Material: 304 SS.	Ambient air. No insulation.	3	–	Cold leg:*	Cold leg:†	None	None
Primary	Plugging meter	2-ft height. 2-ft width. 6-ft length. Material: 304 SS.	Ambient air.	1	–	Cold leg:*	Cold leg:†	None	None
Primary	Offset globe valve with bellows seal: HIC-510-V	2-in. line size, sched 40 butt weld. 16 in. end-to-end. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Temperature: 1200°F Pressure: 100 psi	Hot leg:*	Hot leg:†	None	None
Primary	Offset globe valves with bellows seal: HIC-500-V HIC-501-V HIC-502-V HIC-503-V HIC-508-V HIC-512-V HIC-516-V	2-in. line size, sched 40 butt weld. 16 in. end-to-end. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	7	Temperature: 1200°F Pressure: 100 psi	Cold leg:*	Cold leg:†	None	None
Primary	Offset globe valve with bellows seal: V-517-V	1-in. line size, sched 40 butt weld. 16 in. end-to-end. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Temperature: 1200°F Pressure: 100 psi	Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 4 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Gate-valve with gas-cooled freeze seal: HIC-110-V	10-in. line size, sched 40 butt weld. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Temperature: 1300°F Pressure: 600 psi	Cold leg:*	Cold leg:†	1	Item 9
Primary	Expansion joints: XJ-1 XJ-2 XJ-3	10 in. line size. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer. Hot air preheat.	3	Temperature: 1300°F Pressure: 125 psi	Cold leg:*	Cold leg:†	None	None
Primary	Expansion joints: XJ-4 XJ-5	10-in. line size. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer. Hot air preheat.	2	Temperature: 1300°F Pressure: 125 psi	Cold leg:*	Cold leg:†	1	Item 1
Primary	Pipe leg: 501	10-in. line size, sched 40. 89-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer. Hot air preheat.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Hot leg:*	Hot leg:†	None	None
Primary	Pipe leg: 502	10-in. line size, sched 40. 65-ft length. Material: 304 SS.	↓	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 503	10-in. line size, sched 40. 48-ft length. Material: 304 SS	↓	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	1	Item 2
Primary	Pipe leg: 504	10-in. line size, sched 40. 45-ft length. Material: 304 SS.	↓	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 5 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Pipe leg: 505	10-in. line size, sched 40. 66-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer. Hot air preheat.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Hot leg:*	Hot leg:†	None	None
Primary	Pipe leg: 506	6-in. line size, sched 40. 93-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Hot leg:*	Hot leg:†	None	None
Primary	Pipe leg: 507	6-in. line size, sched 40. 40-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Hot leg:*	Hot leg:†	None	None
Primary	Pipe leg: 508	6-in. line size, sched 40. 73-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 509	3-in. line size, sched 40. 31-ft length. Material: 304 SS.	Ambient air. Type I insulation, 1-1/2-in. outer layer. Type II insulation, 1-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 510	3-in. line size, sched 40. 16-ft length. Material: 304 SS.	Ambient air, Type I insulation, 1-1/2-in. outer layer. Type II insulation, 1-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 511	10-in line size. sched 40. 55-ft length. Material: 304 SS.	Ambient air. Type I insulation. 2-1/2-in. outer layer. Type II insulation. 2-1/2-in. inner layer.	1	Maximum temperature: 1300°F Maximum pressure: 125 psig	Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 6 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Pipe leg: 601	2-in. line size, sched 40. 85-ft length. Material: 304 SS.	Ambient air, Type I insulation, 3-in. layer.	1	Maximum temperature: 850°F Maximum pressure: 100 psia	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 602	2-in. line size, sched 40. 35-ft length. Material: 304 SS .		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 603	1-in. line size, sched 40. 5-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 604	2-in. line size, sched 40. 29-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 605	2-in. line size, sched 40. 4-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 606	2-in. line size, sched 40. 41-ft length. Material: 304 SS.		1	Maximum temperature: 850°F Maximum pressure: 100 psia	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 607	2-in. line size, sched 40. 53-ft length. Material: 304 SS.		1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 608	2-in. line size, sched 40. 21-ft length. Material: 304 SS.		1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 609	1-in. line size, sched 40. 10-ft length. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 7 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Pipe leg: 610	1-in. line size, sched 40. 12-ft length. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 618	2-in. line size, sched 40. 65-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 619	2-in. line size, sched 40. 20-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 622	2-in. line size, sched 40. 4-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 623	2-in. line size, sched 40. 20-ft length. Material: 304 SS		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 624	2-in. line size, sched 40. 15-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 625	2-in line size, sched 40. 17-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 629	1-1/2 in. line size, sched 40. 21-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 630	1-1/2 in. line size, sched 40. 2/3-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 8 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Primary	Pipe leg: 632	1-in. line size, sched 40. 1/3-ft length. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 633	1-in. line size, sched 40. 1/3-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 634	1-1/2 in. line size, sched 40, 1/3-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 635	1-in. line size, sched 40. 2-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 636	1-in. line size, sched 40. 2-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 638	1-in. line size, sched 40. 1/3-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 640	2-in. line size, sched 40. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None
Primary	Pipe leg: 651	2-in. line size, sched 40. 13-ft length. Material: 304 SS.		1		Cold leg:*	Cold leg:†	None	None

*Hot leg and Cold leg temperatures same as above for all primary system components.
†Hot leg and Cold leg exposure time same as above for all primary system components

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 9 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Secondary	IHX (tube side)	462 tubes. 1/2-in. OD. 0.035-in. wall thickness. 25-ft length. Material: 316 SS.	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer.	1	Inlet temperature: 775°F Outlet temperature: 1175°F Press: 150 psig at 1200°F Flowrate: 855,000 lb/hr	Hot leg: <400 400-500 500-600 600-700 700-800 800-900 900-1000 1000-1100 1100-1200	Hot leg: 36,020 2,490 864 774 746 234 108 120 72	None	None
Secondary	Steam Generator (shell side)	32-in. shell diameter. 45-ft length. 360 bimetallic tubes. 1/2-in. OD. 0.104-in. wall thickness. Material: 316 SS on sodium side, inconel on water side		1	Inlet temperature: 1175°F Outlet temperature: 775°F Press (gas blanket): 100 psig Rated flow at 100% load: 855,000 lb/hr	Hot leg:*	Hot leg:†	2	Items 4 and 10
Secondary	Pump	1-1/2-ft OD. 8-ft length. Case and impeller material: 304 SS.	Ambient air. Type I insulation, 3-in. outer layer. Type II insulation, 3-in. inner layer.	1	Inlet temperature: 775°F Inlet pressure: 11 psig Outlet pressure: 123 psig Flowrate: 3600 gpm	Cold leg: <400 400-500 500-600 600-700 700-800 800-900 900-1000 1000-1100 1100-1200	Cold leg: 36,106 2,562 1,158 1,266 290 10 - 32 -	None	None
Secondary	Expansion tank	5-ft diameter. 10-ft length. 1000-gal capacity. Material: 304 SS.		1	Temperature: 1000°F Pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Fill & drain tank	8-ft diameter. 16-ft length. 5000-gal capacity. material: carbon steel, spec SA-212, Grade B.		1	Temperature: 850°F Cover gas pressure: 60 psig	Cold leg:*	Cold leg:†	None	None

*Hot and Cold leg temperatures same as above for all secondary components.
†Hot and Cold leg exposure time same as above for all secondary components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 10 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Secondary	Freeze trap: FT-8	1-in. OD finned tubing. 2-1/2 ft length. Material: 304 SS.	Ambient air. No insulation.	1		Hot leg:*	Hot leg:†	None	None
Secondary	Plugging meter	2-ft height. 2-ft width. 6-ft length. Material: 304 SS.	Ambient Air	1		Cold leg:*	Cold leg:†	None	None
Secondary	Offset globe-valves modified with freeze seal: V-510 V-522B V-539 V-627	2-in. line size, sched 40. 16 in. end-to-end. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	4	Temperature: 1200°F Pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Offset globe-valves HIC-504-V HIC-505-V HIC-506-V HIC-509-V HIC-518-V	2-in. line size, sched 40 butt weld. 16-in. end-to-end. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	5	Temperature: 1200°F Pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Valve with bellows seal: HIC-519-V	1-in. line size, sched 40 butt weld. 16-in. end-to-end. Material: 304 SS.	↓	1	Na temperature: 1200°F Pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Butterfly valve with freeze seal: FRC-106-V	8-in. line size, sched 40 butt weld. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1		Cold leg:*	Cold leg:†	None	None
Secondary	Gate valve with freeze seal: HIC-116-V	10-in. line size, sched 40 butt weld. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-inner layer.	1		Hot leg:*	Hot leg:†	None	None
Secondary	HIC-105-V	↓	↓	1		Cold leg:*	Hot leg:†	None	None

*Hot and Cold leg temperatures same as above for all secondary components.
†Hot and Cold leg exposure time same as above for all secondary components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 11 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Secondary	Expansion joints: XJ-7 XJ-8 XJ-9	10-in. line size. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	3	Na temperature: 1300 F Pressure: 125 psig	Hot leg:*	Hot leg:†	1	Item 6
Secondary	Pipe leg: 551	10-in. line size, sched 40. 91-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Max temperature: 1300°F Max pressure: 125 psig	Hot leg:*	Hot leg:†	None	None
Secondary	Pipe leg: 552	10-in. line size, sched 40. 105-ft length. Material: 304 SS.	↓	1	Max temperature: 1300°F Max pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 553	10-in. line size, sched 40. 36-ft length. Material: 304 SS.	Ambient air. Type I insulation, 2-1/2-in. outer layer. Type II insulation, 2-1/2-in. inner layer.	1	Max temperature: 1300°F Max pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 554	10-in. line size, sched 40. 84-ft length. Material: 304 SS.	↓	1	Max temperature: 1300°F Max pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 555	6-in. line size, sched 40. 32-ft length. Material: 304 SS.	↓	1	Max temperature: 1300°F Max pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 556	2-in. line size, sched 40. 28-ft length. Material: 304 SS.	Ambient air, Type I insulation, 3-in. layer.	1	Max temperature: 1300°F Max pressure: 125 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Steam generator relief line: 557	12-in. line size, sched 40. Material: 304 SS.	↓	1				None	None

*Hot and Cold leg temperatures same as above for all secondary components.
†Hot and Cold leg exposure time same as above for all secondary components.

TABLE 1-203

SCTI DESIGN AND OPERATING DATA
(Sheet 12 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Secondary	Steam generator relief line: 558	12-in. line size, sched 40. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1				None	None
Secondary	Pipe leg: 611	2-in. line size, sched 40. 101-ft length. Material: 304 SS.	↓	1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 612	2-in. line size, sched 40. 21-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 613	1-in. line size, sched 40. 9-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 614	2-in. line size, sched 40. 5-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 615	↓	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 616	1-in. line size, sched 40. 15-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 617	1-1/2-in. line size, sched 40. 7-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None
Secondary	Pipe leg: 620	2-in. line size, sched 40. 15-ft length. Material: 304 SS.	↓	1	↓	Cold leg:*	Cold leg:†	None	None

*Hot and Cold leg temperatures same as above for all secondary components.
†Hot and Cold leg exposure time same as above for all secondary components.

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SCTI DESIGN AND OPERATING DATA
(Sheet 13 of 13)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-210
Secondary	Pipe leg: 621	2-in. line size, sched 40. 11-ft length. Material: 304 SS.	Ambient air. Type I insulation, 3-in. layer.	1	Maximum temperature: 850°F Maximum pressure: 100 psig	Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg: 626	2-in. line size, sched 40. 21-ft length. Material: 304 SS.	↓	1	↓	Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg: 627	2-in. line size, sched 40. 17-ft length. Material: 304 SS.		1		Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg: 628	1-1/2-in. line size, sched 40. 1-ft length. Material: 304 SS.		1		Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg: 631	↓		1		Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg: 637	3/4-in. line size, sched 40. 2/3-ft length. Material: 304 SS.		1		Cold leg: *	Cold leg: †	None	None
Secondary	Pipe leg:	2-in. line size, sched 40. 20-ft length. Material: 304 SS.		1		Cold leg: *	Cold leg: †	None	None

*Hot and Cold leg temperatures same as above for all secondary components.
†Hot and Cold leg exposure time same as above for all secondary components.

TABLE 1-204

LCTL DESIGN AND OPERATING DATA
(Sheet 1 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperature (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-211
Six-in. loop	Piping	6-in. 80 ft. 2.25 Cr-1 Mo alloy steel, ASTM - A335, grade P22	Electrically trace heated. Metal heat reflector and 4-in. super X insulation.	1	To 1963: 1200 gpm 1000°F From 1963: 2000 gpm 1000°F	350-1000	Total: 60,000 From 1969 startup: 2220	None	None
Three-in. loop	Piping	3-in. 120 ft. To 1963: 2.25 Cr-1 Mo. alloy steel From 1963: 304 SS	Electrically trace heated. Metal heat reflector and 4-in. super X insulation.	1	To 1963: 120 gpm 1000°F From 1963: 130 gpm 1200°F	From initial startup: 350-1000 From 1963: 350-1300	Total: 60,000 From 1969 startup: 2220	1	Item 1
Eight-in. supply line	Piping	8-in. 210 ft. 2.25 Cr-1 Mo. alloy steel.	Electrically trace heated. Metal heat reflector and 4-in. super X insulation.	1	2000 gpm 1000°F	350-1000	Total: 60,000 From 1969 startup: 2220	None	None
Core tank	Tank	96-in. ID 26-3/4-ft height. 9550 gal. 5/8-in. thick. Material: 304 SS	Electrically trace heated. Insulated.	1	1200°F	350-1200	Total: 60,000 From 1969 startup: 2220	None	None
Supply tank	Tank	102-in. ID. 19-ft long. 9800 gal. 5/8-in. thick. Material: 304 SS	Electrically trace heated. Insulated.	1	1200°F	350-1200	Total: 60,000 From 1969 startup: 2220	None	None
Drain tank	Tank	102-in. ID. 24-1/2-ft long. 11,000 gal. 5/8-in. thick. Material: 304 SS	Electrically trace heated.	1	1200°F	350-1200	Total: 60,000 From 1969 startup: 2220	None	None
Six-in. loop	Sodium pump	6 x 8 pump. Material: 304 SS	Freeze seal	1	2000 gpm 1000°F 65-ft head	350-1000	Total: 60,000 From 1969 startup: 2220	None	None
Three-in. loop	Sodium pump	2 x 3 pump. Material: 304 SS	Freeze seal	1	130 gpm 1200°F 24-ft head	From initial startup: 350-1000 From 1963: 350-1300	Total: 60,000 From 1969 startup: 2220	None	None

TABLE 1-204

LCTL DESIGN AND OPERATING DATA
(Sheet 2 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-211
Six-in. loop	Air-cooled heat exchanger.	5-ft, 3-in. dia x 5-ft finned tubes. 0.3 hp blower		1	2000 gpm 1000°F	350-1000	Total: 60, 000 From 1969 startup: 2220	None	None
	Immersion heater.	72 kw. Material: 304 SS		1	2000 gpm 1000°F	350-1000		None	None
	Diffusion cold trap.	6-in. dia x 2-ft Material: 304 SS		1	2000 gpm 1000°F	350-1000		None	None
Sodium service	Sodium pump	2 x 3 pump	Freeze seal	1	130 gpm 1200°F 24-ft head	350-1200	Total: 60, 000 From 1969 startup: 2220	None	None
Three-in. loop	Heater	275 kw. 36 sheathed tubular heaters in 8-in. pipe. Material: 304 SS		1	130 gpm 1200°F	From initial startup: 350-1000 From 1963: 350-1300	Total: 60, 000 From 1969 startup: 2220	None	None
Six-in. loop	Gate valve	8-in. Material: 304 SS	Freeze seal, insulated.	1	From core tank: 2000 gpm 1000°F	350-1000	Total: 60, 000 From 1969 startup: 2220	None	None
	Piston-operated gate valve.	6-in. Material: 304 SS	Freeze seal, insulated.	1	To core tank: 2000 gpm 1000°F			None	None
	Gate valve.	6-in. Material: 304 SS	Freeze seal, insulated.	2	In loop (2): 2000 gpm 1000°F			None	None
	Piston-operated gate valve.	6-in. Material: 304 SS	Freeze seal, insulated.	1	In loop: 2000 gpm 1000°F			None	None
Three-in. loop	Gate valve.	3-in. Material: 304 SS	Freeze seal, insulated.	4	From supply tank (1) in loop (3): 130 gpm 1200°F	From initial startup: 350-1000 From 1963 piping material change: 350-1300	Total: 60, 000 From 1969 startup: 2220	None	None
	Piston-operated gate valve.	3-in. Material: 304 SS	Freeze seal, insulated.	3	From supply tank (1) to core tank (1): 130 gpm 1200°F			None	None

TABLE 1-204

LCTL DESIGN AND OPERATING DATA
(Sheet 3 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-211
Eight-in. supply and drain	Gate valve.	8-in. Material: 304 SS	Freeze seal, insulated.	1	From core to drain tanks (1): 2000 gpm 1000°F From supply tank (1): 2000 gpm 1000°F	350-1000	Total: 60,000 From 1969 startup: 2220	None	None
	Piston-operated gate valve.	8-in. Material: 304 SS	Freeze seal, insulated.	1				None	None
Purification and sodium service	Piping	3-in. OD (390-ft long). 2-in. OD (160-ft long).	Insulated		300 gpm 1200°F	From initial startup: 350-1000 From 1963: (3-in. loop) 350-1300 (6-in. loop) 350-1000 From 1969 startup: 350-750	Total: (3-in. and 2-in.) 60,000 (1-in.) 8,000 From 1969 startup: 2220	1	Item 7
		1-in. OD (50-ft long).			1000°F				
Purification loops	Cold trap.	17-in. dia x 5-ft, 9-in. 3 hp blower. Material: 304 SS		1	750°F 100 psig	350-700	Total: 60,000	None	None
	Plugging meter.	Material: 304 SS		1	750°F	350-700	From 1969 startup: 2220	None	None
Purification loops	Gate valve.	3-in. Material: 304 SS	Freeze seal, insulated.	7	Cold trap bypass (1). Plugging meter bypass (1): 50 gpm 700°F	350-700	Total: 60,000 From 1969 startup: 2220	3	Items 2, 3, and 4
		1-1/2-in.	Freeze seal, insulated.		To cold trap (1): from cold trap (1): 50 gpm 700°F			None	None
		1-in.	Freeze seal, insulated.		To plugging meter (2); from plugging meter (1): 50 gpm 700°F				
	"Y" pattern gate valve.	1-in.	Freeze seal, insulated.	1	In plugging meter: 50 gpm 700°F				

TABLE 1-204

LCTL DESIGN AND OPERATING DATA
(Sheet 4 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperature (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-211
Sodium service	Globe valve.	2-in. Material: 304 SS	Bellows seal	9	Fill and vent system: 350°F	From initial setup: 350-1000 From 1963: (3-in. loop) 350-1300 (6-in. loop) 350-1000 From 1969 startup: 350-750	Total: 60,000 From 1969 startup: 2220	1	Item 5
Sodium service	Gate valve.	3-in. Material: 304 SS	Bellows seal	6	6-in. loop heat exchanger drain (3): 1000°F Immersion heater, Internal (3): 1000°F	From initial startup: 350-1000 From 1969 startup: 350-750	Total: 60,000 From 1969 startup: 2220	None	None
Sodium service	Check valve.	2-in. Material: 304 SS		1	Fill connection: 350°F	350	Total: 60,000 From 1969 startup: 2220	None	None
Sodium service	Gate valve.	2-in. Material: 304 SS 3-in. Material: 304 SS 3-in. Material: 304 SS 2-in. Material: 304 SS 3-in. Material: 304 SS 2-in. Material: 304 SS 3-in. Material: 304 SS	Freeze seal, insulation. Freeze seal, insulation. Freeze seal, insulation. Freeze seal Freeze seal Freeze seal Freeze seal	10	3-in. loop to drain (2): 300 gpm 1200°F 6-in. loop to drain (1): 300 gpm 1200°F Transfer pump inlet to supply tank (1): 50 gpm 700°F Level indicator supply tank (2): 1200°F Core tank (2): 1200°F Drain tank (1): 1200°F Transfer pump to vent (1): 130 gpm 1200°F	From initial startup: 350-1000 From 1963: (3-in. loop) 350-1300 (6-in. loop) 350-1000 From 1969 startup: 350-750	Total: 60,000 From 1969 startup: 2220	None	None

TABLE 1-204

LCTL DESIGN AND OPERATING DATA
(Sheet 5 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Esposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-211
Sodium service	Piston-operated valve.	3-in.	Freeze seal	8	3-in. loop to drain (1): 300 gpm 1200°F	From initial startup: 350-1000	Total: 60,000	None	None
		3-in.	Freeze seal		Core tank to drain (1): 300 gpm 1200°F	From 1963: (3-in. loop) 350-1300			
		3-in.	Freeze seal		To drain tank (1): 300 gpm 1200°F	(6-in. loop) 350-1000			
		6-in. Material: 304 SS	Freeze seal		6-in. immersion heater loop (1): 2000 gpm 1000°F	From 1969 startup: 350-750	From 1969 startup: 2220	1	Item 6
		3-in. Material: 304 SS	Freeze seal		Immersion heater to drain tank (1): 300 gpm 1000°F			None	None
		3-in. Material: 304 SS	Freeze seal		To transfer pump (1): 130 gpm 1200°F				
		3-in. Material: 304 SS	Freeze seal		Transfer pump to drain tank (1): 130 gpm 1200°F				
		3-in. Material: 304 SS	Freeze seal		Transfer pump to supply tank (1): 130 gpm 1200°F				

TABLE 1-205A

SRE DESIGN AND OPERATING DATA
(Sheet 1 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Primary	Vessel (reactor)	304 SS 1-1/2 in. thick. 135-in. dia. 228-in. length.	Helium atmosphere temperature. Same as interior.	1	Inlet: 650°F Outlet: 1200°F	Outlet: 300-700 700-800 800-960 960-1030 Inlet: 300-600	 65,488 2,776 3,580 356 72,200	None	None
Primary (main)	Piping	Schedule 40. 6-in. OD. 140-ft length. Material: 304 SS. 2-1/2-in. OD. 55-ft length. Material: 304 SS.	Dehumidified nitrogen. Temperature: 100°F.		1200°F max.	Hot leg: 300-700 700-800 800-960 960-1030 Cold leg: 300-600	 65,488 2,776 3,580 356 72,200	None	None
Primary heat transfer auxiliary	Piping	2-in. OD. 150-ft length. Material: 304 SS.	Dehumidified nitrogen.		24,250 lb/hr 1200°F	300-700 700-1030	65,488 6,712	None	None
Primary (main)	Centrifugal pump	Freeze seal. Material: 304 SS.	Dehumidified nitrogen. Temperature: 100°F	1	485,000 lb/hr 1200°F	300-700 700-800 800-960 960-1030	65,488 2,776 3,580 356	None	None
Primary (auxiliary)	Centrifugal pump	Freeze seal. Material: 304 SS.	Dehumidified nitrogen.	1	24,250 lb/hr 1200°F	300-700 700-800 800-960 960-1030	65,488 2,776 3,580 356	None	None
Primary-secondary (main)	Intermediate heat exchanger	Material: 304 SS.	Dehumidified nitrogen.	1	Primary side: Inlet: 1200°F Outlet: 600°F	Hot leg (inlet): 300-700 700-800 800-960 960-1030 Cold leg (outlet): 300-600	 65,488 2,776 3,580 356 72,200	None	None
Primary-secondary (auxiliary)	Intermediate heat exchanger	Material: 304 SS.	Dehumidified nitrogen.	1	1200°F	Inlet: 300-700 700-800 800-960 960-1030 Outlet: 300-600	 65,488 2,776 3,580 356 72,200	None	None

TABLE 1-205A

SRE DESIGN AND OPERATING DATA
(Sheet 2 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Secondary heat transfer	Piping	6-in. OD. 146-ft length. Material: 304 SS.	Ambient air.		485,000 lb/hr 1140°F	300-700 700-1030	65,488 6,712	None	None
Secondary (auxiliary)	Piping	2-in. OD. 150-ft length. Material: 304 SS.	Ambient air.		24,250 lb/hr 1140°F	300-700 700-1000	65,488 6,712	None	None
Primary purification loops	Globe valve	1-1/2 in.	Bellows seal.	6	To and from main primary pump (1 each): 1000 lb/hr 960°F To hot traps (2): 10,000 lb/hr 1190°F From hot traps (2): 10,000 lb/hr 1210°F	300-700 700-800 800-960 960-1030	65,488 2,776 3,580 356	None	None
Primary sodium service	Globe valve	2-1/2 in.	Toluene jacket around stem creates a sodium freeze seal. Dehumidified nitrogen.	1	Second return line to reactor tank picked off from downstream of cold leg plug valve: 34,000 lb/hr 500°F (732°F max.)	300-600	72,200	None	None
		1 in.		2	Hot and cold leg flush lines (1 each): 1200°F	300-600	72,200	None	None
Auxiliary primary heat transfer	Wedge-type plug valve	2 in.	Toluene jacket around stem creates a sodium freeze seal.	2	Main loop: Hot leg: 24,250 lb/hr 1200°F max. Cold leg: 24,250 lb/hr 732°F	Hot leg: 300-700 700-800 800-960 960-1030 Cold leg: 300-600	65,488 2,776 3,580 356 72,200	None	None
Auxiliary primary heat transfer	Check valve	2 in.		1	Main loop cold leg: 24,250 lb/hr 732°F	300-600	72,200	None	None

TABLE 1-205A

SRE DESIGN AND OPERATING DATA
(Sheet 3 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Auxiliary primary purification	Globe valve	1 in.	Bellows seal.	8	Cold trap loop: 3620 lb/hr 732°F	300-600	72,200	None	None
Auxiliary primary sodium service	Globe valve	1 in.	Bellows seal.	4	Flush lines: 1200°F	300-600	72,200	None	None
Secondary heat transfer	Wedge-type plug valve	6 in. Material: 304 SS.	Toluene jacket around stem creates a freeze seal. Ambient air.	2	Downstream of air-blast heat exchanger and Edison steam generator (parallel systems) (1 each): 485,000 lb/hr 440°F (674°F max.)	300-600	72,200	None	None
Secondary (main)	Pump (freeze-seal centrifugal)	Material: 304 SS.	Dehumidified nitrogen.	1	485,000 lb/hr 674°F	300-600	72,200	None	None
Secondary (auxiliary)	Pump (freeze-seal centrifugal)	Material: 304 SS.	Dehumidified nitrogen.	1	24,250 lb/hr 674°F	300-600	72,200	None	None
Secondary heat transfer	Expansion tank	88 ft^3 (650 gal.). Material: 304 SS.	Ambient air.	1	485,000 lb/hr 1140°F	300-600	72,200	None	None
Auxiliary secondary heat transfer	Expansion tank	4 ft^3 (30 gal.). Material: 304 SS.	Ambient air.	1	24,250 lb/hr 674°F	300-600	72,200	None	None
Secondary (main)	Steam generator		Ambient air.	1	1200°F 750 psig	300-700 700-1030	65,488 6,712	None	None
	Air-blast heat exchanger		Ambient air.	1	1200°F	300-1030	50,000	None	None
Secondary (auxiliary)	Air-blast heat exchanger		Ambient air.	1		300-700 700-1000	65,488 6,712	None	None

TABLE 1-205A

SRE DESIGN AND OPERATING DATA
(Sheet 4 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Primary heat transfer	Wedge-type plug valves	6 in.	Toluene jacket around stem creates a sodium freeze seal. Dehumidified nitrogen.	2	Cold leg: 485, 000 lb/hr 500°F (732°F max.)	300-600	72, 200	None	None
					Hot leg: 485, 000 lb/hr 960°F (1200°F max.)	300-700 700-800 800-960 960-1030	65, 488 2, 776 3, 580 356		
Primary sodium service	Globe valve	2 in.	Bellows seal. Dehumidified nitrogen.	3	Fill, drain, and flush lines: 26, 700 lb/hr 350-1200°F	Hot leg: 300-700 700-800 800-960 960-1030	 65, 488 2, 776 3, 580 356	None	None
		1 in.		3		Cold leg: 300-600	72, 200	None	None
Primary purification loops	Globe valve	1 in.	Bellows seal. Dehumidified nitrogen.	12	Mass transfer assembly (4): 2400 lb/hr 1200°F	300-700 700-800 800-960 960-1030	23, 288 2, 776 3, 580 356	13	Items 1, 4, 7, 8, 9, 13, 14, 16, 17, 18, 19, 20, and 21
					Cold trap loop (8): 1340 lb/hr 732°F	300-600	72, 200		
Secondary sodium service	Globe valve	2 in.	Bellows seal. Ambient air.	6	Fill and drain lines: 26, 700 lb/hr 350°F	300-600	72, 200	One	Item 6
		1 in. Material: 304 SS.		2	Edison steam generator bypass: 1200°F	300-1000	72, 200	None	None
Secondary purification loops	Globe valve	1 in. Material: 304 SS.	Bellows seal. Ambient air.	6	Cold trap loop: 2280 lb/hr 674°F	300-600	72, 200	Ten	Items 2, 3, 5, 10, 11, 12, 15, 22, 23, and 24
Secondary heat transfer	Globe	6 in. Material: 304 SS.	Toluene jacket around stem creates a freeze seal. Ambient air.	2	Upstream of air-blast heat exchanger and Edison steam generator (parallel systems) (1 each): 485, 000 lb/hr 900°F (1140°F max.)	300-1000	72, 200	None	None

TABLE 1-205A

SRE DESIGN AND OPERATING DATA
(Sheet 5 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Auxiliary secondary purification	Globe valve	1 in. Material: 304 SS.	Bellows seal. Ambient air.	3	Plugging meter loop: 2280 lb/hr 674°F	300-600	72, 200	None	None
Auxiliary secondary sodium service	Globe valve	2 in.	Bellows seal. Ambient air.	1	Drain fill line: 550°F	300-600	72, 200	None	None
General sodium service system	Globe valve	2 in.	Bellows seal. Dehumidified nitrogen.	1	General fill and drain system: 550°F	300-600	72, 200	None	None
		1 in.		1				None	None
		1-1/2 in.		14				None	None
General sodium service system	Check valve	1-1/2 in.	Dehumidified nitrogen.	1	From melt station to primary fill tank (1): 4500 lb/hr 350°F	300-600	72, 200	None	None
		2 in.		1	From melt station to transfer tank (1): 4500 lb/hr 350°F	300-600	72, 200	None	None
General sodium service system	Gate valve	2 in.	Dehumidified nitrogen.	4	Melt and fill systems: 550°F	300-600	72, 200	None	None
		1-1/2 in.		4				None	None

TABLE 1-205B

SRE-PEP DESIGN AND OPERATING DATA
(Sheet 1 of 4)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Primary	Vessel (reactor)	1-1/2-in. thick. 135-in. dia. 228-in. length Material: 304 SS.	Helium atmosphere.	1	Inlet: 1200°F Outlet: 600°F 0.5 psi at free sodium surface	700 350	4,386 17,014	None	None
Primary (main)	Piping	Schedule 20: 8-in. OD. 125-ft length. 6-in. OD. 15-ft length. 3-in. OD. 55-ft length. Material: 304 SS.	Dehumidified nitrogen.		1200°F 2700 gpm	Hot leg: 700 350 Cold leg: 300-600	4,386 17,014 21,400	None	None
Primary (auxiliary)	Piping	2-in. OD. 150-ft length. Material: 304 SS.	Ambient air.		1200°F 102 gpm	700 350	3,800 17,600	None	None
Primary (main)	Pump, free-surface, centrifugal	Material: 304 SS.	Dehumidified nitrogen.	1	1200°F 62 psi 2700 gpm	700 350	4,386 17,014	None	None
Primary (auxiliary)	Pump, free-surface, centrifugal	Material: 304 SS.	Dehumidified nitrogen.	1	1200°F 12 psi 102 gpm	700 350	3,800 17,600	None	None
Primary secondary	Intermediate heat exchanger	555 tubes of 5/8-in. OD .042-in. thick. Material: 304 SS.	Dehumidified.	1	1200°F 110 psig	On primary side: 700 350	4,386 17,014	None	None
Primary secondary (auxiliary)	Intermediate heat exchanger	Material: 304 SS.	Ambient air.	1	1200°F 100 psig 93 gpm	700 350	3,800 17,600	None	None
Secondary (main)	Piping	Schedule 20: 8-in. OD. 143-ft length. Schedule 40: 6-in. OD. 3-ft length. Material: 304 SS.	Dehumidified nitrogen.		Inlet: 616°F Outlet: 1166°F 2500 gpm	300-600	21,400	None	None
Secondary (auxiliary)	Piping	2-in. OD. 150-ft length. Material: 304 SS.	Dehumidified nitrogen.		1200°F 93 gpm	300-600	21,400	None	None

TABLE 1-205B

SRE-PEP DESIGN AND OPERATING DATA
(Sheet 2 of 4)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Secondary (main)	Pump, free-surface, centrifugal (integral expansion tank)	Material: 304 SS. (1120 gal.).	Inside expansion tank: Sodium at 620°F. Helium. Dehumidified nitrogen.	1	800°F 94 psig 2500 gpm	300-600	21,400	None	None
Secondary (auxiliary)	Pump (integral expansion tank)	Material: 304 SS. (30 gal.).	Inside expansion tank: Helium. Dehumidified nitrogen.	1	800°F 100 psig 93 gpm	300-600	21,400	None	None
Secondary (main)	Steam generator	Material: 304 SS.	Ambient air.	1	1200°F 1410 gpm 750 psig	300-600	21,400	None	None
Secondary (auxiliary)	Air-blast heat exchanger	Material: 304 SS.	Ambient air.	1	1200°F 50 psig	300-600	21,400	None	None
Primary heat transfer	Globe valve	8-in. Material: 304 SS.	Dehumidified nitrogen.	1	619,000 lb/hr 650°F 18.7 psig	Cold leg: 300-600	21,400	None	None
Primary purification loops	Globe valve	1-1/2 in. Material: 304 SS.	Gas-cooled freeze seal. Dehumidified nitrogen.	4	To hot traps: 3890 lb/hr 1200°F 21 psig	700 350	4,386 17,014	None	None
					From hot traps (2): 5750 lb/hr 1250°F 11.3 psig	700 350	4,386 17,014		
					To cold trap: 5760 lb/hr 650°F 18.7 psig	300-600	21,400		
	"Y" pattern globe valve	1-1/2 in. Material: 304 SS.	Bellows seal.	1	From cold trap: 5750 lb/hr 600°F	300-600	21,400	None	None
	Globe angle valve	1-1/2 in. Material: 304 SS.	Gas-cooled freeze seal.	2	From cold trap (D/S of above): 5750 lb/hr 600°F	300-600	21,400	None	None
					From purification loop: 5750 lb/hr 1250°F	350-700	21,400		

TABLE 1-205B

SRE-PEP DESIGN AND OPERATING DATA (Sheet 3 of 4)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Primary purification loops	Globe valve	1-1/2 in. Material: 304 SS.	Gas-cooled freeze seal. Dehumidified nitrogen.	2	Plugging meter: 435 lb/hr 650°F 18.7 psig	300-600	21,400	None	None
Primary heat transfer	Globe valve	3-in. Material: 304 SS.	Gas-cooled freeze seal. Dehumidified nitrogen.	1	Moderator plenum: 87,300 lb/hr 650°F	300-600	21,400	None	None
Secondary heat transfer	Globe angle valve	6-in. Material: 304 SS.	Bellows seal. Ambient air.	2	Hot leg: 619,000 lb/hr 1166°F 47.1 psig Cold leg: 619,000 lb/hr 616°F 35.6 psig	350	21,400	None	None
Secondary heat transfer	Globe angle valve	1-in. Material: 304 SS.	Bellows seal.	2	Heat exchanger bypass: 1200°F	350	21,400	None	None
Secondary purification loops	"Y" pattern globe valve.	1-in. Material: 304 SS.	Bellows seal. Ambient air.	1	To plugging meter: 437 lb/hr	350	21,400	None	None
	Globe valve.	1-in. Material: 304 SS.	Gas-cooled freeze seal. Ambient air.	4	To cold trap loop: 6387 lb/hr max. 616°F 76 psig	350	21,400	None	None
Auxiliary secondary heat transfer	Globe angle valve	2-in. Material: 304 SS.	Bellows seal.	1	40,800 lb/hr 1166°F 10.5 psig	300-600	21,400	None	None
Auxiliary secondary purification	Globe valve	1-in.	Gas-cooled freeze seal.	3	To cold trap loop: 5950 lb/hr 616°F 76.0 psig	300-600	21,400	None	None
Primary sodium service	Globe valve.	4-in.	Freeze seal.	1	Fill, drain, and vent lines: 4500 lb/hr 350-1200°F	700	4,386	None	None
	Globe angle valve.	2-in.	Bellows seal.	5		350	17,014	None	None
	Globe valve.	2-in.	Freeze seal.	2				None	None
	Globe angle valve.	1-1/2 in.	Freeze seal.	3				None	None
	Globe valve.	1-1/2 in.	Bellows seal.	2				None	None

TABLE 1-205B

SRE-PEP DESIGN AND OPERATING DATA
(Sheet 4 of 4)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Sodium service	Globe valve	2-in.	Bellows freeze seal.	3	350°F	350	21,400	None	None
	Globe valve	1-1/2 in.	Bellows freeze seal.	4	350°F	350	21,400	None	None
Sodium service	Check valve	1-1/2 in.	Ambient air.	1	Melt station to primary storage tank: 7000 lb/hr 350°F	350	21,400	None	None

TABLE 1-205C

SRE AND SRE-PEP DESIGN AND OPERATING DATA
(Sheet 1 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Primary and auxiliary. Primary purification and sodium service	Piping	1-in. OD, 18 ft. 1-1/2-in. OD, 411 ft. 2-in. OD, 164 ft. Material: 304 SS.	Dehumidified nitrogen.		Hot leg: 10,000 lb/hr 1210°F Cold leg: 3620 lb/hr 500°F	SRE: 300-700 700-1030 SRE-PEP: 300-600 300-600	SRE: 65,488 6,712 SRE-PEP: 21,400 SRE: 72,200 SRE-PEP: 21,400	1	Item 26
Primary and auxiliary. Primary purification	Cold trap	Material: 304 SS.	Dehumidified nitrogen.	2, one in each system	1340 lb/hr 500°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Primary auxiliary. Primary purification	Plugging meter	Material: 304 SS.	Dehumidified nitrogen	2, one in each system	2280 lb/hr 500°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Primary purification	Mass transfer assembly	Material: 304 SS.	Dehumidified nitrogen.	1	1200 lb/hr 960°F	SRE: 300-700 700-1030	SRE: 23,288 6,712	None	None
Primary purification	Hot traps	Material: 304 SS.	Dehumidified nitrogen.	2	10,000 lb/hr 1210°F	SRE: 300-700 700-1030 SRE-PEP: 300-600	SRE: 65,488 6,712 SRE-PEP: 27,400	None	None
Primary and auxiliary. Primary sodium service	Fill tank	8850 gal. Material: 304 SS.	Dehumidified nitrogen.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Secondary and auxiliary. Secondary purification and sodium service	Piping	1-in. OD, 14 ft. 1-1/2-in. OD, 185 ft. 2-in. OD, 118 ft. Material: 304 SS.	Ambient air.		3620 lb/hr 440°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None

TABLE 1-205C

SRE AND SRE-PEP DESIGN AND OPERATING DATA
(Sheet 2 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Secondary purification	Cold trap	Material: 304 SS.	Ambient air.	1	1340 lb/hr 440°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Auxiliary secondary purification	Plugging meter	Material: 304 SS.	Ambient air.	2, one each system	2280 lb/hr 440°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Secondary and auxiliary secondary sodium service	Fill tank	2625 gal. Material: 304 SS.	Ambient air.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
Secondary and auxiliary secondary sodium service	Diffusion cold trap	Material: 304 SS.	Ambient air.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
General sodium service	Flush and drain tank	160 gal. Material: 304 SS.	Ambient air.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
General sodium service	Cold trap	Material: 304 SS.	Ambient air.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
General sodium service	Transfer tank	80 gal. Material: carbon steel.	Ambient air.	1	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	None	None
General sodium service	Sodium filter	2-in. line Material: 304 SS.	Ambient air.	2	350°F	300-600	SRE: 72,200 SRE-PEP: 21,400	1	Item 25
Primary sodium service	EM pump	2-in. line. Material: 304 SS.	Dehumidified nitrogen.	2	1200°F	SRE: 300-700 700-1030 SRE-PEP: 300-600	SRE: 65,488 6,712 SRE-PEP: 21,400	None	None

TABLE 1-205C

SRE AND SRE-PEP DESIGN AND OPERATING DATA
(Sheet 3 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-212
Secondary sodium service	EM pump	2-in. line. Material: 304 SS.	Ambient air.	1	1200°F	SRE: 300-700 700-1030 SRE-PEP: 300-600	SRE: 65,488 6,712 SRE-PEP: 21,400	None	None

TABLE 1-206

HALLAM DESIGN AND OPERATING DATA
(Sheet 1 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-213
Primary heat transfer	Reactor vessel	33-ft length. 19-ft dia. Material: 304 SS.	Helium gas. Containment tank. Thermal shields. Thermal insulation. Cavity liner.	1	1000°F 8,400,000 lb/hr	350-600 600-950	14,000 8,000	None	None
Primary heat transfer	Piping	Reactor to pumps: 16-in. dia. 0.25-in. wall. 250-ft length (each). Material: 304 SS. Pump, through IHX to reactor: 14-in. dia. 0.25-in. wall. 250-ft length (each). Material: 304 SS.	Dehumidified nitrogen. To primary block valves: outer containment pipe Block valves to pumps: shielded pipe tunnels Pump, thru IHX, to throttle valves: shielded pipe tunnels Throttle valves to reactor: outer containment pipe	3 loops 3 loops	1000°F 2,800,000 lb/hr each Pumps to IHX: 1000°F 2,800,000 lb/hr each IHX to reactor: 650°F 2,800,000 lb/hr each	350-600 600-950 350-600 600-950 350-600	14,000 8,000 14,000 8,000 22,000	None None	None None
Primary heat transfer	Pump	16-in. suction. 14-in. discharge. 6-in. overflow. Material: 304 SS.	Dehumidified nitrogen. Mounted in shielded cell.	3 - 1 in each loop	1000°F 2,800,000 lb/hr each	350-600 600-950	14,000 8,000	None	None
Primary heat transfer	Gate valve (block valve)	14 in. Material: 304 SS.	Dehumidified nitrogen. Frozen sodium stem seal plus backup mechanical packing seals.	3 - 1 in each loop	1000°F 2,800,000 lb/hr each	350-600 600-950	14,000 8,000	None	None
Primary heat transfer	Globe valve (throttle valve)	14 in. Material: 304 SS.	Dehumidified nitrogen. Frozen sodium stem seal plus backup mechanical packing seals.	3 - 1 in each loop	650°F 2,800,000 lb/hr each	350-600	22,000	None	None
Primary and secondary	Heat exchanger (shell and tube counter-flow design)	18-ft length. 3-ft dia. Material: 304 SS.	Dehumidified nitrogen. Mounted in shielded cell.	6 - 2 mounted parallel in each loop	Primary loop tubes: 1000°F in 650°F out 2,800,000 lb/hr each pair Secondary loop shell: 600°F in 950°F out 2,800,000 lb/hr each pair	350-600 600-950	14,000 8,000	None	None

TABLE 1-206

HALLAM DESIGN AND OPERATING DATA
(Sheet 2 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-213
Secondary heat transfer	Piping	14-in. dia. 0.25-in. wall. 400-ft length (each).	Dehumidified nitrogen.	3	Hot leg: 950°F 2,800,000 lb/hr Cold leg: 600°F 2,800,000 lb/hr	350-600 600-950 350-600	11,000 8,000 19,000	None	None
		8-in. dia overflow (pump to expansion tank). 50-ft length (each). Material: 304 SS.		3	950°F	350-600 600-950	11,000 8,000		
Secondary heat transfer	Expansion tank	300 ft^3. Material: 304 SS.	Dehumidified nitrogen.	3 - 1 in each loop	950°F	350-600 600-950	11,000 8,000	1	Item 1
Secondary heat transfer	Pump	14-in. suction. 14-in. discharge. Material: 304 SS.	Dehumidified nitrogen. Unshielded.	3 - 1 in each loop	950°F 2,800,000 lb/hr each	350-600 600-950	11,000 8,000	1	Item 2
Secondary heat transfer	Globe valve (throttle valve)	14-in. Material: 304 SS.	Dehumidified nitrogen. Frozen sodium stem seal plus backup mechanical packing seals.	3 - 1 in each loop	600°F 2,800,000 lb/hr each	350-600	19,000	None	None
Secondary heat transfer	Steam generator (super-heater plus evaporator)	5 CR - 1/2 Mo	Dehumidified nitrogen. Duplex tubes with helium monitor.	3 - 1 in each loop	Sodium side: 950°F in 600°F out 2,800,000 lb/hr each 100 psig Water side: 825°F out 800 psig 251,000 lb/hr each	350-600 600-950	11,000 8,000	None	None
Primary heat transfer	Check valve	14 in. Material: 304 SS.	Dehumidified nitrogen. Shielded cell.	3 - 1 in each loop	650°F 2,800,000 lb/hr each	350-600	22,000	None	None

TABLE 1-206

HALLAM DESIGN AND OPERATING DATA
(Sheet 3 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-213
Primary purification loop	Gate valve.	3 in. Material: 304 SS.	Freeze seal, auxiliary stem packing.	6	650°F 100 gpm	350-600	22,000	None	None
	Globe valve.	3 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	5	650°F 100 gpm			3	Items 5, 6 and 8
	Globe valve.	2 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	8	650°F 20 gpm			2	Items 3 and 7
Primary sodium service	Gate valve.	2 in. Material: 304 SS.	Freeze seal, auxiliary stem packing.	7	650°F	350-600	22,000	None	None
	Globe valve.	3 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	20	650°F			1	Item 4
	Globe valve.	2 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	13	650°F			None	None
	Gate valve.	3 in. Material: 304 SS.		8	650°F			None	None
	Gate valve.	2 in. Material: 304 SS.		6	650°F			None	None
	Gate valve.	1 in. Material: 304 SS.		2	650°F			None	None
	Check valve.	3 in. Material: 304 SS.		2	650°F			None	None
Primary sodium service	Fill tanks.	2150 ft^3. Material: 304 SS.	Dehumidified nitrogen.	5	650°F	350-600	22,000	None	None
	Transfer tanks.	20 ft^3. Material: carbon steel.	Dehumidified nitrogen.	1	650°F			None	None
	Containment drain tank.	20 ft^3. Material: 304 SS.	Dehumidified nitrogen.	1	1000°F			None	None
	Service drain tank.	20 ft^3. Material: 304 SS.	Dehumidified nitrogen.	1	1000°F			None	None

TABLE 1-206

HALLAM DESIGN AND OPERATING DATA
(Sheet 4 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-213
Primary purification loop	Cold trap.	Carbon steel.	Freeze traps.	2	650°F 20 gpm	350-600 600-950	14,000 8,000	2	Items 10 and 11
	Carbon trap.	Material: 304 SS.	Freeze traps.	1	1200°F 40 gpm			1	Item 13
	Plugging meter.	Material: 304 SS.	Dehumidified nitrogen.	2				None	None
Primary sodium service	EM pump	3-in. pipe size		2	650°F	350-600	22,000	None	None
Secondary purification loop	Cold trap.	Material: carbon steel.	Freeze trap.	1	950°F 10 gpm	350-600	19,000	None	None
	Plugging meter.	Material: 304 SS.	Dehumidified nitrogen.	1				None	None
Secondary purification loop	Gate valve.	3 in. Material: 304 SS.	Freeze seal, auxiliary stem packing.	6	950°F 30 gpm	350-600 600-950	11,000 8,000	None	None
	Globe valve.	3 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	1	950°F 100 gpm			1	Item 9
	Globe valve.	2 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	4	950°F 10 gpm			None	None
Secondary sodium service	Fill tanks	1375 ft^3. Material: 304 SS.	Dehumidified nitrogen.	3	950°F	350-600	19,000	None	None
	Drain tanks	10 ft^3. Material: 304 SS.	Dehumidified nitrogen.	1	950°F			None	None
Secondary sodium service	Gate valve	2 in. Material: 304 SS.	Freeze seal, auxiliary stem packing.	3	950°F	350-600	19,000	None	None
	Globe valve	3 in. Material: 304 SS.	Bellows seal, auxiliary stem packing.	11	950°F			None	None
Secondary sodium service	EM pump	3-in. pipe size		1	650°F	350	19,000	None	None

TABLE 1-206

HALLAM DESIGN AND OPERATING DATA
(Sheet 5 of 5)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-213
Primary purification and sodium service	Piping	2-in. dia. 3-in. dia. 5500-ft long. Material: 304 SS.	Dehumidified nitrogen.		1200°F	350-600 600-950	14,000 8,000	1	Item 12
Secondary purification and sodium service	Piping	2-in. dia. 3-in. dia. 3500-ft long. Material: 304 SS.	Dehumidified nitrogen.		950°F	350-600	19,000	None	None
Sodium service	Filters	3-in. pipe size.		2	650°F	350	22,000	None	None
Sodium service	EM pump	3-in. pipe size.		1	650°F	350	22,000	None	None

TABLE 1-207

EBR-II DESIGN AND OPERATING DATA
(Sheet 1 of 2)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-214
Primary	Reactor vessel	26 ft x 26 ft x 1/2 in. Material: 304 Cres.	Nitrogen gas at pressure: ± 6 in. of H_2O	1	750°F - 23.8 ft/min	700 300-699	56,000 8,000	None	None
Primary	Piping	Hot leg: 14 in. OD (43 ft long), jacketed by 18 in. Cold leg: 12-in. OD (54 ft long). 12-in. pipe to outer blanket: 6-in. OD (8 ft long). 4-in. OD (92 ft long). Material: 304 Cres.	Sodium vapor + liquid at 700°F	-	3,574,000 lb/hr 900°F 100 psi	Hot leg: 300-699°F 700-850°F Cold leg: 300-700°F	46,000 18,000 64,000	None	None
Primary	Pump, free-surface centrifugal	Material: 304 Cres.	Sodium vapor + liquid at 700°F	2	85 psi 4500 gpm	300-700 (in cold leg)	64,000	None	None
Primary	Throttling valves	6-in. angle-type bellows seal. Material: 304 Cres.	Sodium at 700°F	2	150 psig 800°F	60 psig 15.2 ft/sec 300-700 (located in cold leg)	64,000	None	None
Primary purification	Piping	20-in. OD. 130-ft long. Material: 304 Cres.		-	700°F 20-60 gpm 5-15 psig	300-700 20-40 gpm 5-18 psig	64,000	None	None
	EM pump	304 SS		1	700°F	300-700	64,000	1	Item 1
	Surge tank	64-in. high t = 0.134 in. 304 SS.		1	700°F	300-700	64,000	None	None
	Regenerative heat exchanger	304 SS		1	700°F	300-700	64,000	None	None
	Cold trap.	5-ft length. 6-ft OD. 1/4-in. thick. Material: 304 SS		1	350°F	200-400	64,000	None	None
	Plugging meter.	Material: 304 SS		2	350 F	200-400	64,000	None	None
	Valves	Pneumatically operated. Hand operated.		9	350-700°F	300-700	64,000	5	Items 3, 4, 5 6, and 7

TABLE 1-207

EBR-II DESIGN AND OPERATING DATA
(Sheet 2 of 2)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-214
Primary and secondary	Intermediate heat exchanger IHX	Material: 304 Cres.	Sodium vapor + liquid at 700°F	1	Shell side: 900°F in 700°F out 3.4 psig Tube side: 588°F in 866°F out 10 psig	300-700 700-850	46,000 18,000	None	None
Secondary	Piping	Hot leg: 12-in. OD (279-ft long). 10-in. OD (105-ft long). 8-in.OD (374-ft long). Cold leg: 16-in. OD (14-ft long). 12-in. OD (294-ft long). 8-in. OD (176-ft long). Material: 304 Cres.		-	2.2 x 10^6 lb/hr 900°F	Hot leg: 300-700 700-850 Cold leg: 300-700	46,000 18,000 64,000	None	None
Secondary	EM pump			-	900°F	300-700	64,000	1	Item 2
Secondary	Surge tank	Material: 304 Cres.		1	600°F nominal	300-700	64,000	None	None
Secondary (Purification)	Piping	4-in OD (107-ft long). 2-in. OD (156-ft long). Material: 304 SS.		-	700°F	300-700	64,000	None	None
	EM pump	Material: 304 SS		2	700°F	300-700	64,000	None	None
	Storage tank	Material: 304 SS		1	600°F	300-700	64,000	None	None
	Economizer	Material: 304 SS		1	600°F	300-700	64,000	None	None
	Cold trap Plugging meter.	Material: 304 SS		1 1	350°F	200-400	64,000 64,000	None None	None None
	Valves	Material: 304 SS		18	700°F	300-700	64,000	9	Items 8 through 16
Secondary	Superheater	Material: 304 SS	Ambient air	2	880°F in 800°F out	300-700 700-850	46,000 18,000	None None	None None
Secondary	Evaporator	Material: 304 SS	Ambient air	8	800°F in 600°F out	300-700 700-850	46,000 18,000	None None	None None

TABLE 1-208

FERMI DESIGN AND OPERATING DATA
(Sheet 1 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-215
Primary heat transfer	Reactor vessel	36.3-ft height. 14.5-ft maximum dia. 2-in. maximum wall. Material: 304 SS	Argon gas	1	1000°F 110 psi	<600 >600	45,700 3,500	None	None
Primary heat transfer	Piping	Per loop - Hot leg: 30-in. OD (75-ft long). Cold leg: 30-in. OD (5-ft long). 18-in. OD (3-ft long). 16-in OD (67-ft long). 14-in. OD (73-ft long). Flow to blanket: 6-in OD (80-ft long).	Argon gas. Secondary containment using heavy gage carbon steel pipe plus insulation.	3 separate loops	Reactor to pump: 1000°F 4.9 ft/sec 125 psig Pump discharge: 1000°F 17.5 ft/sec 125 psig Flow to core: 1000°F 21.0 ft/sec 125 psig Flow to blanket: 1000°F 11.0 ft/sec 125 psig	Reactor to heat exchanger (hot leg): <600 >600 Heat exchanger, through pump to reactor (cold leg): 300-600	45,700 3,500 49,200	None	None
Primary heat transfer	Pump	30-in. inlet. 16-in. outlet. Material: 304 SS	Argon gas	3-1 in each loop	11,800 gpm 1000°F Total dynamic heat: 310 ft	300-600	49,200	None	None
Primary heat transfer	Check valve	16-in. Material: 304 SS.	Argon gas	3-1 in each loop	4.4 x 10^6 lb/hr 1000°F	300-600	49,200	None	None
Primary heat transfer	Angle-type gate valve	6-in. Material: 304 SS.	Argon gas. Double-bellows seal.	3-1 in each loop	0.88 x 10^6 lb/hr 1000°F	300-600	49,200	1	Item 1
Primary and Secondary	IHX	Tube size: 7/8-in. OD x 0.049-in. wall. 1860 tubes. Material: 304 SS.	Argon gas	3-1 in each loop	Shellside flow: 5.3 x 10^6 lb/hr 900°F in 600°F out 125 psig Flow in tubes: 5.3 x 10^6 lb/hr 520°F in 820°F out 300 psig	<600 >600	45,700 3,500	None	None

TABLE 1-208

FERMI DESIGN AND OPERATING DATA
(Sheet 2 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-21[illegible]
Secondary heat transfer	Piping	Per loop: 18-in. OD (183-ft long). 12-in. OD (147-ft long). Material: 2.25 Cr - 1 Mo.	Argon gas	3 separate loops	4.4×10^6 lb/hr 1000°F 300 psig	Hot leg: <600 >600 Cold leg: 300-600	 45,700 3,500 49,200	None	None
Secondary heat transfer	Pump	18-in. inlet. 12-in. outlet. Material: 2.25 Cr - 1 Mo.	Argon gas	3-1 in each loop	12,000 gpm 675°F Total dynamic head: 350 psi	300-600	49,200	None	None
Secondary heat transfer	Steam generator	Total heat transfer area 10,800 ft^2. 1200 tubes. 5/8-in. OD x 0.042-in. wall. Material: 2.25 Cr - 1 Mo.		3-1 in each loop	Shellside flow (sodium): 4.4×10^6 lb/hr 750°F in 500°F out 300 psig Tube flow (water-steam): 320,000 lb/hr 340°F in 742°F out 600 psig	<600 >600	45,700 3,500	None	None
Primary purification and sodium service	Piping	3 in. 1273 ft. 2 in. 329 ft. 1 in. 67 ft. Material: 304 SS.	Dehumidified nitrogen. Shielded cells.		444 lb/hr 1000°F	300-600	49,200	None	None
Primary purification	Cold trap. Hot trap. Plugging meter. EM pump.	Material: 304 SS. Material: 304 SS. Material: 304 SS. Material: 304 SS.	Dehumidified nitrogen. Dehumidified nitrogen. Dehumidified nitrogen. Dehumidified nitrogen.	1 1 1 1	900°F 1000°F 900°F 900°F	300-600 300-600 300-600 300-600	49,200 49,200 49,200 49,200	1 None None None	Item 8 None None None
Primary purification and sodium service	Overflow pump. Overflow tank. Expansion tank. Storage tank.	Material: 304 SS. Material: 304 SS. Material: 304 SS. 15000 gal. Material: 2.25 Cr - 1 Mo.	Dehumidified nitrogen. Dehumidified nitrogen. Dehumidified nitrogen. Resistance heaters.	2 1 3 3	100 gpm 75-ft discharge head 1000°F 1000°F 900°F 700°F	300-600 300-600 300-600 300-600	49,200 49,200 49,200 49,200	None None None None	None None None None

TABLE 1-208

FERMI DESIGN AND OPERATING DATA
(Sheet 3 of 3)

System	Component Type	Component Size and Material of Construction	External Environmental Conditions and Protections	Number of Like Components In System	Design Temperature Pressure and Velocity	Operating Temperatures (°F)	Exposure to Internal Environment (hr)	Number of Sodium Leaks	Item Reference In Table 1-215
Primary purification and sodium service	Gate valve	3 in. 2 in. 1 in. Material: 304 SS.	Dehumidified nitrogen	22 2 9	300-900°F	300-600	49,200	4	Items 2, 3, 4, and 7
Primary sodium service	Filter	Material: 304 SS		1	700°F	300-600	49,200	None	None
Secondary purification and sodium service	Piping	3 in. 463 ft. 1 in. 175 ft. Material: 304 SS			350-900°F	300-600	49,200	None	None
Secondary purification	Cold trap. Plugging meter. EM pump.	Material: 304 SS Material: 304 SS Material: 304 SS		1 4 1	900°F 900°F 900°F	300-600 300-600 300-600	49,200 49,200 49,200	None None None	None None None
Secondary purification and sodium service	Dump tank	12,000 gal. 304 SS.		3	900°F	300-600	49,200	None	None
Secondary purification and sodium service	Gate valve	3 in. 1 in. Material: 304 SS.		30 6	350-900°F 350-900°F	300-600 300-600	49,200 49,200	2	Items 5 and 6

TABLE 1-209

PLANT COMPONENT INVENTORY

Component	SCTI	LCTL	SRE	Hallam	EBR-II	Fermi
Sodium heaters	2	2	0	0	0	0
Sodium coolers	1	1	2	0	0	0
IHX	1	0	3	6	1	3
Steam generators	1	0	2	3	2	3
Pumps (mechanical)	2	3	8	6	2	8
Pumps (EM)	1	0	3	4	4	2
Vessels	4	3	6	15	4	10
Filters	0	0	2	2	0	1
Purification system components	3	3	11	7	5	8
Valves	40	56	98	114	29	75
Piping (ft)	1723	1010	1850	2192	2064	4205
Reactors	0	0	1	1	1	1

TABLE 1-210

SCTI SODIUM LEAK INCIDENT SUMMARY
(Sheet 1 of 3)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	Expansion joint XJ-5 (10-in.-diam line)	Sodium leaked from pin holes and cracks in the expansion joint bellows and penetrated cracks in the thermal insulation. There was no fire. The bellows failed from metal sensitization during its manufacture.	1	612	Visual	a) Incident Report (IR) No. 34, 8-25-65 b) FDH;* LMEC-Memo-69-7
2.	Pipe leg 503 (10-in.-diam line)	A small sodium leak occurred through a 1/8-in. hole in the pipe during primary system fill. The leak resulted in a small fire. The hole was inadvertently made when a plumb bob was tack welded to the pipe. Human error was cause of failure.	10	1208	Visual	a) IR-60, 11-4-65 b) LMEC FDH
3.	Primary pump level sensing line (2-in.-diam line)	Sodium oozed out from a substandard weld joint (porous connection) in the primary pump level sensing line. A small fire resulted from leak.	2	613	Operational monitor	a) IR-87, 12-23-65 b) LMEC FDH
4.	Steam generator rupture disc - RD-2	A pinhole-size sodium leak developed in a seal weld where the rupture disc and its support ring were welded to the face of the support flange on the steam generator side of the joint. No sodium spillage or open flame resulted from the leak Sodium oxide formation was observed on the RD-2 flange insulation during inspection of a nearby valve.	1	5302	Visual	a) IR-93, 1-14-66 b) LMEC FDH
5.	Expansion joint XJ-10 (10-in.-diam line)	The leak detector on XJ-10 alarmed and indicated sodium leakage at the first stages of sodium oxide formation. No open fire resulted from the leak.	1	612	Leak detector	a) IR-108, 3-1-66 b) LMEC FDH

*Failure Data Handbook

TABLE 1-210

SCTI SODIUM LEAK INCIDENT SUMMARY
(Sheet 2 of 3)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
6.	Expansion joint XJ-8 (10-in.-diam line)	The leak detector on XJ-8 alarmed and indicated sodium leakage at the first stages of sodium oxide formation. No open fire resulted from the leak.	1	887	Leak detector	a) IR-114, 3-17-66 b) LMEC FDH
7.	Sodium he heater H-1 (10-in.-diam line)	Sodium leaked through cracks in the heater tubes. The tube cracks were stress cracks. Sodium leaked at a rate of 1.4 gal/min. There was a moderate fire; however, damage was light.	400	9580	Operational monitor (smoke detectors)	a) IR-302, 6-5-66 b) LMEC FDH
8.	Freeze trap FT-1	A small sodium leak was discovered in the vicinity of the base of FT-1 at the outlet of the main gas-fired heater. After the removal of thermal insulation, the leak was found in a weld joint and the sodium/sodium oxide buildup around the leak was 3 in. in diameter. The leak did not result in a fire. Metallurgical examination of FT-1 established that the failure occurred in an extraordinarily large weld bead used to attach a thermocouple to the relatively thin-walled finned tube. The quantity of sodium leaked was less than 1 lb.	1	Unknown	Alarm	a) IMPR-352, 3-10-69 b) LMEC FDH
9.	IHX primary sodium outlet gate valve (10-in.-diam line)	Frequent improper operation of the valve resulted in sodium extruding from the freeze stem packing gland. The extruded sodium caused a small fire.	2	Unknown	Protective system	a) IMPR-359, 3-26-69 b) LMEC FDH

TABLE 1-210

SCTI SODIUM LEAK INCIDENT SUMMARY
(Sheet 3 of 3)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
10.	Steam generator	Sodium leak through steam generator level control displacer cage gasket. Sodium leaked from the system with nominal damage to the leveltrol and no damage to other equipment. The leak occurred during the performance of a special sodium flushing procedure.	10	Unknown	Visual	a) IMPR-376, 12-27-69 b) LMEC FDH

TABLE 1-211

LCTL SODIUM LEAK INCIDENT SUMMARY

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	Pipe (3-in.-diam line)	Sodium leak resulted from intergranular corrosion caused by impurities and moisture in pipe insulation. Leak was small and left an insulation area 1 in. in diameter covered with sodium oxide. No fire. Pipe section was replaced.	1	Unknown	Visual	a) IMPR-12, 7-1-69
2.	Valve - cold trap inlet (1-1/2-in.-diam line)	Flange bolts worked loose and caused a sodium leak. No fire. Flange was welded. Valve not originally design for sodium service.	1	Unknown	Visual	a) Lab Notebook No. B-041182, 10-11-61 b) LMEC FDH
3.	Valve - 3-in. thermal shock loop	Flange bolts worked loose and caused a sodium leak. No fire. Flange was welded. Valve not originally designed for sodium service.	1	Unknown	Visual	a) Lab Notebook No. B-041183, 10-17-61 b) LMEC FDH
4.	Valve - 3-in. magnetic trap	Flange bolts worked loose and a sodium leak occurred. Fire. Tightened flange bolts.	5	Unknown	Visual	a) Lab Notebook No. A-086329, 9-22-59 b) LMEC FDH
5.	Valve (V-23A) - 2 x 3 loop vent (2-in.-diam line)	Bellows ruptured. Fire. Replaced bellows.	5	Unknown	Visual	a) Lab Notebook No. A-086374, 4-20-60 b) LMEC FDH
6.	Valve - 6 x 8 test section (6-in.-diam line)	Bellows ruptured. Small fire. Replaced bellows.	5	Unknown	Visual	a) Lab Notebook No. 086361, 11-16-59 b) LMEC FDH
7.	1-in. pipe elbow - plugging loop	Small sodium leak — immediately covered with calcium carbonate. Small fire occurred.	5	Unknown	Visual	a) IMPR-021, 11-15-69

TABLE 1-212

SRE SODIUM LEAK INCIDENT SUMMARY
(Sheet 1 of 4)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	Valve (PMV) - main primary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	5,760	Visual	a) Operation Log book, 1-29-63 b) LMEC FDH
2.	Valve (V-124) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	16,400	Visual	a) Operation Log book No. 51, 2-24-63 b) LMEC FDH
3.	Valve (V-124) - main secondary sodium service (1-in.-diam line)	Bellows leaked due to assembly error. No fire. Part replaced.	1	336	Visual	a) Operation Log book No. 51, 3-6-63 b) LMEC FDH
4.	Valve (V-644) - main primary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	18,100	Visual	a) Maintenance Log book, 7-10-63 b) LMEC FDH
5.	Valve (PMV) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	3,600	Visual	a) Operation Log book No. 9 b) LMEC FDH
6.	Valve (V-166) - main secondary fill and drain (2-in.- diam line)	Bellows failed. No fire. Part replaced.	1	15,100	Visual	a) Operation Log book No. 11, 11-25-58 b) LMEC FDH
7.	Valve (PMV) - main primary sodium service (1-in.-diam line)	Bellows ruptured. No fire. Part replaced.	1	18,720	Visual	a) Operation Log book No. 13, 6-23-59 b) LMEC FDH
8.	Valve (V-105) - main primary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	7,200	Visual	a) Operation Log book No. 6, 1-4-58 b) LMEC FDH

TABLE 1-212

SRE SODIUM LEAK INCIDENT SUMMARY
(Sheet 2 of 4)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
9.	Valve (V-624) - primary freeze trap (1-in.-diam line)	Bellows ruptured. No fire. Part replaced.	1	9,360	Visual	a) Operation Log book No. 7, 6-1-58 b) LMEC FDH
10.	Valve (V-126) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	9,360	Visual	a) Operation Log book No. 7, 6-16-58 b) LMEC FDH
11.	Valve (PMV) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	4,080	Visual	a) Operation Log book No. 7, 6-24-58 b) LMEC FDH
12.	Valve (PMV) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	4,200	Visual	a) Operation Log book, 8-12-60 b) LMEC FDH
13.	Valve (V-634) - main primary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	9,720	Visual	a) Operation Log book, 3-10-60 b) LMEC FDH
14.	Valve (V-617) - main primary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	9,720	Visual	a) Operation Log book No. 24, 9-30-60 b) LMEC FDH
15.	Valve (V-125) - main secondary sodium service (1-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	13,600	Visual	a) Operation Log book No. 25, 12-28-60 b) LMEC FDH
16.	Valve (V-620) - main primary sodium service (1-in.-diam line)	Bellows ruptured. No fire. Part replaced.	1	12,100	Visual	a) Operation Log book No. 26, 1-13-61 b) LMEC FDH

TABLE 1-212

SRE SODIUM LEAK INCIDENT SUMMARY
(Sheet 3 of 4)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
17.	Valve (V-620) - main primary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	12,100	Visual	a) Operation Log book No. 26, 1-28-61 b) LMEC FDH
18.	Valve (V-618) - main primary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	13,000	Visual	a) Operation Log book No. 26, 3-30-61 b) LMEC FDH
19.	Valve (PMV) - main primary plugging meter (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	11,000	Visual	a) Operation Log book No. 35, 11-8-61 b) LMEC FDH
20.	Valve (V-635) - main primary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	12,000	Visual	a) Operation Log book No. 35, 2-6-62 b) LMEC FDH
21.	Valve (PMV) - main primary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	3,600	Visual	a) Operation Log book No. 8, 6-24-58 b) LMEC FDH
22.	Valve (V-124) - main secondary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	4,560	Visual	a) Operation Log book No. 8, 7-2-58 b) LMEC FDH
23.	Valve (V-127) - main secondary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	10,800	Visual	a) Operation Log book No. 8, 7-13-58 b) LMEC FDH

TABLE 1-212

SRE SODIUM LEAK INCIDENT SUMMARY
(Sheet 4 of 4)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
24.	Valve (V-124) - main secondary sodium service (1-in.-diam line)	Bellows failed. No fire. Part replaced.	1	10,800	Visual	a) Operation Log book No. 8, 8-16-58
25.	Filter - main primary sodium service	Sodium leak, flange bolts not properly torqued. No fire.	1	Unknown	Visual	a) SRE Log book b) LMEC FDH
26.	Pipe (2-in.-diam line) primary sodium service	Sodium leak. Hole in line caused by an electric arc from a shorted line heater. Fire resulted. Gallery not under inert atmosphere due to maintenance. Damage to heater and lead wires by fire.	10	6,000	Visual	a) 69LMEC-2368, 12-8-69

TABLE 1-213

HALLAM SODIUM LEAK INCIDENT SUMMARY
(Sheet 1 of 2)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	Expansion tank - secondary system	Tank leak caused stress corrosion cracking and leak at junction of 8-in. overflow line and tank. No fire resulted from the leak.	10	15,000	Visual	a) Conference 650620
2.	Pump - secondary system	Loose bolts resulted in a sodium leak during preoperational testing. No fire resulted from the leak	2	0	Visual	a) Work Request No. 909, 4-6-62 b) LMEC FDH
3.	Valve - primary cold trap inlet (2-in.-diam line)	Bellows ruptured. Detected during actuation. No fire. Part replaced.	1	5,280	Unknown	a) Monthly Highlights, 10-12-62 b) LMEC FDH
4.	Valve - primary fill and drain line (3-in.-diam line)	Bellows leaked. Detected during actuation. No fire. Part replaced.	1	4,320	Unknown	a) Work Request No. 2092 b) LMEC FDH
5.	Valve - primary hot trap (3-in.-diam line)	Bellows leaked. Valve operated before properly preheated. Detected during actuation. No fire.	1	15,744	Unknown	a) Monthly Operating Report No. 10081 b) LMEC FDH
6.	Valve (V-476) - primary block (3-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	21,000	Protective system	a) Monthly Operating Report No. 10113 b) LMEC FDH
7.	Valve (V-443) - primary meter (2-in.-diam line)	Bellows leaked. Detected during actuation. No fire. Part replaced.	1	1,440	Unknown	a) Work Request No. 1432 b) LMEC FDH
8.	Valve (471) - primary hot trap (3-in.-diam line)	Bellows leaked. Detected during actuation. No fire. Part replaced.	1	3,600	Unknown	a) Work Request No. 1772 b) LMEC FDH

TABLE 1-213

HALLAM SODIUM LEAK INCIDENT SUMMARY
(Sheet 2 of 2)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
9.	Valve (491) - secondary fill tank outlet (3-in.-diam line)	Bellows leaked. No fire. Part replaced.	1	18,840	Visual	a) Monthly Operating Report No. 10089 b) LMEC FDH
10.	Cold trap - primary cell No. 2	Visual observation after operation monitor alarm revealed sodium on floor and nitrogen ducting. No fire. Part replaced.	2	Unknown	Leak detector	a) Monthly Operating Report No. 6 b) LMEC FDH
11.	Cold trap - primary cell No. 2	Misalignment of inlet flange caused sodium leak. No fire. Local repair.	1	Unknown	Operational monitors	a) Monthly Operating Report No. 7 b) LMEC FDH
12.	Piping and fitting gasket No.2 drum melt station	Sodium leak around gasket between piping and drain bung. No fire. New gasket installed.	1	Unknown	Visual	a) AI Monthly Report, 1-11-63 b) LMEC FDH
13.	Hot trap (carbon) sampler	One man sprayed with sodium while removing a sample, but was not burned due to protective clothing.	1	2,400	Visual	a) Monthly Operating Report No. 5 b) LMEC FDH

TABLE 1-214

EBR-II SODIUM LEAK INCIDENT SUMMARY
(Sheet 1 of 2)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	EM DC conduction pump - sodium purification system (temporary)	Pump duct leaked sodium. No fire. Pump duct removed.	2	Unknown	Visual	a) ANL-6739 b) LMEC FDH
2.	EM AC linear induction pumps - main secondary system	Small leak through cracks resulting from a combination of very low inlet pressure to the duct at a high flowrate. No fire. Repaired in field by curring circular discs containing the cracks from the duct and welding in new discs.	10	55	Operational monitors	a) ANL-6885 b) ANL-6904 c) EBR-II STP Vol C-9 d) ANS-100 e) LMEC FDH
3.	Valve - primary cold trap bypass	Bellows leaked. No fire. Part replaced.	1	100	Visual	a) ANL-6810, 12-63 b) LMEC FDH
4.	Valve - primary system plugging loop	Bellows ruptured. No fire. Part replaced.	1	8,800	Visual	a) PMMR-86 b) LMEC FDH
5.	Valve - primary system plugging loop	Bellows ruptured. No fire. Part replaced.	1	8,800	Visual	a) PMMR-86 b) LMEC FDH
6.	Valve - primary purification system	Bellows ruptured. No fire. Valve replaced.	1	15,000	Visual	a) Operations Weekly Report, 4-10-68 b) LMEC FDH
7.	Valve - primary sodium sampling waste line	Bellows leaked. Small fire. Valve replaced.	2	9,400	Visual	a) Report of EBR-II operations, 4-1-67 through 6-30-67

TABLE 1-214

EBR-II SODIUM LEAK INCIDENT SUMMARY
(Sheet 2 of 2)

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
8.	Valve - secondary plugging meter	Bellows ruptured. No fire. Part replaced.	1	2,608	Operational monitors	a) ANL-6965, 10-64 b) LMEC FDH
9.	Valve - secondary surge tank vent	Bellows ruptured. No fire. Part replaced.	1	2,608	Visual	a) PMMR-25 b) LMEC FDH
10.	Valve - secondary surge tank vent	Bellows ruptured. No fire. Part replaced.	1	3,208	Visual	a) PMMR-33 b) LMEC FDH
11.	Valve - secondary plugging loop	Bellows leaked. No fire. Part replaced.	1	7,290	Visual	a) PMMR-77 b) LMEC FDH
12.	Valve - secondary plugging loop	Bellows leaked. No fire. Part replaced.	1	10,100	Visual	a) PMMR-92 b) LMEC FDH
13.	Valve - secondary plugging loop	Bellows leaked. No fire. Part replaced.	1	10,800	Visual	a) PMMR-102 b) LMEC FDH
14.	Valve - secondary sodium service	Bellows leaked. No fire. Part replaced.	1	14,500	Visual	a) Operations Weekly Report, 2-14-68 b) LMEC FDH
15.	Valve - secondary plugging loop	Bellows leaked. Leak was small. No fire. Part replaced.	1	18,600	Visual	a) Report of EBR-II operations, 5-21-29 through 6-26-69 b) LMEC FDH
16.	Pipe	Sodium leak during valve repair. Valve cut out of pipe, pipe heaters turned on, sodium melted out and caused major fire. Human error was cause of failure.	600	Unknown	Visual	a) EBR-II Operation Report

TABLE 1-215

FERMI SODIUM LEAK INCIDENT SUMMARY

Item No.	Component	Incident Description	Leak Magnitude (lb)	Operating Hours	Detection	Failure Sources
1.	Valve - primary sodium system (6-in.-diam line)	Bellows leaked. No fire. Vendor repair.	1	15,000	Operational monitors	a) ADPA CFE-11 b) LMEC FDH
2.	Valve - primary sodium service (3-in.-diam line)	Bellows leaked. No fire. Vendor repair.	1	15,000	Operational monitors	a) ADPA CFE-11, page 22 b) LMEC FDH
3.	Valve - primary sodium service (3-in.-diam line)	Bellows leaked. No fire. Vendor repair.	1	1,632	Operational monitors	a) ADPA CFE-11, page 22 b) LMEC FDH
4.	Valve - primary sodium service (3-in.-diam line)	Bellows leaked. No fire. Vendor repair.	1	13,400	Operational monitors	a) EF-26, page 3 b) LMEC FDH
5.	Valve - secondary sodium plugging	Bellows leaked. No fire. Bellows replaced.	1	13,400	Operational monitors	a) EF-26, page 5 b) LMEC FDH
6.	Valve - secondary cold trap (3-in.-diam line)	Bellows ruptured. No fire. Bellows replaced.	1	11,010	Visual	a) EF-21 b) LMEC FDH
7.	Valve - transfer tank to cold trap (3-in.-diam line)	Bellows leaked. No fire. Defective component returned to manufacturer.	1	15,000	Leak detector	a) EF-52 b) LMEC FDH
8.	Cold trap - cold trap room	Sodium leaked through union seal ring joint. No fire. Local repair.	1	5,643	Leak detector	a) EFAFF-MR-44 b) LMEC FDH

TABLE 1-216

PLANT SODIUM LEAK INCIDENT DISTRIBUTION

Plant	Number of Incidents/Leak Magnitude (lb)						Plant Totals
	1	2	5	10	400	600	
SCTI	5	2		2	1		10
LCTL	3		4				7
SRE	25			1			26
Hallam	10	2		1			13
EBR-II	12	2		1		1	16
Fermi	8						8
Totals:	63	6	4	5	1	1	
Grand Total:							80

TABLE 1-217

COMPONENT SODIUM LEAK INCIDENT DISTRIBUTION

Components	Number of Incidents/Leak Magnitude (lb)						Component Totals
	1	2	5	10	400	600	
Sodium heaters					1		1
Steam generators				1			1
Pumps (mechanical)		1					1
Pumps (EM)		1		1			2
Tanks				1			1
Filters	1						1
Purification system components	2	1					3
Valves	52	2	3				57
Piping	5	1	1	1			8
Rupture discs	1						1
Freeze traps	1						1
Human error	1			1		1	3
Totals:	63	6	4	5	1	1	
Grand Total:							80

TABLE 1-218

COMPONENT FAILURE RATES

Component	Failure Rate $\left(\frac{\text{Failures}}{10^6 \text{ exposure hours}}\right)$
Sodium heaters	4.93
Steam generators	2.14
Pumps (mechanical)	0.78
Pumps (EM)	2.62
Tanks	0.51
Filters	3.57
Purification system components	1.41
Valves	2.75
Piping	0.0089
Rupture discs	12.08
Freeze traps	3.02
Human errors	9.09

PART 2. ADVERSE EVENTS OCCURRING PRIOR TO STARTUP

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I. INTRODUCTION

A. GENERAL

There exists increased concern with respect to events which have contributed to personnel injury and/or significant programmatic delay or cost increase for AEC facilities under construction or major modification. These unplanned events occur during material procurement, fabrication, shipping, and construction, and fall within the classification of the RDT definition of an incident. For the purpose of broadening sample coverage, less significant events which fall under the LMEC definition of Minor Malfunctions, Problems, or Non-Conformance Events, are also included. These are events which are not of a magnitude which the project is willing to define as significant but which, nevertheless, have importance in evaluating the effectiveness of the local quality assurance program and/or of applied specifications and standards.

B. APPLICATIONS

These data are used primarily by Program Management, Design Procurement, and Quality Assurance to:

1) Establish better control over fabrication through improved procurement specifications as standards, and more exacting acceptance specifications and procedures

2) Improve packaging and shipping procedures including logistics

3) Indicate deficiencies with respect to installation standards, rigging methods, and construction procedures including incompatibility of welding or other materials

4) Indicate the need for study or R&D in critical areas

5) Establish a basis for vendor, architectural engineer, and contractor evaluation with respect to performance capability of a specific system or component request for bid

6) Establish the need for additional incentive to encourage new industry to enter specific areas of very limited competition.

Failure rates have little meaning for these events since, if the cause is known, preventive measures will surely be initiated. Rather, as information is accumulated, appropriate frequency distribution curves will be shown for categories of importance to guide the user to those areas where initial effort might most profitably be directed.

Emphasis is placed on the mode of failure and its cause. Where available, incremental cost and programmatic delay time are to be used as weighting factors in contingency planning and logistic scheduling.

While it is a definite part of the overall program objective of the Maintenance and Malfunction Analysis Program to collect and evaluate historical data on preoperational events for publishing in this section of the handbook, LMEC has not been directed to proceed with the general collection of such data during the next fiscal year. The more important events (classed as Incidents), however, will be received and will contribute to a buildup of information in this category. Reported events will be divided into three important subcategories: fabrication and assembly, shipping or procurement, and construction.

For this issue, however, certain aspects of typical events which are encountered during the pre-startup design or fabrication period for either a new construction, a modification, or a test article installation are evidenced through review of LMEC's Quality Assurance Nonconformance Reports. These were initiated in July 1968 as an LMEC Quality Assurance control document. Some 61 Nonconformance Reports have been prepared during the past year. While some are related to minor quality control problems, many are more serious.

II. SUMMARY OF LMEC EVENTS REQUIRING NONCONFORMANCE REPORTS

A. FABRICATION AND ASSEMBLY

Approximately 50% of all nonconformance was associated with fabrication, although nearly half of these could be used in the as-received state.

Weld defects were by far the greatest problem. Other typical defects were:

1) Burrs
2) Lack of drawing checks, manufacturer's identification, testing
3) Demineralizer, pipe, seals, bearing housing studs, and instruments not meeting specification
4) Dirt contamination during fabrication or storage
5) Improper torquing during assembly, leading to leaks.

B. SHIPPING AND PROCUREMENT

Approximately 10% of reported events were associated with shipping and another 10% with procurement.

Shipping damage occurred to test articles, major system components, and minor parts. Two of these had the potential for creation of serious delays to the programs.

Procurement problems were associated with pipe material, pipe fittings, bearing types, and the wrong instrumentation. Defective pipe material did cause a serious programmatic delay.

C. CONSTRUCTION

Twenty-five percent of the problems were associated with field run welds during plant modifications. Other construction problems were negligible.

D. MISCELLANEOUS

Some non-conformance reports resulted from procedural violations.

Insufficient information is available here for specific recommendations, but the need for improved vendor quality assurance is evident. Welding problems in stainless steel systems are to receive more thorough investigation than any other problems.

PART 3
RELIABILITY/AVAILABILITY ANALYSIS

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I. INTRODUCTION

A. SCOPE

Part 3 expands the concept of reliability assurance for nuclear facilities beyond the fundamental failure mechanisms analysis emphasized in Parts 1 and 2. Improved understanding of failure mechanisms and their relative importance is most effective in the evolvement of greater reliability assurance during the test and prototype development stages and during initial design and construction of a new nuclear facility. As experience is gained from prototype and large-component test facilities, it is possible to gradually apply specific macroscopic information amassed over the years from research and development projects that have been undertaken in small test loops and laboratories. Accumulated statistical failure and fabrication tolerance data can then be applied to predict system, component, or facility reliability and availability.

Part 3 of this handbook does not develop the fundamental mechanics of reliability analysis. However, a fairly complete bibliography (Section VII) has been compiled on reliability, maintainability, system effectiveness, probability, and statistics to aid the reader in expanding his cognizance of reliability for specific applications. Also compiled is a list of current standards, specifications, and periodicals associated with these subjects.

Part 3 describes just enough of reliability fundamentals to permit the engineer or project manager to be aware of the pitfalls associated with application of various types of failure data and to more readily understand subsequent summary discussions on the current state-of-the-art.

As of this publication, few, if any, of these concepts have been developed to a state where they can be indiscriminately used by the layman. However, it is very important that responsible persons in the nuclear industry are aware of current technological development of tools available both presently and in the near future. A brief review and analysis of some of these concepts is given followed by a fairly extensive development of "fault tree" analysis with examples of applicability to availability and safety evaluation and conceptual design tradeoff studies.

Future expansion of Part 3 will maintain pace with the state-of-the-art and will develop and describe these concepts for use by both the layman and the expert as theory and experience progress permit.

B. PURPOSE

Emphasis in this handbook is upon large mechanical systems for which no other domestic program has been conducted to collect statistical failure data (random or other) in the volume necessary for confident reliability analysis and prediction. The aerospace industry has placed great store in the development of reliability prediction models for large propulsion systems using the design margin concept with normal or other stress-environment distribution functions. Considerable additional effort by theorists has gone into empirical molding of these model theories with small data sample failure experiences through Bayesian statistical methods. Validation of model theory through experiences has met with some success.

A concerted effort to develop this model concept through collection and application of: (1) stress/strain data, (2) fabrication tolerance and acceptance data, and (3) operational variances of specific component models coupled to verification by discrete tests holds the greatest potential for early attainment of a reliability prediction method for large mechanical components.

Conversely, it is impossible to perform system/component availability prediction without good component reliability data and specific knowledge of planned inspection periods and repair times. In the case of long lead-time items, warehousing logistics also become important. However, for preliminary system design evaluation of percent improvement in plant availability to be expected for specific modification or added redundancy, very crude component block reliability estimates are often sufficiently accurate to permit execution of sound programmatic decisions. The "Reliability Engineering" handbook, NAVWEPS 00-650502, discusses one estimation method. There are many others. Many methods of "failure tree" analysis have been developed. One of the most successful was that used in development of the Minute Man missile, the "fault tree" method. Fault tree, described later, was used in conjunction with failure modes and effects analysis to develop this most reliable missile.

C. APPLICATIONS

The following are typical applications:

1) Preliminary program planning and design optimization and trade-off studies

2) Plant modification trade-off studies

3) Establishment of effective design stress safety margins for components in a given variable evnironment

4) Statistical analysis of collective stress time effects from multiple environmental sources

5) Evaluation of the combined effect of cyclic transients and normal time effects

6) Prediction of expected component/system reliability

7) Application of methods for statistical design of additional R&D experimentation.

Failure mode and maintenance data from USAEC test facilities over the next few years should afford good data on failure modes, design limits, distributions, and very conservative lower limits on expected Mean Time Between Failure (MTBF). Good reliability data for sodium system design margins should be available from LMFBR prototype construction. Data on many of the other reliability parameters, such as maintainability, repair, inspection, etc., will be well established. Good reliability data on MTBF probably will not be available until 2 to 3 years after the first prototype is in operation.

From this it must be concluded that good availability analyses could not be conducted for 5 to 8 years on the sodium system. This is, however, the time it will be most needed. Ample data should be available on all other systems; and all of the other end item functions could be performed prior to prototype design, even if some conclusions are overconservative.

A quick review of the relationship between specific distribution functions, system types, and environmental conditions will help in clarification. In reliability analysis, extensive tests have indicated that failure patterns can generally be expressed by either the normal (Gaussian) or exponential distributions. Typical curves of both types are shown in Figure 3-1. A density function is defined as the probability that a certain value of a discrete variable will occur, expressed as a function of that variable. In reliability work, this variable is usually time, but may be any environmental design parameter. Data from test and experimental facilities will often afford much more reliable density functions for variables such as temperature, pressure, stress, and corrosion, etc., than for time dependent failure rates.

The normal distribution is generally used where the age of the item is significant to the failure rate. In this distribution, age significance is usually in the burn-in (preoperational period) or in the wearout portion of the life-cycle of the item. The exponential distribution is used for a reliability analysis where the probability of the cause of failure is random or unpredictable and where deterioration is not a cause of failure. The "random or unpredictable" test is

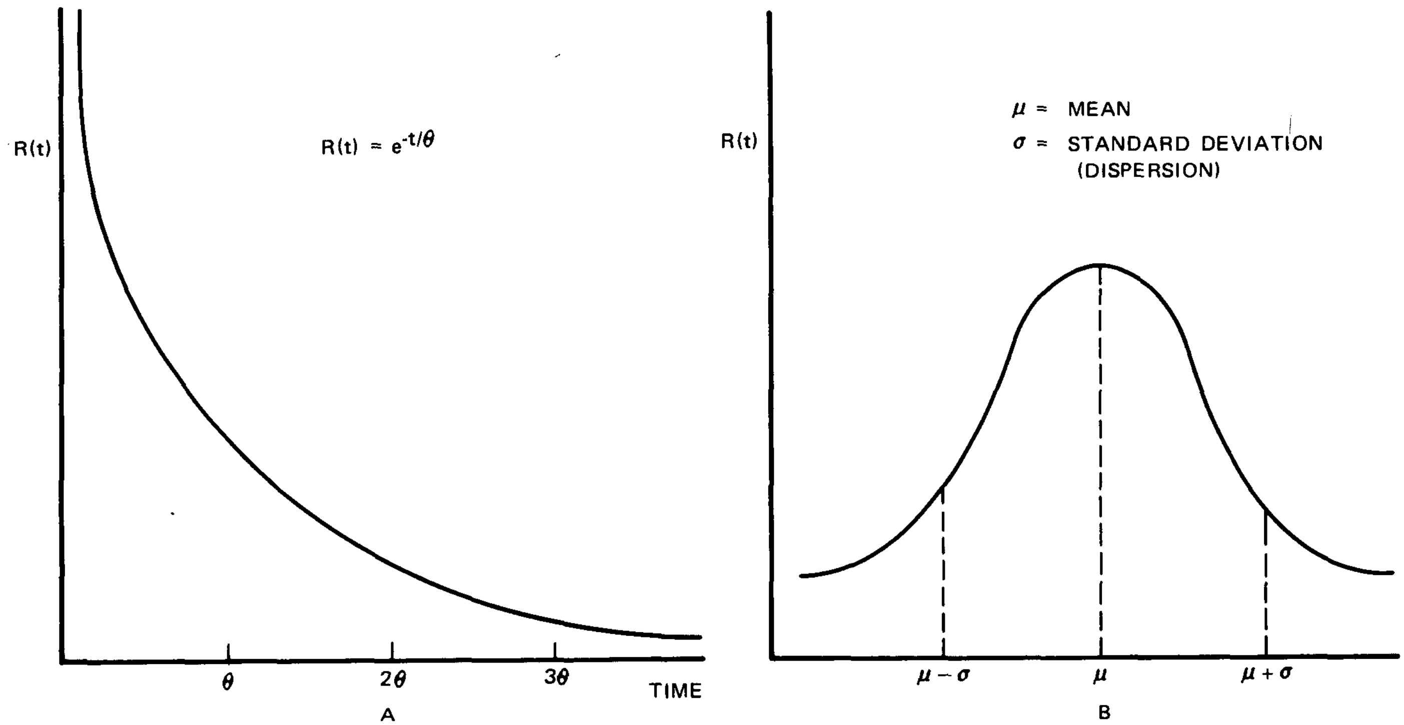

Figure 3-1. Exponential Reliability Function and Normal Function

well satisfied in most electronic systems and in very large or complex collections of mechanical systems past the burn-in period and after several repairs have tended to establish a constant failure rate. In most instances for mechanical systems, however, a single unit of equipment is being considered and either a normal or Weibull distribution should be used.

Figure 3-2 is an illustration of a typical failure rate-versus-time curve for electrical equipment and components. This is known as the "bathtub" failure rate curve. In the time period 0-T_1, the failure rate is constant and is categorized as random-catastrophic (comparable to burn-in). After T_1, wearout effects become apparent with increasing frequency, so that probability of failure increases. The significance of the burn-in period is more pronounced in systems in the developmental stage than in operational field performance. The LMFBR program will be in the developmental stage for several years to come with respect to many sodium components. Examination of the basic frequency

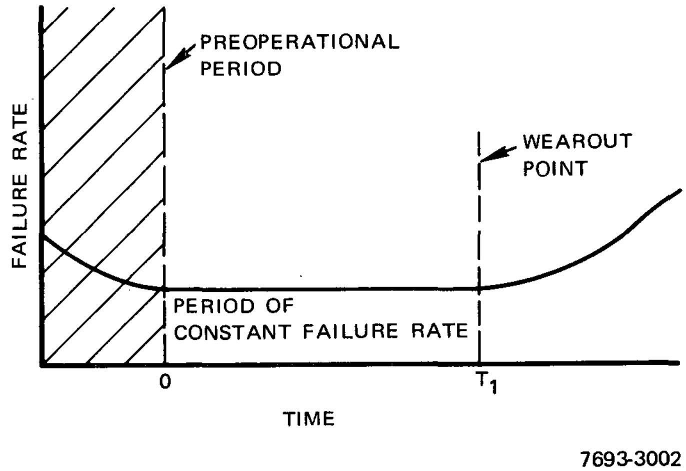

Figure 3-2. "Bathtub" Failure Rate Curve

function equation will afford a better interpretation of Figures 3-1 and 3-2. The reliability of the exponential function is given in Figure 3-1A as

$$R(t) = e^{-t/\theta}, \text{ where } \theta = \text{MTBF}$$

Conversely, the unreliability or expectation of failure is $1 - e^{-t/\theta}$. If $t/\theta \leq 10^{-3}$, then

$$1 - e^{-t/\theta} \cong t/\theta$$

Thus, $1/\theta$ is the constant failure rate between time 0 and T_1 in Figure 3-2. This is a highly desirable mathematical situation for system reliability and availability analysis.

On the other hand, the unreliability for the normal function of Figure 3-1B is 1-R(t) or an inversion of the indicated reliability curve. The failure rate then would resemble Figure 3-2 with the constant failure rate section removed. In LMFBR test facilities, data could be expected with very small standard deviation for specific components under test and considerably larger mean and standard deviation for support equipment. Large operating power plants should gradually approach a flatter distribution about the mean for some systems in which the concept of constant failure rate will become more applicable through random repair and replacement.

The Weibull distribution function has been found to fit experimental data better than the normal where burn-in failure rate is small (as in reasonably reliable mechanical components) and the time element of interest is small compared to mission objective. It is also much more preferable for computer analysis.

Acquisition and evaluation of nonconservative statistical parameters of reliability having a high confidence level (say 90%) is further complicated in the nuclear power reactor field by the fact that past experience indicates most severe faults occur during startup or while shutting the plant down. Many others have occurred during shutdown while performing maintenance or handling fuel. This necessitates division of the expected small volume of data into at least four operational environment categories as well as the numerous test level conditions.

It is concluded that adequate sampling is going to take a long time, but methods and theories are available to get started. The program must be well planned and work toward specific objectives. Some of these potential objectives are shown in Figure 3-3.

A discussion of fundamentals of reliability is hardly complete without examining the concept of confidence level or confidence limits. A theory relating confidence levels for normally distributed test data to the exponential case is developed by application of the Weibull distribution function. Symbols used in the following discussion are defined as:

t = available test time

θ_L = mean life, hence, MTFF (5 yr, 30 yr, etc.)

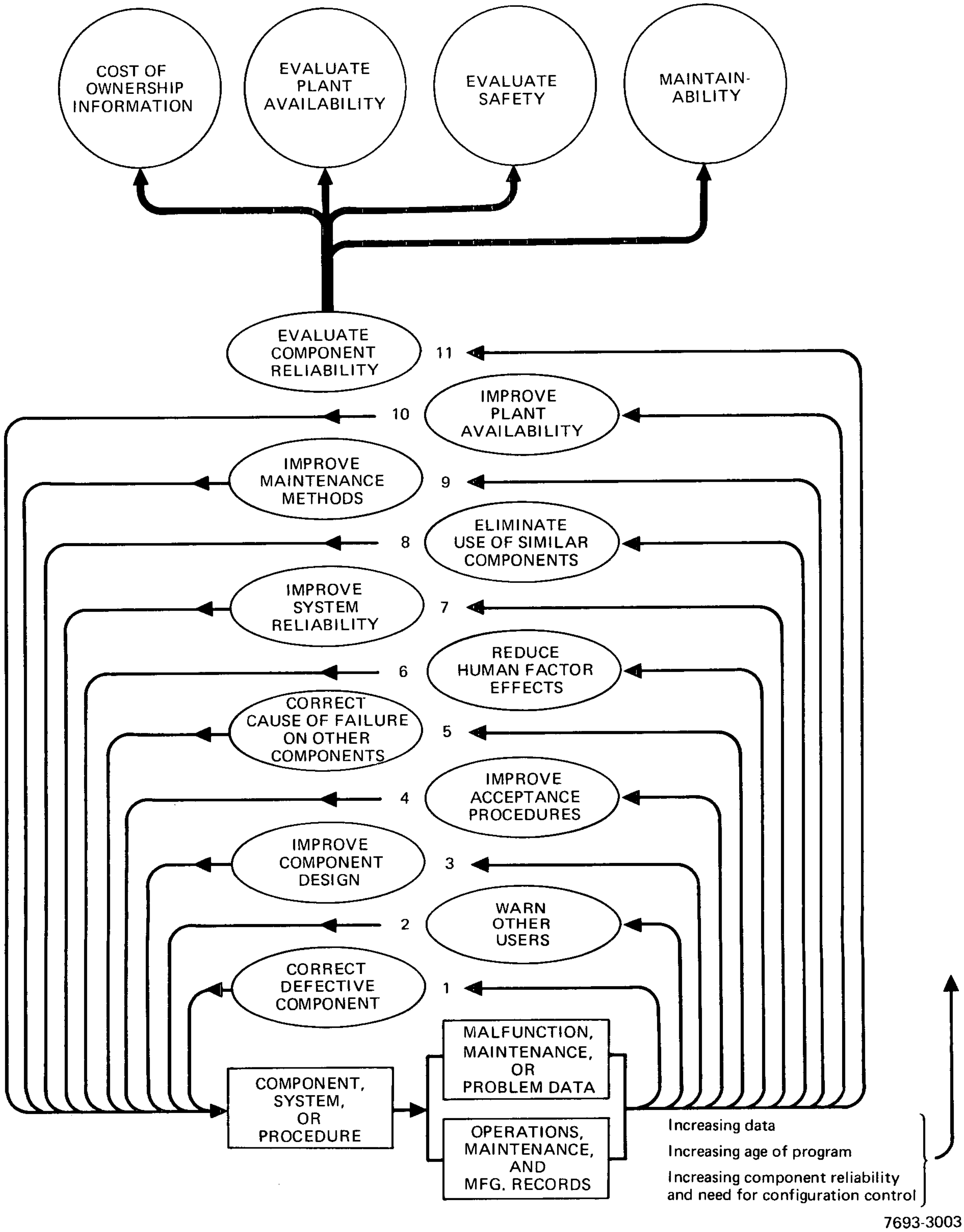

Figure 3-3. Progression of Quality with Timeliness for Collective Disciplines

γ = confidence coefficient or level, hence, the lower limit of the confidence interval, with the upper limit being 1 (100%)

F = number of failures of any of the test specimens

N = (number of test specimens), hence, number of independent trials whereby an independent trial is a complete test sequence of an individual test specimen, suggested by performing simulations to satisfy the appropriate environmental operating conditions

R = the true reliability

p = a probability of failure.

Under the assumption that N independent trials are being made, if F is the number of failures observed in these N trials, a statement may be made that:

$$p = 1 - R,$$

the true unreliability (probability of failure) is not more than C(F), hence

$$p < C(F) \quad ,$$

or, the reliability R,

$$R = 1 - p > 1 - C(F);$$

which implies that the experimentally established mean time to first failure will be equal to or better than the test results implied by the F failures during N trials, where the outcome of the test can only be called success or failure.

It must be noted that although the inequality,

$$0 < \gamma < 1,$$

is always true, a typical target value for the confidence coefficient is $\gamma = 0.75$. Furthermore, for the probability of failure, p,

$$0 \leq p \leq 1.$$

p here is unknown. Considering that the sample space is the number of failures (viz. 0, 1, . . . , N), the resulting binomial probability density function provides

$$I - \gamma = \sum_{j=o}^{F} \binom{N}{j} \left[C(F)\right]^j \left[1 - C(F)\right]^{N-j},$$

where j is an integer between 0 and F. Thus, a function, g(x), may be established so that

$$g(x) = \sum_{j=o}^{F} \binom{N}{j} x^j (1 - x)^{N-j},$$

which implies that a discrete number N can be determined for any particular given combination of γ and C(F), or that the value of the confidence level (coefficient) is clearly determined by the mathematical rule of the binomial theorem in the case of an exponential failure distribution.

Having an exponential distribution

$$R = e^{-\lambda t} = e^{-\frac{t}{\theta_L}},$$

for any ratio, t/θ_L, then any ratio of the testing time of the N independent trials to the desired mean time to first failure, G_L, of the test item, determines the minimum reliability provided that the failure follows the simple law of the exponential function. For these cases, numerical values have been developed, and graphs or tables have been devised where the ratio t/θ_L is plotted versus the number of failures for given values of the confidence level, γ , which determine the minimum number of independent trials necessary to prove that the desired mean time to failure, G_L, is either met or may be exceeded as a result of the test performance. For example, such tables are given by Lloyd and Lipow.*

To demonstrate the use of these tables, the following example is considered: Assume a hypothetical requirement for mean time to first failure to be 5 yr, so that

$$\theta_L = 60 \text{ months.}$$

Select a total available test time of 3 months, to obtain

$$t = 90 \text{ days.}$$

Then if a 75% confidence,

$$\gamma = 0.75,$$

is required, the following values are obtained:

$$\frac{t}{\theta_L} = \frac{3}{60} = 0.05,$$

$$F = 0,$$

$$N = 28.$$

This implies (as per Table A.2, page 488*) that in the case of 0 failures (F = 0), a minimum of 28 sample test specimens need to be selected for these independent trials to prove that a mean time to first failure of 60 months or better can be predicted. If there should be one failure during the test period, the number of samples needs to be increased to 55, or the test period needs to be increased to 6 months to prove the same reliability, etc.

---

*D.K. Lloyd and M. Lipow, Reliability: Management, Methods, and Mathematics (Prentice-Hall, Inc., Englewood Cliffs, N.J., 1962) pp 488-492

While this very simple relationship provides an easy determination of numbers, it is not, however, perfectly met in practical installations and in particular it is not seen by typically mechanical items which do not fail at random (as do electronic devices) but rather through wearout, with failure characteristics approaching a normal instead of an experimental distribution.

Because of the overpowering influence of wearout failures, it is felt that it is necessary to consider a failure density function other than the simple exponential law, but not necessarily a pure normal distribution.

As is known from the practical recording of scattergrams, failure density functions while approaching the form of a normal distribution curve may be skewed, either in the direction toward the origin of the plot or in the opposite direction. To assess the influence of such a normal distribution law or its skewed varieties, this phenomenon is best understood by using the Weibull distribution function,

$$1 - R(y) = 1 - e^{-y^{\beta}},$$

where

$$y = \frac{x - \gamma}{\eta} = t/\eta .$$

The shift of the distribution curve away from origin is expressed by the variable $x - \gamma$, and the compensation for the variation for scale is η; in this manner, it is possible to bring a family or Weibull curves together into the same plot. Figure 3-4 shows a family of Weibull reliability functions; the more familiar of the two is the family of Weibull (failure-rate) density functions for various cases of the exponent β.

It should be noted that two of the classic cases of Weibull density function plots for reliability are expressed by $\beta = 1$ and $\beta = 3.33$ (approximately); the former case is the pure exponential law and the latter case is the pure normal distribution law. The density curve plot shows that deviations from $\beta = 3.33$ produce skewed curves and in a manner that if β is larger than 3-1/3 (for

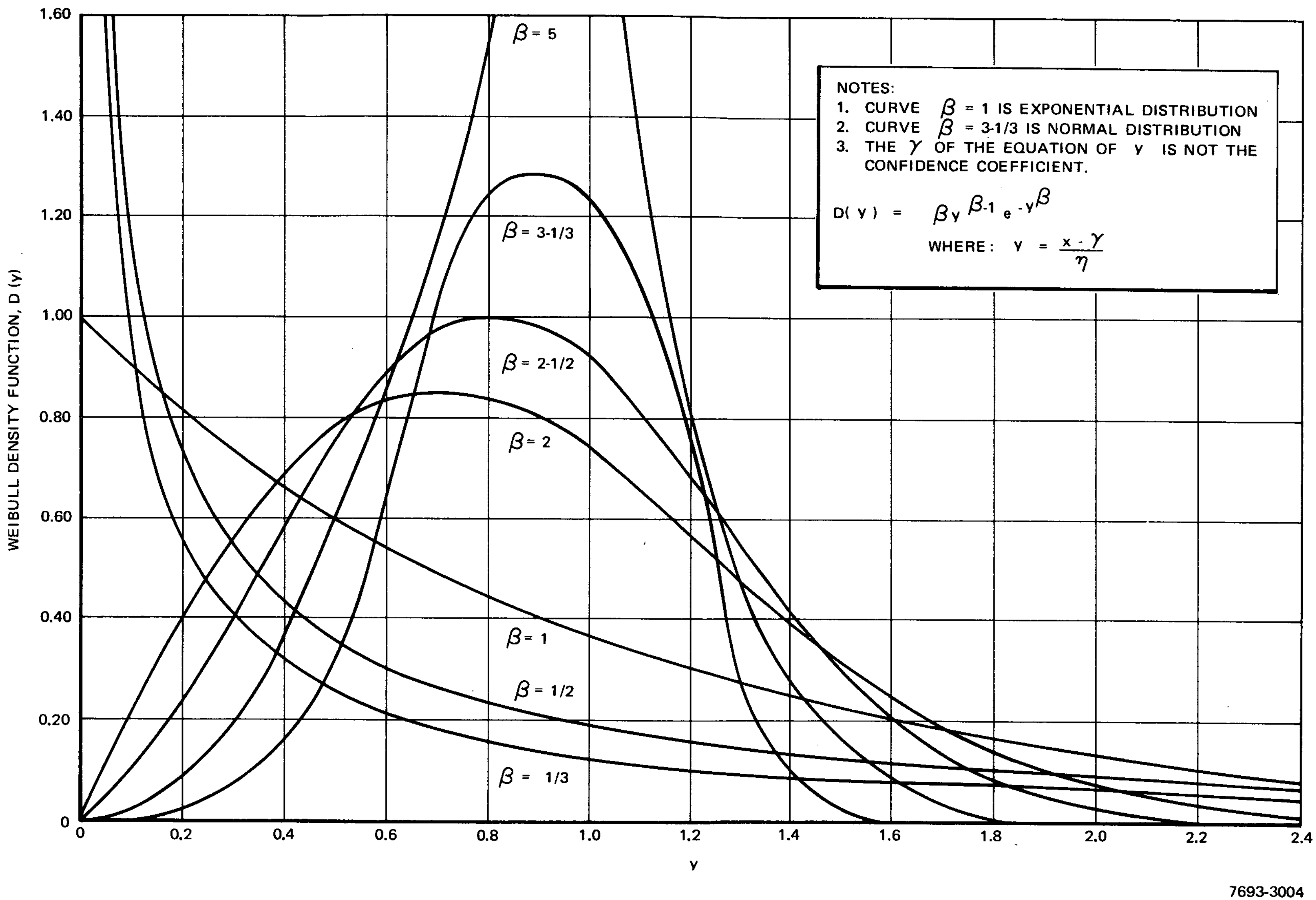

Figure 3-4. Family of Weibull (Failure Rate) Density Functions for Various Cases of Beta

example, 5), then the plot is skewed toward the origin; on the other hand, if β is smaller than 3-1/3 (for example, 2), then the plot is skewed away from the origin. The respective skewed curves indicate cases where the majority of the scattergram points would be nearer to the origin or further away. This implies that if a requirement for a stipulated MTFF value needs to be met, or exceeded, then quite obviously the normal distribution would need to be accepted as the worst case, or that a majority of points of any skewed approximation of the normal distribution needs to show better (hence, higher MTFF) values, and not the opposite, should test results be used for confirming the prediction. Hence, for all practical purposes, $\beta = 3\text{-}1/3$ must be accepted as an upper limit; and having obviously accepted $\beta = 1$ as a lower limit, a range of Weibull functions is now established within which the true failure density distribution may be found.

Having thus gained an understanding of the significance of the magnitude of the double exponential value and its practical limits, the analyst may proceed to investigate the influence of the variables introduced by the application of the Weibull function. This, however, is a complicated process and cannot be presented in a simple manner.

Lloyd and Lipow show that because

$$P\left[R \geq \exp\left(-\frac{\lambda T^{\alpha} \chi^2_{2\eta,\ 1-\gamma}}{2\eta}\right)\right] = \gamma,$$

where $\chi^2_{2\eta,\ 1-\gamma}$ is established by table review, a reliability prediction can be met at a given confidence level, γ, provided that α and λ are known, and at least N samples (hence, N independent trials) are available; and proves that the established reliability through the Weibull function is slightly better than the one through the exponential function for a particular example (a monitor generator failure histogram).

If, however, only a crude first approximation is desired, Figure 3-5 implies that for proposing a test plan with a limited number of test samples, the MTFF values based on the exponential distribution should be considered to offer a conservative estimate and is, therefore, acceptable. Should, however, cost limitations prove such that a test program be prohibitive, the contractor should be

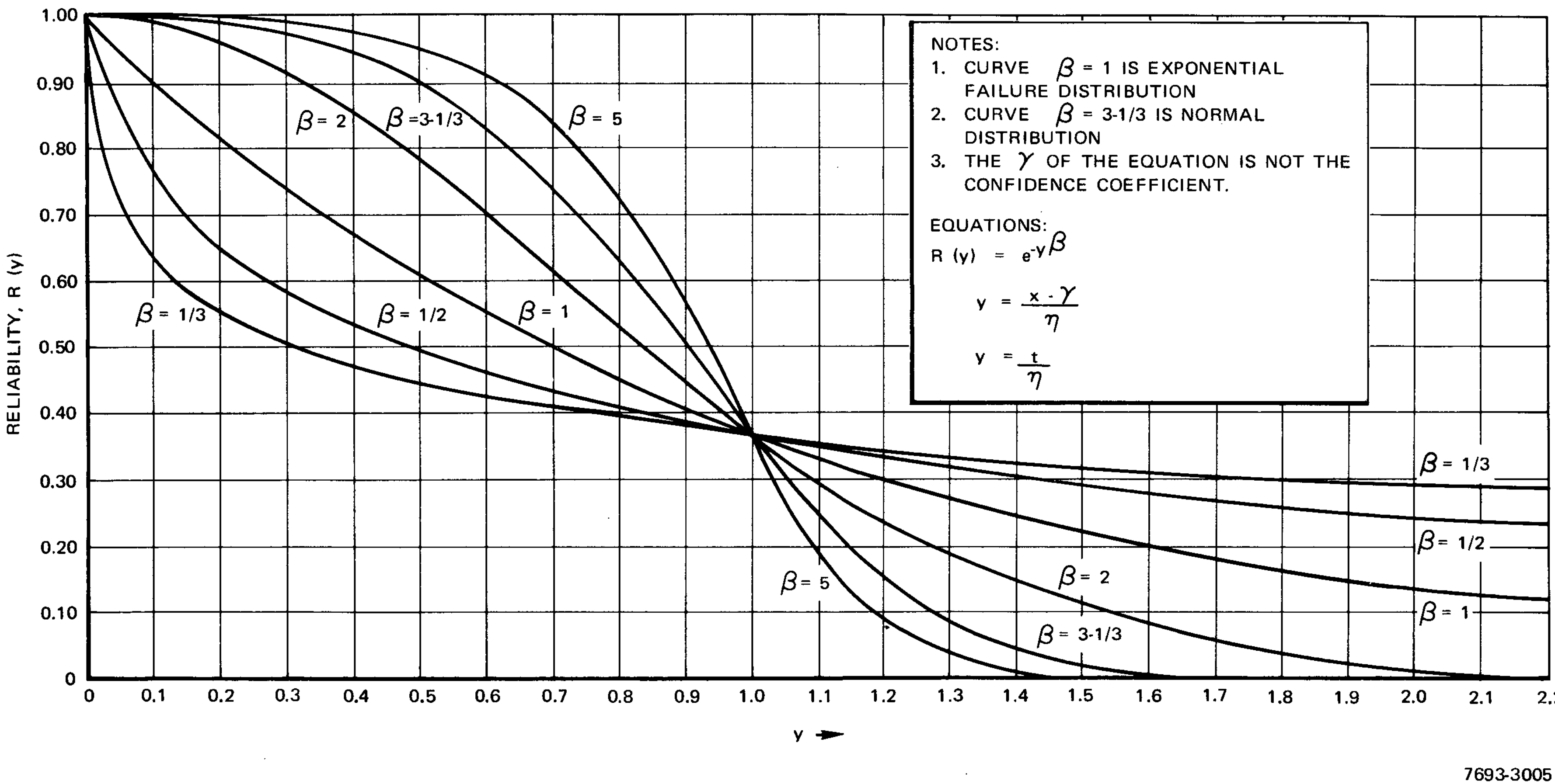

Figure 3-5. Family of Weibull Reliability Functions for Various Cases of Beta

required by his own analysis and field experience data to prove that a smaller number of test samples or shorter test periods, or both, will still provide a satisfactory MTFF prediction because of a more faborable failure density distribution.

III. APPLICATIONS OF RELIABILITY THROUGH USE OF DESIGN MARGIN

The Space Division of North American Rockwell Corporation made extensive use of relating the overlap of a specific threshold failure design margin and a variance magnitude-dependent reliability margin as an estimate of failure probability. In particular, this method was applied to the reliability evaluation of the APOLLO thrust engines for which, obviously, a large failure rate sampling could not be obtained. This reliability assessment could then be converted to MTBF. The principle is briefly explained in this section.

One comparison between design margins and the level of quality achieved is illustrated in Figures 3-6 and 3-7. As shown, a reliability margin can be obtained either by a large design margin and low level of quality or by a smaller design margin and high level of quality. The choice depends on feasibility and cost considerations. The reliability problem is: (1) to provide a design margin that will tolerate the level of quality actually achieved or (2) to provide a level of quality compatible with the design margin that can be provided.

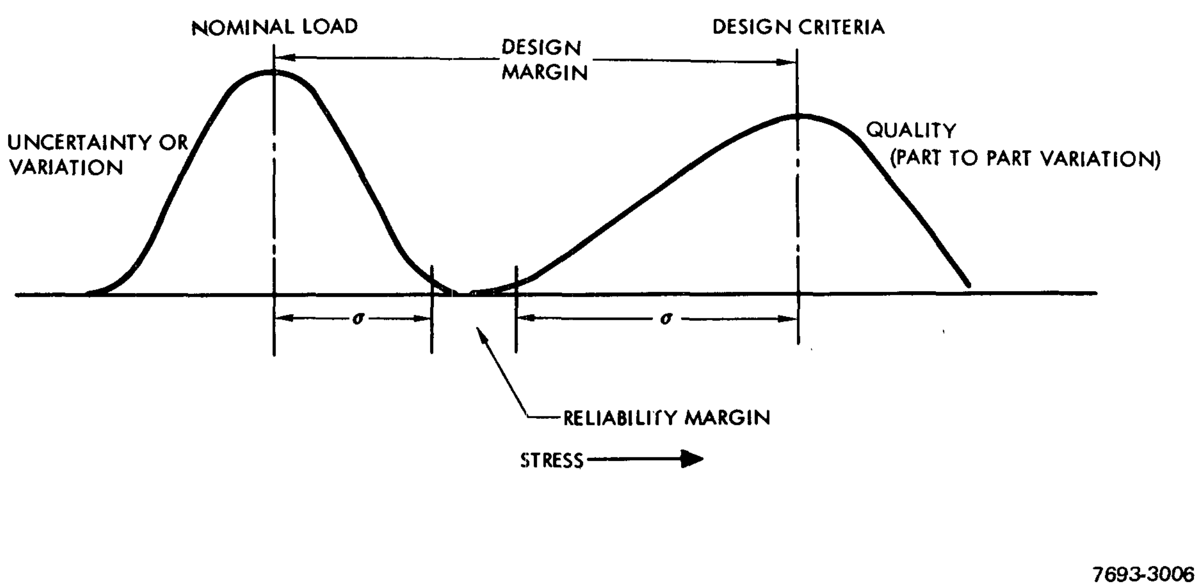

Figure 3-6. Design-Quality Relationship I

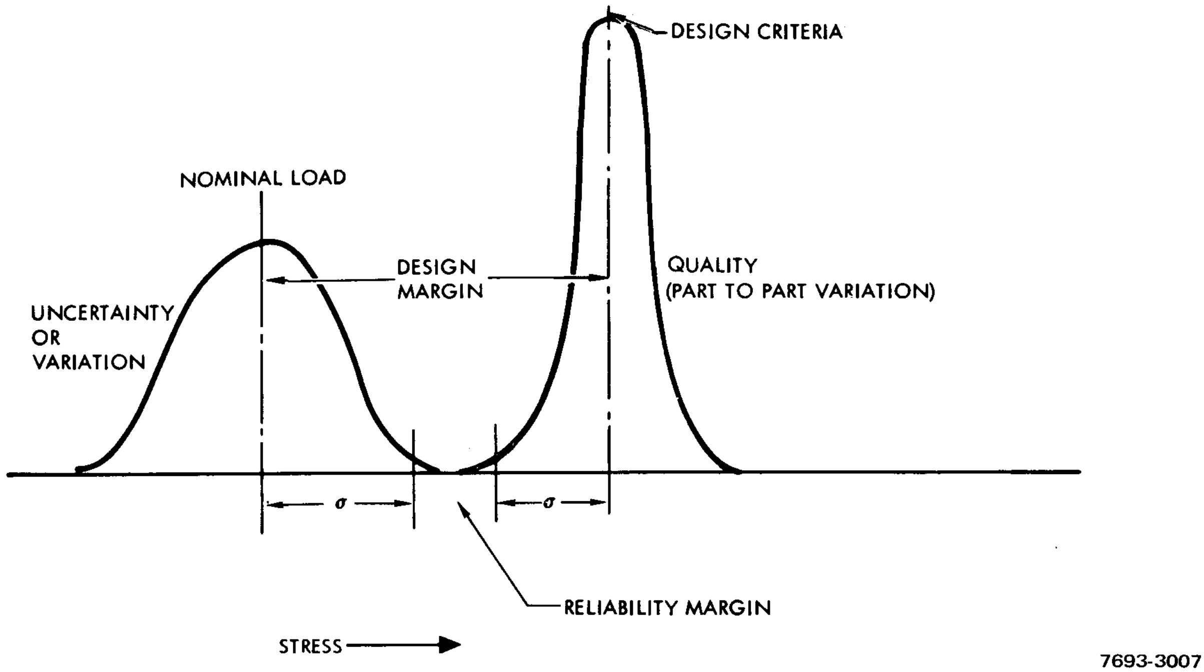

Figure 3-7. Design-Quality Relationship II

The influence of time and mission environments on the equipment characteristics is illustrated in Figures 3-8 and 3-9. This influence must also be considered in a reliability control program, because it results generally in a broadening of the distribution of equipment characteristics which, in turn, reduces or eliminates the reliability margin that may have existed when the equipment was new.

Past programs have been characterized by their extensive flight test efforts and by an uncertain reliability that has gradually improved through extensive failure-reporting systems and field modification. In space programs involving only a few vehicles, there is little or no opportunity for reliability growth through a feedback and improvement process.

The statistical treatment of the resulting data will produce the frequency distributions of Figure 3-10, including assessments of the probability that thrust will fall below the acceptable minimum or that a weak case and high case pressure will exist simultaneously and result in case rupture. The

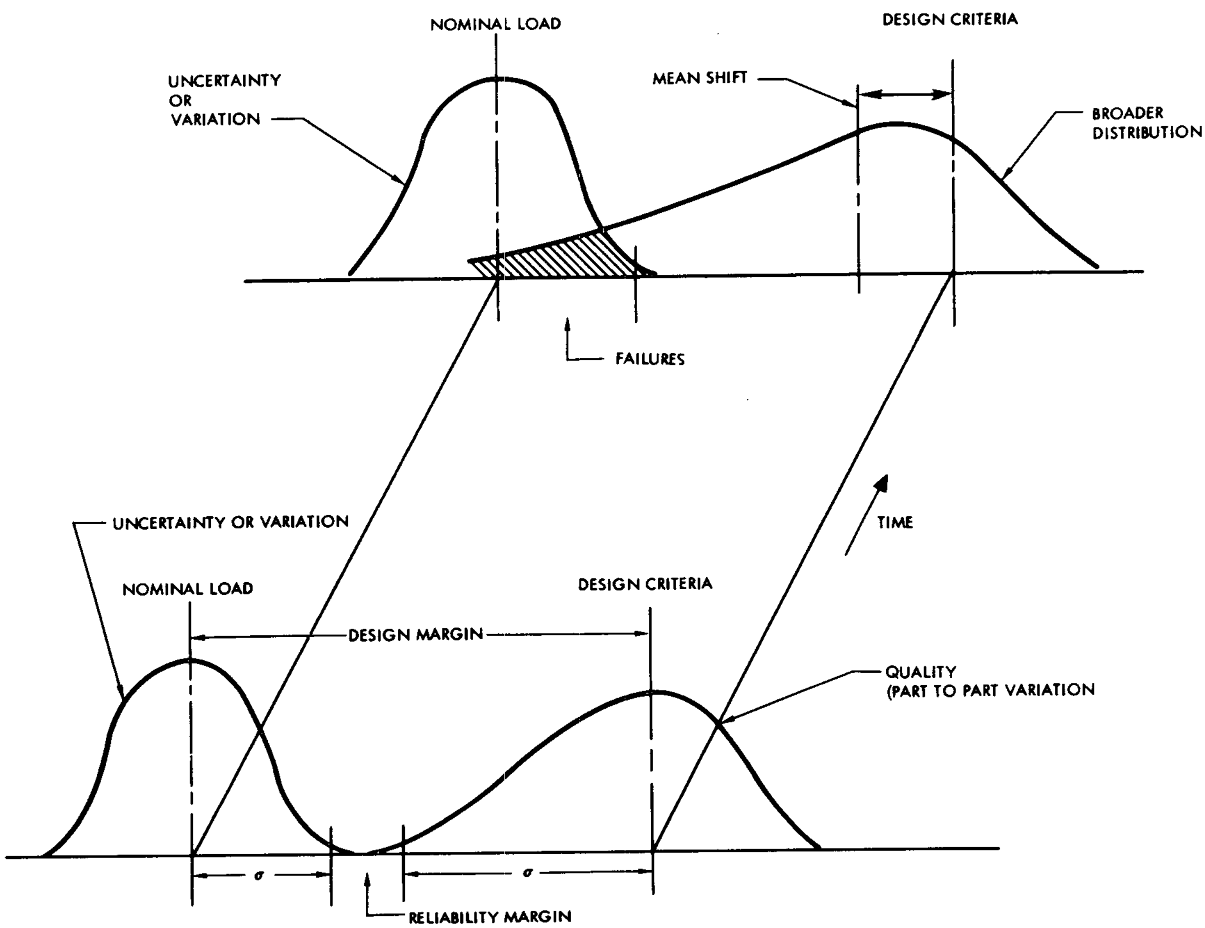

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Figure 3-8. Design-Quality Relationship III

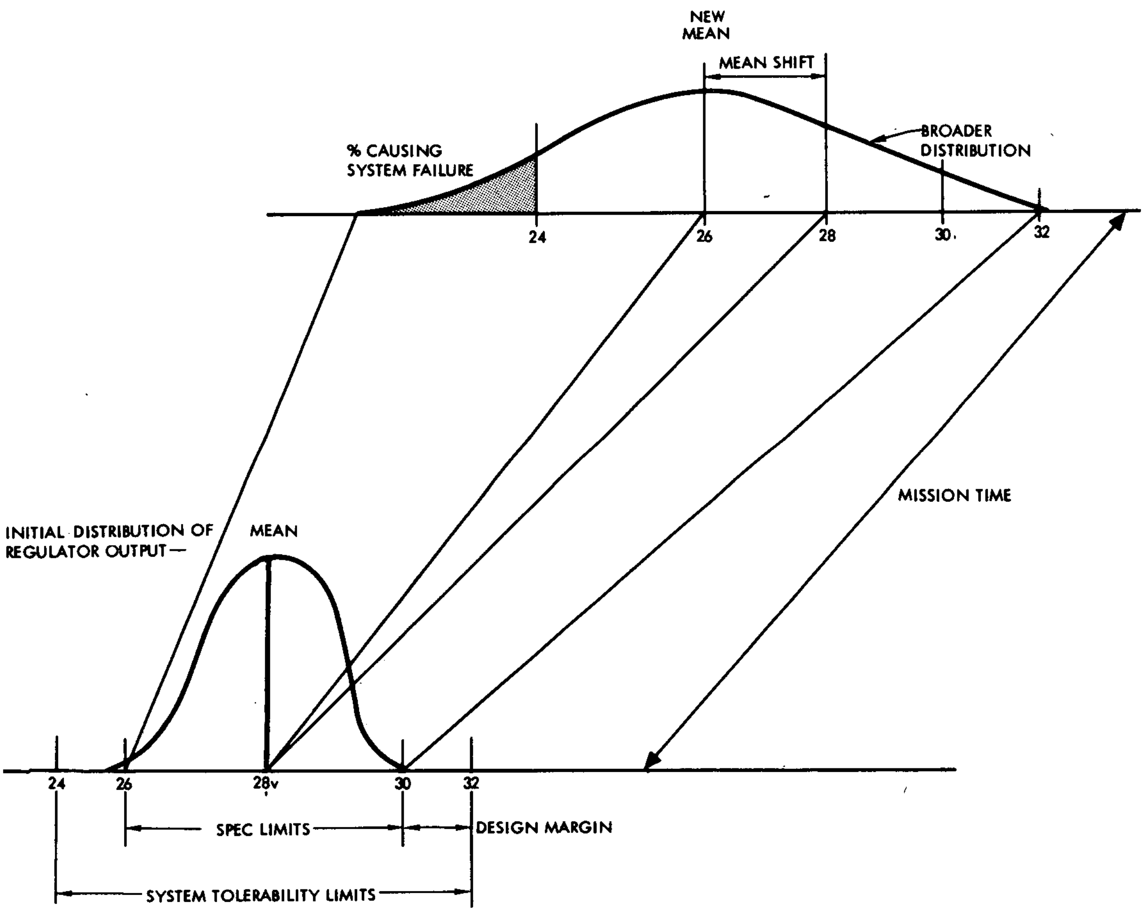


Figure 3-9. Influence of Mission Time on Variance

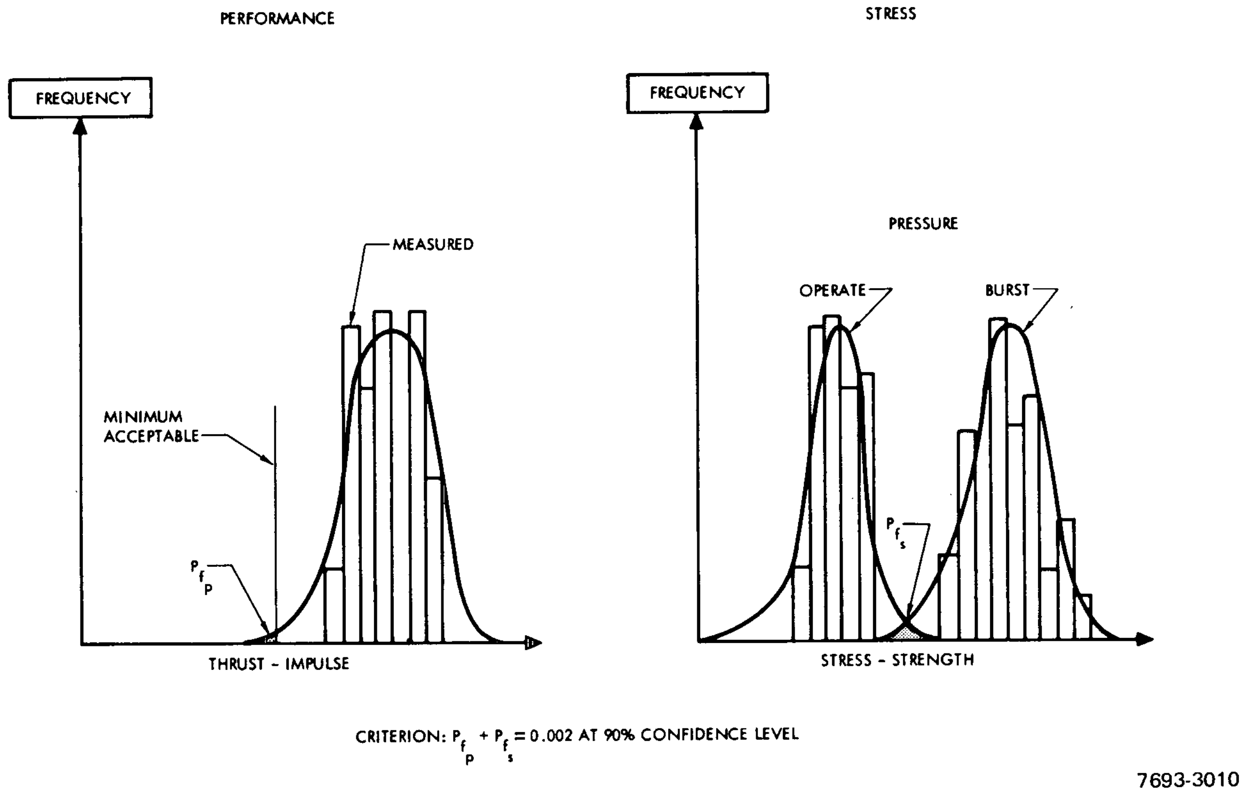
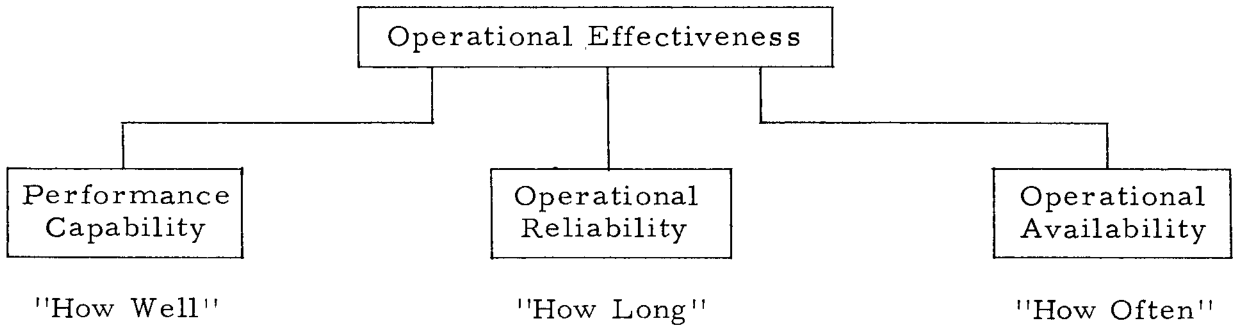


Figure 3-10. Statistical Analysis

reliability of the motor then can be synthesized from these and other similar probability statements derived from motor-firing data. If the tests have been planned to yield adequate data, a high-level confidence statement also can be attached to the assessment.

IV. FUNDAMENTALS OF PROJECT PLANNING*

A. OPERATIONAL EFFECTIVENESS



Effectiveness (E) = Performance (P) x Reliability (R) x Availability (A).

Example:

Plant, when in operation, averages 90% of desired load factor.

$$P = 0.9$$

Probability of plant failure between scheduled outages is 20%.

$$R = 0.8$$

Probability of additional outages is 10%.

$$A = 0.9$$

$$E = 0.9 \times 0.8 \times 0.9 = 0.65$$

B. OPERATIONAL RELIABILITY

Operational reliability equals manufactured reliability times installed and used reliability. If λ_i = basic failure rate (inherent) and K_r is the degradation factor, then λ_s (the system failure rate) = $K_r \lambda_i$.

$$R = (1 - K_r \lambda_i \tau_i) = (1 - \lambda_s \tau_i).$$

---

*Excerpted from Handbook-Reliability Engineering, NAVWEPS 00-65-502

$$\lambda_i \rightarrow \tau_s \text{ under true field test conditions.}$$

$$\text{Exponent of } R_i(\tau_o) = e^{-\lambda_i \tau_o} \text{ (check against actual approximate).}$$

C. OPERATIONAL AVAILABILITY

Operational availability equals intrinsic availability times degradation effect. The equations are the same as for Operation Reliability, except that the τ's are modified to account for the repair time.

D. SYSTEM AVAILABILITY AS FUNCTION OF MTBF AND MAINTAINABILITY

$$A = \frac{MTBF}{MTBF + \overline{T}_r} = \frac{1}{1 + \frac{\overline{T}_r}{MTBF}}$$

where

λ = failure rate

$\overline{T}_r$ = mean downtime due to failure.

MTBF here refers to a composit system MTBF.

Observed MTBF averaged about 1/7 of MTBF specified to vendor for complex fleet operations elements. Ask for 200 hr MTBF if you really require 100 hr.

The effect of nonindependence of failure might be expected to contribute to this difference between theoretical and observed failure rates.

A project engineer must:

1) Know and define the level of reliability he wants

2) Recognize the disparity between what he wants and what he probably will get unless he exercises the required degree of "control" over the reliability growth process

11

3) Understand the application of certain of the "tools" available to him by which this controlled reliability growth can be assured — not merely promised.

E. OPERATIONAL REQUIREMENTS AND ALLOCATION

The procedural steps (project engineer steps in technical development planning) are as follows:

Step 1. Total system functional diagram (interdependence). Subsystem block diagram with interfaces (operational). Define typical applications.

Step 2. Define anticipated use and environmental conditions.

Step 3. Establish duty cycle. Tabulate interaction and subsystem involvement — operating times, etc.

Step 4. Effectiveness requirements. Joint probability is defined as being ready to perform on demand, and of surviving required performance period without failure and "at the specified level of performance." (The latter is sometimes assumed as equal to 1.)

Step 5. Define system performance requirements and system "failure" by operating mode. May be described as distribution functions with lower allowable limits and specific goal. Noninterdependence of failures must be recognized. (Usually the lower 90% confidence level is applied.)

Step 6. Define reliability requirements. Construct preliminary reliability block diagram from the functional diagram of Step 1. This should show series-parallel relationship, etc., for reliability objective. A failure mode and effect block diagram would be applicable or a fault tree (Section VI) could be used here as an unreliability diagram, but evaluation of the validity of the approximation,

$$(1 - e^{-\lambda\tau}) \cong \lambda\tau \text{ if } \lambda\tau < 10^{-3},$$

should be checked for error in applying the $\lambda\tau$ fault tree method of analysis.

Again, "nominal" and "minimum" reliabilities are calculated. Nominal makes use of performance goal capabilities while minimum uses the lower 90% confidence level.

On-line maintenance is sometimes shown as a partial redundancy. Also planned potentials for redundancy should be shown.

In failure modes-and-effects type analysis, alternate paths must be evaluated and the composite reliability determined.

Step 7. Define availability and maintainability requirements. Establish required design criteria for MTBF, repair time, or both (establishes interdependency).

F. RELIABILITY, FEASIBILITY, ETC., AND ALLOCATION

Failure rates for acceptable system reliability must be apportioned between the subsystem and components for compliance by development contractors.

Determine requirements for:

1) R&D

2) Precontract award reliability studies

3) Trade-off studies

4) Contractual monitoring program

5) More accurate scheduling prediction.

Active Element Groups (AEG) are defined as the smallest practical building block which can be economically considered, where active element is defined as a device which controls or converts energy.

Procedural steps are as follows:

Step 1. Develop Reliability block diagram.

Step 2. Devise mathematical models.

Step 3. Establish complexity and MTBF of AEG systems.

Step 4. Establish AEG subsystem failure rates.

Step 5. Establish feasible MTBF and reliability.

Step 6. Allocate λ and reliability.

Step 7. Consider redundant configuration.

Step 8. Evaluate feasibility of allocated requirements.

Steps 1 and 2 are typical and are handled classically as F, M, and E diagrams or fault tree with appropriate logic.

Step 3 uses the bandwidth of equivalent system experience factor to relate the stipulated AEG complexity to a range of expected MTBF. This step applies to the first level of block diagram of the major system (see Figure 3-11).

Step 4 repeats Step 3 for subsystem if sufficient design detail is available.

Extend the analysis to catastrophic and interacting failures with the following rules:

1) Subsystem complexities are not interdependent.

2) Power system AEG's have expected failure rates twice that of analog type systems of similar complexity (see Figure 3-11).*

3) Digital systems differ from their analog counter-parts by 10 to 1 (i. e., the complexity may be divided by 10).

Step 5 makes use of the distribution bandwidth to predict expected minimum, maximum, and average reliabilities for the desired mission time.

Step 6 takes estimated subsystem failure rate ratios for anticipated reliability and uses these ratios to allocate required failure rates for required reliability (assume same series construction).

Step 7 formalizes simple math technology for insertion of redundancy to obtain desired subsystem improved failure rate. The example uses no approximation except for addition in a series circuit.

*With time, this type of information should be developed for systems other than electronic.

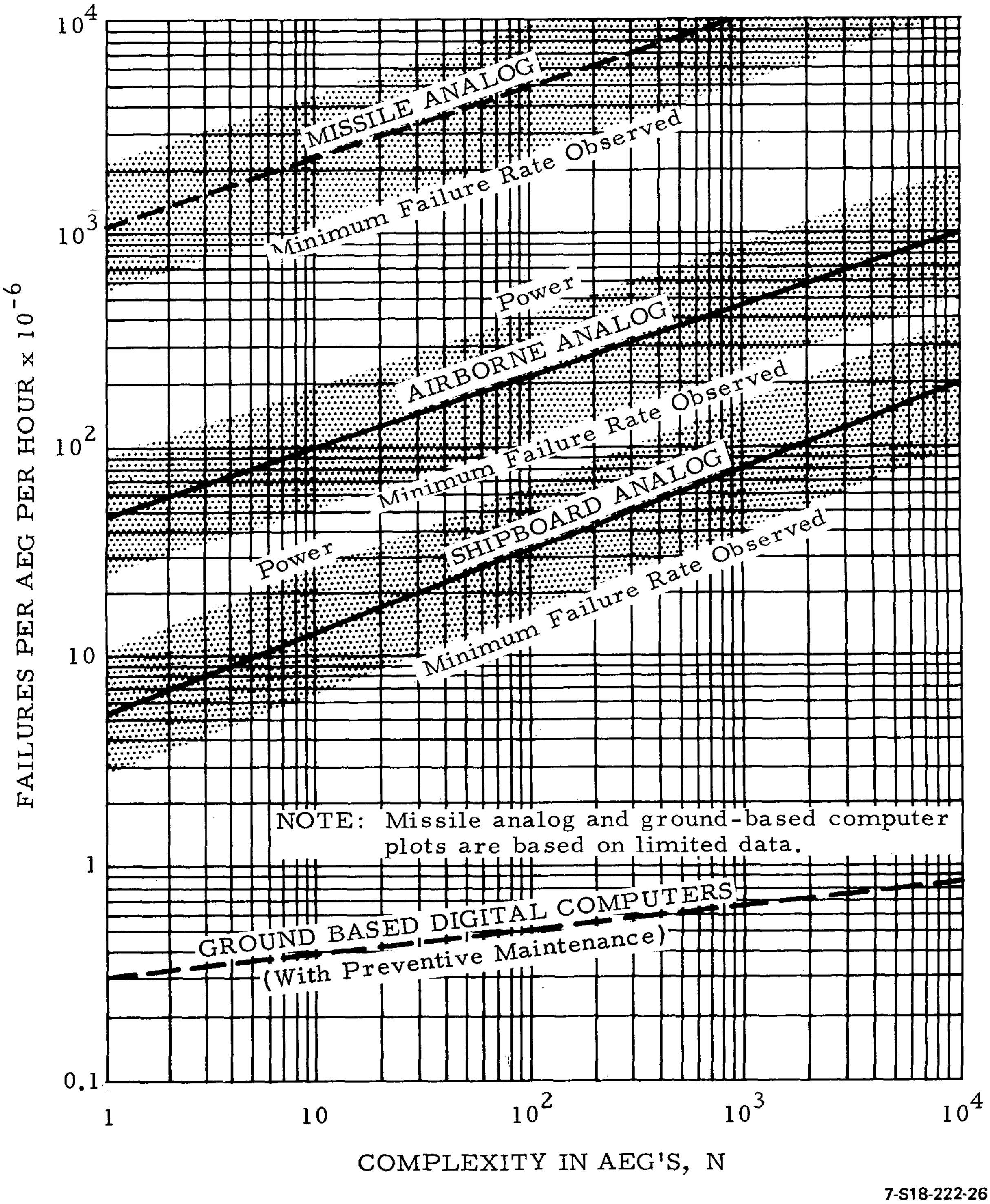


Figure 3-11. AEG Failure Rates for Reliability Estimation When the Number of Active Elements is Known

Step 8, feasibility of requirements is evaluated in accordance with the following guide lines:

1) Level A - "Practically" Feasible. Required reduction in failure rate by factor of 2 under conventional design. (R&D and test program required)

2) Level B - "Conditionally" Feasible. Required reduction of between 3 and 10 over an operating period not exceeding the expected mean life. (R&D, tests, and redundancy required)

3) Level C - "Remotely" Feasible. Required reduction of 1 to 2 orders of magnitude over a period exceeding mean life expectation. (Basic applied research required)

Specifications are:

1) Level A - specify as from design requirement.

2) Level B - specify as from design requirement but final layout, complexity, and additional space requirements may be prohibitive and require specification revision.

3) Level C - specify as design objective in a formal research program to assist in establishing final design specifications.

G. ESTABLISHMENT OF MAINTAINABILITY AND AVAILABILITY IN THE DESIGN PHASE

Step 1.

$$\text{Availability (A)} = \frac{\text{Uptime}}{\text{Uptime + Maintenance Downtime}}$$

$$= \frac{1}{1 + \frac{\text{Mean time to Repair (MTR)}}{\text{MTBF}}}$$

$$\text{MTR (required)} = \left(\frac{1}{A^*} - 1\right) \text{MTBF}^*$$

*Tentative design specification.

MTR is defined as total time lost due to the malfunction (including detection time). The definition may be expanded to include preventative maintenance (PM).

Step 2. Estimate AEG feasibility from experience charts for conventional design (see Figure 3-11). Using minimum MTR and maximum MTBF as indicated from figure bandwidth, an estimation of maximum feasibility can be obtained.

Step 3. Estimate maintenance feasibility by analysis of design concept. Analyze each subsystem for complexity, failure rate, failure rate or redundancy improvement, mean repair time (no waiting time), and mean waiting time. Solve for availability and compare with that required.

Design improvement is given by:

$$\text{Improvement} = \frac{1 - A\ (\text{expected})}{1 - A\ (\text{predicted})} .$$

Step 4. Evaluate effect of duty cycle on subsystem availability. It is usually assumed that no deterioration of mechanical systems occurs during study. This assumption must be reviewed for each subsystem and converted if warranted.

Repairs during study or idle time are weighed in by adjustment of MTR.

Example: If upon a random demand the equipment is needed only 10% of the total time (such as startup equipment following a scram) and repair can be accomplished during reactor operation, then

$$A_o = \frac{1}{1 + \frac{\text{MTR (D)}}{\text{MTBF}_o}} .$$

D is the fractional duty cycle (i. e., 0.1 for example). This also applies to on-line repair of standby redundant equipment. Active redundant equipment must be analyzed differently since the system MTBF also varies during the on-line repair, unless modular replacement is a function of design.

If deterioration occurs during standby, the probability of availability during standby is

$$A_s = \frac{1}{1 + \frac{MTR_s\,(1-D)}{MTBF_s}}$$

where (1-D) = the standby duty cycle, D = the fractional duty cycle, and $MTBF_s$ and MTR_s are for standby duty cycle.

Actual availability:

$$A = A_o A_s = \frac{1}{1 + \frac{MTR_o\,(D)}{MTBF_o}} \times \frac{1}{1 + \frac{MTR_s\,(1-D)}{MTBF_s}}$$

$R_o(t)$ (operational reliability) = $\exp \frac{-t}{MTBF_o}$

$R_s(t)$ (Standby Reliability) = $\exp \frac{-t}{MTBF_s}$

$E(t)$ (Effectiveness) = $A \times R(t)$.

Step 5. Assess effectiveness growth potential. Compare effectiveness of "conventional" design with predicted "feasible" level of effectiveness achieved by proposed new design. Plot these as a function of mission time and examine improvement ratio.

V. CURRENT STATE-OF-THE-ART

The most current information on the state of reliability methods as applied to mechanical systems was given at the 7th Annual Reliability and Maintainability Conference at San Francisco, California, July 14-17, 1968.

A. SUMMARY

A review of portions of the transactions, "Annals of Assurance Sciences, 1968," follows. LMEC feels that the work presented in the last two sessions will be of particular value in assisting the development of reliability and availability and of evaluation models of sodium components and systems.

Reliability Techniques and Their Role in Program Optimization

This session summarizes very well the history of reliability development during the last few years, and denotes the relationship between Reliability Engineering, Quality Assurance, and Management.

Assurance by Testing, Aging, and Surveillance

The evaluation of aging is rather new to the reliability field. This session described extensive work being conducted in endeavors to understand the molecular and atomic transitions which occur during aging. In defining the technical representation of these effects, a correlation was made with the wearout portion of the bathtub curve.

While aging was the topic of this meeting, the aging concept could readily apply technically to better understanding of the concept of wearout.

Human Error Prediction and Control Through Human Factors Engineering

Throughout much of the work conducted at LMEC in evaluating malfunction data, it has been shown that human factors have contributed to approximately 35% of the failures. These papers described development over the last couple of years in refining the methods of understanding and correcting human error as contributing to massive failures in the aerospace systems.

Bayesian Applications to Reliability and Maintainability

Bayesian applications have been known for many years to those who deal in cost analysis and logistics from the statistical standpoint. The great advantage associated with the Bayesian method was that it tends to define a degree of confidence in statistical results without the need of a large population sample examination. On the surface, it would tend to be assumed that this would be actually the type of analytical method needed for reliability applications to analysis of mechanical systems wherein a large population sample is impossible to obtain. In 1967, LMEC examined the potential of this approach by studying the literature available at that time and arrived at the conclusion that the theory was not acceptable with any degree of confidence to LMEC needs. This is the first Rel. and Maint. Conf. session given on Bayesian applications to reliability and maintainability. Much theoretical work has gone into development of more refined techniques of applying the method to mechanical components and complex analytical systems. The fundamental idea is to make greater use of individual experiences over the many past years of in-house operational, maintenance, and construction personnel to come up with a reasonable a priori estimation of life for specific components in a specified environment even though very little or no actual failure data are recorded. These guesses are designated as priors to reliability calculations. Compared with system tests, each failure or success weights the prior expectation. Details of this method will be extensively studied* and should prove very valuable to LMEC.

Research (Structural and Mechanical)

This probably was the most important session in so far as mechanical components are concerned. It followed rather logically the Bayesian session since the speaker was again talking about applying best guess through extrapolation of data to analytical model development of failure distribution functions and

*LMEC has published a report on its initial investigation into Bayesian applications. It is titled, "Bayesian Statistical Model Theory for Mechanical Systems," by J. P. Walter, LMEC-69-8.

comparing these estimates to a minimum of experimental data. The safety margin concept applied by North American Rockwell Space Division and Rocketdyne to the evaluation of expectation of reliability for the propulsion motors did not prove very successful as applied. However, there have been recent indications of technology improvement. Much work has been done both by industry and by university professors and graduate students to expand the theory and correct the facilities in the engineering models. Dr. Kececioglu, of the University of Arizona at Tuscon, has been especially active in advancing the technological aspects of this endeavor. Several additional parameters have been added to the original model concept and the details of analysis have been very carefully developed along with some graphic models for data evaluation. These models were for exponential, normal, and log-normal distributions and will prove of extensive value to LMEC.

B. DISCUSSION

1. Reliability Techniques and Their Role in Program Optimization (Session 1)

"Survey of Reliability Prediction Techniques," by C. M. Ryerson, Senior Scientist, Hughes Aircraft, Culver City, California

MIL-HDBK-217A, which is essentially the principal reference document on electronic failure evaluation, is to be supplemented with MIL-HDBK-217B in which mechanical system failures have been developed. Normalization factors have been applied to some equipment in order to relate laboratory environment data to the worst condition of actual environment. (This handbook was developed by Hughes Aircraft Company under contract to NASA and has since been released.)

Some 12 methods of reliability prediction were discussed with respect to effectiveness and application to specific areas. Methods 6, 7, and 8 were derating approaches and were considered as being a sound basis for purification of data and clearing up numerical discrepancies. Method 9 is used as a confirmation of assumptions urgently needed with respect to interface conditions at the time of the test. The author felt that these methods were the most important available and could be applied with confidence if used in proper perspective.

"System Analysis Via Probability Diagrams," by R. W. Stoffel, Martin Marietta, Denver, Colorado

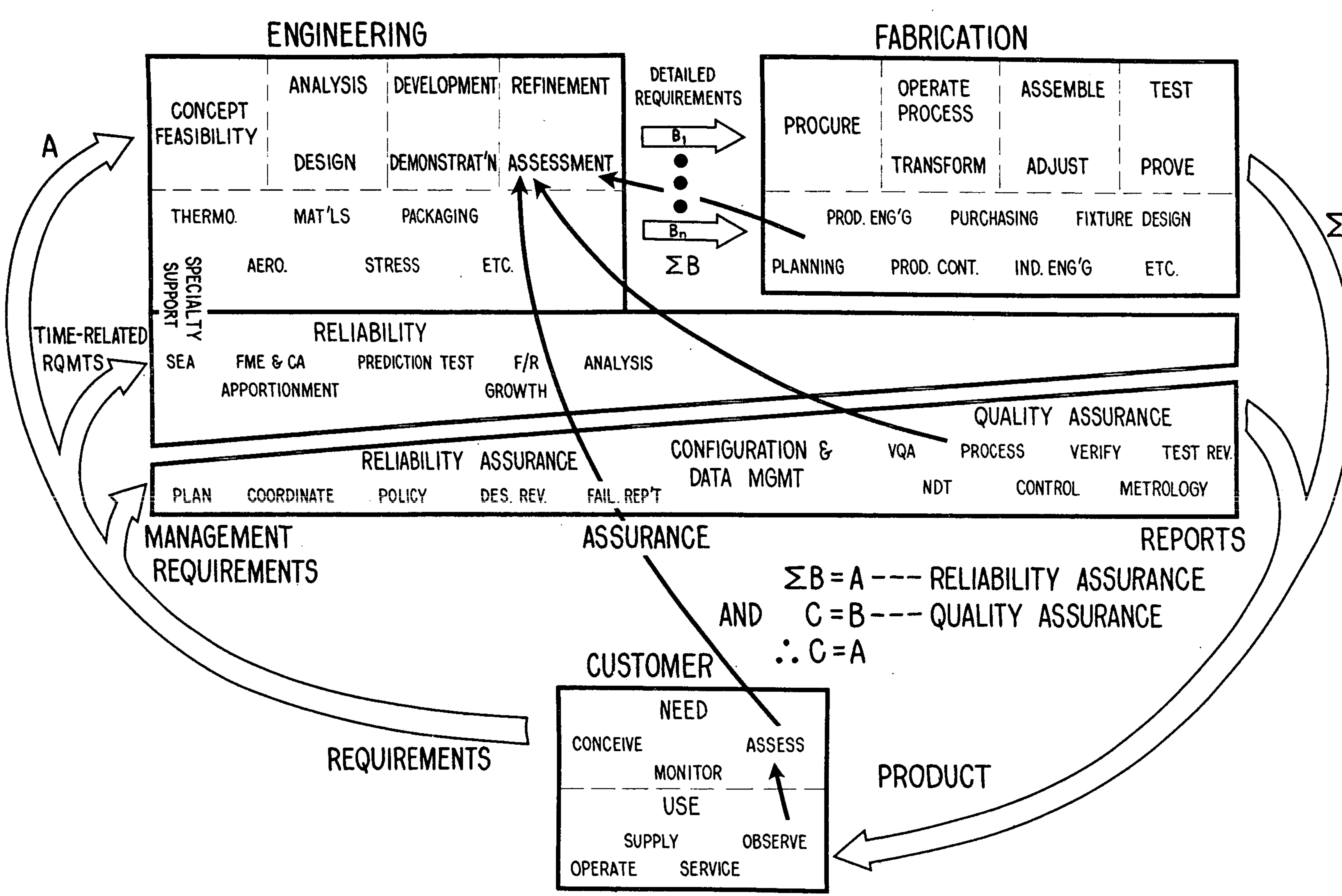
This paper is an interesting treatise on methods of representing system reliability evaluation through block diagrams set up similar to Karnaugh maps. Several new roles have been applied to increase the variety and versatility of the techniques.

"Role of Reliability and Quality Assurance in Program Management," by M. N. Olsen, Manager, Florida Operations, TRW Systems, Cape Canaveral, Florida, and W. H. Shaw, Manager-Product Assurance, Systems Engineering and Integration Division, TRW Systems, Redondo Beach, California

This paper is an excellent treatise on the discussion of responsibility within NASA organizations between engineering design, fabrication, reliability, reliability assurance, configuration and data management, and quality assurance. The paper is well worth reading by all LMFBR managerial personnel and a reproduction of the managerial flow chart, which is almost self-explanatory, is shown in Figure 3-12.

2. Assurance By Testing, Aging, and Surveillance (Session 2)

This session was opened with a discussion by the chairman, C. A. Locurto, Manager of Aging and Surveillance Programs, General Electric Co., Philadelphia, Pa. Reference here was made to MIL-STD-785. The chairman made a strong recommendation that the government should initiate a program for acquisition and dissemination of data on aging in storage, warehousing, and shipping. He stipulated that there is a large gap in knowledge and in development of aging characteristics, and that little is known of the effect on reliability of the low stresses incurred during a long-term storage. It is known that the usual checkout procedures of systems in receiving are not designed to detect degradation functions associated with this type of aging. Extrapolation of aging data can be ineffectual in estimation of service life methods. What is needed is to design a firm theory on inspection methods for incipient degradation, then correlate actual test data to confirm the validity of the defined theory. Preferentially,



7693-3011

Figure 3-12. The Industrial Process

investigation should be made on aging mechanisms that indicate a high activity rate, since investigation of low activation rate mechanisms have generally proven fruitless. It has also been shown that acceleration tests with high stress rates are also unreliable for age determination. The field of age evaluation is a highly technological field which must attract highly qualified personnel in order to incorporate aging into its truly important status as a core part of reliability engineering.

"Aging Characteristics Identified by Instrumental Analytical Methods," by J. A. Levisky and C. W. Rogers, AFLC Ogden AMA, Hill Air Force Base, Utah

Mr. Levisky's paper concentrated on describing atomic/molecular changes in component materials which contribute to the aging phenomenon. One of the methods of detecting these changes in the materials was chromatographic sampling. Most of his presentation covered the aging of organic materials such as fuels and lubricants. One of the important facets of this effort was associated with determining the reversability characteristics of the aging phenomenon. In performing these analyses, samples must be from identical materials if a comparison is to be made between aged and non-aged samples. This is found to be particularly critical with respect to various types of Teflon and rubber. Criteria for developing confidence limits associated with service life prediction of aged materials are given on page 192 of the transactions.

"Service Life Prediction Program With a Minuteman LGM/30 Propulsion System," by J. L. Myers, Head, Systems Engineering Support Section, Chemical Engineering, and E. L. Moon, TRW Systems, Redondo Beach, California

Of particular interest is development of organizational steps in establishing procedures for service life prediction and isolation of aging variables. Use is made of the term Initial Service Life Estimate (ISLE). When Minuteman was first initiated, no analytical method or familiarity with age testing was available. The closest correlation to statistical aging was the tail end of the familiar bathtub curve in which wearout was represented. By applying the same mathematical approach for wearout to evaluation of aging, development of a basic theory was initiated. In work at LMEC, since mechanical systems are subjected to wearout, the aging theory developed will be reversed and applied to wearout analysis. Heavy emphasis is placed on the need of long lead time during the development of any complex program such as Minuteman. In the 7 yr during which Minuteman was developed, 5 yr was used in design modification and improvement and the last 2 yr was needed for lead time. This lead time was used to provide advanced information on cost effectiveness and for development of maintenance requirements and life expectancy estimation of each of the critical components. (The same concept of 2-yr lead time to develop detailed maintenance procedures on large civilian aircraft is a requirement by the Federal Aviation Agency.)

Estimates of ISLE are used to calculate life expectancies of components, to evaluate compliance by vendors to minimum life requirements, to identify critical elements where design changes are needed, to eliminate intensive approximations, to identify missing information, and to design test requirements. Many tests are made which afford considerable useless information in that applications of the test data were not designed or related to a specific need or environmental condition. As a result, the data could not be applied to any actual environmental condition. Emphasis was again made that accelerated aging tests would not give useful information, only qualitative indications of trends. Program planning is essential with respect to vendor compliance and bidding on contracts; test analysis procedures must be uniform between contractors. The project must form ground rules and assumptions which are clearly understood. The author feels that the use of a three-sigma limit in these studies is far more useful and easier to understand than confidence limits.

"Advanced Missile Models and Methods for Availability Prediction," by I. Doshay, Chief AS&T Program Effectiveness Branch, Effectiveness Engineering, and D. P. Shube, Douglas Aircraft Co., Santa Monica, California

Mr. Doshay questioned whether tests are run to determine prior aging failures through continuous checks at receiving and how the possibility is weighed that there still exist undetected failures. He lists several checkout methods of evaluating these probabilities on page 207 of the transactions. Trade-offs are made of the number of checks conducted (i.e., inspection, etc.) against the true value of availability expectation. These studies and qualifications are based on the basic assumption that, given a failure, the component which failed is replaced with a new un-aged component, and the checkout is then continued.

Inspection and replacement of components having rapid aging tend to negate the effects of components in the complex system which have long-aging characteristics due to more continuous inspection of the latter. This paper combines statistical analyses with testing and maintenance.

"Testing For Spacecraft Reliability - A Management Overview," by A. M. Smith, Manager Advanced Concepts, and W. R. Waltz, General Electric Co., Philadelphia, Pa.

At what level of system complexity should tests be conducted? This question has been posed to attempt to resolve the fact that components act considerably different, whether they are treated as ideally located in a laboratory setup or whether they are mounted within their allocated system location and subjected to the environmental and aging conditions which the system may contribute. A good deal of discussion was conducted in this paper on acceptance test adequacy. Specifically, differentiation is made between qualification test adequacy and the functional phase which includes manufacturing and test design. The various areas and levels of responsibility are developed in rather interesting detail and are based on considerable knowledge of the author and his associates. The most important factor emphasized by this paper and by many of the others was that the failure analyses of the systems has to be implemented very early in the design and development stage.

It was pointed out that the component failure distribution functions tend not to be normal but to have long extended tails which contain 5% of the major components, but that these 5% contribute to a very large portion of the total critical failures associated with aborting a mission or loss of system availability.

3. Human Error Prediction and Control Through Human Factors Engineering (Session 3)

The session chairman, J. A. Kraft, Assistant Manager, Biotechnology, Lockheed Missiles and Space Co., Sunnyvale, California, introduced the session by discussing effect of human errors on operational safety and cost of the facility, and stipulated that human errors are not design-in errors and that human engineers should work very closely with the facility designers.

'The Classification of Human Reliability," by D. B. Jones, Human Factors Branch, Missile and Space Systems Div., McDonnell-Douglas Corp., Culver City, California was not published in the transactions but can be obtained by request.

Evaluation was made of the failure or rejection reports referred to as FAR's. Generally, human error, as defined by human factors engineers, does not include workmanship, initiation, design of procedures, or overall inadequacy of leadership. Human error decreases more rapidly with time than the total error function. He gave some examples of distribution of human error which Douglas has encountered. He says that handling and inspection accounted for 53%, inadequate human engineering and design for 28%, and inappropriate procedures and inherent lack of understanding for 19%. Included in these could be a fourth category, shipping, packaging, and hauling. Another breakdown listed receiving and inspection as 11%, fabrication assembly as 23%, installation 32%, checkout 25%, launch operation 9%. Labor, equipment, or design changes tend to increase human error about 20% from the normal level after the experience curve has leveled out. Usually this returns to a normal of about 30% of the functional error, but only 9% of all failures reported.

The question and answer period was also interesting: "Are reports prepared not by experienced analysists but by human factor engineers?" Answer: "These are major functional failures only, and not those discovered and corrected on the spot. They are prepared by human factors engineers and the time dependency tends to follow the equation,

$$Y = K + X \ln t$$ "

where K and X are proportionally constant and t is time. Question: "Is there a reluctance to report on human errors?" Answer: "Yes. That is why we tend to bend over backwards to negate punitive implication from reporting. We have been partially successful in this."

'Measurement of Human Errors with Existing Data," by K. Inaba and R. Matson, Serendipity Associates, Chatsworth, California

Mr. Inaba's paper relates maintenance and human error. In their experience at Serendipity Associates, they find that they get better data on human error by sticking to existing data records. This is because forms meet with adverse reaction and are quite often falsified or shaded to reduce the punitive implication.

By going to the direct records, they are better able to correlate human error with its effect upon performance. They break down the information area of human error through four categories: (1) good called bad, (2) bad called good, (3) evaluated the wrong component, and (4) induced a malfunction. The method of handling and processing the data was indicated in a detailed flow chart, Figure 1 of page 303 of the transactions. The computer program used to process the data is quite detailed, somewhat along the order of a FARADA type system, even to the point of following actions under specific chief operators in the facility. One trend in maintenance which came to light was the fact that systems sent in for shop maintenance often were sent back to the field incomplete in that shop maintenance tend to buck-pass some of their work to field maintenance. One of the questions from the audience was as to whether they had endeavored to associate carbon dioxide content in breathing air with a change in human error frequency. The answer was no, that in their studies they had made no endeavor to associate any cause with the mode of failure. They were interested only in studying modes and classifying them.

"Potential Damage Evaluation - A Method for Determining the Potential for Human-Caused Damage in Operating Systems," by P. F. Muller, Human Factors Staff Engineer, Lockheed Missiles and Space Co., Sunnyvale, California

Mr. Muller is an engineering psychologist in charge of human factor engineering at Lockheed Missile and Space Company. He states that one of the major problems with the use of trouble and failure reports in evaluating human error is that usually the cause is unknown. In the Polaris logistics studies, it was found that 25% of the failures or suspected failures were due to repeated handling of the missile, so they set up logistic flow charts to follow the many handlings of the missile being shipped to various destinations throughout the world. They then identified the potential damage to be expected at each location by conducting interviews with the field operators in which they were requested to fill out the blanks in a sheet which listed all of the operations conducted at a specific location with a number from 1 to 100 showing their expressed opinion as to the relative possibility that a failure could be incurred by that operation at that facility. Five operators' opinions were considered sufficient for averaging purposes. Any number of 10 or less was considered to be essentially 0 and equated to 10. A big point here was to make use of the maintenance and operator personnel to obtain an opinion, but only for relative scoring of potential expectation. Subsequent opinion stated that, generally, the field man is not in a position to describe why a thing occurred. He should only be asked to describe what occurred. The definition of why should be left to the investigating specialists such as system engineers, human engineers, reliability engineers, and quality assurance personnel.

"Effects of Assembly Error on Product Acceptance and Reliability," by L. V. Rigby and A. D. Swain, Systems Reliability Division, Sandia Corp., Albuquerque, New Mexico.

Mr. Rigby investigated the probability that an assembly error gets through inspection to cause a system failure and goes on to develop weighting factors to relate the probability of detection or failure to detect such events by an inspector. These weighting factors are obtained again by direct consultation with the men in the field. That is, the inspectors are questioned and asked to rate themselves on a specific operation. The paper was heavily oriented toward electronics and goes through details on planning, fabrication, construction procedures, and prediction of expectation of human malfunction and inspection.

4. <u>Bayesian Application to Reliability and Maintainability (Session 4)</u>

Introductory remarks were made by the chairman, W. T. Weir, Manager, Reliability and Effectiveness Analysis, General Electric Co. (RSD), Philadelphia, Pa.

Mr. Weir reviewed the basic principles of Bayes' Theorem and the normal applications as applied to conditional probability relationships. The primary question, to set the mood for the session, was "Can engineering judgment be included in reliability equations with any degree of legitimate confidence?"

"Bayesian Estimation of Time-Varying Reliability," by A. M. Breipohl, Associate Professor, School of Electrical Engineering, Oklahoma State University, and W. C. McCormick, Jr., Director of Technical Support, Air Force Missile Development Center, Holloman Air Force Base, New Mexico

Mr. Breipohl's discussion went through the graphic application of the step-by-step time development extrapolation of refining the initial estimate for these successive data points. The primary advice to the Bayesian statistician is to always record your subjective estimation and the assumptions that go with these estimates, since these are the fiducial point of origin. Question: "What about the independence requirements of the separate subjective estimation parameters?" The answer: "If the parameters are not independent, then the data acquisition gets out of hand. Experienced judgment has usually been able to design reasonably independent parameters." Question: "What about real system validation of the theory?" The answer: "The present contract only called for development of the theory."

"Use of Bayes Theorem in Its Discrete Formulation for Reliability Estimation Purposes," by W. J. MacFarland, Reliability Engineer, General Electric Research and Development Center, Schenectady, New York

This paper began by advising that any assumed hypotheses should be assigned at least some uncertainty weighting factor. The emphasis is placed on a strong belief method as differentiated from a weak belief method. Of the two, the weak belief method should be used in the original guess if only a small sample exists prior to initiation. Thus, the sample exerts greater influence. Extensive examples are given in applications of the two methods and their relative validity.

"Some Comparisons of Bayesian and Classical Confidence Intervals in the Exponential Case," by J. J. Deely and W. J. Zimmer, Staff Members, Sandia Laboratory, Statistical Research Division, Albuquerque, New Mexico

Numerous involved formulas and charts are presented for comparing classical confidence intervals and the savings associated with the number of tests to the Bayesian confidence intervals and makes extensive use of the inverse gamma function parameter as implementation of the Bayesian reliability and measurement program. The author has actually applied some of these theories to obtain higher reliability of structural components. The gamma distribution is applied to simulation of other probability of obtaining system success. In the future, they would like to apply the theory to test planning. The absolute determination of realistic reliability of specific structures is still in doubt since the validity of the results depends very heavily on the qualification of the estimator and the validity of the estimation method. Question from the audience was what about the application of iteration to resolve the test data with a new guess. The answer was that this is regarded by certain Bayesian statisticians as valid, but that others feel that if your initial guess was made with any degree of confidence, then it should be retained in its original form because the data samples may not be true samples.

The chairman of this session summarized by stating that while Bayesian theory has a long way to go in this area before it can be applied with the confidence of pure statistical sampling, it is still far better than the purely subjunctive approach of relying entirely upon the guess. Whether the designer or the analyst realize it or not, they are continually applying Bayesian thinking to all preliminary analysis or design work.

5. Research (Structural and Mechanical) (Session 5)

Chairman of the session, Dr. D. Kececioglu, Professor of Aerospace and Mechanical Engineering, University of Arizona, Tucson, Arizona, making his introductory remarks suggested that the expected reliability of a component or system should be obtained before it is ever designed. Reliability analyses to affect design objectives should be inserted into the early conceptual design trade-off studies.

"Designing for Reliability Based on Probabilistic Modeling Using Remote Access Computer Systems," by G. E. Ingram, C. R. Herrmann, and E. L. Welker, TEMPO-General Electric Co. (Center for Advanced Studies), Santa Barbara, California

Dr. G. E. Ingram presented a mathematical dissertation here which is considerably new in that methods of addition, multiplication, division, and subtraction of distribution functions are given both mathematically and with illustrations. The methods developed are easily understood and simple to use by the average reliability engineer. They do not go into the heavy mathematics of the convolution integral functions.

"Probabilistic Strength Mapping-Reliability vs Life Prediction Tool," by M. J. Bratt, H. A. Truscott, and G. W. Weber, General Electric Co., Cincinnati, Ohio

G. E. analyzed a turbinewheel dove-tail-post metallurgical fatigue failure through mockup tests of a similar material and analysis of the mechanisms of failure under ideally simulated cyclic stress initiation. Since this was low-cycle fatigue, an area in which very little data have been accumulated, it was necessary to make assumptions through an initial guess as to the shape of the Modified Goodman Diagram for cyclic stress analysis. These guesses are then applied to the Bayesian mathematical approach in an endeavor to develop a systematic correlation analysis of the data. The paper was of considerable interest with many questions from the floor. Final concensus of opinion was that the method was worthy of extensive additional investigation, but that the conclusions, as presented, could not be relied upon too extensively.

"Designing for Expected Fatigue Life," by E. R. Forrester and V. H. Thevenow, Allison Division, General Motors Corp., Indianapolis, Indiana

It was pointed out that the log-normal failure description function generally fitted fatigue life. The authors felt that the cumulative damage effect method was alright, but that no experience had been obtained for verification of the data. This was in reference to the previous paper. This paper went extensively into the use of the Modified Goodman Diagram again and developed a concept of summation of the various environmental effects such as disintegrating factors, type of loading, material processing, size effect, surface finish, surface treatment, stress concentration, speed of loading, and certain combinations of these.

"A Unified Look at Design Safety Factors, Safety Margins and Measures of Reliability," by D. Kececioglu (Session Chairman) and E. B. Haugen (Session Co-Chairman)

Dr. Kececioglu effectively summarized developmental work over the last couple of years in improving the mathematical methods of relating stress distribution functions to strain distribution functions. These were extensively used by North American Aviation in the Apollo Program, but left much to be desired with correlation between theory and actual experience (see previous section). Prior to this meeting, LMEC was given to understand that considerable work had been going on in various parts of the country to improve the theoretical method. The improved parametric selection and correlation methods have been excellently summarized in this paper; and the authors express the feeling that with these improvements, considerably better correlation between theory and experience should result in the future. Some laboratory model testing has been done on sample torsion bars with some degree or correlation. Under the direction of the author, considerable work has been done by graduate students at the University of Arizona in developing graphical methods for direct determination of expected reliability given the parameters of the distribution functions and whether they are normal or log-normal distributions. The next period of investigation is to extend the development of graphical methods to other distribution functions such as the Weibull, etc.

VI. FAULT TREE ANALYSIS

A. INTRODUCTION

The Fault Tree method of analysis was first applied to the Minuteman ICBM missile when it was found that established methods of determining performance reliability, such as failure-mode-and-effects analysis, were very difficult to apply to the cumbersome six-company organization involved in the design. Specific probabilistic computer techniques were developed for fault tree analysis. These include Monte Carlo, $\lambda \tau$ approximation, and use of special hybrid computer in addition to other digital computer programs.

A fault tree is a graphic method of tracing and analyzing the potential of one or more casualties to produce an undesirable event. Probability of occurrence, repair time, inspection intervals, and protective action are parameters incorporated in the analysis. Physically, the fault tree appears as tree roots (events and actions) terminating in the tree trunk (the undesirable event which is not wanted to occur). Standardized symbols (which are sometimes modified for special problems) for fault tree construction are shown in Figure 3-13. The OR gate is activated if any or all of the input events are present while the AND gate required all inputs to exist. Priorities and restrictions may be placed on any gate. Branches of the fault tree may be developed downward to as fine a detailed level as nuts, bolts, transistors, and relay logic. The desired level of development depends upon the status of design and the immediate objective. The undesirable events will be different at the top levels for a fault tree on system operation reliability than for safety reliability. The nuts and bolts branches, however, may be quite similar. Fault trees may be quickly put together as graphic representations of relative safety for talking purposes or design review. In final complex tree development, each branch of the tree is assigned statistical parameters and analyzed for the probabilistic occurrence of the undesirable event or events. Every potential accident, no matter how improbable, is placed upon the fault tree initially. This forces examination and reduces the potential that something will be overlooked. As the design is formed, most of the protective system and redundancy requirements have evolved. There is every

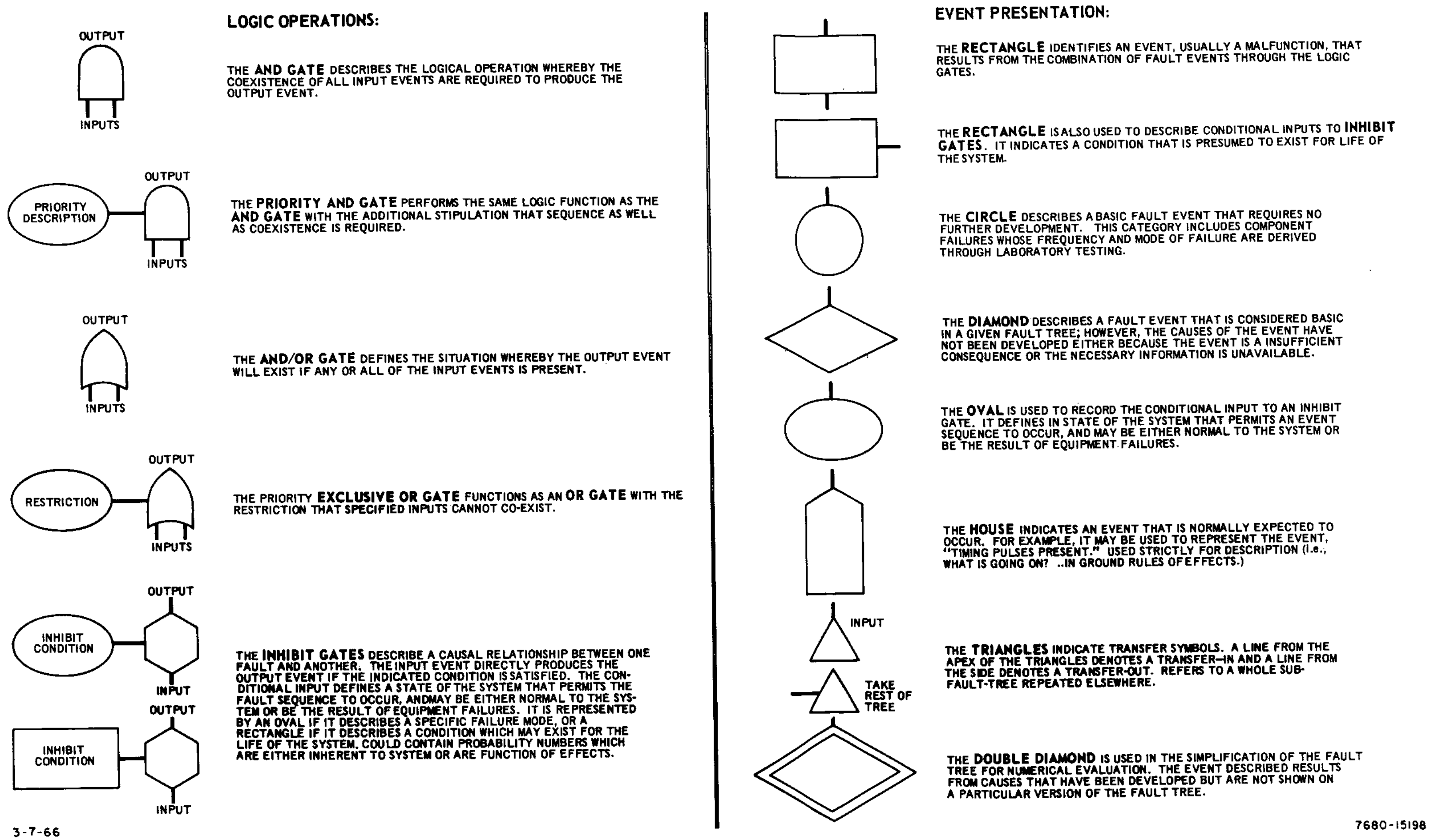


Figure 3-13. Standardized Symbols and Symbol Definition for Fault Tree Construction

indication that future power reactors will be required to undergo a probabilistic analysis of malfunction and risk. This is the task for which the fault tree was specifically created.

The fault tree technique by itself should not be construed to be a panacea. It must be combined with failure-mode-and-effects analysis and skilled "eye-balling" in order to be effective. The outstanding value of fault tree is the capacity to analyze a system in greater detail and less time than is possible for any other method to date.

One great advantage of fault tree methods is that none of the branches cross over each other and all lead to a common "undesired event." This permits detailed fault tree development of specific components on subsystems which may be used repeatedly as building blocks in completely different facility system designs. The aerospace industry constructed a book of such fault trees especially adaptable to that industry.

B. STEPS IN FAULT TREE DEVELOPMENT FOR AVAILABILITY ANALYSIS AND UPGRADING OF POWER PLANTS

1. Step 1 - Obtaining Required Information on Plant or Facility

This information will generally consist of the following:

1) A detailed description of the reactor and fuel processing systems. This will include reactor heat transfer, electrical distribution, instrumentation, fuel handling, fuel processing, and auxiliary systems.

2) A description of operating, fuel processing, and preventive maintenance procedures and schedules.

3) A detailed description of any special test loops.

In addition to the above, historical data concerning reactor operation, reactor trips (both manual and automatic), component failures, and preventive maintenance will be needed prior to the performance of a quantitative analysis of plant availability.

2. Step 2 - Constructing the Paths

Select a specific "undesired event" and begin the construction of a fault tree by indicating all events which could lead to the "undesired event" and all events which could inhibit it or protect against it. As the construction of the fault tree and the evaluation of historical data on the plant progresses, weaknesses in system design, operating and maintenance procedures, and scheduling will become obvious on a qualitative basis. A description of these areas, along with preliminary suggestions for improvement, are then developed.

In conceptual plant design trade-off studies, several iterations of Step 2 transpire as a result of the "eyeballing" or critical path approach long before any attempt at statistical probability analysis is made.

3. Step 3 - Approximation

Compilation of "best guess" component failure rate data will be pursued throughout this step. This data will be obtained partially from generic failure rates and partially from historic operating failure rates observed at similar facilities. The failure rate data will continually be upgraded as additional failure rates will be generic and poorly associated to the plant; the comparative availability analysis of individual branches and perturbations will be reasonably accurate.

4. Step 4 - Analysis

Initial quantitative analysis of availability is usually performed using a Boolean algebra method called the $\lambda\tau$; however, the generating function approach mentioned earlier may be employed in certain areas. Holmes and Narver, Inc., in HN-190, modified a digital program, developed by North American Rockwell for fault tree evaluation of a missile reliability, called the ARMM program, for power plant availability analysis. This method is fine for certain applications; there are many others.

A careful evaluation of the analytical results is then made to establish the regions where (by either design, scheduling, or manpower utilization changes) it would be feasible to increase the plant availability. Once these specific planned changes have been established, an analysis is made, assuming the changes, to determine the approximate magnitude of the effect of each change on predicted plant availability. If the predicted availability is less than that desired, the procedure is repeated until the predicted availability reaches the desired value.

The procedure is very similar for plant safety evaluation. The primary "undesired event" must be related as "Excessive Radiological Release to the Environs."

C. STATISTICAL AND PROBABILISTIC ANALYSIS METHODS

1. Introduction

Many methods have been devised for evolution of fault trees for probability of occurrence assuming the existence of reasonably acceptable and applicable failure rate data. The following have been devised for small fault trees or subsystems:

1) Boolean algebra
2) $\lambda\tau$ method (the hand or computer calculation of fault tree probability under assumptions of no repair, constant interval, and/or constant repair)
3) Boolean matrices (Boolean algebra matrix method of transmission function analysis for complex relay circuits)
4) Karnaugh maps (binary transmission function utilizing multidimensional lattices).

The following methods have been devised for complex fault trees:

1) Hybrid computer methods
2) Monte Carlo - random input function generation (Phyllis M. Negel, Boeing, has developed this area very extensively)
3) Digital programs with prestipulated probability of occurrence (North American Rockwell ARMM program revised by Holmes and Narver in HN-190).

For the following example, the $\lambda\tau$ fault tree method is discussed.

Definitions:

$\lambda = \frac{1}{\hat{\theta}}$ = failure rate where $\hat{\theta}$ = MTBF

τ = time interval of interest

ξ = an undesirable event

$Q(\xi)$ = probability of $\xi = (1-e^{-\lambda_\xi \tau_\xi})$ - for an assumed exponential distribution

$$(1-e^{-\lambda_\xi \tau_\xi}) \cong \lambda_\xi \tau_\xi \text{ for } \lambda_\xi \tau_\xi < 10^{-3}.$$

The $\lambda\tau$ mathematical method is not as accurate or as versatile as stochastic coincidence methods (for which specific distribution functions other than or including the exponential may be selected for each fundamental input) but is very amenable to hand calculation. It is quite good for probabilistic comparison of two systems. Three common repair or inspection techniques are applicable:

1) No repair (very conservative)

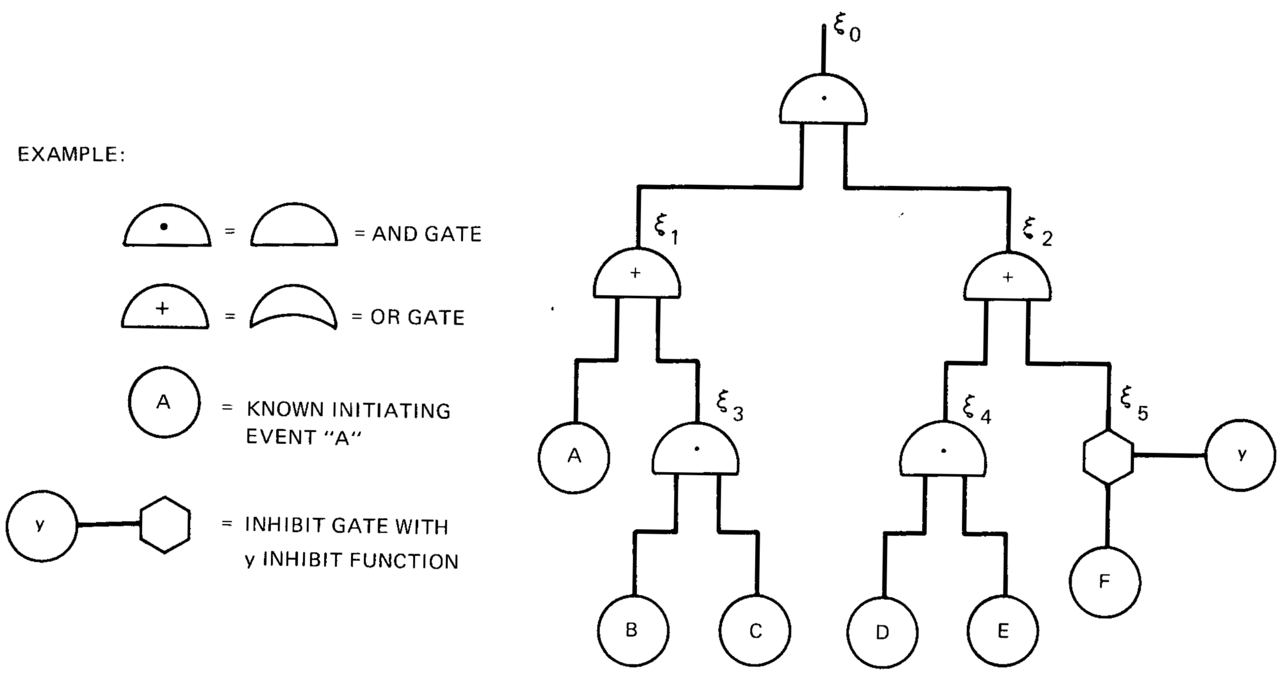
2) Constant interval (low)

3) Constant repair (more realistic).

Symbols:

Boolean $\cap$ = and
$\cup$ = or

Fault Tree



The failure rates are given as:

$\lambda_A = 10^{-4}$ (per unit)

$\lambda_B = 2 \times 10^{-4}$

$\lambda_C = 4 \times 10^{-4}$

$\lambda_D = 5 \times 10^{-4}$ τ_o = system life = 100 time units

$\lambda_E = 10^{-3}$

$\lambda_F = 10^{-4}$

$y = 0.5$ - the inhibit gate

Inhibit function $y = 0.5$ means that although $MTBF_F$ $(\lambda_F) = 10^{-4}$, only failures of a given type contribute to event $Q(\xi_o)$ and that these are only 0.5 of probability of failure F, Q(F).

The example may be represented as the equation,

$$\xi_o = \xi_1 \xi_2 = (A + BC)(DE + yF) = ADE + BCDE + yAF + yBCF. \quad \ldots(1)$$

2. Type I - No Repair (During Plant Life)

$$Q(\xi_o) = Q(ADE) + Q(BCDE) + Q(yAF) + Q(yBCF) \quad \ldots(2)$$

$$= \lambda_A \tau_o \lambda_D \tau_o \lambda_E \tau_o + --- + --- + ---$$

$$= \lambda_A \lambda_D \lambda_E \tau_o^3 + \lambda_B \lambda_C \lambda_D \lambda_E \tau_o^4 + y \lambda_A \lambda_F \tau_o^2$$
$$+ \lambda_B \lambda_C \lambda_F \tau_o^3 \quad \ldots(3)$$

$$= 5 \times 10^{-5} + 4 \times 10^{-6} + 5 \times 10^{-5} + 4 \times 10^{-6}$$

$$= 1.08 \times 10^{-4}$$

3. Type II - Constant Interval

This technique assumes regular inspection and complete repair at a regular specified interval, τ_1, with no repair requirement during the interval. As applied to the fault tree, it means that the tree is analyzed for the time base, τ_1, to obtain an equivalent overall failure rate, λ'_o, and the total probability of failure during τ_o is λ'_o times the number of new time units $\tau'_o = \tau_o/\tau_1$

or

$$Q(\xi_o) = \lambda'_o \, \tau_o/\tau_1 = \lambda'_o \tau'_o. \qquad \ldots(4)$$

Equation 3 thus becomes

$$Q(\xi_o) = \left(\lambda_A \lambda_D \lambda_E \tau_1^3 + \lambda_B \lambda_C \lambda_D \lambda_E \tau_1^4 + y\lambda_A \lambda_F \tau_1^2 + y\lambda_B \lambda_C \lambda_F \tau_1^3\right) \tau_o/\tau_1 \qquad \ldots(5)$$

The term in the bracket is λ'_o. If the constant interval is selected as $\tau_1 = 10$, then

$$Q(\xi_o) = \left(5 \times 10^{-8} + 4 \times 10^{-10} + 5 \times 10^{-7} + 4 \times 10^{-9}\right) \frac{10^2}{10}$$

$$= \lambda'_o \tau'_o = (5.54 \times 10^{-7})\ 10$$

$$= 5.54\ 10^{-6}.$$

4. Type III - Constant Repair

This technique includes all contributions to outage or its elimination such as inspection, repair time, etc. Again, each new $\lambda_i \tau_i$ establishes the new failure rate, λ_i, for the fault tree branch, ξ_i, and its new interval time base, τ_i. For subsequent analysis, the branch, ξ_i, is no longer required; but a clear understanding of τ_i is required.

As an example, events A, B, C, D, F are given τ_i of

$\tau_A = 10$ $\tau_D = 50$

$\tau_B = 1$ $\tau_E = 10$

$\tau_C = 5$ $\tau_F = 50.$

Tables have been developed for assisting in the computations, one of which is reproduced here as Table 3-1. From this table, λ_i and τ_i are calculated for the output of each "and" or "or" gate event, ξ_i.

Applying Table 3-1 to the foregoing sample sketch,

$$\lambda \xi_3 \cap = \lambda_B \lambda_C (\tau_B + \tau_C) = 4.8 \times 10^{-7}$$

$$\tau \xi_3 \cap = \frac{\tau_B \tau_C}{\tau_B + \tau_C} = \frac{5}{6}$$

$$\lambda \xi_4 \cap = \lambda_D \lambda_E (\tau_D + \tau_E) = 3 \times 10^{-5}$$

$$\tau \xi_4 \cap = \frac{\tau_D \tau_E}{\tau_D + \tau_E} = \frac{500}{60} = \frac{50}{6}$$

$$\lambda \xi_5 \text{ (inhibit gate)} = y \lambda_5 = 0.5 \times 10^{-4} = 5 \times 10^{-5}$$

$$\tau \xi_5 = \tau_F = 50$$

$$\lambda \xi_1 = \lambda_A + \lambda \xi_3 = 4.8 \times 10^{-7} + 1 \times 10^{-4} = 1 \times 10^{-4}$$

$$\tau \xi_1 \cup = \frac{\lambda A \, \tau A + \lambda \xi 3 \, \tau \xi 3}{\lambda_A + \lambda \xi_3} = \frac{(10^{-4})\, 10 + (4.8 \times 10^{-7}) \frac{5}{6}}{10^{-4} + 4.8 \times 10^{-7}}$$

$$= 10 + 4 \times 10^{-3} = 10$$

$$\lambda \xi_2 \cup = \lambda \xi_4 + \lambda \xi_5 = 3 \times 10^{-5} + 5 \times 10^{-5} = 8 \times 10^{-5}$$

$$\tau \xi_2 \cup = \frac{\lambda \xi 4 \, \tau \xi 4 + \lambda \xi 5 \, \tau \xi 5}{\lambda \xi 4 + \lambda \xi 5} = \frac{3 \times 10^{-5} (\frac{50}{6}) + 5 \times 10^{-5} \times 50}{3 \times 10^{-5} + 5 \times 10^{-5}}$$

$$= \frac{275}{8}.$$

TABLE 3-1

"λτ" COMBINATION

			2 Inputs	3 Inputs	n Inputs
AND	τ's UNEQUAL	λ∩	$\lambda_1\lambda_2(\tau_1 + \tau_2)$	$\lambda_1\lambda_2\lambda_3(\tau_2\tau_3 + \tau_1\tau_3 + \tau_1\tau_2)$	$\lambda_1\lambda_2 \cdots \lambda_n(\tau_2\tau_3 \cdots \tau_n + \tau_1\tau_3 \cdots \tau_n + \cdots + \tau_1\tau_2 \cdots \tau_{n-1})$
		τ∩	$\frac{\tau_1\tau_2}{\tau_1 + \tau_2}$	$\frac{\tau_1\tau_2\tau_3}{\tau_2\tau_3 + \tau_1\tau_3 + \tau_1\tau_2}$	$\frac{1}{\frac{1}{\tau_1} + \frac{1}{\tau_2} + \cdots + \frac{1}{\tau_n}}$
	τ's EQUAL	λ∩	$2\lambda_1\lambda_2\tau$	$3\lambda_1\lambda_2\lambda_3\tau^2$	$n\lambda_1\lambda_2 \cdots \lambda_n\tau^{n-1}$
		τ∩	$\frac{\tau}{2}$	$\frac{\tau}{3}$	$\frac{\tau}{n}$
OR	τ's UNEQUAL	λ∪	$\lambda_1 + \lambda_2$	$\lambda_1 + \lambda_2 + \lambda_3$	$\lambda_1 + \lambda_2 + \cdots + \lambda_n$
		τ∪	$\frac{\lambda_1\tau_1 + \lambda_2\tau_2}{\lambda_1 + \lambda_2}$	$\frac{\lambda_1\tau_1 + \lambda_2\tau_2 + \lambda_3\tau_3}{\lambda_1 + \lambda_2 + \lambda_3}$	$\frac{\lambda_1\tau_1 + \lambda_2\tau_2 + \cdots + \lambda_n\tau_n}{\lambda_1 + \lambda_2 + \cdots + \lambda_n}$
	τ's EQUAL	λ∪	$\lambda_1 + \lambda_2$	$\lambda_1 + \lambda_2 + \lambda_3$	$\lambda_1 + \lambda_2 + \cdots + \lambda_n$
		τ∪	τ	τ	τ

The failure rate,

$$\lambda \xi_o = \lambda \xi_o \cap$$

$$= \lambda_1 \lambda_2 (\tau_1 + \tau_2)$$

$$= 10^{-4} \times 8 \times 10^{-5} (10 + \frac{275}{8})$$

$$= \frac{8 \times 10^{-9}}{8} \times 355 = 3.55 \times 10^{-7}$$

$$Q(\xi_o) = \lambda \xi_o \tau_o = 3.55 \times 10^{-7} (100) = 3.55 \times 10^{-5}. \quad \ldots(6)$$

This could have been solved from the Canonical form of Equation 2.

$$Q(ADE) = Q\ (A \Omega D \Omega E)$$ - an "and" gate with 3 inputs.

From Table 3-1,

$$\lambda_{ADE\cap} = \lambda_A \lambda_D \lambda_E (\tau_A \tau_D + \tau_A \tau_E + \tau_D \tau_E)$$

$$= 10^{-4} \times 5 \times 10^{-4} \times 10^{-3} (500 + 100 + 500) = 5.5 \times 10^{-8}$$

$$Q(ADE) \cong \lambda_{ADE} \tau_o = 5.5 \times 10^{-8} (100) = 5.5 \times 10^{-6}.$$

Applying Table 3-1 to the other 3 gates,

$$Q(BCDE),\ Q(\gamma AF),\ \text{and } Q\ (\gamma BCF),$$

and summing to obtain $Q(\xi_o)$, the result will be the same.

It should be observed, however, that gates with sequencing conditions or other conditions difficult to describe as a simple number are readily handled by direct application to the TREE, but are very difficult to apply to the canonical approach.

5. Summary

The value of $Q(\xi_o) = 1.08 \times 10^{-4}$ for no repair is seen to be considerably overconservative, and the constant repair time value of 3.55×10^{-5} is seen to be somewhat in between.

D. EXAMPLES OF FAULT TREE APPLICATION

1. Example No. 1

An excellent example of fault tree application to resolution of conceptual design problems is the preliminary work performed at Atomics International in 1966 on the 500-Mwe Heavy Water Organic Cooled Reactor (HWOCR) Demonstration Plant, a concept no longer under USAEC consideration. This first example demonstrates the fundamentals of Steps 1 and 2 in which no mathematical probability analysis is required or even anticipated.

The fault tree constructed for the demonstration plant is depicted in Figures 3-14 through 3-18. The top of the tree is shown on Figure 3-14 with "Excessive Radiological Release to Environs" defined as the undesirable event. The remaining figures shown in the branches of the tree will carry the development to lower levels of detail.

Figure 3-14 indicates that excessive radiological release to environs can result from any of three input events: (1) excessive release from auxiliary structure, (2) excessive release from containment structure, or (3) solid waste handling. The solid waste handling accident is not of interest at this time and thus has not been developed. A "release from the auxiliary structures" can result from a release from any of the following: (1) radioactive liquid waste system, (2) radioactive waste gas system, (3) D_2O processing and handling system, or (4) either of the two coolant loops. Each of the above branches is discussed below; however, since the coolant loops are identical, only the first coolant loop is discussed.

The release from the first coolant loop is the output from an AND gate which represents the containment effect of the piping and vessels comprising the coolant loop. In the event of an accidental radiological release to the first coolant loop system, either the coolant loop or coolant process system must be breached before a release to the auxiliary structure can occur. In addition, to obtain a radiological release to the portion of the first coolant loop exterior to the containment building, the isolation valves between the core and the steam generator (see Figure 3-19) must have failed. The steam generator is outside of the containment in the auxiliary building. In addition, fission products in the reactor coolant system can only result from fuel melting or a large number of cladding

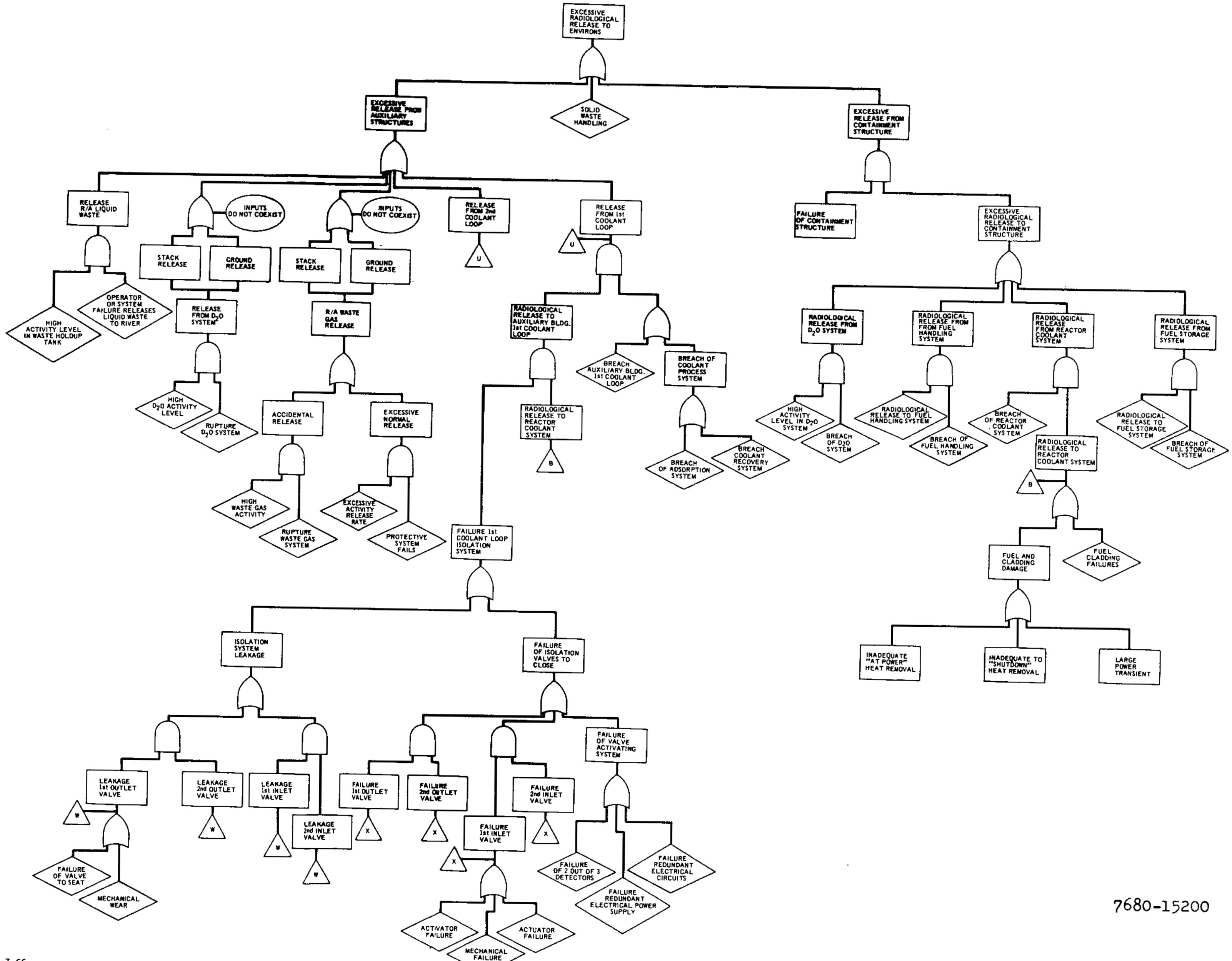


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Figure 3-14. Excessive Radiological Release to Environs

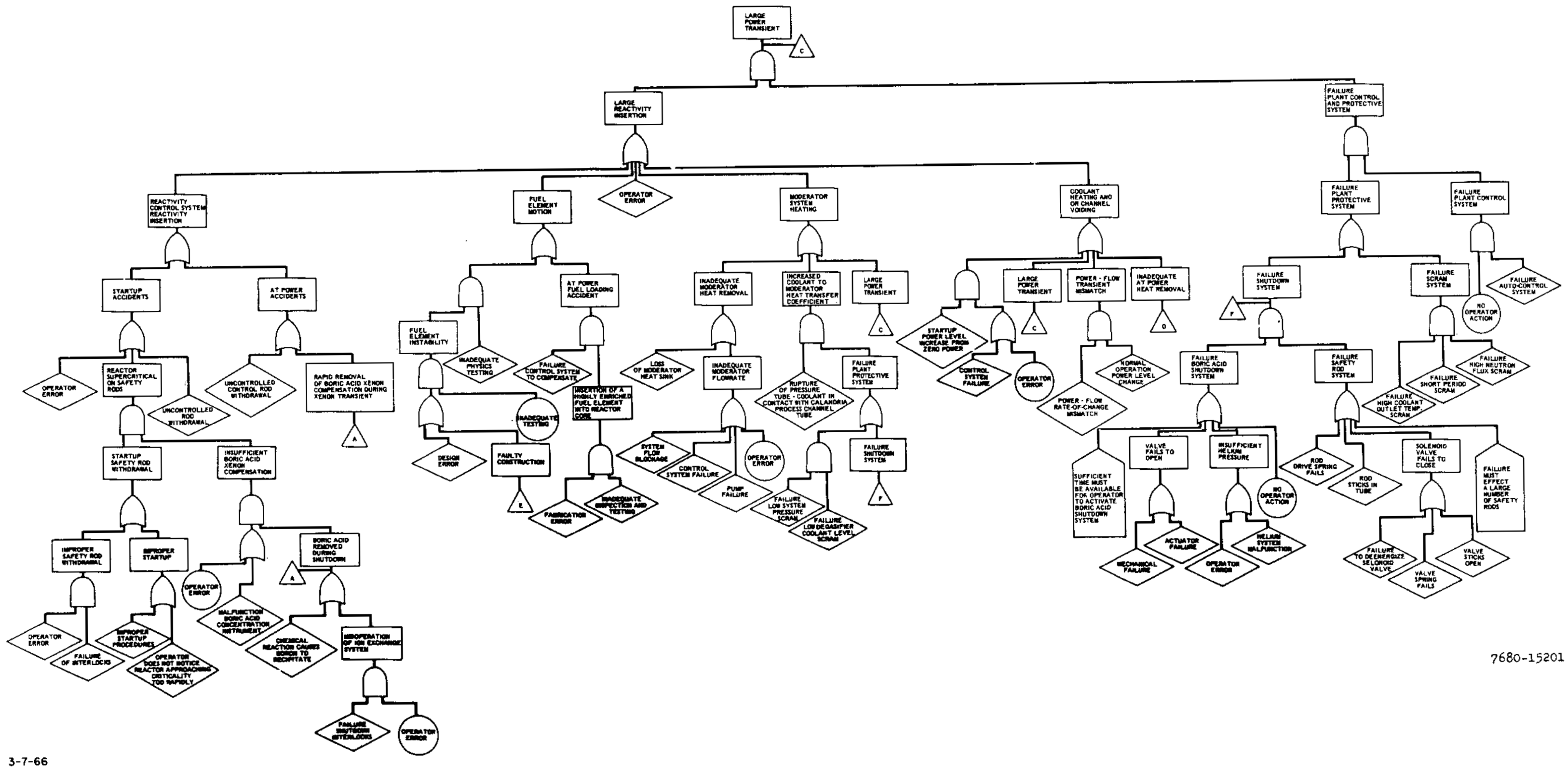

Figure 3-15. Large Power Transient

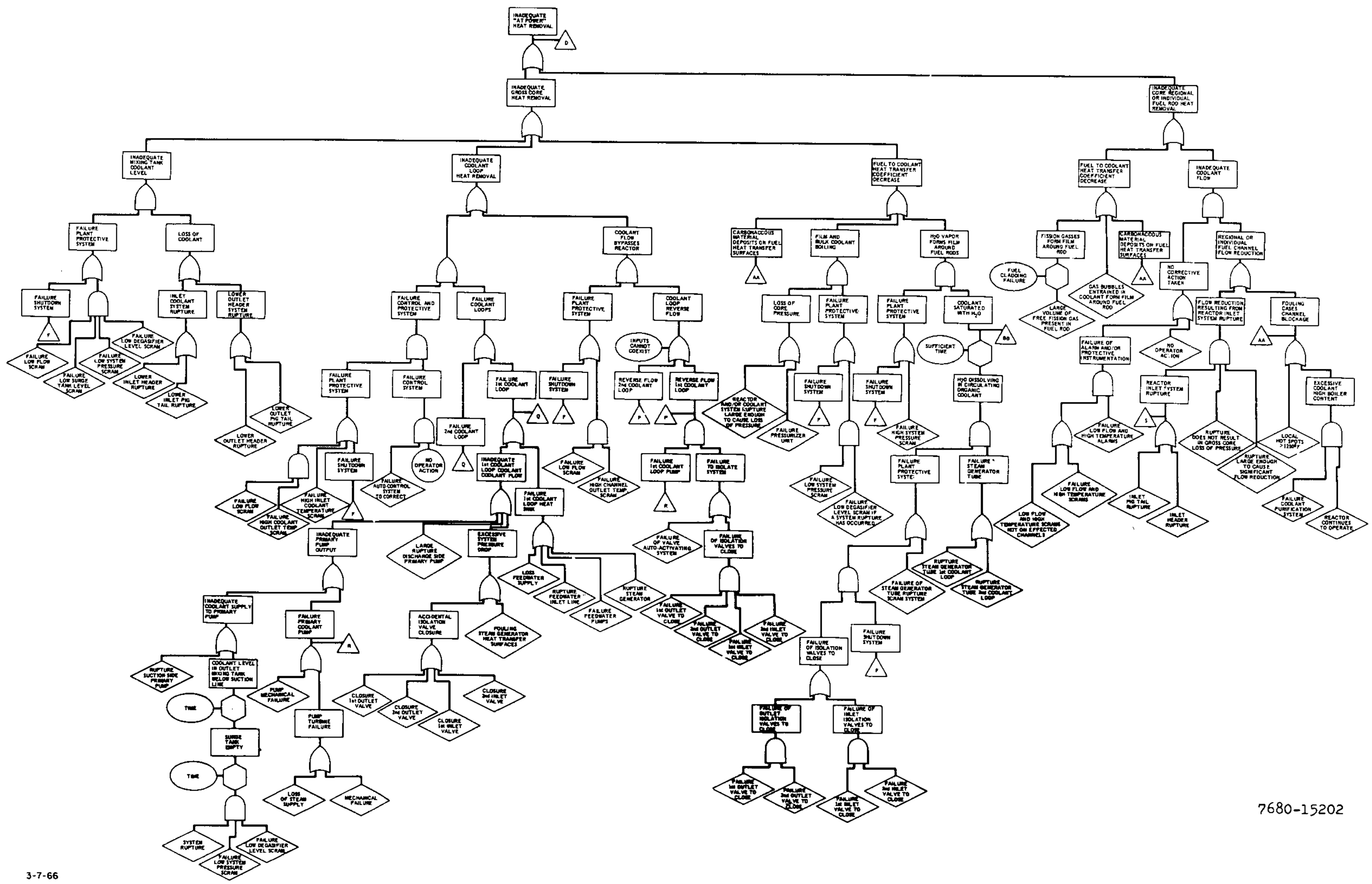

Figure 3-16. Inadequate At-Power Heat Removal

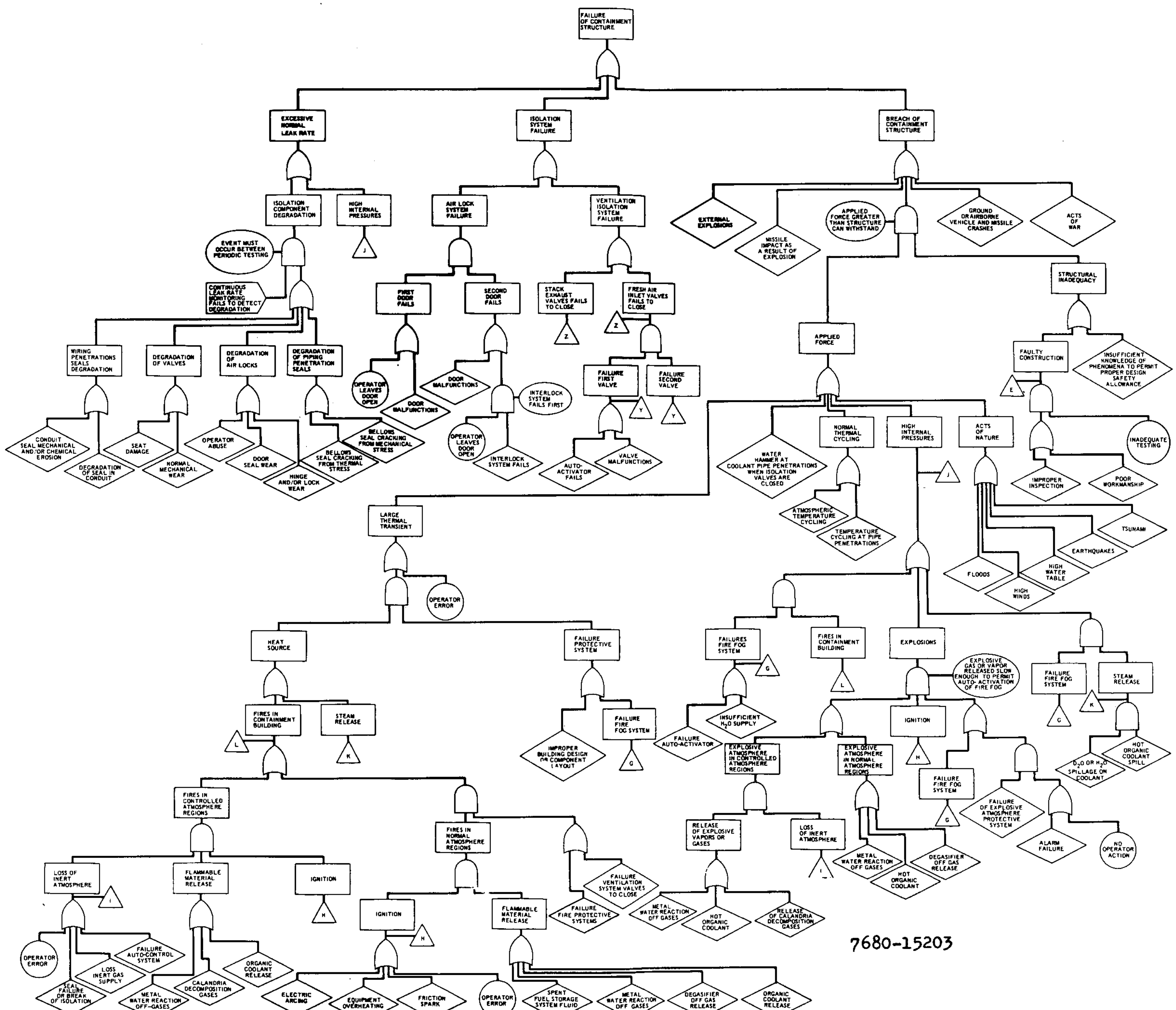

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Figure 3-17. Failure of Containment Structure

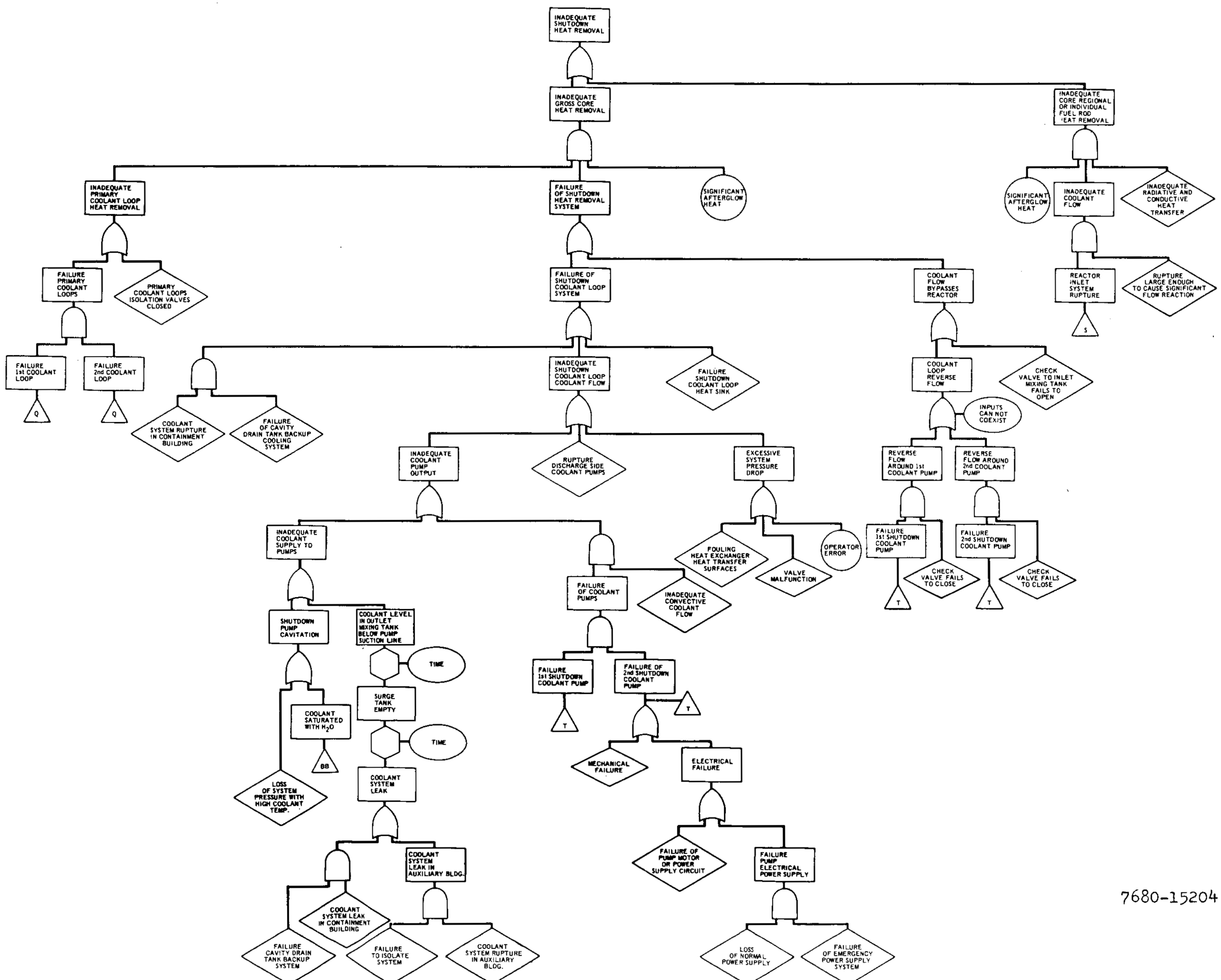

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Figure 3-18. Inadequate Shutdown Heat Removal

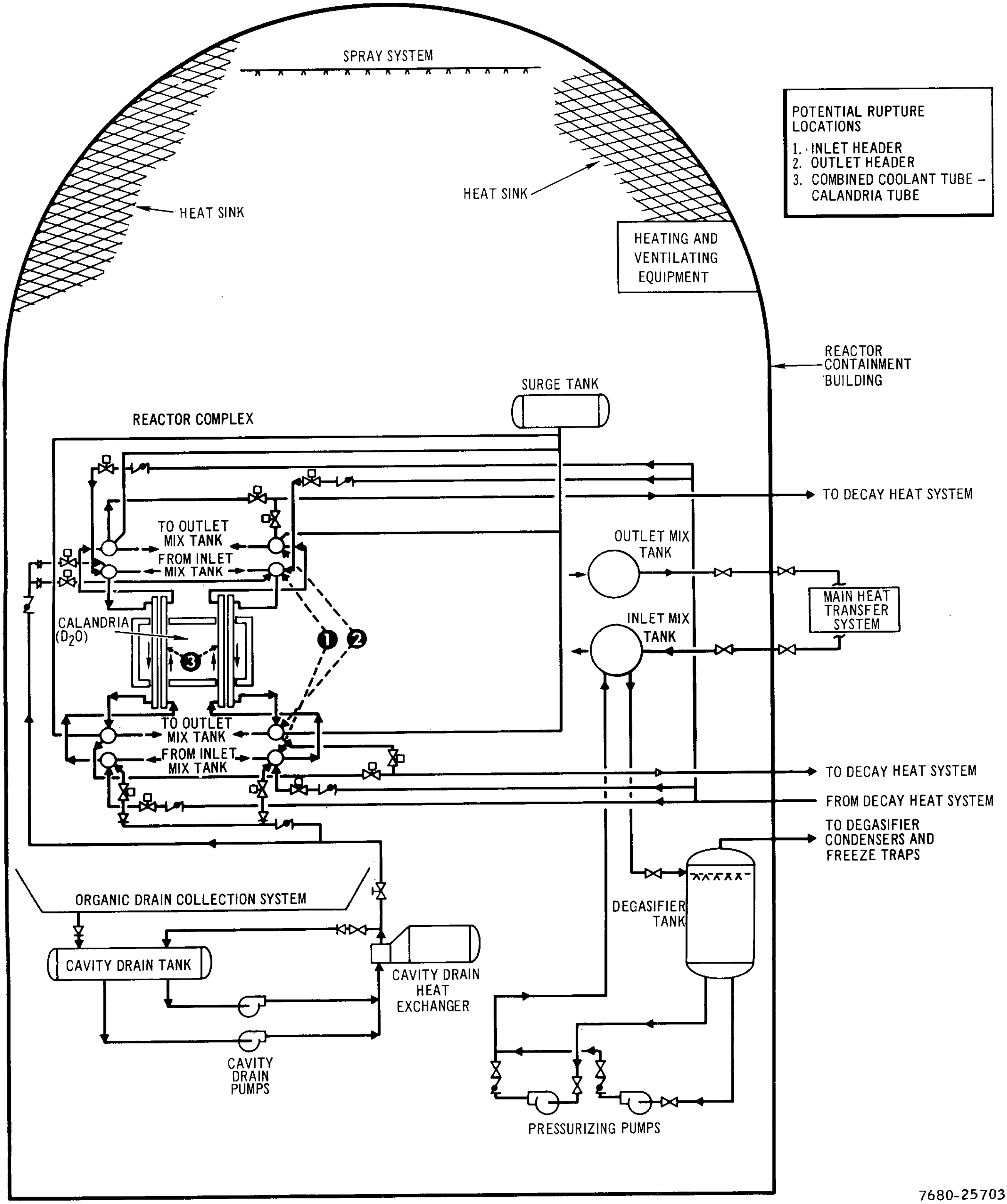

Figure 3-19. HWOCR Demonstration Plant Schematic Diagram

failures. Thus, this system provides redundant protection against a release to the auxiliary building. Further, no credit is taken for the fire protection devices in the auxiliary building as it has been assumed that the activity released with the coolant is immediately released to the environs.

The isolation system failure is shown as resulting from valve leakage or failure to close. Since the valves on both the inlet and outlet lines are redundant, both inlet or both outlet valves must leak to constitute a failure. Failure of the valves to close can result from an individual failure or a failure of the activating system. The effects of an individual valve failure are again reduced by the double isolation valve construction and individual activators and actuators. Since failure of the valve activating system will result in the failure of all the valves on all three coolant loops to close, all components of this system (detectors, power supplies, electrical circuits, etc.) must be redundant. Additional fault tree development of the isolation valve activators, actuators, and actuating system will be prepared as analysis of this system continues.

The absence of an AND gate between the top and bottom of the tree with respect to "activating system" failure requires that this system be designed with extreme care both from a standpoint of adequate redundance to assure activation and of adequate coincidence to prevent false tripping.

Excessive radiological release to environs from the radioactive waste gas system can result from either the rupture of a portion of the system containing highly active gases or the failure of the auto-control valve to close when, for some reason, the normal gaseous activity released becomes excessively high. The severity of the release is dependent on whether it is a ground release or a stack release and on the maximum allowable activity for each case to determine the necessity of providing stack fan backup. Additional effort will be required to complete the analysis of this system.

The radiological release from the D_20 system results from a high activity in the D_20 and a rupture of the system. The tritium problem was evaluated separately.

The major concern regarding a liquid waste release centers about the possibility of dumping liquid waste from the holdup tank to the river. This could result from either an operator error or the malfunction of a valve. For this reason, redundant valving and a radiation detector with an alarm should be installed on the dump line. The installation of a detector downstream from the adsorber and filter to prevent the pumping of highly radioactive waste to the holdup tank would also be desirable. The maximum allowable activity inventory in the holdup tank will be determined.

The excessive radiological release from the containment structure event is the output from an AND gate which requires the coexistence of both inputs (failure of the containment structure and radiological release to the containment structure) to produce the output event. This AND gate represents the effect of the containment structure in preventing a radiological release to the environs.

The failure of containment structure branch is shown in Figure 3-14 and will be discussed later.

The important facet under excessive radiological release to the containment structure is that a radiological release from the reactor coolant system requires both a release to the reactor coolant system and a breach of the coolant system. The release to the coolant system can result from fuel cladding failures or fuel and cladding damage. The fuel cladding failures referred to are the cracking of cladding, etc., without any fuel damage. A number of such failures can be tolerated without exceeding release limits. Fuel and cladding damage can result from inadequate at-power heat removal, large power transient, or inadequate shutdown heat removal. The branches leading to these events are depicted in Figures 3-15, 3-16, and 3-17.

Failure of containment structure (see Figure 3-15) can result from an excessive normal leak rate, isolation system failure, or a breach of the containment structure.

The excessive normal leak can result from high internal pressure or isolation component degradation. Protection is provided against the component degradation event, as is indicated by the AND gate, by requiring both continuous leak rate monitoring and periodic pressure testing. The use of both methods of leak rate testing will greatly reduce the probability of this event.

Isolation system failure can result from an air lock failure or a ventilation system failure. Redundant inlet and outlet valving on the ventilation system and the double doors with both mechanical and electrical interlocks on the airlocks act to reduce the likelihood of this event. Coolant system isolation valves are not shown under this event as they are covered under the release from the auxiliary structure.

A number of input events leading to the breach of the containment structure have been considered, even though some are highly improbable.

The inadequate at-power heat removal (see Figure 3-16) event is shown as resulting from either inadequate gross core heat removal, inadequate core regional, or individual fuel rod heat removal. Inadequate core regional or individual fuel rod heat removal is the more probable cause of fuel damage because of the lack of protective system action (as is indicated by the absence of AND gates in this branch of the tree). Low channel coolant flow and high channel coolant outlet temperature alarms on each channel will provide a warning to the operator. Inadequate gross core heat removal could result from any of the three input events. A loss of core pressure, resulting in a fuel-to-coolant heat transfer coefficient decrease, does not have the redundant scram protection of other accidents, except in the case of a system rupture. It therefore probably represents the more critical input. Redundant scram protection is provided for the other accidents leading to the inadequate gross core heat removal event.

Several critical areas exist in the large power transient (see Figure 3-17) branch of the tree. The positive coolant and moderator temperature reactivity coefficients are a source of concern. As a result of these coefficients, the large power transient event is an input event leading to the coolant heating and/or channel void and moderator system heating events. This closed loop effect is of concern from both safety and plant control viewpoints. A careful investigation of this area is required.

A second area of concern is the boric acid xenon compensation system. The inadvertent removal of boric acid during shutdown poses a startup accident problem. Shutdown interlocks which prevent boric acid removal during reactor shutdown, and the boric acid concentration monitor and alarm when coupled with adequate startup procedures, should provide adequate protection in this area.

Inadequate core regional or individual fuel rod heat removal (see Figure 3-18) is not as critical in the inadequate shutdown heat removal branch as in the inadequate at-power heat removal branch because of the greatly reduced heat flux and the backup cooling system.

If, in the case of a system leak, the backup cooling system failed, a gross core, rather than regional effect, could be expected The critical area of the inadequate gross core heat removal branch is the rupture of the primary coolant system in the auxiliary building coupled with a failure to isolate the rupture coolant loop. Under these circumstances, the backup coolant system has to be supplied coolant from makeup tanks and sufficient coolant may not be available. Provisions for pumping primary system coolant from the auxiliary building back into the system might be desirable.

Several months following this work, a fault tree was also prepared for the FBR Design Basis Accident (fuel melting). In this case, relative order of magnitude probabilities were assigned to the various fault modes and the critical paths were scribed on the fault tree diagrams by variation of the lines connecting events (others have used color coding with red for critical).

Though this approach is qualitative, it was valuable in pointing out areas of design weaknesses; e.g., the need for in-core flow and/or temperature protective instrumentation was indicated in the "Inadequate At-Power Heat Removal" by the total lack of AND gates in the network leading to and from the "inadequate Core Regional and/or Individual Fuel Pin Heat Removal" event. This lack of protective instrumentation rendered this as the most probable mode of failure leading to the output event.

Of interest is the fact that, even for such widely different concepts as the HWOCR and FBR, the fundamental structure of many of the fault tree branches developed for the HWOCR were applicable to the FBR concepts. Thus, when a fault tree for a specific reactor has been constructed, much of the fundamental structure can be applied to other reactor concepts.

2. Example No. 2

In this example, the question to be answered was whether the configuration analyzed in example No. 1 and schematically represented in Figure 3-19 (Scheme A) would be as safe from the standpoint of potential radiological release to the environs as a larger containment vessel with the steam generators placed within the containment (Scheme B). The latter would relieve the dependence upon isolation valves in the primary system but would require more containment penetrations and a larger heating and ventilating system.

In this analysis, a gross fuel failure was assumed to have occurred and the probability of release traced through the fault tree for each scheme.

The following are excerpts from the Addendum to AI-CE Engineering Document TSR-014-93-002, dated 4/27/67, which shows the results, assumptions, and fault tree simplifications from previous Scheme A fault trees and their expansion to include the new configuration of Scheme B. These fault trees are shown in Figures 3-20 through 3-23 with the containment penetration schemes shown in Figures 3-24 and 3-25. The sketches and calculations follow the method as explained and may be obtained from information contained in Table 3-2, but are not repeated here. The reader should note that while the results are reasonably convincing, the numerical magnitude of difference will change quite drastically with changes in some of the design assumptions, but very little with reasonable changes in the expected failure rate.

The probabilities of radioactivity release for Schemes A and B are summarized as follows:

	Probability of Release from Auxiliary Structures	Probability of Release from Reactor Containment Structure	Total Probability of Release
Scheme A (Reactor Containment)	$Q_1 = 1.06 \times 10^{-7}$	$Q_2 = 4.62 \times 10^{-5}$	$Q_o = 4.63 \times 10^{-5}$
Scheme B (Reactor + Loop Containment)	$Q_1 = 7.08 \times 10^{-8}$	$Q_2 = 7.55 \times 10^{-5}$	$Q_o = 7.56 \times 10^{-5}$

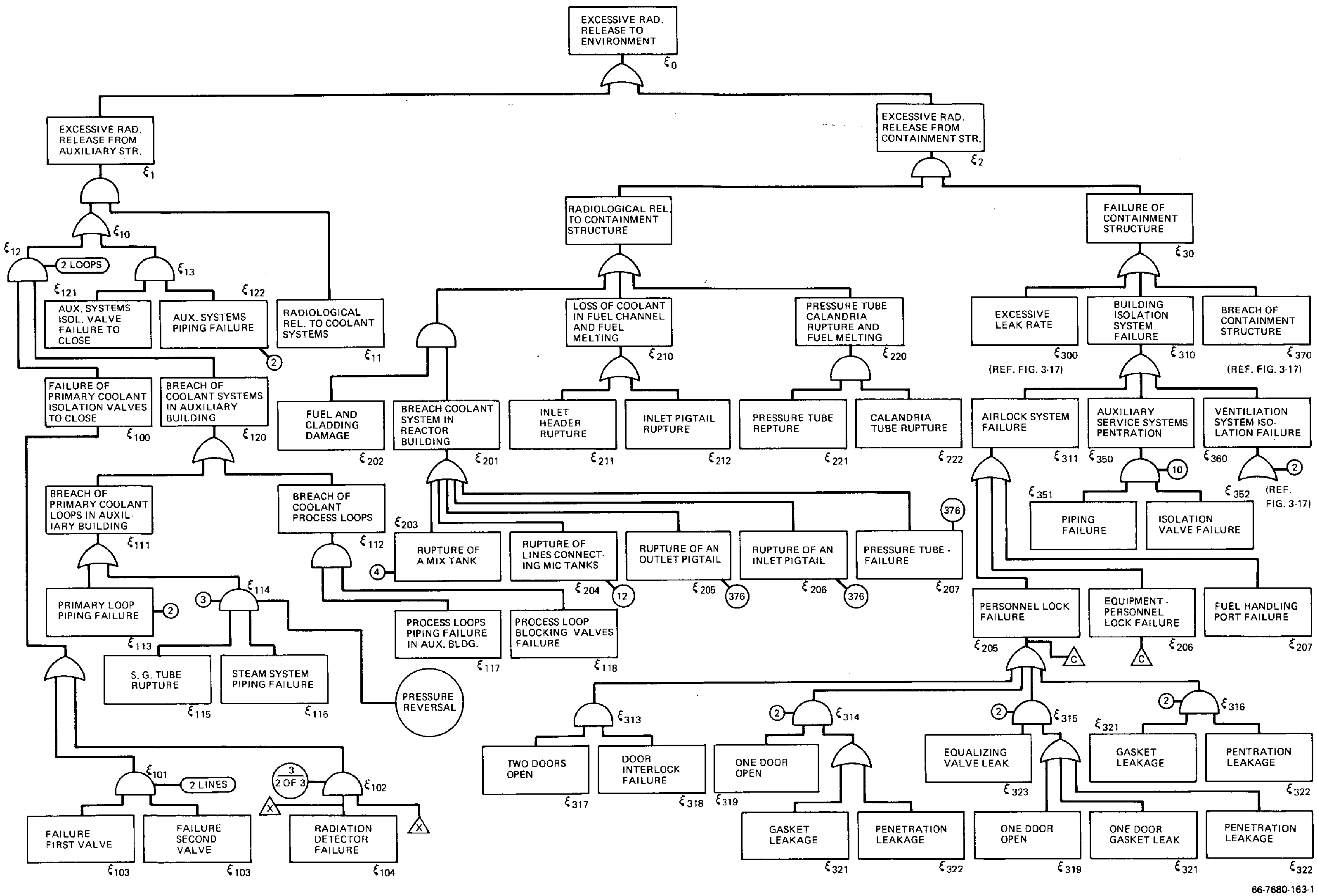

Figure 3-20. Reactor Containment Fault Tree, Scheme A

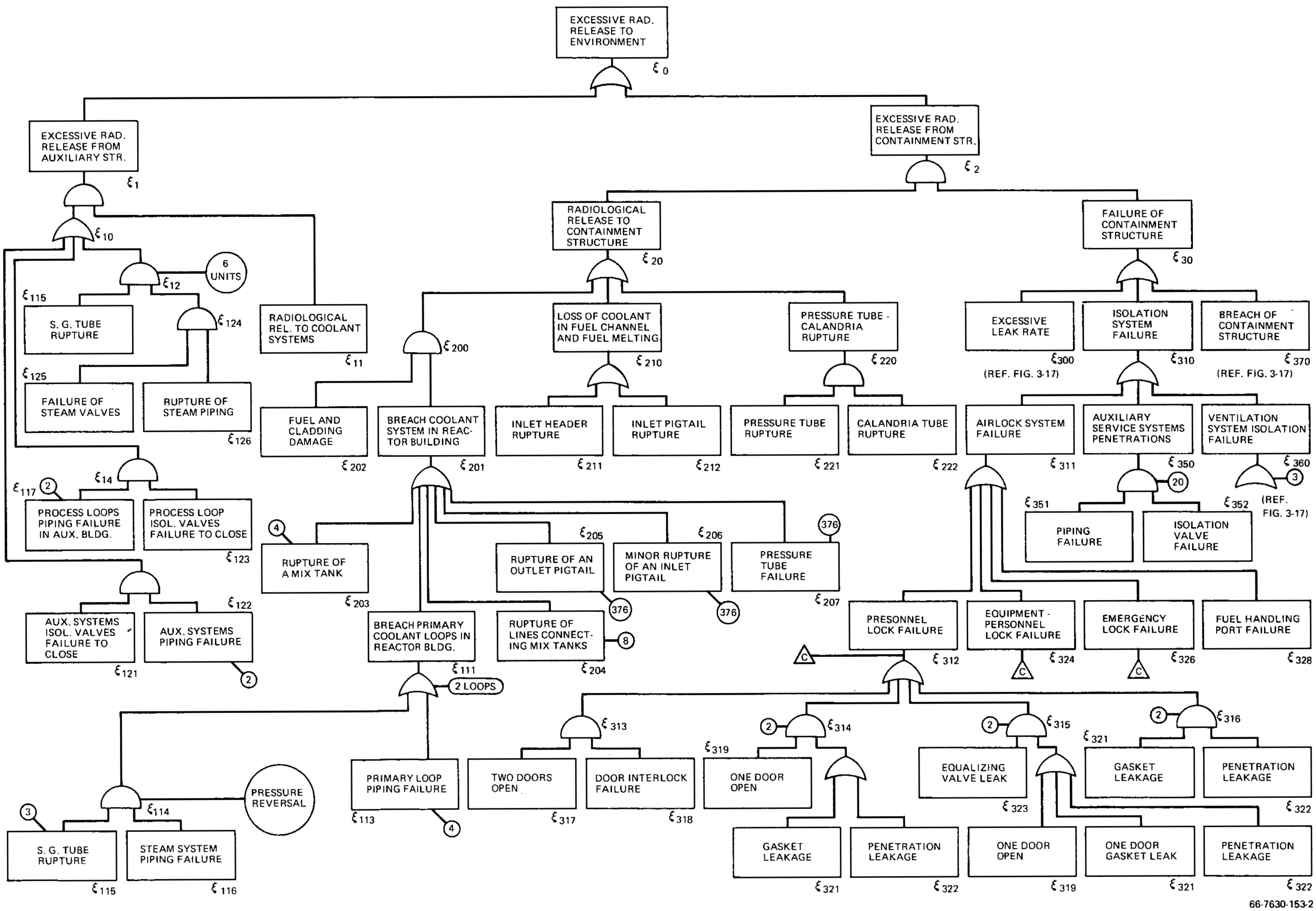

Figure 3-21. Reactor-Loop Containment Fault Tree, Scheme B

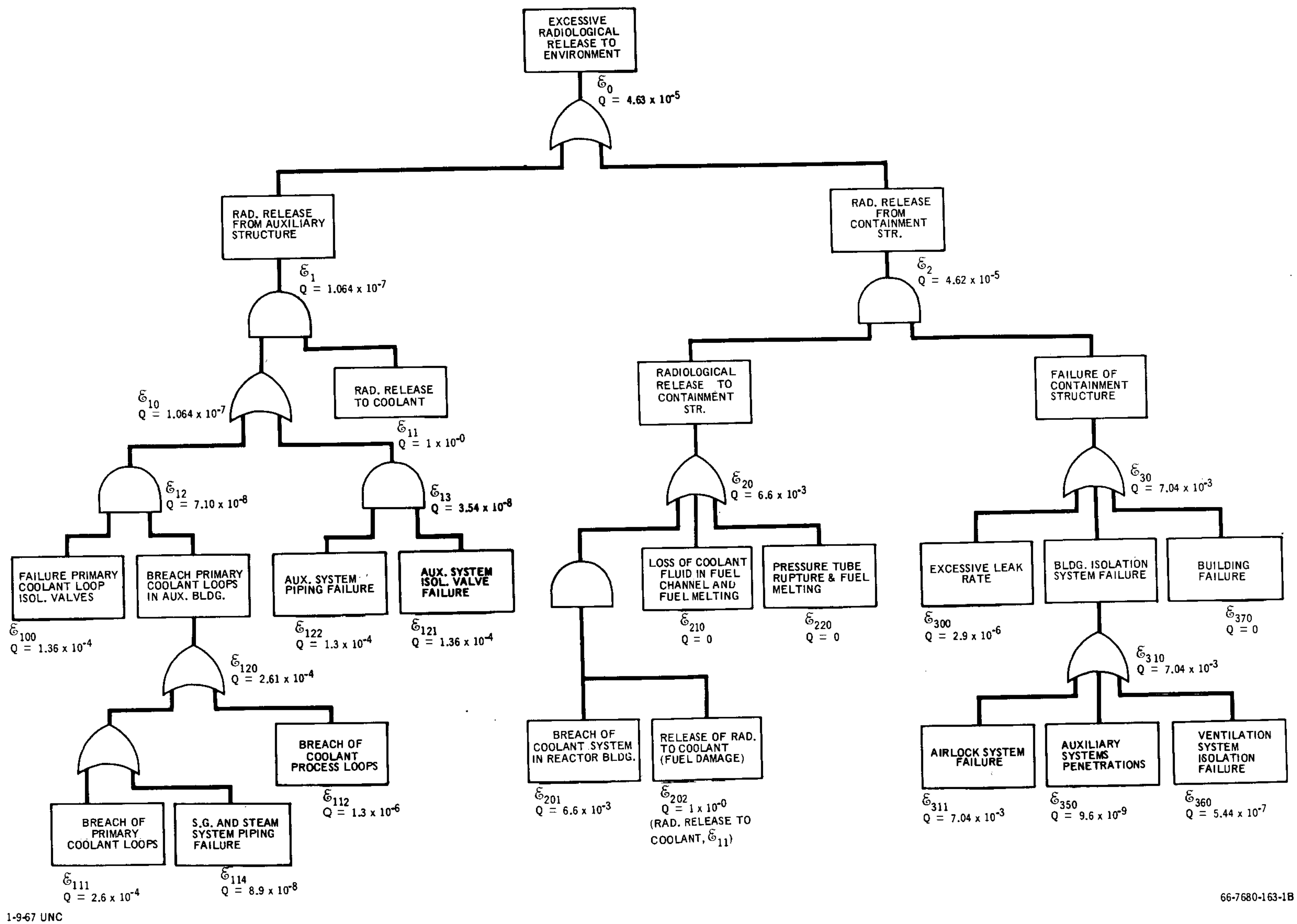

Figure 3-22. Reactor Containment Gross Fuel Damage Accident, Scheme A

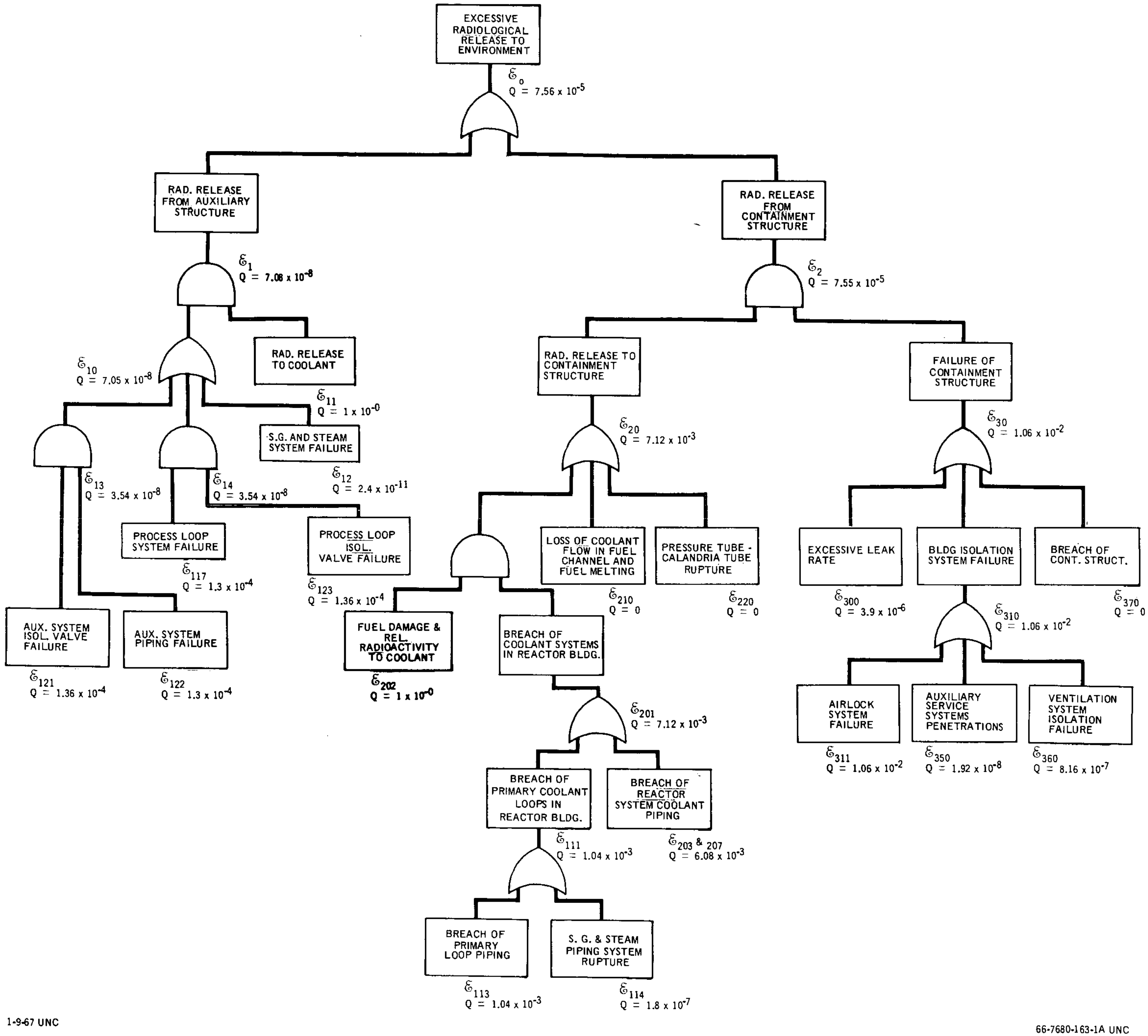

Figure 3-23. Reactor-Loop Containment Gross Fuel Damage Accident, Scheme B

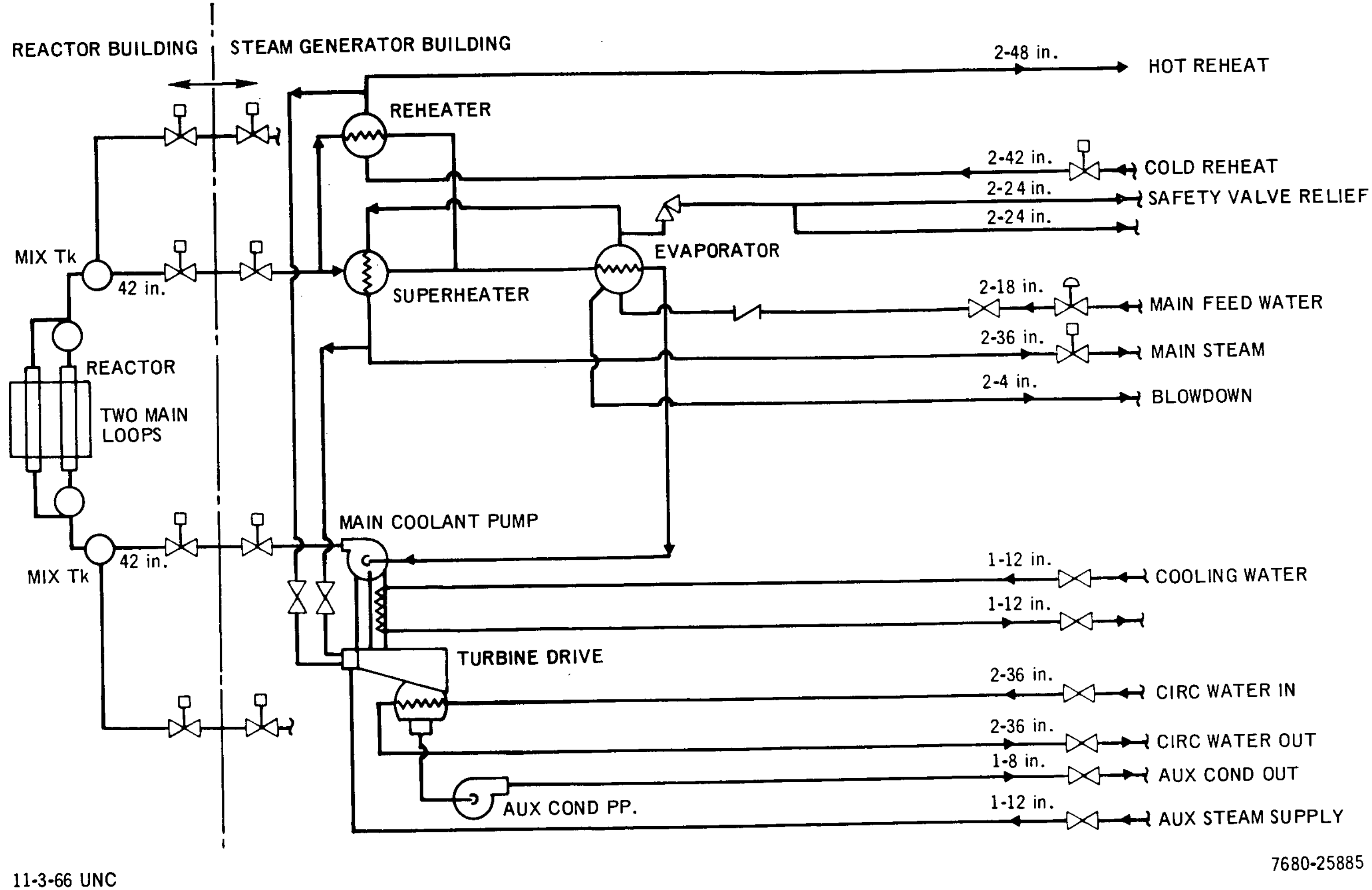

Figure 3-24. HWOCR Demonstration Plant Containment Flow Schematic, Scheme A

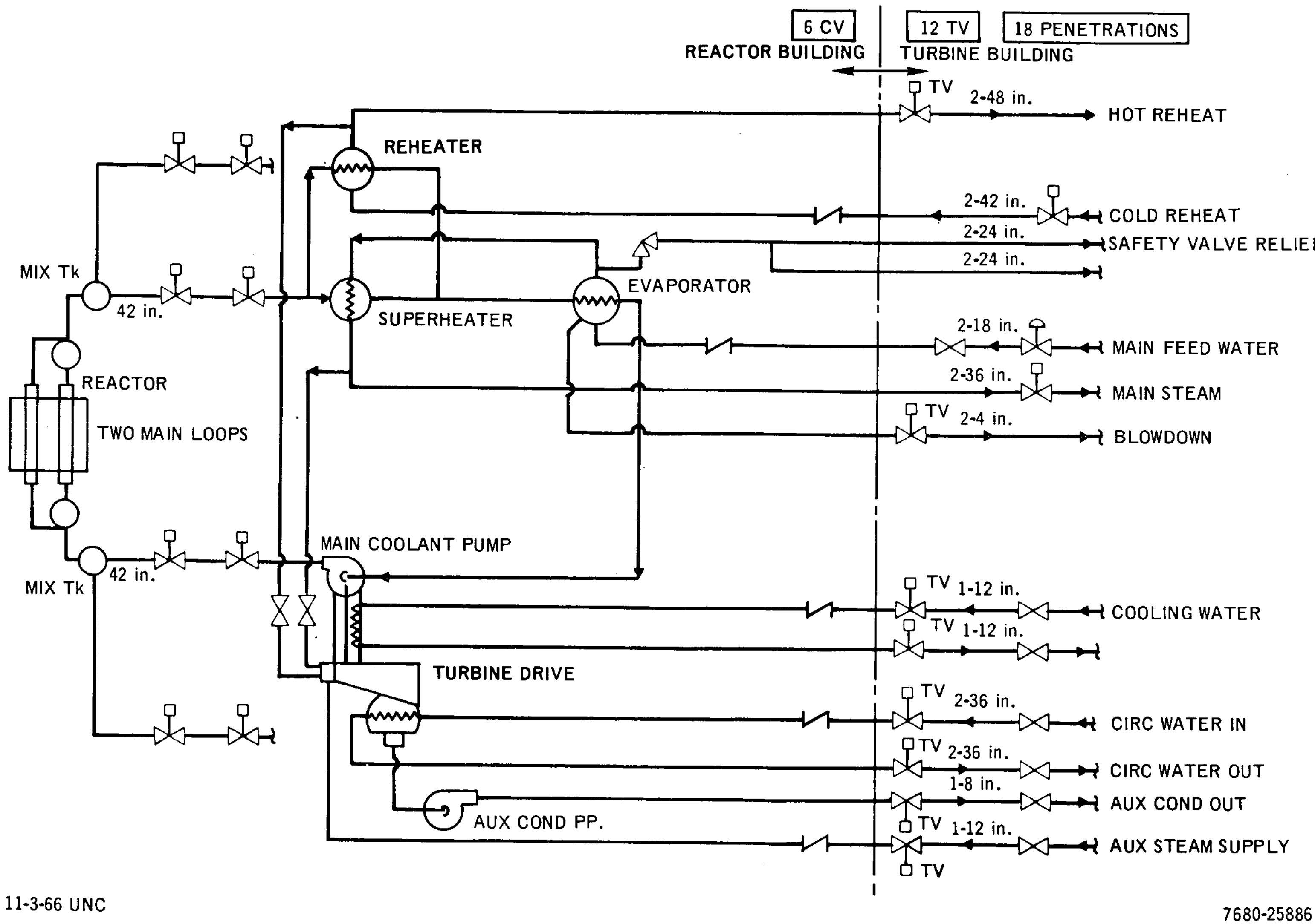

Figure 3-25. HWOCR Demonstration Plant Reactor and Loop Containment Flow Schematic, Scheme B

TABLE 3-2

INPUT DATA FOR FAULT TREE INITIATING EVENTS
(Sheet 1 of 5)

Component/Event	Reference No. ξ	λ (failures/hr)	τ (hrs)	Reference/Remarks
Radiological Release to Coolant System	11	1	-	Assumed to have occurred. Same as event 202 (fuel and cladding damage)
Coolant Isolation Valve	103	8.6×10^{-6}	720	EEI Publication No. 63-42, Edison Electric Institute, N.Y. 17; (F.W. Valves and Piping, Table 2E)
Coolant Radiation Detection System	104	2.7×10^{-5}	168	AHSB(S)R99, Reliability Assessment of Protective Equipment for Nuclear Installations (Table II)
Coolant Loop Piping	113	5.6×10^{-6}	24	Assume 3σ standard deviation stress margin at end of life (30 yr) per section of pipe (n). A section of pipe is defined as that length of pipe between those supports which constitute calculational end points.
Heat Exchanger Tubes	115	9.4×10^{-6}	24	Reference same as 103 (Failure Rate for Generating Tubes, Table 2E)
Steam System Piping	116	5.6×10^{-6}	24	Reference same as 103 (Failure Rate for Steam Valves and Piping, Table 2E)
Process Loop Piping System	117	5.6×10^{-6}	24	Same as event 116
Process Loop Blocking Valve	118	4.6×10^{-6}	2160	Martin-Denver Reliability Handbook (Glove, Gate, and Ball Valve Failure Rate)

TABLE 3-2

INPUT DATA FOR FAULT TREE INITIATING EVENTS
(Sheet 2 of 5)

Component/Event	Reference No. ξ	λ (Failures/hr)	τ (hrs)	Reference/Remarks
Auxiliary System Isolation Valves	121	See remarks	-	Same probability as $Q_{\xi 100}$
Auxiliary System Piping	122	5.6×10^{-6}	24	Same as event 113
Process Loop Isolation Valves	123	See remarks	-	Same probability as $Q_{\xi 100}$
Steam Isolation Valves	125	See remarks	-	Same probability as $Q_{\xi 100}$
Steam Piping	126	5.6×10^{-6}	24	Same as event 113
Mix Tank	203	4×10^{-9}	24	Assume 3σ standard deviation stress margin at end of life (30 yr)
Lines Interconnecting Mix Tanks	204	5.6×10^{-6}	24	Same as event 113
Outlet Pigtail Rupture	205	4×10^{-8}	168	Reduce by 2 orders of magnitude to reflect instrument penetrations
Inlet Pigtail Rupture	206	4×10^{-8}	168	Same as event 205
Pressure Tube Rupture	207	4×10^{-9}	1	Assume reliability of 0.999 per pressure tube. Assume end seal bellows will fail concurrently.
Fuel and Cladding Damage	202	1	-	Assumed to have occurred. Same as event 11 (radiological release to coolant)

TABLE 3-2

INPUT DATA FOR FAULT TREE INITIATING EVENTS
(Sheet 3 of 5)

Component/Event	Reference No. ξ	λ (failures/hr)	τ (hrs)	Reference/Remarks
Fuel Damage Due to Loss of Coolant	210	0	-	This analysis has assumed fuel damage from another course and that this event does not occur concurrently
Pressure Tube - Calandria Tube Failure	220	0	-	Same as event 210
Degradation of Wire Penetration Seals	301	Single Seal, 1×10^{-7}; Double Seal, 1×10^{-14}	0	Single failure rate calculated from Holmes and Narver Nuclear Plant Safety Study, HN-185 (preissue copy). Ref. Supplement I to IL from C. W. Griffin, Relative Integrity of HWOCR Containment Configurations, dated October 3, 1966, Continuous Leak Monitoring.
Degradation of Ventilation Valves	305	1×10^{-7}	8766	Assumed to be same failure rate for wiring penetrations, event 301. No continuous monitoring.
Degradation of Piping Penetrations	303	Single Seal, 1×10^{-7}; Double Seal, 1×10^{-4}	0	Same as event 301. Continuous monitoring.
Other Leakage Paths (i.e., liner welds)	304	~0	-	Assume double containment around all welds

TABLE 3-2

INPUT DATA FOR FAULT TREE INITIATING EVENTS
(Sheet 4 of 5)

Component/Event	Reference No. ξ	λ (failures/hr)	τ (hrs)	Reference/Remarks
Two Air Lock Doors Open and Interlock Failure	313	~0	-	Assumes interlock failure and subsequent failure of operator to close two doors negligible
One Air Lock Door Open	319	10^{-2}	1/4	Assumed that only 1 in 100 operators would leave a door open under an emergency condition. τ = 15 min. was assumed to be the time required for detection and subsequent closing of the door.
Personnel, Equipment, Air Lock and Emergency Door Gasket Leakage	321	4.6×10^{-6}	4383	Reference same as event 301. Used higher equipment air lock failure rate data to assure this value is conservative
Personnel, Equipment, Air Lock and Emergency Penetration	322	4.6×10^{-6}	4383	Same as event 321.
Fuel Handling Port	328	~0		For leakage to occur, four valves must fail or two valves and a pipe; this would be $Q \cong 10^{-20}$
Personnel and Equipment, Air Lock and Emergency Equalizing Valve Leakage	323	4.6×10^{-6}	4383	Same as event 321.
Auxiliary and Service Piping Systems	351	5.6×10^{-6}	24	Same as event 113

TABLE 3-2

INPUT DATA FOR FAULT TREE INITIATING EVENTS
(Sheet 5 of 5)

Component/Event	Reference No. ξ	λ (failures/hr)	τ (hrs)	Reference/Remarks
Isolation Valve Failure	351	4.6×10^{-6}	2160	Same as event 118
Ventilation Valve Failure	363	4.8×10^{-7}	780	Reference same as event 301; failure rate is for ventilation valves.
Breach of Containment Structure	370	~0		Insignificant probability
NOTE: Equipment - Personnel Air Lock consists of large bolted door with personnel door in it.				

The numbers indicate that the probability of releasing radioactive material to the environs is greater for Scheme B than for Scheme A for the accident studied (gross fuel failure). There are, of course, other important accidents which must be studied to determine the overall relative reliability between the two concepts.

An examination of Figures 3-22 and 3-23 indicates that the higher degree of relative reliability of Schem A over Scheme B (for the gross fuel damage accident) is primarily due to the following:

1) The containment building for Scheme B is larger, has more piping and electrical penetrations, more ventilation system penetrations, and an additional air-lock. These increase the probability that the containment building will not be isolated when required. The isolation feature comparison (event ξ_{310}) shows that the probability of failure for Scheme B is 1.06×10^{-2}, compared to 7.04×10^{-3} for Scheme A. This is a ratio of $10.6 \times 10^{-3}/7.04 \times 10^{-3} = 1.5$.

2) The combined probability of failure of the primary coolant loop isolation valves (ξ_{100}) to close and the failure of the primary loops (ξ_{120}) is low. This value, $(\xi_{12})Q = 7.1 \times 10^{-8}$, does not result in a significant probability of release of radioactivity from the auxiliary structure, $(\xi_{1})Q = 1.06 \times 10^{-7}$.

3) The placing of the main heat transfer loop into the containment building does not significantly increase the probability of radioactive coolant getting into the building. The fault rate data indicate that the probability of failure in the reactor system coolant piping (inlet and outlet pigtails, pressure tube, inlet and outlet headers, etc.) is about six times greater than the probability of release from the primary coolant loops.

$$(\xi_{203} \ \& \ \xi_{207})/\xi_{111} = 6.08 \times 10^{-3}/1.04 \times 10^{-3}$$

VII. BIBLIOGRAPHY

A. INTRODUCTION

The literature search that resulted in this compilation of titles, authors, books, articles, papers, reports, and specifications was undertaken for the Pacific Northwest Laboratories (PNL) in conjunction with reliability development in the Fast Flux Test Facility (FFTF). It is recognized that there may be omissions and that while the compiler rated publications to the best of his knowledge with respect to FFTF applicability, these may be subject to controversy.

The following categories are identified:

A. Mathematical and Statistical Tables and Formulas

B. Theory of Statistics, Probability and Logic of Design

C. The Design of the Statistical Experiment

D. Reliability Engineering and Management

E. Maintainability, Availability, and Logistic

F. Environmental Testing and Effects of Environment

G. Nondestructive Testing Methods

H. Data Handling Methods for Statistical Applications

I. Failure Rates and Failure Modes

J. Miscellaneous Other Texts

K. Reliability Documentation

L. Quality Assurance

M. Maintainability

N. Safety Documents

O. Human Factors

P. Value Engineering

Q. Technical Journals and Periodicals

Categories A through J are ranked as to the degree of applicability of the text to reliability engineering for reactor design work. The following four ranks, identified by numerals 1, 2, 3, and 4, in the second column of the tables have been established:

1. Most of the text is directly applicable to the type of reliability engineering required for past, present, or future reactor development work.
2. Some of the text is directly applicable and most of the text can be applied by engineering interpretation for past, present, or future reactor development work.
3. None of the text is directly applicable, but some of the text can be applied by engineering interpretation for past, present, or future reactor development work.
4. None of the text is directly applicable and little of the text can be applied by engineering interpretation for past, present, or future reactor development work.

The term, "Most", signifies the great majority if not the complete content of the text, and the term, "Some", signifies an Appreciable Part of the text, hence, more than just a few paragraphs or a few selected pages.

In general, it should be realized that almost all of the listed references, specifications, and data have been developed in engineering fields which are unrelated to atomic energy and reactor application design. The operating environments of power generating plants are vastly different from those affecting the operations of airborne systems, spacecrafts, or ground support-digital computers, yet most failure data available are concerned with these types of hardware. Interpolation to account for the differences in the mode of operation, in the magnitude of environmental stress, etc., are necessary and will influence the ultimate release of new data and reports specifically written for the field of atomic reactor design and application.

The extreme right-hand column of categories A through J also indicates the physical form of the text by the following code: "B" for hard-bound book, "A" for a single article published in a technical magazine, "P" for a single paper delivered at a technical meeting or symposium, and "S" for a soft-bound book or brochure.

B. REFERENCES ON RELIABILITY-MAINTAINABILITY-SYSTEM EFFECTIVENESS AND RELATED SUBJECTS APPLICABLE TO FFTF

1. Category A - Mathematical and Statistical Tables and Formulas

No.	Rank	Author(s)	Title	Publisher/Year	Code
A-1	1	Burington-May	Probability and Statistics Handbook Presenting both tables and theory, arranged for handy application for the reliability engineer and statistician. Reviewed by American Statistical Association.	McGraw-Hill, NY, 1951	B
A-2	1	NBS	Tables of the Binominal Probability Distribution, National Bureau of Standards Inexpensive compilation of the 7 - place table. Applied Mathematics Series # 6.	U.S. Government Printing Office, Washington D.C., 1949	B
A-3	2	Ryswick-Weiss	Tables of the Incomplete Gamma Function of Integral Order NAVWEPS Report 7292	U.S. Naval Ordnance Lab, White Oak, Md. 1960	S
A-4	1	Defense System Dept G. E.	Tables of the Individual and Cumulative Terms of Poisson Distribution (8 Places)	D. Van Nostrand Company, NY	B
A-5	1	NBS	Tables of Normal Probability Functions National Bureau of Standards Applied Mathematics Series # 23	National Bureau of Standards, 1953	B
A-6	1	No Author	Tables of the Cumulative Binomial Probability Distribution	Harvard University Press, Cambridge, Mass. 1953	B
A-7	2	NBS	Probability Tables for the Analysis of Extreme Value Data Applied Mathematics Series # 22	National Bureau of Standards, 1953	B
A-8	1	Jahnke/Emde	Tables of Functions 4th Edition A good report for reliability estimates.	Dover Publications Inc., New York	B
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B-86	3	Aitchison, J. and Brown, J.	The Log Normal Distribution	Cambridge University Press, Cambridge, England, 1957	B
B-87	2	Steck, G. P.	Upper Confidence Limits for the Failure Probability of Complex Systems/Exponential Sampling Plans JC-4133 (TR)	Sandia Corporation, Albuquerque, New Mexico, 1959	S

3. Category C - Design of the Statistical Experiment

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C-1	3	Lipp, J. P.	Topology of Switching Elements versus Reliability IRE Transactions in Reliability and Q. C., PGRQC-10	1957	S
C-2	2	Sparling, Rebecca M.	Testing in the Guided Missile Industry ASTM Bulletin No. 218, pp 52-56 General consideration on the subject.	1956	S
C-3	2	Culbertson-Vorhees	Control Charts and Automation Applied to Analysis of Field Failure Data Proceedings of the 2nd National Symposium on Quality Control and Reliability in Electronics, Washington, D. C. January 1956.	Available from IRE, 1 E 79 Street, N. Y. 21, N. Y.	S
C-4	2	Zelen, M.	Factorial Experiments in Life Testing Article, Technometrics, pp 269-288	1959	A
C-5	3	Zelen, M. Danne-miller	Are Life Testing Procedures Robust? Proceedings of the 6th National Symposium on Reliability and Quality Control in Electronics (IRE) Washington, D. C.	1960	P
C-6	1	Deming, W. E.	Some Theory of Sampling Recommended by Lloyd-Lipow	John Wiley & Sons, New York, 1950	B
C-7	3	Acheson, M. A.	Life Factors Affecting Acceptance Procedures Proceedings of the 2nd National Symposium in Quality Control and Reliability in Electronics, Washington, D. C.	1956	P
C-8	2	Allen, W. R.	Inference From Tests with Continuously Increasing Stress Operations Research, pp 303-312	1957	P
C-9	3	Bartholomew, D. J.	Testing for Departure from the Experimental Distribution Biometrika, Parts 1 & 2, pp 253-257	1957	A
C-10	3	Bartholomew, D. J.	A Problem of Life Testing Journal of the American Statistical Association, pp 350-354	1957	P
C-11	3	Walsh, J. E.	Assymptotic Efficiencies of a Nonparametric Life Test for Smaller Percentiles of a Gamma Distribution Journal of the American Statistical Association, pp 467-480	1956	P
C-12	2	Brown, H. B.	The Role of Specifications in Predicting Equipment Performance Proceedings of the 2nd National Symposium on Q. C. and Reliability, Washington, D. C.	1956	P

No.	Rank	Author(s)	Title	Publisher/Year	Code
C-13	2	Jobel, M. and TischenDorf,	Acceptance Sampling with New Life Test Objectives Proceedings of the 5th National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pa., January 1959	1959	S
C-14	2	Goode and Kao	Sampling Plans Based in the Weibull Distribution Proceedings of the 7th National Symposium on Reliability and Quality Control in Electronics, Philadelphia, Pa., January 1961	1961	S
C-15	1	PB 171581	Statistical Techniques in Life Testing U. S. Department of Commerce Office of Technical Services, Washington 25, D. C.	1961	S
C-16	1	Epstein-Sobel	Segmential Life Tests In the Exponential Case Annals of Mathematical Statistics, pp 82-93	1955	P
C-17	1	Epstein-Sobel	Life Testing Journal of the American Statistical Association, pp 486-502	1953	P
C-18	3	Breakwell, J. V.	Economically Optimum Acceptance Tests Journal of the American Statistical Association, June 1956, pp 243-256	1956	P
C-19	3	Epstein, B	Statistical Developments in Life Testing Proceedings of the 3rd National Symposium on Reliability and Quality Control, Washington, D. C., January 1957	1957	S
C-20	2	Moriguti, Sigeiti	Efficiency of a Sampling Inspection Plan Reports of Statistical Applications Research, Union of Japanese Scientists and Engineering	1956	S
C-21	2	Sobel, M.	Statistical Techniques for Reducing the Experiment Time in Reliability Studies Bell System Technical Journal, pp 179-202	1956	P
C-22	3	Ayer-Brunk-Ewing, etc.	An Empirical Distribution Function For Sampling With Incomplete Information Annals of Mathematical Statistics, pp 641-647	1955	A
C-23	3	Gabriel, K. R.	The Distribution of the Number of Successes in a Sequence of Dependent Trials Parts 3 and 4, Biometriku, pp 454-460	1959	A
C-24	1	Davies, O. L.	Design and Analysis of Industrial Experiments	Oliver and Boyd, London and Edinburgh	B

No.	Rank	Author(s)	Title	Publisher/Year	Code
C-25	2	Cochran, W.G. Cox, G.M.	Experimental Design 2nd Edition	John Wiley & Sons, New York City, 1957	B
C-26	2	KempThorne, V.	The Design and Analysis of Experiment Recommended by Lloyd - Lipow	John Wiley & Sons, New York City, 1952	B
C-27	3	Hartvigsen, D. E. and Lloyd, D. K.	The Application of Statistical Test Designs to Qualification Testing of Rockets in Guided Missiles Proceedings Western Regional Conference, ASAC, San Francisco, Calif.	1957	P
C-28	3	Acheson, M.A.	Quality Acceptance Practices in Specifications Proceedings of the 3rd National Symposium on Reliability and Quality Control in Electronics, (IRE) pp 136-140	1957	P
C-29	2	Kuzmin, W.R.	Experiments to Expose Marginal Reliability Design Proceedings of the 5th National Symposium on Reliability and Quality Control in Electronics, (IRE) pp 55-64	1959	P
C-30	3	Zelen, M.	Problems in Life Testing: Factorial Experiments Transactions of the 13th Mid-West Quality Control Conference, ASQC, November 1958, pp 21-33	1958	S
C-31	3	Anscombe, F. J.	Quick Analysis Methods for Random Balance Screening Experiments Technometrics, pp 195-209	1959	A
C-32	2	Hiltz, P.A. SID 67-480	Testing Data for the Representative Distribution Space Division - NR report How to interpret data retrieved from quantitative testing of spacecraft components.	North American Rockewell, 1967	S
C-33	3	Smith - Waltz	Testing for Spacecraft Reliability - A Management Overview Annals of Assurance Sciences, 7th Reliability and Maintainability Conference, San Francisco, Calif.	ASME, 1968	P
C-34	2	Box, Connor, Cousins, Davis, etal	Design and Analysis of Industrial Experiments	Hafner, New York, 1956	B
C-35	2	Fisher, Sir R. A.	The Design of Experiments 6th Edition	Oliver & Boyd, London, 1951	B
C-36	3	USAF, WADC 59-490	Environmental Test Sequence and Number of Test Items ASD Wright Patterson Air Force Base, Ohio	1959	S

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C-37	4	Stewart, Walter A.	Statistical Method from the Viewpoint of Quality Control Graduate School, U. S. Dept of Agriculture, Washington, D. C. Recommended by Thein, USAF, as use of the fundamental books for Q. C.	1939	B
C-38	2	Freeman, D. and Weiss, L.	Sampling Plans Which Minimize the Maximum Expected Sample Size Journal of the American Statistical Association Vol 59, pp 67-88	1964	A
C-39	2	Joreskog, K. G.	Testing A Simple Structure Hypothesis in Factor Analysis Educational Testing Services, Research Bulletin RB-65-1 Princeton University, New Jersey	1965	S
C-40	1	Lehman, E.	Testing Statistical Hypothesis	John Wiley & Sons, New York City, 1959	B
C-41	3	Pugachev, V. S.	Theory of Random Functions and Application to Control Problem	Pergamon Press, New York City, 1965	B
C-42	1	Stuart, Alan	Basic Ideas of Scientific Sampling	Hafner, New York City, 1962	B
C-43	4	Thomas, R. E. and Mendelhall, R. V. ECRC Report No. 2	Development of Models for Analysis of Accelerated Test Data Battelle Memorial Institute, Columbus, Ohio	1961	S
C-44	4	Thomas, R. E. and Drennan, J. E. ECRC No. 3	Development of Models for Analysis of Accelerated Test Data Battelle Memorial Institute, Columbus, Ohio	1961	S
C-45	3	Bailey, J. H. and Mikhail, W. F.	Segmential Testing of Electronic Systems Development Labs, Systems Division, IBM - Poughkeepsie, New York 9th National Symposium on Reliability and Quality Control	IBM, 1963	S
C-46	4	Goldin, Paul J.	RCA's Experience With AGREE Testing Aerospace Communication and Controls Division, RCA-Camden 9th National Symposium on Reliability and Quality Control	1963	S
C-47	3	Conner, W. S.	Evaluation by Overstress Research Triangle Institute Industrial and Engineering Chemistry, Vol 53, P 73A	1961	A
C-48	3	Paccone, R. H.	A Proposed Program for the Evaluation of Electrical Connections Report No. 58-816-39, IBM Corp., Unego, New York	IBM, 1958	S

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C-49	3	Plumb, S. C.	A Program for Statistical Reliability Evaluation by Synthetic Sampling (Stress) IBM - Poughkeepsie, New York TR 00, 834	IBM, 1962	S
C-50	2	Ryerson, C. M.	Reliability Testing Theroy Based on the Poisson Distribution Proceedings, 4th National Symposium for Reliability and Q.C., pp 3-18	1958	S
C-51	3	Smith, J. H.	Significance Tests of Effects of Wear-out Failures Proceedings, 3rd National Symposium for Reliability and Q.C. pp 103-107		S

4. Category D - Reliability Engineering and Management

No.	Rank	Author(s)	Title	Publisher/Year	Code
D-1	3	Hiltz, P. A. SID 67-726	Equivalent Linear Representations of Nonlinear Electronic Elements Space Division - NR report	North American Rockwell	S
D-2	1	Bollman, J. H.	Instructions and Data for Failure and Prediction Report Bell Telephone Laboratories	1957	S
D-3	2	TR59-46-1	Reliability Stress Analysis for Electronic Equipment RCA Technical Report, Camden, New Jersey		S
D-4	3	Ketelle, J.	Least Cost Allocation of Redundancy Presented at the Seventh National Meeting of the Operations Research Society of America		P
D-5	4	AGREE Report	Reliability of Military Electronic Equipment This book contains the original work of the Advisory Group in Reliability of Electronic Equipment ordered by the Assistant Secretary of Defense	U. S. Government Printing Office, Washington, D. C. 1957	B
D-6	2	Hall, A. D.	A Methodology for Systems Engineering Relation of system development to reliability engineering; fairly basic; in frequent use.	D. Van Nostrand, Princeton, N. J. 1962	B
D-7	3	Henney, K.	Reliability Factors for Ground Electronic Equipment A book written primarily for ground installation (ground support equipment) but perhaps outdated because of greater accumulation of data from later equipment.	McGraw Hill, New York 1956	B
D-8	2	Flagly, C. D. Huggins, Ray	System Engineering and Operations Research Emphasis in Operations Research leads to the application of reliability engineering techniques.	John Hopkins Press, Baltimore, Md. 1960	B
D-9	1	Sandler, G. H.	System Reliability Engineering Favors the statistical approach with emphasis on maintained and nonmaintained systems	Prentice Hall, New Jersey 1963	B
D-10	1	Lloyd, D. K. and Lipow, M.	Reliability: Management, Methods and Mathematics One of the better books on the subject, it favors the statistical and probability analysis approach; heavy in mathematics.	Prentice Hall, New Jersey 1962	B
D-11	1	Calabro, S. R.	Reliability, Principles and Practices Includes good sections in maintainability-availability. Emphasis is on the practical approach to reliability engineering.	McGraw Hill, New York 1962	B

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D-12	1	Van Alvin	Reliability Engineering One of the best and latest books in this subject, it reflects the vast experience of ARINC Research in the AVIONIC field.	Prentice Hall, New Jersey 1966	B
D-13	1	Haugen, E. B.	Probabilistic Approach to Design A new approach, which ties design factors in structural design to the probabilistic distribution of tolerance and failures.	John Wiley & Sons, New York 1968	B
D-14	1	Welker-Horne (ARINC Monograph No. 9)	Concepts Associated with System Effectiveness ARINC Research Corp, Washington, D. C. Some of the first considerations which led to the basic principle of system effectiveness.	1960	S
D-15	2	Kneale, S. G.	Reliability of Parallel Systems With Repair and Switching 7th National Symposium on Reliability and Q. C. in Electronics	1961	S
D-16	2	Soucy, Chester I.	A Broad Survey of the Military Electronic Equipment Reliability Problem and Its Controlling Factors. Proceedings, Electronic Components Symposium, May 1956. A general interest-type study, perhaps useful for reactor appliaction.	1956	S
D-17	1	Connor, J. A.	A Systematic Plan for Predicting Equipment Reliability Proceedings, Electronic Component Symposium, May 1956. Practical considerations on the planning and operations of reliability program plans.	1956	P
D-18	2	Matosoff, H. I.	Corrective Action in a Quality Control Program. Industrial Quality Control, January 1956		A
D-19	2	Warner, W. K.	Benefits of Time Recording for Producer and Consumer ASQC National Convention Transactions, 1959, pp 597-602. Reliability consideration and time.		P
D-20	1	Bazovsky, Igor	Reliability Theory and Practice Recommended by G. E., Defense System Dept	Prentice Hall, New Jersey 1961	B
D-21	1	Chorafas, D. M.	Statistical Processes and Reliability Engineering Statistical theory, engineering oriented. Popular text.	D. Van Nostrand Co. 1960	B
D-22	1	Goode, H. H. and Machol, R. E.	System Engineering: An Introduction to the Design of Large Scale Systems	McGraw Hill Book Co., New York 1957	B
D-23	2	Dreste, F. E.	A Reliability Handbook for Design Engineers Electronic Engineers, pp 508-512 Only a skeleton of a handbook, but handy reference tables and graphs.	1958	A

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D-24	2	Cox, D. R.	The Analysis of Exponentially Distributed Life Times With Two Types of Failure Journal of the Royal Statistical Society, London, pp 411-421	1959	P
D-25	1	Eldredge, G. G.	Analysis of Corrosion Pitting by Extreme - Value Statistics and Its Application to Oil Well Tubing Caliper Surveys. Corrosion, pp 51t - 60t	1957	A
D-26	1	Herd, G. R.	Estimation of Reliability Functions Proceedings of the 3rd National Symposium on Reliability and Quality Control in Electronics, (IRE) Washington, D. C.	1957	P
D-27	1	Connor, W. S.	Interpreting Reliability by Fitting Theoretical Distribution to Failure Data Ind. Chem. Eng., February and April 1960	1960	A
D-28	2	Aroian, L. A. and Myers, R.H.	Redundancy Considerations in Space and Satellite Systems Proceedings of the 7th National Symposium on Reliability and Quality Control, Philadelphia, January 1961	1961	P
D-29	2	Cohen, G. D.	Predicting Performance Failures Machine Design, 29/20, pp 106-111 Considering some mechanical aspects on failure prediction.	McGraw Hill, New York 1957	A
D-30	3	Box, G. E. P.	Evolutionery Operation: A Method for Increasing Industrial Productivity Applied Statistics, pp 3-23	1957	A
D-31	3	Box-Wilson	On the Experimental Attainment of Optimum Conditions Journal of the Royal Statistical Society, Series B, p 18	1951	P
D-32	1	Hiltz, P. A.	Fundamentals of Fault Tree Analysis Space Division - NR report Introductory treatment for space applications.	North American Rockwell, Downey, California	S
D-33	2	General Dynamics Corp.	Reliability Design Handbook Not too involved in theory, the book offers a fairly good approach for the reliability engineer of small electronic-electro-mechanical components with ground-to-ground missile application.	General Dynamics, Pomona Division, Pomona, California	S
D-34	2	Barker-Blais-Hansen-Underwood	Rift Reliability and Maintainability Considerations Arising from Nuclear Propulsion Proceedings, 4th Annual Seminar on Reliability in Space Vechiles	1964	P
D-35	3	Boehm, G. A.W.	Reliability Engineering Fortune 72, 4, pp 124-127, 181-182, 184, 186	1963	A

No.	Rank	Author(s)	Title	Publisher/Year	Code
D-36	1	Shooman, Martin L.	Probabilistic Reliability: An Engineering Approach Presenting method in which probability theory can be used to model, analyze, and synthesize component-system reliability.	McGraw Hill Book Co., New York City 1968	B
D-37	2	Dieckkamp-Falcon-Hoffman	Planning Today to Meet Tomorrow's Nuclear Needs Nuclear News	American Nuclear Society 1967	A
D-38	2	Olsen-Shaw	The Role of Reliability and Quality Assurance in Program Management Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York 1968	P
D-39	3	Levinsky-Rogers	Aging Characteristics Identified by Instrumental Analytical Methods Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York 1968	P
D-40	3	Myers-Moon (TRW Systems)	Service Life Prediction Program for the Minuteman LGM 30 Proportion System Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York 1968	P
D-41	3	Soltau, R.	Reliability in Space Vehicles	Engineering Publishers, Elizabeth, New Jersey	S
D-42	2	Kececioglu-Haugen	A Unified Look at Design Safety Factors, Safety Factors, Safety Margins, and Measures of Reliability Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York 1968	P
D-43	3	Koch, I. R.	Experience Derived Guidelines for Effective Failure Analysis (based on case histories of X-15, Centaur, Gemini, and PRIME programs) Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York 1968	P
D-44	2	Winthrop, A. F.	Implementation of a Design Review Program (as used by Space Tech Lab - TRW) IRE Seminar of Space Vehicles, Los Angeles	1962	S
D-45	4	Hodgeman, Weast, and Selby	Handbook of Chemistry and Physics	The Chemical Rubber Publishing Co., Cleveland, Ohio 1961	B
D-46	3	Davis, D. J. and Verhulst	Operational Research in Practice	Perganon Press, New York 1958	B
D-47	2	Williams, J. D.	The Complete Strategyst	McGraw Hill Book Co., New York City 1954	B
D-48	3	Davis, D. J.	An Analysis of Some Failure Data Journal of the American Statistical Association No. 258, pp 113-150		A

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D-50	2	Good, C. V. and Seates, D. E.	Methods of Research	Appleton-Century, Crofts 1954	B
D-51	2	Hadley, G.	Introduction to Probability and Statistical Decision Theory	Holden-Day, San Francisco 1967	B
D-52	3	Hold, Anders	Statistical Theory with Engineering Applications	John Wiley & Sons, New York City 1952	B
D-53	1	Mack, C.	Essentials of Statistics for Scientists and Technologists	Plenum Press, New York 1967	B
D-54	3	Frederick, W. C.	System Worth and Incentive Contracts ARINC Research Corporation Proceedings, 9th National Symposium on Reliability and Quality Control	1963	P
D-55	2	Pieruschka, Erich	Mathematical Foundation of Reliability Theory Research and Advanced Development Division Ordnance Missile Labs, Redstone Arsenal	1958	P
D-56	3	Masafume, Sasaki	An Easy Allotment Method Achieving Maximum System Reliability Electrical Engineering Dept, Defense Academy, Yokosuka, Japan 9th National Symposium on Reliability and Quality Control	1963	P
D-57	2	Tiger, B. and Smith, M. J.	Methodology for System Reliability Analysis Proceedings, 8th National Symposium on Reliability and Quality Control	1962	P
D-58	2	McClure, J. Y. and Winlund, E. S.	Design Review Philosophy-Policy 9th National Symposium on Reliability and Quality Control	1963	P
D-59	4	Bracha, Lt. Col. Vincent J.	Analysis of Reliability Management in Defense Industries, BSD-TDR-62-48 USAF Ballistic System Div., Air Force System Command, USAF	1962	S
D-60	4	Norris, R. H.	"RUN IN - BURN IN" of Electronic Parts A comprehensive quantitative basis for Choice of Temperature, Stress, and Duration General Engineering Labs, G. E., Schenectady, New York 9th National Symposium on Reliability and Q. C.	1963	P
D-61	4	Shwop, J. E. and Sullivan, H. J.	Comparison of Operating Life Tests and Storage Tests Chapter 13, Semi Conductor Reliability	Reinbold Publishing & Engineering Publishers, Elizabeth, New Jersey 1961	B

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D-62	3	Gladstone, S. et al	The Theory of Rate Processes (The kinetics of chemical reaction, diffusion, and electro-chemical phenomena)	McGraw Hill Book Co., New York City 1941	B
D-63	2	Weibull, W.	A Statistical Representation of Fatigue Failures in Solids Royal Institute of Technology, Stockholm, Sweden	1949	S
D-64	3	Katzenstein, Henry	System Design for Reliability 9th National Symposium on Reliability and Quality Control	Solid State Publications, Inc. Los Angeles, Calif. 1963	B
D-65	2	Breslow, D. H.	Automatic Fault Location Using Building Block Logic Proceedings, 6th National Symposium on Reliability and Quality Control	1960	S
D-66	2	Bryson, H. C.	The Training Aspects of Design Reviews Proceedings, 4th National Symposium on Reliability and Quality Control	1958	S
D-67	3	Earles, D. R.	Reliability Application and Analysis Guide Martin Co., AD 262390	1961	S
D-68	3	Fridell, H. G.	System Operational Effectiveness - Reliability/Performance/Maintainability Proceedings, 5th National Symposium on Reliability and Quality Control	1959	S
D-69	2	Griswald, J. W.	Management of Engineering Reliability Activities Proceedings, 8th National Symposium on Reliability and Quality Control	1962	P
D-70	4	Keller, J. L.	Forced Air Cooling and Reliability Proceedings, 8th National Symposium on Reliability and Quality Control, pp 408-415	1962	P
D-71	3	Kirkpatrick, I.	Predicting Reliability of Electro-Mechanical Devices Proceedings, 6th National Symposium on Reliability and Quality Control, pp 272-281	1960	P
D-72	2	Kuehn, R. E.	Reliability Aspects of Environmental Testing Report 59-816-80	IBM Corporation, Owego, New York 1959	S
D-73	2	Mackechnie, H. K.	General Procedures for Establishing and Conducting Design Reviews Proceedings, 8th National Symposium on Reliability and Quality Control	1962	P
D-74	3	Marble, Q. G.	Factors in Reliability Prediction 61-907-44, Report	IBM Corporation, Owego, New York 1960	S
D-75	2	Moore, C. G.	A Summary of Reliability Literature Proceedings, 3rd National Symposium on Reliability and Quality Control, pp 291-331	1957	P

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D-76	3	Motes, J. H.	KWIC Index to Reliability and Quality Control Proceedings, 9th National Symposium on Reliability and Quality Control, pp 556-581	1963	S
D-77	3	ARINC	Effects of Cycling in Reliability of Electronic Tubes and Equipment Volume 1, Overall Test Results Volume 2, Results of Test by Type of Equipment ARINC Research Corp, Publication 101-26-160	ARINC Research Corp 1960	B
D-78	2	Raymond, G. A.	Reliability Versus the Cost of Failure Proceedings, 4th National Symposium on Reliability and Quality Control, pp 187-188	1958	S
D-79	1	Ryerson, C. M.	Glossary and Dictionary of Terms and Definitions Relating Specifically to Reliability Proceedings, 3rd National Symposium on Reliability and Quality Control, pp 59-84	1957	S
D-80	2	Saltz, M. H.	Methods for Evaluating Reliability Growth and Ultimate Reliability During Development of a Complex System Proceedings, 5th National Symposium on Reliability and Quality Control, pp 89-97	1959	S
D-81	4	Scott, D.	The Effects of Politics on Quality Control The Garrett Corporation, El Segundo, Calif.	1961	S
D-82	3	Shainin, D.	Techniques for Determining Cause and Effect in the Presence of Many Variables Proceedings, 3rd National Symposium on Reliability and Quality Control, pp 220-222		S
D-83	1	Tall, M. M.	Reliability Management Proceedings, 5th National Symposium on Reliability and Quality Control, pp 137-145	1959	P

5. Category E - Maintainability, Availability, and Logistics

No.	Rank	Author(s)	Title	Publisher/Year	Code
E-1	2	Morse, P. M. M.	Queues, Inventories, and Maintenance Recommended by G. H. Sandler	John Wiley & Sons, New York City, 1958	B
E-2	3	Cox, D. R. and Smith, N. L.	Queues	Methues & Co. Ltd, London, and John Wiley & Sons, New York City, 1961	B
E-3	2	Barlow, R. E. and Proschan, F.	Planned Replacement Boeing Scientific Research Laboratories Seattle, Washington	Boeing Aircraft Co., 1961	S
E-4	2	Hall, K. M.	System Maintainability Proceedings of the 8th National Symposium on Reliability and Quality Control in Electronics, Washington, D. C.	1962	P
E-5	2	Kamins, M.	Determining Checkout Intervals for Systems Subject to Random Failures Rand Corp, Research Memorandum	Rand Corporation, Santa Monica, Calif. 1960	S
E-6	1	Lahs, W. R. and Ohlenkamp	Availability Assessment of Nuclear Plants Transactions, 1968 Annals of Assurance Science, 7th Reliability and Maintainability Conference, San Francisco, July 14-17, 1968	ASME, New York 1968	P
E-7	1	Edison Electric Institute	Analytical Report of Equipment Availability for a Seven Year Period, 1955-61	Edison Electric Institute Publications 1963	S
E-8	1	Edison Electric Institute	Report on Equipment Availability for the Seven Year Period, 1960-1966	Edison Electric Institute Publications 1967	S
E-9	2	Holland, M. M.	A Technique for Availability Prediction for Advanced Support Program Development Annals of Assurance Sciences, 7th Reliability and Maintainability Conference, San Francisco, Calif.	1968	S
E-10	3	Kennedy, Max K.	A Closed Loop Logistic Study in a Coolant Environment (Project PACER SORT, USAF) Annals of Assurance Sciences, 7th Reliability and Maintainability Conference, San Francisco, Calif.	ASME, New York 1968	P
E-11	2	Davenport, George	System Availability, A Management Approach Launch Support Division, Bendix Corp. Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	ASME, New York	P
E-12	1	Drummond, A. Harrison, G T.	Maintainability Prediction - Theoretical Basis and Practical Approach ARING Research Corporation . 207-1-275	ARINC Research Corp., Washington, D. C. 1962	S

No.	Rank	Author(s)	Title	Publisher/Year	Code
E-13	3	Margulies, G. and Sacks, J.	Bureau of Ships Maintainability Specification System Effectiveness Section, Bureau of Ships, 9th National Symposium on Reliability and Quality Control	1963	P
E-14	3	Nagy, George	The Reliability of Repairable Systems Goodyear Aircraft Co., Akron, Ohio 9th National Symposium on Reliability and Quality Control. Includes curves of reliability versus MTF and MR for T = 1000 hr. and different availability ratings.	1963	P
E-15	3	Bryan, G. L., et al	The Role of Humans in Complex Computer Systems: Maintenance EPR No. 26 University of Southern California	1959	S
E-16	3	Cooper, J. I. and Rigby, L. V.	Proceedings of Short Sleeve Seminar on Maintainability Report NOR 60-320 NORAIR Division, Northrop Aircraft Corp., Hawthorne, California	1960	S
E-17	2	Fitzpatrick, R., et al	The Design of Test Devices for Preventative Maintenance of Ground Electronic Equipment, Test Report RADC, 58-172 Rome Air Development Center Griffin Air Force Base, New York	USAF 1958	S
E-18	3	Folley, J. D. Jr.	Maintenance Job Simplification Without Automation AIR Memo No. 14 American Institute for Research, Pittsburch, Pa.	1959	S
E-19	2	Franks, P. E. and Furnish, C. W.	Automated Maintenance: Theory, Practice, and Implication for Training, WADD Tech Report 60-412, Wright Air Development Div., Wright-Patterson Air Force Base, Ohio	USAF 1960	S
E-20	4	Miller, R. B.	Anticipating Tomorrow's Maintenance Job, Research Review No. 53-1 Human Resources Research Center Lackland Air Force Base, Texas	USAF 1953	S
E-21	3	Cho, H. H.	On the Proper Preventative Maintenance LFE Electronics Systems Div., Lab for Electronics, Boston 9th National Symposium on Reliability and Quality Control	1963	P
E-22	2	Harrison, George	A Practical Approach to Maintainability Prediction ARING Research Corporation, Washington, D. C. 9th National Symposium on Reliability and Quality Control	1963	P

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F-132	2	No author	Symposium in Radiation Effects on Material Proceedings from Symposium Vol 1 (1956), Vol 2 (1957), Vol 3 (1958), etc.		S
F-133	2	ASTM	Radiation Effects on Materials, 3 Volumes American Society for Testing and Materials, Philadelphia, Pa.	1957-58	S
F-134	2	Billington, D. S.	How Radiation Affects Materials Nucleonics, Vol 14, p 55	1956	A
F-135	2	Harwood, J. J.	Effects of Radiation on Materials Symposium on the modification of physical, chemical, electronic and optical properties.	Reinhold Publishing Co., New York 1958	B
F-136	2	Sun, K. H.	Effects of Atomic Radiation on High Polymers Modern Plastics, Vol 32, p 141	1954	A

7. Category G - Nondestructive Testing Methods

No.	Rank	Author(s)	Title	Publisher/Year	Code
G-1	1	Parker, Henry	Simplified Mechanics and Strength of Materials	John Wiley & Sons, New York 1951	B
G-2	2	Manson, S. S.	Fatigue, A Complex Subject - Some Simple Approximations Experimental Mechanics, Vol 5, No. 7	1965	A
G-3	4	Coffin, L. F. Jr.	A Study of the Effects of Cyclic Thermal Stresses in a Ductile Metal Transactions of the ASME, Vol 76	American Society of Mechanical Engineers, New York City 1954	S
G-4	3	Hirschberg-Manson-Smith D-1574	Fatigue Behavior of Materials Under Strain Cycling in the Low and Intermediate Life Range NASA Technical Note	National Aeronautical and Space Agency, Washington, D. C. 1963	S
G-5	2	Juvenall, R. C. and Lipson, C.	Handbook of Stress and Strength Recommended by Truscott of G. E. (Cincinnati) as good reference, applicable to structural and electromechanical design	McMillan Co. 1963	B
G-6	1	Peterson, R. E.	Stress Concentration Design Factors	John Wiley & Sons, New York City 1953	B
G-7	2	Peterson, R. E.	Analytical Approach to Stress Concentration Effect in Fatigue of Aircraft Materials WADC TR 59-507	USAF 1959	S
G-8	2	Kooistra, L. F.	Effect of Plastic Fatigue in Pressure Vessel Materials and Design Welding Research Supplement	1957	
G-9	1	Manson, S. S.	Thermal Stress and Low Cycle Fatigue	McGraw Hill Book Co., New York City 1966	B
G-10	3	Freche-Nachtigall-Manson	A Proposed Relation for Cumulative Fatigue Damage in Bending Proceedings of ASTM	American Society for Testing of Material, Philadelphia, Pa. 1961	S
G-11	2	Bratt-Truscott Weber	Probabilistic Strength Mapping A Reliability Versus Life Prediction Tool (G. E.) Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York City 1968	P
G-12	3	Forrester-Thevenow	Designing for Expected Fatigue Life (S-N diagrams and their application to Reliability) Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	American Society of Mechanical Engineers, New York City 1968	P

No.	Rank	Author(s)	Title	Publisher/Year	Code
G-13	3	Van Valkenburg, H. E.	The Theory of Ultrasonic Material Testing Mechanical Engineering, Vol 71, No. 10, pp 817-820	1949	S
G-14	2	Turan, Jos. M.	Quality Control Handbook	McGraw Hill Book Co., New York City 1951	B
G-15	4	Vanzetti, Dr. Ricardo	Infrared Techniques Enhance Electronic Reliability Equipment Division, Raytheon Co. 9th National Symposium on Reliability and Quality Control *New inspection methods with ultraviolet, black lights, etc.*	1962	S
G-16	3	Unknown	The Weibull Distribution Function for Fatigue Life Materials Research and Standards, Vol 2, No. 5, p 405	1962	A
G-17	4	Altman, J. W. Folley, J. D. Jr. Wilkinson, F. R.	A Study to Determine the Feasibility of Fully Routine Trouble Shooting Procedures American Institute for Research, Pittsburgh, Pa. AIR-37-59-FR-213	1959	S

8. Category H - Data Handling Methods for Statistical Applications

No.	Rank	Author(s)	Title	Publisher/Year	Code
H-1	2	Culbertson-Vorhees	Control Charts and Automation Applied to Analysis of Field Failure Data		
H-2	3	Howard, R.	Dynamic Programming and Markov Processes Recommended by Sandler	MIT Technology Press, Cambridge, Mass. 1960	B
H-3	2	Bellman, R.	Dynamic Programming	Princeton University Press, Princeton, N. J. 1957	B
H-4	2	Riley, V. and Gass, S. I.	Linear Programming and Associated Techniques: A Comprehensive Bibliography in Linear, Non-Linear and Dynamic Programming	The John Hopkins Press, Baltimore, Md. 1958	B
H-5	4	Kao, J. H. K.	Computer Methods for Estimating Weibull Parameters in Reliability Studies IRE Transactions, Reliability and Quality Control	1958	P
H-6	3	Pierce, W. H.	Asymptotic Properties of Systems Synthesized for Maximum Reliability Information Control 7.3, pp 340-359	1964	P
H-7	1	Orchard-Hays	Advanced Linear-Programming Computing Techniques Good information for the experienced computer programmer, including linear programming, the math of algorithms, debugging, basic documentation, etc.	McGraw Hill Book Co., New York City, 1968	B
H-8	4	Collopy-Serlogi	Digital Computer Application to Non-Linear Vibrations AVCO Corporation Vibration and Shock Bulletin 34-II-85	Defense Documentation Center, Washington D. C.	S
H-9	2	Korn, G. A.	Random Process Simulation and Measurement	McGraw Hill Book Co., New York City	B
H-10	1	Leeds, Herbert D. and Weinberg, G. M.	Computer Programming Fundamentals	McGraw Hill Book Co., New York City, 1961	B
H-11	3	O'Connel, E. P.	Utilization of the IBM 650 Computer in the Analysis of Field Failure Data Proceedings, 6th National Symposium on Reliability and Quality Control, pp 489-496	1960	P
H-12	3	Reeve, E. A.	Circuit Reliability Life Test Planning and Data Reduction Methods IBM Corp., Owego, New York, Report No. 59-816-61	1959	S

9. Category I - Failure Rates and Failure Modes

No.	Rank	Author(s)	Title	Publisher/Year	Code
I-1	1	DOD MIL-HDBK-217	Military Standardization Handbook Reliability Stress and Failure Rate Data for Electronic Equipment The data compiled here is essentially based on RCA Report TR-1100, but has been enlarged and experience of the Rome Air Development Center is included.	Defense Documentation Center, Washington, D. C., 1962	S
I-2	1	RADC RD 161894-1	U. S. Department of Commerce, Office of Technical Services, Rome Air Development Center Reliability Notebook Original release contains Sections 1 through 7; Supplement 1 contains Sections 8, Part Reliability Factors	Defense Documentation Center, Washington, D. C. 1961 (+ late revision)	S
I-3	2	TR-59-416-1	Reliability Stress Analysis for Electronic Equipment RCA Technical Report Camden, N. J.	Radio Corporation of America, 1959	S
I-4	2	TR-1 33 NAVSHIP 93820	Handbook for the Prediction of Shipboard and Their Electronic Equipment Reliability Vitro Laboratories	1961	S
I-5	3	General Dynamics	Reliability Design Handbook General Dynamics Corp, Pomona Division Includes a table of generic failure data with upper and lower extremes, as applicable to the small missile system, Army-Navy-Marine use.		S
I-6	3	Hughes Aircraft RS-305	Research Study Electronic Parts Failure Rate Analysis Aerospace Group, HAC, Culver City, Calif.		S
I-7	2	Supt. /Documents H 109	Quality Control and Reliability Handbook (Interim edition) Superintendant of Documents, Washington, D. C.	1960	S
I-8	4	Hecht, Bernard	Prediction of Failure Rate with Accelerated Life Tests Sprague Electric Co. Sprague Technical Paper 58-1		P
I-9	2	Brauer, Joseph	Phy sics of Failure Technical Memorandum RAD-TM-62-1, Applied Research Lab., Rome Air Development Center, USAF	Defense Documentation Center, Washington, D. C., 1962	S
I-10	3	Brown, J. M. Leve, H. L. and White, P. H.	Reliability Design Criteria Hughes Aircraft Co., Culver City, Calif	1959	S
I-11	2	Earles, D. R. and Eddins, Mary F.	Failure Criteria Reliability Engineering Data Series AVCO Research and Advanced Development Division	1962	S

No.	Rank	Author(s)	Title	Publisher/Year	Code
I-12	2	Earles, D.R. and Eddins, Mary F.	Failure Mechanisms and Failure Rates Reliability Engineering Data Series AVCO Research and Advanced Development Division	1962	S
I-13	3	Earles, D.R. and Eddins, Mary F.	Reliability Physics (inclusive Failure Rate Tables), and G. E. / Daytona Beach, 9th National Symposium on Reliability and Quality Control	1963	P
I-14	3	Adams, Daniel A.	Component - Part Failure Rate Curve Consideration Space Guidance Center, IBM-Oswego, New York 9th National Symposium on Reliability and Quality Control	1963	S
I-15	3	Ebel, George H. and Lang, A. J.	Reliability Approach to the pare Parts Problem (With Failure Rate Examples) 9th National Symposium on Reliability and Quality Control	1963	P
I-16	4	Hepp, J. D.	Failure Modes of Precision Potentiometers Proceedings, 6th National Symposium on Reliability and Quality Control, pp 183-184	1960	P
I-17	3	Hopkinson, K.	Reliable Values and their Performance in Service Equipment Proceedings, 5th National Symposium on Reliability and Quality Control	1959	P
I-18	2	Horn, R. L.	Determination and Use of Failure Patterns Proceedings, 8th National Symposium on Reliability and Quality Control	1962	P
I-19	3	Jeffcoat, C. D.	Failure Modes of Component Parts Proceedings, 6th National Symposium on Reliability and Quality Control	1960	P
I-20	4	Lotka, A.	A Contribution to the Theory of Self-Renewing Aggregates with Special Reference to Industrial Replacement Annals of Mathematical Statistics, Vol 10, pp 1-25	1939	S
I-21	4	Pieruschka, E. G.	Failure Categories of Guided Missiles Proceedings, 6th National Symposium on Reliability and Quality Control	1960	S
I-22	3	Price, W.C.	Mean Life of Parallel Electronic Components - Exponential Distribution Case Proceedings of the Symposium on Redundancy Techniques for Computing Systems	Spartan Books Inc, Washington, D.C. 1962	B

10. Category J - Miscellaneous Other Texts

No.	Rank	Author(s)	Title	Publisher/Year	Code
J-1	3	Myers-Holm-McAllister	Handbook of Ocean and Underwater Engineering Sponsored by Ocean Systems Operations, North American Rockwell	McGraw Hill Book Co., New York, 1968	B
J-2	3	Siegel, S.	Non-Parametric Statistics forthe Behavioral Sciences	McGraw Hill Book Co., New York, 1956	B
J-3	3	Inaba-Matson	Measurement of Human Errors with Existing Data Annals of Assurance Sciences, 7th Reliability and Maintainability Conference	1968	P
J-4	2	USAF DH-1	System Safety Handbook System Engineering Group Wright-Patterson AFB, Ohio	Defense Documentation Center, Washington, D. C., 1967	S
J-5	4	Hurlbut, Jr., C. S.	Dana's Manual of Mineralogy 16th Edition	John Wiley & Sons, New York City, 1953	B
J-6	3	Lee, Y. W.	Statistical Theory of Communication	John Wiley & Sons, New York City, 1960	B
J-7	4	Gardner, W. R., Morgan, C. T. and Chapanis	Applied Experimental Psychology	John Wiley & Sons, New York City, 1949	B

C. CURRENT MILITARY, NASA, OR EQUIVALENT INDUSTRIAL SPECIFICATIONS AND STANDARDS ON RELIABILITY, MAINTAINABILITY, AND SYSTEM EFFECTIVENESS (INCLUDING TESTING)

The list of Current Military, NASA or Equivalent Industrial Specifications and Standards on Reliability, Maintainability, and System Effectiveness (Including Testing) contains a number of documents, which have been superseded. They have been included because many long-term contracts are based on these obsolete documents.

Symbology

Most of the listed publications have been assigned a serial number prefixed with one of the following codes:

ABMA	Army Ballistic Missile Agency
AFBSD	Air Force Ballistic Systems Division
AFL	Air Force Logistics
AFLC	Air Force Logistics Command
AFM	Air Force Manual
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AFSCR	Air Force Systems Command Regulation
AMC	Air Material Command
AMCR	Air Material Command Regulation
ASPR	Armed Service Procurement Regulations
ASTIA	Armed Service Technical Information Agency
DDC	Defense Documentation Center
DODD	Dept of Defense Directive
DODH	Dept of Defense Handbook
DODI	Dept of Defense Instruction
DSAH	Defense Supply Agency Handbook
DSAM	Defense Supply Agency Manual
DSAR	Defense Supply Agency Regulation
GSE	Ground Support Equipment
MIL-HDBK	Military Handbook
MIL-STD-	Military Standard
MSFC	Marshall Space Flight Center, Huntsville, Ala.
OD	Ordnance Department
SAFR	Special Air Force Regulation
SPINST	Special Projects Instruction (USN)
TR	Technical Report
WADD	Wright Air Development Depot
NASA	National Aeronautical & Space Agency

1. Category K — Reliability Documentation

No.	Specification No.	Title	Remarks
K-1	MIL-STD-441	Reliability of Military Electronic Equipment	Superseded by MIL-STD-785
K-2	MIL-STD-690A	Life Testing Sampling Proc. for Estab. Levels of Rel. & Confidence in Elect. Parts Specifications	Released 7/65
K-3	MIL-STD-721A	Definitions of Terms for Reliability Engineering	
K-4	MIL-STD-756A	Proc. for Pred. & Reporting Pred. of Reliability of Weapon Systems	
K-5	MIL-STD-757	Reliability Evaluation from Demonstration Area	
K-6	MIL-STD-781A	Test Levels and Accept/Reject Criteria for Rel. of Non-Expendable Equip. Effective 12/10/65 Note: Supersedes MIL-STD-781, MIL-R-23094A, MIL-R-26667A	
K-7	MIL-STD-785	Requirements for Reliability Program for Systems & Equipment Note: Supersedes MIL-STD-441, WS 3250, MIL-R-22256, MIL-R-26474, MIL-R-27070, MIL-R-27542, MIL-R-55231 (EL)	Effective 6/30/65
K-8	MIL-STD-790	Life Test Sampling Proc. for Established Levels of Rel. & Confidence in Elect. Parts Specifications	
K-9	MIL-STD-790A	Reliability Assurance Program for Elect. Part Specifications	
K-10	MIL-STD-810A	Military Standard-Environmental Test Methods for Aerospace & Ground Equipment	USAF, 23 June, 1964
K-11	MIL-STD-839	Parts with Established Rel. Levels, Selection and Use of	
K-12	MIL-STD-1304	Reliability Reports	Effective 7/66
K-13	LeRC-REL-1a	Reliability Program Privisions for Research & Development Contracts	NASA LEWIS Document
K-14	AFBSD 61-55	Proc. for Conduct of Prel. Design Reviews and Critical Design Reviews	
K-15	AFR 80-5	Reliability Program for Systems, Subsystems and Equipment (R&D)	Supersedes AFR 375-5
K-16	D.O.D. H-108	Sampling Proc. & Table for Life and Rel. Testing (Based on Exponential Dist.)	

No.	Specification No.	Title	Remarks
K-17	NASA NPC 250-1	Reliability Program Provisions for Space System Contractors	
K-18	NASA Circular #293	Integration of Reliability Requirements into NASA Procurements	
K-19	OCTI 300-6-60	Special Weapons Stockpile Reliability	
K-20	USAF BLTN 519	Bibliography of Reliability Documents	Cancelled
K-21	AR-705-5	Research and Development of Material	
K-22	AR-705-15	Operation of Material Under Extreme Conditions of Environment	
K-23	AR-705-25	Reliability Program for Material and Equipment	
K-24	USAF BLTN 2629	Reliability Requirements for Ground Electronic Equipment	
K-25	WS-3250 (BUWEPS)	General Specifications for Reliability	Superseded by MIL-STD-785
K-26	NASA NHB 5320.2	Contractor Reliability Plans and Performance Evaluation Manual	Effective 10/65
K-27	NASA-SP-6001	Apollo Terminology	Effective 8/63
K-28	NASA-SP-6002	Program Standards, Reliability Program Evaluation Procedures	Released 10/63
K-29	MIL-A-8866 (ASG)	Airplane Strength and Rigidity Rel. Req., Repeated Loads & Fatigue	
K-30	MIL-R-19610	General Specification for Reliability of Prod. Electronic Equipment	
K-31	MIL-R-22732B	Reliability Req. for Shipboard and Ground Electronic Equipment	
K-32	MIL-R-22973	General Spec. for Rel. Index Determination for Avionic Equip. Models	
K-33	MIL-R-26484A	Reliability Req. for Development of Electronic Subsystems for Equip.	
K-34	MIL-R-27173	Reliability Requirements for Electronic Ground Checkout Equip.	
K-35	MIL-R-38100B	General Spec. for Reliability and Q.A. Req. for Established Rel. Parts	
K-36	MIL-R-55413	Reliability Prediction & Demonstration for Airborne Surveillance System	Superseded by MIL-STD-785
K-37	AFBM-STL	Reliability Policies and Procedures	

No.	Specification No.	Title	Remarks
K-38	AGREE Report	Reliability of Military Electronic Equipment	
K-39	IDEP I	Interservice Data Exchange Program I	
K-40	IDEP II	Interservice Data Exchange Program II	
K-41	NARM Report	Reliability Guidelines for Relays	Released 6/63, National Assoc. of Relay Manuf.
K-42	NARM Report	Recommended Specification for High Reliability Relays	
K-43	PSMR-1	Volumes I and II, Part Specification Management for Reliability	Known as Darnell Report
K-44	TPS-4	Reliability Control in Aerospace Equipment Development (SAE)	Outstanding Ref. Doc.
K-45	AFSC-TR-4	Sampling Proc. & Tables for Life and Reliability Testing, Weibull Dist.	Hazard Rate Criterion
K-46	AFSC-TR-6	Sampling Proc. & Tables for Life, Reliability Testing, Weibull Dist.	Reliable Life Criterion
K-47	AFSC-TR-7	Factors & Procedures for Applying MIL-STD-105D to Life & Rel. Testing	
K-48	SPL-TI-7-58	Integrated Polaris Missile System Reliability Program	Navy
K-49	1IND-P-393	Suggestions for Designers of Electronic Equipment	Same as NEL 1058-59
K-50	NAVWEPS 00-65-502	Handbook Reliability Engineering	
K-51	SPL-TI-22-64	Fleet Ballistic Missile Trouble and Failure Report System	
K-52	SPL TD 46-61	Reliability, Central Source	Navy
K-53	SP 63-467- & 470	Failure Rate Data Handbook (FARADA)	
K-54	N 64 27220	Bibliography on Reliability (1957 through 1963)	25 pages of ref. articles
K-55	SSD Exhibit 64-3	Standard Format for Reliability Program Plan	
K-56	AFSC-TR-65-1	Requirements Methodology	
K-57	AFSC-TR-65-2	Prediction Measurement	
K-58	AFSC-TR-65-3	Data Collection and Management Reports	
K-59	AFSC-TR-65-4	Cost Effectiveness Optimization	
K-60	AFSC-TR-65-5	Management Systems	

No.	Specification No.	Title	Remarks
K-61	AFSC-TR-65-6	Chairman's Final Report	
K-62	AMCP 74-1	Supplement to Task Group #1 of AGREE	Also called AMC 74-1
K-63	AMCP 74-1	Description of AGREE Task Group #III	
K-64	AFSC-TR-80	Techniques for Rel. Measurement and Pred. Based on Field Failure Data	
K-65	ESDP 80-3	General Req. for Rel. & Maint, Data Collection & Evaluation System for Elect. Systems	
K-66	ESDP 80-4	Rel. & Maint. Prog. Problems Observed During Contractor Monitoring	
K-67	ESDP 80-6	Guidance on Proposal Content for Rel. & Maint. in System/Equip. Procurements	
K-68	ESDP 80-7	Monitoring of Contractors Reliability & Maintainability Programs	
K-69	MIL-HDBK-217A	Rel. Stress & Failure Rate Data for Electronic Equipment	
K-70	OP 400	General Instructions: Design, Manuf. & Inspection of Naval Ord. Equip.	
K-71	AFR 400-46	Increased Reliability of Operational Systems (IROS)	
K-72	AMCR 700-15	Reliability Program for AMC Material	
K-73	MICOM REG. 702-1	Reliability, Q. A. & Maintainability	
K-74	RCR 800-A	Reliability Prog. Req. for Missile Systems & Associate Equipment	U. S. Army Missile Command
K-75	SPINST 3100. 1A	FBM Weapon System Trouble and Failure Report System	
K-76	SPINST 3900. 1	Reliability and Failure Rate	
K-77	SPINST 3900. 2	Reliability Reporting Requirements for the FBM Weapon System	Confidential
K-78	NASA SP-6501	Introduction to Evaluation of Rel. Programs	
K-79	OD 21612	Reliability Requirements for Primary Subcontractors	
K-80	OD 21613	Reliability Requirements for Secondary Subcontractors	
K-81	OD 29304	Guide Manual for Reliability Measurement Program	

No.	Specification No.	Title	Remarks
K-82	PB 121838	NEL Reliability Bibliography	
K-83	PB 121839	Reliability Design Handbook	
K-84	PB 131678	Reliability Stress Analysis for Electronic Equipment	Also called TR-1100
K-85	AD 148801	Methods of Field Data Acquisition, Reduction and Analysis	ASTIA Document
K-86	PB 161894	RADC Reliability Notebook	Latest revision is -3. Same as TR-58-111 or AD-148868
K-87	PB 181080	Rel. Analysis Data for Systems & Components Design Engineers	
K-88	WD-25477	Reliability Engineering Spec. & Rel. Assurance	Film MN 877F
K-89	AD 265577	A Survey of Literature of Reliability	ASTIA Document lists 521
K-90	AD 426501	A Reliability-Maint. Tradeoff Proc. for Navy Electronic Equip.	
K-91	AD 622676	Survey of Studies & Computer Programming Efforts for Rel., Maint. & Systems Effectiveness	DOD Report, 9/65
K-92	NAVSHIPS 93820	Handbook for Pred. of Shipboard & Shore Electronic Equip. Rel.	
K-93	NAVSHIPS 94501	Bureau of Ship Reliability Design Handbook Review of Quality and Reliability of D.O.D. Material	Dated 12/4/62
K-94	NAVWEPS 00-65-502	Handbook Reliability Engineering Bureau of Naval Weapons	6/1/64

2. Category L — Quality Assurance

No.	Specification No.	Title	Remarks
L-1	MIL-STD-105D	Sampling Procedures and Tables for Inspection by Attributes	Also called ABC-STD-105, (American-British-Canadian)
L-2	MIL-STD-109A	Quality Assurance Terms & Definitions	
L-3	MIL-STD-252	Wired Equipment Classification of Visual and Mechanical Defects	
L-4	MIL-STD-414	Sampling Procedures and Tables, Inspection by Variables for % Defective	
L-5	MIL-STD-643	Evaluation of Contractor Quality Control Systems	
L-6	MIL-Q-9858A	Quality Control System Requirements for use by Army, Navy and Air Force, Basic DOD QC Spec.	Basic DOD QC Spec.
L-7	MRB Nr 515	Control of Nonconforming Supplies (Tied to MIL-Q-9858 by Notice #2)	Basic MRB Spec.
L-8	D.O.D. H-50	Evaluation of Contractor Quality Control Systems	Explains MIL-Q-9858A
L-9	NASA-LEWIS QA-2A	Quality Assurance Prog. Provisions, Research, Test & Dev. Programs	
L-10	ASPR 14-001.2	Procurement Quality Assurance	Details contractual regulations
L-11	WR-43 (BUWEPS)	Preparation of Quality Assurance Provisions	
L-12	AFR 74-1	Assuring Quality of Production of Complex Supplies and Equipment	
L-13	AFSC 74-1	Quality Assurance Management	
L-14	AFR 74-9	Inspection of Purchase Manufactured by Subcontractors and Vendors	
L-15	RCAF PROC. 101-1	Specification for Quality Control of Aircraft and Associated Equipment	RCAF equivalent of MIL-Q-9858
L-16	DODH 105	Sampling Procedure for Acceptance Inspection	
L-17	DODH 106	Multilevel Continuous Sampling Proc. and Tables, Insp. by Attributes	
L-18	DODH 107	Single Level Continuous Sampling Proc. and Tables, Insp. by Attributes	
L-19	DODH 109	Statistical Proc. for Determining Validity of Suppliers' Attributes Insp.	
L-20	NASA NPC 200-1A	Quality Assurance Provisions for Government Agencies	Instructions for NASA Insp.
L-21	NASA NPC 200-2	Quality Program Provisions for Space System Contractors	Basic NASA QA Spec.

No.	Specification No.	Title	Remarks
L-22	NASA NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services	
L-23	ORD-M608-10	Ordnance Inspection Handbook--Sampling Inspection by Variables	
L-24	ORD-M608-11	Ordnance Inspection Handbook--Proc. & Tables for Cont. Sampling by Attributes	
L-25	AMCR 700-6	Quality Assurance System	
L-26	AMCR 715-509	Army Quality Assurance Technical Procedures	Was ORDM 4-12
L-27	DCAS	Purchased Material Quality Implementation Manual	
L-28	DODD 4155. 11	Improved Management for Quality & Reliability Assurance of Material	
L-29	SPINST 4200. 1	Waivers & Deviations, Special Proj. Office Policy	
L-30	BUWEPS INST. 4355. 12	Bureau of Naval Weapons Policy for Material Review	Was BUAER Inst. 4355. 11
L-31	BUWEPS INST. 4355. 20	Procedure for Granting Waivers for Nonconforming Material	
L-32	DSAM 8200. 1	Procurement Quality Assurance Manual	
L-33	DSAR 8205. 1	Preparation and Distribution of Material Insp. & Receiving Reports	Inst. for DD Form 250
L-34	MIL-G-14461	General Quality Control Requirements	U. S. Army
L-35	OD 21454	Ordnance Classification of Defects (OCD) Prod. & Promulgation Inst.	
L-36	MIL-Q-21549B/SPL4	Supplier Product Quality Program Requirements Document for Primary Suppliers	Polaris, Poseidon, Programs
L-37	MIL-Q-21549B/SPL5	Supplier Product Quality Program Requirements Document for Secondary Suppliers	Polaris, Poseidon, Programs
L-38	MIL-Q-22631B	Q. C., Metal Wrought Products Except Forgings Procured to Non Gov. Spec.	
L-39	OD 28800	Shelf Life Control of Rubber and Bulk Materials	
L-40	MSFC	Material Review Requirements	Effective 3/63

3. Category M — Maintainability

No.	Specification No.	Title	Remarks
M-1	MIL-STD-280	Definitions of Terms for Equipment Divisions	
M-2	MIL-STD-470	Maintainability Requirements for Systems & Equipment Note: Supersedes MIL-M-26512C (USAF), MIL-M-55214 (EL), MIL-M-45765 (WI), MIL-M-23313A (SHIPS), MIL-M-23603 (WEPS), MIL-STD-1228 (ARMY), WS-3009 (WEPS)	Effective 3/21/66
M-3	MIL-STD-471	Maintainability Demonstration	2/15/66
M-4	MIL-STD-721	Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors & Safety	
M-5	MIL-STD-778	Maintainability Terms & Definitions	Cancelled 8/66
M-6	MIL-STD-829	Terms and Definitions for Maintainability	Cancelled 6/64
M-7	MIL-STD-1228	Maintainability Criteria for Tank-Automative Material	Superseded by MIL-STD-470
M-8	WR-30	Integrated Maint. Management for Aeronautical Weapons, Weapons Systems & Releated Equipment	
M-9	XWR-30A	Integrated Logistic Support Program Requirements for Weapons Systems Equipment	
M-10	WS-3099 (BUWEPS)	General Specification for Maintainability	Superseded by MIL-STD-470
M-11	AFBM 59-32	Design for Maintainability Program for Weapon and Space Systems	
M-12	ASD 61-381	Guide to Design of Mechanical Equip. for Maintainability	Same as ASTIA 269332
M-13	ASD 61-424	Guide to Integrated System Design for Maintainability	
M-14	AFBSD 62-53	Maintainability Design Criteria	
M-15	AFR 66-1	Policy, Objectives & Responsibilities - Depot, Field & Organization Maint.	
M-16	AFM 66-1	Maintenance Management - Depot, Field & Organizational Maintenance	
M-17	AFM 66-2	Maintenance Engineering Methods and Management	
M-18	AFM 66-5	Maintainability in Air Force Equipment	
M-19	AFM 66-29	Maintainability - Weapon, Support, Command & Control Systems	

No.	Specification No.	Title	Remarks
M-20	AFR 66-29	Maintainability - Program for Systems, Subsystems & Equipment	
M-21	AFSCM 80-3	Handbook Instructions for Personnel Subsystem Designers	Referenced in MIL-M-26512C
M-22	AFSCM 80-5	Handbook Instructions for Ground Equipment Designers	Referenced in MIL-M-26512C
M-23	AFSCM 80-6	Handbook Instructions for Ground Support Equipment	Referenced in MIL-M-26512C
M-24	AFSCM 80-9	Handbook Instruction for Weapon System Designer	Referenced in MIL-M-26512C
M-25	AFSCR 80-9	Maintainability Policy for Research & Development	
M-26	MIL-HDBK-472	Maintainability Prediction	
M-27	AR-750-6	Maintenance Planning Allocation and Coordination	
M-28	MIL-I-85000	Interchangeability & Replaceability of Component Parts for Aircraft & Missiles	
M-29	USA OMC	Maintainability Design Factors	
M-30	T.O. 00-20 Series	Supplements to AFM 66-1	
M-31	ORD P 20-134	Maintenance Engineering Guide for Ordnance Design	Same as PB 18132
M-32	RADC TN-60-5	Methods of Maintainability Measurements and Predictions	
M-33	WADD TN 60-82	Maintainability and Supportability Evaluation Technique	
M-34	WWDPR Exhibit 61-42	Maintainability Req. for Reconnaissance Sub-system, Ground Support Systems & Equipment	
M-35	RADC TRD 63-85	Maintainability Engineering	USAF
M-36	CRD 63-140 (AD 405-779)	Criteria for Discard at Failure Maintenance	
M-37	RC-S-64-1	Maintainability Engineering Guide	
M-38	TRD ESD-TDD 64-616	Handbook for Reliability and Maintainability Monitors	Same as AD 611-577
M-39	NAVTRADEVCEN 330-1 Series	Design for Maintainability	Has four additional supplements: -1, -2, -3, & -4

No.	Specification No.	Title	Remarks
M-40	AD 415-416	Verification of Quantitative Maintainability Requirements	
M-41	AR 705-26	Maintainability Program for Material and Equipment	Note: to be combined with and released as AR-705-25 After 6/66
M-42	AMCP 706-134	Engineering Design Handbook, Maintainability Guide for Design	Effective 2/66
M-43	AMCR 750-6	Maintenance Engineering Objectives	
M-44	AMCR 750-7	Depot Maintenance Pilot Overhaul & Recondition Testing	
M-45	AMCR 750-15	Maintenance Support Planning	
M-46	SLC 4301D (SIG)	Maintainability Design	See MIL-M-55214
M-47	DDC NO. AD 440-381	Mathematical Models for Maintainability Evaluation	
M-48	SPINST P4700. 1A	Special Projects Office Preventative Maintenance Program (SSB (N))	
M-49	OPNAV Instr. 4700.16	Preventative Maintenance System	
M-50	NAVSHIPS 4855	Operational Time Log (5-61)	
M-51	Instruction 5420.48	Maintenance & Material Management Project Group	
M-52	NAVSHIPS NO. 8461	Concepts Associated with Systems Effectiveness	
M-53	BUSHIPS 10050-1	Failure/Replacement Report	
M-54	OD 28801	Service Life Evaluation Program	
M-55	DDC NO. AD 601080	Maintainability... A Primer in Designing for Profit	
M-56	DDC NO. AD 603241	Maintainability Prediction Methods and Results	

4. Category N — Safety Documents

No.	Specification No.	Title	Remarks
N-1	ORD M 7-224	Ordnance Safety Manual	
N-2	SWG 9S-6005	Handbook of Nuclear Weapon System Safety Check	
N-3	10-CRF-20	Code of Federal Regulation on Radiation	
N-4	AFM 32-3	Accident Prevention Handbook	
N-5	AFSWG TR-60-28	Handbook of Nuclear Systems Safety Design Check	
N-6	AFBSD 62-41	System Safety Engineering: General Spec. for Dev. of AF Ballistic Missile Systems	
N-7	AFBSD 62-82	Weapon System Safety Criteria	
N-8	AFBSD 63-8	System Safety Engineering: Safety Design Criteria for Dev. of Electro-Explosive Ordnance Systems	
N-9	AFM 122-1	The Nuclear Weapon Safety Program	References several dozen specific AFR's on subject
N-10	EM 385-1-1	Corps of Engineers Safety Manual	
N-11	AEC 500	Federal Regulation Handling Radiation Materials	
N-12	OPMAN INST 5510.83	Criteria and Standards for Safeguarding Nuclear Weapons	
N-13	DOD INST 5530.15	Safety Studies and Reviews of Atomic Weapons Systems	
N-14	OPNAV INST. 8020.9A	Safety Studies and Review Involving Nuclear Weapons Systems	
N-15	MIL-S-38130	Safety Engineering of Systems and Associated Subsystems and Equipment	
N-16	MIL-S-58077	General Spec. for Safety Eng. of Aircraft Systems, Subsystems Equipment	
N-17	Office of Industrial Hazards, Bureau of Labor Institute, U.S. Dept of Labor	A Selected Bibliography of Major References Material in Safety Engineering and Related Fields	Dated 9/15/66, 212 pages

5. Category O — Human Factors

No.	Specification No.	Title	Remarks
O-1	HEL Standard S-4-65	Human Factors Engineering Requirements for the Dev. of Army Material	
O-2	HEL Standard S-5-65	An Evaluation Guide for Army-Aviation Human Factors Engineering Requirements	
O-3	AMC P.I. 7-380	Human Factors Engineering Contract Clause	
O-4	AMCR 10-4	Organizations & Functions, Mission & Functions, of Human Engineering Labs	
O-5	TM 21-62	Manual of Standard Practice for Human Factors in Vehicle Design	
O-6	AFM 35-99	Human Reliability Program - Military Personnel	Effective 7/65
O-7	WADC TR-56-488	Human Engineering Guide for Equipment Design	
O-8	WDT 57-8A	Human Engineering Design Standards for Missile System Equipment	
O-9	WADD TR-60-36	Human Eng. Testing & Malfunction Data Collection in Weapon System Test Programs	
O-10	AFBM 60-65A	Aerospace System Personnel - Equip. Data for Personnel Subsystem Develop.	
O-11	AR 70-8	Human Factors Operations Research	
O-12	AFSCM 80-3	Handbook Instructions for Personnel Subsystem Designers	
O-13	AFL 375-5	Planning and Programming for System Personnel	
O-14	MSFC-STD-391	Human Factors Engineering Programs	Effective 7/65
O-15	MIL-STD-803A (3 Vols) Part I & II	Human Engineering Criteria for Aircraft, Missile and Space Systems Ground Support Equipment	
O-16	SCL 1787	Human Factors Engineering for Signal Corps System and Equipment	
O-17	MIS 10017	Human Factors Engineering Development of Missile Systems	
O-18	MIL-H-24148	Human Engineering Requirements for Bureau of Ships-Systems & Equipment	
O-19	MIL-D-26239	Data, Qualitative and Quantitative Personnel Requirements Information	
O-20	MIL-S-26634	Preparation of Specifications, Weapons System, and Support System Mockups	

No.	Specification No.	Title	Remarks
O-21	MIL-H-27894A	Human Engineering Requirements for Aerospace Systems and Equipment	
O-22	MIL-H-46819	Human Factors Engineering in Development of Missile Systems	
O-23	AR 594-5-62-601	U.S. Government Regulatory Documents Applicable to Human Engineering	References over 100 documents on subject
O-24	RH 3398, IDEP Report # 347.10.00	Basic References and Sources of Information in Human Factors Engineering	References 434 documents on subject
O-25	DDC NO. AD 604513	Human Factors in Maintainability	
	Also see other AFSCM 80 series handbooks under MAINTAINABILITY, GENERAL DOCUMENTATION as an important source of additional Human Factors Specifications and Documentation.		

6. Category P — Value Engineering

No.	Specification No.	Title	Remarks
P-1	ASPR I-1705	Value Engineering	Contracting details
P-2	AMCR 11-23	Value Engineering	
P-3	IRDO 40-2	Value Analysis	
P-4	BSD AFPI Supp 57	Value Engineering, General Provisions	
P-5	ASDP 70-1	Guide to Value Engineering	
P-6	AFR 70-16	Value Engineering	Procurement
P-7	D. O. D. H-111	Value Engineering	Released March, 1963
P-8	DSAR 4140.21	DSA Value Engineering/Analysis Program	
P-9	D. O. D. I 5010.8	D. O. D. Value Engineering Program	
P-10	MIL-V-38352	Value Engineering Program Requirements	
P-11	MIL-V-55051	Value Engineering of Signal Corps Equipment	Some copies released accidentally as MIL-E-55051

D. CATEGORY Q – TECHNICAL JOURNALS AND PERIODICALS AND THEIR DATA SOURCES, PERTAINING TO RELIABILITY AND MAINTAINABILITY

Industrial Quality Control — monthly
Journal of the American Society for Quality Control
161 West Wisconsin Ave., Milwaukee, Wisconsin 53203

The Journal of Environmental Sciences — bimonthly
Institute of Environmental Sciences
940 East, Northwest Highway, Mt Prospect, Ill. 60056

Journal of Research, National Bureau of Standards
Section A. Physics and Chemistry — bimonthly
Section B. Mathematics and Mathematical Physics — quarterly
Section C. Engineering and Instrumentation — quarterly
Superintendent of Documents
U.S. Government Printing Office, Washington, D.C. 20402

Technical News Bulletin, National Bureau of Standards — monthly
Superintendent of Documents
U.S. Government Printing Office, Washington, D.C. 20402

Nuclear Safety — quarterly
U.S. Atomic Energy Commission — quarterly
Superintendent of Documents,
U.S. Government Printing Office, Washington, D.C. 20402

Nuclear Design and Engineering — bimonthly
North Holland Publishing Co.
68-70 N.Z. Voorburgwal, Box 103,
Amsterdam C., Netherlands

Nuclear Industry
Atomic Industrial FORUM, Inc.
850 Third Avenue, New York, New York 10022

Nuclear News — monthly
American Nuclear Society
244 E. Ogden Avenue
Hinsdale, Illinois

IEEE Transactions — bimonthly
IEEE Transactions on Human Factors in Electronics
John Hopkins Press, Baltimore, Md. 21218

Bulletin of the Operations Research Society of America and Operations Research
The Society, Mt Royal and Guilford Aves, Baltimore, Md. 21202

The Annals of Mathematical Statistics
c/o Institute of Mathematical Statistics
Prof. George J. Resnikoff, California State College of Hayward,
Hayward, California 94542

Edison Electrical Institute Bulletins — monthly
750 Third Avenue
New York, New York 10017

IBM - Computing Report for the Scientist and Engineer — bimonthly
IBM/Data Processing Division
112 East Post Road, White Plains, New York 10601

Quality — quarterly
Secretariat of the European Org. for Q. C.
Rotterdam, Ween 700; Netherlands

National Safety News
National Safety Council
425 N. Michigan Avenue, Chicago, Ill. 60611

Experimental Mechanics
Society for Experimental Stress Analysis
21 Bridge Square, Westport, Connecticut 06880

Science — weekly
American Association for the Advancement of Science
1515 Massachusetts Ave., N.W., Washington, D.C. 20005

Science and Technology — 3/year
Fountain Press
46-47 Chancery Lane, London W. C2, England

Scientific American — monthly
Scientific American Inc.
415 Madison Ave., New York, New York 10017

Engineering News — weekly
Heywood-Temple Industrial Publications, Ltd.
33/39 Bowling Green Lane, London, E.C. 1, England

Test Engineering and Management — monthly
Mattingley Publishing Co.
Oakhurst, New York

Journal of the American Statistical Association — quarterly
American Statistical Association
810, 18th Street, N.W., Washington, D.C. 20006

Biometrics, Journal of the Biometric Society Biometric Business Office: Dept. Biometry Upper Gate House, Emory University School of Medicine Atlanta, Georgia 30322	quarterly
Review of the International Statistical Institute 2 Oostduinlaan The Hague, Netherlands	3/year
Journal of the Royal Statistical Society Royal Society of London - Notes and Records Burlington House, Picadilly, London W 1, England	irregular
Biometrika Biometrika Trust, University College Gower Street, London, W.C. 1, England	monthly
Technometrics P.O. Box 587 Benjamin Franklin Station, Washington, D.C. 20044	monthly
Quality Assurance Hitchcock Publishing Co. Wheaton, Illinois 60187	monthly
Quality Engineer Institution of Engineering Inspection 45 Great Russell Street, London W.C. 1 England	monthly
Testing, Instruments and Controls c/o W. Meagher P.O. Box 250, N. Sidney NSW, Australia	monthly
Quality Control and Applied Science Executive Sciences Institute Inc. Whippany, New Jersey	quarterly

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PART 4. MAINTAINABILITY

I. INTRODUCTION

This section has been prepared as a source of nuclear power plant maintainability information. It is essentially a summary of the concepts, facts, data, principles, and techniques which comprise this new technology.

At this time the material contained herein, is general and focuses on those topics which directly affect design. However, subsequent revisions will incorporate more specific information and detailed data and will encompass other aspects of maintainability such as testing techniques, assurance procedures, personnel training, maintenance methods, and data collection systems. Emphasis will be placed on those maintainability problems peculiar to mechanical components of nuclear power plants.

Although a number of references were used, Department of the Army Pamphlet 705-1 supplied the bulk of the information contained in this section.

II. ANALYSIS AND PREDICTION

The optimum opportunity for incorporating maintainability features in a new system occurs during the conceptual and early design phases. Consequently initial efforts center about the analysis of system requirements for maximum maintainability.

As the design of the system takes shape, definite maintainability goals in the form of repair time allocations are established. They become more specific and are refined by prediction as design progresses. The prediction effort starts late in the concept stage and continues until design is completed.

The third stage of the maintainability effort is a demonstration of the validity of the predictions made. This may be done during the design stage if mockups are available, or it may be performed on the actual hardware during the development stage.

A. QUALITATIVE AND QUANTITATIVE MAINTAINABILITY

Because the design features on which maintainability depends are so varied and their interrelationships are so complex, no single all-encompassing factor can be determined as representing desired maintainability characteristics for a given system. Instead, a series of qualitative and quantitative requirements is established for this purpose. Qualitative and quantitative maintainability requirements as used in this content are defined as follows:

1) Qualitative Maintainability Requirement: A qualitative maintainability requirement, as the term suggests, is a general nonquantitative statement of a desired feature or characteristic to be incorporated in a system.

2) Quantitative Maintainability Requirement: A quantitative maintainability requirement, is a definite statement of the allowable resources or time to be required to perform a given type of support task in the final product. Concepts such as downtime, repair time, turnaround time, and availability are used to formulate the requirement.

1. Maintainability Indexes

Maintainability indexes are quantitative criteria used to determine whether the maintainability requirement stated in the overall system specification has been complied with. The indexes, normally based on time (time-to-repair, time-between-repairs, etc.), are reliable measures of the success or failure of the system's maintainability design.

The overall reference is the point of time a system is operable, as against the period during which it cannot be operated (downtime). Downtime is defined as consisting of active downtime and delay downtime. Active downtime is the period spent in performing inspection, testing, repair, replacement, checkout, and related support activities. Delay downtime consists of the periods of system inoperability attributed to the administration of maintenance and support, unavailability of tools, test equipment and spares, and such other delays not directly attributable to active corrective or preventative action.

With this general concept applied, the basic element of the maintainability indexes is found to be repair time (R_t). This is defined as the period of active downtime required to return a failed system to normal operation. Frequently referred to as corrective action time (M_{ct}), it is the period needed to locate, isolate, and correct the fault, to make such readjustments and realignments as are required, and to test to make sure that the fault has been satisfactorily corrected.

1) Mean-Time-To-Repair (MTTR): Mean corrective action time ($\overline{M}_{ct}$) is often construed as being synonymous with mean-time-to-repair. It is the statistical mean of the times required to repair an item or a system, and as such, represents the summation of all repair times, divided by the total number of failures that occurred during a given period. It is expressed by the following equation:

$$\text{MTTR} = \frac{\sum_{i=1}^{n} R_{t_i}}{n}$$

where n is the number of failures, and R_t is the time to repair each sample.

2) Mean Preventive Action Time ($\overline{M}_{pt}$): To reduce the probability that a system will require corrective action, it normally is taken out of operation from time to time for preventive action (lubrication, cleaning, adjustment, calibration, etc.). Because the time required for this type of action represents a portion of the total period of a system's inoperability, it must be calculated as contributing to total system downtime. Mean preventive action time thus is defined as the statistical mean of the summation of periods required for preventive action, divided by the total number of preventive actions scheduled for a given period as follows:

$$\overline{M}_{pt} = \frac{\sum_{i=1}^{n} M_{pt_i}}{n}$$

where n is the number of preventive maintenance actions.

3) Mean Active Corrective and Preventive Action Time ($\overline{M}$): This index is established to represent all system downtime resulting from both corrective and preventive activities; as such, it represents active downtime, thereby excluding the downtime for which administrative actions, unavailability of tools, etc., are responsible. It is the statistical mean of the periods during which corrective and preventive work is performed on a system during a given period, divided by the total number of all such maintenance actions. It is calculated by use of the following equation:

$$\overline{M} = \frac{\overline{M}_{ct} f_c + \overline{M}_{pt} f_p}{f_c + f_p}$$

where f_c is the number of corrective actions

f_p is the number of preventive actions.

4) Mean Downtime (MDT): Mean downtime, which is an index used in computing the operational availability of a system, is the sum of mean active corrective and preventive action time ($\overline{M}$) and mean

delay time for that system during a specified period. Because delay time is determined by administrative and supply factors that cannot accurately be anticipated, they are beyond a designer's control, and accordingly, can play little part in maintainability design.

2. Availability

Inasmuch as availability is both a goal to be accomplished by design and a measurable characteristic of a developed system, it is defined in its various aspects as follows:

1) Inherent Availability (A_i) is defined as the probability that, when used under stated conditions in an ideal environment without consideration for preventive action, a system will operate satisfactorily at any time. The "ideal support environment" referred to exists when the stipulated tools, parts, skilled manpower, manuals, and other support items required are available. As such, the concept of inherent availability excludes whatever ready time, preventive maintenance downtime, supply downtime, and administrative downtime a system may require. It is expressed by the formula:

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

where MTBF is mean-time-between failures
MTTR is mean-time-to-repair.

2) Achieved Availability (A_a) is defined as the probability that, when used under stated conditions in an ideal support environment, a system will operate satisfactorily at any time. As is readily recognized, it differs from inherent availability only in its inclusion of consideration for preventive action; as in the case of inherent availability, it excludes supply downtime and administrative downtime. It may be expressed as:

$$A_a = \frac{MTBM}{MTBM + \overline{M}}$$

where MTBM is the mean-time-between-required-actions, resulting from MTBF and mean-time-between-preventive-actions, and $\overline{M}$ is mean active downtime resulting from both preventive and corrective actions.

3) Operational availability (A_O) is defined as the probability that, when used under stated conditions in an actual support environment, a system will operate satisfactorily at any time. It may be expressed as:

$$A_o = \frac{MTBM}{MTBM + MDT}$$

where MDT is mean downtime.

These three concepts of availability have different uses for both a procuring agency and the contractor who designs and develops systems for the agency. Inherent availability and achieved availability summarize the extent to which the contractor has achieved maintainability and reliability by his design of a system; accordingly, they are established as quantitative goals by the procuring agency at the time a contract is let, and the contractor is required to demonstrate the system's capability of attaining them. Operational availability, on the other hand, is a significant characteristic of the system developed, and includes delay time contributions to the downtime of the system. As such, it aids greatly in planning operations in which the system will be used, and is also of special value in estimating total system cost.

3. Failure Rate Data

Failure-rate data usually are estimated during the design of a given system by the reliability group, for which purpose they are compiled on the basis of so many failures per thousand hours of operation. Such reliability estimates directly affect the development of both the qualitative and the quantitative maintainability requirements for the system; that is to say, a highly reliable system can permit a long downtime and yet attain the availability goal, whereas a system with low reliability requires minimal downtime. A comparable principle applies to components, in that components of low reliability must be much more readily accessible than those of high reliability.

Since maintainability computations are no better than the reliability data upon which they are based, the data must be examined carefully to determine their validity before they are used.

B. MAINTAINABILITY ANALYSIS

Maintainability and support analyses, which begin in the conceptual stage of the development of a system, provide the following:

1) Comprehensive documentation of the specific maintainability requirements to be met in designing the system.
2) A list of checkpoints to ensure that appropriate features to meet these maintainability requirements satisfactorily will be incorporated in the system's design, together with an indication, in each instance, of the type of feature that will produce the quantitative result required.
3) A list of the corrective and preventative tasks and support requirements for the developed system.

C. SUPPORT ANALYSIS

Concurrent with the start of the maintainability analysis, a systematic support analysis is undertaken. It establishes the basic requirements for the development of the support plan for the system.

Subsystems are analyzed for these purposes as soon as functional data are available. The analysis thus initiated entails a step-by-step accounting of the results of logical diagnosis of possible failures. Beginning with estimates of probable required support, each step for locating a defective part or deficiency is determined; in every instance of this procedure, consideration of access problems and resources is essential.

Because the mean-time-to-repair (MTTR) for a new system is the principal maintainability requirement, a means must be developed early in the program for allocating and controlling the time-to-repair of each subsystem and/or its components. Basically such an allocation procedure consists of (1) determination of the contribution of active downtime, and (2) evaluation of these contributions against the established MTTR for the system.

If the computed MTTR for the system exceeds the system's MTTR goal, three possible courses of action are open: (1) decrease failure rates, (2) decrease mean corrective maintenance times, and (3) decrease either or both on a trade-off basis.

D. PREDICTION

Maintainability prediction is a method for forecasting the effects of design on system repair. Its findings indicate the extent to which design is contributing to ease of support, and therefore what additional maintainability features will be required. Prediction methods have been developed by intensive work on the part of industry and the military services. It is the means by which reasonably accurate quantitative estimates, based on actual hardware design, are made of the time required for support of a system.

Predictions thus indicate, in advance of a system's operation in the field, the downtime to be expected and also which of its features will be likely to cause serious trouble.

A number of prediction methods, which differ widely in their respective approaches, have been developed. One type employs extrapolations based on the premise that the performance of new equipment can be reasonably predicted from past experience with similar equipment. A second type is a time-summation method based on the breakdown of support effort into discrete work tasks, and on the establishment of average time for the accomplishment of each task. A third type is a checklist procedure which provides that significant procedures of a system be classified and evaluated, and the values then entered on a list.

Although the prediction methods described in the following paragraphs were originally developed for electrical systems, they are, in principle, equally applicable to mechanical systems. These methods represent a cross section of the prediction methodology now in use and also indicate the extent to which industry and government have attempted to reduce maintainability requirements and features to quantitative form. Each method has its own distinct advantages and disadvantages, therefore, selection of a method should be based upon its suitability for the system under consideration.

1. <u>Federal Electric Method</u>

The Federal Electric method applies time analysis to complex maintenance tasks. Its four major steps for any given equipment are as follows:

1) Identification of principal parts.
2) Determination of the failure rate of each part.
3) Determination of the time required for the maintenance of each part.
4) Computation of the expected maintenance time of the entire equipment from the data obtained in the first three steps.

2. <u>Martin Method</u>

The Martin method or the Technique for Evaluation and Analysis of Maintainability (TEAM) represents a method which departs from the principle of reliance on experience. TEAM depends on the graphic presentation of a trouble-shooting scheme which begins with the symptom of a failure and works logically towards a solution. The time required for each step of the repair process thus traced is estimated for prediction purposes.

3. <u>RCA Method</u>

The RCA method is a checklist technique whereby support time is regarded as the criterion of maintainability. For these purposes, support time is regarded as a function of physical design features, support requirements, and personnel requirements, as measured by the maintenance skills dictated by design.

III. DESIGN CONSIDERATIONS

The ultimate goals of maintainability design are reduction to a minimum of a system's support requirements, and the facilitation of whatever maintenance work the system will require. Important design factors which influence maintainability are diagnostics, automatic checkout equipment, accessibility, throwaway maintenance, standardization, interchangeability, functional modularization, and mounting and packaging.

All combinations of maintainability design features, together with the cost in dollars and associated repair times of each, are considered in order to find the combinations that best meet the systems maintainability requirements. The combinations selected for design incorporation are those that produce a degree of maintainability that satisfactorily meets repair-time requirements at minimum total system dollar cost.

A. DIAGNOSTIC TECHNIQUES

In maintainability engineering, the term diagnostics refers to actions required for actual failure or incipient failure location in an operational system; it is better known as troubleshooting. The primary objective of diagnostics is an overall reduction of system downtime by providing for the rapid location of failures or incipient failures. Different diagnostic techniques are as follows:

1) Manual: Manual techniques (which are the type most frequently referred to as troubleshooting) are basically trial-and-error efforts by skilled technicians, who use diagnostic instrumentation, as well as detailed procedures and schematics, to isolate a malfunctioning component by progressively testing all components and eliminating those that are still functioning.

2) Semiautomatic: Semiautomatic techniques represent one or more steps toward automation of the failure isolation function. However, they fall short of complete elimination of dependence on direct participation by technicians. The indicators either identify the subsystem, or component in which a malfunction exists, or they direct the technician to the next action to be taken.

3) Automatic: Automatic techniques completely eliminate the need for a technician's participation in locating a failure. Upon failure of a component, a system fitted with automatic techniques switches to a diagnostic mode and isolates and identifies the malfunctioning item to the repair-by-replacement level.

B. AUTOMATIC CHECKOUT EQUIPMENT

Automatic checkout equipment is usually tailored for a particular system or equipment group. It differs from integral test equipment in that its primary use is to check a system prior to operation rather than to monitor it during operation. Automatic checkout equipment may be appended to a system or may be independently packaged, to be connected to it when needed.

C. ACCESSIBILITY

As a prime design factor in relation to maintainability, accessibility relates to the configuration of hardware, rather than to the physical and other limitations of personnel. As such, it is clearly related to packaging requirements.

Accessibility should penetrate design down to the throw-away level only; a module that will be discarded at failure creates no problems of accessibility for its components. On the other hand, it is very important that the modules themselves be readily accessible, the need for this being in direct ratio to their several probable failure rates. Each module must be easily removable.

Accessibility must also be considered for the purposes of testing. If external test equipment is required for fault isolation, the equipment test points or regions must be readily accessible.

D. THROW-AWAY MAINTENANCE

Throw-away maintenance is a maintenance policy whereby components or items of equipment to a given level are discarded at failure, rather than repaired. As a policy, it is based on the principle that every system design has a level of repair at which it is more practical and economically feasible to throw away a failing item or component than it is to repair that item or component.

The level of throw-away to be selected for a given design is dependent on a great many factors, and may be established at any point between the entire system and any of the piece parts of its subsystems. The higher levels of throw-away obviously provide for increased availability, but they may dictate costs of such magnitude that a lower level must be chosen. High levels of throw-away are universally acceptable wherever costs are not a determining factor.

Somewhere between the two extremes of throw-away level is the optimum level of throw-away for system design. Selection of that level for a given system depends not only on the cost of initial hardware procurement, as weighted by availability requirements, but also on the user's support costs. A trade-off between pertinent factors is normally accomplished to determine the throw-away level to be adopted by the designer.

E. CONTRIBUTING MAINTAINABILITY FACTORS

Contributing maintainability factors are those, other than the prime factors of diagnostics, accessibility, and throw-away design, that have significant effect on the maintainability of systems. Some of them are prerequisite to consideration of the prime factors, some directly affect system maintainability without influencing any of the prime factors, and a few affect system maintainability indirectly.

1. Standardization

Standardization is a design feature for restricting to a minimum the variety of parts that will meet the majority of a system's hardware requirements. It is important that the design of assemblies and components for a given system be physically and functionally interchangeable with other assemblies and components of the system. Standardization is a major consideration of maintainability design, because it significantly reduces both the original and the support costs of a system.

In any attempt to achieve standardization, the following principles must be carefully considered:

1) Make maximum use of common parts in all assemblies.

2) Reduce to a minimum the variety of assemblies and parts required, and in doing so, make certain that the basic types are (a) used

consistently for each given application, (b) compatible with existing usages and practices, and (c) clearly distinguishable to prevent misapplication.

3) By careful study of the simplification thus attained, reduce to a minimum the problems of supply, storage, and stocking.

4) By the same means, simplify practices in the coding and numbering of parts.

5) Make maximum use of off-the-shelf components and other items.

The experience gained by design engineers and the users of systems during the past several decades has established a number of basic principles of standardization design that today are generally accepted:

1) Design for liberal (rather than merely adequate) performance margins, to permit increased employment of given assemblies and parts.

2) Whenever possible, design equipment that can be supported by tools and test equipment already in common use.

3) Design units that are symmetrical as regards a centerline, to eliminate requirements for right- and left-hand parts.

4) Specify standard sizes and gauges.

2. Interchangeability

Functional interchangeability is attained when a part or unit, regardless of its physical specifications, can perform the specific functions of another part or unit. Physical interchangeability exists when any two or more parts or units made to the same specifications can be mounted, connected, and used effectively in the same position in an assembly or system.

To attain maximum interchangeability of parts and units in a given system, design engineers must insure:

1) That functional interchangeability exists wherever physical interchangeability is a design characteristic.

2) That physical interchangeability does not exist wherever functional interchangeability is not intended.

3) That wherever complete (functional and physical) interchangeability is impracticable, the parts and units are designed for functional interchangeability, and adapters are provided to make possible physical interchangeability wherever practicable.

4) That sufficient information is provided in job instructions and on identification plates to enable a user to decide definitely whether or not two similar parts or units are actually interchangeable.

5) That differences are avoided in the size, shape, and mounting, and in other physical characteristics.

6) That modifications of parts and units do not change the ways of mounting, connecting, and otherwise incorporating them in an assembly or system.

7) That complete interchangeability is provided for all parts and units that (1) are intended to be identical, (2) are identified as being interchangeable, (3) have the same manufacturer's number or other identification, and (4) have the same function in different applications (this is especially important for parts and units whose failure rates are high).

To attain effective interchangeability of parts in units in systems being designed, the design engineers should give special attention to the following practical principles:

1) Identical parts are to be used wherever possible in similar equipment and in a series of equipments of common type.

2) Parts, fasteners and connectors, lines and cables, etc., are to be standardized throughout a system, particularly from unit to unit within a system.

3) Mounting holes and brackets are to be made to accommodate parts and units of different makes.

3. Functional Modularization

Functional modularization is the packaging of components and subassemblies in self-contained functional units to facilitate both the operation and the maintenance of a system. Although broad in its applications, functional modularization is specific in its use as a maintainability design factor for complex systems. Its effective employment results in the following advantages:

1) Properly employed, functional modularization greatly simplifies troubleshooting.

2) The use of automatic and semiautomatic diagnostic techniques is facilitated by functional packaging, inasmuch as modularization allows for the ready prediction of such faults as occur in a system.

3) The two results of functional modularization just noted make possible major reduction of the requirements for maintenance personnel and their training, as well as the overall requirements for manuals and other technical information.

F. MOUNTING AND PACKAGING

The requirement for mounting individual parts and subassemblies is a maintainability consideration. For any system, a majority of the parts and subassemblies could be placed in several alternative locations, only some of which would afford maximum advantage to the overall system design. Therefore the decision for the final arrangement of such parts should be based on the following considerations:

1) Accessibility: The limitations of the individual operator and technician, and their needs while performing their tasks, are important aspects to be considered in designing for accessibility. Consideration of the failure rates of parts and subassemblies is equally important.

2) Environmental Protection: Those parts and subassemblies unusually sensitive to environmental conditions (operating stress, vibration, temperature changes, and the like) deserve special attention. Obviously, such parts must not only be placed in preferential locations, but also must be carefully mounted.

3) Built-in Equipment: The requirements for built-in test and fault-isolation equipment must be established, and provisions made for suitable location and mounting.

IV. HUMAN FACTORS

Human engineering is concerned with the evaluation of technical design in terms of the physical and psychological limitations of the men who are to operate and service the equipment and systems produced.

To maintain a system in a state of readiness, design features to make this possible must be considered from the beginning of work on the system's overall design.

Among the many aspects of a system's support requirements that require maintainability design, those in which human factors play a part, are as follows:

1) The capabilities and limitations of personnel.
2) Equipment considerations; namely, that equipment design may not require a man to exceed his physical and psychological limitations.
3) Environmental considerations; namely, controls to offset adverse environmental conditions and to prevent the deterioration of an individual's performance as a result of environmental conditions.
4) Safety conditions.

A. THE CAPABILITIES AND LIMITATIONS OF PERSONNEL

The fundamental characteristics of man have not changed during the ages, even though life expectancy and height have increased in some parts of the world. On the other hand, the advances of science and technology made during the last century have created an urgent need for balancing human behavior, as a constant, against the machine in an attempt to create effective and efficient man-machine combinations.

1. Physical Capabilities and Limitations

Individuals vary in size and strength. The minimums and maximums, in terms of which designers must work should be within the capabilities and limitations of at least 95 percent of the technicians who are expected to work under the environmental conditions in which equipment will be operated and maintained.

Lifting, carrying, and strength capabilities of personnel are important considerations. If maintenance or repair tasks require the handling of system equipment beyond established physical capabilities, provisions should be made to eliminate or facilitate such handling.

2. Technician Skills

Physical capabilities and limitations are not the only factors that affect a man's ability to perform work. Intelligence level and intellectual experience and alertness (best expressed as skill level) must also be taken into consideration. Skill level is especially critical, because skilled technicians are normally in short supply. Despite in-service training in both industrial and government fields, shortages continue to exist in the higher skill levels (two or more years of experience), even though surpluses are found in the lower skill levels (less than two years' experience).

Fortunately, training and stratification are not the only means used to solve the problems created by the shortage of skilled technicians. The designing of equipment to require low skills for its support is more and more resorted to, and as such maintainability programs progress, the difficulties created by the shortage of skilled technicians will be alleviated. For the foreseeable future, however, the designers of equipment must stress this phase of their work.

In conjunction with such design work, support concepts and techniques must be developed that are commensurate with the skill levels of the personnel available, if maximum efficiency is to be attained. When a malfunction occurs, the trouble must first be diagnosed before the appropriate remedial action can be taken. An individual's ability to diagnose is usually proportional to his other maintenance skill levels, which means, of course, that highly skilled maintenance diagnosticians are in short supply. Hence the growing trend toward the development of automatic and semiautomatic checkout and failure-locating equipment, and also the increasing use of throw-away modules. Without such designs, successful performances of corrective maintenance might not be possible within acceptable time limits. In this connection, however, a word of caution is needed: it is dangerous to regard automation as a cure-all for maintenance problems and as a satisfactory substitute for continued emphasis on technician training.

One of the principal objectives of this training must continue to be in the area of the diagnosing of failures. As was stated earlier, the time required for locating the trouble in a defective system accounts for as much as 75 percent of active maintenance downtime. To keep failure location time to a minimum, systematic troubleshooting procedures must be developed for technicians to use with every type of equipment, and the technicians must be trained to use them effectively. The pattern that all such procedures must follow is reasonably standard, as follows:

1) Performance of a routine check to identify the symptoms of malfunction.

2) Analysis of these symptoms to identify the area in which the malfunction has occurred.

3) Special tests and checks to locate the malfunction as either a replaceable or a repairable part or unit.

3. Human Errors in Maintenance Work

An accident study made by the armed forces, revealed that many of the equipment failures that produced them occurred shortly after completion of periodic inspections. It also showed that many of the mistakes made were repetitious. It was concluded, therefore, that the basic causes of the human failures which resulted in equipment failures were:

1) Inadequate basic training in the relevant maintenance practices, policies, and procedures.

2) Lack of training in the maintenance of the types and modules of the equipment being maintained.

3) Inadequate or improper supervision.

4) Inadequate inspection.

It follows that the principal goals towards which designers should work to minimize human failure are:

1) Reduce to a minimum the number of support tasks to be performed for each system.

2) Design equipment so that the support tasks required can be performed easily and simply by personnel of specified skills working in specified environments.

3) Design equipment with features that make it difficult or impossible for a task to be performed improperly or incompletely.

B. EQUIPMENT CONSIDERATIONS

Human factor considerations of accessibility, indicator design, and control design contribute to the reduction of maintenance and repair time.

1. Accessibility and Working-Space Requirements

Accessibility requirements are determined by the maintenance action required, which may be visual or physical, or both, depending on whether the task be inspection, servicing, adjusting, repairing, or replacing. Generally, they represent two needs; namely, access to an item for inspection and testing, and space in which to adjust, repair, or replace it.

Downtime for a new system can be minimized by giving appropriate consideration to the location and mounting of equipment and by providing access to components. General guidelines for designers to follow in providing for accessibility include the following:

1) Locate assemblies, subassemblies, and parts to make possible inspection, servicing, replacement, and/or repair, as required, without removing them and without interference from them.

2) When such provisions cannot be made, place the items that are expected to require maintenance most frequently where they will be most accessible.

Once access has been gained to an area in which an assembly or part is to be repaired or replaced, access to that item must be provided. Guidelines for the designer in planning for ease of maintenance work include:

1) Locate assemblies and parts so that structural units and other parts do not block access to them.

2) Place assemblies and parts so that sufficient room is available for the use of test probes and other tools needed.

3) Place all throw-away items so that they can be removed without the necessity of removing other items.

4) Design each assembly so that it need not be removed to troubleshoot any of its components.

5) Use plug-in modules wherever feasible.

2. Indicator Requirements

The designing of effective indicators for maintenance use consists of selecting the types desired, deciding where they can best be located, determining the scale markings to be used, and labeling each device properly.

3. Control Requirements

Considerations that influence the design of controls are much the same as those for indicators.

C. ENVIRONMENTAL CONSIDERATIONS

The machine components of man-machine systems are normally designed to give maximum performance within specified environmental limits; when these limits are exceeded, both performance and reliability suffer. Some support is required under all conditions.

In contrast to equipment, the design of which can be changed, the human being has inherent and relatively inflexible "design" characteristics. The only alternative available is, wherever possible, the exercise of control over environmental conditions to provide reasonably acceptable working conditions.

The principal means of controlling conditions in work areas are heating, cooling, and ventilating equipment, and insulation. Whenever this is not possible, personnel efficiency can be increased in a numer of ways, as follows:

1) Rotation of personnel at work stations.

2) Decreased work loads.

3) Increased work space.

4) Individual protection measures.

5) Acclimatization (conditioning) of personnel.

It should be noted, however, that adoption of any of these methods will increase support costs by requiring either additional personnel or additional time for training.

Four principal environmental conditions affect man's efficiency during performance of his work.

1. Ambient Air

Temperature, relative humidity, air circulation, and the purity of air all affect human performance. For practical purposes, temperature, relative humidity, and air movement are often combined, and as such, are referred to as Effective Temperature or ET. This is an empirical index that expresses the combined effects of these three characteristics in terms of the subjective feeling of warmth. When the ambient air is completely saturated (100 percent relative humidity) and air velocity is zero, the value of ET is that of the air temperature. Any combinations of temperature, humidity, and air movement that produce the same subjective feeling of warmth are given the same ET value.

2. Illumination

Where expected conditions and facilities will permit optimum illumination to be used, the design of systems should provide for it. In considering what constitutes optimum illumination, the following factors should be noted:

1) The level of illumination required.

2) Uniformity of lighting throughout the work space.

3) Color composition of the light source.

4) Brightness contrast between the work and its background.

5) Glare.

In addition, safety hazards created by poor illumination should not be forgotten.

3. Noise

Excessive noise in a work area usually reduces the efficiency of the workers, and thus, indirectly, may reduce overall system readiness if the work performed is maintenance.

Exposure to noise of more than 80 db may result in temporary or permanent loss of hearing, the extent of damage being determined by the length of exposure.

Excessive noise also affects personnel psychologically; fatigue occurs more rapidly, ability to concentrate decreases, and annoyance increases. As a result, efficiency declines. Noise conditions in maintenance work areas should be studied and, when necessary, reduced. If reduction is not feasible, the workers should be issued protective devices.

4. Vibration

Low-frequency high-amplitude vibration of the working level frequently causes motion sickness; in the ranges of 25 to 40 cps and 60 to 90 cps, visual acuity may be impaired. Equipment that is vibrating when being worked on by a maintenance man creates many small and large problems for him, ranging from the manipulation of controls to the reading of indicators and labels; in any event, his efficiency is reduced.

Designers should make every reasonable attempt to eliminate vibration from the equipment that maintenance men must work on. The principal means by which this is accomplished, apart from major design features, are vibration insulation, rubber shock mounts, and the cushioning of work platforms and seats.

5. Radiation

The nuclear power plant designer must consider radiation as an additional environmental effect on component maintainability; that is, radioactive contamination of the component or high levels of radiation in proximity to the component location.

A component can be contaminated by: (1) direct irradiation in a neutron flux; (2) fission product deposition from the coolant through mass transport to the cooler regions of the system; (3) activation of dissolved impurities in the coolant which then plate out on the component; or (4) by the freezing of activated or contaminated sodium trapped in the component subsequent to sodium system draining.

High radiation levels in potential working areas result from: activated vessles, piping, or walls; fission products in the coolant of undrained adjacent systems; or adjacent activated primary sodium systems.

Recent experiences with nuclear reactor system repair strongly reinforce the need for a drastic change in maintainability planning by the designer when considering incore components, and primary vessels and piping.

With the advent of the LMFBR, designers must also consider the special problems associated with activated or contaminated sodium systems and provide for ease of access in order to limit personnel exposure time in areas which have the potential for high levels of radiation. Modular construction of large component subassemblies should be considered to permit ready replacement while affording ample time to clean and decontaminate the component under controlled and unhurried conditions.

V. TRADE-OFFS

Trade-off techniques are analytic processes whereby a complex problem of maintainability design, involving the selection of one of several possible design variants (parameters), is broken down into a number of smaller problems, the successive solutions of which lead directly to solution of the basic problem. Each smaller problem represents one of possible designs to be adopted; having been carefully defined, it is studied in the light of all of the system parameters (e.g., reliability, availability, safety, production schedule) its particular design will affect, and a weighting factor is assigned to the relationship of this design feature with each such parameter to indicate the relative significance of each such relationship. Solution of each smaller problem is arrived at by balancing the advantages and disadvantages to be gained by a particular design feature and expressing the results quantitatively. Step-by-step summation of the findings of all the minor problems produces a numerical basis for solving the major problem, while at the same time providing whatever solutions of intermediate problems may be required.

The principal goal of the trade-off techniques, so applied, is objectively expressed in numerical terms for use in substantiating optimum design decisions. It should be noted here, however, that the optimization of judgment desired can be attained only by considering all the elements of a problem. Incompleteness of treatment is the principal pitfall in the conduct of trade-off studies.

Formally developed trade-off studies are needed at every stage of the design and development of new systems. At the beginning stage, they determine the feasibility of a program. System requirements must be analyzed and weighed in terms of such factors as state of the art, development time required, total cost, extent to which off-the-shelf hardware can be used, potential consumer demand, company capabilities, and profit margin. After the feasibility study has produced a positive finding and design work begins, trade-off techniques are applied to such problems as determining the relative advantage of various system concepts, throw-away-at-failure versus piece-part repair, different packaging concepts, and at every level, variant specific design features.

Trade-offs also play a primary role in decision-making during design review, when the diverse interests of several project objectives must be reconciled.

The NSIA and Parametric Time/Cost Comparison methods are two of the more widely used trade-off techniques.