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PRELIMINARY REVIEW OF CRITICAL SHUTDOWN HEAT
REMOVAL ITEMS FOR COMMON CAUSE
FAILURE SUSCEPTIBILITY ON LMFBR'S

MASTER

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By:

L.T. Allard
J.G. Elerath

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FAST BREEDER REACTOR DEPARTMENT
Energy Systems & Technology Division
General Electric Company
Sunnyvale, California

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PRELIMINARY REVIEW OF CRITICAL
SHUTDOWN HEAT REMOVAL ITEMS FOR
COMMON CAUSE FAILURE SUSCEPTIBILITY

ABSTRACT

This document presents a common cause failure analysis for Critical LMFBR Shutdown Heat Removal Systems. The report is intended to outline a systematic approach to defining areas with significant potential for common causes of failure, and ultimately provide inputs to the reliability prediction model.

A preliminary evaluation of postulated single initiating causes resulting in multiple failures of LMFBR-SHRS items is presented in Appendix C of this report.

This document will be periodically updated to reflect new information and activity.

INTRODUCTION

This preliminary review studies postulated accident scenarios of LMFBR shutdown heat removal systems for failure of redundant or supposedly independent systems triggered by a single common cause.

Common causes of failures have become widely recognized in recent years as a significant obstacle to reaching substantially lower probabilities of failure in safety systems. In the past, common mode failures have not been studied on a broad enough scale to encompass the bulk of the linked failure modes that have been seen to exist in nuclear reactor plants.

The majority of the individual failure events under consideration are assumed to be independent, reflecting deliberate design efforts to assure that redundant elements are not affected by single events. In no case, however, will the system elements be totally independent. A variety of interdependencies will exist in any system, and no study will be complete without the assessment of the possible influence of such interdependencies upon system failure events. The procedures for making this assessment of dependent effects, which share a common cause or other common characteristics, can be termed "common mode failure analysis", or "common cause failure analysis".

Common mode failure analysis historically has been used to describe the approach of assessing the probability of having a common cause failure. But since a single cause of an event is the triggering point for one or more common modes of failure it is simpler to discuss the single cause. Also for purposes of attempting to reduce confusion the common cause is the more logical starting point and not the common mode. For these reasons, and for the sake of consistency, the remainder of this report will use the terms Common Cause Failure (CCF) and Common Cause Failure Analysis (CCFA). The term "event" will be used interchangeably with the term "cause" but, the term "event" will be used here to encompass combinations of causative factors, such as, temperature and pressure resulting in the event of "departure from nucleate boiling (DNB) in steam generator tubes". A definition of terms is included in the background section of this report.

This report evaluates the following critical SHRS items.

- o Intermediate Heat Transport System (IHTS)
- o Steam Generator System (SGS)
- o Steam Generator Auxiliary Heat Removal System (SGAHRs)
- o Auxiliary Feedwater System (AFWS)
- o Main Feedwater System (MFWS)
- o AC Power

PURPOSE

The purpose of this review is the identification of areas wherein Shutdown Heat Removal Systems (SHRS) might be particularly vulnerable to common cause failure(s).

The preliminary review of potential common causes of SHRS failures introduces a systematic approach for detecting linked failure modes of components thought to be independent.

Succeeding studies will provide more depth and seek to attach probabilities to common events that could trigger a combination of failures capable of defeating the shutdown heat removal function.

BACKGROUND

Evaluation techniques for identifying random breakdown of system hardware are relatively well developed compared to techniques for identifying events internal or external to the system which could initiate a combination of failures.

Since the advent of redundant safety systems most random independent component failures have relatively little influence on the overall failure probability of redundant systems. The greatest vulnerability is shifted to the universe of common external influences or common links between redundant systems. Component failures caused by common miscalibration, acts of God or power interruptions become real concerns. The potential coupling of components to a common triggering cause of this nature must be accounted for in determining overall SHRS reliability.

Vulnerability to these influences can be reduced substantially through the use of diverse hardware and careful plant layout, once these influences and their effects have been identified.

The most thorough approach to common mode failures on light water reactors has been presented in the Reactor Safety Study, WASH-1400, Appendix IV, August 1974, entitled "Common Mode Failures". In that report, the main problem in identifying common failure causes is attributed to the wide unbounded spectrum of possibilities other than common materials and properties of the hardware. The spectrum includes such unknowns as man-induced failures, machine-induced failures, environmentally-induced failures and hazards of conjuncture of these events. This report attempts to cover the spectrum for LMFBR's in a logical manner.

The report addresses the relationship of common cause with that of time. Common cause failures include concurrent failures, or those occurring simultaneously due to the same initiating event. Additionally cascading failures that occur within a critical time frame have been considered. The critical time frame is defined as the time between failures where protective action cannot be implemented in time to remedy the cascading effect(s) before the loss of two independent systems.

The common cause failure susceptibility study attempts to deal with a universe of events that take into account:

- o Common Properties
- o Common Materials
- o Common Processes
- o Common Locations
- o Common Environments
- o Common Catastrophies
(Man Made & Acts of God)
- o Common Human Intervention
- o Common Maintenance Acts
- o Common Testing

which are associated with the subsystems and components in the shutdown heat removal system. A detailed common causative checklist is shown in Figure 1, and for convenience added where applicable to common mode failure worksheets.

The common cause failure analysis will be used to identify potential common cause situations and test the ability of the SHRS to successfully cope with them.

Definitions

For purposes of this report the following definitions of terms apply:

1. Common Mode Failure - Multiple failures attributable to a common cause (per IEEE STD. 352, General Principles for Reliability Analysis of Nuclear Power Generating Station Protection Systems)
2. Common Causative Factor - The initial factor that could lead to multiple SHRS equipment failures.
3. Intrinsic Common Cause - Failure cause(s) inherent to the item's design or manufacture that could lead to common failure modes. (e.g.; S.F. Rupture Discs, etc.)
4. Extrinsic Common Cause - Failure cause(s) external to the item's design and operation that could lead to linked failure modes. (e.g.; flood, fire, etc.)
5. Lines of Influence - Links common to two or more systems being analyzed the links may include lines of communication, power and common process fluids.

FIGURE I
COMMON CAUSATIVE FACTORS

INHERENT TO ITEM

Common Properties (Of Design)

- o Common Elements (i.e. materials and parts)
- o Unrecognized Interdependencies (i.e. sneak circuits, lube systems, etc.)
- o Dependent Faults (i.e. inadequate safety margins, etc.)

Common Processes* (Of Manufacture)

- o Materials or Parts from the Same Lot
- o Inadvertent Test or Inspection Damage

EXTERNAL TO ITEM

Test & Maintenance Acts*

- o Miscalibration
- o Improper Testing
- o Outdated Prints or Procedures

Human Intervention

- o Operator Error
- o Incorrect Instruction(s)
- o Sabotage

Common Handling*

- o Shipping Damage
- o Storage Degradation (aging)
- o Installation Errors

*The only common failures to be considered are those that would not be normally detected during routine inspection, test and shakedown activities.

FIGURE I
COMMON CAUSATIVE FACTORS
(CONT'D)

Common Location

- o Same Building/Room
- o Same Support
- o Proximity to Degrading Influences (i.e. hot pipes, fly wheels that could fracture, etc.)

External Catastrophies

- o Tornado
- o Flood
- o Fire
- o Earthquake
- o Missiles

Extreme Environments

- o Water Release (i.e. pipe break, etc.)
- o Storms
- o Lightning

Normal Environments

- o Temperature
 - o Pressure
 - o Moisture
 - o Vibration
 - o Irradiation
 - o Foreign Material
 - o Wear/Fatigue
 - o Electrical Interference
 - o Power Supply Variations
 - o Sodium Contact
 - o DNB or Other Areas
- Exclusive to LMFBRs

FIGURE 2
A FAULT TREE
OF POTENTIAL COMMON FAILURE EVENTS

ANALYSIS APPROACH

General

The process of screening all of an unbounded universe of potential common causes is an endless task. Methods to be employed herein include reducing the universe to only causes of common mode failures that result in an increase in the probability of adverse safety consequences and implementing a three-prong systematic screening technique. Figure 2, a fault tree of potential common failure events, graphically presents the separation of common failure events or common failure causes into logical groupings.

The screening technique basically evaluates the SHRS hardware from three viewpoints. The first screening method asks "what can happen to the hardware during design and manufacture". The second screening question asks "what influence do various system interface ties have on SHRS safety considerations". The third screening technique evaluates the affect of events external to SHRS components and their safety consequences. Future studies should incorporate a fourth screening technique, one that asks the question, "what operational procedures have common mode implications as would be expected in practical utility operational conditions".

To illustrate use of this screening process for uncovering common causative factors, an example is offered. Steam generator tubes similar in design on all nine modules in the three intermediate heat transport loops are manufactured at a common manufacturer with common materials and techniques. The welding process will be common to all steam generators. The x-ray procedures will be common and the interpretation of x-rays may be by the same individual. These all are potential intrinsic causative factors for a common mode of failure and correspond to data to be recorded in Table I found in Appendix C and described in the format section herein.

Extrinsic common causative factors include (1) identical rail car shipment of all modules, (2) a common installation team at Clinch River, (3) a common building but different bays in the building. Additionally, all modules will see common temperature and pressures and possibly DNB or dryout affects. These entries would be part of Table II described here in.

Common links among all modules include the sodium and water supplies. There may be common ties between the warning systems, such as the leak detection system.

Thus, the process of looking at the item of concern for common properties and manufacturing approaches, followed by a look at common links with other systems, then a look at what external influences could cause loss of an item's functions, can be seen to offer a simple and effective method of identifying common causes of failures.

Analysis Procedure

- o A thorough knowledge of the SHRS physical system to the degree the design exists is needed. (See Appendix D, location of critical items). Any balance-of-plant components that interface with SHRS should be considered.
- o With a knowledge of the existing SHRS redundancies and diversities a most important part of this study is an understanding of the nature and causes of potential common mode effects.
- o Using as background information results from an SHRS failures modes and effects analysis (see Appendix A), the screening technique seeking common properties and common processes can be implemented. The data ordered by system elements provides a starting point for the uncovering of common material, parts, or processes.
- o The second screening technique involves reordering the FMEA by cause rather than system element. Then a search is made of the causative factor checklist and the FMEA for relevant causes and combinations of causes that could affect the SHRS safety function as a whole. With the aid of a fault tree (See Appendix B) all events or causes of common failures can be more easily identified and thoroughly covered. Fault trees are also the best source for evaluating effects of secondary failure causing events.
- o A third screening approach concentrates solely on the links or interfaces between systems and their common mode failure and effects.

- o Incorporate all dependent relationships found into appropriate system logic diagrams to determine potential safety consequences. Formally record all common causes having potential safety consequences.
- o Examine all combinations of dependent events for commonality. Assess the probability subjectively for this report and quantitatively measure the probabilities in future reports.
- o Assess the type of corrective measures that might be required, or why the common cause is adequately protected against by inherent design features or proposed operational procedures.

ANALYSIS DOCUMENTATION FORMAT

The results of this analysis are formally documented on the worksheets which form Appendix C of this report. Appendix C is a compilation of the effort to date in identifying specific common modes and common causes on SHRS. Areas that require further information or analysis are designated by "To Be Determined (TBD)" or "To Be Supplied (TBS)" symbols. Information could be lacking as a result of lack of design definition or lack of time to thoroughly investigate events for this preliminary study. The TBD designations will act as a starting point for future studies.

Table I, Common Mode Failures - Intrinsic Common Causes, lifts much of its information from the FMEA in Appendix A. The table evaluates the thought process of starting with a critical item (see Appendix D), whose failure modes are inherent to the hardware being evaluated and seeks their causative factor.

Table II, Common Mode Failures - Extrinsic Common Causes, reverses the process in Table I in going from potential causative factors to the resultant common mode. The causative factors in this case are not inherent to the hardware. The potential common causes are external to the design or manufacture. However, an overlap is expected in common failure modes and effects, since the failure mode for an outside cause, i.e. fire or flood, is not necessarily different from an internal hardware failure, i.e. short or open circuit. The reason for this Table is to identify areas that do not overlap.

Table III, Common Mode Failures - Lines of Influence, is comparable to Table I in its structure. But, instead of starting with a critical hardware item a critical link between systems is analyzed to assure that all common links with safety consequences are covered rigorously.

The terminology utilized on the three forms used in Appendix C of this report consists of:

Table I

Critical Item:	Identifies the SHRS component or system which is considered to have failed. The items have been previously selected in the Critical Items List, NEDM-14088, reproduced in part in Appendix D of this report. Areas to be supplied by Westinghouse include, the overflow heat removal system, reactor vessel, core support, and the primary heat transport systems.
System:	The system in which the Critical Item is located.
Item Function(s) Affected:	An enumeration of all of the major functions which the critical item must perform.
Potential Common Failure Mode(s):	Identified the manner in which the critical item is assumed to have failed. The failure modes should in some way reflect the loss of the items critical functions, i.e., if a pressure vessel function is to retain structural integrity its failure modes would be leakage or rupture, not corrosion or other causative factors. Note: All failure modes which could be attributed to the same cause(s) can be enumerated on one worksheet. Failure modes which have different potential causes require separate sheets.
Failure Effect On Shutdown/SHRS:	Describe whether a reactor trip occurs or the effect on SHRS redundancies.
Safety Consequences:	The overall effect of the common mode failure upon plant shutdown and/or plant safety.

Causative Factors: Beneath this heading is a checklist of the most common causes of common mode design or manufacture problems. The column should contain as much detail as is known about the common causative factor in this particular application.

Failure Mechanism: This column describes the system conditions leading to the local failed condition or common cause. For example, if a component is assumed to have failed due to excessive temperature, the system cause could have been failure of the air conditioning system.

Preventive Measures: This column is used for facts of design that may lessen the impact of a common cause of failure or make the common failure cause of a component unlikely. Identified causative factors may result in E-spec reliability requirements, and possibly new or modified procedures, manuals, training programs, test and maintenance requirements.

Recommendations and Remarks: This column is set up to allow for inclusion of pertinent remarks that fit nowhere else. Also it is used to point out areas requiring further analysis.

Table II

Critical Item(s) Affected: Identify the items which are considered to have failed once an external causative factor, such as flood or fire, is hypothesized to have occurred.

Location of Critical Items: Identifies where the critical items affected are located so that the type of environment that the common event might be subjected to can be determined.

Causative Factors: Enumerate one or more external causative factors from the checklist provided or any other source that reasonably could have been the cause of a common mode failure.

All other columns have been previously covered in the Table I description.

TABLE III

Common Link	Enter the common line of communication or common tie between systems, which may have a potential of influencing failures in systems linked to a failed system or a failed link.
Redundant or Diverse Systems Affected	Enter those systems tied to a common link.

All other columns have been previously covered in the description provided for Table I.

RESULTS

Upon completion of the analysis sheets, the CCF's which had adverse safety consequence were listed with their potential causes. This list still did not meet the criteria for identifying the "particularly vulnerable" failures.

A further engineering review was then conducted to remove from the list those failures which were judged to be highly unlikely. In conducting the review each failure and failure cause was individually considered taking into account available information.

Component History
Reliability Information
Manufacturing Controls
Q.C. Procedures
Type and frequency of periodic testing

When the above review was completed there remained a number of plausible common mode failures. Those potential failures that remained are summarized below, categorized by the potential cause of failure.

It should not be concluded that this list is the final listing of "particularly vulnerable" failures for as noted previously this is a preliminary study of a preliminary design. Many of these items may be removed from consideration when plant layouts, environmental controls and operating/maintenance procedures are fixed more permanently.

I. MISCALIBRATION

This includes the physical act of setting and adjusting a piece of equipment so that its output is not the designed or expected output for a given input condition. It can be the result of systematic error being made by the person doing the calibration, by a faulty piece of test equipment, etc.

Critical systems whose items may be frequently calibrated were analyzed. The items which had the greatest potential for being commonly miscalibrated and accordingly increasing the probability of multiple failures are:

- A. Steam drum level transmitter (3/loop)
- B. Steam drum pressure transmitter (3/loop)
- C. Steam drum differential pressure transmitter (3/loop)
- D. Auxiliary feedwater flow transmitter (6/plant)
- E. Power supply
- F. Protected water storage tank level (1/plant)
- G. PACC condensate return flow transmitters (3/plant)
- H. PACC leak detection transmitters (3/plant)

Problem Assessment

This can be a very real source of common mode failure; but fortunately, the likelihood of its being a serious problem can be made negligible through the use of appropriate controls. Besides accurately calibrating test equipment and test meters to national standards periodically, care will be taken that critical sensors are calibrated to General Electric and manufacturers specifications. This applies to such factors as temperature, static pressure, etc.

Three safeguards to inadvertent miscalibration included in the current design are (1) critical instrumentation racks will be locked up with one set of keys under responsibility of the plant supervisor, (2) all valves left in the test position rather than run position after checkout will trigger a warning signal in the main control room, (3) stem lock needle valves will be used which free wheel until a set screw is tightened.

Procedures to verify the calibration and operation of a critical piece of test equipment before and after use are being considered.

II. Environmental Conditions Within Control Room Type Areas

Included in this are such factors as temperature and humidity in the area as well as other factors that might be responsible for some local abnormal conditions, such as proximity to steam pipes, local fires, magnetic disturbances, etc. Items having this susceptibility include:

- A. Power supplies
- B. Switchgears
- C. Relays
- D. Meters

Problem Assessment:

A worst case environment is described in these areas. The equipment located in these areas is qualified to operate correctly over the range of environmental conditions specified. Accordingly, as long as the area environment remains within the worst case limits, the equipment should not be expected to fail for environmental reasons.

III SEVERING OF COMMON AIR SUPPLIES

The main air supply could be disrupted by such things as a seismic occurrence, a missile, poor joint connection(s), or a movement of restraints used to keep the equipment and lines in place.

The items that would present a safety problem should common mode failure be caused by the above are:

- A. Turbine By-Pass Valves (4to 8/plant)
- B. Sodium Drain Valves (11/loop)
- C. Water Drain Valves (4/loop)
- D. S.G. Isolation Valves (4/loop)
- E. Main Feedwater Isolation Valves (2/plant)
- F. Auxiliary Feedwater Isolation Valves (15/plant)

Problem Assessment:

The probability of a failure for this reason can be made negligible by proper location of equipment and air piping runs. Back-up air bottles are provided on safety related systems (the main F.W. isolation & turbine bypass valves are not safety rated) that must cycle during cool down.. Safety related valves include accumulators and check valves to protect against an air leak upstream of the check valve(s). Up to ten cycles of operation are available from these backup air bottles. Additionally to assure proper installation has been obtained and joints are secure, over pressure leak checks are planned.

IV VIBRATION INDUCED EFFECTS

The most sensitive components to vibration are those having thin unsupported areas. Examples would be sensors, burst discs, bellows, diaphragms, etc. Accordingly all parts whose natural frequency can be triggered by vibrational inputs are candidates for common mode failure. These would shutdown the plant before stronger parts are damaged by vibration, and thus will be the only items considered here.

The items that would present a safety related problem should common mode failure be caused by vibration are:

- A. IHTS water & steam piping
- B. Isolation valves
- C. Drain valves
- D. Motor operated pumps
- E. Burst discs
- F. High speed pressure transducers @ burst discs
- G. TBD

Problem Assessment:

The vibrational sensitive components are expected to undergo vibrational testing during development testing. Safety related components must be designed for safe shutdown earthquake loading requirements. Periodic inspections or testing following excessive vibration would reduce the risk of deteriorated or failed hardware existing in a standby operational mode. Selection of hardware and materials have taken into account the loading during transportation and operation.

V ELECTRICAL POWER SUPPLY

Included in this category are three sources of SHRS Power: Redundant preferred power lines, redundant reserve powerlines, and the diesel power emergency supply.

The sources assessed most likely to simultaneously remove all preferred and reserve power are tornadoes, out-of-tolerance power and grid blackout conditions. The emergency power supply's two diesel generators have common fuel cooling and exhausts, each having the potential to fail both diesel generators.

Critical items requiring inputs from one of the three electrical power sources are:

- A. Motor operated valves (20) (SGAHRS, Main and Auxiliary Feedwater)
- B. AFW Motor driven pumps (2)
- C. SGAHRS I & C
- D. Steam Generators & IHTS I & C
- E. TBD

Problem Assessment:

The electrical supplies are safety grade class I-E which involves meeting IEEE standards, i.e., for redundancy of buses, etc.

The likelihood of failure due to loss of all four outside power lines from a tornadoe are very remote. The likelihood of all grids having a blackout for any extended period of time is equally remote. The likelihood of failure due to out-of-tolerance power is greatly reduced because the power supplies are regulated and can compensate for variations of the vital instrument buses. Redundant circuit breakers are provided so that no single circuit breaker failure could eliminate a bus.

VI INCORRECT OPERATOR ACTION

No system is totally independent of human factors. Highly automated systems are conceived, designed, constructed, tested, adjusted, repaired, maintained & operated by human activities. A human failure might result from no action, wrong action, over action, or under action.

This particular category includes only those actions that an operator might take which affects the SHRS functional criteria such as introducing by-passes, etc. It does not include items such as adjusting pressure transducers or setpoints incorrectly; such items are considered under the miscalibration category.

The items that would present a safety problem should operator error be introduced are:

- A. SWRPRS trip controls
- B. Main F.W. isolation valves controls
- C. Water and/or sodium drain/dump valve controls
- D. Water and/or sodium pump controls
- E. Turbine by-pass valve controls
- F. TBD

Problem Assessment:

The instrumentation for each loop is independent and set up so that no single inadvertent act by the operator could change the position of more than one switch. No one system or loop can be down for repair without two back-up systems or loops made available, again, so that no single inadvertent act can cause a safety problem.

VII EXCESSIVE TEMPERATURE CYCLING

Included in this category are temperature transients whose source is internal to the heat transfer equipment. Departure from nucleate boiling (DNB), dry out phenomena, and an excessive number of scrams or shutdowns could lead to thermal fatigue.

The equipment suspected of being most susceptible should this common mode failure be caused by the above are:

- A. Steam Generator Tubing
- B. TBD

Problem Assessment:

The presence of DNB or dryout conditions in steam generator module tubes and the degree of temperature fluctuations are currently unknowns. Extensive development tests are underway to pinpoint the magnitude of the problem or if the problem exists.

Selection of tubing thickness, manufacturing techniques, and operational procedures will be established such that their design safety margins exceeds the environment that it will be subject to.

APPENDIX A
FAILURE MODES AND EFFECTS ANALYSIS

DESCRIPTION

The purpose of this FMEA is to screen the Shutdown Heat Removal System design at the system level for all singular disabling (or potentially disabling) hardware failures. Appendix A reflects an update of the FEMA presented in the PSAR.

The tabular format selected conforms to the format recommended in the LMFBR Reliability Manual, Revision 1.

DISCUSSION OF THE FMEA FORMAT COLUMNS

Reference Number	For reference identification purposes
Item Name/Function	Name as corresponds to drawings. All functions of the component in order to meet safety success criteria.
Failure Modes	States in which an item is prevented from executing its functions.
Failure Parameter	Best available probability of failure taken from the Probabilistic Data Sheets. In terms of failure rate (failures per million hours).
Failure Cause	All failure mode initiators.
Detectability	The same from 1 to 5 is defined as follows: 5 = cannot be detected or as redefined on FMEA 4 = can be detected, will have adverse impact 3 = may not always be detected or corrected in time to prevent adverse impacts. 2 = can be detected and normally corrected in time 1 = can be detected and always corrected in time
Failure Effects	- State the immediate potential impact or consequence arising on the <u>item in question</u> as a result of the failure mode identified.

Criticality* - Relates to the safety aspect of the SHRS function:
A = Failure (or potential failure) to perform safety function.
B = No effect on safety function.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM: PRIMARY LOOP

SUBSYSTEM:

PREPARED BY RJW/LTAREL. REVIEW CRHDATE 11/20/75DATE 11/21/75PAGE 1 OF 15

1	2	3	4	5	6	7	8	9
REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER $\lambda/10^6$ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CILITY	REMARKS
1.1	REACTOR VESSEL	LEAKAGE	0.01	Corrosion, erosion, thermal shock and excessive loads.	4	Sodium would fill limited volume between reactor and the guard vessel up to elevation of leak.	A	
	- Provides leak free sodium containment and a pressure vessel.	RUPTURE	0.0001	Thermal shock and excessive loads.	4	Plant shutdown.	A	
1.1.1	REACTOR GUARD VESSEL	LEAKAGE	0.01	Corrosion, erosion, thermal shock and excessive loads.	4	Plant shutdown.	A	
	- Provides sodium containment assuming reactor vessel fails.	RUPTURE	0.0001	Corrosion, erosion, thermal shock and excessive loads.	4	Plant shutdown.	A	
1.2	PIPING	LEAKAGE	0.63	Bending fatigue, creep strain, joint leakage.	4	Plant shutdown, loop drained.	A	
	- Provides leak free conduit for sodium transfer.	RUPTURE	0.4×10^{-6}	Bending fatigue, creep strain, joint rupture.	4	Plant shutdown, loop drained.	A	
1.3	CHECK VALVE	EXTERNAL LEAKAGE	0.11	Thermal, mechanical load- ing, weld defect.	4	Plant shutdown, loop drained.	A	
		RUPTURE	0.07×10^{-6}	Thermal or mechanical shock loads.	4	Plant shutdown.	A	
1.4	PRIMARY PUMPS	LEAKAGE	0.21	Mechanical and/or thermal loads, weld failure at joints.	4	Plant shutdown, loop drained.	A	
	- Provides flow control and sodium circulation capability for the pri- mary loop.	RUPTURE	0.14×10^{-6}	Mechanical and/or thermal loads, weld joint failure.	4	Plant shutdown, loop drained.	A	
		PUMP MECH. FAILURE	*	Bearing failure, rotor binds, shaft or struct. failure.	4	Plant shutdown.	B	
		PUMP ELECT. FAILURE	*	Short circuit, open circuit.	4	Plant shutdown.	B	

* These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM: PRIMARY LOOP

SUBSYSTEM:

PREPARED BY RJW/LTA

REL. REVIEW CRH

DATE 11-20-75

DATE 11-21-75

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1	2	3	4	5	6	7	8	9
REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER $\lambda/10^6$ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
1.5	INTERMEDIATE HEAT EXCHANGER (SHELL SIDE) - Provides heat transfer path. Provides leak free boundary between primary Na and atmosphere.	PONY MOTOR FAILURE SHELL LEAKAGE SHELL RUPTURE SUPPORT FAILURE	0.0013 0.38 0.25×10^{-6}	Control failure, short circuit, open circuit. Thermal shock, inlet/outlet nozzle weld leak. Thermal shock, inlet/outlet nozzle failure.	1 4 4	Fixed during scheduled outage. Plant shutdown, loop drain. Plant shutdown, loop drain.	A A A	Pony motors are triply redundant with respect to OHRS operation. Single motor failure rate - 24×10^{-6} .
1.6	DRAIN VALVES - Provides drain for primary loop (2 in series per loop).	EXTERNAL LEAK RUPTURE	0.21 0.14×10^{-6}	Thermal, mechanical loading, weld leak. Thermal, mechanical loading, weld rupture.	4 4	Plant shutdown Plant shutdown	A A	
1.7	PIPING BELLOWS - Acts as a seal between piping wall and containment wall.	LEAKAGE RUPTURE	* *	Fatigue, corrosion Fatigue, trapped sodium, corrosion, excessive loads.	4 4	Plant shutdown Plant shutdown	B B	
1.8	INSTRUMENTATION AND CONTROL (I&C) - Provided primary system electrical control and instrumentation for monitoring safety-related functions.	ELECTRICAL FAILURE MECHANICAL FAILURE	* *	Control failure, short circuit, open circuit, intermittent operation, sensor failure. Excess loads, heating, wear, fatigue, contaminants, corrosion.	2 2	Fix during next scheduled outage. Fix during next scheduled outage.	B B	No impact on reliability.

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERINGSYSTEM. INTERMEDIATE LOOP

SUBSYSTEM. _____

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REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER 10 ⁶ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CILITY	REMARKS
2.1	PIPING	LEAKAGE	1.3	Bending fatigue at corners, creep strain.	4	Plant shutdown loop drained.	A	
	- Provides leak free conduit for sodium transfer.	RUPTURE	0.8×10^{-6}	Bending fatigue, creep strain.	4	Plant shutdown, loop drain.	A	
2.2	INTERMEDIATE PUMP	LEAKAGE	0.21	Mechanical and/or thermal loads. Weld defects.	4	Plant shutdown loop drained.	A	
	- Provides circulation and flow control capabilities for the intermediate loop.	RUPTURE	0.14×10^{-6}	Mechanical and/or thermal loads. Weld defects.	4	Plant shutdown loop drained.	A	
		PUMP MECHANICAL FAILURE	*	Bearing failure, rotor binds, shaft or structural failure.	4	Plant shutdown	B	Pump not needed for shutdown heat removal. Natural circulation is sufficient.
		PUMP ELECTRICAL FAILURE	*	Short circuit, open circuit.	4	Plant shutdown	B	Pump not needed for shutdown heat removal. Natural circulation is sufficient.
		PUMP MOTOR FAILURE	*	Control failure, short or open circuit.	1	Fixed during scheduled outages.	B	Pump not needed for shutdown heat removal. Natural circulation is sufficient.
2.3	VENTURI	LEAKAGE OR RUPTURE	0.0114	Excessive loads	4	Plant shutdown, loop drain.	A	
	- Provides flow metering.							
2.4	INTERMEDIATE HEAT EXCHANGER (TUBE SIDE)	TUBE LEAKAGE	0.5	Corrosion, bending, creep fatigue, weld failures, galling	2	Plant shutdown, loop drain.	A	B = shutdown for small leak, but able to remove reactor heat.
	- Provides heat transfer path. Provides leak free boundary between primary sodium and intermediate sodium.	RUPTURE	0.06×10^{-6}	Corrosion, bending, creep fatigue, weld failures, galling.	4	Plant shutdown, loop drain.	A	A = shutdown for large leak or rupture, unable to remove reactor heat with tied loop (rely on redundant and/or diverse heat removal loops for shutdown heat removal).

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM: INTERMEDIATE LOOP

SUBSYSTEM:

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REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER 1/10 ⁶ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
2.5	INSTRUMENTATION AND CONTROL	ELECTRICAL FAILURE	*	Control failure, short circuit, open circuit, intermediate operation, sensor failure.	2	Fix during next scheduled outage.	B	No impact on reliability.
	- Provides intermediate system control and instrumentation capabilities for monitoring safety-related functions.	MECHANICAL FAILURE	*	Structural failures of mechanical instrumentation.	2	Fix during next scheduled outage.	B	No impact on reliability.
2.6	EXPANSION TANK	LEAKAGE OR RUPTURE	*	Excessive mechanical or thermal loads, corrosion.	4	Plant shutdown	B	No impact on reliability.
	- Provides containment for expanding sodium as a protection to the intermediate loop components.							

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A
FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LM-300 RELIABILITY
ENGINEERING

SYSTEM: SOD 53

SUBSYSTEM: STEAM GENERATOR LOOP

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REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER $\lambda/10^6$ hr	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
3.1	DRAIN VALVES - Provides intermediate sodium removal route for maintenance.	EXTERNAL LEAKAGE	0.63	Thermal and/or mechanical loading. Weld leakage, corrosion.	4	Plant shutdown, loop drain.	A	6 per loop, 3 loops
		RUPTURE	0.0021	Thermal and/or mechanical loading. Weld rupture.	4	Plant shutdown, loop drain	A	Only 3 per loop considered, due to 3 pairs each pair in series.
3.2	STEAM GENERATORS - Provides heat transfer path and leak free boundary between sodium and water, (also between sodium and atmosphere, also water and atmosphere).	SMALL LEAK H_2O - Na (.072 lbs/hr to 360 lbs/hr)	21.12	Weld porosity, fatigue failure, wall thinning, creep, mech. stress overload, corrosion.	4	Plant shutdown	A	3 per loop, 3 loops on superheater and evaporators. A = shutdown for large leaks or rupture, an inability to remove reactor heat in affected loop (rely on redundant and diverse heat removal loops for shutdown heat removal).
		MEDIUM LEAK H_2O - Na (.072 lbs/hr to 7200 lbs/hr)	4.22	Weld porosity, fatigue, creep, wall thinning, mechanical stress overload, corrosion.	4	Plant shutdown	A	B = shutdown for small leak but able to remove reactor heat in affected loop.
		LARGE LEAK H_2O - Na (Over 7200 lbs/hr)	0.85	Growth of undetected small leak or operator decision to continue with leak.	4	Plant shutdown, loop drain	A	Small leak detection - H_2 diffusion tube. Operator action required to limit damage to adjacent tubes.
		VESSEL LEAKAGE	3.0	Inlet or outlet nozzle rupture, thermal shock or excessive loads, corrosion.	4	Plant shutdown, loop drain	A	Intermediate leak detection - H_2 diffusion tube, high IHIS pressure, high IHIS exp tank level. Operator action required to damage.
3.3	SODIUM RELIEF SYSTEM (SWRPS) - Provides safety relief over pressure system that must be leak free prior to need.	RUPTURE DISK LEAKAGE	8.0	Weld leakage, pressure pulse, corrosion.	3	Plant shutdown.	A	Per loop basis for failure rate.
		PREMATURE RUPTURE	3.0	Improper burst strength, corrosion.	4	Plant shutdown, loop drain.	A	
3.4	HYDROGEN DETECTION SYSTEM - Provides monitoring of sodium intermediate loop in order to detect tube leak in steam generators.	OPERATES FALSELY	3.8	Pressure transients, thermal transients, high background hydrogen levels.	3	Plant shutdown.	A	Removal of loop for decay heat removal if loop is desired.

APPENDIX A
FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM SDD 53

SUBSYSTEM STEAM GENERATOR LOOP

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3.5	INSTRUMENTATION AND CONTROL (SODIUM SIDE)	PENETRATION LEAK	1.8	Excessive load, corro- sion.	4	Plant shutdown, loop drain.	A	
	- Provides I&C for intermediate loop sodium.	FAILS TO OPERATE (CORRECTLY)	*	Control logic failure; electrical failure.	3	Fix at next outage or while on-line.	B	
3.6	PIPING - STEAM/WATER	LEAKAGE	2.0	Joint leakage, creep- fatigue, excessive loads.	4	Plant shutdown.	A	
	- Provides leak free conduit for steam or water transport.	RUPTURE	0.1	Joint failure, creep strain, fatigue, exces- sive loads.	4	Plant shutdown	A	
3.7	ISOLATION VALVES	EXTERNAL LEAKAGE	2.0	Thermal cycling defect, improper weld, corrosion	4	Plant shutdown	A	Six per loop
	- Provides isolation of the superheat- er.	RUPTURE	0.2	Joint failure, excess loads.	4	Plant shutdown	A	
3.8	SAFETY VALVES	EXTERNAL LEAKAGE	0.60	Excess loads, corrosion	4	Plant shutdown	A	On steam drums and steam generator outlet*
	- Provides over pressure relief of steam generator system.	RUPTURE	0.006	Excess loads.	4	Plant shutdown	A	Nine per loop
		FAILURE TO RECLOSE	1.0	Excess loads, jamming, corrosion.	4	Plant shutdown	A	Too much steam blow down, unable to maintain water level.
3.9	STEAM DRUM	LEAKAGE	0.4	Excess loads, corrosion.	4	Plant shutdown	A	
	- Provides containment for the steam water separation, and water storage for evaporators.	RUPTURE	0.1	Excess loads at nozzles, thermal shock, shell fracture.	4	Plant shutdown	A	
		FAILURE OF INTERNALS	0.1	Excess loads.	4	Plant shutdown	A	
3.10	INSTRUMENTATION AND CONTROL - H ₂ O/ STEAM	PENETRATION RUPTURES	0.3	Weld cracked, excessive loads, creep strain.	4	Plant shutdown	A	Extensive repair required.
	- Provides I&C for water side of steam generator loop.	OPERATES FALSELY	*	Control logic failure, short or open circuit.	3	Plant shutdown or wait till scheduled outage.	B	Fix at next scheduled outage or quick repair, no impact on SHRS reliability.

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A
FAILURE MODE AND EFFECTS ANALYSIS -- CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM. SDD - 53

SUBSYSTEM STEAM GENERATOR LOOP

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3.11	WATER ISOLATION AND DUMP SYSTEM - Provides for isolation and dump of water side of steam generator loop.	LEAKAGE	0.6	Joint leakage, corrosion	4	Plant shutdown	A	
		RUPTURE	0.006	Excessive loads.	4	Plant shutdown	A	
		OPERATES FALSELY	5.0	Human error.	4	Plant shutdown	A	
3.12	RECIRCULATION PUMPS - Provides water circulation capability.	LEAKAGE	0.21	Joint failure, mechanical and/or thermal loads.	4	Plant shutdown	A	
		RUPTURE	0.0021	Weld rupture, mechanical and/or thermal over loads.	4	Plant shutdown	A	
		PUMP ELECTRICAL FAILURE	*	Short circuit, open cir- cuit.	4	Plant shutdown	B	No impact on reliability to remove reactor heat.
		PUMP MECHANICAL FAILURE	*	Bearing failure, rotor binds, shaft or struc- tural failure.	4	Plant shutdown	B	

*These components have no impact on heat removal capability and their failure rates are not used in computing unreliability.

APPENDIX A
FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM STEAM GENERATOR AUXILIARY HEAT RE- SUBSYSTEM PACC

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4.1	PROTECTED WATER STORAGE TANK - Long term function combined with PACC's is to provide containment of auxiliary feedwater and cooling water makeup for leakage.	RUPTURE	0.001	<ul style="list-style-type: none"> o Earthquake greater than SSE. o Corrosion o Over heating o Over pressure (vent failure) 	2	Must rely on condensate storage tank as backup.	A	Seismic Cat. 1.
4.2	PIPING - Provides leak free conduit for water transport.	LEAKAGE	0.1	<ul style="list-style-type: none"> o Improper weld o Thermal cycling 	4	Shutdown loop	A	Steam drum would probably fail before piping.
		RUPTURE	0.01	<ul style="list-style-type: none"> o Thermal cycling o Improper weld 	4	Shutdown loop	A	
4.3	ISOLATION VALVES - Normally open manual valves utilized for maintenance of PACC's	LEAKAGE	0.43	<ul style="list-style-type: none"> o Stem leakage o Improper weld o Thermal cycling 	4	Shutdown loop	A	Small stem leak would not preclude heat removal.
		RUPTURE	0.008	<ul style="list-style-type: none"> o Bonnet blows off o Improper weld 	4	Shutdown loop	A	
		FAILS CLOSED	0.15	<ul style="list-style-type: none"> o Thermal cycling 	4	Shutdown loop	A	
4.4	PROTECTED AIR COOLED CONDENSERS (PACC) - Provides shutdown heat removal path by transferring heat from steam/H ₂ O off the steam drum to the atmosphere.	FAILS TO OPERATE	0.01	<ul style="list-style-type: none"> o Two parallel fans fail o Finned tubing fails o Two sets of doors bind 	4	Forces an increased heat load for auxiliary F.W.	A	Normally open. Relief valves are redundant to PACC's for up to 20 days.
		OPERATES FALSELY	0.1	<ul style="list-style-type: none"> o Louvers close improperly. 	1	Forces an increased heat load for auxiliary F.W.	A	Manual backup.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERINGSYSTEM SGAHRsSUBSYSTEM AUXILIARY FEEDWATER SYSTEMSPREPARED BY RJW/LTA REL. REVIEW CRH
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5.1	PROTECTED WATER STORAGE TANK - Short term function combined with relief valves and PACC's is to provide auxiliary feedwater to steam drums.	RUPTURE	(0.001)		2		A	See SGAHRs, Ref. No. 4.1
5.2	ALTERNATE WATER SUPPLY (CONDENSATE STORAGE TANK AND PIPING) - Provides the alternate feedwater supply to the steam drums.	CONTAINMENT RUPTURE	0.01	Condensate storage tank weld or outlet rupture.	2	Unable to provide cooling water to steam drums.	A	Redundant to protected storage tanks but not seismic Cat. 1.
5.3	ISOLATION AND CONTROL VALVES - Provides isolation and control of the auxiliary feedwater system.	EXTERNAL LEAKAGE	0.003	Thermal cycling, improper weld, corrosion.	2	Requires two failures. Rely on main feedwater or OHRS.	A	Requires more than one valve fail to repair valves while on line.
		RUPTURE	0.001	Thermal cycling, improper weld, corrosion.	2	Requires two failures. Rely on main feedwater or OHRS.	A	Failure to valve off (multiple failures) result in loss of decay heat removal capability, except for OHRS.
		FAILS TO OPERATE	*	Short or open circuit, contamination, corrosion.	2	Requires two failures. Rely on main feedwater or OHRS.	b	Adequate I&C redundancy (requires two failures).
5.4	CHECK VALVES - Prevents reverse flow of auxiliary feedwater.	EXTERNAL LEAKAGE	0.003	Thermal cycling, improper weld, corrosion.	2	Requires two failures. Rely on main feedwater or OHRS.	A	To be considered criticality = 5, must be accompanied with loss of turbine pump, 1 of main feed pumps, and OHRS inoperable.
		RUPTURE	0.001	Thermal cycling, improper weld, corrosion.	2	Requires two failures. Rely on main feedwater or OHRS.	A	
5.5	MOTOR DRIVEN PUMPS - Provides auxiliary feedwater flow to the steam drums.	EXTERNAL LEAKAGE	2.0	Thermal cycling, improper weld, corrosion.	4	Requires two failures. Rely on main feedwater or OHRS.	A	
		CASE RUPTURE	0.02	Thermal cycling, improper weld, corrosion.	4	Requires two failures. Rely on main feedwater or OHRS.	A	
		FAILS TO RUN	14	Loss of motor, bearing seizure, loss of power	4	Redundant turbine pump.	A	

*No impact on heat removal capability

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM SGARHS

SUBSYSTEM AUXILIARY FEEDWATER SYSTEMS

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5.6	TURBINE DRIVEN PUMP - Provides auxiliary feedwater flow to the steam drums.	FAILS TO START	(0.02/cycle or (.0001/cycle)	**Diesel generator sets fail to operate, loss of power.	4	Redundant turbine pump	A	$\lambda = (.02/\text{cycle})$ -both pumps required. $\lambda = (.0001/\text{cycle})$ -pumps are redundant.
		VALVING EXTERNAL LEAKAGE OR RUPTURE	2.4	Thermal cycling, improper welds, corrosion.	4	Rely on motor driven pumps as backup.	A	To be considered criticality = 5 must be accompanied by loss of motor driven pump loss of main feedwater pumps and GHRs be inoperable.
		PRESSURE REDUCER EXTERNAL LEAKAGE OR RUPTURE	0.5	Thermal cycling, improper welds, corrosion.	4	Rely on motor driven pumps as backup.	A	
		TURBINE FAILS TO OPERATE	10.0	Corrosion, turbine blade separation, bearing seizure, control failure.	4	Rely on motor driven pumps as backup.	A	
		PUMP FAILS TO RUN	7.9	Bearing seizure, warpage.	4	Rely on motor driven pumps as backup.	A	
		VENTILATION FAILURE	1.0	Plugging	4	Rely on motor driven pumps as backup.	A	
		TURBINE CONTROL FAILS TO OPERATE	11.7	Actuator fails, electro-mechanical failure.	4	Rely on motor driven pumps as backup.	A	
		TOTAL	33.5					
		FAILS TO START	(.001/cycle)	*Turbine binds, control system failure, bearing seizure.	4	Rely on motor driven pumps as backup.	A	Turbine exhaust blockage.

*Probability of failing to start the turbine pump = .001 failures/cycle/pump

**Probability of failure to start = 0.01 failures/cycle/pump = 0.02 failures/cycle/both pumps.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERINGSYSTEM: OVERFLOW HEAT REMOVAL

SUBSYSTEM: _____

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6.1	OVERFLOW VESSEL	EXTERNAL LEAKAGE	0.050	Corrosion, joint leakage.	4	Unable to remove decay heat.	A	Must rely on redundant PACC.
	- Provides reactor vessel overflow containment of radioactive sodium.	RUPTURE	0.001	Weld separation, mechanical overload.	4	Unable to remove decay heat.	A	Must rely on redundant PACC.
6.2	Na EM PUMPS	EXTERNAL LEAKAGE	0.02	Mechanical overloads, corrosion.	4	Unable to remove decay heat.	A	$\lambda = .01/10^6/\text{pump}$
	- Provides makeup water when required.	RUPTURE	0.002	Mechanical and/or thermal transients, weld joint failure.	4	Unable to remove decay heat.	A	$\lambda = .001/10^6/\text{pump}$
		FAIL TO OPERATE	2.0	Open or short circuit, windings fail, structural failure presenting operation.	4	Unable to remove decay heat.	A	$\lambda = 1/10^6/\text{pump}$
6.3	PIPING AND VALVING	PIPE LEAKAGE	0.137	Corrosion, fatigue, wall thinning.	4	Unable to remove decay heat.	A	
	- Sodium	PIPE RUPTURE	0.001	Excessive loads, joint failure.	4	Unable to remove decay heat.	A	
	- Provides routes for leak free sodium flow control and transfer in OHXs.	VALVE EXTERNAL LEAKAGE AND RUPTURE	0.012	Corrosion, mechanical overloads.	4	Unable to remove decay heat.	A	$\lambda = .001/10^6/\text{valve}$
		VALVE FAILS TO OPERATE	0.20	Short or open circuit, contamination or corrosion.	4	Unable to remove decay heat.	A	$\lambda = .05/10^6/\text{valve}$
6.4	COLD TRAPS	FAILS TO OPERATE	*	Excessive loads, corrosion, weld failure or joint failure.	1	Repair without shutdown.	B	Valve off and repair.
	- Provides cleanup system for the primary system.							
6.5	OVERFLOW HEAT EXCHANGER (HX)	LARGE TUBE LEAKAGE	0.011	Thermal shock, inlet or outlet nozzle leakage.	4	Unable to remove decay heat.	A	$\lambda = .106/10^6/\text{for all leakage}$ λ large leak = 1/10 λ any HX leak not use during normal operation.
	- Provides heat transfer path, and a leak free boundary for removal of some decay heat.	RUPTURE	0.001	Thermal shock, inlet or outlet nozzle/joint rupture.	4	Unable to remove decay heat.	A	Valve off and repair.

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS — CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM: OVERFLOW HEAT REMOVAL SERVICE

SUBSYSTEM: _____

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6.6	NaK EM PUMP - Provides flow control for NaK loop. - Provides free boundary.	EXTERNAL LEAKAGE RUPTURE FAILS TO OPERATE	0.02 0.002 2.0	Mechanical overloads, corrosion. Excessive loads, weld joint failure. Open or short circuit, windings fail structural failure preventing operation.	4 4 4	Unable to remove decay heat. Unable to remove decay heat. Unable to remove decay heat.	A A A	Two pumps $\lambda = .01/10^6$ /pump $\lambda = .001/10^6$ /pump $\lambda = 1.0/10^6$ /pump
6.7	NaK PIPING AND VALVING - Provides routes for leak free transfer of NaK in CHRS.	PIPE LEAKAGE PIPE RUPTURE *VALVE EXTERNAL LEAKAGE AND/OR RUPTURE VALVE FAILS TO OPERATE	0.150 0.001 0.003 0.100	Mechanical overload, corrosion, fatigue, wall thinning. Excessive loads weld joint failures. Corrosion, mechanical overload. Short or open circuits, contamination or corrosion structural mechanism failure.	4 4 4 4	Unable to remove decay heat. Unable to remove decay heat. Unable to remove decay heat. Unable to remove decay heat.	A A A A	$\lambda = .001/10^6$ /valve $\lambda = .05/10^6$ /valve
6.8	AIR BLAST HEAT EXCHANGER - Provides method of removing heat from NaK.	LEAKAGE RUPTURE FAILS TO OPERATE	0.008 0.002 20.0	Corrosion Excessive loads, inlet or outlet nozzle failure shell rupture. Failure of louvers to open, loss of fan(s).	4 4 4	Unable to remove decay heat. Unable to remove decay heat. Unable to remove decay heat.	A A A	$\lambda = .044/10^6$ /AB/HX Two air blast heat exchangers needed. $\lambda = .001/10^6$ /ABHX $\lambda 10/10^6$ /ABHX
6.9	NaK EXPANSION TANK PROVIDES CONTAINMENT FOR EXPANDING NaK - Provides containment for expanding NaK.	LEAKAGE RUPTURE	0.168 0.002	Corrosion, excessive loads. Excessive loads, weld on joint failure.	4 4	Unable to remove decay heat. Unable to remove decay heat.	A A	Two tanks needed $\lambda = .084/10^6$ /tank $\lambda = .001/10^6$ /tank
6.10	NaK COOLER	LARGE LEAKAGE	0.008	Corrosion, inlet or outlet joint failure.	4	Unable to remove decay heat.	A	Two coolers needed $\lambda = .036/10^6$ /cooler for all leakage $\lambda = 1/10$ λ all leaks for large leaks

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERINGSYSTEM. OVERFLOW HEAT REMOVAL SERVICE

SUBSYSTEM. _____

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1	2	3	4	5	6	7	8	9
REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER	FAILURE CAUSES	DETECT ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
5.10 (cont)	- Provides cooling for ex-vessel storage tank.	RUPTURE	0.002	Excessive loads, weld failure, joint failure.	4	Unable to remove decay heat.	A	$\lambda = .001/10^6/\text{cooler.}$

APPENDIX A

FAILURE MODE AND EFFECTS ANALYSIS - CRITICALITY ANALYSIS

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SYSTEM: _____

SUBSYSTEMS: FEEDWATER, CONDENSER, TURBINE BY-PASS

PREPARED BY RJW/LTA REL. REVIEW CPHDATE 11/20/75 DATE 11/21/75PAGE 14 OF 15

1	2	3	4	5	6	7	8	9
REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER $\lambda/10^6$ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
7.1	FEEDWATER PIPING - Provides leak free conduit for feed- water transport.	LEAKAGE	0.5	Joint leakage, fatigue, corrosion.	4	Shutdown, must rely on auxiliary feedwater.	A	Rely on auxiliary feedwater system if other 2 loops fail.
		RUPTURE	0.01	Joint rupture, excessive loads.	4	Shutdown, must rely on auxiliary feedwater.	A	
7.2	FEEDWATER PUMPS - Provides flow control and feedwater circulation.	LEAKAGE	0.3	Mechanical loads, corro- sion.	4	Shutdown, must rely on auxiliary feedwater.	A	Three pumps.
		RUPTURE	0.03	Mechanical overload, weld failure.	4	Shutdown, must rely on auxiliary feedwater.	A	
		FAIL TO OPERATE	13.0	Motor fails, pump fails, loss of off site power.	4	Shutdown, must rely on auxiliary feedwater.	A	All three must fail (CMF). Single unit 21.0×10^{-6} /hr. Four turbine, by-pass valves. Rely on PACC's to remove heat after one ho.
7.3	TURBINE BY-PASS VALVE - Provides steam by-pass of turbine to the main condenser.	EXTERNAL LEAKAGE	0.1	Weld leakage, joint damage, corrosion.	4	Rely on auxiliary feed- water and venting from steam drum.	A	
		RUPTURE	0.01	Mechanical stress, weld on joint failure.	4	Rely on auxiliary feed- water and venting from steam drum.	A	
		FAILS TO OPERATE	0.01	Valve hang-ups, electri- cal malfunctions.	4	Rely on auxiliary feed- water and venting from steam drum.	A	
7.4	MAIN CONDENSER - Condensation of steam from turbine to main feedwater.	FAILS TO OPERATE	10	Control failure, excess loading.	4	Rely on auxiliary feed- water and venting from steam drum.	A	Rely on PACC's to remove heat after one (Loss of off site power causes all of t main feedwater system to be unavailable is accounted for once in the main feed FTO mode.)
7.5	INSTRUMENTATION & CONTROL - MAIN FEED- WATER - Provides I&C for feedwater system monitoring.	ELECTRICAL FAILURE	*	Control failure, short circuit, open circuit, sensor failure, intermit- tant operation. Loss of off-site power.	2	Adequate redundancy fix while at power or at next scheduled outage.	B	
		MECHANICAL FAILURE	*	Structural failure of controls.	2		B	No impact on SHRS unreliability predict

*These components have no impact on heat removal capability and their failure rates are not used in computing SHRS unreliability.

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

SUBSYSTEM:

GENERAL ELECTRIC
LMFBR RELIABILITY
ENGINEERING

1	2	3	4	5	6	7	8	9
REF. NO.	ITEM NAME (NUMBER) DESCRIPTION FUNCTION	FAILURE MODES	FAILURE PARAMETER 1/10 ⁶ HRS	FAILURE CAUSES	DETECT- ABILITY	FAILURE EFFECTS	CRITI- CALITY	REMARKS
8	AC Electrical Components - Provides AC electrical power to SHRS components	Off-Site Power Failure	0.18	Excessive power loads, switching station failure.	4	Loss of power to site. Need to rely on alter- ate power.	A	Plant power is assumed to be loss with loss of off-site power. λ based on T/ letter P.S. Van Nort to G. Williams "NE Questions on the CRBRP PSAR", July 30, Duration of loss of off-site power is 2 minutes based on LWR operating experien
		Failure of Diesel Generator Set A	0.01/ cycle*	Failure to start, failure to operate.	4	Loss of power to bus A. Rely on set B.	A	
		Failure of Diesel Generator Set B	0.01/ cycle*	Failure to start, failure to operate .	4	Loss of power to bus B. Rely on set A.	A	Loss of AC power requires simultaneous loss of off-site power and loss of die generator sets A and B.

*Probability of failure = 0.01 failures/cycle/diesel generator set.

APPENDIX B

FAULT TREE

APPENDIX C
COMMON MODE FAILURE ANALYSIS

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: EMERGENCY DIESEL GENERATORS SYSTEM: AUX. FEEDWATER SYSTEM
 ITEM(S) AFFECTED: Supply Auxiliary Electricity to Plant (See Appendix D for Component Listing)

PREPARED BY: J.G. ELERATH
 DATE: 2-19-76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
Fail to supply Emergency Power (upon loss of preferred and alternate offsite power).	Loss of Current to: 1. Motor Driven Auxiliary Feedwater Pumps 2. Primary & Secondary Sodium Pumps 3. PACC'S 4. OHRS 5. Main Feedwater System 6. Valving (OHRS, Na, H ₂ O)	Must Rely On: (1) Natural Circulation of Na, (2) Safety Power Relief Valve Steam Venting, and (3) Aux. F.W. Turbine for Shutdown Heat Removal.

POTENTIAL INHRENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
<ul style="list-style-type: none"> Common Elements Unrecognized Interdependences 	1. Contamination of Common Diesel Fuel Supply 2. Exhaust Fire in Common Exhaust Stack 3. Restriction of Common Air Supply 4. Loss of Common Cooling Water 5. Fuel Supply Prematurely expended or cut-off.	Separation of fuel tanks	<ul style="list-style-type: none"> Diversify both Diesel Generators and separate common interfaces Fuel supply should be periodically monitored. Fuel supply lines should be separated.
CHECKLIST OF POTENTIAL CAUSATIVE FACTORS <div style="display: flex; justify-content: space-between;"> <div> <u>COMMON DESIGN PROPERTIES</u> <ul style="list-style-type: none"> o COMMON ELEMENT (MATERIALS & PARTS) o UNRECOGNIZED INTERDEPENDENCE o INADEQUATE TOLERANCES OR SAFETY MARGINS </div> <div> <u>COMMON PROCESSES</u> <ul style="list-style-type: none"> o ITEMS FROM SAME LOT o INADEQUATE QC o INCORRECT ASSEMBLY </div> </div>			

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: Auxiliary Feedwater Pumps SYSTEM: A.F.W.SITEM(S) AFFECTED: Provide Auxiliary Feedwater Flow to Steam DrumsPREPARED BY: L.T.A./J.G.E.DATE: 2/19/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
1. Loss of pumping capability	1. Loss of auxiliary feedwater flow from two or more pumps	1. Loss of auxiliary feedwater steam venting capability.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS				
1. Overspeed trip activation	<ul style="list-style-type: none">o False signalso Miscalibration	<ul style="list-style-type: none">o EMD suppression circuits					
2. Common elements	<ul style="list-style-type: none">o Common impeller material or fabrication defectso Common defective bearingso Common connections	<ul style="list-style-type: none">o Diverse pumps - two motor operated, one steam driven.					
3. Cavitation	<ul style="list-style-type: none">o Out-of-balance common partso Misalignment during repairo Wear of componentso TBD	<ul style="list-style-type: none">o High head pressure design					
4. Fatigue of drivelines	<ul style="list-style-type: none">o Misaligned shaftso Unbalanced loads (i. e. seismic)o TBD	<ul style="list-style-type: none">o Natural circulation potential exists					
<p style="text-align: center;"><u>CHECKLIST OF POTENTIAL CAUSATIVE FACTORS</u></p> <table><tr><td><u>COMMON DESIGN PROPERTIES</u></td><td><u>COMMON PROCESSES</u></td></tr><tr><td><ul style="list-style-type: none">o COMMON ELEMENT (MATERIALS & PARTS)o UNRECOGNIZED INTERDEPENDENCEo INADEQUATE TOLERANCES OR SAFETY MARGINS</td><td><ul style="list-style-type: none">o ITEMS FROM SAME LOTo INADEQUATE QCo INCORRECT ASSEMBLY</td></tr></table>				<u>COMMON DESIGN PROPERTIES</u>	<u>COMMON PROCESSES</u>	<ul style="list-style-type: none">o COMMON ELEMENT (MATERIALS & PARTS)o UNRECOGNIZED INTERDEPENDENCEo INADEQUATE TOLERANCES OR SAFETY MARGINS	<ul style="list-style-type: none">o ITEMS FROM SAME LOTo INADEQUATE QCo INCORRECT ASSEMBLY
<u>COMMON DESIGN PROPERTIES</u>	<u>COMMON PROCESSES</u>						
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TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: Rupture Discs SYSTEM: Sodium Relief System (SWRPRS)
 ITEM(S) AFFECTED: Provide Safety Relief, Over-Pressure System

PREPARED BY: J.G. Elerath
 DATE: 2/19/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
o Failure to rupture when design pressure was exceeded.	o Increase pressure in IHTS and IHX	o Damage of IHX's causing loss of loop
o Rupture below design pressure	o Premature loss of sodium in affected loops	o Loss of heat transfer capabilities in affected loops.
o <u>Design pressure inadequate</u>		

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
Failure to Rupture at Design Strength			
1. Too high fracture strength	1.1 Rupture discs fail to burst when exposed to high pressure pulse initiated by a sodium/water reaction 1.2 Rupture criteria above some system elements structural strength limits.	1. Rupture discs have been incorporated into a testing program to verify fracture strength.	1.1 Consider diverse materials fabrication of rupture discs 1.2. Consider diverse rupture disc designs for each heat transfer loop e.g., put rupture discs above Na level.
2. Too low fracture strength	2. Premature rupture of discs	2. See 1 above	2. See 1 above
3. Unrecognized interdependence between rupture discs and affects of other systems (e.g. pressure and thermal transients).	3. Inadvertant rupture of discs	3. See 1 above	3. See 1 above

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON DESIGN PROPERTIES

- o COMMON ELEMENT (MATERIALS & PARTS)
- o UNRECOGNIZED INTERDEPENDENCE
- o INADEQUATE TOLERANCES OR SAFETY MARGINS

COMMON PROCESSES

- o ITEMS FROM SAME LOT
- o INADEQUATE QC
- o INCORRECT ASSEMBLY

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: STEAM GENERATOR MODULES (TUBES & SHELLS) SYSTEM: STEAM GENERATOR SYSTEM
 ITEM(S) AFFECTED: Provides Heat Transfer Path and Physical Boundary between A,B. & C.
 A. Sodium & Water
 B. Sodium & Atmosphere
 C. Water & Atmosphere

PREPARED BY: J. G. ELERATH
 DATE: 2-18-76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
Loss of boundary between sodium & water or loss of sodium & air boundary.	Loss of intermediate loops which contain affected steam generator modules.	Loss of heat removal path(s) will necessitate reliance on OHRS and unaffected loops.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Excessive Temperature Cycling due to: o Departure from Nucleate Boiling o Normal Duty Cycles o Dryout Conditions 2. Weld Porosity 3. Common materials & parts	1. Thermal Fatigue 2. Inherent to Welding Process; Mechanical Welders out of tolerance 3. Creep, Decarburization, Wall-Thinning (erosion) or Mechanical Stress overload leading to tube failure.	o Development testing is underway. o Sophisticated Q.C. inspection of weld & weld processes. o Weld testing is planned. o The best porosity identification X-Ray equipment available will be utilized. o Hydrogen & Oxygen Leak Detection Equipment provided. o Other safeguards include a pressure relief system & automatic system shutdown.	o Reduce spurious event probabilities in order to reduce the number of thermal cycles experienced during a S.G.'s lifetime. o Diversity in steam generator tubes (i.e. one loop having double wall-ed S.G.'s) would remove the present non-diversity in heat removal loops.
CHECKLIST OF POTENTIAL CAUSATIVE FACTORS			
COMMON DESIGN PROPERTIES		COMMON PROCESSES	
o COMMON ELEMENT (MATERIALS & PARTS)		o ITEMS FROM SAME LOT	
o UNRECOGNIZED INTERDEPENDENCE		o INADEQUATE QC	
o INADEQUATE TOLERANCES OR SAFETY MARGINS		o INCORRECT ASSEMBLY	

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: Protected Air Cooled Condensers (PACC) SYSTEM: Steam Generator Auxiliary Heat Removal System
 ITEM(S) AFFECTED: Provide Shutdown Heat Removal Path by Transferring Heat from Steam /H₂O at the Steam Drum to the Air.

PREPARED BY: J. G. Elerath
 DATE: 2/18/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
Failure to Provide a Heat Removal Path o Tubing or piping weld porosity o Louvers jammed closed o Doors bind closed	o Loss of steam/water to air heat sink	o Loss of heat removal capabilities provided by (up to 3) PACC's and forces an increased heat load for the auxiliary feedwater - venting system.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Weld porosity 2. Inadequate tolerance on safety margins	1. Inherent to welding process or mechanical welders out of tolerance 2. Louvers jammed closed Doors bound closed	1. High sophistication in Q.C. inspection of weld and weld processes 2. TBS	

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON DESIGN PROPERTIES

- o COMMON ELEMENT (MATERIALS & PARTS)
- o UNRECOGNIZED INTERDEPENDENCE
- o INADEQUATE TOLERANCES OR SAFETY MARGINS

COMMON PROCESSES

- o ITEMS FROM SAME LOT
- o INADEQUATE QC
- o INCORRECT ASSEMBLY

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: INTERMEDIATE HEAT EXCHANGER SYSTEM: HEAT TRANSPORT SYSTEM
 ITEM(S) AFFECTED: Provides Heat Transfer Path by Maintaining Leak Free Boundary between Primary Sodium and Intermediate Sodium

PREPARED BY: J. G. ELERATH
 DATE: 2-18-76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
Failure to provide heat transfer path or violation of boundary requirements.	Loss of Loops containing affected Heat Exchangers	OHRS backup available & unaffected heat loops.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
Common Materials & Parts Erosion and Corrosion. Welding Anomalies	<ul style="list-style-type: none"> o Material transport from hot end to cold end of IHX. o Inadequate welding technique o Contaminated welds o Common weld Materials 	Stainless steel materials Code Materials Qualification of welders and welding processes. F2-2 requirements on procurements and processes.	Recommend diversity in materials and manufacturers where feasible.
<p style="text-align: center;"><u>CHECKLIST OF POTENTIAL CAUSATIVE FACTORS</u></p> <div style="display: flex; justify-content: space-between;"> <div> <p><u>COMMON DESIGN PROPERTIES</u></p> <ul style="list-style-type: none"> o COMMON ELEMENT (MATERIALS & PARTS) o UNRECOGNIZED INTERDEPENDENCE o INADEQUATE TOLERANCES OR SAFETY MARGINS </div> <div> <p><u>COMMON PROCESSES</u></p> <ul style="list-style-type: none"> o ITEMS FROM SAME LOT o INADEQUATE QC o INCORRECT ASSEMBLY </div> </div>			

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: SWRPPS Instrumentation (Pressure Transm) SYSTEM: SWRPPS I & CPREPARED BY: J.G. ElerathITEM(S) AFFECTED: Accurate Detection of Pressure (Flow) Between Rupture DiscsDATE: 2/19/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
o Spurious Detection	o Premature evacuation of water (SGS) in steam generator modules (without rupturing discs).	o Loss of heat removal capabilities in affected loops
o No detection of pressure between discs	o Failure to initiate SWRPPS signal (discs ruptured)	o Damage to IHTS & IHX due to extreme pressure

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Common Materials & Parts	1. Vibration during transit or operation 2. Common process defects	1. Two out of three voting above a threshold valve, needed to initiate SWRPPS signal	1. Diversify materials parts and processes.
<p style="text-align: center;"><u>CHECKLIST OF POTENTIAL CAUSATIVE FACTORS</u></p> <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p><u>COMMON DESIGN PROPERTIES</u></p> <ul style="list-style-type: none"> o COMMON ELEMENT (MATERIALS & PARTS) o UNRECOGNIZED INTERDEPENDENCE o INADEQUATE TOLERANCES OR SAFETY MARGINS </div> <div style="width: 48%;"> <p><u>COMMON PROCESSES</u></p> <ul style="list-style-type: none"> o ITEMS FROM SAME LOT o INADEQUATE QC o INCORRECT ASSEMBLY </div> </div>			

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: Valves-Diaphragm/Spring Opposed SYSTEM: AFWS -3/Plant; Main F.W. System -1/Loop
 ITEM(S) AFFECTED: Control of Aux. F.W. Bypass Flow; Control of Main F.W. Flow to Steam Drums

PREPARED BY: J.G. Elerath
 DATE: 2/18/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
o Fail to "Fail Safe" position	o Allows full A.F.W. Bypass flow o (Main F.W. Control fail safe position is TBD)	o Reduces F.W. flow to steam drum o TBD

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Common Parts	1. Diaphragm Failures 2. TBD		1. Use diverse types or manufacturers of diaphragm/spring opposed valves.
<div><div><p><u>CHECKLIST OF POTENTIAL CAUSATIVE FACTORS</u></p><div><div><p><u>COMMON DESIGN PROPERTIES</u></p><ul style="list-style-type: none">o COMMON ELEMENT (MATERIALS & PARTS)o UNRECOGNIZED INTERDEPENDENCEo INADEQUATE TOLERANCES OR SAFETY MARGINS</div><div><p><u>COMMON PROCESSES</u></p><ul style="list-style-type: none">o ITEMS FROM SAME LOTo INADEQUATE QCo INCORRECT ASSEMBLY</div></div></div></div>			

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: Valves - Safety Pressure Relief SYSTEM: Steam Generation SystemPREPARED BY: J.G. ElerathITEM(S) AFFECTED: Vent Steam During Over Pressurization of Steam Generation SystemDATE: 2/18/76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
o Fail to open at designed pressure level	o Increase pressures in steam generator modules, steam drum, & PACC's	o May damage steam generator modules steam drums, PACC's or IHX's

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Common parts	1. All fail closed due to common defects		1. Consider diverse safety pressure relief valves.
<p style="text-align: center;"><u>CHECKLIST OF POTENTIAL CAUSATIVE FACTORS</u></p> <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p><u>COMMON DESIGN PROPERTIES</u></p> <ul style="list-style-type: none"> o COMMON ELEMENT (MATERIALS & PARTS) o UNRECOGNIZED INTERDEPENDENCE o INADEQUATE TOLERANCES OR SAFETY MARGINS </div> <div style="width: 48%;"> <p><u>COMMON PROCESSES</u></p> <ul style="list-style-type: none"> o ITEMS FROM SAME LOT o INADEQUATE QC o INCORRECT ASSEMBLY </div> </div>			

TABLE I

COMMON MODE FAILURES - INTRINSIC COMMON CAUSES

CRITICAL ITEM: STEAM DRUMS SYSTEM: STEAM GENERATOR LOOP
 ITEM(S) AFFECTED: Provides: A) Containment for Steam-Water Separation and
B) Water Storage for Evaporators

PREPARED BY: J. G. ELERATH
 DATE: 2-18-76

POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN /SHRS	SAFETY CONSEQUENCES
Loss of Containment of Steam Water	Loss of Heat Removal Paths Requiring Steam Drums	Rely on OHRS and unaffected loops, if any.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS AND REMARKS
1. Excessive Pressure Transients 2. Common Materials & Parts	1. Failure of Pressure Relief Valves on Steam Drums causes excessive leakage or rupture. 2. Corrosion (due to normal use environment) leading to shell fracture.	1. Safety Pressure Relief Vent Valves are provided on steam drums.	

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON DESIGN PROPERTIES

- o COMMON ELEMENT (MATERIALS & PARTS)
- o UNRECOGNIZED INTERDEPENDENCE
- o INADEQUATE TOLERANCES OR SAFETY MARGINS

COMMON PROCESSES

- o ITEMS FROM SAME LOT
- o INADEQUATE QC
- o INCORRECT ASSEMBLY

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Emergency Diesel-GeneratorsLOCATION OF CRITICAL ITEMS: Aux F.W. SystemPREPARED BY: J. G. Elerath
DATE: 2/17/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Water release (PWST)	1.1 Short in Generators 1.2 (See contaminants, (3) in causative factors).	1-4 Loss of diesel-generator set	1.1 Loss of emergency electrical power 1.2 Loss of Aux. feed water & emergency electrical power	1. Diesels are 18" above floor and sump pumps are present	
2. Fire or high temperature	2.1 Generator winding failure 2.2 Over heat diesels causing them to shut down		2.1 See 1.1 2.2 See 1.2		
3. Contaminants in fuel supply, air supply	3. Diesels fail to operate		3. See 1.2	3. Air and fuel filters inherent to system design	
4. Excessive moisture or contaminants	4. Circuit breaker trips		4. See 1.2		

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: AUXILIARY FEEDWATER PUMPSLOCATION OF CRITICAL ITEMS: BENEATH PWSTPREPARED BY: J. G. Elerath
DATE: 2-19-76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1 Water Release (PWST Failure due to S G Building Collapse, etc)	1 External Leakage	1 thru 3 Loss of Auxiliary Feedwater Supply to Steam-Drums	o Steam Venting may not be Used as a Method of Heat Removal Must Rely on Closed Loop Heat Removal Emergency Electrical Power cannot be Supplied	o Pumps are Mounted 18" above Floor, Sump Pumps are also Provided o Natural Circulation Potential Exists	o Submersible Pumps are Recommended o Design pumps for potential thermal shock when submerged
2 Loss of Lubricant	2 (See Table III, Lubrication)				
3. Back Pressure as a Result of the Downstream By-pass Valves Remaining Closed	3 Loss of Flow				

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Steam Generator Modules (Shells)PREPARED BY: J.G. Elerath
DATE: 2/18/76LOCATION OF CRITICAL ITEMS: Steam Generator Bays

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Earthquake	1. Rupture	1. Loss of sodium in IHTS.	1. Loss of heat removal capabilities in loops with affected modules.		
2. Vibration	2. Fatigue	2. Seal above.	2. See 1 above		

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Steam Generator Modules - (Tubes)
 LOCATION OF CRITICAL ITEMS: Steam Generator Building

PREPARED BY: J.G. Elerath
 DATE: 2/19/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
o Earthquake or vibration induced fatigue	o Failure to maintain sodium water boundary (resulting in sodium/water reaction).	o Loss of affected heat transport loops	o Must rely on OHRS and any loops not affected for SHRS.		

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR
- o HUMAN ERROR

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

PREPARED BY: J.G. ELERATH

DATE: 2-18-76

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

PREPARED BY: J. G. Elerath
 DATE: 2/19/76

CRITICAL ITEM(S) AFFECTED: SWRPRS INSTRUMENTATION (PRESSURE TRANSDUCERS)

LOCATION OF CRITICAL ITEMS: One Set Of 3 Is Between Each Set Of Rupture Discs (3 Sets/Loop; 9 Sets/Plant)

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Miscalibration (Low Setting) and/or Set Point Drift (To A Low Setting) 2. Plant Vibration Or Design Basis Earthquake	1,2 & 3 Premature SWRPRS Signal To Plant Protection System	1,2 & 3 Loss of Water In Affecte Steam Generator Loops. (Upon SWRPRS Signal)	1,2 & 3 Loss of Heat Removal Capabilities in Affected Loops	o Two Out of 3 P.T. Voting Logic, Above Threshold Value, Needed To Initiate SWRPRS Signal o Plant HVAC Controls The Atmosphere In Most Buildings.	1. Diversify Maintenance Teams And Equipment 2. Recommend Seismic Testing Of These Sensitive Components 3. Recommend Sealing Parts Suseptible To Moisture

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Valves - Safety Pressure ReliefLOCATION OF CRITICAL ITEMS: Steam Drum (2/S. D); Evaporator Outlet (2/EVAP); Sup. Heated Outlet (3/S.H.)PREPARED BY: J. G. Elerath
DATE: 2/18/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Contaminants - corrosion caused by moisture in system.	1. Fail - stuck closed.	1. Reduces number of vent valves which open under high pressure.	1. Degradation of heat removal capabilities by venting. May cause high pressures resulting in damage to S.G. Modules, PACC's, IHX's or steam drums		
2. Miscalibration	2. Relief Pressures all set too high	2. Fail to vent at designed pressure	2. -See 1 above		2. Diversify calibration of set points (different people & instruments) methods. Calibrate checkout equipment before & after usage.

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o FIRE
- o TORNADO
- o LIGHTENING
- o FLOOD
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Valves-Motor Operated (SGAHRs Pressure Relief-2/loop; Main F.W-3/plant; Auxiliary F.W.-11/plant)
 LOCATION OF CRITICAL ITEMS: SGAHRs-1 on Steam Drum, 1 on S.H. Outlet; Main F.W.-Pump Outlets; Aux.-F.W. Pump Outlets, Turbine(Steam) Inlet; between CST & PWST

PREPARED BY: J. G. ELERATH
 DATE:

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Miscalibration	1.1A Insufficient Flow through SGAHRs pressure relief system.	1.1.A SGAHRs Pressure Relief Valves will not provide sufficient Heat Dissipation by venting	1.1.A Must rely on Safety Power Relief valves for removal of initial Shutdown Heat	1.1.A TBD	1.1 Safety Power Relief Valves must be relied upon when pressures rise sufficiently.
	1.2.A Insufficient Flow through main F.W. system.	1.2.A Must rely on Aux. F.W. system	1.2.A May preclude Heat Removal Capabilities in main feed-water sys.	1.2.A TBD	
	1.3.A Insufficient Flow through A.F.W. syst.	1.3.A Reduces Venting Cooling Capability	1.3.A May preclude Heat Removal Capabilities in Aux F.W. system	1.3.A TBD	
	1.1.B Too much flow in SGAHRs pressure relief system when not desired.	1.1.B Loss of Steam when not desired.	1.1.B Inability to isolate low pressure main-feed pump	1.1.B TBD	
	1.2.B Allows flow in Main F.W. when not desired.	1.2.B Must rely on redundant pneumatic valves for isolation of low pressure Aux. Feed Pump	1.2.B Inability to maintain closed system Heat Removal (PACC's)	1.2.B TBD	
2. Fire or Excessive Heat	1.3.B Allows Flow in Aux. F.W. when not desired	2.1 See 1.1.A	1.1.B Inability to maintain closed system Heat Removal (PACC's)	1.3.B Diversity & Redundancy	1.2.B The necessity to isolate the main feed pump discharges and failure of the motor operators assumes two independent failures and, therefore, is beyond the scope of this analysis 1.3.B There is sufficient redundancy and diversity in valve operators that several common failures would be required to cause total loss of Aux. F.W. system
	2.1 SGAHRs Pressure relief valves fail in position (closed).	2.2 See 1.2.B	1.2.B This mode is not critical (see remarks)	2.1 TBD	
	2.2 Main F.W. valves fail in position (open)	2.3 See 1.3.B	1.3.B Not critical (see remarks)	2.2 TBD	
	2.3 Aux. F.W. valves fail in position		2.3 See 1.3.B	2.3 TBD	
			2.1 See 1.1.A 2.2 See 1.2.B 2.3 See 1.3.B		

(continued on next page)

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTNING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR

TABLE II

PAGE 2

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: VALVES MOTOR OPERATED (CONTINUED)PREPARED BY: _____
DATE: _____

LOCATION OF CRITICAL ITEMS: _____

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
3. EXCESSIVE MOISTURE	3.1 - SEE 2.1 3.2 - SEE 2.2 3.3 - SEE 2.3	3.1 - SEE 1.1.A 3.2 - SEE 1.2.B 3.3 - SEE 1.3.B	3.1 - SEE 1.1.A 3.2 - SEE 1.2.B 3.3 - SEE 1.3.B	TBD TBD TBD	
4. VIBRATION CAUSING LOOSENED OR BROKEN ELECTRICAL CONNECTIONS	4.1 - SEE 2.1 4.2 - SEE 2.2 4.3 - SEE 2.3	4.1 - SEE 1.1.A 4.2 - SEE 1.2.B 4.3 - SEE 1.3.B	4.1 - SEE 1.1.A 4.2 - SEE 1.2.B 4.3 - SEE 1.3.B	TBD TBD TBD	
5. IMPROPER VOLTAGE SUPPLIED TO MOTORS	5.1 - SEE 2.1 5.2 - SEE 2.2 5.3 - SEE 2.3	5.1 - SEE 1.1.A 5.2 - SEE 1.2.B 5.3 - SEE 1.3.B	5.1 - SEE 1.1.A 5.2 - SEE 1.2.B 5.3 - SEE 1.3.B	TBD TBD TBD	5. SEE LINKS, TABLE III FOR CAUSES OF ELECTRICAL PROBLEMS
6. CONTAMINANTS, SUCH AS DIRT OR GREASE IN ELECTRICAL CONTACTS	6.1 - SEE 2.1 6.2 - SEE 2.2 6.3 - SEE 2.3	6.1 - SEE 1.1.A 6.2 - SEE 1.2.B 6.3 - SEE 1.3.B	6.1 - SEE 1.1.A 6.2 - SEE 1.2.B 6.3 - SEE 1.3.B	TBD	

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- ☐ SHIPPING DAMAGE
- ☐ STORAGE DEGRADATION
- ☐ INSTALLATION ERRORS

COMMON ENVIRONMENT

- ☐ TEMPERATURE
- ☐ VIBRATION
- ☐ MOISTURE
- ☐ CONTAMINATES
- ☐ PRESSURE
- ☐ IRRADIATION

COMMON CATASTROPHIES

- ☐ EARTHQUAKE
- ☐ TORNADO
- ☐ FLOOD
- ☐ FIRE
- ☐ LIGHTENING
- ☐ WATER RELEASE

HUMAN INTERVENTION

- ☐ MISCALIBRATION
- ☐ TESTING AND MAINTENANCE
- ☐ IMPROPER INSTRUCTIONS OR
OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: VALVES-AIR OPERATED (AFW FLOW CONTROL - 15/PLANT; SGS-4/LOOP; MAIN F.W.-2/LOOP; H₂O DRAIN-4/LOOP)
 LOCATION OF CRITICAL ITEMS: AFW SYSTEM; EVAP & S.H. INLETS AND S.H. OUTLET; Na DRAIN LINES; H₂O DRAINLINES; MAIN F.W. INLET LINES)

PREPARED BY: J.G. ELERATH
 DATE: 2-18-76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Electrical Failure of Solenoid o No Electricity Available o Improper Voltage Supplied Causing Solenoid Burn-Out o Loose Electrical Connectors due to Vibration o Water Release o Fire or Excessive Temperature	1.1 All Air Operated Valves in AFW Syst. Fail Open	1.1 A.F.W. System Loses some Isolation Capabilities	1.1 Must Rely on Motor Operated Valves for Isolation	1.1 TBS	1.1 See Links, Table III for Common Electrical Problems
	1.2 S.H. & Evap. Inlet Isol Valves Fail Open, S.H. Outlet Valves Fail Closed	1.2 Closes Heat Path from Sup. Heater to Main Condenser	1.2 Precludes heat removal through Main Condenser and affects Isol. of S.G. Modules	1.2 TBS	
	1.3 Both Main F.W. Inlet Isolation Valves Fail Closed	1.3 Prevents Main F.W. Flow to Steam Drums	1.3 Precludes Heat Removal through the Main Condenser; must rely on AFW	1.3 TBS	
	1.4 All H ₂ O Drain Valves Fail Closed	1.4 Prevents Drainage of H ₂ O out of Evaporators	1.4 Prevents H ₂ O Evacuation upon Sodium/Water Reaction	1.4 TBS	
2. Pneumatic Failure A. Loss of Air Pressure B. Corrosion Caused by Moisture in Air o Failure of poppets o Blockage of Air Vent	2.1.A - SEE 1.1 2.2.A - SEE 1.2 2.3.A - SEE 1.3 2.4.A - SEE 1.4	2.1.A - SEE 1.1 2.2.A - SEE 1.2 2.3.A - SEE 1.3 2.4.A - SEE 1.4	2.1.A - SEE 1.1 2.2.A - SEE 1.2 2.3.A - SEE 1.3 2.4.A - SEE 1.4		2.1.A - See Links, Table III for Common Causes of Pneumatics Failures 2.1.B - Degradation of A.F.W. System may Occur with Little Effect on Heat Removal, However, it may also have severe Effects on (Shutdown) Heat Removal
	2.1.B A.F.W. Valves Fail in Normal Position o A.F.W. Inlet - F.O. o A.F.W. Outlet - F.C. o Turbin Steam Inlet - F.C.	2.1.B Degrades Aux F.W. System	2.1.B Degrades Heat Removal by Venting because of Disabled A.F.W. System		

(Continued on Next Page)

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o FIRE
- o TORNADO
- o LIGHTENING
- o FLOOD
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: VALVES - AIR OPERATED - CONTINUED

PREPARED BY: J. G. Elorath
DATE: 2/18/76

LOCATION OF CRITICAL ITEMS: _____

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
2. (Continued)	2.2.B. S.H. & Evap. Isol Valves Fail Open SH Outlet Valve Fails Open 2.3.B Main F.W. Valves Fail Open 2.4.B Water Drain Valves Fail Closed	2.2.B Prevents Isolation of S.G. Modules 2.3.B Prevents/ Isolation of Main F.W. System 2.4.B See 1.4	2.2.B Prevents S.G. Isolation Upon Sodium/Water Reaction 2.3.B Not Critical See Remarks 2.4.B See 1.4	2.3.B Diversity & Redundancy	2.3.B A.F.W. pressure would not be lost unless there were additional failures of the check valves in the main F.W. lines.

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: VALVES - DIAPHRAGM/SPRING OPPOSED
 LOCATION OF CRITICAL ITEMS: AFWS-3/PLANT; MAIN FW SYSTEM-1/LOOP

PREPARED BY J.G. FLEBATH
 DATE: 2-18-76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. ELECTRICAL FAILURE OF SOLENOID <ul style="list-style-type: none"> o NO ELECTRICITY o IMPROPER VOLTAGE SUPPLIED CAUSING SOLENOID FAILURE o LOOSE OR BROKEN ELECTRICAL CONNECTORS DUE TO VIBRATION o WATER RELEASE (CAUSING SHORTS) o FIRE OR EXCESSIVE HEAT 	1.1 "FAILED SAFE" POSITION OF AFW BYPASS VALVES IS IN OPEN POSITION 1.2 MAIN FW-TBD	1.1 ALLOWS FULL AFW BYPASS FLOW 1.2 TBD	1.1 REDUCES AFW FLOW TO STEAM DRUM 1.2 TBD	1.1 RESTRICTING ORIFICES DOWNSTREAM OF THE BYPASS CONTROL VALVE LIMITS BY-PASS FLOW 2.1 - SEE 1.1 2.2 TBD	
2. PNEUMATIC FAILURE <ul style="list-style-type: none"> o LOSS OF AIR PRESSURE 	2.1 - SEE 1.1 2.2 TBD	2.1 - SEE 1.1 2.2 TBD	2.1 - SEE 1.1 2.2 TBD	2.1 - SEE 1.1 2.2 TBD	
3. MISCALIBRATION	3.1.A A FWS BYPASS SET TOO HIGH 3.1.B AFWS BYPASS SET TOO LOW 3.2 MAIN F.W. FLOW CONTROL SET TOO LOW	3.1.A ALLOWS MORE THAN DESIRED AFW BYPASS FLOW 3.1.B ALLOWS LESS THAN DESIRED AFW 3.2 PREVENTS DESIRED MAIN F.W. FLOW	3.1.A REDUCES AFW FLOW TO STEAM DRUM 3.1.B INSUFFICIENT FLOW TO STEAM DRUM 3.2 INSUFFICIENT FLOW TO STEAM DRUM	3.1.A - SEE 1.1	

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHES

- o EARTHQUAKE
- o FIRE
- o TORNADO
- o LIGHTNING
- o FLOOD
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: IHX
 LOCATION OF CRITICAL ITEMS: PHTS - IHTS Interface

PREPARED BY: J. G. Elerath
 DATE: 2/18/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Extreme pressure transients	(1, 2, 3) Violation of: A. Primary sodium-atmosphere boundary B. Primary sodium-intermediate sodium boundary C. Intermediate sodium-atmosphere boundary	(1, 2, 3) Loss of affected IHX	(1, 2, 3) Loss of heat removal capability affected loops	(1, 2, 3) Rupture discs at sup. heater inserts and evaporator outlets	(1, 2, 3) The rupture discs may fail to burst at designed pressure causing overpressuring of IHX (See table I, rupture discs).
2. Seismic					
3. Vibration					

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- ☐ SHIPPING DAMAGE
- ☐ STORAGE DEGRADATION
- ☐ INSTALLATION ERRORS

COMMON ENVIRONMENT

- ☐ TEMPERATURE
- ☐ VIBRATION
- ☐ MOISTURE
- ☐ CONTAMINATES
- ☐ PRESSURE
- ☐ IRRADIATION

COMMON CATASTROPHIES

- ☐ EARTHQUAKE
- ☐ TORNADO
- ☐ FLOOD
- ☐ FIRE
- ☐ LIGHTENING
- ☐ WATER RELEASE

HUMAN INTERVENTION

- ☐ MISCALIBRATION
- ☐ TESTING AND MAINTENANCE
- ☐ IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Main Feed Water System

LOCATION OF CRITICAL ITEMS: _____

PREPARED BY: J.G. Elerath
DATE: 2/19/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
					<ul style="list-style-type: none"> No known common mode failures due to serial nature of components. The system is not seismic hardened since it is not considered a safety rated system.

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE II

COMMON MODE FAILURES - EXTRINSIC COMMON CAUSES

CRITICAL ITEM(S) AFFECTED: Turbine By-Pass ValveLOCATION OF CRITICAL ITEMS: Mezzanine Level, East Side of Turbine BuildingPREPARED BY: L. T. Allard
DATE: 2/23/76

CAUSATIVE FACTORS	POTENTIAL COMMON FAILURE MODE(S)	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES	CURRENT PREVENTIVE MEASURES	RECOMMENDATIONS & REMARKS
1. Loss of air supply	1. All valves fail closed.	1. Normally closed valves protect the turbine from overheating	1. Loss of energy sink routes to the main condenser.	1. SHRS safety relief system is only alternative.	1. 4, 6 or 8 balance-plug caged-valves will be used depending on economic considerations. No redundancy is planned. But each valve will handle 1/4th, 1/6th or 1/8th of the 2,160,000 lbs/hr. of steam. All electrical circuits are diverse to each valve.

CHECKLIST OF POTENTIAL CAUSATIVE FACTORS

COMMON HANDLING

- o SHIPPING DAMAGE
- o STORAGE DEGRADATION
- o INSTALLATION ERRORS

COMMON ENVIRONMENT

- o TEMPERATURE
- o VIBRATION
- o MOISTURE
- o CONTAMINATES
- o PRESSURE
- o IRRADIATION

COMMON CATASTROPHIES

- o EARTHQUAKE
- o TORNADO
- o FLOOD
- o FIRE
- o LIGHTENING
- o WATER RELEASE

HUMAN INTERVENTION

- o MISCALIBRATION
- o TESTING AND MAINTENANCE
- o IMPROPER INSTRUCTIONS OR OPERATOR ERROR

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. AllardDATE: 2/13/76COMMON LINK: Power Transmission System - Preferred, Reserve and Emergency SourcesSYSTEMS AFFECTED Two Preferred Power Lines, Two Reserve Power Lines, Two Diesel Generators, Circuit Breakers, Common Busses

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
<ul style="list-style-type: none"> Loss of Power Supply 	<ul style="list-style-type: none"> Partial or total loss of electrically driven pumps and valveing 	<ul style="list-style-type: none"> System designed to fail-safe with respect to lost power. Steam driven pumps and air operated valves could provide the cooling flow needed for shutdown heat removal.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
<u>Emergency Power Supply</u> <ul style="list-style-type: none"> Common diesel fuel supply Common cooling source Common exhaust system Common electrical bus 	<ul style="list-style-type: none"> Contaminated or inadequate fuel supply. Oil cooler malfunctions Inadvertent exhaust closure Bus failure Exhaust fire 	<ul style="list-style-type: none"> Thirty day diesel fuel supply for each generator One bus per loop 	<ul style="list-style-type: none"> Consider independent fuel, cooling and exhausts for each Diesel Generator
<u>Reserve (Off-site) Power Supply</u> <ul style="list-style-type: none"> Transmission lines (2) fail Switchyard equipment failure 	<ul style="list-style-type: none"> Tornado Seismic occurrences Failure of restraints Lightening Missiles Blackout 	<ul style="list-style-type: none"> Design for proper location and separation of redundant cables. The diesel electrical power backup designed to emergency safety criteria. 	<ul style="list-style-type: none"> Require three loops to be wired through two separate cable spreading rooms to avoid the Brown's Ferry type incident
<u>Preferred (Off-site) Power Supply</u> <ul style="list-style-type: none"> Transmission lines (2) fail Switchyard equipment failure 			

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

- o INFORMATION SIGNALS
- o POWER TRANSMISSION SYSTEM

- o LUBRICATION SYSTEM
- o PNEUMATIC SYSTEM

- o WATER SUPPLY SYSTEM
- o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. AllardDATE: 2/13/76COMMON LINK: Power Transmission System - Preferred Reserve and Emergency Sources (Continued)SYSTEMS AFFECTED Two Preferred Power Lines, Two Reserve Power Lines, Two Diesel Generators, Circuit Breakers, Common Busses

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
<u>All Power Supplies</u> <ul style="list-style-type: none"> • Circuit breakers and/or bus malfunction 	<ul style="list-style-type: none"> • Improper test or maintenance • Common manufacture defect • Improper installation • Out-of-tolerance power 	<ul style="list-style-type: none"> • Burns & Roe must meet the cable separation criteria to be established by G. E. in the future. • Power supplies are regulated and can compensate for variations of the vital instrument buses. 	<ul style="list-style-type: none"> • Suggest diverse manufacturers and types of circuit breakers. • Consider a third bus and third diesel generator for complete independence.

CHECKLIST OF POTENTIAL COMMON LINKSLINES OF INFLUENCE

- o INFORMATION SIGNALS
- o POWER TRANSMISSION SYSTEM

- o LUBRICATION SYSTEM
- o PNEUMATIC SYSTEM

- o WATER SUPPLY SYSTEM
- o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. Allard
 DATE: 2-12-76

COMMON LINK: INFORMATION SIGNALS

SYSTEMS AFFECTED (1) SGAHRS Six Isolation Valve Actuators, SGAHRS Six Control Valve Actuators, other Electrically Operated Aux. F.W. Valves & Pumps
 (2) Main Feedwater/Steam Valving and Pumps
 (3) Sodium Drain Valves & Sodium Pumps

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
Erroneous Signals	(1) Loss of SDD52 (SGAHRs) (2) Loss of Main feedwater redundancy (3) Loss of sodium system redundancy	(1) Loss of auxiliary feedwater system, which assumes loss of main feedwater initially for the Aux. to be needed, leading to OHRS as the only heat removal path. (2) Partial or total loss of main Feedwater Sys. (3) Partial or total loss of sodium IHTS.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
<ul style="list-style-type: none"> o Meter Input Failure o Incorrect Operator Action o Electrical Interference o Miscalibration of Meters 	<ul style="list-style-type: none"> o Defective Sensor or Meter o Misinterpretation of Meters o Misinterpretation of Instructions o Magnetic Disturbance o Power Surge o Test or Maintenance Action 	<ul style="list-style-type: none"> o Steam Drum(Level & Pressure)Signals to utilize a median selection logic where the middle reading is the one transmitted. o EMD suppression circuits to be provided. o Administration Control of access to instrumentation. 	<p>The isolation and the control valves are non-diverse in design, manufacturer and input signals. It is suggested that for SDD52 the turbine pump supply line contain diverse signals, valve types, and valve manufactures for both its isolation valves and control valves. The motor operated pumps and valves can remain non-diverse.</p>

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

o INFORMATION SIGNALS
 o POWER TRANSMISSION SYSTEM

o LUBRICATION SYSTEM
 o PNEUMATIC SYSTEM

o WATER SUPPLY SYSTEM
 o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. AllardDATE: 2-17-76COMMON LINK: PNEUMATIC SYSTEM

SYSTEMS AFFECTED REDUNDANT AIR COMPRESSORS, CHECK VALVES, SODIUM DRAIN VALVES (11/LOOP), WATER DRAIN VALVES (4/LOOP, 2 IN. SERIES), S.G. ISOLATION VALVES (4/LOOP), MAIN F.W. ISOLATION VALVES (2+/PLANT), AUXILIARY F.W. ISOLATION VALVES (15/PLANT), AND FOR EACH VALVE TENTATIVELY A BACKUP ACCUMULATOR, AIR REGULATOR AND FILTER-DRYER WILL BE SUPPLIED

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
EXCESSIVE AIR LEAKAGE	Insufficient Pressure to Drain or Isolate on Demand: o Failure to Drain Before 1015°F is Reached could Fail the S.G. Cold Leg piping and Dumptank. o Failure of Check Valve (Secondary Failure but with a High Failure Rate) to Stop Reverse Flow Could Bleed Off Air Provided by Air Bottle Backup.	Loss of one to three Loops Depending on where Air Leak Occurs.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
1) Poor Joint Connections	1) Human Intervention	1) A. Probable Welded Joints B. An Overpressure Leak Check is Planned after Installation	The Series Redundant Drain Valves double the Risk of a single Drain Valves Failure to Open.
2) Seismic Damage	2) Act of God	2) Air Bottle Backup up to Ten Cycles of Operation. Seismic I Bottles with Check Valves to Provide Protection from the Non-Seismic Portion of the Pneumatic System	
3) Missile Impact Damage	3) Low Probability Random Events	3) Check Valve & Air Bottle Backup Protection for Severed Line.	

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

o INFORMATION SIGNALS
o POWER TRANSMISSION SYSTEM

o LUBRICATION SYSTEM
o PNEUMATIC SYSTEM

o WATER SUPPLY SYSTEM
o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L.T. AllardDATE: 2/12/76COMMON LINK: Lubrication SystemSYSTEMS AFFECTED The only common ties are between the oil cooling source for the motor operated pumps in SDD 52, and possibly the type of lubricant utilized

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
<ul style="list-style-type: none"> o Loss of emergency power supply o Increased friction causing bearing seizure 	<ul style="list-style-type: none"> o Loss of motor operated SGAHRS pumps o Loss of equipment being lubricated 	<ul style="list-style-type: none"> o Steam driven turbine pump still available o TBD, depends on number and location of items lubricated identically

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
<ul style="list-style-type: none"> o AC power loss o Improper lubricant 	<ul style="list-style-type: none"> o Loss of unit coolers o Maintenance error 	<ul style="list-style-type: none"> o Unit coolers are redundant o Quality assurance controls 	

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

- o INFORMATION SIGNALS
- o POWER TRANSMISSION SYSTEM

- o LUBRICATION SYSTEM
- o PNEUMATIC SYSTEM

- o WATER SUPPLY SYSTEM
- o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. Allard
 DATE: 2-13-76

COMMON LINK: WATER & STEAM SYSTEM - (PAGE 1)

SYSTEMS AFFECTED MAIN F.W. PIPING, AUXILIARY FEEDWATER PIPING, ISOLATION VALVES, HEATERS, COOLERS, 2 MOTOR OPERATED PUMPS, A STEAM DRIVEN PUMP, OTHER PUMPS, DRAIN VALVES.

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
RUPTURED STEAM PIPING	o Pipe Whip under 2000 psi Pressure could Damage all Nearby Equipment. Potential Duplicate Failures could occur in each Loop since the Piping and Equipment is Non-Diverse.	o Loss of one to three Heat Removal Loops.
LEAKAGE OR RUPTURE OF WATER PIPING	o Requires Make-Up Water or Isolation of Failed Loop.	o None until makeup Water Supply is Expended, then OHRS is Required

POTENTIAL INDEPENDENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
o Seismic (> SSE) o Excessive Pressure Oscillations o Common Weak Design Link in each Loop (Continued on Next Page)	o Act of God o Thermal Cycling o Rapid Closure of 3 Main Steam Isolation Valves o Condensate Slugs in Areas Designed for Steam o Manufacturing Defect o Design Flaw o Interface Problem	o OHRS Backup o Bays Isolate each Steam Generator Loop	o The OHRS Start-up Delay Time should be Inconsequential and a Super OHRS might make the Seismic Hardening of the S.G. Building Unnecessary.

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

o INFORMATION SIGNALS
 o POWER TRANSMISSION SYSTEM

o LUBRICATION SYSTEM
 o PNEUMATIC SYSTEM

o WATER SUPPLY SYSTEM
 o SODIUM SYSTEM

TABLE III

COMMON MODE FAILURES - LINES OF INFLUENCE

PREPARED BY: L. T. ALLARDDATE: 2-13-76COMMON LINK: WATER & STEAM SYSTEM (Page 2)

SYSTEMS AFFECTED _____

POTENTIAL COMMON FAILURE MODE	FAILURE EFFECT ON SHUTDOWN/SHRS	SAFETY CONSEQUENCES
Water Dump of one or more Loops.	Loss of one or more Loops Heat Removal Capability.	Dumping of all intermediate Loops would require the use of OHRS.

POTENTIAL INHERENT CAUSES OF COMMON MODE FAILURES

CAUSATIVE FACTORS	FAILURE MECHANISM	PREVENTIVE MEASURES OR SAFEGUARDS	RECOMMENDATIONS & COMMENTS
<ul style="list-style-type: none"> o Seismic or System induced vibrations. o Human Intervention. o Common Water Supply source. 	<ul style="list-style-type: none"> o Sets off High Speed Pressure Transducer which trips plant & activates SWRPRS. o Common Rupture Discs burst simultaneously. o Activation of one or more Dump Buttons. o Steam Generator Building Temperatures cause dryout of the concrete leading to spalling, collapse of ceiling and loss of PWST. o PWST Structural Support failure. 	<ul style="list-style-type: none"> o Two out of three voting logic above a threshold value. o Currently designed to 1.8g's. o Each loop has a separate Dump Button. o HVAC of the S.G. Building controls the atmosphere within its capabilities. 	<ul style="list-style-type: none"> o Recommend Seismic Testing of sensitive system components. o High Speed Press. Transducers below the Rupture Disc are part of the FFTF Design but without seismic requirements.

CHECKLIST OF POTENTIAL COMMON LINKS

LINES OF INFLUENCE

- o INFORMATION SIGNALS
- o POWER TRANSMISSION SYSTEM

- o LUBRICATION SYSTEM
- o PNEUMATIC SYSTEM

- o WATER SUPPLY SYSTEM
- o SODIUM SYSTEM

APPENDIX D
LOCATION OF CRITICAL ITEMS

Development of Critical Item List for Common Cause/Failure Analysis

The critical items used in this analysis are the same as those considered in NEDM-14088, "Critical Items List for LMFBR Shutdown Heat Removal Systems", January 1976. However, the list was rearranged to incorporate more detail and depth. Areas such as valves, piping and the Auxiliary Feedwater System (AFWS) were reduced to their common subsystems for ease of CCFA. The Overflow Heat Removal System (OHRS), the Reactor, and Primary Heat Removal System (PHRS) except for the Intermediate Heat Exchanger (IHX) are being analyzed by W-ARD and therefore are not included here.

The resulting revised critical items list, Table IV, includes the quantity of components and indicates a reference number which corresponds to the item as shown on the Plant Shutdown Heat Removal Schematic (Figure III) Appendix D.

As more detailed breakdown of SHRS subsystems and items are formalized a revised more detailed Fault Tree will be constructed. The critical items list will be changed to reflect the updated information, and common cause analyses will be performed as required. Several items which are critical in a single point failure analysis appear not to be susceptible to failure by common causes, and are not included in the revised critical items list: notably the PWST, Main Condenser and Main Feedwater Pumps.

TABLE IV

REVISED CRITICAL ITEMS LIST

<u>Item</u>	<u>Quantity</u>	<u>Ref. No.</u>
Valves		
Air Operated		
Water Drain Valves	4/loop	1
Steam Generator System Valves	4/loop	2
Main Feedwater System Valves	>2/loop	3
Auxiliary Feedwater System Valves	15/plant	4
Motor Operated		
SGAHRs Relief Valves	2/loop	5
Main Feedwater System Valves	3/plant	6
Auxiliary Feedwater System Valves	11/plant	7
Safety Pressure Relief		
Steam Generator System Valves	9/loop	8
Control Valves-Diaphragm/Spring Opposed		
Auxiliary Feedwater System Valves	3/plant	9
Main Feedwater System Valves	1/loop	10
Manual Isolation Valves		
Protected Air Cooled Condensers	4/loop	11
Piping		
Heat Exchangers (Tubes)		
Intermediate Heat Exchangers	1/loop	12
Steam Generator Modules	3/loop	13
PACC's (Finned Tubing)	1/loop	14
Sodium Piping		
IHTS Piping	3/loop	15
Venturi	2/loop	16
Sodium Drain Lines (Up to Drain Valves)	5/loop	17
Water/Steam Piping		
Steam Generator System Piping	3/loop	18
Water Drain Lines (Up to Dump Valves)	2/loop	19
Venturi in Steam Generator System	1/loop	20
Main Feedwater Piping	3/loop	21
AFW Piping	1 system/plant	22
PACC Piping	1/loop	23

TABLE IV
(CONT.)

<u>Item</u>	<u>Quantity</u>	<u>Ref. No.</u>
Tank or Vessel		
IHTS Sodium Expansion Tank	1/loop	24
IHX Shell	1/loop	25
Steam Generator Module Shells	3/loop	24
Steam Drums	1/loop	27
Pumps		
AFW Turbine Driven Pump	1/plant	28
AFW Motor Driven Pumps (and Motors)	2/plant	29
Other		
Rupture Discs	6/loop	30
IHTS-Detection of Flow Past Rupture Discs	9/loop	31
AFW Turbine	1/plant	32
AFW Diesels & Generators	2/plant	33
PACC's	1/loop	34

FIGURE III - PLANT SHUTDOWN HEAT REMOVAL SCHEMATIC

Distribution:

Director, RDD	(1)
Deputy Director for Development and Technology, RDD	(1)
Assistant Director for Programs, RDD	(1)
Assistant Director for Reactor Safety RDD	(1)
ERDA/RDD-Wash. R. W. Cochran, Acting Director, CRBRP Program	(2)
ERDA/RDD-Oak Ridge, L. W. Caffey, Director, CRBRP Project Office	(2)
ERDA/SAN-PMRS, Sunnyvale	(1)
ARD-Oak Ridge - W. M. Jacobi, CRBRP Project Manager	(2)
ARD-Pa. - C. A. Anderson, Jr., CRBRP Project Manager	(2)
ARD-Oak Ridge - G. D. Collins, GE Site aep. @ Oak Ridge	(1)
ARD-SVL - D. N. Fultonberg, Res. Manager @ GE	(1)
AI - R. Balent, Vice President	(2)
B&R - W. H. Young, CRBRP Project Manager	(2)

Bcc:

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