Quarterly Technical Progress Report Liquid Metal Engineering Center (LMEC)

January — March 1968

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Liquid Metal Engineering Center

Operated for

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

A Division of North American Rockwell Corporation

Contract: AT(04-3)-700

Issued: OCT 1 - 1968

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The progress report for the
previous quarter was
LMEC-68-1

Program: Liquid Metal Engineering Center	
Project: AEC Assistance and Consultation	
Project Manager: R. W. Dickinson	Project Engineer: R. W. Dickinson
Reporting Period: January-March 1968	AEC Category: 04-01-61-03.1
General Order: 7693	Subaccount: 12100

I. PROJECT OBJECTIVES

The objectives of this project are to support the Liquid Metal Fast Breeder Reactor (LMFBR) program by preparing engineering standards, specifications, and practices for liquid metal systems and components; performing inspection and technical consultation services as requested by the AEC; and monitoring system and component performance and development as authorized by the AEC.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

A. STANDARDS AND SPECIFICATIONS TASK UNIT

Four tentative draft standards were forwarded to RDT and ORNL for their review and comments:

- 1) RDT-M-700, Sodium Quality
- 2) RDT-M-701, Sodium Cover Gas Quality
- 3) RDT-S-973, Cleaning and Cleanliness Requirements for Sodium Systems and Components
- 4) RDT-S-976, Welding for Liquid Metal Systems.

Discussions were held with ORNL on the development of material standards for application to both water reactors and liquid metal systems. A proposed format for the material standards was jointly prepared by ORNL and LMEC. LMEC provided information to ORNL on LMFBR requirements recommended for incorporation in four material standards.

A revised detailed work plan for the LMEC effort on standards and specifications was forwarded to the AEC.

The Bechtel Corporation of San Francisco, under contract to LMEC, prepared draft standards and other documentation covering welding, materials, quality assurance, and sodium component cleaning.

Two quality assurance specifications, intended for application to field construction work at the SCTI, were reviewed and processed.

B. PUMPS TASK UNIT

Guidelines were prepared for the design development of centrifugal pumps capable of delivering up to 120,000 gpm of 1200°F sodium. An operating condition of 60,000 gpm of 1200°F sodium to be pumped against a head of 350 ft with 40 ft of NPSH available has been chosen as the basis for reference pump designs. A cover gas pressure of 1 psig has been selected as a reference value to aid in design of shaft seals to retain pump cover gas.

Phase I reports prepared by the pump study contractors have been reviewed and appropriate recommendations and comments were forwarded to the respective organizations and to RDT.

C. PIPING TASK UNIT

Approval has been received to collect pipe samples and develop plans for HNPF post-operation examination. Piping material samples have been received and are undergoing examination.

The use of HNPF main sodium piping elbows was suggested to APDA personnel for assistance in developing welding and inspection techniques required for the planned "foreign object" removal from the reactor.

Reviews of Task Area 3, "Coolant Transport and Storage Systems," of Section 3, "Components," and selected task areas of Section 2, "Plant Design," of the LMFBR Program Plan were completed and comments were submitted.

Initial definition of tasks for inclusion in Form 189's was completed. Preliminary definition of piping system test requirements was submitted.

Information was obtained of techniques and developments in other industrial piping systems applicable to LMFBR piping systems.

D. HEAT EXCHANGERS AND STEAM GENERATORS TASK UNIT

Publication and distribution of NAA-SR-12534, "Liquid-Metal-Heated Steam Generator Operating Experience," was completed. This report summarizes the results of operation and tests and, in addition, presents an evaluation of failures and a compilation of factors that should be considered in steam generator design.

A draft was completed of the "Scope and Plan of Action" for preparation of the steam generator standard. Included are functional requirements, liquid-metal-heated steam generator state-of-the-art summary, and an outline of the standard to be prepared.

A draft of the "Scope and Plan of Action" for preparation of an LMFBR intermediate heat exchanger standard has been prepared and distributed to the LMEC technical staff for review and comments.

E. INCIDENT REPORTING SYSTEM TASK UNIT

1. Data Collection and Reporting System

A presentation was made to RDT-HQ encompassing LMEC's concept of an optimum program. LMEC, and most of the reviewing contractors, considered that this program, as presented, was the minimum level of effort which could assure a well organized data collection and LMFBR system/component design improvement function. The important factors resulting from the meeting were the agreements as to plan and objective. A request for an informal submittal of a possible reduced effort for budgetary reasons would constitute a delay in several facets of the program but would not result in downgrading.

A visit was made to ORNL to discuss interface areas between the CHORDS program and the LMFBR suggested program for failure reporting. In particular, the subject of system, subsystem, and component identification was discussed. The same subject was broached later with Holmes and Narver (H&N) on their efforts with the water reactor safety evaluation and reliability program.

In a subsequent meeting between PPCo, ORNL, H&N, and LMEC at H&N, several points of agreement were developed. However, objectives and end-item printouts for all three programs were seen to be widely different.

The following categories were agreed upon:

- 1) A variation of the AEC Docket Number for nuclear power plants.
- 2) CHORDS had been directed to use the official PSAR outline as a systems identification code; this outline is inadequate for reliability, availability, or reliability assurance data processing. For programs other than CHORDS, the AEC Code of Accounts as described in TID-7025 will, with minor revisions, be used.

3) A modification of the IDEP and FARADA systems for component/part identification and identification of their environmental classification will be used.

4) Failure data will be classified by cause of failure, failure mode, and effect of failure.

2. Digital Sorting Program

A preliminary digital computer program was developed for the purpose of searching, sorting, and manipulating numerical files as required for data processing activities.

3. Historic Failure Data Evaluation

All SCTI data to date and the previously published data on ANL experimental loops were evaluated and tables were published.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT

LMEC-Memo-68-2, "Combined Unit Reactor Vessel (CURV) Systems State-of-the-Art Study," was published.

A preliminary evaluation of the state-of-the-art as it applied to the CURV Study was completed. The evaluation was documented in LMEC-Memo-68-11, "Combined Unit Reactor Vessel (CURV), A Preliminary Evaluation," which was forwarded to a controlled RDT distribution.

G. INSPECTION AND QUALITY ASSURANCE TASK UNIT

Titles, scopes, and applicabilities were prepared for five LMFBR quality assurance standards. These standards included requirements for project management, plant design, field construction, and quality assurance and inspection systems considered necessary to obtain a quality facility.

Two specifications were issued delineating the quality assurance requirements for the steam line modifications of SCTI. One of these specifications defines activities which must be performed by LMEC, while the other defines activities which must be performed by Bechtel Corporation during the field construction.

Review of the "Sodium Pump Test Facility QA Program Plan," prepared by C. F. Braun and Company, was initiated. The first package of minimum inspection requirements applying to pressure vessels was prepared and distributed to LMEC personnel for comment.

H. SODIUM TECHNOLOGY TASK UNIT

Current activities at LMEC and capabilities for future work were reviewed with the Sodium Technology Section of the LMFBR program office at ANL.

Requirements for a sodium purification component test installation were developed.

A tentative work scope for the examination of HNPF valves was outlined.

III. PROGRESS DURING REPORT PERIOD

A. STANDARDS AND SPECIFICATIONS TASK UNIT (R. J. Edwards)

A tentative draft of standard RDT-S-976, "Welding for Liquid Metal Systems," was completed and forwarded to ORNL and RDT for review and comments. Following a review of the standard, ORNL representatives visited LMEC for a detailed discussion of welding requirements and procedures. It appears that ORNL and LMEC will be able to develop a single welding standard for application to both water and liquid metal systems.

A tentative draft of RDT-S-973, "Cleaning and Cleanliness Requirements for Sodium Systems and Components," and the associated Commentary which provides background information on requirements included in the standard, were submitted to ORNL and RDT for their review and comments.

A meeting was held with ORNL materials personnel to develop a tentative format for use by LMEC and ORNL in the preparation of materials standards for common application to both the LMFBR and water reactor programs. The recommended format consists of four major sections: (1) an introduction, (2) a listing of modifications to the ASTM standard covering the material, (3) a listing of additional requirements not provided for by the reference ASTM standard, and (4) a listing of optional requirements which are applicable only when specifically called for in a purchase document. Final preparation and issuance of the joint LMEC-ORNL materials standards will be conducted by ORNL, using ORNL-assigned standard numbers.

LMEC provided ORNL with input, in the form of preliminary draft standards, for four materials standards to be prepared in the tentative format. These standards are as follows:

<u>Previous LMEC No.</u>	<u>Present ORNL-LMEC Designation</u>	<u>Title</u>
RDT-M-702	RDT-MA-182	Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
RDT-M-703	RDT-MA-213	Seamless Ferritic and Austenitic Alloy Steel Tubes
RDT-M-706	RDT-MA-336	Alloy Steel Drum Forgings
RDT-M-712	RDT-MA-217	Chromium-Molybdenum Alloy Steel Castings for Pressure Containing Parts for High Temperature Service.

A second set of comments was received from ORNL to complete their review of the LMEC-prepared tentative draft standard RDT-M-700, "Sodium Quality." Further work on this standard was deferred pending receipt of comments from RDT-HQ.

Comments were received from ORNL on the tentative draft of RDT-M-701, "Sodium Cover Gas Quality." The comments were associated with sampling and gas analysis techniques. Further processing of this standard has been deferred until comments are received from RDT-HQ.

Steps were initiated to subcontract for the technical review of the LMEC-prepared preliminary draft standard RDT-E-70, "LMFBR Reactor Vessel for Loop Type Systems," by a vessel manufacturer and by an authority on vessel design and analysis. A Request for Proposal for this work has been issued by Purchasing.

Work was continued on the sodium piping system standard with the effort being concentrated on the acquisition and evaluation of data and experience on existing liquid metal systems. The basis for the existing system designs, including codes and standards used, material selection, special design techniques, and analytical procedures, is being evaluated in relation to current piping design techniques and to future LMFBR piping systems requirements. The analytical procedures given in the Nuclear Power Piping Code (tentative) are being reviewed for possible application to LMFBR piping system designs.

A literature search of LMIC acquisitions was completed to obtain information for the preparation of a standard on cleaning of systems and components

which have been in operation in sodium. A preliminary outline of this standard was prepared. Detailed review of pertinent documents and applicable sections of the sodium and NaK Engineering Handbook is in progress.

Comments received from reviewers on the preliminary draft of the large sodium pump standard were reviewed. Reports on sodium pump technology were studied for pertinent information.

The "Scope and Plan of Action" for preparation of the standard for intermediate heat exchangers was released for review by the LMEC staff.

Acquisition of engineering data and specifications on existing liquid metal-to-air heat exchangers was continued. Manufacturers' literature on air coolers was collected and reviewed.

LMEC review of the preliminary draft of RDT-E-71, "Blocking Valves for LMFBR Systems," was completed. Work was started on the preparation of a recommended method for determining the body stresses in the sodium valves covered by the standard.

A preliminary draft of RDT-E-76, "Circulating Cold Trap for LMFBR and Test System Service," was completed and distributed within LMEC for review and comments.

B. PUMPS TASK UNIT (R. W. Atz)

At the request of RDT, a procedure was developed for collecting, collating, and distributing comments and suggestions concerning the pump study contractors' Phase I reports.

Resolution of comments generated by the review of the first report enabled the LMEC to recommend initiation of Phase II activity by one contractor. Review of the second report has been preliminary and further resolution of comments will be required before a recommendation to start Phase II activity can be offered.

Estimates of "wetted weights" of pumps intended to generate 440 ft of head at 12,000 gpm and 350 ft of head at 60,000 gpm (FFTF and SPTF conditions) were developed for use in SPTF thermal transient studies. These data have been released to the SPTF project and will be published in the Phase I reports issued by the pump study contractors.

C. PIPING TASK UNIT (E. N. Pearson)

Approval was received to proceed on the collection of pipe samples and development of plans for HNPF post-operation examination. Two requirements were specified:

- 1) There shall be no interference with Hallam retirement activities.
- 2) Destructive examination of components require RDT approval.

Forty-one Type 304 stainless-steel samples of pipe were obtained from HNPF, selected by LMEC personnel. Each 4-in.-diameter, 1/4-in.-thick sample was individually packaged and identified by line number. The samples were cut from 14- and 16-in. sodium pipes as part of the requirements of the HNPF retirement program, and would normally be considered scrap material.

The 41 samples consisted of the following:

- 1) Primary — 14 from the hot leg (950 °F)
13 from the cold leg (600 °F)
- 2) Secondary — 7 from the hot leg (925 °F)
7 from the cold leg (575 °F).

Approximately 12 samples were selected for metallurgical examination, 8 from the hot legs (primary and secondary) and 4 from the cold legs (primary and secondary). Preliminary metallurgical examination showed no evidence of corrosion or mass transfer after approximately 14,000 hr in sodium service. All 8 hot-leg samples showed evidence of sensitization (i.e., grain boundary precipitation), which is to be expected. One of the 4 cold-leg samples indicated sensitization, which was surprising because of the low-temperature (600 °F) exposure. Further details will be presented in a subsequent topical report.

Effort on developing an overall HNPF post-operation examination plan was re-established. The plan will cover piping and components.

Delineation of recommended LMFBR piping tasks for FY 1969 and FY 1970 have been developed. Approximately 30 tasks have been identified to date.

In support of SPTF, a brief review of some of the literature pertaining to thermal fatigue and thermal shock testing was made. Several references to

thermal shock testing were found in British journals. One reference* concluded that standardizing the rate of cooling was important. This was based on the observation that air-cooling the 1/2-in.-diameter specimen from 950 °C (1742 °F) resulted in cracking after 25,000 cycles; but using water quenching, cracks appeared after 75 cycles.

Abstracts of Japanese technical journals indicate that an extensive amount of effort has been made on thermal fatigue and thermal shock testing. Two journals had a total of 12 articles on this subject during 1964. Only abstracts are available at this time, and the significance of the work cannot be judged without a complete translation.

It appears that this basic type of thermal fatigue and thermal shock testing is not being performed in the United States at this time. With the current effort on the LMFBR program, this could be an important test for evaluating materials, welds, and basic configurations.

The proposed hydrotest for the SPTF[†] was evaluated in an internal memorandum. Several questions were raised that will be evaluated during Title I by the A-E. Hydrotesting at the HWCTR (using H₂O) was discussed in DP-991,[§] and some of the results were considered applicable to the SPTF.

D. HEAT EXCHANGERS AND STEAM GENERATORS TASK UNIT (K. L. Adler and G. S. Budney)

A draft of the "Scope and Plan of Action" for preparation of the LMFBR intermediate heat exchanger standard (Standard RDT-E-82) has been prepared. The draft has been distributed internally and to the PNL FFTF project office for review and comments. An outline of the proposed standard is appended to the document.

Performance testing of a prototype FFTF IHX and air-cooled heat dump module has been reviewed with the PNL FFTF project office. Timely testing of a full-scale IHX (133 Mw) is not feasible in existing or projected LMEC facilities. The SCTI appears to be a suitable facility for testing a quarter-scale prototype model of the IHX and one full-scale (33 Mwt) or two half-scale heat dump modules.

*M. Riddihough, "A Thermal Cracking Test for Steels and Alloys," Metallurgia, August 1960

†"Conceptual System Design Description II, Main Flow Loop System, Sodium Pump Test Facility," CFB-2964-102 (November 17, 1967)

§"Operational Summary of the HWCTR," DP-991

The comments received on Chapter 9, "Steam Generators," of the Sodium and NaK Engineering Handbook were reviewed and rewriting of the chapter was begun. The rewrite consists of expanding the data on operating experience, adding figures of the HNPF 3-Mw developmental steam generator, and improving figures of the model steam generators to be tested in the SCTI. A discussion of the current fabrication problems with the B&W model steam generator and possible redesign of the unit is to be included. In addition, data will be included on the UK Prototype Fast Reactor steam generators.

The B&W topical report, "Redesign of Prototype Steam Generator, Vol 1, Evaluation of Alternate Designs," was reviewed. The report presents several design alternates to the prototype steam generator that B&W is fabricating for the AEC. All of the alternate designs substitute 2-1/4 Croloy tubing for the austenitic-stainless-steel tubing in the present prototype. In addition, the recommended Alternate No. 4 incorporates: (1) change in design criteria, (2) change to continuous evaporator-superheater tube design, (3) change in tube size, (4) change in tube wall thickness, and (5) change in location of feedwater inlet and steam outlet nozzles. Comments and recommendations were forwarded to RDT.

The B&W topical report, "Redesign of Prototype Steam Generator, Vol 2, Program Plan - Design, Fabrication, and Testing," was also reviewed. The information contained in this volume discussed the critical design areas and presented a detailed, systematic engineering and development program for resolving them.

Close liaison has been maintained between RDT-HQ, B&W, and LMEC regarding the redesign of the prototype steam generator and the testing capability of the SCTI facility. The discussions have resulted in a plan to trade off steam generator modeling compromises against SCTI modifications, including cost and schedule efforts.

E. INCIDENT REPORTING SYSTEM TASK UNIT (C. W. Griffin)

1. Data Collection and Reporting System

Proposed failure category nomenclature and examples of usage were prepared for application to analysis of historical failure data which have been collected by LMEC and which are presently being submitted for engineering

evaluation. In concurrence with agreements between PPCo, H&N, ORNL, and LMEC, these categories were prepared to be generally applicable to reliability and safety evaluation of all nuclear reactor types. The proposed failure category nomenclature, shown in Appendix A, was submitted to RDT along with a request for permission to submit this document for general LMFBR contractor evaluation.

2. Historical Failure Data Evaluation

All SCTI incident reports of past occurrence have been received and evaluated. The results are given in Appendix B. In all future studies, the broader table format shown in Appendix A will be used; the format shown is an example only.

Detailed analysis of data collected from EBR-II and HNPF continues.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT (A. C. Williams)

A coordination meeting with RDT personnel in the early part of the report period resulted in a shift of emphasis toward the vessel and vessel cover structure, with consideration of other portions of the system only as they relate to and influence these components.

The preliminary evaluation was completed and documented in LMEC-Memo-68-11, "Combined Unit Reactor Vessel (CURV), A Preliminary Evaluation," which was published and forwarded to RDT on a controlled distribution.

G. INSPECTION AND QUALITY ASSURANCE TASK UNIT (G. A. Beer)

The specification delineating quality assurance requirements to be satisfied by the construction contractor was transmitted to Bechtel Corporation for comment. In addition, members from the LMEC Quality Assurance Task Unit and the SCTI Project visited Bechtel and reviewed this specification with Bechtel's project engineer and quality assurance personnel. Bechtel personnel foresaw no problem in meeting the requirements of the specification.

The SPTF Quality Assurance Program Plan was reviewed in detail and comments were supplied to the LMEC SPTF project manager. These comments required re-alignment of the responsibilities associated with the procurement of long-lead and critical items and a clearer definition of the quality assurance activities to be performed by the various parties involved. LMEC comments

were presented to C. F. Braun personnel, including project management, quality assurance, and inspection supervisors. A subsequent partial review with RDT revealed that LMEC and RDT comments were similar.

An audit was performed of the quality assurance being practiced on the seal test rig program. Due to the state of completion of the seal test rig and the conditions found, the results of this audit will cause only slight changes in the project activities. However, the information gained will aid in preparation of future quality assurance plans and procedures.

During inspection of a weld internal to the seal test rig sodium test vessel, evidence of corrosive attack on the vessel shell-to-flange weld was noticed. The reporting of this condition resulted in an evaluation which determined that the weld had been made using the wrong filler material. Correction is now being made by the vendor; this error indicates a requirement for close control of weld rod issuance, which has been instituted at LMEC.

Revised drafts of RDT-S-974, "Inspection System Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components and Systems," and RDT-S-975, "Quality Assurance Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components and Systems," were prepared and reviewed by Quality Assurance Task Unit personnel. Resulting comments were incorporated, and a new draft circulated to other LMEC personnel for comment.

An RDT presentation resulted in redirection to emphasize formal definition of a QA system to be implemented at LMEC. Work was initiated on the development of LMEC operating procedures and policy statements covering the LMEC quality assurance system.

H. SODIUM TECHNOLOGY TASK UNIT (R. B. Hinze)

Sodium valves from HNPF have been assigned to LMEC for post-operation examination and subsequent use in test facilities. The tentative scope of examination has been established. Tests and examinations are summarized in Table 1. Emphasis has been placed on the largest (14-in. size) valves, since there has been little previous experience with valves of this size. Certain of the smaller valves also will be tested.

Two acceptance tests, leakage across the seat and pressure, will be repeated. The seat leakage test will give valuable information on the durability

of the inner valve, particularly the disk and seat interface. Repetition of the pressure acceptance test will reveal the presence of any serious internal cracks which may have developed during service at HNPF or distortion of the containment shell significant from a structural standpoint.

A limited number of valves will be selected for disassembly. Selection for disassembly will be based on results of the seat leakage test, visual examination, and history of operation (severity of service). Disassembly will permit detailed visual examination and dimensional checking of the internal configuration and dye penetrant examination of mating surfaces. These inspections will reveal the extent of any wear on valve guides, stem, and seating surfaces.

While Table 1 shows only two metallographic examinations, a number of piping samples obtained adjacent to the valves will be examined metallographically, as part of the piping evaluation. Additional metallographic work will be done on valve specimens if warranted. Since future use of these valves is an objective, destructive examination will be minimized. Only one small valve is being considered for destruction (any destructive examination is subject to RDT approval). Disks in the 14-in. block valve are replaceable.

TABLE 1
HNPF SODIUM VALVE SELECTION FOR EXAMINATION

Valve Type (Stem Seal Type)	Tests and Examination (number of items)			
	Seat Leakage Test	Pressure Test (600 psig)	Disassembly and Internal Examination	Metallography
14-in. throttle (freeze)	6	6	1	-
14-in. block (freeze)	3	3	1	1 disk
14-in. check	3	3	1	
2-in. globe (freeze)	2	2	1*	
3-in. globe (freeze)	1	1	1*	
2-in. globe (bellows)	1	1	1	1 seat

*One globe valve, either a 2- or 3-in., will be disassembled.

IV. NEXT REPORT PERIOD ACTIVITIES

A. STANDARDS AND SPECIFICATIONS TASK UNIT

It is expected that recommended LMFBR requirements for five material standards will be submitted to ORNL. Further discussion with ORNL will be held to determine whether the LMEC input to these RDT material standards should be submitted as draft standards or as a listing of comments and recommendations for the revision of standards previously issued by ORNL.

It is anticipated that contractual arrangements will be completed for the technical review of the LMFBR reactor vessel standard by consultants or firms that have specific experience in the design and manufacture of reactor vessels.

Work will be continued on standards for valves, piping, piping supports, free-surface sodium pump, sodium-to-air cooler, circulating cold trap, and sodium impurities measurement instrumentation.

B. PUMPS TASK UNIT

It is anticipated that both Phase I portions of the Large Sodium Pump Study Project will be completed and that Phase II, detailed design of selected pumps, will be started.

C. PIPING TASK UNIT

Examination of HNPF sodium piping as part of the HNPF Post-Operative Evaluation Program will continue.

Program Plan review and revision will be continued.

Monitoring and review of industrial piping developments will be continued.

D. HEAT EXCHANGERS AND STEAM GENERATORS TASK UNIT

LMEC will furnish support to PNL in a study to determine whether FFTF system design conditions represent problem areas relative to the current state of heat exchanger technology.

Further work is planned on establishing requirements for thermal transient testing capabilities in LMEC component testing facilities.

The trade-off study between B&W prototype steam generator modeling and SCTI facility modification, along with cost and schedule estimates, is expected to be well in progress.

E. INCIDENT REPORTING SYSTEM TASK UNIT

Effort for the next reporting period will be concentrated toward: (1) resolving questions on sorting categories and formats, (2) setting up of the microfilm (Miracode) system, (3) completing first evaluation of EBR-II historical failure data, and (4) completing first evaluation of HNPF historical data on sodium valves and piping.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT

Work plans will be written for RDT review and use in obtaining contractor assistance for the CURV study. Meetings will be held with the 1000-Mwe follow-on contractors to review program progress. The effort will be coordinated with the LMFBR Program Office to ensure mutual understanding of the study objectives and direction. Contact will be established with DRL and other safety-oriented organizations to obtain benefit of their thinking. Initial contact with prospective contractors will be made. Efforts to obtain detailed engineering information on the PFR will continue.

G. INSPECTION AND QUALITY ASSURANCE TASK UNIT

The major quality assurance effort anticipated during the next report period will be to define the LMEC quality assurance system, using established LMEC operating procedures. Additional inspection instructions will be prepared giving minimum inspection requirements for LMEC equipment.

RDT-S-974, "Inspection System Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components and Systems," and RDT-S-975, "Quality Assurance Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components and Systems," will be revised with comments received from LMEC personnel. This revision will be submitted to members of the RDT Quality Assurance Steering Committee for use by Idaho Nuclear Corporation as reference material in their newly assigned task of preparing RDT standards.

Review of quality assurance provisions in RDT equipment and process specifications will continue.

H. SODIUM TECHNOLOGY TASK UNIT

A detailed test plan for examination of HNPF valves will be prepared.

The purification chapter of the Sodium and NaK Engineering Handbook will be rewritten to include recent information and to reflect comments received from reviewers of the first draft.

Program: Liquid Metal Engineering Center

Project: Operation of Sodium Component Test Installation

Project Manager: R. W. Dickinson

Project Engineer: J. A. Leppard

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.6

General Order: 7693, 7694

Subaccount: 13200

I. PROJECT OBJECTIVES

The project objective is to operate the Sodium Component Test Installation (SCTI) and to test, obtain data on, and evaluate the performance of prototype intermediate heat exchangers and prototype steam generators.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

Design for the reconstruction of the high-pressure steam piping system was revised and all applicable documents prepared for final review prior to issuance as a construction package. Most of the material and equipment required to accomplish the construction was received. An order for procurement of the full-flow condensate polish demineralizer was placed with a manufacturer.

III. PROGRESS DURING REPORT PERIOD

Representatives of the Bechtel Corporation and SCTI/LMEC staff members met with RDT-HQ to discuss and resolve remaining questions concerning the design of the steam line fix. As a result of this meeting, an approval to proceed with reconstruction was given subject to accomplishing several revisions to the design as discussed in the following paragraphs.

Design of the safety valve connections was revised to provide a fabricated right-angle tee and a forged 35-degree elbow at each of the two connections to the main steam line. This arrangement permits the required vertical mounting of the valves and a more accurate calculation of stresses in the connections. Revised drawings of this arrangement and stress calculations have been transmitted to the LMEC for review. As a backup action, delivery schedules for forged tees are being determined.

Bechtel has continued the investigation of the best techniques available for application of the Inconel overlay at the steam generator outlet nozzle joint. A special procedure has been written and several development welds performed. The procedure involves the use of a hand-held tool with which to apply the Inconel from the inside of the joint after the Type 316 stainless-steel welding is completed. The LMEC also made a parallel study of possible techniques. A welding specialty company demonstrated an automatic welding tool used for inside work in deep holes. This vendor will perform several development welds also, and is willing to consider performing the final weld under a separate subcontract.

Bechtel is seeking additional information on the industrial use of gasketed lap joint flange connections. SCTI has prepared a maintenance procedure required to accomplish replacement of a gasket in the subject joint.

Design of the dummy pipe supports was modified to include full penetration welds at each piping support. This will provide better joints and will permit adequate inspection of the connections.

A physical support for the topworks of the horizontally mounted, first-stage pressure reducing valve was designed. This support was included to limit unanticipated vibration of the topworks during dynamic flow conditions. (It was agreed at the meeting that this valve will be repositioned with the stem vertical at the time the B&W steam generator is installed.)

Agreement was reached to perform impact tests on all material heats of the chrome-moly material for which excess material is available. Acceptable impact values are 30 ft-lb at 10°F. Evaluation of the results of the impact testing will be used to determine the proper temperature for the hydrostatic test to be made after construction is completed.

The fourth phase of the existing contract with Bechtel was put into effect; a statement of work for this phase has been prepared and will be incorporated with the contract early in the next reporting period. Bechtel is continuing the preparation of a QA plan and a new construction schedule. Subject to the completion of LMEC review of all the documents from Bechtel, it appears that pipe fabrication could begin early in the next reporting period. It is estimated that all construction activities can be completed late in July 1968.

Due to more pressing technical requirements, a minimal effort was expended toward completion of the ALCO IHX vibration test report. The analysis of recorded data has been essentially completed. The text of the report is about 30% complete. The most recent work centered on a detailed examination of the high gain data (10 to 250 cps) and the low-frequency modulation of the high-frequency data in a final attempt to identify impacting type noises at IHX tube resonant frequencies. Only a small indication of impacting type noise has been identified to date.

Several of the modifications being made as a result of Bechtel's study of the total steam and feedwater system are described as follows:

- 1) A supply of auxiliary steam from the preheat boiler will be supplied to the deaerating heater. This permits placing the deaerating heater in service during the preheat cycle, thereby improving the removal of dissolved oxygen during this operation.
- 2) The steam generator startup recirculation line will be rerouted to the high-pressure flash tank. This provides improved control of plant operation during the switchover from steam generator preheating to steaming operation. The present system requires placing the main steam line in service immediately when the switchover is made; this operation requires very strict control to minimize pressure transients and moisture carryover into the steam line. The modified system will permit going to steaming operation by exhausting this steam to the flash tank. Transfer to normal steaming operation can then be accomplished slowly when dry superheated steam is being produced.
- 3) Two modifications will be made to increase the available NPSH for the condensate pump. These consist of increasing the operating level in the condenser by relocating the hot-well level controller and increasing the size of the pump suction line from 4 to 6 in.
- 4) Two dissolved oxygen analyzers will be installed to permit checking the condition of condensate at the inlet and outlet of the deaerator. The present method of running oxygen determinations in the laboratory does not provide adequate monitoring of the oxygen concentration.

- 5) All water purity instruments are being replaced or refurbished. Originally installed pH instruments for the condensate and cooling water system have proved to be unreliable and have required extensive maintenance. In an attempt to obtain more reliable instruments, industrial pH instruments supplied by two different manufacturers were tested under simulated operating conditions. Based on these tests, new instruments were selected. The required redesign has been accomplished and procurement of instruments has been initiated.

Maintenance activities during this period include the following:

- 1) Cleaning and painting of heat exchangers for the boiler feed pump (P-1) and the condensate booster pump (P-3)
- 2) Inspection of the SCTI cooling water tower by a vendor's representative. No indication of deterioration was found and only a few boards were broken or out of place; these pieces have since been replaced.
- 3) Cleaning, servicing, and load testing of the emergency diesel generator
- 4) Inspection of the ALCO/BLH steam generator by the corporate (NAR) insurance representative for renewal of the State Operating permit
- 5) Changing of the filter materials and desiccants in the instrument air driers and overhauling of the crossover valves
- 6) The drive motor and magnetic coupling for the sodium cooler (E-8) blower was sent out for dipping and baking of the windings and replacement of bearings. The drive motor for the instrument air compressor (A-1b) was serviced in the same manner.
- 7) The condensate booster pump (P-3) was disassembled, overhauled, and the clearances were measured; it was found to be in good condition and has been returned to normal service.
- 8) The deaerating heater was opened, inspected, and found to be in good condition.

During this report period, the final shipment of spare parts for the boiler feed pump was received. This includes a spare impeller and shaft assembly and volute assembly. Receipt of these items completes the acquisition of spare parts for the SCTI plant, a program which was begun nearly two years ago.

IV. NEXT REPORT PERIOD ACTIVITIES

All Bechtel design drawings and applicable specifications will be assembled into a construction package, bids will be obtained, and a contract will be awarded. Pipe fabrication will be completed and field construction started. Engineering of the other changes to the steam and feedwater system will be completed, materials ordered, and construction initiated. The as-built "Sodium Components Test Installation (SCTI) System Design Description," NAA-SR-Memo-11671, will be issued. A flowmeter positioning test will be performed in behalf of the FFTF program.

Program: Liquid Metal Engineering Center

Project: Liquid Metals Information Center

Project Manager: R. W. Dickinson

Project Engineer: J. J. Droher

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.9

General Order: 7693

Subaccount: 13300

I. PROJECT OBJECTIVES

The project objective is to operate and maintain the Liquid Metals Information Center (LMIC) which serves as a focal point for technically evaluated information and data on liquid metals technology and components, with initial emphasis on sodium and NaK alloys as heat transfer and transport fluids. State-of-the-art reports and an updated version of the Liquid Metals Handbook, covering unclassified material on sodium and NaK, are to be prepared.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The LMIC has responded to 254 requests for information from various organizations, including all of the major participants in the LMFBR Program, since the start of the current fiscal year. These requests have involved 447 separate subject categories, for which computerized searches were performed resulting in a total of 51,464 printouts containing bibliographic data and abstracts of documents with pertinent information. Additional entries have been prepared for supplemental files utilized by LMIC to increase the comprehensiveness of coverage in responding to inquiries; these files include a Project File encompassing reports with distribution limitations, and KWIC (Key Word in Context) Indexes encompassing all reference reports and all existing files. Copies of the manuscript for the Sodium-NaK Supplement to the Liquid Metals Handbook (subsequently changed to Sodium and NaK Engineering Handbook) have been distributed by the Commission for review; comments and suggestions have been received from most of the reviewers, and the draft is being revised to incorporate these comments.

III. PROGRESS DURING REPORT PERIOD

During this quarter, 123 additional documents were processed, making a total of 5,586 documents in the LMIC data bank. The Center responded to 96 inquiries for information during the quarter, of which 88 were for specific technical information while the remainder were for general information about the Center and its activities. Many of the requests for specific technical information involved more than one question, so that responding to these requests required computerized searches covering 134 different subject categories, yielding a total of 14,436 computer-produced printouts.

A trial computer run was made of the procedure to establish and maintain an LMIC Thesaurus Master File of descriptive terms. Several minor changes were required before the program would run successfully. A computer-produced printout of this Thesaurus File was obtained and is now being reviewed to detect any errors or omissions. Each time the Thesaurus File is updated, a current printout of the Thesaurus is produced for use by LMIC staff members in selecting retrieval terms for searching the computerized data bank.

Assignments have been made for modification of each chapter in the preliminary draft of the Sodium and NaK Engineering Handbook to incorporate comments received from reviewers as well as any new information which has been published in the interim. Modifications have been completed for Chapter 13, "Valves," and Chapter 16, "Auxiliary Components and System Accessories."

IV. NEXT REPORT PERIOD ACTIVITIES

The LMIC will continue to collect, evaluate, store, and disseminate information on liquid metals technology. Additional sources of information will be sought and requests for future services will be honored.

Modifications to incorporate comments and include recent data will be completed for all of the remaining chapters of the Sodium and NaK Engineering Handbook; final editing will not occur until the first quarter of FY 1969.

Program: Liquid Metal Engineering Center

Project: Sodium Pump Test Facility (SPTF)

Project Manager: R. L. Cummings

Project Engineer: S. L. Pfahler

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.7

General Order: 7693

Subaccount: 13400

I. PROJECT OBJECTIVES

The objectives of this project are to design and construct a large sodium pump and component test installation. Major milestones for this fiscal year are: (1) complete optimization studies, (2) issue Conceptual System Design Description (CSDD), (3) complete Title I design, (4) issue Preliminary SDD, and (5) initiate Title II design.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The optimization and preliminary design studies were completed. Based on these studies, Conceptual System Design Descriptions (CSDD) were written, printed, and distributed. The Title I level of effort, schedule, and manhour estimate were completed. A portion of the revised Quality Assurance Plan to be implemented during Titles I, II, and III was submitted by the Architect-Engineer (C. F. Braun & Co.) for LMEC review.

Equations for thermal transient flow-mixing calculations were programmed on a digital computer by LMEC. Braun has prepared a mathematical model simulating the control dynamics of the test loop which they propose to use in Title I.

III. PROGRESS DURING REPORT PERIOD

Equations for thermal transient flow-mixing calculations were programmed on a digital computer by LMEC. The analytical model of the main flow loop described in this program is more rigorous than those previously used. Provisions are included in the program to change loop length, number of nodes,

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Figure 1. Thermal Transient Cycle Capability for Type 304 Stainless-Steel Straight Pipe

node length, location of feed and drain lines, and heat transfer coefficient from the sodium to the piping and pump.

Results indicate that the sodium inventory in the CSDD design is adequate for all the thermal transients now being considered, that the required sodium feed rates for the more severe transient of 30°F/sec for 10 sec are higher than predicted earlier, and that the location of the feed line has a large effect on the required feed rate. It has been concluded that the feed line and the drain line should be located as close to the pump as possible. Braun has completed a study on methods of analyzing the thermal transient flow-mixing problem and has developed a mathematical model which they propose to use on an analog computer in Title I. This model is based on a heat percolation calculation technique developed by Takahashi. Braun's model includes provisions for investigating the control dynamics of the complete main flow loop system. A preliminary comparison of results between the LMEC digital program and Braun's mathematical model shows agreement within 10%.

The thermal transient cycle capability of pipe is governed by the transient conditions, pipe material, and configuration. Cycle capability for Type 304 stainless-steel pipe for a number of transients is shown in Figure 1.

In the Conceptual System Design Description transmittal letters, areas of uncertainty and R&D requirements in support of the SPTF were described. The two R&D requirements which may have an urgent bearing on the design and construction schedule are valve development and Type 304H stainless-steel materials properties determination. All of the R&D requirements and areas of uncertainty are listed as follows:

- 1) CSDD I, Test Facility – areas to be defined:
 - a) Test parameters for test pumps defined in detail
 - b) The types of pumps, drivers, and the weights and sizes of pumps
 - c) Analysis to determine minimum flow rate in heater-cooler to prevent freezing
 - d) The effect of pump mass on the transient flow rates

- e) System discharge pressure design is 225 psig at 1210°F (expected operating is 185 psig at 1200°F). If higher discharge pressures are expected, either reduce maximum operating temperature (1200°F) or increase design pressure
- f) Define pump suction pressure (NPSH). Presently 4 to 50 psig — pressure lower than 4 psig requires a vacuum system
- g) Temperature range is presently controlled from 400 to 1200°F
- h) Define pump speed control system(s) for SPTF
- i) Specify allowable particle size in flowing sodium to prevent damage to pump (pump vendors)
- j) Define modifications to SPTF to test first pump (FFTF)
- k) A study to determine whether to use one driver and pump speed control system for the test pumps; i.e., one driver and control system for each loop
- l) Study to determine whether sodium spills in the test building can be effectively controlled, the building concept is safe, and evacuation procedures are adequate
- m) Optimize the location of the control building
- n) Study to determine effects of welding on austenitic stainless steels exposed to 1200°F sodium. Study creep-rupture and fatigue properties of Type 304 weldments. Tests should be performed in sodium with expected impurity levels.
- o) Study cyclic fatigue based on thermal transients. Actual tests should be performed.
- p) Study the effect of liquid sodium on creep characteristics of Type 304H. Tests should be performed.
- q) Studies and tests to better define limitations of stress analysis. Areas of unknowns include strain ratcheting and strain concentrations in the material in the creep range.

- r) Define SPTF thermal transient test requirements. Each loop is presently designed for 100 transient cycles total. Type of transients are described in the CSDD. Study to determine cyclic life of various components and influence of discontinuities. If greater cyclic life is required, new concepts may be required.
- s) Evaluate possibility and desirability of simulating actual reactor transients in the SPTF.

2) CSDD II:

- a) Study the flow control valves in the main loop
- b) Study the effect of nitrogen buildup in the cover gas and nitriding SPTF materials
- c) Develop strain gages for 1200°F sodium service
- d) R&D program to design and test block valves (through 24 in.) and control valves (16 through 30 in.)
- e) Study cavitation as related to piping, flowmeters, valves, test pumps, and other components
- f) Study vortexing of sodium leaving the feed tanks. Scale model testing should be done.
- g) Define acceptable pump nozzle loading forces (pump vendor)
- h) Stress analysis of cooler-heater design to see if they can withstand transients
- i) Design a mixing section or tee for the main system
- j) Define the requirements and establish the design for the electrical preheating system
- h) Define size and weight of E-M flowmeters for SPTF.

3) CSDD III:

- a) Study cavitation problem in relation to location of sodium flow-meter
- b) Study the use of multiple series-connected control valves for controlling sodium flow in SPTF

- c) R&D effort for a reliable carbon meter
- d) R&D effort for sodium leak detection
- e) Evaluate the use of an analog simulator for use in the SPTF.
- 4) CSDD IV: Study the possible use of a portable, vendor-supplied, high-pressure inert gas storage system for transient tests.
- 5) CSDD V:
 - a) Define the size and location of new substation to serve SPTF. The substation can influence the location of the SPTF.
 - b) The present inrush for motors on the present Edison system is limited. This may present problems for the 120,000-gpm motor drives.
 - c) The design and testing requirements for large E-M pumps need defining.
- 6) CSDD VI: Study the advantages and disadvantages of lowering the main loop below grade level (not listed).
- 7) CSDD VII: Study to determine the rate of sodium propylate concentration in alcohol.
- 8) CSDD VIII: Study to determine advisability of changing cold traps from carbon steel to stainless steel.
- 9) CSDD IX: Confirm the use of kerosene as the cooling medium for the pump speed control system.
- 10) CSDD XI: Study to size and select hydraulic fluid for hydraulic system.
- 11) SPTF - R&D:
 - a) Test weldments on austenitic stainless steel exposed to 1200°F sodium (creep, fatigue)
 - b) Tests for cyclic fatigue on Type 304H materials
 - c) Tests for creep fatigue on Type 304H materials

- d) Tests for strain ratcheting and strain concentrations in materials in the creep range
- e) Develop strain gages for 1200°F sodium
- f) Test valve designs for block valves through 24 in. and control valves 16 through 30 in.
- g) Test flow model for vortexing problems in feed tanks
- h) Develop reliable carbon meter
- i) Develop reliable sodium leak detector.

The SPTF design was reviewed to determine the possibility of increasing the thermal transient cycle life of the SPTF by providing a "lining" or thermal barrier between the flowing fluid and the pressure-containing components. An investigation was also made to determine whether any piping systems with thermal barriers in the major portions have been built. The results indicated the following:

- 1) There are no known process systems that are fully lined for thermal shock protection.
- 2) There is no practical experience for the design, fabrication, installation, testing, operation, and reliability of such systems.
- 3) Thermal barriers have been used in specific areas such as nozzles.
- 4) A cost estimate for a piping system with a thermal barrier is two to three times that of an unlined system.
- 5) A thermal shock lining for the entire SPTF piping system is not recommended.

LMEC recommended thermal transient design criteria for the SPTF which are shown in Table 2. These are based on a survey of known and expected thermal transients in existing sodium systems, preliminary information from 1000-Mwe study contractors, and the expected thermal transient test requirements shown in Table 3. Table 3 was developed based on the assumption that meaningful test results can be obtained from thermal shocking the test pumps to a fraction of the actual thermal transient fatigue life as long as the number

TABLE 2
RECOMMENDED SPTF THERMAL TRANSIENT DESIGN CRITERIA

Rate (°F/sec)	Duration (sec)	Temperature Change (°F)	Number of Cycles*	Remarks
+4	120	ΔT -480 (600 to 1080)	1000	Covers all anticipated LMFBR core ΔT 's; determines SPTF sodium inventory
+10	30	ΔT -30 (800 to 1100)	50	Stress level in piping approximates +35°F/sec for 6 sec followed by +2 °F/sec for 100 sec
Non-linear -35 to -10	6	ΔT -300 (1200 to 900)	50	Based on latest LMFBR plant study data; does not affect SPTF concept or sodium inventory
-10 to -2	24			

*Recommend use of single-wall pipe; sections of main loop piping may have to be replaced to satisfy cycle requirements.

of tests exceeds the number of transients expected between plant refueling periods in an LMFBR.

Since the rotating element is considered to be the fatigue-life-limiting part of the pump, it could be removed for inspection, repair, or replacement during the refueling periods.

Modifications necessary to the SPTF for testing the FFTF pumps were determined. The following is a summary of the changes:

- 1) Replace the present main flow loop control valves with smaller valves.
- 2) Add a 16-in. flowmeter and replace 20 ft of 30-in. pipe for the 16-in. flowmeter run. The main 30-in. flowmeter remains in place.
- 3) Replace the drain loop control valves with smaller valves.
- 4) Add a smaller cooler-heater.
- 5) Add two vacuum pumps, two knockout drums, and a gas pressure control station.

TABLE 3
SPTF THERMAL TRANSIENT CYCLE LIFE REQUIREMENTS

Component	Number of Pumps	Test	Number of Cycles	
			Low Rate	High Rate
FFTF Primary Pump	1	Proof	30	2
FFTF Secondary Pump	1	Proof	30	2
Demonstration Plant Primary Pump	3	Proof	90	6
Demonstration Plant Secondary Pump	3	Proof	90	6
LMFBR Primary Pump	3	Proof	90	6
LMFBR Secondary Pump	3	Proof	90	6
Demonstration Plant Pump	3	Proof Retest	90	6
LMFBR Pump	3	Proof Retest	90	6
FFTF Primary Pump	2	Acceptance	2	0
FFTF Secondary Pump	2	Acceptance	2	0
Demonstration Plant Primary Pump	3	Acceptance	3	0
Demonstration Plant Secondary Pump	3	Acceptance	3	0
LMFBR Primary Pump	3	Acceptance	3	0
LMFBR Secondary Pump	3	Acceptance	3	0
Valves	-	-	300	20
Total	36		916	60

A cost estimate for a pump test facility consisting of two 30,000-gpm loops was completed. The cost of the two-small-loop facility is approximately 16% lower than that of the two-60,000-gpm-loop CSDD design.

On February 5 through 7, a working meeting was held at AEC-HQ. Conceptual evaluation charts were prepared for eleven SPTF alternates studied by Braun and four alternates proposed by RDT Components Branch. These evaluation charts form the basis for selecting the concept to be developed in Title I.

The Quality Assurance Plan prepared by Braun was evaluated by the LMEC. The cost for implementing the plan is estimated to be approximately 10% of the total SPTF cost. LMEC comments to the preliminary Quality Assurance Plan were transmitted to Braun. A revised first section has been received for LMEC review. A definition of technical and administrative interfaces between LMEC, AI, and AEC was prepared for two alternate procurement and inspection schemes. In one scheme, procurement and inspection are performed by separate organizations; and in the other scheme, they are performed by the same organization. LMEC's recommendation of the latter scheme was forwarded to the AEC.

A preliminary PERT diagram of Title I work was prepared by Braun and evaluated by LMEC. LMEC prepared examples of the planning and control documents necessary for Title I work.

A preliminary numbering system for all SPTF equipment to be used in the final cost report was developed. A code of accounts and the final cost report format have been prepared in draft form and forwarded to the AEC for comments. The proposed format for the final cost report utilizes a data processing machine program which is available to the LMEC.

IV. NEXT REPORT PERIOD ACTIVITIES

Title I design effort and preparation of the Preliminary System Design Descriptions will be started.

Program: Liquid Metal Engineering Center	
Project: Sodium Pump Seal Test Program	
Project Manager: R. W. Dickinson	Project Engineer: L. B. Copeland
Reporting Period: January-March 1968	AEC Category: 04-01-61-03.8
General Order: 7693, 7694	Subaccount: 14100

I. PROJECT OBJECTIVE

The project objective is to determine, by study and experiment, the suitability of candidate shaft seals for 60,000-gpm sodium pumps and the FFTF sodium pump being designed as a part of the LMFBF program of the USAEC. From evaluation of test data and performance characteristics, seal suitability will be determined in relation to reliability, life, efficiency, and maintenance requirements.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The seal test facility Preliminary System Design Description (PSDD) and a revised Program Plan have been submitted to the AEC. Design of the basic test rig for testing of gas- or oil-type seals has been completed. Assembly of the Shaft Adjustment and Drive Assembly (Dwg.No.N68214003) for both test rigs has been completed.

III. PROGRESS DURING REPORT PERIOD

Initial review of the seal test facility PSDD was completed by the AEC and informal comments were received. LMEC was requested to arrange for an independent review by a qualified organization. Accordingly, a quotation was solicited and received, and contract negotiations were initiated.

Westinghouse review comments on the PSDD and a revised equipment specification for a test seal were received and reviewed. Since the Westinghouse comments included a value for maximum seal torque and, in effect, revised the original Westinghouse-recommended drive motor size, LMEC agrees with the recommendation to use a smaller motor and lower-range torque pickup. Agreement applies to the gas-type seal test facility, but not necessarily to the oil-type seal test facility. In the case of the latter, Byron Jackson has indicated continued agreement with the selections made.

Review of the PSDD and all released drawings by a health and safety engineer was completed. The preliminary design, as presented, was found to provide adequate personnel safeguards and facility protection as required by the General Industry Safety Orders and the Electrical Safety Orders of the California Division of Industrial Safety.

In anticipation of possible testing of a gas-type FFTF seal, an analysis was made of the effects of testing with helium rather than argon. For the same seal, the flow rate would be 11% greater and the gas cost, assuming no recycling or recovery, would be 280% greater. Little modification of the test facility would be required to test comparable size seals with helium; however, a significant change in seal size would necessitate instrumentation and control changes. It is believed such changes could be accommodated without delaying seal testing.

Discussions were held with Westinghouse and Byron Jackson concerning seal design information required by LMEC. As a result, Westinghouse revised their original document covering seal design and test facility requirements and Byron Jackson initiated preparation of a similar document. The revised Westinghouse document contains all pertinent seal data and is considered by LMEC to be as complete as practically possible at this time (i.e., prior to detail designing of the seal).

Review of the test seal proposal from Westinghouse was completed and technical and contractual aspects were discussed with an RDT-SO representative. In accordance with RDT guidance, LMEC prepared instructions to AI Purchasing regarding negotiation requirements. Westinghouse was advised of proposal items requiring clarifications and agreements. In a subsequent meeting at WAED, all differences between WAED and LMEC were apparently resolved and revision of the proposal was started by Westinghouse.

A test seal proposal was received from Byron Jackson and, after initial review, an addendum was also received. At the completion of LMEC review, Byron Jackson was apprised of items that require clarification, agreement, and/or discussion before a test seal package can be purchased. Byron Jackson started the revision of their proposal.

Corrosion areas were found on the flange-to-shell welds of the test vessels. The corrosion areas border repair welds made on the parent weld. Since preliminary investigations indicated the weld material was not of the proper

composition, chemical analyses were made. Although the test report for the filler wire received by the vendor shows the composition to be Type 308 stainless steel, chemical analyses of weld material by three independent laboratories showed conclusively that the weld wire could not have been the specified E 308 or ER 308 material. In fact, analyses showed the material to be martensitic, most likely Type 410 stainless steel.

Tensile strength of the weld material is adequate, but the ductility is much lower and notch sensitivity is much higher than desirable. Since no post-weld heat treatment was performed, severe residual stresses probably exist and severe internal micro-cracking is suspect. Thermal stress calculations indicate a vessel life limitation of only 100 thermal cycles at the maximum flange operating temperature, assuming a stress concentration factor of three at the flange-to-shell junction. After extensive review by metallurgical, welding, and stress analysis specialists, the vessels were rejected. The vessels were removed from the test structures and returned to the supplier for removal of the flange and upper portion of the shell and refabrication with an integral-type flange. Rework procedures and redesign details of the vendor were reviewed and returned with comments.

Assembly of both Shaft Adjustment and Drive Assemblies (Dwg.No. N68214003) was completed. Static tests and preliminary calibrations were completed and preparations for dynamic checks were started. A demonstration of two auto-collimators for measuring angular alignment of the seal driver shaft was made on one drive assembly. The demonstration further served to verify calibration of the mechanical indicator as accurate to within 10 sec of arc. One such device will be procured for use with both drive assemblies for periodic verification of indicator calibration. A modification of the angular alignment assembly was made to provide a positive, mechanical means to lock the drive shaft in a true vertical position to recheck the dial indicator zero reading.

Erection of work platforms for both test rigs was completed. The platforms are constructed to provide a two-level working area since test procedures will require operators to perform test functions at seal installation and shaft alignment fixture levels. The work platform as well as the test vessel and structure assembly and temporarily mounted shaft adjustment and drive assembly of Seal Test Rig No.1 is shown in Figure 2. This figure also shows, typically, the

Figure 2. Seal Test Rig Assemblies

extent of assembly reached prior to removal of the test vessels for rework. In addition, electrical connections of Seal Test Rig No.2 were completed between the control console and the drive motor, tachometer, and torque pickup. Control console panels were energized, and correct direction of rotation of the motor-generator set and drive motor was established.

IV. NEXT REPORT PERIOD ACTIVITIES

Results of the independent and Byron Jackson reviews of the PSDD will be received. The PSDD will be revised in accordance with LMEC evaluation of all review comments and, after informal AEC review, will be submitted to the AEC.

Test vessels will be returned and assembly and checkout of the basic test rigs will be completed as will the fabrication and assembly of the sodium systems. Test seal proposals will be finalized and approved, and contracts will be awarded to both of the pump study contractors. Selection, procurement, and installation of seal service instrumentation and controls will be continued in consonance with information supplied by the study contractors.

Program: Liquid Metal Engineering Center

Project: Sodium Pump Bearing Test Program

Project Manager: R. W. Dickinson

Project Engineer: R. E. Douglas

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693, 7694

Subaccount: 14200

I. PROJECT OBJECTIVES

The objective of this program is to determine the suitability of bearing designs proposed for large sodium pumps being considered for the LMFBR program. Performance characteristics of bearings must be assessed by means of engineering test and analysis, and evaluated in relation to performance criteria. Under this program, suitability is to be demonstrated by operation of bearings exposed to expected environmental conditions. The purpose of this program is to achieve, jointly with the bearing and pump design program, bearing performance consistent with highest standards. Adequacy of bearing performance is to be demonstrated prior to incorporation of bearing design into LMFBR sodium pumps.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

This is the first report period for this project. Previous progress was reported under Subaccount 14100, Sodium Pump Bearing and Seal Test Program.

Overall Conceptual System Design Descriptions (OCSDD) for hydrostatic and hydrodynamic bearing test facilities were submitted. Review comments were received, providing definitive technical guidance for program planning.

III. PROGRESS DURING REPORT PERIOD

Several changes in program planning were discussed with RDT. The most significant change consists of including the provision for testing FFTF pump bearings. Additional clarification was provided by RDT for preparation and use of SDD's. Emphasis is to be placed on preparation of an acceptable OCSDD as early as possible with the objective of starting preliminary facility studies early in FY 1969.

A tentative schedule for FFTF bearing testing was derived from the current FFTF pump schedule. It now appears that FFTF pump bearing tests must be completed by December 1970. Technical requirements for FFTF pump bearing testing are not available at this time.

A test specification for the tentatively selected Westinghouse 60,000-gpm-size bearing was issued. The test specification is to become part of test operations and procedures, supplementing the SDD.

A Program Plan was issued in which planning for bearing tests was separated from the Seal Test Program in accordance with new program structure.

Requests for quotation for 60,000-gpm pump size test bearings were sent to Westinghouse and Byron Jackson. The pump study contractors were requested to incorporate latest reference design information so that the test bearings will represent, as nearly as possible at this early stage in bearing design, the finally selected design for the prototype 60,000-gpm pumps.

Westinghouse document WAED No. 3813 Revision 1, "Bearing Selection and Sizing for 60,000 and 120,000 gpm 350-ft Head Sodium Pumps," was received for review and evaluation of test facility requirements. Results will be used in preparation of a revised OCSDD. The bearing section of the Byron Jackson Pump Study report, Phase I, was reviewed and comments were transmitted to Byron Jackson.

Consulting services of a specialist representing Case Institute, who is currently working actively in the field of bearing technology, have been obtained. His first visit at LMEC will be for the purpose of determining areas of the bearing program in which his services will be of greatest value.

IV. NEXT REPORT PERIOD ACTIVITIES

A revised OCSDD will be prepared and issued. A Bearing Test Specification for the Byron Jackson test bearing will be prepared. Quotations for test bearings will be received from the two pump study contractors for review.

Program: Liquid Metal Engineering Center

Project: Precision Mechanisms in Sodium

Project Manager: R. W. Dickinson

Project Engineer: W. J. Freede

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693, 7694

Subaccount: 15100

I. PROJECT OBJECTIVES

Objective of this project is to obtain special engineering information needed for design of mechanical elements required to operate reliably in sodium liquid and vapor to 650 °C (1200 °F) in nuclear reactors. It is intended that this information may be employed in the design of fuel handling devices, control rod drives, and fuel holddown mechanisms for sodium-cooled fast breeder reactors planned for the immediate future.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

Topical report NAA-SR-12446, "Static and Sliding Contact Behavior of Materials in Sodium Environments at Elevated Temperatures," by W. J. Freede et al, contains a description of apparatus and procedures employed for all tests summarized in this progress report, and presents test results for FY 1967 and early FY 1968.

A Technical Data Record report, LMEC-TDR-68-8, "Austenitic Steel Type 347 Welded Nested Bellows Qualification Tests in Sodium Environments," was published describing the bellows qualification tests conducted during FY 1967.

Static contact tests were completed to determine self-welding characteristics of the second group of material combinations (54 total) described in NAA-SR-12446. These tests were conducted at 650 °C (1200 °F) in circulating liquid cold-trapped and hot-trapped sodium as well as in sodium vapor.

Tests were continued using sliding contact equipment and procedures described in NAA-SR-12446 to determine coefficients of friction and wear behavior of various materials in 427 to 650 °C (800 to 1200 °F) liquid and vapor sodium.

Equipment fabrication and initial shakedown operations were completed on apparatus associated with rolling element thrust bearing tests and latch surface tests.

A number of meetings were held with PNL personnel regarding data reported in NAA-SR-12446, LMEC test facilities, and test performance procedures in connection with required FFTF mechanical element test tasks.

III. PROGRESS DURING REPORT PERIOD

Reports were published and forwarded to AEC-RDT for approval of review of mechanisms in sodium at EBR-II and SRE facilities. Similar data were gathered for a report on HNPF mechanisms, and arrangements were made to obtain the same type of information which has resulted from tests and operations at the Fermi facility.

Sliding contact tests were completed on alloy Ampco 18HT13 under former and future planned EBR-II coolant conditions. Ampco 18HT13 (10.6% Al, 3.6% Fe, 85.8% Cu) is an alloy being considered for use as a replacement material for beryllium-copper alloy parts which deteriorated in the EBR-II sodium coolant during past operations.

The data in Table 4 were obtained from 200-hr sliding contact tests in sodium under the test conditions described in NAA-SR-12446.

IV. NEXT REPORT PERIOD ACTIVITIES

Sliding contact tests in 427 to 650°C (800 to 1200°F) in cold-trapped and hot-trapped liquid sodium and sodium vapor environments will be continued. A limited number of sliding contact tests will be performed using candidate materials (Al_2O_3 Lucalox and Udimet-630) not previously examined.

Exploratory tests will be conducted to determine how variations in loading and velocity will influence sliding contact wear rates and adhesive wear material transfer effects. Specimen materials will be selected from those considered the better combinations.

TABLE 4
SLIDING CONTACT TEST RESULTS

Sodium Environment* (°F)	Materials		Coefficient of Sliding Friction		Pin Specific Wear (cm ³ /cm·kg)
	Pins	Plate	Initial	Final	
LCT, 1200	Inconel-750	K-95 (WC)	0.40	1.30	66.1 x 10 ⁻¹¹
V, 1200	Inconel-718	Stellite-6B	0.37	0.62	1456 x 10 ⁻¹¹
V, 1200	Stellite-3	Stellite-6B	0.49	0.42	Material Buildup
V, 1200	Star-J	Stellite-6B	0.36	0.43	2.58 x 10 ⁻¹¹
V, 1200	Stellite-1	Stellite-6B	0.45	0.28	4 x 10 ⁻¹¹
V, 1200	Stellite-273	Inconel-718	0.28	0.30	Material Buildup
V, 1200	TZM	Inconel-718	0.27	0.42	Material Buildup
V, 1200	Hastelloy-C	Hastelloy-C	0.19	0.37	62.3 x 10 ⁻¹¹
LCT, 1200	Stellite-6B	K-801 (WC)	0.40	0.41	12.8 x 10 ⁻¹¹
LCT, 1200	Inconel-718	K-801 (WC)	0.58	0.66	8.9 x 10 ⁻¹¹
LCT, 1200	Inconel-750	K-95	0.40	1.30	66.1 x 10 ⁻¹¹
LCT, 700	Ampco-18HT13	304 SS	0.45	0.23	288.6 x 10 ⁻¹¹
LHT, 1200	TZM	Inconel-718	0.23	0.27	3.56 x 10 ⁻¹¹
LHT, 1200	Molybdenum	Stellite-6B	0.24	0.62	Material Buildup
LHT, 1200	Stellite-3	Colmonoy-75	0.31	0.18	22.8 x 10 ⁻¹¹
LCT, 1200	K-95	K-95	0.19	1.02	2.23 x 10 ⁻¹¹
LCT, 1200	Hastelloy-C	Stellite-1016	0.32	0.36	1.62 x 10 ⁻¹¹
LCT, 1200	Stellite-6B	Inconel-718	0.31	0.27	20.8 x 10 ⁻¹¹
LCT, 1200	Stellite-6B	Stellite-1	0.42	0.32	9.3 x 10 ⁻¹¹
LCT, 1200	Hastelloy-C	TZM	0.29	0.39	9.4 x 10 ⁻¹¹
LCT, 1200	Hastelloy-C	Stellite-3	0.25	0.27	13.4 x 10 ⁻¹¹
LCT, 1200	Stellite-273	Stellite-1016	0.32	0.32	2.8 x 10 ⁻¹¹
LCT, 1200	Colmonoy-5	Colmonoy-75	0.35	0.39	125.6 x 10 ⁻¹¹
LCT, 600	304 SS	304 SS	0.22	0.44	Galled and 11.4 x 10 ⁻¹¹
LCT, 800	Inconel-718	Rex-49	0.25	0.49	9 x 10 ⁻¹¹
LCT, 800	Rex-49	Rex-49	0.25	0.46	10.3 x 10 ⁻¹¹
LCT, 800	Rex-49	Inconel-718	0.34	0.41	3.9 x 10 ⁻¹¹
LCT, 1200	Al ₂ O ₃ (Coors)	Al ₂ O ₃ (Coors)	0.87	0.56	17.9 x 10 ⁻¹¹
LCT, 845	Ampco-18-13	Cr-plated 304 SS	0.32	0.32	1763 x 10 ⁻¹¹
LHT, 1200	Stellite-273	Stellite-1	0.26	0.22	4.3 x 10 ⁻¹¹
LHT, 1200	Stellite-273	Stellite-6B	0.24	0.26	11.6 x 10 ⁻¹¹
LHT, 1200	Stellite-1016	Inconel-718	0.21	0.25	10.4 x 10 ⁻¹¹
LCT, 845	Ampco-18-13	Stellite-6B	0.42	0.63	1130 x 10 ⁻¹¹
LHT, 1200	Stellite-6B	Stellite-6B	0.24	0.28	9.1 x 10 ⁻¹¹
LHT, 1200	Hastelloy-C	Stellite-6B	0.29	0.31	1.8 x 10 ⁻¹¹
LHT, 1200	Star-J	K-95	0.39	0.45	12.2 x 10 ⁻¹¹
LCT, 1200	Inconel-718	Al ₂ O ₃ (Coors)	0.44	0.44	Material Buildup

*V = sodium vapor over cold-trapped liquid sodium in an inert gas (argon) atmosphere

LCT = liquid cold-trapped sodium with 20 to 30 ppm O₂ content

LHT = liquid hot-trapped sodium with <5 ppm O₂ content

Test plans pertaining to rolling element thrust bearings, journal bearings, spur gears, and latch surfaces in sodium environments will be completed and forwarded to RDT for review. After approval is obtained, formal testing of these mechanical elements will be initiated.

Efforts will be continued toward identifying, collecting, and assembling experience histories relating to mechanical devices at Fermi and HNPF reactor facilities. Reduction and evaluation of these data will be performed and results will be presented in a topical report. This information will also be included in LMEC-68-5, "Literature and Experience Survey: Mechanical Elements Operating in Sodium and Other Alkali Metals." This report is scheduled to be published in FY 1969.

A Technical Data Record report, LMEC-TDR-68-12, "Stroke Multiplication Mechanism Qualification Tests in 1200 °F Sodium," will be published.

Detailed designs of various types of mechanisms in the FFTF will be reviewed and evaluated on a continuous basis. Guidance will be offered on the selection of mechanical contact materials and specialized design parameters.

Program: Liquid Metal Engineering Center	
Project: Modification to Auxiliary Component Test Installation (ACTI)	
Project Manager: O. J. Foust	Project Engineer: H. B. Dietz
Reporting Period: January-March 1968	AEC Category: 04-01-61-03.8
General Order: 7693	Subaccount: 16100

I. PROJECT OBJECTIVES

The overall objective of this project is to design and construct a facility for the calibration and performance testing of certain sodium instruments and components in support of the LMFBR program. Specific objectives are:

- 1) To develop and maintain flow standards of measurements (the term "standard" is further delineated here as sodium flow instruments calibrated and maintained to provide accurate, reproducible readings under fixed, given conditions)
- 2) To provide fixed, reproducible, known sodium environment conditions; and to perform test, calibration, and standardization functions for sodium flow instruments and components
- 3) To provide flexibility in the form of stub-offs for inserting test loops or fixtures for testing instruments or components.

Objectives have been expanded to perform a more complete trade-off study of LMFBR test requirements matched to specific facilities; specifically, to identify deficiencies in test facility accommodations.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The ACTI Overall Conceptual System Design Description (OCSDD) was completed.

Phase I of the review of total LMFBR testing and facility needs requested by RDT has been completed and submitted to RDT in letter 68LMEC-2, "LMFBR Testing and Facility Requirements," dated January 12, 1968.

III. PROGRESS DURING REPORT PERIOD

First in priority has been an expanded study to encompass a two-phase review of the total LMFBR testing and facility needs. The first phase, completed in January, is an accelerated review and evaluation of test requirements and planned test facility accommodations with recommendations to rectify deficiencies. The second phase is a continuation of the first phase plus detailed evaluation of non-LMEC test facilities suitable for LMFBR testing. A continuing review in depth of the LMFBR testing requirements will be maintained utilizing Phase I results and consultations with the program office and LMFBR program contract personnel. Results of the Phase I study (Letter 68LMEC-2) include: (1) LMFBR component and instrument performance test requirements, (2) existing and proposed facilities for LMFBR testing, and (3) a trade-off matrix matching test requirements with appropriate test facilities.

A. TEST REQUIREMENTS

The summarized overall LMFBR component and instrument performance test requirements are based on published documents, statements, and correspondence, including the LMFBR Program Plan, and supplemented by LMEC judgment in case of apparent omissions or conflicts.

Five main categories are used to delineate these test requirements for each component and instrument. The first four categories are adapted to the four basic parameters: temperature, pressure, flow, and thermal transients. The fifth and last category includes everything not covered in the first four, and is identified as specific testing.

The requirements are presented in Appendix C, Table C-1, for each component and instrument in terms of these five categories.

The main purpose in categorizing test requirements in this fashion is to facilitate definition of test facility requirements and the ultimate matching of test requirements and test facilities. For example, if a component such as a pump, valve, bearing, IHX, or steam generator must be operable and withstand thermal shock in 1200 °F sodium, then it is considered impractical to postulate that adequate performance testing may be accomplished in a 900 °F isothermal loop. However, partial testing may be possible in such a loop, depending on the

suitability of flow and pressure. Ultimately, temperature and transient testing should be performed, and in many cases will require specified pressure and flow conditions in addition to the temperature and transient requirements.

It is desirable to satisfy the test requirements for a given component or instrument in a single test facility. It may often be difficult, however, to justify the expense required to implement such an ideal test program. Therefore, from a practical standpoint, test requirements must be compromised in many areas, depending on the testing budget and schedule requirements.

A flowmeter, for example, may be given thermal shock in a low-flow facility, then further tested and flow calibrated in a low-temperature, isothermal facility of adequate flow.

It may be necessary to test an IHX at full flow but less than full ΔT ; or it may be advisable to test IHX and steam generator small-scale models, or even small tube bundles, in lieu of prototype or medium sized models.

In certain instances, high pressure requirements will inevitably be compromised. In others, such as in-core flowmeters where specified flow velocity must be passed through a flow restriction, compromises in pressure are not acceptable.

LMFBR component test requirements as presently projected and as summarized in Appendix C are intended as an initial requirement digest for use in implementing plans for test facilities. These requirements are subject to change and refinement as program requirements and objectives become more clearly established.

B. TEST FACILITIES

Test facilities have been selected as candidates for LMFBR performance testing; their selection is based on comparing test requirements with existing and planned test facility capabilities. In this respect, a facility's usefulness depends primarily on its temperature, pressure, flow, and thermal transient limitations. Accordingly, considerations were given for proposed new facilities and for modifications to existing facilities to satisfy apparent deficiencies in the present facility plans.

A directory of candidate test facilities is included in Letter 68LMEC-2. The selection is based primarily on one or more of the three parameters: flow, pressure, and temperature. In all cases, regardless of other limitations, a

facility is given consideration if the flow capability is above 1000 gpm. Also, a facility is usually considered a candidate if temperature limits exceed 1100 °F or if pressure capability exceeds 100 psig. A facility is not considered a likely prospect for LMFBR testing when all of these parameters are low (<1100 °F, <100 psig, <1000 gpm or 2-in. pipe, and no thermal transient capability).

Existing LMEC facilities and recommended modifications to LMEC test facilities are described, along with new facilities recommended for considerations, in Appendix C.

It is not recommended that a program be initiated to construct and operate all facilities described in Appendix C. Complete facility information is necessary, however, in order to adapt test requirements to facility capabilities.

IV. NEXT REPORT PERIOD ACTIVITIES

Phase II of total LMFBR testing and facility needs will be continued. Trips to non-LMEC facilities are anticipated to evaluate actual testing capabilities.

The FFTF flowmeter position test will be completed.

Rewrite of the ACTI OCSDD will be started.

Program: Liquid Metal Engineering Center

Project: Instrumentation Testing, Evaluation, Calibration, and Standardization

Project Manager: R. W. Dickinson

Project Engineer: J. T. Meyer

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693

Subaccount: 17100

I. PROJECT OBJECTIVES

The overall objectives of this project are: (1) to establish capabilities and facilities to develop and maintain standards of measurement; (2) to provide fixed, reproducible, known, sodium environmental conditions; and (3) to perform testing, calibration, and standardization functions for instrumentation used in the LMFBR program. Included in this project will be the determination of testing and test facilities requirements, modification of existing LMEC facilities, and design of new installations for testing and calibrating instrumentation developed under the LMFBR program. The basis for all planning and testing of instrumentation will be Task 34, Section 4, of the LMFBR Program Plan.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The final revisions to the Sodium Components Test Installation - Data Acquisition System (SCTI-DAS) specification were approved and it was issued as Specification 7693-CE12100-1, dated November 15, 1967. Approval to request bids was received and invitations to bid were sent to vendors on November 29, 1967.

The LMEC instrumentation maintenance, repair, and calibration effort was initiated and is proceeding on a firm, well-planned basis. Extensive excess equipment has been or is presently being procured. This procurement will furnish the greater part of equipment needed to provide adequate instrumentation service to LMEC facilities.

A review of available information on existing sodium testing facilities and installations has been conducted to determine their applicability to testing and/or calibration of instruments required for the LMFBR and associated programs. These facilities capabilities have been reviewed to ascertain their applicability to both the immediate needs of the FFTF and SPTF programs and the longer-

term requirements of the overall LMFBR Program. This preliminary information has been tabulated listing the types of instruments, test requirements, and the test facilities, both existing and planned, that can meet some of these requirements.

State-of-the-art reports on Sodium Liquid Level Measurement and Sodium Impurity Measurement have been written and distributed.

III. PROGRESS DURING REPORT PERIOD

The final specification for the SCTI - Data Acquisition System was distributed to 14 vendors who were invited to submit proposals. Three of the low bidders, adjudged both technically competent and most responsive to the specification, were invited to give technical presentations of their systems. The final evaluation of these proposals and the material to comply with AEC Manual Section 1801 requirements have been submitted to AEC-CPAO for review. The AEC has requested additional backup information as required by AEC circular A-54.

State-of-the-art studies were initiated on the following sodium instrumentation technologies: (1) flowmeters, (2) temperature, (3) pressure, and (4) sodium impurity measurements. The reports on sodium impurity measurement instrumentation (LMEC-Memo-68-3) and sodium pressure measurement instrumentation (LMEC-Memo-68-7) have been distributed according to the authorized LMFBR distribution list. The report on temperature measurement is in final editing, and work on the flowmeter report is continuing.

The rewrite of material for the chapter on instrumentation for the Sodium and NaK Engineering Handbook was initiated. Substantial revisions were made to include the additional data received since copies of the rough draft were submitted for review and to orient the presentation toward more practical applications rather than discussions of basic operating principles. The draft has been completed and is in final editing.

The study to define specific functional testing requirements and testing facilities requirements for instrumentation and control components, based on Task 1.4 and associated task of Section 4 of the LMFBR Program Plan, is ready for printing. Preliminary drafts of the report were forwarded to RDT,

the LMFBR Program Office, and to the FFTF Project for review and comments prior to finalization. Meetings were held at LMEC during the week of February 25 to review this preliminary draft and to discuss instrumentation testing facility requirements at LMEC. This meeting was held at the request of RDT and included representatives from RDT, the LMFBR Program Office, the FFTF Project, and LMEC.

It was generally agreed that the basic content of the report was satisfactory and the Program Office agreed to supply additional and updated performance requirements data. Major revisions in the organization of the report and the use of tabulated summaries have been utilized to improve the presentation of the material in the final draft.

Plans for flowmeter position testing at SCTI were developed in conjunction with FFTF and SCTI personnel. The purpose of these tests is to provide information on the effect of upstream and downstream flow disturbances (such as elbows) on the output of a magnetic flowmeter. The tests will be performed with the flowmeter at various distances from the elbows so that FFTF will have some basis for a decision on how long the flowmetering sections must be in FFTF piping. A flowmeter magnet from the HNPF secondary loop has been procured for use in these tests. Measurement of the magnet magnetic field strength and testing of the necessary measurement instrumentation is in progress in preparation for the tests. A means for locating and moving the 540-lb magnet along the piping is being investigated.

A survey of LMEC instrumentation has been completed and a systematic instrumentation calibration program has been initiated. Calibration record forms have been printed. A series of decals and stickers has been designed and procured for use on instruments to facilitate the identification and control of their calibration status. Calibration procedures are available for all instruments, utilizing AI and Autonetics procedures until such time that they are deemed necessary to be superseded by updated procedures generated at LMEC. Present NBS traceability, or state-of-the-art industrial standards, as applicable, have been implemented using the AI standards facilities. The LMEC Operating Procedures for Instrumentation Calibration and Maintenance is in final editing.

The planning of the physical facilities for the LMEC Instrument Test, Calibration, and Standards Laboratory was initiated. Alternate facilities plans were prepared by Industrial Planning. These, together with LMEC requirements,

have been submitted for review by AEC-CPAO, AI, and LMEC. These facilities are to include office space; laboratory space for storage, cleaning, repair, and calibration of instrumentation; and a standards laboratory for support of the calibration effort.

IV. NEXT REPORT PERIOD ACTIVITIES

Upon receipt of approval to purchase by AEC-CPAO, a purchase order for the SCTI-DAS will be placed with the successful bidder.

The state-of-the-art study on temperature measurements is scheduled to be printed and distributed by May 15, 1968.

The state-of-the-art study on sodium flow measurement is scheduled to be printed and distributed by June 1, 1968.

The rewrite of the material for the chapter on instrumentation for the Sodium and NaK Engineering Handbook will be completed.

The report on LMFBR Instrumentation Functional Testing and Test Facility Requirements will be printed and distributed by April 15, 1968.

The effort on the tests for FFTF to determine the effect of upstream and downstream flow disturbances on flowmeter accuracy will continue.

The effort to provide sodium instrument standards in conjunction with the LMEC Specifications and Standards Task Unit will continue.

Additional studies as requested by AEC-RDT for sodium instrumentation and calibration facilities will be initiated. Various alternate approaches and trade-off studies for three new facilities will be investigated. These facilities are: (1) the Sodium Instruments Test Tower for testing and calibrating temperature, pressure, and level measurement instruments with sodium immersion depths up to 50 ft; (2) the Temperature-Pressure Test Chamber for testing and calibrating temperature and pressure instruments with lead lengths up to 50 ft in an inert gas environment; and (3) an in-core instrumentation facility for the test and calibration of in-core flowmeters and temperature and pressure sensors in flowing sodium at temperatures up to 1400°F.

As requested by RDT, a better assessment of the design support and/or development required for SPTF instrumentation will be initiated. Recommendations will be submitted as to those areas requiring immediate design support and development contracts. Work scopes will be prepared for guidance of these efforts.

Program: Liquid Metal Engineering Center

Project: High-Temperature Strain Measurements

Project Manager: R. W. Dickinson

Project Engineer: M. M. Lemcoe

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693

Subaccount: 52110

I. PROJECT OBJECTIVES

The primary objectives of this project are to:

- 1) Calibrate or evaluate strain gages and other special purpose instruments for measurement of strain, displacement, or vibration on LMFBR sodium components at temperatures up to 1200 °F in or out of sodium
- 2) Complete the remaining development work to be performed at the LMEC on the 1200 °F wire, foil, and sodium gages by the end of FY 1968
- 3) Calibrate or evaluate strain gages and other special purpose instruments, in or out of sodium, for RDT contractors and national laboratories as directed by RDT.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

Two special facilities for evaluating strain gages, in or out of sodium, were designed, assembled, and put into operation. These facilities permit gage evaluation for prolonged periods of time at temperatures up to 1200 °F under steady-state temperature or stress conditions or under repeated thermal shock conditions. Sodium pressures up to 125 psig can be imposed on the gage (or protective cover). Gages can be shocked in air or sodium at heating rates up to 100 °F/sec, depending upon the size of specimen.

Final design of a facility was completed for precise calibration of gages, under pure axial loading, at temperatures up to 1200 °F. The microprobe, emission spectrograph, and chemical analyses of failed Microdot SG423 strain gages and gage components were completed. Causes of the poor performance and premature failure of these gages were established.

It was demonstrated that it is possible to clad Armour-D wire and produce gages which can withstand both the prolonged temperatures and thermal shocks encountered in testing LMFBF sodium components. The achievement of a reliable metallurgical bond between the cladding and the base material was demonstrated by testing gages at 1200 °F for 1000 hr and subjecting them to 120 thermal shocks at rates up to 30 °F/sec. This proves the feasibility of the gage concept.

III. PROGRESS DURING REPORT PERIOD

Adjustment of system parameters to achieve maximum heating rates with the induction heating system of the facility for thermal shocking or soaking gages in sodium was completed. Checkout of the leak detection system was also completed, and the facility is now fully operational. To check out the facility, four B&W huts, attached to a specimen which was subjected to an axial tensile stress of 5750 psi, were subjected to 1000 hr of exposure in 900 °F sodium and to 60 thermal shocks at heating rates of 17 °F/sec. No malfunctions of the facility were observed.

Measurements of the electrical "noise" induced in strain gages and thermocouples installed on test specimens were completed. These specimens were tested in the facility for thermal shocking gages in air by means of direct resistance heating. The levels were found to be substantial, even with proper grounding and the use of shielded leads. The noise was eliminated by means of a filter network comprised of capacitors and chokes, and the system is now fully operational. With this facility, it is now possible to perform thermal shock tests in a fraction of the time previously required with the radiant heating facility, because of freedom from malfunctioning and the enhanced cooling capacity. Further, the temperature gradients in the specimen and gage, which are inherent in a radiant heating system at the higher heating rates, were eliminated.

Pilot evaluation of several special LMEC clad Armour-D wire gages continues. The gages were subjected to approximately 1000 hr of exposure at 1200 °F and to 120 thermal shocks, consisting of 40 at 10 °F/sec, 40 at 20 °F/sec, and 40 at 30 °F/sec. No signs of mechanical or electrical degradation were observed. This established the metallurgical integrity of the bond and proves the feasibility of the gage concept.

Fabrication and evaluation of LMEC Armour-D foil gages and clad Armour-D foil gages was delayed, owing to delays in remelting the Armour-D ingots into rounds and a slab. The latter shape will be rolled into Armour-D foil. The round ingots were extruded into bars approximately 3/4 in. in diameter; they are being sent to a vendor specializing in wire drawing to be drawn into strain gage wire sizes.

Fabrication of gages at Microdot of all-nickel exterior construction has been held up because of difficulties in procurement of the nickel tubing. Delivery of these gages is now scheduled for the first part of June 1968.

Six Armour-D strain gage filaments with gold-plated shanks have been received from Microdot and are under test to determine their mechanical strength (freedom from embrittlement) and electrical properties which might be caused by the plating. In that an alkaline plating solution was used, the amount of embrittlement detected should be small. If the tests in progress are satisfactory, the vendor will be authorized to proceed with the fabrication of six special Microdot gages with Armour-D filaments.

Microprobe and emission spectrograph analysis of failed Microdot SG423 gages has been completed. In addition, similar analysis has been performed on out-of-the-bottle Brimor cement for comparison with the Brimor cement in the transition section of the Microdot gage. The results of this exhaustive study were summarized in several reports which will be combined into a summary report at a later date.

The results of microprobe analysis and resistivity measurements on Pt-W wire and Pt-W wire with gold-plated shanks were discussed in the progress report for the previous reporting period. In brief, it was found that there was a lowering in gage resistance owing to diffusion of gold into the platinum-tungsten alloy, and that the greatest reduction in resistance was due to a depletion of tungsten from the platinum-tungsten alloy. By stabilizing for a sufficient period of time at temperature, instability from these sources can be reduced to an acceptable amount.

To determine whether instabilities from other sources were responsible for the low resistance to ground, failure, or erratic behavior of Microdot SG423 gages MB1-2 and MB1-3, postmortem examinations were performed on these gages. The results were as follows:

- 1) There was no migration of gold into the MgO insulation which surrounds the sensing portion of the filaments. This, therefore, could not account for gage instability or low resistance to ground.
- 2) There was a lack of homogeneity of the major elements (P, Si, Ti) in the insulating Brimor cement, which is contained in the transition section, as well as differences in thickness of the Brimor cement surrounding each conductor. This could lower the resistance to ground and affect gage stability.
- 3) Ionic conduction due to the presence of potassium ions in the Brimor cement could lower the resistance to ground. (Sources of potassium would be the flux and impurities in the cement.) Potassium was found to be present in the cement.
- 4) Some of the TiO_2 present in the Brimor cement may have been reduced to a sub-oxide which is electrically conductive and would lower the resistance to ground.
- 5) There is a possibility of attack of any unprotected copper by the phosphoric acid in the Brimor cement. This copper in combination with phosphorus could then migrate into the Brimor cement, making the cement more conductive, electrically. This would lower the resistance to ground. Also, the effective area of the copper conductor might be reduced enough, as a result of chemical attack, to cause a zero shift or gage instability. When the transition section of gage MB1-2 was examined under a microscope, most of the stainless steel protective cladding was found to be missing.

Design of a facility for the precise calibration of strain gages up to 1200 °F, under axial loading, has been completed. Calibration is accomplished by installing the gages on a precisely machined and ground calibration bar and measuring the strain in the bar by means of a micrometer microscope. This is accomplished by measuring the displacement between two optical targets spaced 4 in. apart. With this gage length, the effective resolution of the optical system is about 10 microstrain. To minimize bending due to friction or misalignment in the loading system (60,000-lb capacity WTE universal hydraulic testing machine), a special flexure was installed on each end of the calibration bar. To check out

the facility at room temperature, four room-temperature foil gages were installed every 90 degrees around the circumference at the mid-length of the specimen. The calibration bar was then loaded in increments, and strains and displacements measured. At a maximum mean-value strain level of 683 microstrain, the lower and upper 95% confidence limits for the eight runs were found to be 667 and 698 microstrain, respectively. This corresponds to a maximum deviation of $\pm 2.2\%$ from the mean for a 95% confidence level. A comparison with the four electrical resistance strain gages, accurate to $\pm 1/2\%$, showed agreement between the Gaertner microscope readings and the average readings of these four gages to be within 1.24%, which is considered excellent. Figure 3 shows the excellent correlation between the Gaertner micrometer microscope readings and the strain gage readings.

Purchase orders were released for all components, including a furnace with windows to permit viewing of the optical targets during elevated temperature calibrations. Delivery of all components is expected by May 15, 1968. Shake-down tests of the system should begin not later than June 1, 1968.

To determine whether there would be a significant difference in tension and compression gage factors for Microdot gages, two Microdot SG420 gages were welded directly to a bending calibration bar. Measurements were taken at room temperature, 500, and 950 °F. There was no general trend observed and many of the differences were within the accuracy of measurement. At a strain level of 750 microstrain on the calibration bar, the percent changes in gage factor from compression to tension on gage No.1 were -1.1, +1.9, and +1.2 at room temperature, 500, and 900 °F, respectively. For gage No.2, the corresponding percentages were -2.0, -1.1, and -1.2. Differences this small do not, in general, justify calibration of gages in both tension and compression. However, it remains to be seen whether the differences will be this small when intermediate shims are used.

Evaluation of additional LMEC, Microdot, and other special gages has continued. Table 5 summarizes the performance of these gages to date.

Figure 3. Strain Gage Calibration Readings Compared to Gaertner Micrometer Microscope Readings

IV. NEXT REPORT PERIOD ACTIVITIES

Major attention will be devoted to the evaluation of Microdot SG420 gages and Microdot SG425 gages. Evaluation of the SG420 gage will include evaluations at 800°F, which corresponds to the maximum metal temperature on the ALCO/BLH steam generator. Tests will also be conducted on SG420 gages at temperatures between 900 and 1050°F, which correspond to the maximum temperatures anticipated in the ALCO/BLH IHX. In addition, it is proposed to begin a comprehensive study of the Microdot SG425 gage. A minimum of 12 gages will be subjected to the standard LMEC gage evaluation.

To determine the optimum stabilization time and temperature, a number of SG420 gages will be stabilized at three different temperatures and three different time periods. Drift and other tests will then be conducted to determine the optimum stabilization combination to meet specified criteria with respect to drift rate and repeatability. Rate process theory (activation energy equations) will be used to establish the times and temperatures and to facilitate correlation of the results.

To determine how much gage factor, apparent strain, and other gage characteristics change after final gage installation, using the intermediate shim calibration technique, twelve SG420 gages with intermediate shims will be spot-welded to calibration bars, precalibrated, removed from the calibration bars, and recalibrated. The number of cycles (load and temperature) required to restabilize the gages will be determined. This information is of prime importance, since the extent of the change in gage calibration is not known at present.

Vendor fabrication of Armour-D foil and wire from the re-melted Armour-D ingots should be completed or nearly complete, in addition to fabrication of clad Armour-D foil.

Evaluation of Microdot gages fabricated with Armour-D filaments should be almost 50% completed by the end of the report period.

Evaluation of the tungsten-plated, all-nickel strain gages will begin, assuming no delays in delivery or plating the gages.

The state-of-the-art survey of high-temperature transducers utilizing strain gage sensors to measure pressure, displacement, vibration, etc. will continue with emphasis on pressure transducers. Full use will be made of the information obtained in the literature search made at PNL.

Optimization of the gage geometry for and fabrication of the clad Armour-D wire gage should be completed.

Tests of Microdot SG420 gages, with intermediate shims, will be initiated to determine whether there is a significant difference in gage factor in tension and compression due to shear lag or buckling in the shim. The exact number of gages to be tested will be determined by the scatter from gage to gage.

TABLE 5
EVALUATION OF STRAIN GAGES
(Sheet 1 of 3)

Gage No.	Gage Description (LMEC Gages)	Present Status	Maximum Test Tem- perature (°F)	Total Thermal Soak Time (hr)	Drift Rate (microstrain/hr)		Total Number of Thermal Shocks			Comments
					Since Beginning	Over Last Soak Period	10 °F/sec	20 °F/sec	30 °F/sec	
D13-3	All Armour-D, wire	12th series shock pending	1200	3607	3.8	2.3	110	110	110	Outstanding life with excellent drift characteristics
D23-1	Armour-D-Pt, wire	3rd series soak pending	1200	601	2.4	2.7	20	20	20	Good drift characteristics
D23-2	Armour-D-Pt, wire	3rd series soak pending	1200	601	2.3	2.4	20	20	20	Good drift characteristics
D25-1	Armour-D wire, Pt foil leads	3rd series elevated temperature load test pending	1200	620	2.1	2.1	20	20	20	Good drift characteristics
D25-2	Armour-D wire, Pt foil leads	Same as above	1200	620	2.2	2.1	20	20	17	Gage failed during 8th cycle at 30 °F/sec
D25-3	Armour-D wire, Pt foil leads	Same as above	1200	620	2.2	2.5	20	20	20	Good drift characteristics
D26-1	Armour-D wire, Pt tabs	1st series thermal shock pending	1200	310	1.6	1.6	0	0	0	Very good drift characteristics
D26-2	Same as above	Same as above	1200	310	1.5	1.5	0	0	0	Very good drift characteristics
D27-1	Same as D26 with Pt tabs reversed	1st series thermal shock pending	1200	310	2.9	2.9	0	0	0	Good drift characteristics
D28-1	Armour-D-Pt, wire	1st series thermal shock pending	1200	310	1.5	1.5	0	0	0	Very good drift characteristics
D28-2	Same as above	Same as above	1200	310	1.5	1.5	0	0	0	Very good drift characteristics
D28-3	Same as above	Same as above	1200	310	1.6	1.6	0	0	0	Very good drift characteristics
D28-4	Same as above	Same as above	1200	310	1.4	1.4	0	0	0	Very good drift characteristics
D29-1	Armour-D-Pt, wire	1st series thermal shock pending	1200	295	0.6	0.6	0	0	0	Excellent drift characteristics
D29-2	Same as above	Same as above	1200	295	0.8	0.8	0	0	0	Excellent drift characteristics
D29-3	Same as above	Same as above	1200	295	1.4	1.4	0	0	0	Very good drift characteristics
D29-4	Same as above	Same as above	1200	295	1.1	1.1	0	0	0	Very good drift characteristics

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TABLE 5
EVALUATION OF STRAIN GAGES
(Sheet 2 of 3)

Gage No.	Gage Description (Die-Cut Foil Gages)	Present Status	Maximum Test Tem- perature (°F)	Total Thermal Soak Time (hr)	Drift Rate (microstrain/hr)		Total Number of Thermal Shocks			Comments
					Since Beginning	Over Last Soak Period	10 °F/sec	20 °F/sec	30 °F/sec	
DEN1-1	Pt-W	10th series thermal shock pending	1200	2687	7.7	2.9	90	90	90	Outstanding life, satisfactory drift
DEN2-1	Pt-W	Out	1200	1780	2.1	2.7	53	50	50	Failed during 4th cycle, 10 °F/sec, 6th series
DEN4-2	Pt-W	4th series thermal shock pending	1200	1200	3.2	3.2	30	30	20	Good drift characteristics
DEN4-3	Pt-W	Same as above	1200	1200	3.0	3.2	30	30	20	Good drift characteristics
DEN4-4	Pt-W	Same as above	1200	1200	3.0	2.7	30	30	20	Good drift characteristics
DEN8-1	LMEC Composite	2nd series thermal soak pending	1200	311	1.5	1.5	10	10	10	Very good drift characteristics
DEN8-2	S700-Pt	Same as above	1200	311	1.5	1.5	10	10	10	Very good drift characteristics
DEN8-3	S700-Pt	Same as above	1200	311	1.5	1.5	10	10	10	Very good drift characteristics
DEN8-4	S700-Pt	Same as above	1200	311	1.8	1.8	10	10	10	Very good drift characteristics
DEN9-1	All S700 Alloy	3rd series load test pending	1200	610	2.1	1.6	20	20	20	Very good drift characteristics
DEN9-2	All S700 Alloy	Same as above	1200	610	2.5	1.8	20	20	20	Very good drift characteristics
DEN9-3	All S700 Alloy	Same as above	1200	610	2.2	1.7	20	20	20	Very good drift characteristics
DEN9-4	All S700 Alloy	Same as above	1200	610	2.4	1.8	20	20	20	Very good drift characteristics
DEN10-1	All S700 Alloy	Out	1200	610	8.1	13.7	20	20	20	Failed during 1st cycle of 3rd apparent strain
DEN10-2	All S700 Alloy	3rd series load test pending	1200	610	2.2	1.6	20	20	20	Very good drift characteristics
DEN11-1	All S700 Alloy	3rd series load test pending	1200	610	2.3	1.9	20	20	20	Very good drift characteristics
DEN11-2	All S700 Alloy	2nd series apparent strain test pending	1200	610	2.2	1.8	20	20	20	Very good drift characteristics
DEN12-1	Fe-Cr-Al	2nd series thermal soak pending	1200	291	1.3	1.3	10	10	10	Very good drift characteristics
DEN12-2	Fe-Cr-Al	Same as above	1200	291	1.3	1.3	10	10	10	Very good drift characteristics
DEN12-3	Fe-Cr-Al	Same as above	1200	291	1.3	1.3	10	10	10	Very good drift characteristics
DEN12-4	Fe-Cr-Al	Same as above	1200	291	1.3	1.3	10	10	10	Very good drift characteristics

TABLE 5
EVALUATION OF STRAIN GAGES
(Sheet 3 of 3)

Gage No.	Gage Description (Microdot Gages)	Present Status	Maximum Test Tem- perature (°F)	Total Thermal Soak Time (hr)	Drift Rate (microstrain/hr)		Total Number of Thermal Shocks			Comments
					Since Beginning	Over Last Soak Period	10 °F/sec	20 °F/sec	30 °F/sec	
MA1-1	SG423	8th series soak pending	950	1400	1.7	1.0	70	70	70	Very good drift characteristics
MA1-2	SG423	Same as above	950	1400	2.1	1.9	70	70	70	Under 750 microstrain mech- anical load (4th series)
ML1-1	SG420	6th series soak in progress	900	209	1.8	1.8	10	10	10	Very good drift characteristics
ML1-2	SG420		900	209	1.6	1.6	10	10	10	Very good drift characteristics
ML2-1	SG420		900	209	0.9	0.9	10	10	10	Under 750 microstrain mechanical load. Excellent drift characteristics
ML2-2	SG420		900	209	0.8	0.8	10	10	10	Under 750 microstrain mechanical load. Excellent drift characteristics
ML1-1	SG420		950	192	2.0	2.0	10	10	10	Good drift characteristics
ML1-2	SG420		950	192	3.5	3.5	10	10	10	Satisfactory drift characteristics
ML2-1	SG420		950	192	2.1	2.1	10	10	10	Under 750 microstrain mechanical load. Good drift characteristics
ML2-2	SG420		950	192	1.8	1.8	10	10	10	Very good drift characteristics
ML1-1	SG420		1000	192	5.2	5.2	10	10	10	Power failure — excessive drift
ML1-2	SG420		1000	192	4.1	4.1	10	10	10	Power failure — excessive drift
ML2-1	SG420		1000	192	4.6	4.6	10	10	10	Power failure — excessive drift
ML2-2	SG420		1000	192	-	-	10	10	10	Recording instrument failed
ML1-1	SG420		1050	198	1.6	1.6	10	10	10	Very good drift characteristics
ML1-2	SG420		1050	198	0.8	0.8	10	10	10	Excellent drift characteristics
ML2-1	SG420		1050	198	1.2	1.2	10	10	10	Very good drift characteristics
ML2-2	SG420		1050	198	5.8	5.8	10	10	10	Excessive drift characteristics
ML1-1	SG420		1100	200	1.9	1.9	10	10	10	Very good drift characteristics
ML1-2	SG420		1100	200	0.8	0.8	10	10	10	Excellent drift characteristics
ML2-1	SG420		1100	200	1.2	1.2	10	10	10	Very good drift characteristics
ML2-2	SG420		1100	200	1.8	1.8	10	10	10	Very good drift characteristics
ML1-1	SG420		1150	125	13.2	-	0	0	0	Excessive drift
ML1-2	SG420		1150	125	10.9	-	0	0	0	Excessive drift
ML2-1	SG420		1150	125	6.0	-	0	0	0	Excessive drift
ML2-2	SG420		1150	125	11.3	-	0	0	0	Excessive drift
MS1-1	SG425	1st series apparent strain	900	0	-	-	0	0	0	-
MS1-2	SG425	Same as above	900	0	-	-	0	0	0	-

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Program: Liquid Metal Engineering Center

Project: LMEC Laboratory Support

Project Manager: R. W. Dickinson

Project Engineer: R. K. Wagner

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693

Subaccount: 89110

I. PROJECT OBJECTIVES

The objectives of this project are: (1) to plan and execute a systematic metallurgical and chemical surveillance of materials and coolants used in the LMEC, (2) to maintain operating histories of the equipment to allow correlation of surveillance data with operating environments, and (3) to compile materials behavior data for large liquid metal heat transfer systems.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

The metallurgical and chemical laboratory has become operational and, during this period, performed principally in a service capacity. Routine sodium analyses and metallographic examinations were performed in support of other LMEC projects.

Installation, alignment, and calibration of the three-meter emission spectrograph was completed with the assistance of the manufacturer's service engineer.

Major consulting activities were confined to the SCTI program (steam line modification) and the Sodium Pump Seal Test (sodium vessels).

III. PROGRESS DURING REPORT PERIOD

A. CHEMICAL LABORATORY

A flame spectrophotometer obtained from surplus has been fully reconditioned and permanently installed in the chemical laboratory. Performance characteristics were subsequently established and two liquid metal standards (sodium and potassium) were analyzed. The potassium content of a proprietary cement was also determined. The spectrophotometer provides the laboratory

with a capability to determine metallic impurities (Fe, Cr, Ni, Ca, K) in sodium and minor alloy elements in structural materials (e.g., stainless steel).

The services of the manufacturer's technical representative were obtained to assist in the alignment and final adjustment of the recently installed three-meter emission spectrograph. The adjustments included the optical alignment and calibration of the instrument for wave lengths in the 2000 to 10,000 Å range. The capability of the instrument to cover this range is considered adequate for the anticipated analyses and will permit detection of those trace metallic impurities normally found in sodium, NaK, stainless steel, and other structural materials of interest.

Acceptance of the carbon train has been delayed by inconsistent and erratic performance. Initially, high blank values were obtained in early determinations where the high-temperature combustion - gas chromatography method was employed. The high blank values were due to a glassware defect which permitted the sweep gas mixture (oxygen/helium) to bypass the CO₂ absorbent. Replacement of the defective glassware resulted in satisfactory blank measurements. However, the performance when analyzing sodium samples continues to be erratic. Because blank values are satisfactory, the sample transfer technique is suspect and a reappraisal of this procedure is in progress. In support of this appraisal, samples have been procured from the sodium inventory used for the 1963 carbon-in-sodium round-robin.

Oxygen analyses were performed on sodium samples taken from a number of LMEC systems. These samples represent a wide variety of conditions:

- 1) 450 °F flowing sodium from the SCTI primary system
- 2) 1200 °F static sodium from the Precision Mechanisms in Sodium (PMIS) test systems
- 3) Frozen sodium (for 6 yr) from the cooler bypass line of ACTI (formerly HNPF Pump Test Loop).

A total of seven samples (24 determinations) have been analyzed. All of the determinations were made using the modified Pepkowitz amalgamation - titration method.* Sample removal and amalgamation procedures were performed in an atmosphere-controlled dri-box. Oxygen and moisture monitors

*Bolz, Kermoshchuk, and Meacham, "The Determination of Oxygen in Sodium Metal," APDA-168 (July 1965)

attached to the dri-box indicated levels of 0.6 ppm oxygen and 0.1 ppm moisture. Typical oxygen values for three of the seven samples are tabulated as follows:

<u>SCTI</u>	<u>ACTI</u>	<u>PMIS</u>
13.6	7.7	12.7
13.8	11.2	8.1
12.8	13.8	8.6
10.4	7.0	

These values agree with those expected for cold-trapped systems such as SCTI and ACTI. Recent plugging meter measurements at SCTI indicated an oxygen level of approximately 10 ppm. Oxygen values below 10 ppm were expected from the hot-trapped PMIS system. Based on the results obtained to date, the confidence level for this analytical capability is justifiably high.

Analytical services were provided to the Sodium Pump Seal Test project. These involved the chlorine content of a high-temperature lubricant and of an organic/graphite base heat transfer compound. Drillings from a submerged-arc weld were analyzed for composition.

B. METALLURGICAL LABORATORY

A total of 41 Type 304 stainless-steel pipe samples (4-in.-diameter discs) taken from HNPF sodium lines were submitted for metallographic examination. Twelve samples were prepared using standard mounting, grinding, and polishing techniques with no difficulties encountered. Preliminary examinations have not revealed any unusual microstructures or characteristics that could be attributed to sodium service. Evidence of sensitization was found in those sections taken from the high-temperature (900 °F) lines. Thin layers identified as corrosion products found on the inside and outside surfaces of the high-temperature sections are not considered unusual or significant.

Four sections of nickel and platinum clad strain gage wire were prepared and examined. These examinations were made to characterize the as-received quality and microstructure and to establish the effect of a thermal treatment at 1200 °F. There was no evidence of a reaction between the cladding and the core material.

Consultation services provided to the SCTI project included discussions with RDT-HQ regarding the stress corrosion experienced in the stainless-steel steam line and metallurgical problems related to the ferritic steel replacement piping. Of particular concern were a dissimilar metal weld joint (austenitic stainless-to-ferritic steel), the impact strength and transition temperature of all heats of the ferritic steel replacement piping, and a nickel alloy overlay at the existing steam generator outlet nozzle. Recommendations were made for joint qualification testing to verify the procedure for the Inconel-overlaid stainless-steel fusion weld joint.

Metallurgical and chemical services were also provided to the Sodium Pump Seal Test project. These involved a welding problem associated with the system's sodium containment tanks. In this case, the tank supplier used misidentified wire and flux to produce a submerged-arc weld joint. Metallurgical testing and subsequent analyses established that the deposited metal was of improper composition. This experience reinforces the growing concern over existing welding standards and specifications and provides firm support for a perceptive appraisal of their requirements and quality control provisions.*

The material surveillance phase of this project was initiated for the Sodium Pump Seal Test project with the partial delivery of representative seam welds and tank material. Laboratory characterization of the tank materials in this system will be completed after delivery of ring sections from the high-temperature (1200 °F) tanks. Sections of these materials will also be placed in the system for monitoring purposes.

IV. NEXT REPORT PERIOD ACTIVITIES

Metallurgical and chemical services and consulting activities will be provided to all other LMEC experimental and operating programs and to other LMFBR Program activities as required.

Exposure of the 18-18-2 stainless-steel samples in 1200 °F sodium should have accumulated sufficient time (3000 hr) to permit completion of this preliminary evaluation.

All samples representing the Sodium Pump Seal Test vessel material should be delivered and the laboratory characterization completed.

*Current reports from Dounreay regarding the apparent relationship between their NaK leak and a sub-standard weld lends additional support.

Program: Liquid Metal Engineering Center

Project: Maintenance of Temporarily Idle Equipment

Project Manager: R. W. Dickinson

Project Engineer: W. T. McSweeney

Reporting Period: January-March 1968

AEC Category: 04-01-61-03.8

General Order: 7693

Subaccount: 89200

I. PROJECT OBJECTIVES

The objectives of the project are to: (1) initiate a preventive maintenance program for major components of temporarily idle equipment at the LMEC, (2) maintain surveillance over the test installation to identify and correct unusual potential deterioration, and (3) provide material for maintenance and repair required to adequately preserve equipment.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

A new immersion heater was installed in the 3-in. sodium loop at the LCTL. Four hydraulic snubbers were installed to maintain the LCTL core tank in alignment during expansion, replacing four shackle and turnbuckle assemblies formerly used. A new differential pressure cell used to determine core tank sodium level was installed. Both process piping and electrical drawings of the LCTL have been updated to reflect the present as-built conditions. Procedures for preheating, filling, and operating the 6-by-8-in. sodium loop have been completed. Both sodium pumps were cleaned, inspected, and refurbished.

III. PROGRESS DURING REPORT PERIOD

Sodium was circulated in the 6-by-8-in. loop at the LCTL for a total of 270 hr at a maximum temperature of 630°F. A short circuit, caused by a defective solenoid, resulted in the automatic closing of a sodium flow control valve at the pump outlet. This action caused the pump case and internal assembly to become flooded with sodium, and sodium solidified, stalling the pump. As a result, the pump assembly was removed and steam cleaned. It was then reassembled, complete with new thermocouples and new bearings, and reinstalled in its normal operating position. The solenoid has been replaced with a new sealed operating coil.

The 2-by-3-in. pump was also removed for cleaning and inspection. Several thermocouples were replaced, running clearances were checked, new bearings installed, and the entire assembly replaced in normal operating position.

Compressed air supply to the differential pressure gages for the three sodium tanks was revised to permit individual isolation of the three cells when repairs are required.

Three new piping and instrumentation diagrams were prepared in connection with the updating of the LCTL drawings to current as-built conditions. These three drawings cover the sodium heat transfer and service piping, the cooling water piping, and the inert gas and instrument air piping. New plan elevation drawings of the sodium system piping, a new valve list, and sodium line lists were also completed. The rest of the updating work has been terminated both for budgetary reasons and because of possible system changes resulting from plans for LMFBR testing work.

IV. NEXT REPORT PERIOD ACTIVITIES

The 3-in. and the 6-in. sodium loops will be filled and sodium circulated at the rated temperature for each loop. Routine preventive maintenance will continue on regular schedule.

APPENDIX A
PROPOSED CATEGORY NOMENCLATURE
FOR FAILURE AND MALFUNCTION REPORTING
AND EXAMPLES OF USE

APPENDIX A

PROPOSED CATEGORY NOMENCLATURE FOR FAILURE AND
MALFUNCTION REPORTING AND EXAMPLES OF USE

The EAM (Electric Accounting Machine) card format and associated failure category nomenclature definitions (see Figure A-1) are for digital recording and sorting and for tabular publication of data on sodium system and associated area failures. These categories constitute a complete description of the system, subsystem, component, part, and environmental design parameters as indicated on the EAM card format. It is anticipated that any failure which may be encountered at a given facility will be describable as having a cause of failure, a mode of failure, and an effect resulting from this failure mode. These can be treated successively such that the result of failure of the first mode may be the cause of failure of the second mode, and so on until the failure has attained a complete description.

The data contained herein are the result of LMEC staff comments and a search of the literature on metallurgical failure mode terms. Categories, as selected, however, are intended to be applicable to failure classification of all systems and components in any type of nuclear power reactor plant.

Three somewhat complex failures were selected as examples and are included for clarification of the proposed application. Each failure is described in the following paragraphs; the associated subtleties and sequences of each are graphically represented in simple fault trees; and its interpretation and pertinent associated data are recorded on a tabular format. An explanation of fault tree symbols is shown in Figure A-2.

1. Corrosion on Secondary Expansion Tank - HNPF*

The fault tree analysis of this failure is shown in Figure A-3; an interpretation and pertinent associated data are given in Table A-1.

On October 18, 1964, a puddle of sodium was discovered on the floor under the expansion tank located in the secondary sodium loop No. 3. Draining, insulation removal, and cleanup of large glacier-like globs of reaction products from the pipe and tank surface was followed by detailed examination of the area.

*R. K. Wagner and J. D. Stearns, "Evaluation of Non-Fuel Material Behavior in HNPF," Proceedings of Sodium Components Development Program Information Meeting, CONF-650620 (June 1965)

To determine the cause of failure, a section of the vessel wall, the 8-in.-diameter nozzle, and a section of the 8-in.-diameter overflow line were removed from the tank along with a portion of the baffle section, which was joined by fillet welds to the vessel wall and bottom head. On these sections, the severity of the corrosive attack, at the exterior reactant-tank wall interface was very apparent. In general, the gross attack was localized and took the form of grooves where in some areas the depth was half the vessel wall thickness, 1/4 in. deep. The internal surfaces, vessel, nozzle, and overflow pipe were clean. There was no evidence of either corrosive attack or built-up deposits.

Before sectioning the tank, pressure testing quickly isolated the pinhole leak which had developed in the nozzle portion of the overflow line. Location of the pinhole leak was found in the overflow nozzle at the 8 o'clock position. It was located 1/2 in. away from the circumferential butt weld joining the nozzle to the overflow pipe. This was an area where the corrosion of the external surfaces appeared to be severe.

Dye penetrant and radiographic examinations were performed on the section removed from the tank. The existence of the pinhole, previously defined, was confirmed. In addition, a series of cracks across the vessel wall, in the region of the baffle, was revealed.

During the sectioning and preparation of the metallurgical samples, the following observations were made:

- 1) The visible cracks in the section containing the baffle, fillet welds, and the vessel wall increased in width suggesting high residual stresses.
- 2) The cavity between the baffle and vessel wall contained a hard residue, black in color. This residue, when in contact with water or alcohol, produced reactions typical of a sodium-bearing deposit. Similar behavior was noted in those areas containing cracks.

Examination of the section containing the baffle, vessel wall, and fillet welds revealed a massive network of cracks, principally transgranular in nature. The type of cracks discovered are typical of stress-corrosion cracking found in austenitic stainless steels.

The most revealing information was developed on that deposit taken from the cavity between the baffle and vessel wall. Analysis of the composition of the coatings taken from two sample welding electrodes showed striking similarity to the depos

The most important elements found in the samples analyzed include chlorine and fluorine. Both of these elements are regarded as significant contributors to the stress corrosion of austenitic stainless steels.

The shell stresses were calculated for that region of the shell near the 8-in.-diameter overflow nozzle. Conditions considered included: (1) the basic design, (2) the normal operating conditions, (3) the stiffening effect of the baffle, and (4) the loose (unloaded) condition of the overflow pipe support existing during this operation. A stress of 135,000 psi was calculated, assuming no shell flexibility due to the close proximity of the baffle to the nozzle. The magnitude of the calculated stress is sufficient to warrant consideration as a factor contributing to the stress-corrosion failure discovered in the vessel wall.

It is concluded that:

- 1) The primary leak that developed in the HNPF Expansion Tank No. 3 was caused by stress-corrosion cracking. The cracking occurred in an area of high stress where a cavity, containing a highly corrosive deposit, existed. The deposit has been identified as residual flux from coated welding electrodes.
- 2) A secondary leak developed in the wall of the overflow nozzle as a result of gross attack by the sodium reaction products produced from the sodium released through the primary leak.

2. EBR-II*

The fault tree analysis of this failure is shown in Figure A-4; an interpretation and pertinent associated data are given in Table A-2.

a. Sticking of Control Rod and Oscillator Drive Mechanisms

Investigation of the scram on October 19 showed that the scram was initiated by a malfunction of a relay and was not due to a scram signal. Two control mechanisms, No. 7 and 9, did not drop as called for in a scram. Investigation of the cause was started immediately.

*M. Novick, "Argonne National Laboratory, Reactor Development Program Progress Report," ANL-6965, -6977, -7017 (October 1964, November 1964, February 1965). Also L. P. Barnes, "EBR-II Operating Data Report" (August 5, 1965)

When the primary tank had cooled to 580°F, the sticking No.7 control rod shaft was removed. Inspection showed that small steel balls, about 1/8 in. in diameter, had caused the binding in the reactor vessel cover. Control drive shaft No.9 was also removed, and a similar binding situation was found. The balls apparently came from one or both of the linear ball bushings that failed in the oscillator drive shaft. Presumably, the ball bearings were dislodged from the oscillator shaft and came to rest in the 0.030-in. diametral clearance between the control rod drive shaft labyrinths and the Stellite sleeves in the reactor vessel cover.

When the oscillator drive mechanism was disconnected from the oscillator rod, the rod was stuck in the oscillator thimble.

The oscillator rod and thimble and control rod thimble No.8 were examined in a shielded cell. After disassembly, no debris was found except small ball bearings from the lower guide bushing of the oscillator drive. The oscillator guide thimble and the control rod guide thimble had seized because three balls jammed above the upper piston of the oscillator rod guide thimble. The scoring marks were comparatively light. Four balls were found above the lower piston, but this section had not seized. One ball was found in the spring plunger cavity.

The oscillator rod was jammed by 19 balls in the lower portion of the guide sleeve. Very heavy scoring was observed in two of the three lower guides on the oscillator rod and in the corresponding guide slots of the guide tube. Some fairly heavy scoring marks were also observed on the oscillator rod and lower guide tube above the lower oscillator rod guide. A total of 27 balls were found during disassembly.

Possible binding of the 11 control rods in the reactor grid was checked by raising each rod manually 51 in. All were raised and lowered easily without indication of any binding. Control rod drives No. 7, 8, and 9 were installed. Check of control rod drive grippers and sensing rod functions for all 12 rods was then completed.

b. Condensate Storage Tank Valve P5-VC-620*

The fault tree analysis of this failure is shown in Figure A-5; an interpretation and associated data are given in Table A-2.

*J. D. Leman, "Plant Modification and Maintenance Report," No.25 (April 16, 1965) (unpublished internal document)

Valve P5-VC-620 (located between the condensate storage tank and No. 2 heater) was reported to be leaking through and "heating up" the condensate storage tank. The valve was disassembled, and it was found that the upper and lower stems and bushing were galled; also, a piece of stellite was broken out of the valve seat. It appears that a piece of weld rod, or something similar, had been previously lodged in the valve. Spare parts were not available to repair the valve, so it was reassembled with the original pieces. Some leakage is bound to occur, but will not prevent plant operation. New parts have been ordered.

1.	Facility	41.	Component Replacement
2.	Identification		Functional Importance Order
3.		42.	
4.		43.	Report Number
5.		44.	
6.	Month and Day	45.	Type of Report
7.		46.	
8.		47.	
9.	Year	48.	ID No. of the Subsystem/Component
10.		49.	
11.		50.	
12.		51.	
13.	System and Subsystem	52.	Number of Previous Failures of This
14.		53.	Component
15.		54.	Quantity of Identical Components at
16.		55.	Facility
17.		56.	
18.		57.	Vendor
19.		58.	
20.	Component/Part Identification	59.	Time Since Last Inspection or
21.	Environmental Classification	60.	Maintenance – days
22.	XXXX.XX.XX.XX	61.	
23.		62.	Total Operating Time on
24.		63.	Component/Part – days
25.		64.	
26.		65.	
27.		66.	Component Repair – man days
28.	Cause of Failure	67.	
29.		68.	
30.	Mode of Failure	69.	Repair Time – days
31.		70.	
32.		71.	Total Time No Heat
33.	Effect of Failure	72.	Generation – days
34.		73.	
35.	Method of Failure Detection	74.	Additional Time Generator or Rig
36.	Malfunction Importance	75.	is Off – days
37.	(Safety Implication)	76.	Facility Operation Condition
38.	Corrective Action – Performed	77.	Temperature Peak (Local)
39.	Corrective Action –	78.	Power Peak
	Recommended for Future	79.	Card Identification
	Sequence order of Failure if a	80.	
40.	Cascading Series (i.e., 1st, 2nd,		
	3rd, etc.) in same event		

Figure A-1. EAM Card Format and Failure Category
Nomenclature Definitions
(Sheet 1 of 16)

CAUSE OF FAILURE – COLUMNS 27 TO 29

	<u>27</u>	<u>28</u>	<u>29</u>
Environmental	1	0	0
Deficiency – Mechanical Process	1	1	0
Coolant loss	1	1	1
Coolant reduction	1	1	2
Level low	1	1	3
Lubrication loss or deficiency	1	1	4
Pressure loss	1	1	5
Pressure negative vacuum/low	1	1	6
Mechanical support	1	1	7
Temperature low	1	1	8
Thermal power reduction or dip	1	1	9
Other	1	1	z
Dynamic Stress/Fatigue/ Wear	1	2	0
Crack propagation (incipient cracks)	1	2	1
Pressure cycle	1	2	2
Thermal cycle	1	2	3
Normal cyclic loading (working stress)	1	2	4
Wear (normal degradation)	1	2	5
Wear (excessive)	1	2	6
Vibration (resonance)	1	2	7
Vibration (excessive – nonresonance)	1	2	8
Other	1	2	z
Fluid/Effluent/Chemical Reaction Product Release	1	3	0
Caustic release	1	3	1
Halogen ion release	1	3	2
Hydrogen release	1	3	3
Leak (external)	1	3	4
Leak (internal)	1	3	5
Radiological release	1	3	6
Run (viscous fluid – solder, resin, etc.)	1	3	7
Spill	1	3	8
Toxic release	1	3	9
Other	1	3	z
Dynamic Malfunction (position or directional)	1	4	0
Closed	1	4	1
Dropped/fell over/fell on or in	1	4	2
Lowered	1	4	3
Opened	1	4	4
Operation continuation required with degraded component	1	4	5
Raised	1	4	6
Rotated	1	4	7
Swung or shifted	1	4	8
Worked loose	1	4	9
Other	1	4	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 2 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
Transients — Electrical	1	5	0
Current surge	1	5	1
Voltage surge	1	5	2
Voltage dip	1	5	3
Voltage oscillation	1	5	4
Frequency disturbance transient	1	5	5
Power loss	1	5	6
Erroneous circuit activation	1	5	7
	1	5	8
	1	5	9
Other	1	5	z
Electrical — Steady-State or Slow Drift	1	6	0
Power overload	1	6	1
Power low	1	6	2
Voltage high	1	6	3
Voltage low	1	6	4
Frequency shift	1	6	5
Frequency harmonic or steady disturbance superimposed on normal frequency	1	6	6
	1	6	7
	1	6	8
	1	6	9
Other	1	6	z
Overload Transients — Mechanical Process	1	7	0
Flow surge or pulse	1	7	1
Force — excessively applied	1	7	2
Power surge	1	7	3
Pressure surge	1	7	4
Shockwave or waterhammer	1	7	5
Temperature surge	1	7	6
	1	7	7
	1	7	8
	1	7	9
Other	1	7	z
Overload — Static or Slowly Changing Mechanical Process	1	8	0
Creep	1	8	1
Flow (high magnitude)	1	8	2
Level high	1	8	3
Power (thermal)	1	8	4
Pressure	1	8	5
Speed excessive	1	8	6
Temperature	1	8	7
Thermal ratcheting	1	8	8
Weight excessive	1	8	9
Other	1	8	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 3 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
Process Dynamic Malfunction	1	9	0
Base metal oxide precipitation	1	9	1
Cavitation	1	9	2
Flow (critical)	1	9	3
Flow (high velocity)	1	9	4
Liquid metals oxide precipitation	1	9	5
Power (oscillations)	1	9	6
Vibration or oscillation (no stress)	1	9	7
Dislocated component free to circulate	1	9	8
Other	1	9	z
Impurity Abnormality	2	0	0
In Gas System	2	1	0
Air	2	1	1
Ammonia	2	1	2
Carbon dioxide/monoxide	2	1	3
Hydrogen	2	1	4
Halogen	2	1	5
Nitrogen	2	1	6
Oxygen	2	1	7
Liquid metal vapor condensation	2	1	8
Water vapor condensation	2	1	9
Other	2	1	z
In Gasket Material	2	2	0
Halogens	2	2	1
	2	2	2
	2	2	3
	2	2	4
	2	2	5
	2	2	6
	2	2	7
	2	2	8
	2	2	9
Other	2	2	z
In Insulation Material	2	3	0
Alcohol	2	3	1
Caustic compound	2	3	2
Cleaning solvent	2	3	3
Oil	2	3	4
Liquid metal	2	3	5
Moisture — atmosphere condensation	2	3	6
Water	2	3	7
	2	3	8
	2	3	9
Other	2	3	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 4 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
In Liquid Metals	2	4	0
Air	2	4	1
Grit	2	4	2
Hydrogen	2	4	3
Iron, etc.	2	4	4
Nitrogen	2	4	5
Oil	2	4	6
Oxygen	2	4	7
Water/steam	2	4	8
	2	4	9
Other	2	4	z
In Metals	2	5	0
	2	5	1
	2	5	2
	2	5	3
	2	5	4
	2	5	5
	2	5	6
	2	5	7
	2	5	8
	2	5	9
Other	2	5	z
In Water	2	6	0
Air	2	6	1
Carbon	2	6	2
Grit	2	6	3
Halogen	2	6	4
Iron, etc.	2	6	5
Oil	2	6	6
Acid (pH, high)-	2	6	7
Alkaline (pH, low)	2	6	8
Sodium/Nak	2	6	9
Other	2	6	z
Human Error	3	0	0
Maintenance Judgment Error	3	1	0
Component substitution authorization error	3	1	1
Failure detection method inadequate	3	1	2
Inspection period too long	3	1	3
Materials substitution authorization error	3	1	4
Component cleaning method	3	1	5
	3	1	6
	3	1	7
	3	1	8
	3	1	9
Other	3	1	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 5 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
Maintenance Repair Error	3	2	0
Assembly error	3	2	1
Adjust/setting error	3	2	2
Emergency repair uncorrected	3	2	3
Electrical terminal connected loose/wrong	3	2	4
Material/component wrong	3	2	5
Mechanical attachment loose/wrong	3	2	6
Unsafe action or procedure	3	2	7
Workmanship poor, material left in system	3	2	8
Misuse of equipment	3	2	9
Other	3	2	z
Operation Error	3	3	0
Action (unintentional)	3	3	1
Calculation of parameter error	3	3	2
Control adjustment	3	3	3
Emergency response wrong	3	3	4
Failed to act (omission)	3	3	5
Monitoring equipment hookup or calibration error	3	3	6
Operation or relocation position error	3	3	7
Setting adjustment	3	3	8
Misuse of equipment	3	3	9
Other	3	3	z
Supervisory or Management Error	3	4	0
Operation continuation economic risk decision following indication of wear	3	4	1
Unqualified personnel assigned to task with inadequate instruction or supervision	3	4	2
Procedure nonexistent	3	4	3
Procedure deficiently prepared	3	4	4
Procedure instructions not specified	3	4	5
Procedure compliance not verified	3	4	6
Warehouse inadequately stocked	3	4	7
Preventive maintenance or inspection inadequacy	3	4	8
Indecision	3	4	9
Other	3	4	z
Inherent (infant or break-in failure)	4	0	0
Design, Functional Inadequacy	4	1	0
Coolant or insulation provision	4	1	1
State-of-the-art knowledge deficiency	4	1	2
Expansion or clearance provision	4	1	3
Lubrication provision	4	1	4
Protective action provision (protective system)	4	1	5
Supports or hangers inadequate	4	1	6
System/component functional compatibility, mounting location, or selection	4	1	7
Thermal gradient distortion or cycle analysis	4	1	8
Vibration damping provision	4	1	9
Other	4	1	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 6 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
Design, Safeguards Inadequacy	4	2	0
	4	2	1
	4	2	2
	4	2	3
	4	2	4
	4	2	5
	4	2	6
	4	2	7
	4	2	8
	4	2	9
Other	4	2	z
Design, Human Factors Inadequacy	4	3	0
Accessibility of equipment for operation or maintenance	4	3	1
Audio aids (emergency)	4	3	2
Automation inadequacy or nonexistent	4	3	3
Control console and instrumentation layout (motion/complexity)	4	3	4
Patch/test assemblies complexity	4	3	5
Personnel selection (intelligence, health, color blind, etc.)	4	3	6
Training	4	3	7
Visual aids (emergency)	4	3	8
Visual aids (operations, color coded, etc.)	4	3	9
Other	4	3	z
Material Selection Error	4	4	0
Ductility excessive	4	4	1
Environmental effects improperly analyzed	4	4	2
State-of-the-art knowledge deficiency	4	4	3
Hardness excessive	4	4	4
Incompatible material	4	4	5
Chemical or isotopic control specification poor	4	4	6
Segregation control specification poor	4	4	7
Surface finish or crack control specification poor	4	4	8
Other specification deficiency	4	4	9
Other	4	4	z
Manufacture/Fabrication	4	5	0
Manufacturer unqualified	4	5	1
Material used, below specification	4	5	2
Material used, wrong	4	5	3
Method, process or specification deficient	4	5	4
State-of-art new	4	5	5
Workmanship poor (tolerance not adhered to, etc.)	4	5	6
Material sensitized	4	5	7
Heat treatment poor or improper (include stress relief, etc.)	4	5	8
	4	5	9
Other	4	5	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 7 of 16)

	<u>27</u>	<u>28</u>	<u>29</u>
Product Control Inadequate	4	6	0
Contractor/vendor qualification check, none - poor	4	6	1
Construction/installation control by contractor - poor	4	6	2
Field inspection - poor	4	6	3
Life tests or R&D inadequate	4	6	4
Program/user control generally poor	4	6	5
Source inspection, acceptance tests - poor	4	6	6
Standards poor or nonexistent	4	6	7
Vendor's control poor	4	6	8
Receiving inspection and QC poor	4	6	9
Other	4	6	z
Construction/Installation Error	4	7	0
Construction method or specification deficient	4	7	1
Initial startup or shakedown problem	4	7	2
Installation method or specification deficient	4	7	3
Material used, deviated from specification	4	7	4
Material used, wrong	4	7	5
Safety standard (guards, etc.) not adhered to	4	7	6
Weather exposure on nonweatherproof equipment	4	7	7
Workmanship poor or untrained	4	7	8
Foreign object or material left in system	4	7	9
Other	4	7	z
Natural Phenomena	9	0	0
Earthquakes	9	1	0
Fire	9	2	0
Lightning	9	3	0
Water	9	4	0
Flood	9	4	1
Rain	9	4	2
Sleet	9	4	3
Snow	9	4	4
Tide	9	4	5
Tsunami	9	4	6
Wind	9	5	0
Excessive	9	5	1
Sandstorm	9	5	2
Tornado or hurricane	9	5	3
Unknown	9	z	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 8 of 16)

MODE OF FAILURE – COLUMNS 30 AND 31

	30	31
Electrical	1	0
Arching/ionization/corona	1	1
Burned out	1	2
Circuit shortout or grounded/primary fault	1	3
Circuit intermittent – loosened connection or capacitive breakdown	1	4
Circuit shorted to other circuit	1	5
Fuse blown	1	6
Overheated component	1	7
Resistivity loss (low megger)/leakage	1	8
Wear out or degradation	1	9
Other	1	z
Electrical Functional	2	0
Open circuit	2	1
Cross-current loading	2	2
Hunting – erratic operation	2	3
Ground potential nonuniform	2	4
Nonoperational	2	5
Operation improper or slow	2	6
Synchronization loss	2	7
Runaway	2	8
Magnetic depletion or loss	2	9
Other	2	z
Chemical Reactions	3	0
Acid formation	3	1
Caustic formation	3	2
Fire/smoke (carbon-oxygen)	3	3
Fire/smoke (liquid metal - oxygen)	3	4
Hydrogen - oxygen (explosion)	3	5
Oxygen - iron (rust)	3	6
Water - liquid metal	3	7
Water - aluminum	3	8
Water - zirconium	3	9
Other	3	z
Instrumentation Function	4	0
Calibration faulty	4	1
Drift	4	2
Operation faulty or nonoperative	4	3
Output in error	4	4
Sensitivity loss	4	5
Setting in error due to instrument malfunction	4	6
Shutdown	4	7
Spurious scram	4	8
Spurious alarm	4	9
Other	4	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 9 of 16)

	30	31
Mechanical	5	0
Clog/blockage/plug/restrict flow	5	1
Degradation	5	2
Disconnection or loose	5	3
Distortion (bowing, bending, oscillation, vibration, etc.)	5	4
Jammed/stuck/inoperative/movement obstruction	5	5
Misalignment	5	6
Seizure	5	7
Wearout/aged (includes noisy operation)	5	8
Ruptured/broken	5	9
Other	5	z
Metallurgical – Physical (except fracture)	6	0
Crack generation/propagation	6	1
Deformation	6	2
Embrittlement	6	3
Erosion (cavitation, etc.)	6	4
Erosion (fluid impingement attack)	6	5
Melt	6	6
Porous	6	7
Scored/galled	6	8
Yielded	6	9
Other	6	z
Metallurgical – Physical Fracture (complete separation)	7	0
Brittle – anisotropy	7	1
Brittle – inherent or segregation	7	2
Brittle – notch or crack	7	3
Ductile – creep	7	4
Ductile – overload	7	5
Embrittlement – hydrogen or nitrogen (including work hardening and fatigue)	7	6
Embrittlement – caustic	7	7
	7	8
	7	9
Other	7	z
Metallurgical – Composition Change (no fracture)	8	0
Carburization	8	1
Decarburization	8	2
Film (protective) depletion	8	3
Hydrided	8	4
Nitrided	8	5
Rust (oxidized)	8	6
Surface deposition (mass transfer)	8	7
Radiation hardening (NDT change)	8	8
	8	9
Other	8	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 10 of 16)

	<u>30</u>	<u>31</u>
Metal Corrosion	9	0
Uniform (general, direct attack)	9	1
Pitting	9	2
Selective solution (preferential attack)	9	3
Stress corrosion	9	4
Fretting (vibration activated)	9	5
Corrosion fatigue	9	6
Crevice	9	7
Galvanic	9	8
Unidentified	9	9
Other	9	z
Reactivity Change Mechanism	A	0
Bowling, fuel element	A	1
Bowling, reflector element	A	2
Channel voiding (boiling/large gas bubbles/etc.)	A	3
Cold shock	A	4
Control element shift, drop, or rotation	A	5
Core rearrangement	A	6
Gas entrainment	A	7
Hot shock	A	8
Other	A	9
Other	B	0
Burned	B	1
Decomposed	B	2
Degassed	B	3
Disintegrated	B	4
Dried out	B	5
Soaked	B	6
Closed	B	7
Opened	B	8
Radiological contamination	B	9
Undiagnosed	B	z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 11 of 16)

EFFECT OF FAILURE – COLUMNS 32 TO 34

	32	33	34
Environmental	1	0	0
Deficiency – Mechanical Process	1	1	0
Coolant loss	1	1	1
Coolant reduction	1	1	2
Level low	1	1	3
Lubrication loss or deficiency	1	1	4
Pressure loss	1	1	5
Pressure/negative vacuum/low	1	1	6
Mechanical support	1	1	7
Temperature low	1	1	8
Thermal power reduction or dip	1	1	9
Other	1	1	z
Dynamic Stress/Fatigue/Wear	1	2	0
Crack propagation (incipient cracks)	1	2	1
Pressure cycle	1	2	2
Thermal cycle	1	2	3
Normal cyclic loading (working stress)	1	2	4
Wear (normal degradation)	1	2	5
Wear (excessive)	1	2	6
Vibration (resonance)	1	2	7
Vibration (excessive – nonresonance)	1	2	8
Other	1	2	9
Other	1	2	z
Fluid/Effluent/Chemical Reaction Product Release	1	3	0
Caustic release	1	3	1
Halogen ion release	1	3	2
Hydrogen release	1	3	3
Leak (external)	1	3	4
Leak (internal)	1	3	5
Radiological release	1	3	6
Run (viscous fluid – solder, resin, etc.)	1	3	7
Spill	1	3	8
Toxic release	1	3	9
Other	1	3	z
Dynamic Malfunction (position or directional)	1	4	0
Closed	1	4	1
Dropped/fell over/fell on or in	1	4	2
Lowered	1	4	3
Opened	1	4	4
Operation continuation required with degraded component	1	4	5
Raised	1	4	6
Rotated	1	4	7
Swung or shifted	1	4	8
Worked loose	1	4	9
Other	1	4	z

(Continue identical to Cause of Failure through classification 4 7 z.)

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 12 of 16)

	32	33	34
General System or Component Effect	5	0	0
Acceptable incipient damage (no requirement for repair)	5	1	0
Plant availability loss (check Malfunction Importance)	5	2	0
Labor and material loss only	5	3	0
Elastic stress only	5	4	0
System/component inoperative	5	5	0
Personnel injury (check Malfunction Importance)	5	6	0
Potential injury to personnel	5	7	0
Potential damage to equipment	5	8	0
No effect	5	9	0
Transient Disturbance Only	6	0	0

METHOD OF FAILURE DETECTION – COLUMN 35

	35
Not used	0
Alarm	A
Audio noise	B
Direct observation (unprogrammed)	C
During routine inspection	D
During preventive maintenance	E
During repair of primary component	F
During repair or inspection of associated system	G
Operational monitors	H
Protective system	I
Routine area watch – direct observation	J
Routine instrument reading – direct observation	K
Vibrational frequency monitoring system	L
Other	Z

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 13 of 16)

MALFUNCTION IMPORTANCE – COLUMNS 36 TO 37

	<u>36</u>	<u>37</u>
Malfunctions or Actions Which Place the Reactor or Plant in a Dangerous State	1	0
Resulting in significant hazard and/or damage to reactor	1	1
Resulting in significant hazard and/or damage to plant	1	2
Resulting in significant hazard or damage to plant and in personnel injury	1	3
Prevented from resulting in significant hazard or damage to reactor or plant or personnel by circumstances outside those envisaged in the equipment design (inherent shutdown mechanism)	1	4
Prevented from resulting in significant hazard or damage to reactor or personnel by the ultimate available protection	1	5
Malfunctions or Actions Which Reduce Reactor Safety	2	0
Failure to operate of any trip equipment which reduces reactor safety	2	1
Malfunctions or actions affecting the correct functioning of important plant equipment (other than trip equipment) which reduces reactor safety (non-failsafe malfunctions)	2	2
Incorrect adjustment of plant trip levels which reduces reactor safety	2	3
Malfunctions or actions which by themselves have not reduced reactor safety but have occurred so frequently as to raise doubts on the safety of the system, whether mechanical or human	2	4
Error by operator in the control of important plant equipment which reduces reactor safety	2	5
Manual trip required	2	6
Malfunctions or Actions Which Do Not Reduce Safety	3	0
Malfunctions or actions which do not reduce safety when considered separately (failsafe malfunctions)	3	1
Reactor trip – functioned correctly	3	2
Reactor trip – spurious	3	3

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 14 of 16)

	<u>36</u>	<u>37</u>
Faults found during routine testing	3	4
Giving rise to high maintenance attention	3	5
Incorrectly displayed information	3	6
Incorrectly annunciated information	3	7
Power setback	3	8
Availability and Management Effect Only	4	0
Time loss due to lack of spare parts	4	1
Time loss due to startup prevention	4	2
Time loss due to requirement to shut down	4	3
Plant efficiency loss due to downgrading or cutback	4	4
Plant efficiency loss due to loop or section shutdown	4	5
Personnel Injury with No Effect upon Plant Operation or Reactor Safety	5	0
Personnel injury without time loss	5	1
Personnel injury with time loss	5	2
Radiation exposure, excessive with physical damage	5	3
Radiation exposure, excessive without serious physical damage	5	4
Problems (not describable in above categories)	6	0
Operating problems	6	1
Maintenance problems	6	2
Functional problems	6	3

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 15 of 16)

CORRECTIVE ACTION PERFORMED – COLUMN 38
CORRECTIVE ACTION RECOMMENDED – COLUMN 39

<u>Corrective Action – Performed</u>	<u>38</u>
None	0
Component Part Replaced	A
Component or Circuit Corrective Modification	B
Information Display Change	C
Local Repair	D
Maintenance Procedure or Schedule Change	E
Operating Limits Change	F
Operational Procedure or Training Change	G
System Design Change	H
Temporary Reassemble for Continued Operation (no parts)	I
Temporary Repair or Jury Rig (time postponement)	J
Vendor Design Modification	K
Vendor Repair of Component	L
<u>Corrective Action – Facility Recommendation for Future</u>	<u>39</u>
None	0
Change Operating Procedures	A
Correct Poor Design Methods	B
Design Modification to Part or Circuit	C
Improve Display Information	D
Improve Maintenance Procedure and Training	E
Improve Maintenance Schedule	F
Increase Redundancy	G
Materials – Select for Environment	H
Quality Assurance Needs Improvement	I
Reduce Procurement Lead Time or Increase Spares	J
Reduce Operating Limits	K
Reliability Acceptance Procedure Need Improvement	L
Standards Need Improvement	M
System Redesign	N
Vendor Improve Future Design	O
Vendor Redesign and General Replacement	P

Figure A-1. EAM Card Format and Failure Category Nomenclature Definitions
(Sheet 16 of 16)

Figure A-2. Explanation of Fault Tree Symbols

7693-2520

Figure A-3. Fault Tree for HNPF Expansion Tank Failure

7693-2521

Figure A-4. Fault Tree for EBR-II Oscillator and Control Rod Drive Mechanism Failure

7693-2522

Figure A-5. Fault Tree for EBR-II Condensate System
Valve P5-VC-620 Failure

TABLE A-1

MALFUNCTION, MAINTENANCE, OR PROBLEM ANALYSIS DATA

FACILITY HNPF

*Legend: F = Fundamental
M = Maintenance
P = Problem

Sheet 1 of 2

Sequence and Order*	Component/Part ID No. System/Subsystem ID No. & Size	Event Description				Corrective Action	
		1) Data Source - Date 2) Date of Event 3) Detection Method	Cause of Failure	Mode of Failure	Effect of Failure	1) Performed 2) Total Repair Time 3) Total Operating Time 4) Facility Recommendation	LMEC Engineering Analysis and Recommendations
1F ₁	Tank Baffle/Weld Secondary Sodium System/ Expansion Tank/3-300 ft ³ Type 304 SS	1) Conf 650620, p. 42 6-16-65 and personnel communication 2) 10-18-64 3) Routine instrumentation reading Direct Observation (No. K)	"Fabrication—Method process or specification deficient," (No. 454). Weld flux material deposited behind baffle plate during fabrication; also moisture in contact with flux material. Moisture source unknown.	"Chemical reaction" (No. 3Z)	"Halogen ion release" (No. 13Z)	1) "None" (No. 0). Tank removed from system 2) "Not repaired" 3) 15,000 hr	More rigid weld specifications and controls to include full penetration welds. All welds on sodium system must be regarded as containment welds. Nondestructive testing requirements expanded to include dye-penetrant and radiography of root passes as well as the final pass.
1F ₂	Pipe/Hanger		"Preventive maintenance or inspection inadequacy" (No. 348)	"Loose" (No. 52)	"Mechanical support deficiency" (No. 118)		Establish procedures for routine maintenance. It was observed that the pipe hangers on tanks 1 and 2 were also loose.
2F	Tank/Wall		"Halogen ion release" (No. 13Z) and "Mechanical support deficiency" (No. 118)	"Stress corrosion" (No. 94) — Cracking	"Leak" (external) (No. 134) — Minor		
3F	Tank/Insulation/Hydrated Calcium Silicate		"Leak" (external) (No. 134) — Moisture source in insulation	"Caustic formation" (No. 32)	"Caustic release" (No. 131)		Do not use hydrated insulation on sodium piping.
4F	Tank/Nozzle — 8 in. overflow		"Caustic release" (No. 131)	"Uniform corrosion, general attack (No. 91)	"Leak" (external) (No. 134) — Gross		Establish procedures for routine area watch in accessible sodium system areas.

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TABLE A-1

MALFUNCTION, MAINTENANCE, OR PROBLEM ANALYSIS DATA

FACILITY HNPf

Sheet 2 of 2

1) No Heat Generation 2) Generator Off (days) 3) Repair (man-hours)	Time Since Last Inspection or Maintenance (days)	Malfunction Importance (safety implication)	1) Identical Units at Facility 2) Previous Failures of Unit	Normal Environmental Operating Condition of Component (rating)	Facility Operating Condition	Comments
1) Plant shut down in September and was not restarted 3) Plant decommis- sioned; not repaired	No routine main- tenance established.	Resulting in significant hazard and damage to plant (No. 12)	1) Three 2) None	During normal power genera- tion, the secondary hot-leg temperature was 915°F with the pressure in the tank at 19 psig.	At the time the leak was discovered, the loop was isothermal at 415°F. The pressure in the expansion tank was 18.5 psig.	Unknown factors: (1) when leak originated (life of leak prior to detection - hours, weeks, months); (2) source of moisture, if required, for initia- tion of stress corrosion; and (3) when stress cor- rosion initiated (storage after mfg, during instal- lation, and operation). Subsequent ultrasonic inspection of 2 unfailed tanks showed indications similar to the crack in- dications found on sec- tions of failed tank. Gross attack on external surfaces aroused sus- picion that thermal in- sulation may have con- tributed by reaction with leaking sodium. While detailed metal- lurgical analyses was performed, no controlled lab verification test was performed to confirm failure mechanism as postulated.

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TABLE A-2

MALFUNCTION, MAINTENANCE, OR PROBLEM ANALYSIS DATA

FACILITY EBR-II

*Legend: F = Fundamental
M = Maintenance
P = Problem

Sheet 1 of 2

Sequence and Order *	Component/Part ID No. System/Subsystem ID No. & Size	Event Description				Corrective Action	
		1) Data Source - Date 2) Date of Event 3) Detection Method	Cause of Failure	Mode of Failure	Effect of Failure	1) Performed 2) Total Repair Time 3) Total Operating Time 4) Facility Recommendation	LMEC Engineering Analysis and Recommendations
1F	Valve/Seat P5-VC-620 Condensate System	1) PMMR 25 4-1-65 2) 4-8-65 3) Operational Monitor (No. H)	"Foreign object or material left in system" (No. 479)	"Broken" (No. 59)	"Leak (internal)" (No. 135)	1) "Temporarily reassembled for continued operation, no parts" (No. I) 2) Not required 3) Not obtained	As the state-of-the-art advances with larger FBR's, adequate storing of spare parts should be more closely planned.
1M	Valve/Bushing (upper)	3) During repair of primary component		"Galled" (No. 68)	"No effect" (No. 590) When components are replaced will be "Plant availability loss" (No. 520)		
1M	Valve/Bushing (lower)						
1M	Valve/Stem						
1F	Ball Bushing Oscillator Rod Oscillator System	1) ANL-6965, 6967, and 7017 - Report of EBR-II Operating Data, July 1964 to June 1965 2) 10-19-64 3) Protective system (No. I)	"Unknown" (No. 9ZZ)	"Broken" (No. 59)	"Foreign material - iron in liquid metal systems" (No. 244) Balls from bearings	1) "System design change" (No. H) - Changed from a vertical oscillator reciprocating drive. Use of balls and bearings was discontinued. 3) 3 months of intermittent operation	None
2F ₁	Oscillator Rod Drive (Labyrinth Seal Section) Oscillator System		"Dynamic malfunction - Fell in" (No. 142) - Balls	"Jammed" (No. 55)	"Component inoperative" (No. 550)		
2F ₂	Control Rod Drive No. 7 (Labyrinth Seal Section) Reactor Control System						
2F ₃	Control Rod Drive No. 9 (Labyrinth Seal Section) Reactor Control System						
						1) Components replaced (No. A) 2) Not determined 3) ~940 hr	

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TABLE A-2

MALFUNCTION, MAINTENANCE, OR PROBLEM ANALYSIS DATA

FACILITY EBR-II

Sheet 2 of 2

1) No Heat Generation 2) Generator Off (days) 3) Repair (man-hours)	Time Since Last Inspection or Maintenance (days)	Malfunction Importance (safety implication)	1) Identical Units at Facility 2) Previous Failures of Unit	Normal Environmental Operating Condition of Component (rating)	Facility Operating Condition	Comments
1) Not required 2) Not required 3) Not required	No previous report.	Maintenance problem (No. 62)	2) No previous report			None
1) 155 days 2) 160 days 3) Not determined	Oscillator installed 3 months previous. No inspection on control rods.	"Failure to operate of any trip equipment which reduces reactor safety." (No. 21)	1) One oscillator - 12 con- trol rods 2) None	Oscillator rod ball bushings; 700°F liquid sodium - Control rod (labyrinth seal section); 900°F liquid sodium	Not required	None

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APPENDIX B
SODIUM LOOP FAILURE REPORTS FROM THE
SODIUM COMPONENT TEST INSTALLATION

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: ELECTRICAL CIRCUIT BREAKER (to A-5)					
For Primary Na Pump (P-5) Mfr: Cutler-Hammer Model: Unitrol 480 V Run time = 270 hr Run time = 317 hr Run time = 383 hr Run time = 563 hr Run time = 587 hr Run time = 635 hr	Pump motor tripped	Inconclusive detection of cause	Motor could be restarted without repair		Incident Report (IR) No. 1 (6-2-65)
					IR No. 3 (6-4-65)
					IR No. 20 (7-29-65)
			Recording ammeter connected to check possible overload or occasional grounding		IR No. 24 (8-6-65)
		Loose electrical contacts of relay enclosed in bakelite housing tripped motor	Since no fault indication on recording ammeter, circuit breaker disassembled and relay housing replaced	Stock replacement components (SCTI) Executed	IR No. 26 (8-13-65)
		Unknown	Pump restarted without repair	Not needed	IR No. 100 (2-3-66)
For Secondary Na Pump (P-6) Mfr: Westinghouse Electric Co. Class: 11,202, HS-2 Rating: 4160 V 350 hp Run time = 900 hr	Control circuit relay chattering	Faulty relay shading coil	Control circuit relay replaced	Not needed	IR No. 132 (5-15-66)
For Boiler Feed Pump (P-1) Mfr: Federal Pacific Electric Co. Model: DSTS-150 Rating: 6 kv, 1200 amp Run time = 6635 hr	Maintenance check discovered broken contactor on arc suppressor	Faulty bonding during fabrication	Contacts replaced	Not needed	IR No. 329 (12-5-67)
COMPONENT: ELECTRICAL JUNCTION BOX (to A-5)					
Junction Box for Primary Na Pump Level Gage Heater (electric) Htr Mfr: Arcosec Inc. Rating: 2000 w, 220 V Run time = 487 hr	Heater circuit breaker contacts did not stay closed	Electrical insulation of heater elements worn due to vibration; shorted wires to junction box	As temporary correction, the heater terminal junction box was relocated. Later the level sensing lines were modified	Improved inspection standards during plant construction (LMEC)	IR No. 23 (8-3-65)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
Junction Box for Air Compressor Terminals (A5A) Run time = 9925 hr	During plant startup procedure low resistance readings on compressor motor terminals were obtained	Rain water leaked into junction box through deteriorated cover seal	Conduit connections and junction box cover sealed with Glyptol	Maintenance manual should establish checking period on rain-tight cover seals (SCTI) regularly megger circuits and leads, and investigate low readings (SCTI) Executed	IR No. 327 (11-20-67)

COMPONENT: ELECTRICAL PIPE LINE HEATER

Electrical Heater for Primary Na Heater Drain Line Material: 304 SS Schedule: 40 Size: 2 in. Run time = 4100 hr	Na frozen in drain line (607) due to grounded heater element	One of the primary piping preheat circuits discharged in the proximity of heater leads. Deteriorated plastic insulation and grounded heater element	Hot air discharge path and conduit direction was changed	Improve design standards (LMEC)	IR No. 70 (11-23-65)
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COMPONENT: ELECTRICAL MOTOR (to A-8)

Drive for Secondary Na Pump (P-6) Run time = 0	Motor winding shorted to ground	The motor was operating in pressurized argon environment, where arc-over voltage is less than in air; an arc developed between the motor winding and ground potential, which shorted and burned the motor	Motor rewound and argon pressure increased to 15 psig	See notes for IR No. 31	IR No. 2 (6-4-65)
Drive for Secondary Na Pump (P-6) Mfr: Allis Chalmers Model: Type AZV-30KS8 Rating: 350 hp, 4160 V, 1180 rpm Run time = 9 hr Run time = 115 hr	Motor starter tripped	Corona effect increased motor current above its load limit because the applied argon atmosphere of 5 psig has ~4 times lower breakdown voltage than an air atmosphere for which motor was designed	Installed air-cooled electric motor with gas seal to retain argon gas on pump side	Since air is the most effective coolant for electrical equipment, this should be the primary design consideration; however if another gas is required, consideration must be given to the Corona (arcing) problems in the procurement specification (LMEC)	IR No. 31 (8-20-65) IR No. 32 (8-25-65)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: BEARING					
Bearing between Primary Na Pump (P-5) and Drive Motor Pump Mfr: Byron Jackson Model: HH Size: 8x10x16 1750 rpm Run time = 586 hr	Pump cover gas leaked through shaft bearing	Pump casing cover not bolted down to internal plate cover, permitting interior gas pressure to lift pump ease cover and allow O-ring to slip out of its groove and be sheared off.	O-ring replaced after casing cover plate tightened; personnel have been trained in the procedure of tightening cover plate bolts.	Improve maintenance personnel training (SCTI) Executed	IR No. 29 (8-17-65)
Bearing between Na Cooler Fan and Drive Motor Fan Mfr: American Standard Model: CCW-UBD Size: 54 in. 75000 cfm 526 rpm 190 hp Run time = 103 hr	Erratic fan speed	Grease seal ring of bearing became loose because of loose setscrew	Flatplate ring and gasket substituted for grease seal ring	Grease seal has been modified (SCTI)	IR No. 85 (12-20-65)
Top Bearing of Secondary Na Pump Motor Motor Mfr: Electric Machinery Corp. Model: 2419-VS 4160 V 1175 rpm 450 hp Run time = 555 hr	Noisy top motor bearing	Information at installation stated that motor was equipped with sealed bearing; inspection revealed bearing was dry and open type	Bearing was replaced with a factory sealed type	Not needed	IR No. 86 (12-21-65)
Induced Draft Fan Motor Bearing Motor Mfr: Reliance Electric and Engr Co. Model: Type SB Rating: 1/3 hp 1725 rpm Serial: 385119, WB Frame: K-48, BHT Run time = 4518 hr	Motor stopped and generated smoke	Motor bearings seized because rain entered bearings	Bearings replaced; metal hood installed over motor. Chimney section Carbofrax insulation installed to protect motor from hot chimney section walls; metal hood placed over chimney section. Start and stop procedures during plant startup and shutdown modified	Design should call for weather tight motor if it is exposed to rain (LMEC)	IR No. 312 (10-30-66)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: BEARING (Continued)					
Bearing of Condensate Pump (P-4) Motor Motor Mfr: Louis Allis Co. Model: Type C06X Rating: 40 hp 3550 rpm 320/440 V Frame: 3260 pt Run time = 5200 hr	Noisy motor bearing	Motor bearing seized because rain entered outside bearing	Bearings replaced with factory-sealed bearings; winding was dipped and baked and rain shield placed over the motor		IR No. 326 (11-29-67)
Bearings for Forced-Draft Fan of Na Gas Heater Run time = 19,222 hr	Noisy fan bearings	Bearing surfaces were broken; normal wear of bearing	Replaced with new bearings	No recommendation	IR No. 320 (10-20-67)
COMPONENT: SODIUM LEVEL CONTROL (to A-2)					
Level Control of Primary Na Pump (P-5) Run time = 611 hr	Automatic level control became inoperative	Na leaked into unheated suction of level control bubbler tube and solidified	Na pump operated on manual level control until electrical heaters installed on bubbler tubes	Adequate heating should be provided for that part of a component where Na can leak-in, solidify, and disturb proper operation (SCTI) Executed	IR No. 33 (8-25-65)
Run time = 827 hr	Na fire developed at level controller sensing line	Na oozed through a porous weld and caught fire	After pump was stopped, the fire was extinguished and the system Na was drained, the faulty weld was repaired and pressure checked.	Weld checking should be performed properly (SCTI)	IR No. 87 (12-23-65)
Level Sensing Line of Primary Na Pump LIC-100 Run time = 613 hr	Above normal pressure	Na was frozen in the primary Na pump level sensing line, which rendered the pressure controller inoperative at low load and low temp conditions	Level controller switched to manual operation and sensing lines were thawed out	Heating method should be developed for any pump load and temp conditions (LMEC)	IR No. 81 (12-13-65)
Run time = 4722 hr	Plant scram followed a low Na flow signal from the primary Na loop	Probable cause: Na frozen in primary Na pump level sensing line; the level control was in manual position. This may have given rise to excessive gas flow into the pump case			IR No. 135 (5-30-66)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: SODIUM LEVEL CONTROL (to A-2) (Continued)					
		and gas bubbles entrainment, which resulted in low flow signal at EM flow-meter.			
COMPONENT: INTERMEDIATE HEAT EXCHANGER (IHX)					
Mfr: Alco Products Flow: 1,140,000 lb/hr Temp: 1200°F Press: 100 psig Run time = 611 hr	Unstable level in primary surge tank	Cover gas trapped in top of IHX. Pressure, temp and flow changes in IHX caused excessive level fluctuations in primary surge tank	Vent line with manually operated valve was installed from the IHX shell top to the primary expansion tank	Include vent valve actuation in plant operation manual (SCTI, LMEC) Executed	IR No. 46 (9-27-65)
COMPONENT: VALVE FOR SODIUM WITH FREEZE-SEAL					
HIC-510V Valve from Primary Cold Trap to Secondary Loop Mfr: William Powell Co. Rating: 100 psig 1200°F Size: 2 in. Dwg: C-51032 Run time = 210 hr	Continuous level increase in the primary expansion tank	Improperly placed stem stop prevented valve closing	Valve stem stop removed	Improved quality control should reduce this type of failure during receiving (LMEC)	IR No. 48 (10-6-65)
COMPONENT: SODIUM PIPE WELDING					
Primary Na Pump Suction Line Mtl: ASTM A403 Grade WP304 Temp: 1300°F Press: 125 psig Size: 10-in. Sch 40 Run time = 1208 hr	Na leaked from primary pump suction line during primary loop filling resulted in fire	A welder, tack welding plumb bobs hangers, apparently burned a 1/8-in.-diameter hole in pipe	Hole was welded	Check tack welds in the same way as any others (SCTI)	IR No. 60 (11-4-65)
COMPONENT: RUPTURE DISC FOR SODIUM SERVICE					
Designation = RD-2 Mfr: Black, Snalls & Bryson Co. Type: III Rating: 950°F 129/173 psi Size: 12 in. Run time = 982 hr Run time = 1150 hr	Na-oxide appeared on the rupture disc flange insulation	A pinhole size leak developed in a seal weld between the rupture disc support ring and flange	The rupture disc was replaced with a welded joint rather than a brazed joint. This proved unsatisfactory and eventually leaked.	State-of-the-art, no recommendation required	IR No. 93 (1-14-66)
		A crack developed from the rupture disc into the support flange	A double-wall rupture disc was designed, fabricated, and installed. A breather pipe vented the disc interspace to the lower relief tank. One leak detector was applied between the discs,	None required	IR No. 98 (1-28-66)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
			another on the relief tank side. Each actuating an alarm in the control room. Function satisfactory to date		
COMPONENT: THERMOCOUPLE WELL					
Thermocouples at IHX Secondary Inlet TR-104 Mfr: Temptron Instrumentation Equipment Model: 1759 Serial 27 Response time: 45-65 sec Run time = 353 hr	TR-104 recorder indicated unreasonable temp due to broken and flooded thermowells	Stress concentration caused the cracking	Thermowells replaced but modified to avoid stress from temperature and pressure	Design specification should include information to avoid stress concentrations in high temp/press systems. This is a common weakness of thermowell designs (LMEC)	IR No. 79 (12-9-65)
COMPONENT: TEMPERATURE CONTROLLER (to A-2)					
Thermocouple at Na Return to Gas-Fired Heater TR-101 Runtime = 18,560 hr	Disconnection of TC wires for calibration purposes scrambled the plant. This TC is part of the plant (safety) protection; disconnection results automatically in plant shutdown. Further investigation disclosed another loose TC wire which could cause similar effect		Temporary jumper on the controller is now used as a bypass for calibration	Operator and maintenance manual should improve the details of calibration procedures (LMEC) Executed	IR No. 321 (11-13-67)
COMPONENT: PIPE FLANGE FOR STEAM LINE					
Valve Flanges of FRC-201V (feed-water to steam generator) Flow Nozzle Flange FRC-200E (steam flow) Steam Pressure Control Valve (from steam generator) PRC-200V Flow Nozzle Flow Straightener Flange (main steam) FRC-200°F Desuperheater Flange (steam line) Run time = 6030	Steam leakage	Difference in thermal expansion between 347 SS flanges, bolts, and carbon steel ring gaskets generated leaks at increased steam pressure, and at decreased temp	Bolts and ring gaskets replaced with high-strength alloy, 19-9 DL; bolts torqued to pre-calculated values. Operating manual revised to reduce steam pressure before reducing temperature	Piping design should give more consideration to high-temp, high-press flange connection details. Maintenance manual should include individual torquing procedure for each flange connection (LMEC)	IR No's 126 to 130 (5-13-66 and 5-14-66)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: PLASTIC PIPE (to A-10)					
D-1 Demineralizer Upper Manifold Mfr: L. A. Water Conditioning Co. Model: SU-24 Ampax Rating: 12,600 gal Press: 100 psig Run time = 2550 hr	During scheduled inspection, the upper manifold found cracked in supporting flange thread	Plastic pipe (Uscolite) could not hold load of lower manifold	Plastic manifold replaced with stainless steel. Operation manual was revised to incorporate instructions that the resin beds should be stirred during long shutdowns to prevent excessive manifold packing	Not needed	IR No. 309 (10-17-66)
COMPONENT: FLOW INDICATOR FOR WATER					
Flow Indicator Sight Glass to Cooling Water Supply Mfr: OPW Corp Cincinnati, Ohio Size: 3/4 in. Press: 125 psig Run time = 3460 hr	Sight glass broken	Pressure surge in cooling-water supply line	Sight glass replaced	A pressure regulator should be installed in supply line. (SCTI) Executed	IR No. 331 (12-24-67)
COMPONENT: pH CONTROL					
pH Control for Cooling Tower Makeup pH-300 Run time = 6729 hr	Low pH readings in circulation cooling water	Plant operator left the acid feed pump actuator switch in manual position (instead of auto)	Proper quantity of sodium-hydroxide flakes were added to the cooling tower basin water, then pump switch was turned to auto position	Closer operator vigilance required, SCTI	IR No. 95 (1-21-66)
Acid Flow Control Valve to Cooling Tower V-3128 Run time = 5020 hr	pH control sounding alarm was actuated	Acid control flow valve was plugged with ferrous sulphate and iron oxide	Old corroded valve replaced with new one, and an air dryer filter installed on the breather pipe for H ₂ SO ₄ storage tank	Design should improve selection of chemical feed components (LMEC)	IR No. 62 (11-6-65)
Pipe to Acid Control Valve of Cooling Tower Run time = 5925 hr		Acid leaked into ground through a corroded pipe	Pipe was replaced	Increase inspection schedule Executed Proper design should have been required	IR No. 80 (12-13-65)
D-1 Demineralizer Acid Inlet Header Mfr: L. A. Water Conditioning Co. Model: SU-24 Ampak Rating: 12,600 gal Run time = 4066 hr	Makeup water pH could not be controlled	Acid inlet header alignment bracket broken. Sagging header tore away tank wall liner (Plastisol = neoprene type rubber)	New reinforced stainless steel header support was welded to the tank wall	More frequent inspection will help (LMEC)	IR No. 328 (12-1-67)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommended	Reference Documents (Date)
COMPONENT: INSTRUMENT AIR SYSTEM (to A-14)					
Air Dryer Desiccant Filter Mfr: R. P. Adams Co, Inc. Model: TR-150 psig Run time = 8438 hr	Irregular air control valve operations in instrument air system	Solid particles of Porostone desiccant filter entered control valve operators causing partial clogging	Valve operator cleaned, instrument air header blown down, new gasket materials (soft) installed beyond the Porostone filter	Maintenance manual should include requirement for periodic Porostone filter inspection (SCTI) Executed	IR No. 94 (1-17-66)
Instrument Air Subheader Run time = 10,025 hr	Air-line thread cracked at lower header	While tightening desuperheater flange bolts operator stepped on an air-line connected to lower air header	Broken line repaired	Operator training should include this type of examples (SCTI) Executed	IR No. 133 (5-25-66)
COMPONENT: WATER PUMP (to A-6)					
Condensate Pump (P-4) Mfr: Byron Jackson Co. Model: #300 VLT Rating: 350 gpm Temp: 225°F Seal: Borg Warner Type U mechanical Run time = 2700 hr	Condensate pump mechanical shaft seal leaked	Worn seal faces	Pump strainer inspected (clean), mechanical seal renewed	Improved preventive maintenance schedule established (SCTI) Executed	IR No. 103 (2-8-66)
Run time = 6215 hr	Zero recirculation flow between pump to condenser and pump to desuperheater was observed during routine operator inspection	Both recirculation shutoff valves were closed due to operator's error	Both valves were opened	Improve training of operators and install tags with appropriate instructions for valve positioning (SCTI) Executed	IR No. 330 (12-8-67)
Run time = 4427 hr	Loss of feedwater flow required manual scram which froze off sodium on the primary expansion tank	Unknown	Thermal insulation was placed on the prim. expansion tank vapor trap to eliminate Na solidification in similar future cases which result in a manual scram of the plant	Not needed	IR No. 134 (5-27-66)
COMPONENT: GAS FIRED SODIUM HEATER					
Mfr: Babcock & Wilcox Model: Built 1956 Rating: 1,260,000 lb Na to 1200°F 35 Mwt output Run time = 4500 hr	Refractory, protecting tube support hangers broken loose	Wire reinforcing was insufficient to support the refractory.	Wire mesh was installed to support refractory; unnecessary refractory was removed	Careful design required (SCTI) Executed	IR No. 63 (11-6-65)
Run time = 9580 hr	Na leak in area where tubes containing Na enter the firebrick roof; Na smoke detected in fuel gas stack	Thermal expansion difference between heater tubes and their rigid insulation spacers caused thermal stress cracks in the tubes	Cracked tubes (29) and nipples (9) were welded, radiographed and pressure checked at 150 psig; insulation was installed with proper expansion gaps between tubes, their insulation, and heater walls.	Design adequate clearances between materials with different expansion coefficients if they are exposed to temp changes (LMEC) Executed	IR No. 302 (6-5-66) NAA-SR-MEMO-12090

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: GAS FIRED SODIUM HEATER (Continued)					
Run time = 4005 hr	Pilot lights to burners flamed out, which tripped the primary Na pump motor	Operator improperly adjusted gas flow rate and combustion air flow	Pilot lights were reignited and primary Na pump restarted.	More operating experience required to avoid this problem. Executed	IR No. 54 (10-14-65)
Run time = 8362 hr	Gas to pilot light of No. 1 burner was manually shut-off by plant operator since the gas pressure gauge indicated no pressure.	Valve to pressure gage was closed	Plant was returned to operating conditions	Temporary changes in plant control equipment positions should be recorded and tagged in accordance with procedure (SCTI) Executed	IR No. 125 (5-10-66)
COMPONENT: ELECTRICAL MOTOR STARTER					
For the Secondary Na Pump (P-6) Mfr: Westinghouse Electric Corp. Rating: 4160 V Class: 11-202H52 350 hp Run time = 450 hr	Motor starter generated chattering noise	Loose shading coil vibration caused electrical contact chattering	Shading coils repaired and reinstalled	Not needed	IR No. 84 (12-16-65)
For the Circulating Water Pump (A-3) Mfr: Federal Pacific Electric Rating: 5 kv Class: Metal-clad 1200 amp Run time = 11,377 hr	Pump could not be started	Mounting screws of latching microswitch were loose	Starter removed, disassembled; microswitch secured in its bakelite enclosure	Design improvement (LMEC)	IR No. 322 (11-14-67)
COMPONENT: ELECTRICAL RELAY					
Scram Interlock Relay R-201 Mfr: Allen Bradley Model: 700 Rating: 120 vac Run time = 4050 hr	Relay caused inlet and outlet sodium valves to steam generator to be closed	While performing secondary Na pressurization procedure, relay R-201 was actuated at high argon pressure, which automatically closed the inlet and outlet valves.	R-201 relay was bypassed during cover gas pressurization to avoid valve closures	Cover gas pressurization procedure should be modified to include bypassing of relay (SCTI) Executed	IR No. 781 (12-7-65)
COMPONENT: ELECTRICAL WIRING					
Electrical Wiring in Motor Control Panel Run time = 1452 hr	Treated-water pump motor tripped	Industrial maintenance man short circuited treated-water motor wires	Circuit breaker reset, motor restarted	Improve design, layout and maintenance methods (LMEC) Executed	IR No. 52 (10-12-65)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: VALVE FOR WATER					
Cooling Tower Makeup Water Valve V-334 Mfr: Fisher Governor Co. Model: 657 AR/316 Rating: 300 psig Size: 3 in. Run time = 4995 hr	Cooling water level dropped 10 in. below normal	Flow rate of dump valve exceeded that of make-up valve in automatic operation	Water dump discharge line size reduced to match the make-up valve flow rate	Proper design considerations should be given to on-off type make-up/drawn controls (LMEC) Executed	IR No. 61 (11-5-65)
COMPONENT: EMERGENCY DIESEL GENERATOR					
Mfr: General Motors Model: GM-16V-71 7162-7200 Rating: 300 kw 277/480 v 3-phase 4-wire 1800 rpm Run time = 58 hr	Burnt wire between starter motor and speed-sensitive switch	Wire was shorted when maintenance men lowered air filter for regular periodic checking	Damaged wires and speed-sensitive relay replaced; air filter holding lugs were rotated to positions which can clear the electrical wires	Compliance with procedures by maintenance men shall be required (SCTI) Design should consider maintainability (LMEC)	IR No. 333 (1-25-68)
COMPONENT: EXPANSION JOINT					
<u>In Primary Na Loop</u> Mfr: Solar Aircraft Model: Gimbal type Rating: 1000°F 125 psig Run time = 612 hr	Na leakage marks detected on trench cover below expansion joint No. 5	Sensitization of bellows material during manufacturing (as an unexpected result of stress relieving part of the specification requirement) caused sensitization corrosion	Replaced with new expansion joint. Final corrective action was replacement of all six expansion joints with new unsensitized joints	All SCTI Na loops should be redesigned, eliminating the expansion joints (SCTI) Executed in secondary loop only.	IR No. 34 (8-25-65) IR No. 38 (9-9-65)
Run time = 612 hr	Leak detector alarm actuated at expansion joint No. 10		Replaced with a new spare		IR No. 108 (3-1-66)
<u>In Secondary Na Loop</u> Mfr: Solar Aircraft Model: Gimbal type Rating: 1000°F 125 psig Run time = 887 hr	Na leak at expansion joint No. 8		Final corrective action was replacement of all six expansion joints with expansion loops	Expansion joints should not be stress relieved in the sensitization region (SCTI, LMEC)	IR No. 114 (3-17-66)

Identification	Failure Mode	Cause of Failure	Corrective Action	SCTI or LMEC Recommendations	Reference Documents (Date)
COMPONENT: PIPING FOR OTHER THAN SODIUM FLOW (to A-11)					
Main Steam Line! Material: 347 SS Size: 4 in. Schedule: 40 Run Time = 88 hr	Steam leak at first-stage pressure-reducing valve PRC-200VB	Cracks due to chloride stress corrosion of 347 SS	(Unrepaired to date)	Reviewers recommend replacement of steam line with new material: 2-1/4 Cr., 1% Mo. *	IR No. 317 (11-5-66)
COMPONENT: BELLOWS FOR SODIUM					
Bellows Seal of Secondary Cold Trap Inlet Valve (HIC-509V) Mfr: Powell Valve Co. Size: 2 in. Rating: 1200°F 100 psig Type: Globe air operated Run time = 282 hr for No. 9 612 hr for No. 37, 39 & 45	Valve was being prepared for conversion to a freeze-seal stem valve. During bellows removal the melted Na caught fire.	After the bellows were cut from the valve body the energized valve heaters ignited the melted Na	After the Na burned out, the valve modification proceeded	Improve training of maintenance personnel handling Na-containing equipment	IR No. 9 (7-2-65)
	Previous SRE preventive maintenance experience predicted more reliable operation for freeze-seal type valves than bellows-seal types	Conversion from bellows-seal to freeze-seal valves was expected to increase plant reliability	17 bellows-seal valves were converted to freeze-seal valves	Not needed	IR No. 37 (8-31-65) IR No. 39, 40, 41 (9-4-65 to 9-9-65) IR No. 45 (9-16-65)

* Execution of recommendations by reviewers pending AEC concurrence.

SUMMARY OF SCTI - FAILURE FREQUENCY DISTRIBUTION

Major System	Basic Cause						
	Improper Design	Manufacturing Errors	Construction and/or Installation Errors	Operator Errors	Maintenance Errors	Random Failures	Other
Sodium Heat Transfer System	21 (42%)	9 (18%)	10 (20%)	5 (10%)	3 (6%)	2 (4%)	0
Steam and Feedwater System	14 (38%)	3 (8%)	0	4 (11%)	9 (24%)	7 (19%)	0
Electrical Power System	5 (11%)	9 (20%)	7 (16%)	3 (7%)	7 (16%)	11 (25%)	2 (5%)
Instrument Air System	1 (5%)	1 (5%)	0	3 (16%)	6 (32%)	8 (42%)	0
Plant Control System	4 (22%)	0	3 (17%)	2 (11%)	0	9 (50%)	0
Circulating Cooling-Water System	5 (64%)	0	0	1 (12%)	1 (12%)	1 (12%)	0
Air Preheat System	0	1 (25%)	0	0	1 (25%)	2 (50%)	0
Undetermined	0	0	0	0	0	0	1

APPENDIX C
LMFBR TESTING AND FACILITY REQUIREMENTS

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 1 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
1. VALVES				
Sodium to 1210 (design)	To 225 (design)	0 to 1000 (service systems) 0 to 20,000 (FFTF main loops, LMFBR service systems) 20,000 to 120,000 (LMFBR main heat transfer loops)	1) 10°F/sec for 30 sec from 800 to 1100°F 2) 10°F/sec for 30 sec from 1200 to 900°F 3) 4°F/sec for 120 sec from 600 to 1080°F 4) 4°F/sec for 120 sec from 1200 to 720°F	1) Testing may be performed on valves from 2 in. to greater than 30 in. 2) Valves will be tested for the following operating character- istics: a) Preheating capability b) Operability during and after temperature changes c) Across-the-seat leakage rate d) Opening and closing torque requirements e) Stem seal leakage 3) Flow tests will be performed to determine: a) Flow characteristics, (throttling valves), including flow transient during opening and closing b) Reproducibility of flow rate c) Vibration d) Snubbing characteristic of check valves e) Endurance testing

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C-3

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 2 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
2. STEAM GENERATORS				
Sodium side – To 1200 Steam side – To 1050	Sodium side – To 225 Steam side – To 2500	<p>1) Steam generator tube bundles (~5 Mwt) or steam generator models (5 to 10 Mwt) 500 to 1000</p> <p>2) ALCO, B&W, and AI modular steam generators (~30 Mwt) ~2700 sodium</p> <p>3) LMFBR prototypes (30 to 50 Mwt) 3000 to 5000 sodium</p>	<p>Required thermal transients have not been established for all steam generators.</p> <p>The ALCO steam generator casualty thermal transients are:</p> <p>1) Stoppage of the primary sodium flow with continued flow of secondary sodium (-35°F/sec for 3 sec, change from 1175 to 775°F in 14 sec.)</p> <p>2) Stoppage of feedwater flow with continued secondary sodium flow (+50°F/sec for 3 sec, change from 775°F to 1175°F in 9 sec)</p> <p>3) Stoppage of secondary flow with continued feedwater flow (-35°F/sec for 3 sec, change from 1175 to 650°F in 16 sec)</p>	<p>1) Steady state heat transfer</p> <p>2) Simulated plant load following tests including low load stability tests</p> <p>3) Thermal transient testing</p> <p>4) Casualty testing (sodium-water reaction in operating steam generator)</p> <p>5) Maintainability testing</p>

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 3 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
3. SODIUM SAMPLER				
To 1200	To 225 where applicable (in sodium) To 50 (in cover gas)	Applicable only to in-line samplers	Applicable only for in-line samplers with mechanical joints	<p>A. Pool Sampler</p> <p>1) Operation, reliability and maintenance of sampler in a large sodium tank</p> <p>2) Effects on sampler of thermal transients associated with insertion and removal from sodium surface</p> <p>3) Retrieval of sodium sample</p> <p>4) Contamination introduced during operation</p> <p>B. In-Line Sampler</p> <p>1) Installation and retrieval of sampler from line</p> <p>2) Operation reliability and maintenance</p> <p>3) Time interval between sampling</p> <p>4) Contamination introduced during operation</p>

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TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 4 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
4. CORE HYDRAULIC TESTS				
To 1300 in sodium	To 225	<1000	Not required	1) Non-radioactive fuel element pressure-drop tests 2) Grid plate leakage tests 3) Control rod pressure drop 4) Core channel variable orifice tests
5. SODIUM PIPING SYSTEMS				
To 1210 (design)	To 225 (design)	Fluid velocities to 40 ft/sec, sizes: 1) Greater than 30 in. (LMFBR main loop) 2) Less than 30 in. (LMFBR service loop)	1) 10°F/sec for 30 sec from 800 to 1100°F 2) 10°F/sec for 30 sec from 1200 to 900°F 3) 4°F/sec for 120 sec from 600 to 1080°F 4) 4°F/sec for 120 sec from 1200 to 720°F	1) Testing of field installation methods 2) Evaluate elastic, plastic, creep fatigue, corrosion, erosion, and instability on sodium piping systems 3) Determine the effects of vibration, shock, fluid hammer and thermal stratification 4) Methods of supporting large size piping 5) Heating requirements 6) Endurance Testing

TABLE C-1

COMPONENT TEST REQUIREMENTS
(Sheet 5 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
6. COOLER (sodium to air)				
To 1000 (sodium side)	To 150 (FFTF module)	To 3000 (FFTF module)	Information not avail- able	1) Pressure drop at full flow (both air and sodium) 2) Demonstrating heat removal capacity of cooler 3) Evaluate preheat system 4) At zero coolant (air) flow: a) Determine heat losses b) Determine temperature profile in tube bundle c) Evaluate stresses in tubes and headers 5) Determine control charac- teristics
7. COOLANT MIXING TEE				
To 1200 ΔT up to 600	To 225	Unknown	Information not available	1) Thermal gradients 2) Stress levels in critical areas 3) Life and thermal transient tests

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C-7

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 6 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
8. EXPANSION JOINTS				
Sodium to 1200	0 to 225	No applicable	1) 10°F/sec for 30 sec from 800 to 1100°F 2) 10°F/sec for 30 sec from 1200 to 900°F 3) 4°F/sec for 120 sec from 600 to 1080°F 4) 4°F/sec for 120 sec from 1200 to 720°F	Each expansion device will be tested under the following conditions: 1) Axial twisting 2) Elongation 3) Internal pressurization 4) Lateral deflection 5) End fitting restraints
9. PIPE AND VESSEL PREHEAT SYSTEMS				
Ambient to 350	Not applicable	Not applicable	Not applicable	Each preheat system will be tested on a sodium system to provide sufficient data to evaluate the following: 1) Uniformity of heating 2) Ease of control for heatup and cooldown 3) Maintenance 4) Reliability 5) Operating costs

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C-8

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 7 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
10. FREEZE TRAPS				
Sodium to 1200 Air to 150	To 225	Not applicable	Not applicable	<p>1) If the trap to be tested contains rotating elements, it must be tested to ensure that galling and binding do not occur; determine torque requirements for rotating elements</p> <p>2) It must be possible to remelt the sodium in the trap in order to reopen the vent line; determine heating requirements for melt-down</p> <p>3) Tests to show that there is no flow of sodium past the trap</p> <p>4) Tests to show thermal effects during filling and draining operation</p>
11. VAPOR TRAPS				
To 1200 vapor	To 50 cover gas pressure	Not applicable (vapor only)	Not applicable	<p>1) Test the vapor removal efficiency and capacity of the various packing and baffle configuration types</p> <p>2) Determine the maximum flow rate per cross-sectional area</p> <p>3) Measure sodium buildup rates in the traps</p> <p>4) Establish that the trap can be blown clear and restored to service without requiring removal from the system</p>

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TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 8 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
12. HOT TRAP (either carbon or oxygen)				
To 1300	To 225	To 100 at 1300 °F To 250 at 1200 °F	Applicable for traps utilizing mechanical joints	Testing will be performed to determine the following: 1) Rates of removal of sodium impurities either carbon or oxygen in prototype traps 2) Performance of hot-trap heaters or furnaces 3) Performance of hot-trap economizers 4) Pressure-drop characteristics 5) Determine trap capacity
13. COLD TRAP				
Sodium to 1200	To 225	0 to 250	Applicable only if mechanical joints are used to connect the trap to the system	Testing will be performed to determine the following: 1) Effectiveness of the trap for removing the various impurities present in sodium 2) Trapping rates for the various impurities 3) Trap capacity 4) Trap response to varying source rates of the impurities 5) Trap operating techniques 6) Pressure drop characteristics 7) Economizer effectiveness 8) Temperature profiles

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C-10

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 9 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
14. HEATERS (electrical)				
To 1300 in sodium; to 1500 in air	To 225 for submersion type	~600 for FFTF closed-loop heater	Not available	Efficiency, life, and maintenance testing
15. SODIUM PUMP SHAFT SEALS				
Sodium vapor to 1200	To 50 (cover gas)	Not applicable	Not applicable	<p>1) Tests will subject the seals to angular misalignment, axial and radial displacement under the range of speed, pressure and temperature conditions to be encountered during reactor service</p> <p>2) Test data to be obtained will include seal fluid leakage rate(s), cover gas leakage, and seal torque under test conditions per (1) above</p> <p>3) Test, examination, and inspection data will be evaluated to determine seal performance in relation to reliability, life, power consumption, ease of maintenance, and costs</p>

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C-11

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 10 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
16. INTERMEDIATE HEAT EXCHANGERS (conventional or pot type)				
To 1200 in sodium; LM Δ T to 200	To 225	1) 0 to 1000 (FFTF closed loop) 2) 0 to 13,000 (FFTF main loop and LMFBR model)	1) 10 °F/sec for 30 sec from 800 to 1100 °F 2) 10 °F/sec for 30 sec from 1200 to 900 °F 3) 4 °F/sec for 120 sec from 600 to 1080 °F 4) 4 °F/sec for 120 sec from 1200 to 720 °F 5) Lesser transients as required	1) Testing for vibration and pressure drop at full flow 2) Testing up to near full power (~80%) to determine flow distri- bution and heat transfer. Esti- mated power requirements for testing are as follows: a) FFTF closed loop ~3 Mwt b) FFTF main loop ~45 Mwt c) LMFBR model ~30-50 Mwt 3) Testing for post-scram con- vection flow rate 4) Testing for maintainability if IHX has a removable tube bundle 5) Stress measurements in critical areas
17. PUMPS				
To 1200	To 225	1) 0 to 3000 (small service pumps) 2) 3000 to 20,000 (FFTF main loop or LMFBR service) 3) 20,000 to 120,000 (LMFBR main loop)	1) 10 °F/sec for 30 sec from 800 to 1100 °F 2) 10 °F/sec for 30 sec from 1200 to 900 °F 3) 4 °F/sec for 120 sec from 600 to 1080 °F 4) 4 °F/sec for 120 sec from 1200 to 720 °F 5) $\pm$ 100 °F/hr from 70 to 1200 °F	1) Pump life, vibration, thermal transient, and flow decay testing 2) Pump maintenance testing and handling 3) Hydraulic testing a) To verify design extrapola- tions by factoring b) To determine effects of chang- ing fluid from water to sodium 4) Determine pump characteristic curves

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C-12

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 11 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
18. SODIUM PUMP BEARINGS (water test only)				
To 300	To 225	0 to 7,000	None	1) Bearing load capacity and performance during initial motion at start of rotation and as the shaft comes to rest 2) Bearing load capacity as affected by shaft speed and bearing supply pressure 3) Performance of the bearing as affected by dynamic imbalance of the shaft and dynamic instability 4) Bearing clearances as a function of load, speed, and mass flow 5) Flow rates as a function of supply pressure 6) Frictional losses as a function of load and speed 7) Pressure distribution inside the bearing as a function of applied load, speed, and flow rate

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C-13

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 12 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
19. SODIUM PUMP BEARINGS (sodium test)				
To 1200	To 120	0 to 7000 (tentative estimate)	<p>A. SPTF design criteria</p> <p>1) 10°F/sec for 30 sec from 800 to 1100°F</p> <p>2) 10°F/sec for 30 sec from 1200 to 900°F</p> <p>3) 4°F/sec for 120 sec from 600 to 1080°F</p> <p>4) 4°F/sec for 120 sec from 1200 to 720°F</p> <p>B. Westinghouse</p> <p>-25°F/sec for the first 6 sec to -50°F/sec for the first 3 sec</p>	<p>1) Stiffness as a function of the ratio of applied load to change of clearance between journal and casing</p> <p>2) Radial load rating, or bearing capacity, and power losses due to friction</p> <p>3) Radial clearance and bearing geometry effect on load capacity and power loss</p> <p>4) Radial misalignment of displace- ment of the shaft in relation to the bearing, and consequent perfor- mance in terms of load capacity and power loss</p> <p>5) Performance of the bearing as affected by dynamic imbalance of the shaft and dynamic instability</p> <p>6) Effects due to surface roughness that may be inherent in material used for bearings</p>

TABLE C-1
COMPONENT TEST REQUIREMENTS
(Sheet 13 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
20. MECHANISMS IN SODIUM				
600 to 1200	Not applicable (cover gas only to ~6)	Flowing sodium (<10)	Confined to specific proto- type mechanism tests	<p>The following experiments are either in progress or proposed:</p> <ol style="list-style-type: none"> 1) Self welding (static contact) 2) Basic wear (sliding contact) 3) Rolling contact (ball and roller bearings) 4) Latch and gripper surfaces (motion transmission) 5) Power transmission (spur gear) 6) Seals (rotary mechanical, linear) 7) Power or motion transmission (worm and cycloid gearing, screws, cams) 8) Shaft support (journals and bushing bearings) 9) Miscellaneous mechanisms (slides, guides, gibs, ways) 10) Fretting wear (fretting damage under vibratory motion) 11) Mechanism maintenance (wipers)

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C-15

TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 14 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
21. NEUTRON DETECTORS				
1) To 1200 for sodium immersed in-core detectors 2) To 1200 for out-of-core detectors	To 225 max	Not applicable	600°F in 1 min with a maximum rate of 60°F/sec	1) In-core neutron detectors a) Proof testing and calibration in a neutron flux up to 10^{16} n/cm ² /sec b) Proof testing and calibration in a gamma field of 10^9 R/hr 2) In-core neutron detectors, reflector or blanket a) Proof testing and calibration in a neutron flux up to 10^{15} n/cm ² /sec b) Proof testing and calibration in a gamma field of $\sim 10^8$ R/hr

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TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 15 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
22. TEMPERATURE MEASURING				
1) To 1400 in sodium or inert gas 2) To 5000 in fuel 3) To 1200 in air	Not applicable	Not applicable	1) 600 °F in 1 min with a maximum rate of 60 °F/ sec for in-core type 2) Thermal transients for fuel temperature measuring devices are not known	1) Proof testing and calibration of temperature measuring devices in sodium up to 1400 °F with flux of 10^{15} n/cm ² /sec and 10 ⁹ R/hr gammas 2) Proof testing and calibration of temperature measuring devices in fuel up to 5000 °F 3) Proof testing and calibration of temperature measuring devices on piping up to 1200 °F (importance of testing in a gamma field is unknown) 4) Thermal cycling from 300 °F to max temperature for all sensors 5) Immersion in inert gas or sodium to depths of 40 to 50 ft for in-vessel devices 6) Proof testing and calibration traceable to NBS 7) Testing with accurately known and controlled sodium purity where applicable 8) Life testing and reliability testing

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C-17

TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 16 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
23. FLOW METERS				
1) Sodium to 1200 for other than in-core flowmeters 2) Sodium to 1400 for in-core flowmeters	To 225	1) 10 to 400 (in-core type) 2) To 3000 (service systems) 3) To 20,000 (FFTF, LM-FBR Service Systems) 4) 20,000 to 120,000 (LMFBR, main heat transfer loops)	600 °F in 1 min with a max rate of 60 °F/sec for in-core flowmeters; lesser transients for other flowmeters	1) Proof testing and calibration will be performed on all flowmeters 2) Tests must be made with accurately known and controlled sodium purity 3) Tests will be performed on 2 in. to 30 in. flowmeters 4) Life tests and reliability 5) Effects of upstream and downstream flow disturbances 6) Calibration traceable to NBS

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C-18

TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 17 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
24. PRESSURE INSTRUMENTS				
To 1400 for in-core sensors and to 1200 for others	Static pressures from 20 in. H ₂ O to 250 psig, and differential pressures from 20 to 400 in. H ₂ O at 250 psig static pressure	Not available	600 °F in 1 min with a max rate of 60 °F/sec for in-core pressure sensors; lesser transients for others	<ol style="list-style-type: none"> 1) Testing will be performed with accurately known and controlled sodium purity 2) Tests will be performed with sensors to be used in-core immersed to depths of 40 to 50 ft in inert gas or sodium with controlled temperature gradients 3) Life testing and reliability testing 4) Calibration traceable to NBS 5) Testing of in-core pressure instruments in a neutron flux of 10^{14} n/cm²/sec and a gamma field of 10^8 R/hr 6) Testing of fuel pressure instruments in a neutron flux of 10^{15} n/cm²/sec and a gamma field of 10^9 R/hr

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TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 18 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
25. STRAIN INSTRUMENTS				
To 1400 in inert gas or sodium	Static to 2400	Not applicable	35 °F/sec for 6 sec max	1) Calibration throughout the temperature range 2) Life testing and reliability testing
26. LEVEL INSTRUMENTS				
Sodium to 1200	To 225	Not applicable	35 °F/sec for 6 sec max	1) Testing will be performed with accurately known and controlled sodium purity 2) Life testing and reliability testing 3) Other tests will be required as dictated by the design of the instrument 4) Calibration traceable to NBS 5) Proof testing in a neutron flux of 10^{14} n/cm ² /sec and a gamma field of 10^8 R/hr for in-reactor- vessel level instruments
27. FISSION PRODUCT MEASUREMENT				
Sodium to 1200	To 225	Unknown at this time	Unknown at this time	Testing in sodium with a gamma field of 10^5 R/hr

TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 19 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
28. UNDER SODIUM VIEWERS				
To 700	To 75	Not applicable	Transients associated with entering and leaving the sodium pool	1) Remote operation 2) Accuracy of locating specific objects under sodium 3) Life testing and maintenance requirements 4) Resolution
29. SODIUM PURITY				
Sodium to 850	To 225	Not applicable	Reactor thermal transients will be reduced by an economizer before the impurities device; transients considered will be those associated with heatups and cool-downs	1) Testing will be performed with precisely known and controlled sodium purity 2) Tests will be performed to show repeatability of measuring device 3) Tests will be performed at various flows within the design capabilities of the measuring device 4) Life testing and reliability testing 5) Proof testing and calibration of instruments for measuring oxygen, carbon, and hydrogen 6) Testing with fission products and gamma activity in the sodium

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TABLE C-1
INSTRUMENT TEST REQUIREMENTS
(Sheet 20 of 20)

Temperature (°F)	Pressure (psig)	Flow (gpm)	Thermal Transients	Specific Testing
30. ELECTRICAL CABLES IN SODIUM				
To 1200	To 225	Not applicable	35 °F/sec for 6 sec max	1) Proof testing and calibration of electrical cable in sodium with a neutron flux of 10^{16} n/cm ² /sec and a gamma field of 10^9 R/hr 2) Life testing and reliability testing 3) Determine effects of thermal gradients in cable performance
31. SODIUM LEAK DETECTORS				
To 1200	Not applicable	Not applicable	Not applicable	Sodium-to-gas and sodium-to-water 1) Life and reliability testing 2) Response time of the detector 3) Testing will be required to determine leak location feasibility

**LMEC
TEST FACILITY COMPLEX
(Proposed)**

PSTF 1 AND 2 - PUMP SHAFT SEAL TEST FACILITY 1 AND 2

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS BOTH TEST FACILITIES ARE PRESENTLY IN THE PRELIMINARY CONSTRUCTION PHASE

FACILITY USE

THE TWO SEAL TEST FACILITIES ARE DESIGNED FOR:

- PROOF-TESTING OF CANDIDATE SHAFT SEALS FOR LARGE (60,000- μ gpm) LMFBR SODIUM PUMPS UNDER SIMULATED ENVIRONMENTAL CONDITIONS EXPECTED TO BE ENCOUNTERED IN ACTUAL PUMP SERVICE
- FACILITY NO. 1 WILL ACCOMMODATE PROOF-TESTING OF GAS-TYPE SEALS, WHILE FACILITY NO. 2 WILL BE UTILIZED FOR OIL-TYPE SEAL TESTING. EITHER FACILITY COULD BE MODIFIED, WITH RELATIVE EASE, FOR TESTING OF OTHER SEAL TYPES.

FACILITY DESCRIPTION

THE TEST FACILITIES WILL BE VERTICAL ASSEMBLIES WITH THE DRIVE MOTOR, FLEXIBLE COUPLINGS, TORQUE TRANSMITTER, BEARING HOUSING, AND ALIGNMENT DEVICE MOUNTED ON THE TOP OF THE RIG DIRECTLY ABOVE A CANDIDATE SHAFT-SEAL ASSEMBLY. THE DRIVE MOTOR WILL BE COUPLED TO A SPINDLE ASSEMBLY CONNECTED TO THE SEAL SHAFT WHICH WILL EXTEND DOWN INTO THE TEST VESSEL. THE TEST VESSEL CONTAINS A CONTROLLED ATMOSPHERE OF ARGON AND SODIUM VAPOR (50 μ sig MAXIMUM) AND A 2-ft DEEP SODIUM POOL (1200°F MAXIMUM) WHICH SIMULATES THE ENVIRONMENT OF A FREE-SURFACE PUMP. THE SEAL DRIVER SHAFT WILL BE SUPPORTED INDEPENDENTLY OF THE SEAL. IT WILL HAVE THE CAPABILITY OF BEING ACCURATELY DISPLACED IN A VERTICAL DIRECTION (± 0.080 in. IN 0.010-in. INCREMENTS) AND IN AN ANGULAR DIRECTION (A MAXIMUM OF ± 30 MINUTES OF ARC FROM THE VERTICAL, IN ONE PLANE).

THE TEST FACILITIES WILL ACCOMMODATE SEAL ASSEMBLIES HAVING A NOMINAL SHAFT DIAMETER OF 8-in., ROTATING AT SPEEDS UP TO 1200 rpm, WITH A MAXIMUM ASSEMBLY ENVELOPE OF 26-in. IN DIAMETER BY 19.81-in. LONG. THE TOP REGION INSIDE THE TEST VESSEL CAN ACCEPT A MOCKUP VAPOR THERMAL BARRIER (UP TO 22.5 in. IN DIAMETER BY 12-in. LONG) OF A DESIGN EXPECTED TO BE USED IN A PROTOTYPE PUMP.

A SEPARATE STAND WILL BE PROVIDED ADJACENT TO THE FACILITIES FOR ASSEMBLY, ADJUSTMENT, AND CALIBRATION OF A TEST SEAL AND/OR DRIVER ASSEMBLY.

THE ARGON GAS SYSTEM CAN ACCOMMODATE A FLOW RATE OF 25 scfm. REDUCING REGULATORS WILL SUPPLY GAS TO THE TEST SEAL, VESSEL, OR SODIUM SUPPLY TANK AT THE APPROPRIATE PRESSURE OR FLOW LEVEL. FOR A GAS-TYPE SEAL, THE SUPPLY CAN BE PRESSURE- OR FLOW-REGULATED WITHIN 0 TO 50 μ sig AND 0 TO 1.0 scfm, RESPECTIVELY. FOR AN OIL-TYPE SEAL, ARGON IS SUPPLIED TO THE TEST VESSEL, SUPPLY TANK, AND AS A SERVICE TO THE OIL SUPPLY SYSTEM WHICH WILL BE SUPPLIED WITH A CANDIDATE OIL-TYPE SEAL.

SODIUM SYSTEM PREHEAT AND STEADY-STATE OPERATION WILL BE MAINTAINED BY ELECTRICAL TRACE HEATERS.

ALL SODIUM SYSTEM DESIGN AND FABRICATION WILL BE IN ACCORDANCE WITH REQUIREMENTS OF SECTION III AND/OR VIII OF THE ASME BOILER AND PRESSURE VESSEL CODE, 1965 EDITION.

SCHEDULE

THE FACILITY WILL BE READY FOR SEAL TESTING IN FY 1969

PUMP SEAL TEST FACILITY (PSTF)

LMEC-68-13
C-25

PBTF - PUMP BEARING TEST FACILITY

LOCATION NOT ASSIGNED

STATUS NEW FACILITY, SODIUM ONLY

FACILITY USE

THE FACILITY WILL BE USED TO SATISFY LMFBR BEARING TEST REQUIREMENTS. DATA MEASUREMENTS INCLUDE FLOWRATES, PRESSURES, TEMPERATURES, ROTATIONAL SPEED, INTERNAL CLEARANCES, TORQUE, AND LOAD. THESE DATA MAY BE USED TO DETERMINE:

- STIFFNESS AS A FUNCTION OF THE RATIO OF APPLIED LOAD TO CHANGE OF CLEARANCE BETWEEN JOURNAL AND CASING
- RADIAL LOAD RATING, OR BEARING CAPACITY, AND POWER LOSSES DUE TO FRICTION
- RADIAL CLEARANCE AND BEARING GEOMETRY EFFECT ON LOAD CAPACITY AND POWER LOSS
- RADIAL MISALIGNMENT OR DISPLACEMENT OF THE SHAFT IN RELATION TO THE BEARING, AND CONSEQUENT PERFORMANCE IN TERMS OF LOAD CAPACITY AND POWER LOSS
- PERFORMANCE OF THE BEARING AS AFFECTED BY DYNAMIC UNBALANCE OF THE SHAFT AND DYNAMIC INSTABILITY
- EFFECTS DUE TO SURFACE ROUGHNESS THAT MAY BE INHERENT IN MATERIAL USED FOR BEARINGS
- BEARING LOAD CAPACITY AS AFFECTED BY SHAFT SPEED AND BEARING SUPPLY PRESSURE
- BEARING LOAD CAPACITY AND PERFORMANCE DURING INITIAL MOTION AT START OF ROTATION AND AS THE SHAFT COMES TO REST.
- THERMAL SHOCK

FACILITY DESCRIPTION

THE FACILITY WILL CONSIST EVENTUALLY OF TWO 4000-gpm PUMPS FOR CIRCULATING SODIUM THROUGH A 14-in. PIPING SYSTEM, A HEATER, FLOWMETERS, A MANIFOLD AND ADJUSTABLE ORIFICES, A SUBMERGED TEST BEARING, AND A DUMP TANK. AN ELECTRIC MOTOR DRIVES THE TEST BEARING JOURNAL.

THE FACILITY IS INTENDED FOR FULL-SCALE BEARING TESTS IN SODIUM WITH FLOWRATES OF 0 TO 8000 gpm, PRESSURES TO 120 psig, TEMPERATURES TO 1200°F AND AT A SHAFT SPEED OF 0 TO 1000 rpm.

LMFC-68-13
C-26

PBTF - PUMP BEARING TEST FACILITY (ALTERNATE)

LOCATION NOT ASSIGNED

STATUS NEW FACILITY, WATER ONLY

FACILITY USE

THE FACILITY WILL BE USED TO SATISFY LMFBR BEARING TEST REQUIREMENTS. DATA MEASUREMENTS INCLUDE FLOWRATES, PRESSURES, TEMPERATURES, ROTATIONAL SPEED, INTERNAL CLEARANCES, TORQUE, AND LOAD. THESE DATA MAY BE USED TO DETERMINE:

- STIFFNESS AS A FUNCTION OF THE RATIO OF APPLIED LOAD TO CHANGE OF CLEARANCE BETWEEN JOURNAL AND CASING
- RADIAL LOAD RATING, OR BEARING CAPACITY, AND POWER LOSSES DUE TO FRICTION
- RADIAL CLEARANCE AND BEARING GEOMETRY EFFECT ON LOAD CAPACITY AND POWER LOSS
- RADIAL MISALIGNMENT OR DISPLACEMENT OF THE SHAFT IN RELATION TO THE BEARING, AND CONSEQUENT PERFORMANCE IN TERMS OF LOAD CAPACITY AND POWER LOSS
- PERFORMANCE OF THE BEARING AS AFFECTED BY DYNAMIC UNBALANCE OF THE SHAFT AND DYNAMIC INSTABILITY
- EFFECTS DUE TO SURFACE ROUGHNESS THAT MAY BE INHERENT IN MATERIAL USED FOR BEARINGS
- BEARING LOAD CAPACITY AS AFFECTED BY SHAFT SPEED AND BEARING SUPPLY PRESSURE
- BEARING LOAD CAPACITY AND PERFORMANCE DURING INITIAL MOTION AT START OF ROTATION AND AS THE SHAFT COMES TO REST.

FACILITY DESCRIPTION

THE FACILITY WILL CONSIST EVENTUALLY OF A 7000-gpm PUMP FOR CIRCULATING WATER THROUGH AN 8-in. PIPING SYSTEM, A HEATER, FLOWMETERS, A MANIFOLD AND ADJUSTABLE ORIFICES, A SUBMERGED TEST BEARING, A DUMP TANK, A FILTER, AND A DEAERATOR.

THE FACILITY IS INTENDED FOR FULL-SCALE BEARING TESTS IN WATER WITH FLOWRATES OF 0 TO 7000 gpm, PRESSURES TO 100 psig, TEMPERATURES TO 300° F AND AT A SHAFT SPEED OF 0 TO 1800 rpm.

SCHEDULE

(PBTF) BEARING TEST FACILITY (WATER)

LMEC-68-13
C-27

SMTI – SODIUM MECHANISMS TEST INSTALLATION

LOCATION: LMCC, SANTA SUSANA, CALIFORNIA

STATUS: BUILDING 006 – 4 OPERATIONAL LOOPS (9 VESSELS) REQUIRING NO MODIFICATION. LOOPS PRESENTLY UNDER CONSTRUCTION – NONE. LOOPS PROPOSED ARE 18 (36 VESSELS) FOR A MINIMUM REQUIREMENT AND ARE TO BE LOCATED IN BUILDING 013.

BUILDING 354 – BASIC TEST TOWER IS AVAILABLE WITH MODIFICATIONS REQUIRED FOR THE TESTS PROPOSED.

FACILITY USE

EXISTING LOOP NUMBER	LOOP APPLICATION	VESSELS	STUDY DESCRIPTION
1 – BLDG. 006	STATIC CONTACT	1	SELF-WELDING
	SLIDING CONTACT	1	BASIC WEAR
	SEALS	1	SEAL QUALIFICATION
2 – BLDG. 006	MOTION TRANSMISSION	1	LATCH SURFACE
3 – BLDG. 006	SLIDING CONTACT	1	BASIC WEAR
4 – BLDG. 006	POWER TRANSMISSION	2	GEAR TESTING (SPUR)
	ROLLING CONTACT	2	BEARINGS (BALL)
PROPOSED LOOP NUMBER	LOOP APPLICATION	VESSELS	STUDY DESCRIPTION
5-7 – BLDG. 006	SEALS	6	SEALS
8-10 – BLDG. 013	ROLLING CONTACT	6	BEARINGS (BALL, ROLLER)
11 – BLDG. 013	POWER TRANSMISSION	2	CHAIN AND SPROCKET
12 – BLDG. 013	POWER TRANSMISSION	2	WORM GEARS
13-14 – BLDG. 013	SHAFT SUPPORT	4	JOURNALS AND BUSHING
15 – BLDG. 013	MISC. MECHANISMS	2	BEARINGS
16 – BLDG. 013	MISC. MECHANISMS	2	GRIPPERS
17 – BLDG. 013	MOTION TRANSMISSION	2	SLIDES, GIBS, WAYS
18 – BLDG. 013	MOTION TRANSMISSION	2	CAM SURFACES
19-20 – BLDG. 013	FRETTING EROSION	4	SCREW THREADS
21 – BLDG. 013	POWER TRANSMISSION	2	FRETTING DAMAGE UNDER
22 – BLDG. 013	MECHANISM MAINTENANCE	2	VIBRATORY LOADS
			CYCLOID GEARING
			WIPERS (ETC.)

BUILDING 354

THE WEST SIDE OF THE TOWER TO BE MODIFIED FOR FUEL CASK STUDIES. THE NORTH SIDE IS TO BE MODIFIED FOR CORE GUIDE TUBE, FUEL HOUSING TUBES, CONTROL RODS, AND OTHER CORE COMPONENT STUDIES.

FACILITY REQUIREMENTS (HIGH BAY WITH CRANE ACCESS)

BUILDING 006 – 4 LOOPS – 1200 ft² (AVAILABLE)

BUILDING 013 – 14 LOOPS – 3800 ft² (AVAILABLE)

BUILDING 354 – NORTH AND WEST END OF TOWER

WEST END – CONSTRUCTION OF SUPPORT PLATFORM AND COLUMN EXTENSIONS.

NOTE: SOUTH END OF BUILDING TO BE USED FOR INSTRUMENTATION TESTING AS DESCRIBED UNDER ANOTHER SECTION.

FACILITY DESCRIPTIONS

1. MECHANISMS IN SODIUM – THE LOOPS ARE SIMILAR IN DESIGN AND CONSTRUCTION (SEE SCHEMATIC). ALL SYSTEM COMPONENTS ARE AUSTENITIC TYPE STAINLESS STEEL. THE VESSELS ARE 12 in. IN DIAMETER AND CONTAIN A 3-in.-DIAMETER COLD TRAP AND A 3-in.-DIAMETER CIRCULATING HOT TRAP WHICH CAN BE ISOLATED FROM THE SYSTEM PRIOR TO ITS USE. TWO METHODS OF SODIUM SAMPLING ARE PLANNED. THESE ARE THE CIRCULATING AND DIP-TUBE TYPES DESCRIBED IN NAA-SR-12446. EACH VESSEL IS FILLED THROUGH A FILTER AND DUMPED THROUGH A BYPASS LINE.

2. TOWER FACILITY – EQUIPMENT AND TEST PROGRAM IN INITIAL PLANNING STAGES FOR FFTF SUPPORT; CONSEQUENTLY, COMPLETE DESCRIPTION IS NOT PRESENTLY AVAILABLE.

SCHEDULE (FABRICATION OF NECESSARY FACILITIES)

TYPICAL LOOP SCHEMATIC

SODIUM VAPOR TEST INSTALLATION

(For Sodium Vapor Deposition And Control)

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS ONE LOOP OPERATIONAL (2 VESSELS), ONE LOOP UNDER CONSTRUCTION, AND ONE TEST STATION (8 VESSELS) PROPOSED.

FACILITY USE

STATUS	LOOP	APPLICATION	VESSELS	
EXISTING	1	DEPOSITION	2	MECHANICAL AND CHEMICAL PROPERTIES
EXISTING	1	CONTROL	2	VAPOR NUCLEATION CONTROL
PROPOSED	1	DEPOSITION AND CONTROL	8	MECHANICAL AND CHEMICAL PROPERTIES

NOTE: ALL TEST LOOPS WILL HAVE SODIUM LIQUID CAPABILITIES UP TO 1200°F

FACILITY REQUIREMENT

BUILDING 006 - 500 R² (AVAILABLE)

FACILITY DESCRIPTION

1. VAPOR DEPOSITION STATION - THE VESSELS ARE SIMILAR IN DESIGN AND CONSTRUCTION (SEE SCHEMATIC). ALL SYSTEM COMPONENTS ARE AUSTENITIC TYPE STAINLESS STEEL. THE VESSELS ARE 12 in. IN DIAMETER AND CONTAIN A 3-in. DIAMETER COLD TRAP. FILL AND DRAIN WOULD BE ACCOMPLISHED THROUGH A 1-in.-DIAMETER LINE FLANGED TO ACCOMMODATE A DUMP STATION LINE. SINCE PREPROGRAMMED IMPURE ARGON ATMOSPHERES WILL BE USED ABOVE THE SODIUM POOL, CONTAMINATED SODIUM WILL BE DISPOSED OF AFTER IMPURITY LEVELS IN THE SODIUM ATTAIN THE LEVEL OF COVER GAS IMPURITIES.

2. VAPOR CONTROL LOOP - PRESENT CONTROL LOOP IS A TWO-PHASE SYSTEM WHICH INCLUDES FLOW IN AEROSOL SODIUM - SODIUM OXIDE VAPOR AND A RETURN FLOW OF SODIUM CONDENSATE NUCLEATED IN A CONTROL VESSEL. THE SYSTEM COMPONENTS INCLUDING THE BLOWER ARE AUSTENITIC TYPE STAINLESS STEEL. THE MAIN VESSEL IS A 12-in. DIAMETER CYCLONE PRECIPITATOR WITH VARIOUS TEST CONTROL SYSTEMS. A LIQUID RETURN LINE FEEDS THE UPPER END OF A 3-in. DIAMETER COLD TRAP.

SCHEDULE (FABRICATION OF NECESSARY FACILITIES)

VAPOR DEPOSITION STATION SCHEMATIC (Typical)

CONTROLLED ATMOSPHERE SPECIMEN EXAMINATION CHAMBER ABOVE VESSELS

VAPOR CONTROL LOOP SCHEMATIC (Typical)

LMEC-68-13
C-29

SITT - SODIUM INSTRUMENTS TEST TOWER

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS MODIFICATION TO CETS (CORE ELEMENT TEST STRUCTURE)

FACILITY USE

IN-SODIUM IMMERSION TESTING OF THERMOCOUPLES, LEVEL GAUGES, AND PRESSURE TRANSDUCERS UP TO 50 ft FOR:

- TEMPERATURE, 300 TO 1400°F
- THERMAL GRADIENTS, 300 to 1400°F
- THERMAL SHOCK, UP TO 600°F/min WITH A MAXIMUM RATE OF 60°F/sec
- THERMAL CYCLING.

FACILITY DESCRIPTION

THIS FACILITY CONSISTS OF A MODIFICATION TO AN EXISTING STRUCTURE. TWO SODIUM THIMBLES AND ASSOCIATED TANKS (SEE SKETCH) WILL BE INSTALLED VERTICALLY ON EITHER SIDE OF THE 20- BY 40- BY 100-ft TOWER FACILITY WHICH IS SERVICED BY AN OVERHEAD 5-ton BRIDGE CRANE. THE 55-ft-LONG BY 2-1/2-in DIAMETER THIMBLES WILL EXTEND FROM A WORKING DECK IN THE TOWER INTO HOLES 10 ft BELOW GROUND LEVEL. A DRAIN TANK, PUMP, COLD TRAP, AND OTHER APPARATUS WILL BE LOCATED IN A PIT 25 ft BELOW GROUND LEVEL. ONE DRAIN TANK WILL BE OF SUFFICIENT SIZE TO SERVICE BOTH THIMBLES AND WILL BE LOCATED SUCH THAT IN CASE OF ACCIDENT OR LOSS OF POWER, THE THIMBLES MAY DRAIN BY GRAVITY. A COLD TRAP AND PLUGGING METER WILL BE PROVIDED FOR SODIUM PURITY.

THE SODIUM THIMBLES WILL BE HEATED BY MEANS OF SEGMENTED HEATING ELEMENTS ALONG THEIR LENGTH. THIS WILL ALLOW FOR THERMAL GRADIENTS TO BE SET UP AS DESIRED BY TEST CRITERIA. THERMAL CYCLING AND SHOCKING WILL BE DONE BY PUMPING OUT HOT SODIUM (1200°F OR MORE) WHILE PUMPING IN COLD SODIUM (300°F) AT SPECIFIED RATES, OR VICE VERSA.

THE SODIUM LEVEL IN EACH THIMBLE CAN BE RAISED AND LOWERED EITHER BY USE OF THE PUMP OR BY PRESSURIZATION OF THE DUMP TANK. PRESSURE VARIATIONS FOR PRESSURE TRANSDUCERS UNDER TEST WILL BE ACCOMPLISHED BY CHANGING THE COVER GAS PRESSURE OR THE SODIUM HEAD (LEVEL)

SCHEDULE

SODIUM INSTRUMENT TEST TOWER (SITT)

SIMI

SODIUM IMPURITIES MEASUREMENTS INSTALLATION

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS NEW FACILITY

FACILITY USE

THE FACILITY MAY BE USED FOR PERFORMANCE EVALUATION AND CALIBRATION OF IN-LINE SODIUM IMPURITY MEASURING INSTRUMENTS. IT IS CAPABLE OF PROVIDING TESTS TO SHOW:

- INSTRUMENT SENSITIVITY TO TEMPERATURE, FLOWRATE, THERMAL CYCLING, AND OPERATING TIME (STABILITY AND DRIFT)
- INSTRUMENT THERMAL SHOCK AND PRESSURE DAMAGE IMMUNITY
- INSTRUMENT CALIBRATION IN TERMS OF STANDARD ANALYTICAL LABORATORY MEASUREMENTS

FACILITY DESCRIPTION

THE FACILITY CONSISTS ESSENTIALLY OF TWO LOOPS CONNECTED TO PROVIDE MIXING AS SHOWN IN THE ACCOMPANYING SKETCH. THE TWO LOOPS ARE SIMILAR AND INCORPORATE TYPE 304 STAINLESS-STEEL VESSELS AND PIPING (SCHEDULE 40). FOR THE HIGHER FLOW-RATE PATHS, 1-1/2-in. PIPE IS USED; ELSEWHERE, 1-in. PIPE IS USED. ELECTRIC HEATERS ARE INSTALLED ON THE PIPING AND TANKS. EACH LOOP INCLUDES AN ELECTROMAGNETIC PUMP, A PURIFICATION APPARATUS, AND SAMPLE STATIONS. LOOP I ACCOMMODATES THE TEST INSTRUMENT(S) WHILE LOOP II PROVIDES THE "VARIABLE" (ADDED IMPURITY IN SOLUTION, OR THERMAL SHOCK). THE VALVE BETWEEN THE LOOPS ENABLES MIXING AND FLOW-METERS INDICATE THE MIXING RATIO. A SUMP TANK IS PROVIDED TO ACCOMMODATE THE SODIUM WHEN LOOP DRAINAGE IS REQUIRED AND SERVES AS A SUPPLY TANK FOR INITIAL FILLING. A PURIFICATION LOOP IS ATTACHED TO THE SUMP TANK TO PROVIDE ADDITIONAL CAPACITY FOR "CLEAN-UP," PARTICULARLY FOR INITIAL FILL OPERATION.

LEGEND

- P₁ PUMP (1 gpm at 4 psi)
P₂ PUMP (25 gpm at 6 psi)
P₃ PUMP (25 gpm at 6 psi)
FM-1 FLOWMETER (0-1 gpm)
FM-2 FLOWMETER (0-10 gpm)
PS PURIFICATION SYSTEM
LG LEVEL GAGE
V&IG VACUUM AND INERT GAS SUPPLY
1 in. ———
1-1/2 in. ———

LMEC-68-13
C-31

SPTI - SODIUM PURIFICATION TEST INSTALLATION

LOCATION LMEC, SANTA SUSANA, CALIFORNIA
STATUS NEW FACILITY

FACILITY USE
THIS SODIUM LOOP AND ITS AUXILIARY SYSTEMS WILL BE USED FOR THE FIRST PROTOTYPE COLD-TRAP TEST, IDENTIFIED IN SUB-TASK 2-A-2 OF THE SODIUM TECHNOLOGY SECTION, LMFBR PROGRAM PLAN. THE FACILITY ALSO WILL HAVE THE CAPABILITY FOR TESTING PROTOTYPE GETTER SYSTEMS.

FACILITY DESCRIPTION
THE ISOTHERMAL, 3-in.-PIPE LOOP INCLUDES A 65,000-lb TANK TO PERMIT SIMULATION OF A LARGE SYSTEM AND PROVISIONS FOR INSTALLATION OF PROTOTYPE TRAPS - EITHER COLD TRAPS OR HOT TRAPS. THE LOOP WILL BE WELL INSTRUMENTED FOR MONITORING IMPURITY CONTENT OF THE SODIUM AND FOR PERTINENT TEMPERATURES, PRESSURES, AND FLOW RATES. PROVISION WILL BE MADE FOR SODIUM SAMPLING.

THE SYSTEM WILL HAVE THE CAPABILITY FOR THE CONTINUOUS ADDITION OF IMPURITIES AT MEASURABLE AND VARIABLE RATES. TO MEET THIS REQUIREMENT, METHODS DEVELOPMENT AND PROOF-TESTING ARE NEEDED PRIOR TO FINALIZING FACILITY DESIGN.

IN ADDITION TO THE SODIUM TEST LOOP, THE FACILITY WILL INCLUDE PROVISIONS FOR DISASSEMBLY AND EXAMINATION OF EXPENDED TRAPS.

SCHEDULE

TPTC - TEMPERATURE-PRESSURE TEST CHAMBER

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS NEW INSTALLATION

FACILITY USE

FOR INERT DRY ATMOSPHERE CALIBRATION OF TEMPERATURE AND PRESSURE INSTRUMENTS AT:

- TEMPERATURE TO 1400°F AMBIENT
- TEMPERATURE HOT SPOT TO 5000°F FOR FUEL ELEMENT THERMOCOUPLES
- PRESSURE TO 250 psig

FACILITY DESCRIPTION

THIS APPARATUS CONSISTS OF A 49-ft-LONG TEST CHAMBER PLUS TEMPERATURE, PRESSURE, AND VACUUM CONTROL EQUIPMENT TO ACCOMMODATE THERMOCOUPLES AND PRESSURE TRANSDUCER CAPILLARIES 50 ft IN LENGTH. IT WILL PROVIDE FOR CALIBRATION OF ABOUT 100 THERMOCOUPLES AT A TIME. IT WILL BE OF MODULAR DESIGN IN A HORIZONTAL CONFIGURATION. THE MODULAR DESIGN WILL ALLOW SECTIONAL CONTROL OF TEMPERATURE TO SIMULATE ANTICIPATED REACTOR TEMPERATURE PROFILE. AT ONE END WILL BE A "HOT-SPOT" TEMPERATURE MODULE TO DEVELOP UP TO 5000°F IN A BLOCK OF TUNGSTEN FOR CALIBRATION OF FUEL ELEMENT THERMOCOUPLES. THIS HOT-SPOT MODULE WILL INCLUDE A RADIATING BLACK BODY FOR OPTICAL PYROMETER CALIBRATION AT THE EXTREME HIGH-TEMPERATURE END. OTHER TEMPERATURES WILL BE CALIBRATED BY SECONDARY STANDARD THERMOCOUPLES.

CONSTRUCTION OF THE TEST CHAMBER WILL INCLUDE AN INNER HEAT (RADIATION) SHIELD WITHIN A VACUUM/PRESSURE CHAMBER. DURING TEMPERATURE TESTS, THE ENTIRE CHAMBER IS PUMPED DOWN TO A HIGH VACUUM. THE OUTER (PRESSURE) SHELL WILL ALSO BE MODULAR IN CONSTRUCTION TO PROVIDE FOR EASE OF FABRICATION AND EFFICIENT MAINTENANCE.

PRESSURE CALIBRATION WILL BE ACCOMPLISHED BY CONNECTING THE TRANSDUCER END OF A GAUGE TO AN EXTERNAL SOURCE OF INERT GAS. PRESSURE MEASUREMENTS CAN THEREFORE BE MADE WITH THE TRANSDUCER AND CAPILLARY SUBJECT TO THE REACTOR TEMPERATURE ENVIRONMENT. SECONDARY STANDARD PRESSURE GAUGES WILL BE UTILIZED FOR NBS TRACEABILITY CALIBRATION.

SCHEDULE

LMEC-68-13
C-33

SCTI-SODIUM COMPONENTS TEST INSTALLATION

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS AN EXISTING FACILITY - MODIFICATIONS ARE REQUIRED TO IMPROVE RELIABILITY.

FACILITY USE

- PROOF TEST ALCO, B&W, AND OTHER ONCE-THROUGH STEAM GENERATORS
- CASUALTY TEST STEAM GENERATORS IN AN OPERATING FACILITY
- PROOF TEST ALCO IHX.
- TEST NEW MATERIALS FOR FUTURE STEAM PLANTS.

FACILITY DESCRIPTION

THE SCTI CONSISTS OF A SODIUM HEATER (PRIMARY HEAT SOURCE), PRIMARY SODIUM HEAT TRANSFER SYSTEM, SECONDARY SODIUM HEAT TRANSFER SYSTEM, STEAM AND FEEDWATER SYSTEM, CIRCULATING COOLING WATER SYSTEM, PLUS CONTROLS AND INSTRUMENTATION AND AUXILIARY SERVICE SYSTEMS.

PRIMARY SODIUM IS CIRCULATED THROUGH THE GAS-FIRED SODIUM HEATER TO THE INTERMEDIATE HEAT EXCHANGER (IHX) WHERE THE HEAT IS TRANSFERRED TO THE SECONDARY SODIUM SYSTEM. THREE BYPASS LOOPS ARE INCORPORATED IN THE PRIMARY SYSTEM TO INDUCE THE VARIOUS TRANSIENTS IN THE TEST UNITS. SECONDARY SODIUM IS CIRCULATED FROM THE IHX THROUGH THE TEST STEAM GENERATOR WHERE HEAT IS TRANSFERRED TO THE STEAM SYSTEM.

THE STEAM PRODUCED IN THE ONCE-THROUGH TEST STEAM GENERATOR IS ROUTED THROUGH THREE PRESSURE-REDUCING STATIONS AND A DESUPERHEATER AND THEN DUMPED TO A SURFACE CONDENSER. STEAM TURBINE OPERATION IS SIMULATED BY MEANS OF THIS SERIES OF PRESSURE-REDUCING STATIONS AND DESUPERHEATER. THE RESULTING CONDENSATE IS DEAERATED AND REHEATED BY THREE FEEDWATER HEATERS AND THEN RETURNED TO THE STEAM GENERATOR. HIGH-PURITY WATER WILL BE MAINTAINED IN THE STEAM SYSTEM USING A NEW CONDENSATE POLISH DEMINERALIZER SYSTEM.

COOLING WATER PICKS UP HEAT FROM THE CONDENSER AND DISSIPATES IT TO THE ATMOSPHERE IN AN INDUCED DRAFT COOLING TOWER.

RUPTURE DISCS ARE PROVIDED TO PROTECT THE STEAM GENERATOR SHELL IN THE EVENT OF A STEAM-TUBE RUPTURE AND ACCOMPANYING SODIUM-STEAM-WATER REACTION. BOTH RUPTURE DISC OUTLETS ARE PIPED TO SURGE TANKS. VENT PIPES LEAD OUT OF THE TOP OF EACH TANK TO BLEED OFF THE GASEOUS REACTION PRODUCTS.

MODIFICATIONS IN PROGRESS TO THE STEAM AND FEEDWATER SYSTEM TO IMPROVE PLANT RELIABILITY ARE:

- REPLACEMENT OF THE STAINLESS-STEEL MAIN STEAM LINE AND VALVES WITH CROLOY PIPING
- REPLACEMENT OF THE BYPASS POLISH DEMINERALIZER WITH A NEW FULL-FLOW CONDENSATE POLISH SYSTEM
- ROUTE ALL HEATER DRAINS TO THE STEAM CONDENSER
- PROPOSED MODIFICATIONS TO THE STEAM AND FEEDWATER SYSTEM TO IMPROVE PLANT RELIABILITY ARE:
 - REPLACE THE PACKED TUBE STEAM CONDENSER
 - REPLACE THE MAIN CONDENSATE PUMP
 - REPLACE INTERMEDIATE-PRESSURE FEEDWATER HEATER

SCHEDULE

SODIUM COMPONENTS TEST INSTALLATION (SCTI)

HVSL - HIGH-VELOCITY SODIUM LOOP

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS NEW PROPOSED TEST FACILITY FOR TESTING THE EFFECT OF HIGH-VELOCITY (UP TO 50 ft/sec) HIGH-TEMPERATURE (1200°F) SODIUM ON STAINLESS-STEEL (TYPE 304) PIPING AND FITTINGS.

FACILITY USE

THE FACILITY MAY BE USED TO:

- EVALUATE EROSION DUE TO SODIUM VELOCITY (20 to 50 ft/sec) AT HIGH TEMPERATURE (1200°F) FOR LONG PERIODS OF TIME (5 yr)
- EVALUATE PIPE VIBRATION DUE TO SODIUM VELOCITY (20 to 60 ft/sec) AT HIGH TEMPERATURE (1200°F)
- DEVELOP NDT (NON-DESTRUCTIVE TESTING) TECHNIQUES FOR SODIUM PIPING EXAMINATION.

FACILITY DESCRIPTION

THE FACILITY WILL CONSIST OF A MEDIUM-SIZE SODIUM PUMP APPROXIMATELY 2000 TO 3000 gpm SUPPLYING SODIUM TO A 6- OR 8-in. PIPE, OR SUPPLY MANIFOLD. SODIUM WILL FLOW BETWEEN THE SUPPLY AND RETURN MANIFOLD VIA THE FOUR TEST SECTIONS; THE FOUR TEST SECTIONS WILL HAVE SODIUM FLOWS EQUIVALENT TO 20, 30, 40, and 50 ft/sec. SIMILAR VALVES, ELBOWS, INSTRUMENTATION, AND HEATERS WILL BE SUPPLIED FOR EACH TEST SECTION. A SODIUM SURGE TANK AND SAMPLING DEVICE WILL ALSO BE REQUIRED.

THE FACILITY WILL BE IN CONTINUOUS OPERATION FOR ABOUT 5 yr. THE FACILITY WILL BE PERIODICALLY SHUT DOWN (EVERY 6 months) TO MEASURE THE EFFECTS OF PREVIOUS OPERATION AND TO PROVIDE A BASIS FOR EXTRAPOLATION TO 30-yr OPERATION OR BEYOND.

EACH TEST SECTION: (1) WILL HAVE BEEN ACCURATELY MEASURED PRIOR TO OPERATION; (2) WILL HAVE PIPING EXTERIOR READILY ACCESSIBLE FOR NDT AND PHYSICAL MEASUREMENTS, WHICH WILL REQUIRE HINGED HEATERS, INSULATION; AND (3) WILL HAVE TWO VALVES, FLOWMETER, THERMOCOUPLES, PRESSURE TRANSMITTERS, AND STRAIN GAGES INSTALLED.

SCHEDULE

HIGH-VELOCITY SODIUM LOOP (HVSL)

SPTF - SODIUM PUMP TEST FACILITY

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS PRESENTLY FUNDED - TITLE I ENGINEERING IN PROGRESS

FACILITY USE

- TEST LARGE SODIUM PUMPS
- TEST LARGE SODIUM COMPONENTS
- PROVIDE INFORMATION AND EXPERIENCE IN THE DESIGN, FABRICATION, AND OPERATION OF LARGE HIGH-TEMPERATURE SODIUM PIPING SYSTEMS

FACILITY DESCRIPTION

THE SPTF CONTAINS TWO SODIUM LOOPS, ALL NECESSARY AUXILIARY EQUIPMENT, AND MOUNTING PROVISIONS FOR THE TESTING OF SODIUM PUMPS. THE TWO FLOW LOOPS ARE IDENTICAL, EACH SIZED FOR A DESIGN FLOWRATE OF 60,000 gpm. PUMPS OF UP TO 60,000 gpm CAN BE OPERATED IN EACH LOOP AND LARGER PUMPS UP TO 120,000 gpm CAN BE TESTED BY USING THE TWO LOOPS AS PARALLEL FLOW PATHS.

EACH LOOP CONTAINS A FEED TANK, A DRAIN TANK, AND A SURGE TANK. THE FEED TANK PROVIDES THE NECESSARY HEAT SINK RESERVOIR FOR THERMAL TRANSIENT TESTS. THE DRAIN TANKS HAVE A CAPACITY SUFFICIENT TO CONTAIN THE ENTIRE SODIUM INVENTORY.

COMMON SERVICE SODIUM-TO-AIR HEAT EXCHANGERS ARE USED FOR PUMP HEAT REMOVAL.

SCHEDULE

SODIUM PUMP TEST FACILITY (SPTF)
(CSSD CONCEPT)

SCTL - SMALL COMPONENTS TEST LOOP (Formerly the Large Components Test Loop, LCTL)

LOCATION LMEC, SANTA SUSANA, CALIFORNIA

STATUS MODIFY LCTL, AN EXISTING FACILITY FOR HIGH-TEMPERATURE AND HIGH-PRESSURE TESTING (1200°F AND 225 psig, RESPECTIVELY).

FACILITY USE

THE TWO SODIUM SYSTEMS MAY BE USED FOR:

- TESTING FFTF CLOSED-LOOP COMPONENTS (MID-1970)
- TESTING FFTF IN-CORE FLOWMETERS (EARLY 1970, AGAIN IN 1971)
- TESTING COMPONENTS UP TO 12 in. FOR THE LMFBR PROGRAM
- TESTING SODIUM PUMP BEARINGS
- GENERAL PURPOSE THERMAL SHOCK TESTING IN EITHER LOOP.

FACILITY DESCRIPTION

REPLACE THE 6-in. CROLOY PIPING WITH 12-in. STAINLESS-STEEL PIPING; INSTALL HIGH-TEMPERATURE AND HIGH-PRESSURE PUMPS CAPABLE OF 8000 gpm, A NEW SODIUM COOLER, AND A NEW SODIUM TRANSFER PUMP (REFER TO SCHEMATIC AT THE RIGHT). THE FACILITY WILL CONSIST OF TWO PIPING LOOPS, EACH CONTAINING PUMPS. ONE LOOP IS 3-in., THE OTHER 12-in. BOTH LOOPS ARE CONNECTED TO A LARGE TANK WHICH MAY BE USED TO MOCKUP NON-RADIOACTIVE CORE COMPONENTS. TWO OTHER TANKS ARE USED FOR THERMAL TRANSIENT TESTING. TESTING OF COMPONENTS OR SUBSYSTEM INSERTS WOULD BE PERFORMED IN THE TEST POSITIONS. SODIUM IS PUMPED FROM THE CORE TANK (EXPANSION TANK), THROUGH THE TEST POSITIONS, AND BACK TO THE CORE TANK. A HEATER AND A COOLER ARE USED FOR CONTROL OF SYSTEM TEMPERATURE DURING TESTING AND FOR HEATING AND COOLING SODIUM IN THE SUPPLY TANK IN PREPARATION FOR THERMAL TRANSIENT TESTING. THERMAL TRANSIENTS ARE EFFECTED BY PASSING HOT OR COLD SODIUM FROM THE SUPPLY TANK, THROUGH THE TEST POSITIONS, TO THE DUMP TANK.

IN-CORE FLOWMETER TEST INSERT

THE FLOWMETER TEST INSERT CONSISTS OF A TEST VESSEL, A HEATER, AND A COOLER. THIS TEST INSERT (SEE INSET SKETCH AT RIGHT) WILL BE CONNECTED TO A TEST POSITION IN THE SCTL. THE IN-CORE TEST INSERT WILL BE DESIGNED SPECIFICALLY FOR TESTING IN-CORE FLOWMETERS FOR THE INITIAL FFTF CORE LOADING, LIMITED TO A MAXIMUM TESTING TEMPERATURE OF 1400°F IN THE CENTER FLOWMETER THROAT. THERMAL SHOCK CAPABILITIES WILL BE PROVIDED. THE CENTER FLOWMETER MAY BE OPERATED AT A HIGHER COOLANT TEMPERATURE THAN THE SURROUNDING FLOWMETERS TO SIMULATE HOT CHANNEL OPERATION. TO SIMULATE OPERATION ABOVE 1200°F, THE HEATER WILL HEAT THE SODIUM ENTERING THE CENTER FLOWMETER. THE MIXED SODIUM OUT OF THE TEST VESSEL IS COOLED PRIOR TO ITS ENTERING THE SCTL SYSTEM.

SCHEDULE (MODIFICATION TO LCTL)*

*THE ENGINEERING AND CONSTRUCTION SCHEDULE OF THE CLOSED-LOOP AND IN-CORE FLOWMETER INSERTS IS APPROXIMATELY THE SAME AS THE SCTL (LCTL) MODIFICATIONS. IF STARTED CONCURRENTLY, THE INSERTS SHOULD BE READY FOR TESTING WHEN THE SCTL (LCTL) IS READY FOR STARTUP.

CLOSED-LOOP INSERT

FFTF CLOSED-LOOP COMPONENTS MAY BE TESTED AS A BUILT-TO-FIT INSERT IN AN SCTL TEST POSITION (SEE MIDDLE SKETCH BELOW). THE SMALL COMPONENTS WOULD BE ASSEMBLED AS AN INSERT, USING THE SCTL SYSTEM FOR SODIUM COOLING, EXPANSION, PURIFICATION, AND STORAGE. TESTING CAPABILITIES WOULD INCLUDE A HEATER, THE FFTF CLOSED-LOOP PROCESS TUBE, PUMPS, AND INTERMEDIATE HEAT EXCHANGER.

SMALL COMPONENTS TEST LOOP (SCTL)

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ACTI - AUXILIARY COMPONENTS TEST INSTALLATION

(Formerly the HNPf Pump Test Loop)

LOCATION LMFC, SANTA SUSANA, CALIFORNIA

STATUS MODIFY THE HNPf PUMP TEST LOOP, AN EXISTING FACILITY.

FACILITY USE

THE SODIUM SYSTEM MAY BE USED FOR:

- TESTING AND CALIBRATION OF SODIUM FLOWMETERS UP TO 20,000 gpm (FFTF FLOWMETERS 1971)
- TESTING INTERMEDIATE SIZE SODIUM PUMPS (FFTF PUMP MID-1970)
- THERMAL TRANSIENT TESTING OF INSTRUMENTS, COMPONENTS, AND PUMPS
- TESTING COOLANT TRANSPORT SYSTEM EQUIPMENT
- TESTING OTHER SODIUM COMPONENTS INsofar AS THE PRIMARY FUNCTION OF CALIBRATING FLOWMETERS IS NOT COMPROMISED.

FACILITY DESCRIPTION

INSTALL TWO HNPf SECONDARY SODIUM PUMPS IN THE EXISTING PUMP BAYS AND REPLACE THE EXISTING 12-in. PIPING WITH 20-in. PIPING DESIGNED FOR 1210° F AND 225 psig. THE TWO PUMPS IN PARALLEL WILL BE CAPABLE OF ABOUT 20,000 gpm TOTAL FLOW. THE EXISTING HNPf PUMPS ARE LIMITED TO ABOUT 1050° F AND 100 psig. THE LARGE TEST LOOP WILL CONTAIN (IN ADDITION TO THE TWO PUMPS) THE INSTRUMENT FLOW CALIBRATION CIRCUITS (20-, 18-, 12-, 8-, 6-, 4-, AND 2-in. PIPE SIZES), A FLOW-THROUGH EXPANSION TANK, A SODIUM-TO-AIR HEAT EXCHANGER FOR DISSIPATION OF PUMP ENERGY, SODIUM PURIFICATION EQUIPMENT, AND FACILITIES FOR THE INSTALLATION OF A TEST PUMP OF UP TO 20,000 gpm CAPACITY. THE THERMAL TRANSIENT SUBSYSTEM WILL CONSIST OF A SODIUM COOLER, SODIUM HEATER, A SMALL PUMP, AND A SMALL EXPANSION TANK WITH CONNECTING LINES TO EACH INSTRUMENT CALIBRATION LOOP AND THE TEST PUMP. THE ENTIRE SODIUM INVENTORY MAY BE STORED IN FILL AND DRAIN TANKS.

SODIUM FOR FLOWMETER CALIBRATION WILL BE SUPPLIED BY EITHER/OR BOTH PUMPS. THE SYSTEM FLOWMETERS (PERMANENT MAGNET) WILL BE INITIALLY CALIBRATED AND PERIODICALLY RECHECKED USING THE TWO PERMANENTLY INSTALLED WATER-CALIBRATED VENTURI METERS (20 AND 8 in.) BY VOLUMETRIC CALIBRATION OR BY THE "BOOTSTRAP" METHOD. A TEST FLOWMETER WILL BE INSTALLED IN SERIES WITH A SYSTEM FLOWMETER OF SUITABLE SIZE AND KNOWN CALIBRATION. CALIBRATION OF A TEST FLOWMETER WILL BE BY DIRECT COMPARISON WITH A CALIBRATED SYSTEM FLOWMETER IN ONE OF THE CALIBRATION CIRCUITS. SODIUM FOR VOLUMETRIC CALIBRATION OF FLOWMETERS WILL BE PUMPED FROM THE FLOW-THROUGH EXPANSION TANK THROUGH THE FLOWMETER BEING CALIBRATED TO THE DRAIN TANK. THE SODIUM LEVEL CHANGE WILL BE MEASURED AND THE FLOWRATE ESTABLISHED.

THE TEST POSITIONS IN THE INSTRUMENT CALIBRATION CIRCUITS AND THE TEST PUMP POSITION MAY BE SUBJECTED TO THERMAL TRANSIENT TESTING.

SCHEDULE

H. B. DIETZ

AUXILIARY COMPONENTS TEST INSTALLATION (ACT I)

SGTF - STEAM GENERATOR TEST FACILITY

LOCATION LMEC, SANTA SUSANA, CALIFORNIA OR AS DIRECTED

STATUS A NEW FACILITY

FACILITY USE

THE FACILITY MAY BE USED FOR:

- TESTING FFTF INTERMEDIATE HEAT EXCHANGER WITH FFTF PUMP AND HEAT DUMP SYSTEM (EARLY 1971)
- TESTING LMFBR PROTOTYPE INTERMEDIATE EXCHANGERS
- TESTING LMFBR PROTOTYPE STEAM GENERATORS (TUBE BUNDLES OR SCALE MODELS)
- GENERAL PURPOSE HEAT EXCHANGER AND STEAM GENERATOR TESTING.

FACILITY DESCRIPTION

THE SGTF WILL INITIALLY PROVIDE TESTING CAPABILITIES FOR THE FFTF INTERMEDIATE HEAT EXCHANGER AND HEAT DUMP SYSTEM. THE COMPLETED FACILITY WILL INCLUDE A STEAM GENERATOR TEST POSITION AND A COMPLETE STEAM SYSTEM WITH FINAL HEAT REJECTION TO THE ATMOSPHERE. THIS FACILITY WILL MEET THE IMMEDIATE NEEDS FOR FFTF HEAT EXCHANGER TESTING AND THE FUTURE LMFBR PROTOTYPE IHX AND STEAM GENERATOR TESTING REQUIREMENTS.

THE FIRST STAGE OF CONSTRUCTION WILL INCLUDE THE PRIMARY AND SECONDARY SODIUM SYSTEMS. A GAS- OR OIL-FIRED SODIUM HEATER OF 50 TO 70 MWt WILL PROVIDE THE HEAT SOURCE. FFTF PUMPS WILL BE USED IN THE SODIUM SYSTEMS. THE PIPING FOR IHX TESTING WILL BE IN A FIGURE-EIGHT CONFIGURATION, USING THE IHX AS A REGENERATIVE HEAT EXCHANGER SO THAT LOWER HEATER INPUTS MAY BE USED AND STILL OBTAIN NEAR-FULL ΔT AT FULL FLOW. THE HEAT DUMP MAY BE DIRECTLY COUPLED (BYPASSING THE IHX) TO THE HEATER TO SIMULATE LOAD. THE HEAT DUMP IS THE FFTF MODULES SIZED TO REMOVE HEATER INPUT HEAT. FFTF COMPONENTS TESTED IN THE SGTF ARE TO REMAIN AS PERMANENT LOOP COMPONENTS.

THE SECOND AND FINAL STAGE OF SGTF CONSTRUCTION WOULD COMPLETE THE STEAM GENERATOR TEST AREA AND THE STEAM AND FEEDWATER SYSTEM. PRESSURE-REDUCING VALVES AND STEAM DESUPERHEATERS WILL PROBABLY BE USED TO SIMULATE TURBINE LOAD. LMFBR PROTOTYPE (SCALED DOWN) STEAM GENERATOR DESIGNS FROM 50 TO 70 MWt MAY BE TESTED. HEAT REJECTION WILL BE TO THE ATMOSPHERE USING A COOLING TOWER. THE STEAM GENERATOR MAY ALSO BE DRIVEN DIRECTLY FROM THE HEATER, BYPASSING THE IHX.

THE SGTF IS CAPABLE OF THERMAL TRANSIENT TESTING. TEMPERATURE UP-RAMPS ARE PERFORMED BY INCREASING THE FIRING RATE OF THE SODIUM HEATER AT REDUCED SODIUM FLOWS. TEMPERATURE DOWN-RAMPS MAY BE INITIATED BY MIXING COLD SODIUM FROM THE COLD LEG WITH SODIUM FROM THE HEATER OUTLET.

SCHEDULE

STEAM GENERATOR TEST FACILITY (SGTF)

SGTF - STEAM GENERATOR TEST FACILITY (ALTERNATE)

LOCATION

LMFC, SANTA SUSANA, CALIFORNIA OR AS DIRECTED

STATUS

A NEW FACILITY

FACILITY USE

THE FACILITY MAY BE USED FOR:

- TESTING LMFBF PROTOTYPE INTERMEDIATE HEAT EXCHANGERS (SCALE MODELS)
- TESTING LMFBF PROTOTYPE STEAM GENERATORS (TUBE BUNDLES OR SCALE MODELS)
- GENERAL PURPOSE HEAT EXCHANGER AND STEAM GENERATOR TESTING.

FACILITY DESCRIPTION

THE SGTF (ALTERNATE) WILL PROVIDE TESTING CAPABILITIES FOR MODEL IHX'S, SODIUM-TO-AIR COOLERS, STEAM GENERATOR TUBE BUNDLES, AND MODEL STEAM GENERATORS. ONLY A MODEL OF THE FFTF IHX MAY BE TESTED IN THE SGTF (ALTERNATE).

THE FACILITY WILL INCLUDE PRIMARY AND SECONDARY SODIUM SYSTEMS. AN OIL- OR GAS-FIRED SODIUM HEATER OF 7 TO 10 Mw_t WILL PROVIDE THE HEAT SOURCE. THE PIPING FOR IHX TESTING WILL BE IN A FIGURE-EIGHT CONFIGURATION, USING THE IHX AS A REGENERATIVE HEAT EXCHANGER SO THAT LOWER HEATER INPUTS MAY BE USED TO SIMULATE POWER LEVELS OF 15 TO 25 Mw_t. THE SODIUM COOLER (HEAT DUMP) MAY BE DIRECTLY COUPLED (BYPASSING THE IHX) TO THE HEATER TO SIMULATE LOAD.

THE STEAM GENERATOR TUBE BUNDLES OR MODEL STEAM GENERATORS WILL BE INSTALLED IN THE SECONDARY SODIUM SYSTEM. PRESSURE-REDUCING VALVES AND STEAM DESUPER-HEATERS WILL PROBABLY BE USED TO SIMULATE TURBINE LOAD. HEAT REJECTION WILL BE TO THE ATMOSPHERE USING A COOLING TOWER. THE STEAM GENERATOR MAY ALSO BE DRIVEN DIRECTLY FROM THE HEATER, BYPASSING THE IHX.

SODIUM COOLERS MAY BE TESTED EXCLUSIVE OF THE IHX AND STEAM GENERATOR.

THE SGTF IS CAPABLE OF THERMAL TRANSIENT TESTING. TEMPERATURE UP-RAMPS ARE PERFORMED BY INCREASING THE FIRING RATE OF THE SODIUM HEATER AT REDUCED SODIUM FLOWS. TEMPERATURE DOWN-RAMPS MAY BE INITIATED BY MIXING COLD SODIUM FROM THE COLD LEG WITH SODIUM FROM THE HEATER OUTLET.

IHX AND STEAM GENERATOR MAY BE TESTED FOR MAINTAINABILITY IN THE SGTF (ALTERNATE).

SCHEDULE

STEAM GENERATOR TEST FACILITY (SGTF) (ALTERNATE)

LMFC-68-13
C-40

HTSG - HIGH TEMPERATURE STRAIN GAGES (Or Strain Gage And Strain Gage Transducer Test Facilities)

LOCATION SANTA SUSANA

STATUS	FACILITY NO.	FUNCTION	STATUS
	1	PERFORM STEADY-STATE STABILITY TESTS IN AIR OR SODIUM UP TO 1400°F	FOUR OF FIVE SYSTEMS COMPLETED AND OPERATIONAL; THESE SYSTEMS WILL PERMIT SIMULTANEOUS TESTING IN ALL FIVE AIR FURNACES. SYSTEM FOR CONDUCTING SIMILAR TESTS IN SODIUM ABOUT 75% COMPLETED.
	2	PERFORM TRANSIENT TESTS IN AIR OR SODIUM UP TO 1400°F, AT HEATING RATES UP TO AT LEAST 30°F/sec	SYSTEM FOR CONDUCTING TESTS IN AIR COMPLETED AND OPERATIONAL. HARDWARE 50% COMPLETE ON SYSTEM FOR CONDUCTING TESTS IN SODIUM; INSTALLATION OF TEMPERATURE AND POWER CONTROL SYSTEM PENDING.
	3	CALIBRATE STRAIN GAGES	TWO OF THREE SYSTEMS FOR CALIBRATION UP TO 1400°F, UNDER FLEXURE, COMPLETED AND OPERATIONAL. DESIGN OF SYSTEM FOR CALIBRATION UP TO 1400°F, UNDER TENSION, 50% COMPLETE.
	4	CALIBRATE TRANSDUCERS EMPLOYING STRAIN GAGE SENSORS (PRESSURE GAGES, ETC.)	ESTABLISHMENT OF SYSTEM DESIGN PARAMETERS IN PROGRESS.

- FACILITY USE**
- CALIBRATE AND EVALUATE STRAIN GAGES, OR TRANSDUCER DEVICES EMPLOYING STRAIN GAGES, IN OR OUT OF SODIUM, FOR RDT CONTRACTORS AND NATIONAL LABORATORIES, AS DIRECTED BY RDT.
 - EVALUATE LATEST COMMERCIALY AVAILABLE HIGH-TEMPERATURE STRAIN GAGE TRANSDUCERS OR GAGES DEVELOPED AT THE LMEC, IN CONJUNCTION WITH THE EFFORT BEING CARRIED OUT UNDER G.O. 7693, S/A 52110, ENTITLED "HIGH TEMPERATURE STRAIN MEASUREMENTS."

FACILITY DESCRIPTION

FACILITY 1
SYSTEMS CONSIST OF HIGH-TEMPERATURE FURNACES AND RELATED SATURABLE CORE REACTORS AND SOLID-STATE TEMPERATURE AND POWER CONTROL SYSTEMS FOR LONG-TERM SOAK TESTS (UP TO 3000 hr) AT TEMPERATURES UP TO 1400°F, IN OR OUT OF SODIUM, WITH OR WITHOUT MECHANICAL STRAIN WHICH IS PROVIDED BY A 0- TO-12,000-lb CAPACITY CREEP MACHINE. READOUT EQUIPMENT PERMITS MONITORING OF STRAIN, TEMPERATURE, AND GAGE RESISTANCE CHARACTERISTICS THROUGHOUT THE TEST; SYSTEM ALSO CAPABLE OF DETECTING LEAKAGE OF SODIUM INTO GAGE.

FACILITY 2

SYSTEM FOR CONDUCTING THERMAL SHOCK TESTS IN AIR CONSISTS OF RADIANT HEATING FURNACE WITH RELATED TEMPERATURE PROGRAMMER CAPABLE OF IMPOSING A SPECIFIED TIME-TEMPERATURE HISTORY ON THE GAGE UNDER TEST. RELATED SYSTEM COMPONENTS INCLUDE A BLOWER SYSTEM TO HASTEN COOLING AFTER HEATING, OSCILLOGRAPHIC EQUIPMENT FOR RECORDING STRAIN AND TEMPERATURE, AS A FUNCTION OF TIME, AND BRIDGE COMPLETION AND SIGNAL-CONDITIONING EQUIPMENT. UP TO SIX GAGES MAY BE TESTED SIMULTANEOUSLY. SYSTEM FOR CONDUCTING THERMAL SHOCK TESTS IN SODIUM CONSISTS OF A SODIUM CAPSULE LARGE ENOUGH TO TEST GAGES PROTECTED WITH MASSIVE HUTS SUCH AS THE B&W HUT, A 40-kw INDUCTION HEATING SYSTEM AND WATER-COOLED HEATING COIL, A PRESSURIZATION SYSTEM FOR APPLYING EXTERNAL PRESSURES ON THE GAGE UP TO 125 psig TO SIMULATE SODIUM PRESSURES ON INTERNALLY MOUNTED GAGES, A LEAK DETECTION SYSTEM TO DETERMINE ANY SODIUM LEAKAGE INTO THE GAGE, AND A TEMPERATURE AND POWER CONTROLLER. READOUT EQUIPMENT IS SAME AS THAT FOR CONDUCTING THERMAL SHOCK TESTS IN AIR. TESTS MAY BE CONDUCTED WITH OR WITHOUT MECHANICAL STRAIN APPLIED TO SPECIMEN BY MEANS OF A 0-TO-12,000-lb CAPACITY CREEP MACHINE.

SCHEDULE

*Δ¹, Δ², Δ³, Δ⁴, ARE COMPLETION DATES PERTAINING TO FACILITIES (1), (2), (3), AND (4).

FACILITY 3

SYSTEMS CONSIST OF "CONSTANT-MOMENT" CALIBRATION BEAMS CONTAINED WITHIN HIGH-TEMPERATURE FURNACES, AND A DIRECT LOAD (TENSILE) FIXTURE WHICH WILL BE INCORPORATED INTO A 60,000-lb CAPACITY WTE TENSILE TESTING MACHINE. SYSTEMS ARE CAPABLE OF CALIBRATING SEVERAL GAGES SIMULTANEOUSLY, AT TEMPERATURES UP TO 1400°F, OVER A WIDE-RANGE STRAIN.

FACILITY 4

SYSTEM TO CONSIST OF ENVIRONMENTAL CHAMBERS CAPABLE OF SUBJECTING THE TRANSDUCER TO A SPECIFIED SET OF CONDITIONS, EMBRACING THE RANGES TO BE COVERED IN ACTUAL OPERATION, WITH AN UPPER TEMPERATURE LIMIT OF 1400°F.

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