MASTER

Quarterly Technical Progress Report Liquid Metal Engineering Center (LMEC)

April — June 1968

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The progress report for the
previous quarter was
LMEC-68-13

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Project: AEC Assistance and Consultation

Project Manager: R. W. Dickinson

Project Engineer: R. W. Dickinson

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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. VALVES AND SODIUM TECHNOLOGY

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 detailed test plan for the examination of 14-in.-diameter throttle, block, and check valves from HNPF was prepared.

Liaison was maintained with AI during the cleaning of HNPF valves. Preliminary observations of abnormal conditions on these valves were made.

B. CODES AND STANDARDS

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

Two tentative draft standards were forwarded to RDT for their review and comments; these were:

- 1) RDT-M-700, Sodium Quality
- 2) RDT-M-701, Sodium Cover Gas Quality.

LMEC provided input to ORNL for development of the following standards:

- 1) Welding
- 2) Cleaning and Cleanliness Requirements for Systems and Components
- 3) Twelve Material Standards
- 4) Two Plant Standards.

This input was in the form of detailed comments and recommendations for revision of existing RDT standards, as well as complete drafts of new standards.

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.

C. PUMPS

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 with the recommendation that Westinghouse be allowed to commence Phase II activity and that additional information be obtained from Byron Jackson for inclusion in their report.

Definition of FFTF primary sodium pump development requirements was initiated. Phase II of the Large Sodium Pump Study was expanded to include requirements of the FFTF pumps.

D. PIPING

The plan for the HNPF Post-Operation Examination Program has been released. Piping material samples and sections of pipe have been received for examination.

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.

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

E. HEAT EXCHANGERS AND STEAM GENERATORS

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 intermediate heat exchanger standard has been prepared and has been reviewed by the LMEC technical staff.

F. INCIDENT REPORTING SYSTEM

1. Data Collection and Reporting System

A proposed failure category nomenclature and examples of usage were prepared for application to analysis of historical failure data collected by LMEC and submitted to 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. Copies of the proposed failure category nomenclature, shown in Appendix A of the preceding quarterly (LMEC-68-13), were submitted to RDT 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, and results were published in Appendix B of the preceding quarterly (LMEC-68-13).

G. COMBINED UNIT REACTOR VESSEL (CURV)

LMEC-Memo-68-2, "Combined Unit Reactor Vessel (Curv) Systems State-of-the-Art Study," was published. Present and proposed CURV systems are

described and relevant design, construction, and operating information from applicable liquid-metal-cooled reactor programs are presented.

A preliminary evaluation of the state-of-the-art as it applies to design, construction, installation, and test of the primary vessel and top closure for CURV systems was completed. The preliminary evaluation was documented in LMEC-Memo-68-11, "Combined Unit Reactor Vessel (CURV), A Preliminary Evaluation."

H. QUALITY ASSURANCE

Drafts of proposed RDT standards, "Inspection System Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components/Systems" and "Quality Assurance Requirements Pertaining to Liquid Metal Fast Breeder Reactor Components/Systems" were prepared and circulated to LMEC personnel for comment.

Specifications for quality assurance required for the main steam line modification to SCTI were transmitted to Bechtel Corporation for comment.

The SPTF Quality Assurance Program Plan prepared by C. F. Braun and Co. was reviewed and comments were submitted to the SPTF Project Manager. Revision of the plan by C. F. Braun was initiated.

A Form 189a, prepared for the quality assurance activities at LMEC, was reviewed with appropriate personnel at RDT. This review resulted in a re-direction of the LMEC activities to accelerate the formal definition of a quality assurance system to be implemented at LMEC. This work was to take priority over and provide the base for LMEC's lead role in the LMFBR Quality Assurance Program. Direction was also received to stop work on the preparation of RDT Quality Assurance Standards other than providing input, via the Quality Assurance Steering Committee, to the effort being provided by Idaho Nuclear Corporation in support of ORNL.

III. PROGRESS DURING REPORT PERIOD

A. VALVES AND SODIUM TECHNOLOGY TASK UNIT (R. B. Hinze)

Sodium valves from the Hallam Nuclear Power Facility (HNPF) have been assigned to LMEC. These valves will be used as required in test facilities. The large, 14-in. size valves will be inspected and tested as part of the post-operation examination of HNPF components and piping. The set of 14-in. valves consists of the following:

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<u>No. of Items</u>	<u>Function</u>	<u>HNPF System</u>	<u>Disc</u>	<u>Stem Seal</u>
3	throttle	primary	ball	freeze
3	throttle	secondary	ball	freeze
3	block	primary	flexible- wedge gate	freeze
3	check	primary	swinging disc	-

A detailed test plan for the examination of the large valves has been prepared. Each of the twelve valves will be given a general visual examination, with appropriate photographic coverage. In addition, specific tests and detailed examinations are planned, as shown in Table 1.

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)	1	1	1	-
14-in. block (freeze)	3	3	1	1 disc
14-in. check	-	-	1	-

Two acceptance tests, leakage across the seat and pressure, will be repeated. These tests were originally performed after the valves were manufactured. The seat leakage test will provide valuable information on the durability of the inner valve, particularly the disc 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.

One valve of each type will be selected for disassembly and detailed examination. A complete visual examination and photographic record will be made. This will be followed by dimensional checking of the stem, disc, and seating surfaces. Measurements will be compared to design data. Dye penetrant

inspection of the body, bonnet, and internal parts will be made. These inspections will reveal the extent of any wear on valve guides, stem, and seating surfaces. Any cracking of surfaces of the structure will also be observed. Any evidence of corrosion or erosion will be noted.

While Table 1 shows only one metallographic examination, 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. The gate valve disc selected for metallographic examination is replaceable, so the valve can be returned to service.

A comparison of this plan with the tentative scope of examination reported in the preceding quarterly progress report (LMEC-68-13) shows that all effort will be concentrated on the large valves, since there has been little previous experience with valves of this size. Testing of the large valves has been simplified by the elimination of seat leakage tests on check valves since seat leakage is not considered critical for this type of valve, and by reduction of seat leakage testing of the dual-function throttle and block valves to one valve because LMEC considers it unlikely that this type of valve will be used for blocking service. Pressure tests will be conducted on one of the throttle valves and on three block valves.

Results and evaluation of these tests and examinations of large sodium valves, together with HNPF service history, will be of value to the LMFBR valve development program and to LMFBR designers. If significant changes have occurred during HNPF service, this examination program will detect the changes and will yield clues to potential long-term failure modes. The absence of any abnormalities in these valves will provide a reference point of satisfactory design for HNPF service conditions.

All twelve of the 14-in.-diameter HNPF sodium valves have been delivered to Atomics International's Radioactive Materials Disposal Unit for cleaning and decontamination. A portion of the first shipment, one block valve (foreground) and one throttle valve, both with secondary containment shells provided on core-coolant loop valves, is shown in Figure 1. After these valves were removed from the HNPF plant, piping connections were blanked with carbon steel plates

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Figure 1. HNPB Block Valve and Throttle Valve as Received at LMEC

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to isolate the sodium in the valves during shipment. The valves were sent to AI because of the availability of their facility for cleaning contaminated equipment at the Field Laboratory.

Cleaning of the valves is being conducted by AI as part of the HNPF retirement program. LMEC established requirements for cleaning the valves and has maintained close liaison with the AI unit performing this task. Draining of sodium and cleaning of the valves is being conducted in a careful manner to avoid any damage to the valves. As an example, heaters and thermocouples are installed to control heating of the valves (to thaw and drain sodium) in the same manner as in a reactor installation. Figure 2 shows the heaters and thermocouples installed on a block valve; the valve is mounted in one of two dollies constructed by LMEC for handling the valves during cleaning and examination.

Some damage was observed upon receipt of the valves at AI's Field Laboratory. On one throttle valve from the primary system (HNPF valve No. 103), three support members of the yoke structure located adjacent to the freeze seal were broken. This condition is shown in Figure 3. The appearance of the fracture where one member was displaced was typical of a recent fracture; i. e., there was no indication of oxidation or wear on the fracture surface. The crack, typical of the damage on two support members, was highlighted with chalk for clarity. The edge of the circular plate at the top of the freeze seal and the surface of the secondary containment shell both showed evidence of contact with another object. It is considered likely that the damage occurred when the valve was being lowered onto the floor after removal from the system.

Removal of throttle valves from the secondary system resulted in conditions which will require special treatment when the valves are being prepared for installation in a test facility. On valves No. 102 and No. 202, a portion of the cast valve body nozzle was removed when the valve was cut out of the piping. The cut was not aligned normal to the pipe centerline; on one side the pipe was cut and on the opposite side some valve material was removed. The condition of the inlet nozzle of valve No. 102, which is typical of both valves, is illustrated in Figure 4; valve material was removed in the lower left area of the photo where cover plate obscures original valve-to-pipe weld bead. This nozzle is also shown on the left side of Figure 5. Some repair or relocation of the weld preparation will be required.

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Figure 2. Heaters and Thermocouples Installed on HNPF Block Valve

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Figure 3. Throttle Valve from HNPf Primary System Showing Damage Incurred after Removal from System

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Figure 4. Inlet Nozzle of HNPF Secondary System Throttle Valve No. 102 Showing where Valve Material was Removed

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Figure 5. HNP Secondary System Throttle Valve No. 102 Showing Damage to Inlet Nozzle and Drain Line

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Also on throttle valve No. 102, the drain line was rather severely marked by a chisel, as shown in the detail photo of Figure 5. The chisel was apparently used in an attempt to remove a bracket from the pipe. On secondary system throttle valve No. 302, the drain line was cut very close to the valve body; this is shown in Figure 6. Here, also, special weld preparation will be required.

Several undesirable conditions resulting from manufacture or operation of the valves have been noted during cleaning of the valves. (Detailed inspection of these valves is scheduled later as part of the valve examination program.) The presence of small cavities or porosity in the nozzles (part of the cast body) of primary throttle valve No. 203 was indicated when moisture and salt deposits were observed at several locations on the inside surface of the nozzles. This condition is shown in Figure 7. (The object reflecting light in the center of the port is the ball, which is in the partially open position.) This moisture was observed to be weeping from the cast material after the valve had been steam cleaned, soaked in demineralized water, drained, and partially dried in air. This solution had a pH of approximately 12. These observations are indicative of cavities, with small openings at the metal surface, which filled with sodium during operation. The opening of the cavity was so small that sodium was not completely removed during the cleaning operation; concentrated sodium hydroxide remained in the cavity after the normal cleaning operation. The valve was soaked in demineralized water a second time, drained, and dried with nitrogen gas. After this second cleaning cycle, the salt deposits were gone, and there was no moisture at the cavity sites. Such cavities are significant in sodium components, because sodium hydroxide remaining after cleaning may cause intergranular attack in austenitic stainless steel.

Two other noteworthy conditions were observed. The stem of primary block valve No. 201 had numerous score marks (shallow grooves) in one area, as shown in Figure 8. There was evidence of sodium extrusion outside the packing gland on all three secondary throttle valves. The white material in the vicinity of the packing-retaining spring shown in Figure 9 is the reaction products of sodium and air. There was very little evidence of sodium extrusion on the primary valves. The difference in extrusion between the primary and secondary valves is being studied.

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Figure 6. HNPf Secondary System Throttle Valve No. 302
Showing Drain Line Damage

Figure 7. HNPF Primary Throttle Valve No.203 Showing Sodium Hydroxide Weeping from Cavities in Nozzle

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7694-5440A

Figure 8. Stem of HNPf Primary Block Valve No.201
Showing Score Marks

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Figure 9. Typical Sodium Extrusion Outside Packing Gland of HNPF Secondary Throttle Valve

B. CODES AND STANDARDS (R. J. Edwards)

LMEC review of a draft LMFBR reactor vessel standard was completed and a revised draft of the standard was prepared. Negotiations were completed with Teledyne Materials Research for review of the standard.

Revision of the cold-trap standard was started. Comments and suggestions received from review of previous drafts by LMEC staff specialists are being incorporated in the latest draft. Revision is 30% complete.

The first draft of a sodium-to-air cooler standard was prepared and distributed for review within LMEC. Comments received to date are being studied.

Due to the 15,000-gpm range required for the free-surface sodium pumps for FFTF, effort on the preparation of sodium pump standards was shifted from the large pump to the 100- to 15,000-gpm mechanical free-surface sodium pump. Several sections of the standard were completed in preliminary draft form.

A second revision of the preliminary draft of the blocking valve standard was completed and issued for review by the LMEC staff. Comments received on the previous draft were incorporated and a section on design analysis was added.

Two LMEC representatives visited ORNL to confer on preparation of piping standards. ORNL concurred with LMEC plans to prepare a code-type document that will include liquid metal system piping requirements. LMEC began a detailed study of the recently issued USAS B31.7 Nuclear Power Piping Code to:

- 1) Evaluate its applicability to LMFBR piping systems
- 2) Become familiar with the format, content, and type of requirements, as a possible model for an LMFBR piping standard.

Work on the standard for cleaning of systems and components after they have been in sodium service was continued at a low level of effort because of higher priority of other standards activities.

An ORNL representative visited LMEC for discussion of an ORNL-prepared draft of a revision of RDT-S-902, tentative RDT standard for welding. This draft incorporates welding requirements for liquid metal systems based on LMEC input to ORNL in previous discussions, technical reviews, and drafts of liquid metal system welding requirements. The latest draft of RDT-S-902 was reviewed and revised in accordance with results of the discussion. A revised tentative standard

is planned for early release by ORNL. This completes LMEC work on the RDT tentative standard for welding, except for possible input to any future revisions of the standard.

Plant Standards RDT-S-923, "Material and Fabrication Requirements for Ni-Cr-Fe Alloy Seal Applications," and RDT-S-924, "Examination Requirements and Acceptance Standards for Seal Membranes," were reviewed and comments were transmitted to ORNL. A recommendation was made to combine the requirements of -923 and -924, as well as the pertinent requirements for liquid metal systems, into a single standard covering both the Ni alloys and the austenitic stainless steels.

Review of seven material standards previously issued by ORNL was completed. Comments were forwarded to ORNL including proposed modifications and additions to the standards that will make them suitable for application to liquid metal systems as well as water reactor systems. The seven standards are as follows:

- 1) RDT-MA-193, "Alloy Steel Bolting Materials for High Temperature Service"
- 2) RDT-MA-240, "Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion-Welded Unfired Pressure Vessels"
- 3) RDT-MA-351, "Austenitic Steel Castings for High Temperature Service"
- 4) RDT-MA-376, "Seamless Austenitic Stainless Steel Pipe"
- 5) RDT-MA-387, "Cr-Mo Steel Plates for Pressure Vessels"
- 6) RDT-MA-403, "Factory Made Wrought Seamless Austenitic Steel Welding Fittings"
- 7) RDT-MA-479, "Stainless and Heat Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels."

Also forwarded to ORNL for their review were two preliminary drafts of LMEC-prepared materials standards. These standards cover product forms that are of interest to liquid metal programs but for which RDT standards do not now exist. The two standards are:

- 1) "Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe"
- 2) "Seamless Ferritic Alloy Steel Pipe for High Temperature Service."

A review was made of RDT-S-934, "Weld Examination Standard," and preliminary comments were prepared. Further study of the standard and review of the preliminary comments are being conducted by appropriate LMEC technical staff members including metallurgy and quality assurance specialists.

Discussions were held with FFTF personnel on the LMFBR standards program and its interface with FFTF project work. Current status of LMEC work on LMFBR standards was reviewed.

C. PUMPS (R. W. Atz)

Discussions were held with Byron Jackson to clarify comments developed concerning the Phase I Report. Resolution of questions which elicited the comments has not been accomplished.

Phase II of the Large Sodium Pump Study project has been expanded to cover requirements of the FFTF primary sodium pumps. Significant aspects of this expansion are the increase of pump shaft length to 40 ft and reduction of available NPSH to 25 ft. (Reference conditions for FFTF primary pumps are 12,000 gpm at 440 ft TDH.)

A review of handling requirements for large sodium pumps was developed which concluded that each major part of the assembly should be shipped separately in a handling fixture which can subsequently be used for verifying structural integrity of the part.

Discussions were initiated with FFTF project personnel to define experimental work needed in support of the primary sodium pump requirements.

D. PIPING (E. N. Pearson)

The work plan for the HNPF Post-Operation Examination Program was issued. It divides the recommended effort into three tasks as follows:

- 1) Task I - nondestructive examination of steam generator, IHX, pumps, and valves
- 2) Task II - destructive examination of steam generator and IHX
- 3) Task III - Complete examination of sodium piping and expansion tank.

Twelve large (14-in.) sodium valves have been received at AI for draining of residual sodium and cleaning. (Additional details are covered in Section III-A.) Piping sections attached to the valves have been removed and are available for nondestructive and destructive examinations. These 14- and 16-in. pipe sections include elbows, mixing tees, and thermowells. Additional piping (designated as scrap) has been received at LMEC from HNPF for examination.

Preliminary contact was made with PKS personnel at Omaha, Nebraska, in regard to the examination of HNPF piping records for technical information. Subsequent followup will be required to determine the technical content of the records with respect to the planned evaluation of HNPF sodium piping.

E. HEAT EXCHANGERS AND STEAM GENERATORS (K. L. Adler and G. S. Budney)

1. HNPF Steam Generator Post-Operation Examination Plan

A preliminary HNPF Steam Generator Examination and Evaluation Program Plan was prepared for consolidation with the HNPF Post-Operation Examination work plan. The HNPF steam generator examination and evaluation plan is divided into four phases as follows:

- 1) Phase I, Documentation
- 2) Phase II, Nondestructive Examination
- 3) Phase III, Destructive Examination
- 4) Phase IV, Evaluation of Examination Results.

Phase III, Destructive Examination, will require AEC authorization and approval before disassembly of the steam generator is begun.

2. B&W Technical Liaison

The technical work defining the modifications required to the SCTI facility to test each of several alternate B&W prototype steam generators has been completed. A study report is being prepared summarizing the results. The report is scheduled for completion on July 8, 1968. The study results will be used by B&W to recommend a specific prototype steam generator design for fabrication and test.

The salient features of the various B&W prototype steam generator design alternates are as follows:

	Alternate A	Alternate B	Alternate C	Alternate D
Flow Modeled	No	Yes	Yes	Yes
Steam-Side ΔP (psi)	254	500	400	500
Number of Tubes	17	17	17	15

The modifications to the sodium systems for all B&W alternates at 100% load and maximum load are conventional changes with the exception of the maximum load condition for B&W - Alternate "B" design. For this design, the existing sodium heater and intermediate heat exchanger may be operated up to approximately 113% load with no changes required to these components. In order to operate the sodium heater and the intermediate heat exchanger at the maximum load condition for the B&W - Alternate "B" design, major equipment modifications would be necessary with resulting higher costs. The existing intermediate heat exchanger could be operated at the maximum load condition if the existing design constraint of a 25°F maximum ΔT across the upper tubesheet was permitted to be increased to 30°F. This appears to be an acceptable change.

Comparing the maximum load cases of the various alternates, the lowest incremental modification cost is for Alternate "A." However, the Alternate "A" steam generator design involves major modeling compromises. Alternate "B," which has fewer modeling compromises, requires the largest number of facility modifications. The incremental cost of these modifications if the maximum load is limited to 113% is nominal. At 125% load, the incremental cost will be significantly higher.

Alternate "D," which is similar to Alternate "B" except that it has 15 tubes instead of 17 tubes, meets the maximum load requirement without changes to the heater or IHX upper tubesheet ΔT . In addition, because of the lower total feedwater flow, a smaller feedwater heater and a smaller boiler feed pump motor and drive train may be utilized to effect some cost savings.

Alternate "C," which also has fewer modeling compromises, can be tested at maximum load without heater or IHX changes.

The longest procurement time item is the high-pressure feedwater heater, which requires 14 months to procure. This change is required for the maximum

load condition of all alternates and for the 100% load condition of all alternates except Alternate "A." Procurement time may not be an influencing factor, since the steam generator fabrication schedule is longer than 14 months. It will be necessary to initiate early procurement of the high-pressure feedwater heater to avoid extending the overall facility modification schedule.

3. Sodium Proof-Testing of FFTF IHX and Heat Dump

Several alternative test plans for proof-testing FFTF heat exchange equipment at the LMEC have been discussed with PNL. The preferred test plan involves the testing of a full-scale IHX in a figure-8 loop at full flow, full ΔT , and full LMTD, and two reduced-surface heat dump modules. The required heat input for this test arrangement is ~ 55 Mw. Since no test rig for such a test is either available or scheduled, it is proposed to perform the test in a one-shot test rig specifically designed for the FFTF heat exchanger testing.

The second-choice test plan would consist of testing a quarter-scale IHX prototype and two full-scale, reduced-surface heat dump modules in a stub-off arrangement in the SCTI. Disadvantages of this test plan, relative to the first-choice plan, are: (1) test objectives and requirements are compromised; (2) the test schedule conflicts with the anticipated schedule for B&W steam generator testing and would cause delay in subsequent steam generator tests; and (3) space availability may present a problem, although not an insurmountable one; an area south of SCTI, tentatively planned for SPTF, would probably have to be used.

4. System Transient Studies

A report is in preparation which summarizes available information on LMFBR system thermal transients, correlating the initiating mechanisms with the resultant system temperature perturbations. This information is to be used to establish rational requirements for transient testing capabilities of LMEC test installations.

F. INCIDENT REPORTING SYSTEM (C. W. Griffin)

1. Historical Failure Data Processing

EBR-II data were reviewed and tabulated for the period from July 1965 to February 1968. Completion of tabulation and engineering review of the first phase is expected in the next reporting period.

HNPF data on all recorded valve failures have been tabulated from the records. These valves include the 14-in. throttle valves, the 2- and 3-in. freeze seal stem valves, the 6-in. moderator coolant throttle valve, and the 2- and 3-in. bellows seal valves. Operating history of each valve prior to failure must now be obtained. Engineering evaluation will follow. This work is being coordinated with the metallurgical evaluation of those valves being shipped from HNPF to LMEC.

2. Malfunction, Maintenance, and Problem Report System

LMEC prepared and submitted to RDT for review a draft of its proposed Malfunction, Maintenance, and Problem Report Procedure. The proposed procedure contains a format for failure data reporting (see Figure 10), the procedure for filling out the format, followup and closeout approval (see Figure 11), a flowsheet covering report processing (see Figure 12), and a description of all associated documents required to implement the processing described in the flowsheet.

LMEC reviewed reactor operating facilities to determine if a controlled and managed system existed for handling "unplanned for" events both during operation and during construction. The first draft of this system was prepared and released by June 28, 1968. This new document for review is a Suggested System for Incorporation of Facility Management Awareness and Executive Direction Into Those Aspects of Quality Assurance Which Adversely Affect Plant Construction, Operation, and Safety. The reporting format and flow diagram were included and are shown in Figures 13 and 14, respectively. The "unplanned for" event category was changed to "Abnormal Occurrence," since it appears to be a term adopted by DRL. The three categories of reports are defined as:

- 1) Malfunction — to include all "Normal Occurrences" for which a corrective action procedure has been prepared or planned but which do not fall either under the category of routine scheduled maintenance or the definition of Abnormal Occurrence
- 2) Abnormal Occurrence —
  - a) An event which causes a maximum safety specification to be exceeded
  - b) Violation of a limiting condition
  - c) Unexplained reactor transient
  - d) Equipment or personnel action which adversely affects plant construction or operation
  - e) Unplanned-for radiation release
- 3) Problems — to include all problem areas which adversely affect operation insufficiently to warrant action, and all near misses with respect to the other two categories.

Malfunctions and problems were included in the reporting option, since they did not change the basic format requirement for an Abnormal Occurrence and since most facilities prefer to use the same format for as many purposes as possible.

As a source of data for LMFBR system/component QA/Reliability improvement for future designs, it can be made to work with the addition of the supplementary data shown in Figure 14.

This system, however, does not provide for: (1) routine AEC monitoring, (2) issuance of emergency flags on events which could be critical at other facilities, or (3) closed-loop followup to ensure prompt completion and issuance of closed-out reports. Most experts in this field feel that the latter is imperative to a successful system.

COMPANY NAME & SYMBOL

MALFUNCTION, MAINTENANCE & PROBLEM REPORT

1. FACILITY

2. TYPE OF REPORT

MALFUNCTION ☐

UNSCHEDULED MAINTENANCE ☐

UNCORRECTED PROBLEM ☐

NO. 00000

3. SYSTEM/SUBSYSTEM NAME		DRAWING OR P&ID NO.		SYS. I.D. NO.		4. DATE		28. REFERENCES			
5. COMPONENT/PART NAME		I.D. NO.		6. OPERATION LEVEL AT TIME OF EVENT		7. METHOD OF SHUTDOWN		OPERATING LOG NO. & PAGE			
				THERMAL POWER (PEAK LOCAL TEMP.)		MANUAL TRIP ☐ NORMAL SHUTDOWN ☐ SET-BACK ☐ CONTROLLED AUTO. TRIP ☐ SELF TERMINATION ☐ NOT APPLICABLE ☐ EMERGENCY ☐					
8. METHOD OF FAILURE DETECTION				9. OPERATION CONDITION AT TIME OF EVENT				MAINTENANCE LOG NO. & PAGE			
ALARM ☐ REPAIR OF P&ID COMP. ☐ ROUTINE INSTR. READING ☐ STEADY FULL POWER ☐ RAISING POWER (GENERATOR ON) ☐ CRITICAL ☐ AUDIO NOISE ☐ REPAIR OR INSP. OF OTHER SYSTEM ☐ VIBRATION MONITOR ☐ STEADY FRACT. POWER ☐ RAISING POWER (GENERATOR OFF) ☐ SUBCRITICAL ☐ DIRECT OBSERV. (UNPROGRAMMED) ☐ OPERATIONAL MONITORS ☐ PERIODIC CIRCUIT CHECK (AUTO.) ☐ STARTUP ☐ REDUCING POWER ☐ EXPERIMENTAL RUN ☐ PREVENTIVE MAINT. ☐ PROTECTIVE SYSTEM ☐ OTHER ☐ SHUTDOWN ☐ BEING SHUTDOWN ☐ FUEL HANDLING ☐								WORK ORDER NO.			
10. DESCRIPTION OF EVENT (CAUSE AND TYPE OF OCCURRENCE, SYMPTOMS, SEVERITY, OBSERVED EFFECT ON SYSTEM, HUMAN FACTORS)									OTHER (FORMAT REPORTS OR PREVIOUS MMFR NO.)		
(ATTACH SHEET IF MORE SPACE IS REQUIRED)											
11. CORRECTIVE ACTION TAKEN AND SUGGESTIONS FOR ADDITIONAL WORK, REWORK OR FUTURE DESIGN MODIFICATION											
									12. APPROVAL SIGNATURE DATE		
13. VENDOR INFORMATION ON PRIMARY UNIT											
VENDOR NAME				TRADE NAME		CAT. NO.		EXIST ☐ NOT EXIST ☐ VALID ☐ EXPIRED ☐		14. REPAIR TIME DATA	
								MAN HOURS CHARGED TO PRIMARY EVENT		REPAIR TIME DAYS	
								DAYS NO HEAT GENERATION		DAYS NO ELECTRICAL GENERATION	
15. WERE OTHER PROBLEMS OR FAILURES RELATED OR NOT RELATED TO THE EVENT NOTED?											
NO ☐ YES ☐ IF YES, PREPARE SEPARATE MMFR MMFR(S) NO. _____											
16. MAINTENANCE ACTION ON PRIMARY UNIT.											
REPAIRED ☐ REWORKED ☐ REPLACED ☐ DESIGN MODIFICATION ☐ OTHER _____											
17. PRIMARY COMPONENT MATERIAL											
18. LIST BELOW ALL PARTS REPLACED, REPAIRED, OR ADJUSTED											
PART NAME		MANUFACTURER		PART NO.		REF. SIZE		MATERIAL		ORIGINAL MATERIAL	
										REWORK ACTION TAKEN (BE SPECIFIC - ALSO STATE VENDOR ACTION)	
ATTACH SHEET IF MORE SPACE IS REQUIRED											
19. EFFECT OF EVENT (PHYSICAL, CASCADING)											
20. RECOMMENDATIONS											
21. COMPONENT HISTORY DATES											
LAST INSPECTION _____ LAST REPAIR/MAINTENANCE _____											
22. APPROVAL - SIGNATURE											
23. CAUSE OF MALFUNCTION, UNSCHEDULED MAINTENANCE OR PROBLEM (DISCUSS ANALYSIS)											
24. EFFECT (ENGINEERING ANALYSIS)											
25. CORRECTIVE ENGINEERING ACTION RECOMMENDED FOR FUTURE											
26. MALFUNCTION IMPORTANCE (SELECT FROM CATEGORIES -)											
COMMENTS											
27. SIGNATURE											

Figure 10

7693-2527

LMEC-68-20

COMPANY NAME & SYMBOL

MALFUNCTION, MAINTENANCE & PROBLEM REPORT CLOSEOUT SHEET

1. FACILITY

2. TYPE OF REPORT

MALFUNCTION ☐

UNSCHEDULED MAINTENANCE ☐

UNCORRECTED PROBLEM ☐

NO. 00000

ORIGINATOR	3. SYSTEM/SUBSYSTEM NAME		DRAWING OR P&ID NO.		SYS. I.D. NO.		4. DATE MO DAY YR		28. REFERENCES	
	5. COMPONENT/PART NAME		I.D. NO.		6. OPERATION LEVEL AT TIME OF EVENT THERMAL POWER ☐ PEAK LOCAL TEMP. ☐		7. METHOD OF SHUTDOWN MANUAL TRIP ☐ NORMAL SHUTDOWN ☐ SET BACK ☐ CONTROLLED ☐ AUTO TRIP ☐ SELF TERMINATION ☐ NOT APPLICABLE ☐ EMERGENCY ☐		OPERATING LOG NO. & PAGE	
FINAL	8. METHOD OF FAILURE DETECTION ALARM ☐ REPAIR OF PRI. COMP. ☐ ROUTINE INSTR. READING ☐ AUDIO NOISE ☐ REPAIR OR INSP. OF OTHER SYSTEM ☐ VIBRATION MONITOR ☐ DIRECT OBSERV. (UNPROGRAMMED) ☐ OPERATIONAL MONITORS ☐ PERIODIC CIRCUIT CHECK (AUTO.) ☐ ROUTINE INSP. ☐ PROTECTIVE SYSTEM ☐ OTHER ☐ PREVENTIVE MAINT. ☐ ROUTINE AREA WATCH ☐		9. OPERATION CONDITION AT TIME OF EVENT STEADY FULL POWER ☐ RAISING POWER (GENERATOR ON) ☐ CRITICAL ☐ STEADY FRACT. POWER ☐ RAISING POWER (GENERATOR OFF) ☐ SUBCRITICAL ☐ STARTUP ☐ REDUCING POWER ☐ EXPERIMENTAL RUN ☐ SHUTDOWN ☐ BEING SHUTDOWN ☐ FUEL HANDLING ☐		MAINTENANCE LOG NO. & PAGE		WORK ORDER NO.		OTHER (FORMAT REPORTS OR PREVIOUS MMR NO.)	
	10. DESCRIPTION OF EVENT (CAUSE AND TYPE OF OCCURRENCE, SYMPTOMS, SEVERITY, OBSERVED EFFECT ON SYSTEM, HUMAN FACTORS)									
DATA PROCESSING	(ATTACH SHEET IF MORE SPACE IS REQUIRED)									
	PROJECT CLOSEOUT COMMENTS									
MMPR CENTER	APPROVAL SIGNATURE		DATE		APPROVAL SIGNATURE		DATE		APPROVAL SIGNATURE	
	MODE OF FAILURE		NO. OF PREVIOUS FAILURES OF THIS COMPONENT		NO. OF IDENTICAL COMPONENTS IN PLANT		TOTAL OPERATING TIME OF COMPONENTS		FAILURE RATE COMPARISON TO AVERAGE - SAME ☐ GREATER THAN ☐ NOT APPLICABLE ☐ LESS THAN ☐	
ENGINEERING ANALYSIS	CAUSE OF FAILURE									
	MODE OF FAILURE									
AEC	EFFECT OF FAILURE									
	CASCADING SEQUENCE									
ENGINEERING EVALUATION OF CORRECTIVE ACTION TAKEN										
STANDING REVIEW PANEL EVALUATION										
DESIGN POLICY RECOMMENDATIONS										
COGNIZANT ENGINEER SIGNATURE										
APPROVAL SIGNATURE										
COMMENTS										
APPROVAL SIGNATURE										

Figure 11

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MALFUNCTION, ABNORMAL OCCURRENCE & PROBLEM REPORT

1. FACILITY

2. TYPE OF REPORT

MALFUNCTION 2

ABNORMAL OCCURRENCE =

UNCORRECTED PROOF

NO. 00000

3. SYSTEM/SUBSYSTEM NAME		DRAWING OR P&ID NO.		SYS. I.D. NO.		4. DATE MO DAY YR		28. REFERENCES			
5. COMPONENT/PART NAME		I.D. NO.		6. OPERATION LEVEL AT TIME OF EVENT THERMAL POWER PEAK LOCAL TEMP.		7. METHOD OF SHUTDOWN MANUAL TRIP ☐ NORMAL SHUTDOWN ☐ SET-BACK ☐ CONTROLLED ☐ AUTO. TRIP ☐ SELF-TERMINATION ☐ NOT APPLICABLE ☐ EMERGENCY ☐		OPERATING LOG NO. & PAGE			
8. METHOD OF FAILURE DETECTION ALARM ☐ REPAIR OF PRI. COMP. ☐ ROUTINE INSTR. READING ☐ AUDIO NOISE ☐ REPAIR OR INSP. OF OTHER SYSTEM ☐ VIBRATION MONITOR ☐ DIRECT OBSERV. (UNPROGRAMMED) ☐ OPERATIONAL MONITOR ☐ PERIODIC CIRCUIT CHECK (AUTO.) ☐ ROUTINE INSP. ☐ PROTECTIVE SYSTEM ☐ OTHER ☐ PREVENTIVE MAINT. ☐ ROUTINE AREA WATCH ☐				9. OPERATION CONDITION AT TIME OF EVENT (IF APPLICABLE) STEADY FULL POWER ☐ RAISING POWER (GENERATOR ON) ☐ CRITICAL ☐ STEADY FRAC. POWER ☐ RAISING POWER (GENERATOR OFF) ☐ SUBCRITICAL ☐ STARTUP ☐ REDUCING POWER ☐ EXPERIMENTAL RUN ☐ SHUTDOWN ☐ BEING SHUTDOWN ☐ FUEL HANDLING ☐				MAINTENANCE LOG NO. & PAGE		WORK ORDER NO.	
10. STATUS OF SYSTEM OR COMPONENT CONSTRUCTION ☐ IN TRANSPORT ☐ SHUTDOWN RUN ☐ OPERATION ☐									OTHER (FORMAT REPORTS OR PREVIOUS MMRP NO.)		
11. DESCRIPTION OF EVENT (CAUSE AND TYPE OF OCCURRENCE, SYMPTOMS, SEVERITY, OBSERVED EFFECT ON SYSTEM, HUMAN FACTORS)											
12. CORRECTIVE ACTION TAKEN AND SUGGESTIONS FOR ADDITIONAL WORK, REWORK OR FUTURE DESIGN MODIFICATION											
13. IS CORRECTIVE ACTION CONSIDERED TO BE TEMPORARY ☐ PERMANENT ☐						14. APPROVAL SIGNATURE		DATE REPORTED			
15. CAUSE OF FAILURE											
16. MODE OF FAILURE											
17. EFFECT OF FAILURE ON OTHER SYSTEMS											
18. WERE OPERATING LIMITS OR TECHNICAL SPECIFICATIONS VIOLATED YES ☐ NO ☐ IF YES, EXPLAIN											
19. WERE RADIOLOGICAL RELEASE REGULATIONS OR PERSONNEL SAFETY INVOLVED YES ☐ NO ☐ IF YES, EXPLAIN											
20. NO. OF PREVIOUS FAILURES OF THIS COMPONENT					21. REFERENCE DOCUMENTS						
22. PERMANENT CORRECTIVE ACTION TAKEN (IF ITEM 13 WAS STATED AS TEMPORARY)											
23. CORRECTIVE ENGINEERING ACTION RECOMMENDED FOR FUTURE (DESIGN CHANGE, R&D, TEST, ETC)											
24. APPROVAL SIGNATURE, TITLE AND DATE					25. SAFETY REVIEW COMMITTEE APPROVAL (IF ITEM 19 IS YES) SIGNATURE						
26. OPERATIONS MANAGEMENT APPROVAL SIGNATURE					27. PROJECT APPROVAL SIGNATURE						
28. APPROVAL SIGNATURE, TITLE AND DATE					29. APPROVAL SIGNATURE, TITLE AND DATE						
30. APPROVAL SIGNATURE, TITLE AND DATE					31. APPROVAL SIGNATURE, TITLE AND DATE						
32. APPROVAL SIGNATURE, TITLE AND DATE					33. APPROVAL SIGNATURE, TITLE AND DATE						
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66. APPROVAL SIGNATURE, TITLE AND DATE					67. APPROVAL SIGNATURE, TITLE AND DATE						
68. APPROVAL SIGNATURE, TITLE AND DATE					69. APPROVAL SIGNATURE, TITLE AND DATE						
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92. APPROVAL SIGNATURE, TITLE AND DATE					93. APPROVAL SIGNATURE, TITLE AND DATE						
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100. APPROVAL SIGNATURE, TITLE AND DATE					101. APPROVAL SIGNATURE, TITLE AND DATE						
102. APPROVAL SIGNATURE, TITLE AND DATE					103. APPROVAL SIGNATURE, TITLE AND DATE						
104. APPROVAL SIGNATURE, TITLE AND DATE					105. APPROVAL SIGNATURE, TITLE AND DATE						
106. APPROVAL SIGNATURE,											

Figure 13
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34

Figure 14. Facility Reporting System Flow Diagram

G. COMBINED UNIT REACTOR VESSEL (CURV) (A. C. Williams)

A conference was held in April between RDT and the CURV Task Unit to review the Preliminary Evaluation Report and to discuss the direction of subsequent investigations. The proposed effort by LMEC — for preparation of work plans with which to initiate detailed investigations by qualified contractors — was deleted as a consequence of these discussions. It was agreed that LMEC would concentrate on preparation of a concluding report which would go further in identifying CURV problems than previous documents and which would serve as the basis for future, in-depth studies if deemed necessary by RDT.

Effort during the report period was concentrated largely on the acquisition of information from the LMFBR Program, FFTF Program Office, ORNL, and 1000-Mwe Follow-on Contractors. Useful information was obtained with regard to design philosophy, safety, test, and inspection requirements that will contribute to the CURV study. Studies of various approaches to the design of earthquake-resistant structures now being developed under the ORNL Safety R&D Program will be utilized where applicable in the CURV study.

H. QUALITY ASSURANCE (G. A. Beer)

Comments were received from LMEC staff members on the two proposed RDT quality assurance standards previously prepared and distributed. These comments were incorporated and/or resolved and the resultant drafts of the standards, "Inspection System Requirements Pertaining to LMFBR Components Systems and Equipment," and "Quality Assurance Requirements Pertaining to LMFBR Components Systems and Equipment" were submitted to Idaho Nuclear Corporation for use in their development of RDT QA standards.

Definition of an LMEC quality assurance system was initiated. A quality assurance policy, defining the quality assurance program and the role of LMEC personnel in the quality assurance program, was issued after coordination with other LMEC organizational units. Assignment of basic responsibilities to the Quality Assurance Task Unit was also included in this policy statement. In addition, work was initiated on many of the management procedures required by a documented quality assurance program. A procedure covering the preparation and review of procurement requisitions was issued for compliance.

Initial steps were taken to establish methods for review of FFTF QA documents per instructions received during the meeting between LMEC and RDT on February 28, 1968. It has been resolved that two quality assurance program plans will be submitted for LMEC review in addition to BNWL-510, "Design and Development Quality Assurance Requirements for FFTF."

A revised issue of the QA Plan for the Sodium Pump Test Facility (SPTF) prepared by C. F. Braun and Co. was received and reviewed in detail. Comments have been prepared and will be submitted to the SPTF Project Manager.

The Bechtel Quality Assurance Plan covering the main steam line modification of the Sodium Components Test Installation (SCTI) has been reviewed and will be approved subject to minor revisions. Monitoring of the quality assurance, provided by Bechtel for the steam line modification, was initiated during manufacture of Charpy V-notch specimens.

IV. NEXT REPORT PERIOD ACTIVITIES

A. VALVES AND SODIUM TECHNOLOGY

Close liaison will be maintained with AI regarding the cleaning of HNPF sodium valves. The valves will be packaged to exclude moisture and stored.

Selected HNPF 14-in. valves will be tested and examined.

B. CODES AND STANDARDS

It is expected that recommended LMFBR requirements for four materials standards will be submitted to ORNL. Review of two plant standards, RDT-S-908, "Nondestructive Test Methods," and RDT-S-934, "Methods of Inspection for Welds for Water Cooled Nuclear Power Plants," will be completed and comments and recommendations will be forwarded to ORNL.

It is anticipated that the cold-trap standard will be completed and a tentative draft standard will be submitted to ORNL and RDT.

A preliminary draft of the reactor vessel standard will be forwarded to FFTF for review. Teledyne Materials Research will start review of the reactor vessel standard.

Review will be completed of the USAS B31.7 Nuclear Power Piping Code and comments will be prepared for transmittal to ORNL and RDT. LMEC will start participation in piping code group activities by sending invited representatives to a meeting of a subgroup of the B31.7 committee.

Work will be continued on the sodium blocking valve standard and sodium-to-air cooler standard. Revised drafts of both standards will be prepared and distributed for review by LMEC staff specialists.

C. PUMPS

It is anticipated that the Byron Jackson Phase I report of the Large Sodium Pump Study project will be completed.

Initiation of Phase II activity on the 60,000-gpm pump study will be started. Completion of the study may be delayed to accommodate requirements of the FFTF pump study.

Experimental activity needed in support of FFTF primary sodium pump development will be defined.

D. PIPING

Examination of HNPF sodium piping as part of the HNPF Post-Operation Evaluation Program will be continued. Technical support will be provided to other AEC programs as required.

E. HEAT EXCHANGERS AND STEAM GENERATORS

The SCTI Modifications Study report will be completed.

Recent inquiries have indicated an interest in the HNPF superheaters for possible use in EBR-II. The HNPF Steam Generator Post-Operational Examination Plan is to be reviewed to assure that superheaters are structurally suitable for use in EBR-II.

LMEC will continue to work with PNL in developing and implementing a program for sodium proof-testing of FFTF intermediate heat exchangers and air-cooled heat dumps.

F. INCIDENT REPORTING SYSTEM

Resolution of the method of following and reporting current component failure events at liquid metal facilities will depend upon RDT review of systems and resulting decisions. These will also determine the level of LMEC involvement in both establishment of a system and in level of data processing.

Plans are to complete analysis of all collected data on SCTI, Fermi, EBR-II, HNPF, ANL loops, and SRE by March 1969 and to summarize the data and engineering evaluation in a looseleaf "Component Malfunction and Maintenance Design Handbook" scheduled for release by July 1969. This handbook will emphasize the how-not-to-design-components approach. A proportionate fraction of the analyses will be completed in the next reporting period. Also, a preliminary draft of a handbook section format will be prepared for user comment.

G. COMBINED UNIT REACTOR VESSEL (CURV)

Background information obtained from the various organizations involved in LMFBR programs relevant to the CURV study will be incorporated in a problem assessment report. LMEC will continue to evaluate the various CURV concepts with the objective of defining specific problem areas associated with the design, construction, and test of coolant boundary components.

H. QUALITY ASSURANCE

The major quality assurance effort anticipated during the next report period will be the continuation of definition of the LMEC quality assurance system. This definition will be made by means of LMEC quality assurance procedures and organization procedures.

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

The historical data collected in support of the maintenance and malfunction reporting system will be reviewed and analyzed for chronic failures and this information in turn will be considered in the development of inspection instructions giving minimum instruction requirements for LMEC equipment.

Efforts will continue to monitor and guide the quality assurance provided by architect-engineers for modification to the Sodium Components Test Installation and for design and construction of the Sodium Pump Test Facility.

Participation in the quality assurance steering committee will be maintained in an effort to help guide and assist the development of a quality assurance program standard for RDT projects and programs. In addition, any specifications or standards generated for LMEC activities will be forwarded to Idaho Nuclear Corporation for their consideration in the preparation of RDT standards.

Quality assurance documents relating to FFTF will be received from Pacific Northwest Laboratories. These documents will be reviewed and comments submitted.

Program: Liquid Metal Engineering Center

Project: Operation of Sodium Component Test Installation

Project Manager: R. W. Dickinson

Project Engineer: J. A. Leppard

Reporting Period: April-June 1968

AEC Category: 04-01-61-03.6

General Order: 7693, 7694

Subaccount: 13200

I. PROJECT OBJECTIVES

The objective of the SCTI is to test and obtain performance data on prototype intermediate heat exchangers and steam generators under steady-state and transient conditions. This program is in support of the Liquid Metal Fast Breeder Reactor (LMFBR) Program.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

All drawings and specifications required for reconstruction of the high-pressure steam piping system were completed. A contract was issued for the fabrication of the new piping. All long delivery components required for construction have been received. A design package providing for additional improvements to the steam and feedwater system was completed.

III. PROGRESS DURING REPORT PERIOD

Revised design drawings and specifications for the main steam line modification, which include RDT-recommended design changes as well as LMEC comments and recommendations, were completed and approved for construction. Previously reported redesign of the safety valve connections utilizing fabricated tees have been changed to incorporate forged tees for which the delivery time is acceptable.

A quality assurance plan covering the construction was prepared, reviewed by the LMEC, and comments were forwarded to Bechtel for incorporation in the final document. All pipe spool drawings have been completed by the pipe fabricator and have been submitted to Bechtel for review and approval. Subsequent to the approval of these drawings, actual fabrication of piping will be initiated.

Bechtel has started the fabrication of three test fixtures which will be used in the development of the procedure for applying Inconel overlay on the critical joint at the steam generator outlet. To provide a backup for Bechtel's program, a parallel development program has been initiated by LMEC in conjunction with the L.A. Division of North American Rockwell Corporation weld development laboratory. Initial results using a MIG process with a push-type wire feed system is very encouraging. Samples of the first test section have been received by LMEC for metallographic evaluation. A second test section is being fabricated which more closely mocks up the joint configuration and material thickness.

Bechtel submitted a new construction schedule and cost estimate for the construction phase. The new schedule indicates a 10-week construction period as compared to the original 6-weeks estimate and the estimated cost has more than doubled. The more stringent quality assurance which has been applied to the job since the previous estimate is the principal reason for the increase. However, Bechtel has indicated that the prior estimate was inordinately low and that a number of items have been overlooked. LMEC considers the new estimates to be accurate and reflecting a carefully and extensively planned construction activity. Factors that were identified as contributing to the schedule and cost increases were as follows:

- 1) The Quality Assurance program requires complete record keeping which is much more extensive than for conventional plant construction.
- 2) A full-time QA engineer is required to be on the job for the entire construction period.
- 3) More frequent quality control inspections and their documentation are required resulting in more difficult scheduling of welders and pipe fitters.
- 4) LMEC's requirement for stringent controlled weld pre-and post-heating with detailed temperature records requires the use of induction coil heating instead of the less time-consuming torch heating method.
- 5) Full-penetration welds are required for the dummy pipe supports.
- 6) Because the job is relatively small, the use of personnel is less efficient.

The steam and feedwater system improvement design package was completed. Included in this modification package are the following:

- 1) The steam generator recirculation line will be rerouted to provide improved operator control of the changeover from steam generator preheating to steaming phase.
- 2) The condensate suction line size will be increased to provide the required net positive suction head for the condensate pump.
- 3) An auxiliary steam line will be connected to the deaerator which will permit it to be placed in service during the preheat operation.
- 4) Piping that does not meet the pressure and temperature rating requisite for future service application will be upgraded.

Bids were received from four contractors who were judged capable of performing the work to the standards required by the LMEC Quality Assurance program. These bids have been evaluated and are being forwarded to the AEC for review and approval. All long-lead-time items were ordered and are currently being received. It is anticipated that construction will start in the first quarter of FY 1969.

The "SCTI System Design Description" (NAA-SR-Memo-11671) was completed and published in May. Revised sections of this SDD will be submitted whenever a design modification results in a change in system capability or in an operating parameter. The SDD will thus reflect current, meaningful as-built plant conditions.

A report, "ALCO Intermediate Heat Exchanger Tube Vibration Test" (LMEC-TDR-68-16) was published.

Sodium flowmeter positioning tests for the FFTF were completed.

Two "Dissolved Oxygen Analyzers" were purchased and installed. This system will continuously monitor the oxygen content of the condensate at the inlet and outlet of the deaerator. Installation of the new pH and conductivity instruments is approximately 90% complete.

A leak was found in the inlet water box of the main condenser. Epoxy, originally applied to the internals of the condenser during modification was removed. A new coating of epoxy, strengthened by Fiberglas sheet, was successfully applied. Preparations are being made for performing a hydrostatic leak test.

Routine maintenance activities and minor modifications performed during this period include the following:

- 1) Various steam and feedwater valves were removed from the system for internal modification. These changes will result in improved controllability during startup and operation.
- 2) The feedwater flow nozzle and metering section was calibrated at the Rocketdyne Instrument Laboratory and has been reinstalled.
- 3) A new sodium sampler assembly, designed for compatibility with LMEC laboratory equipment, has been fabricated.
- 4) Calibration of instruments is continuing to assure that all instruments and controls are in a state of readiness for full plant operation.

IV. NEXT REPORT PERIOD ACTIVITIES

Pipe fabrication for the high-pressure steam line modification will be completed and field construction will be started. The other design improvements to the steam and feedwater system will be completed. Plant performance test procedures, to be used during the initial rise to full power operation following the return to normal operation, will be revised to reflect recent and pending facility modifications.

Program: Liquid Metal Engineering Center

Project: Liquid Metals Information Center

Project Manager: R. W. Dickinson

Project Engineer: J. J. Droher

Reporting Period: April-June 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 363 requests for information from various organizations, including all of the major participants in the LMFBR Program, during the current fiscal year. These requests have involved 585 separate subject categories, for which computerized searches were performed resulting in a total of 63,140 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 work in progress on liquid metals, a Special File encompassing reports with distribution limitations, and KWIC (Key Word In Context) Indices encompassing all reference reports and all existing files. Copies of the manuscript for the 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.

A bibliography of LMEC technical reports published and/or issued during FY 1968 is included at the end of this report.

III. PROGRESS DURING REPORT PERIOD

During this quarter, 185 additional documents were processed, making a total of 5,771 documents in the LMIC data bank. The Center responded to 109 inquiries for information during the quarter, of which 98 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 138 different subject categories and yielding a total of 11,680 computer-produced printouts.

A thorough review of all current progress reports was conducted to detect and correct any omissions or changes in status of tasks in the Project File encompassing work in progress on liquid metals. Similarly, the LMIC Thesaurus Master File of descriptive terms was reviewed to detect any errors or omissions.

Work continued on modification of the preliminary draft of the Sodium and NaK Engineering Handbook to reflect comments received from reviewers and to incorporate new information which has been published in the interim. As of the end of June, modifications and rewriting of text was still in progress for Chapter 3, "Effects on Materials"; Chapter 4, "Fluid Flow"; Chapter 6, "Purification"; and Chapter 20, "Applications." Typing, editing, and art work of final LMEC copy was in progress on Chapter 1, "Physical Properties"; Chapter 2, "Chemistry"; Chapter 7, "Sodium and NaK Systems"; Chapter 8, "Intermediate Heat Exchangers (IHX)"; Chapter 12, "Pumps"; Chapter 14, "Vessels and Piping"; and Chapter 15, "Bearings and Seals." Chapter 10, "Heaters and Coolers"; Chapter 11, "Radiators, Condensers, and Boilers"; and Chapter 19, "Safety," were receiving final review preparatory to mailing to DTIE. All work has been completed on Chapter 5, "Heat Transfer"; Chapter 9, "Steam Generators"; Chapter 13, "Valves"; Chapter 16, "Auxiliary Equipment and System Accessories"; Chapter 17, "Instrumentation"; and Chapter 18, "Handling," and the text and artwork have been mailed to DTIE.

A discussion of "Automated Storage and Retrieval of Technical Information" was presented by the supervisor of the LMIC to a unit of the U.S. Naval Reserve composed of technically trained officers on June 24, 1968, at Santa Monica, California.

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.

Final editing by LMEC personnel will be completed on all revised copy for the Sodium and NaK Engineering Handbook.

Program: Liquid Metal Engineering Center

Project: Sodium Pump Test Facility (SPTF)

Project Manager: R. L. Cummings

Project Engineer: S. L. Pfahler

Reporting Period: April-June 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.

A thermal transient flow mixing and control analog-computer program for the SPTF was developed, checked out, and is fully operational for production work in Title I.

The Sodium Cleaning Facility (SCF) requirements were established. A planning report is being prepared by AI. The SCF will be located on the same site as the SPTF.

A new site was tentatively selected for the SPTF. Recent studies indicate that more space for the SPTF and SCF is required than is available on the present site.

A draft of the SPTF Program Plan was completed. This includes a Title I work scope and a PERT/CPM (critical path method) network for the engineering and construction.

The thermal transient criteria for the SPTF were defined and agreed to by LMEC and RDT for Title I design.

The Quality Assurance Plan for the SPTF engineering and construction was revised.

III. PROGRESS DURING REPORT PERIOD

Discussions were held with C F Braun and Company concerning the development of the SPTF Project Plan. The plan will identify all internal and external interfaces, and include a critical-path network relating these interfaces to the engineering activities. This plan and the revised Title I estimate by Braun based on the work scope being prepared by LMEC will be the basis for Title I negotiations. A draft of the Title I work scope was completed by LMEC and given to Braun. Using this scope of work, Braun has been authorized to proceed with preparing Title I work scope, schedule, and a cost estimate.

A PERT/CPM network, a part of the SPTF Project Plan, was completed. The PERT schedules show the shortest time for completion of the facility, including a 3-month AEC approval time between Title I and Title II work. The time estimate for this approach (Plan 1) is 52 months. An alternate plan (Plan 2), with overlapping Title I and Title II effort for the critical-path work tasks, requires 40 months for completion. Based on latest FFTF pump schedule information (meeting at LMEC with PNL on June 25, 1968), SPTF completion is 22 months after FFTF pump availability based on Plan 1, and 10 months after pump availability based on Plan 2. Detailed steps for accomplishing the work under either Plan 1 or Plan 2 will be discussed in the Project Plan. For either plan, deviations from the step-by-step Title I, Title II, and Title III approach are necessary and it was assumed that Braun was doing the construction and construction management. Preliminary engineering and construction schedules based on PERT information for Plan 1 and Plan 2 are shown in bar chart form in Figures 15 and 16, respectively.

Several revised facility layouts for the SPTF were evaluated by LMEC to determine the adequacy of the proposed site shown in the CSDD and three alternate sites. Based on these layouts, it appears possible that more space will be required than is currently available on the present site. An economic study of the alternate sites was also made by LMEC and AI facilities engineering. Based on the study, a most likely alternate has been selected by facilities engineering. The alternate site is the one on which the Hallam sodium storage tanks are now located. A planning report is currently being prepared by facilities engineering showing the new site as the preferred location for the SPTF and its future requirements. The new site includes space for the following:

7693-2532
Figure 15. Engineering and Construction Schedule for SPTF Plan 1

7693-2533
 Figure 16. Engineering and
 Construction Schedule
 for SPTF Plan 2

- 1) SPTF and its auxiliary systems
- 2) Sodium Cleaning Facility for all LMEC facilities
- 3) Space for the new SPTF maintenance and storage building
- 4) Two areas for future expansion of SPTF
- 5) An area for a future steam station for turbine driven pumps.

The Sodium Cleaning Facility (SCF) requirements were established. The location of the SCF was selected based upon these requirements and considerations of equipment handling. The SCF was located on the same site as the SPTF.

The draft of the planning report prepared by AI for the SCF has been received by LMEC for review.

The thermal transient flow-mixing and control analysis model was mechanized on the analog computer. The system model simulation diagram is shown in Figure 17. Both the open-loop (without control) and the closed-loop (with control) calculations have been checked out. The program is fully operational for production work in Title I. The SPTF main loop configuration consists of a 245-ft-long piping system. The venturi flow nozzle is located approximately 100 ft from the pump discharge connection in the high-pressure piping. The drain line is located 130 ft from the pump discharge. The feed line is located 50 ft upstream of the test pump suction connection. This modified loop arrangement is considered capable of meeting all the design requirements of flow accuracy, piping flexibility, test capability, and minimum sodium inventory. Thermal transient design criteria agreed to by LMEC and RDT for Title I design are presented in Table 2.

A recommendation was forwarded to the RDT concerning the initiation of an SPTF large-valve test program and SPTF materials properties determination program. The severe thermal transient test requirements for SPTF indicate the need for operating test data on commercially available valves and Type 304H austenitic stainless piping under SPTF conditions. A preliminary draft of the "Scope of Work for Development and Test of SPTF Valves" was completed by LMEC for internal review.

Braun has completed their studies to define the requirements for Material Properties R&D and Flowmeter Calibration Capabilities in the SPTF. Reports covering these studies are being prepared.

TABLE 2

SPTF THERMAL TRANSIENT DESIGN BASIS*

Type	Flow Rate (gpm)	Thermal Transient Rate (Shape), Duration		Initial Temperature (°F)	ΔT (°F)	Life No. of Transients
Target Plant Size Pump and Demonstration Plant Size Pump at Full Flow Conditions	120,000	Hot shock	High Rate: 35°F/sec for 6 sec followed by 2°F/sec for 45 sec	800	300	200
	60,000	Cold shock		1000	300	70
	20,000	Hot shock	Low Rate: 4°F/sec for 120 sec	600	480	100
		Cold shock		1100	480	30
Target Plant Size and Demonstration Plant Size Pumps at Turndown or Coastdown Flow Conditions	60,000 size	At 3:1 turndown for high transient rates		Same as above for hot and cold shocks	300	Those transients are included in the total number shown above.
		At 10:1 turndown for low transient rates			480	
	20,000 size	Determine maximum turndown for low transient rates			300	
		Around 3:1 turndown for low transient rates			480	
	All sizes	Determine what transient rates can be run while the pump is coasting down or while pump speed is being reduced				
FFTF Plant Size Pumps	12,000 down to 6,000	Hot shock	24°F/sec for 6 sec followed by 4°F/sec for 50 sec	800	350	40
		Cold shock		900	350	40

*Thermal transient test conditions agreed to by conferees at June 4, 1968, meeting.

A number of plant visits were made to pump and flowmeter suppliers by SPTF and A-E project personnel to investigate design features of existing pump test loops and flowmeter calibration installations. The following questions were explored:

- 1) Can $\pm 1\%$ metering accuracy be achieved at 1200°F based on calibration with water at ambient conditions?
- 2) How are test meters calibrated and what is the accuracy of the tests?
- 3) What are the test codes used by pump manufacturers and to what accuracy are the tests made? What is the accuracy of the pump curves?
- 4) What is the location of the venturi section in the test loops?

A report, LMEC-Memo-68-16, "Trip Report, Instrument Calibration and Pump Test Facilities" (May 24, 1968), was published summarizing the information obtained during this trip, and forwarded to a controlled distribution due to the potentially sensitive information obtained.

The feasibility of using the Hallam main reactor building for the SPTF was evaluated. Conclusions were that the building could be used with some modifications, but that the overall cost would be greater than for the new building proposed in the CSDD. The Hallam building will not be used.

A draft of the Final Cost Report was submitted to the AEC for review and comment.

The revised Quality Assurance plan for the SPTF was received from Braun for LMEC review. The plan was updated to include LMEC comments and RDT guidance. Considerations for purchasing of long-lead-time items by the A-E are also incorporated.

IV. NEXT REPORT PERIOD ACTIVITIES

Title I design 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: April-June 1968

AEC Category: 04-01-61-03.8

General Order: 7693, 7694

Subaccount: 14100

I. PROJECT OBJECTIVES

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 LMFBR 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 were submitted to the AEC. Comments were received from all of the four PSDD reviewing organizations. Pump study contractors supplied all seal design and test criteria that could be determined without having designed the seal and pump. 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

Requested reviews of the seal test facility PSDD were completed with receipt of comments from Byron Jackson and the independent reviewer, Mechanical Technology Incorporated. BJ stated that, with one exception, they "...feel the test rig can subject the seal to the operating conditions which may be present at actual pump installation." MTI reported the conclusion, "...that with but two exceptions, the rig is adequately designed to accomplish its purpose..."

The BJ reservation was that the desired stuffing box temperature and sodium vapor concentration might be difficult to obtain in light of the relatively close

proximity of the liquid sodium to the seal. While this is conceded to be difficult, simulation of pump conditions as predicted by the pump designers will be controlled both by contractor designs of the thermal/vapor barrier and seal shaft and by temperature of the sodium.

One exception by MTI concerned the possibility of a critical speed of the drive and seal shaft assembly being within the design speed range of 0 to 1200 rpm. However, while their computer-performed analysis predicts a critical speed of 1162 rpm, it was based upon assumed seal shaft dimensions given in the AI technical information documents which makes the analysis somewhat academic in this respect; the actual seal shaft design, when made, will have the restriction that critical speed of the seal shaft and bearing spindle must be a minimum of 20% greater than the maximum operating speed of the pump for which the seal is designed and, if greater, the maximum test speed recommended by the designer. (It is also noteworthy that the speeds of the two reference 60,000-gpm pump designs are considerably less than 1162 rpm.) Review of the MTI findings was started by the AI designers and analysts for correlation of analyses and to determine the extent of corrective action.

Final study and evaluation to determine PSSD revision requirements was started with receipt of comments from all reviewers (AEC-RDT, BJ, MTI, and Westinghouse). Subsequent PSSD revision will also reflect additions and changes which have evolved from the considerable additional information that has been received from the pump study contractors since preparation of the original PSSD. Having this additional information also warrants preparing individual PSSD's for the two seal test rigs now instead of awaiting FSDD preparation.

It has been decided to plan for testing an FFTF sodium pump seal and to give FFTF testing precedence over 60,000-gpm pump seal testing. Program plans were revised accordingly. Also as a result of meeting discussions, LMEC started further evaluation of possible testing of other pump seals while awaiting receipt of the first of the planned seals for test. In this regard, consideration was started of technical, schedular, and cost aspects of procuring and testing a seal of the Fermi primary pump design. Fermi seal design and operating data were obtained and a design layout was made of an installation for test requiring only minor modifications to the

seal and the seal test rig. The layout shows that, by fabricating a shorter seal housing (which would be installed on top of the motor mounting barrel of the Fermi seal), the approximately 6-1/2-ft-diameter seal and peripheral equipment could be installed almost intact.

A new test seal proposal was received from Westinghouse which included clarifications and agreements that had been discussed in a meeting at their plant. Evaluation of the new proposal disclosed changes required in instrumentation of the seal. Westinghouse started a revision of their proposal to incorporate the requested changes.

Byron Jackson responded to LMEC comments on their test seal proposal with supplementary information. The information included values for seal nominal characteristics, test limits, and absolute limits for reference, minimum, and maximum size seals for 60,000- and 120,000-gpm pump sizes. LMEC considers the technical information to be as complete as practically possible at this stage of the program. Evaluation of the BJ proposal was completed and a letter report, including a procurement recommendation, was prepared, reviewed, and transmitted to the purchasing department for procurement action.

With receipt of the BJ technical information, tabulations to be included in the PSDD's were made of seal design and test criteria obtained from the pump study contractors and of test facility capabilities as related to the criteria. Regarding the latter, the capability of the test rig to accommodate increased axial displacements of the test seal shaft specified by Westinghouse was verified by study and inspection. The number of bearing spindle shims can be increased sufficiently to impose the maximum predicted displacement (even for the 120,000-gpm size pump seal) because of the combined axial and angular misalignment capability of the gear-type shaft couplings. Drawings were revised and more shims will be ordered. Revision included an interface control drawing change to increase the test seal shaft and housing lengths and, at the same time, to include a note specifically setting critical speed design requirements as previously discussed.

Studies were started to further evaluate seal and test rig instrumentation requirements. One study is of seal shaft dynamics and includes instrumentation requirements and data detection, recording, and display methods, accuracy, and reliability. Preparation was started of a trade study made to establish similar

instrumentation requirements for the measurement of flows and pressure of a barrier-gas-type seal.

The test vessels, rejected because welds had been made with an improper filler wire, were reworked by the supplier and delivered to LMEC. AI rework inspection and documentation is being evaluated by LMEC Quality Assurance to establish acceptability of the vessels. In addition, preparations were started to reinspect some dimensions which could not be properly inspected in the field with available equipment.

Preparation was started of drawings of and for field construction of sodium piping, electrical layouts, and instrumentation and control console layouts. Installation of safety chain supports and chains for ladders and stairways was completed on both test stand work platforms. As-built work platform drawings and plot plan drawings were completed. P&I drawings were revised.

Modification of all valves for sodium service and the installation welding of the modified bonnets and freeze-stems were completed. Due to the additional weight of increased-size diffusion cold traps and valves (from original design assumptions), pipe support hangers were re-evaluated with the resulting addition of two spring hangers and size changes on the other hangers. Sodium supply tank weld and shell material specimens were prepared, attached to sample holders, and installed in the supply tanks.

Descriptive nameplates were made for drive motor circuitry, test console instruments, and heater control circuitry and were installed on Seal Test Rig No. 1. Installation of variable transformers and wiring changes for improving heat control of test vessel vapor zones were completed on Seal Test Rig No. 1. Variable transformers and heater controllers were installed in Seal Test Rig No. 2 and internal wiring of one heater panel was completed. Circuit diagram checks were made and the physical location was determined of wiring connections in the control console of the motor-generator set for Seal Test Rig No. 2. Forming and installation of sodium piping heaters were started. Functional checkout was started of recording and recording instruments per calibration and service procedures.

IV. NEXT REPORT PERIOD ACTIVITIES

The PSDD will be revised in accordance with LMEC evaluation of all review comments and, after informal RDT review, will be submitted to RDT for approval.

Providing the test vessels pass final inspections, assembly and checkout of the basic test rigs will be completed. Also, fabrication and assembly of the sodium systems and process instrumentation and controls will be essentially completed.

The revised Westinghouse proposal will be received and evaluated by LMEC. After AEC approval is obtained, contracts will be let for test seals from both Byron Jackson and Westinghouse. Byron Jackson will start design of their seal.

Preparation of a design specification will be started for a third large-pump test seal. Pump and seal design criteria will be sought from PNL for subsequent planning to procure and test an FFTF pump seal.

Program: Liquid Metal Engineering Center

Project: Sodium Pump Bearing Test Program

Project Manager: R. W. Dickinson

Project Engineer: R. E. Douglas

Reporting Period: April-June 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

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. The OCSDD was revised to incorporate results of the review, and was resubmitted.

III. PROGRESS DURING REPORT PERIOD

Current status of bearing test capability requirements were tabulated, against which feasibility of using an HNPF pump for bearing tests was partially evaluated. Conceptual studies to determine modifications of the pump that are required to accommodate test bearings show that modification requirements are extensive just for the 60,000-gpm pump bearings. It does not appear to be feasible to use the HNPF pump for bearings of 120,000-gpm pump size. Completion of this study is deferred for inclusion with facility trade studies that will be performed by a facility designer in preparation of a CSDD.

A test specification for the Westinghouse 60,000-gpm size test bearing was issued. Comments resulting from review of Sodium Pump Bearing Test Specification (7693-PP-14300-1) were received from Westinghouse. Comments are technically constructive as well as indicative of points in the specification which need clarification. For example, item (g) of WAED E.M.3813, Rev.1, calls for speed tests, implying no-load testing. This was written into the specification. Westinghouse comment on the specification suggests these tests be performed at design loads rather than zero load, thus exemplifying the usefulness of the specification (and the Westinghouse document E.M.3813) in clarifying test requirements and technical considerations.

Estimated schedule for the bearing test program indicates a bearing test facility encompassing all of the currently stated test capability requirements cannot be completed in time to produce bearing test results when required. According to schedule, test bearings will be available for testing about 18 months before facility construction is complete; and the first test pump will be installed in the SPTF about 7 months before the bearing test facility and bearing testing are completed. Alternatives are being studied to determine information that can be obtained within schedule constraints, and to what degree test capability requirements must be compromised.

A revised OCSDD for a Sodium Pump Bearing Test Facility was issued for review. The OCSDD covers ranges of test capability requirements that are to be used as a basis for preliminary engineering studies leading to preparation of a CSDD. Of particular importance to CSDD preparation are results of trade studies specified in the OCSDD. Major areas of uncertainty are exemplified by the specified trade studies, and by the LMEC assumptions appearing in the OCSDD. Assumptions are expected to be reduced by information developed during pump study contractors Phase II studies, and by information developed during FFTF program planning. This information, as it becomes available, will be factored into facility preliminary engineering. Results of trade studies performed by systems designers will provide sufficient technical and programmatic information to allow selection of facility conceptual approach and preparation of a CSDD.

IV. NEXT REPORT PERIOD ACTIVITIES

Upon receipt of OCSDD approval, detailed descriptions of tasks covering trade studies in the OCSDD will be prepared. Negotiations will be started to obtain engineering services required to perform preliminary engineering required by the OCSDD.

Program: Liquid Metal Engineering Center

Project: Precision Mechanisms in Sodium

Project Manager: R. W. Dickinson

Project Engineer: J. H. Brindley

Reporting Period: April-June 1968

AEC Category: 04-01-61-03.8

General Order: 7693, 7694

Subaccount: 15100

I. PROJECT OBJECTIVES

The overall PMIS program objective is to obtain engineering information needed to assist in the design of mechanical elements required for reliable operation in sodium liquid and vapor to 1200°F.

The near-term goal is to test mechanical elements at a minimum of 900°F in a sodium and sodium vapor environment to aid in the original design effort of the FFTF Project.

The information obtained for bearings, gears, seals, latches, guides, spacers, connectors, and various mechanisms should permit a designer of fuel-handling devices, control-rod mechanisms, or core/fuel holddown devices to proceed with confidence as to such factors as allowable loadings and clearances, suitable material couples, friction, and wear factors.

A final published document will contain material-characterization and non-standard design information required for the design of reliable mechanical elements for operation in a sodium environment (liquid or vapor) to 1200°F.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

Static contact tests, to determine self-welding characteristics, were completed on 54 additional material combinations. The material couples were exposed for: (1) 2 months to 1200°F cold-trapped, circulating liquid sodium; (2) 1 month to 1200°F hot-trapped, circulating liquid sodium; and (3) 1 month to 1200°F sodium vapor. Sliding contact tests were continued and, to date, friction and wear coefficients have been determined for 203 material combinations, with the bulk of the data obtained in 1200°F, cold-trapped, circulating liquid sodium. Test results for FY 1967 and early FY 1968, including a description of the test

fixtures and procedures employed, are presented in topical report NAA-SR-12446, "Static and Sliding Contact Behavior of Materials in Sodium Environments at Elevated Temperatures," by W. J. Freede, et al. Detailed analysis of the data is in process and preliminary results appear encouraging from the standpoint of obtaining a correlation among the various material couples as to specific wear rate and material properties. This would be a significant break-through in the state-of-the-art, since it would enable prediction of material performance and, more importantly, lead to specification of new alloys which would be expected to have superior performance in a high-temperature sodium environment.

A Technical Data Record report, LMEC-TDR-68-8, "Austenitic Steel Type 347 Welded Nested Bellows Qualification Tests in Sodium Environments," was published describing bellows qualification tests conducted in: (1) sodium vapor-laden inert gas at 900°F and (2) liquid sodium at 1200°F.

Documentation of experience information on mechanisms operated at EBR-II, SRE, and HNPF were completed and forwarded to AEC-RDT for review and comment.

A Technical Data Record report, LMEC-TDR-68-12, "Stroke Multiplication Mechanism Qualification Tests in 1200°F Sodium," was published describing tests in liquid sodium with a floating pinion, stroke multiplication mechanism fabricated from Hastelloy-C.

A final review draft of the literature search portion of LMEC-68-5, "Mechanical Elements Operating in Sodium and Other Alkali Metals," was forwarded to AEC-RDT for permission to publish. Upon approval, this literature search will be published as Volume I of the report.

A program plan was prepared and submitted to AEC-RDT, reflecting new guidelines received from RDT; namely, the near-term program goal is to test mechanical elements at 900°F in a sodium and sodium vapor environment in direct support of FFTF.

Working meetings were held at PNL with LMEC and FFTF project personnel to define a test program which would be in the best interests of FFTF.

III. PROGRESS DURING REPORT PERIOD

A. LITERATURE/EXPERIENCE SURVEY

A final review draft of the literature search portion of LMEC-68-5, "Mechanical Elements Operating in Sodium and Other Alkali Metals," was forwarded to AEC-RDT for review and approval to publish as Volume I of the report. The bulk of material wear data found applies to liquid metals at less than 1000°F. An extremely limited amount of information was obtained at 1200°F. Test durations reported are short in terms of LMFBR requirements.

Documentation of experience with mechanisms operating in sodium liquid and vapor at HNPF was completed and the report forwarded to AEC-RDT for review and comment. Documentation of mechanism experience at Fermi is in progress. Results of all the experience surveys (EBR-II, SRE, HNPF, and Fermi) will be published in FY 1969 as Volume II of LMEC-68-5.

B. SLIDING WEAR TESTS

Sliding contact test data obtained from 200-hr exposure in various sodium environments are summarized in Table 3.

A report, LMEC-TDR-68-12, "Stroke Multiplication Mechanism Qualification Tests in 1200°F Sodium," was published describing tests performed in liquid sodium with a floating pinion, stroke multiplication mechanism fabricated from Hastelloy-C.

C. DATA ANALYSIS

A total of 150 of the 203 sliding contact tests conducted to date in liquid sodium were reviewed to determine: (1) if existing test data can be used for a quantitative analysis of material wear, (2) what relationship exists between wear and the physical properties of the test materials, and (3) what criteria and procedures should be established for future tests.

A preliminary investigation of the test data revealed that a sharp dividing line exists between the various test results, manifesting itself in the behavior of the frictional coefficient between plate and pins. Of the 150 tests, in 45 the friction coefficient either decreased during the duration of the tests, remained constant, or increased less than 20%. In the other 105 tests, the coefficient

TABLE 3
SLIDING CONTACT WEAR DATA
(Sheet 1 of 2)

Sodium Environment* (1200°F)	Materials		Coefficient of Sliding Friction		Pin Specific Wear (cm ³ /cm-k _g × 10 ⁻¹¹)
	Pins	Plate	Initial	Final	
LHT	Hastelloy-C	Inconel-718	0.23	0.25	15.7
LHT	Hastelloy-C	TZM	0.31	0.37	5.6
LHT	TZM	K-95	0.46	0.67	2.3
LCT	K-95	Stellite-6B	0.24	0.55	2.1
LCT	Stellite-1	Hastelloy-C	0.27	0.31	36.5
LHT	Inconel-718	Inconel-718	0.26	0.38	9.1
LHT	Hastelloy-C	Stellite-1016	0.28	0.30	1.8
LHT	Stellite-6B	Stellite-1	0.28	0.31	5.3
LCT	Al ₂ O ₃ (Lucalox)	Al ₂ O ₃ (Lucalox)	0.46	1.40	704.0
LCT	Stellite-273	K-95	0.51	0.33	125.0
LHT	Hastelloy-C	Stellite-3	0.31	0.22	2.6
LHT	Stellite-273	Stellite-1016	0.27	0.27	2.3
LHT	Stellite-6B	K-95 (WC)	0.80	0.46	3.7
LCT	Molybdenum	K-95 (WC)	0.65	0.98	Material Buildup
LCT	K-95 (WC)	TZM	0.45	1.31	1.8
LCT	Stellite-6H	Stellite-6B	0.26	0.28	Material Buildup
LCT	Stellite-1016	Stellite-6B	0.27	0.37	Material Buildup
LCT	Inconel-750	Stellite-6B	0.30	0.67	648.0
LCT	Inconel-718	K-95	0.45	0.43	33.5
LCT	Stellite-1	Inconel-718	0.33	0.33	7.5
LCT	K-801	Stellite-6B	0.38	0.27	2.1
LCT	Hastelloy-C	K-801	0.34	0.38	27.4
LCT	Stellite-6H	Inconel-718	0.50	0.27	27.7
LCT	K-95	Hastelloy-C	0.36	0.34	1.87
LCT	K-162B	Hastelloy-C	0.26	0.30	1.25
LCT	Colmonoy-75	Hastelloy-C	0.34	0.26	2.25

TABLE 3
SLIDING CONTACT WEAR DATA
(Sheet 2 of 2)

Sodium Environment* (1200°F)	Materials		Coefficient of Sliding Friction		Pin Specific Wear (cm ³ /cm-kg x 10 ⁻¹¹)
	Pins	Plate	Initial	Final	
LCT	Inconel-718	Al ₂ O ₃	0.48	0.26	6.6
LCT	Star-J	Inconel-718	0.33	0.22	8.3
LCT	Stellite-3	Inconel-718	0.33	0.24	15.3
LCT	K-801	K-95	0.33	0.52	Material Buildup
LCT	Colmonoy-75	Stellite-6B	0.32	0.36	4.8
LCT	Hastelloy-C	Stellite-6B	0.35	0.62	264.6
LCT	Stellite-6B	Hastelloy-C	0.31	1.43	342.6
LCT	Inconel-718	Inconel-718	0.26	1.26	25.8
LCT	Colmonoy-75	K-95	0.49	2.25	8.5
LCT	Stellite-6B	Hastelloy-C	0.31	0.34	Material Buildup
LCT	Hastelloy-C	Stellite-6B	0.35	0.35	2.2
LCT	Star-J	Inconel-718	0.32	0.28	7.3
LCT†	304 CRES	Metco-405	0.28	0.48	4.5
LCT	304 CRES	Stellite-1016	0.28	0.33	6.4
LCT	Stellite-6B	Hastelloy-C	0.34	0.44	26.0
LCT	Hastelloy-C	Stellite-6B	0.35	0.26	16.0
LCT	Inconel-718	Inconel-718	0.31	0.36	34.2
LCT	K-95	K-95	0.34	0.98	4.16
LCT	TZM	Inconel-718	0.23	0.38	Material Buildup
LCT	Hastelloy-C	K-95	0.31	0.51	46.9

*LCT = liquid cold-trapped sodium

LHT = liquid hot-trapped sodium

†700°F sodium environment

either increased significantly or behaved extremely erratically. Thirty-eight of the later tests exhibited material buildup on the pins or severe galling. In the 45 tests in which the friction coefficient remained essentially constant, none experienced galling or other severe surface changes. Since only pin data are obtained from a test, each material combination must have been successfully tested in combination as both pin and plate to be considered a complete success. The following is a partial list of material combinations for which successful test results were obtained when tested against one another both as pins and plates:

Material Combination	Combined Specific Wear Rates ($k \times 10^{11} \text{ cm}^3/\text{kg-cm}$)
Hastelloy-C - Stellite-1016	2.99
Stellite-273 - Stellite-1016	16.71
Stellite-273 - Stellite-273	65.00
Stellite-6H - Stellite-6H	19.48
Coors - Coors	35.80

Thus the cobalt base - nickel base alloy combinations look very attractive on the basis of tests completed. Further examination reveals a number of potentially successful combinations where an additional test with the pin-plate material combinations reversed is required for verification. Tungsten and Star-J are an example of the above. When a test combination yields unsuccessful results after the first test, an additional test with the pin-plate material reversed provides little significant information and should be avoided. Stellite-1 and tungsten provide an example of this situation.

Quantitative analysis of a portion of the test data has resulted in the correlation depicted in Figure 18. The k factor as plotted on the ordinate axis is the "dimensionless wear coefficient" described by Rabinowicz.* This k is obtained from the following equation:

$$k = \frac{V_3 p}{L x} , \quad \dots (1)$$

*Ernest Rabinowicz, Friction and Wear of Materials (John Wiley and Sons, New York, 1965)

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Figure 18. Pin Wear Coefficient vs Inverse Square of Pin-to-Plate Hardness Ratio

where

k = dimensionless wear coefficient

V = volume of material transferred (cm^3)

L = load between the wear surfaces (kg)

x = total sliding distance (cm)

p = hot hardness of the softer material (kg/cm^2)

3 = a shape factor resulting from the assumption of circular junctions and hemispherical transfer fragments.

The dimensionless wear coefficient, k, is postulated to be the probability that any junction will lead to the formation of a transfer fragment. The k in this plot would then represent the probability of a pin transfer fragment being formed, since it was computed from pin wear data.

The inverse square of the pin-to-plate hot hardness ratio is plotted on the abscissa, i. e.,

$$\frac{1}{R^2} = \frac{1}{\left(\frac{\text{hardness of pin}}{\text{hardness of plate}} \right)^2} \cdot$$

The pins tested are indicated on the lines and the data points are coded to indicate the plate material upon which the pins were tested.

This approach to data correlation appears quite promising; therefore, effort in this area will continue and, in fact, be expanded upon to try to obtain a more universal correlation in terms of friction, wear, and material adhesive energy.

Comparison of LMEC's data with those of two other investigators^{*†} has been made. Moor ran a hemispherical TZM test pin on a carbide plate in 1200°F potassium and obtained a wear coefficient, k, of 2.5×10^{-6} . LMEC, running flat-surface TZM test pins on a carbide plate in 1200°F sodium, obtained a k of 1.43×10^{-6} . The agreement between these results is considered excellent, since

*Bluford L. Moor and Robert G. Frank, "Friction and Wear of Materials in Sliding Contact from Room Temperature to 1200°F in Liquid Potassium and in High Vacuum (10^{-9} Torr)," Bearing and Seal Design in Nuclear Power Machinery, ASME Symposium on Lubrication in Nuclear Applications, June 5-7, 1967, Miami Beach, Florida

†W. H. Roberts, "Friction and Wear Behavior of Sliding Bearing Materials in Sodium Environments at Temperatures of 600°C," UKAEA TRG Report 1269R (1966)

it is not unusual for differences in wear rates of a factor of 3 or more to be obtained on the same test device. It should be pointed out that Moor was careful to maintain the initial load on his hemispherical pin below 90% of the 0.2% yield stress of the weaker member. Roberts ran a number of materials wear tests in sodium at temperatures to 600°C (1112°F). His test apparatus was of the "crossed-cylinders" type. A test in sodium at 600°C utilizing Stellite-6 on Stellite-1 resulted in a specific wear rate of $\approx 10^{-9}$ (cm³/kg-cm). A similar test by LMEC resulted in a coefficient of only 7.3×10^{-11} (cm³/kg-cm). The difference in wear rates by a factor of ≈ 100 seems excessive; however, compressive stress calculations revealed that initially the 0.2% yield strength had been exceeded by $\approx 20,000$ psi in Robert's experiment. It is believed that this may account for the apparent discrepancy between his and LMEC's results.

It is important to note here that, based on the above comparisons of test data, the adhesive wear Equation 1, which states that wear is proportional to load and not stress, appears to be correct for cases where the 0.2% yield strength is not exceeded.

D. TEST PLANS

Test plans pertaining to rolling element thrust bearings, journal bearings, and spur gears, were completed and forwarded to AEC-RDT for review and approval.

E. PROGRAM PLAN

A program plan containing the latest RDT guidelines for project objectives was prepared and submitted for review. The near-term project objective is to direct the test program to yield mechanism design information for FFTF on a first-priority basis.

F. TECHNICAL LIAISON WITH FFTF

Working meetings, held at PNL between LMEC and FFTF project personnel, resulted in the following plan of action to obtain design information in direct support of FFTF mechanisms. It was agreed by PNL and LMEC that the scope of the program should include the following:

- 1) Basic material tests in support of elemental mechanisms
- 2) Typical mechanical element tests such as bearings and gears
- 3) Basic prototypical assembly tests.

PNL strongly urged that the basic materials tests continue in parallel with the mechanical element tests and, in fact, be expanded to include rolling, fretting, and impact wear tests in sodium and sodium vapor.

PNL expressed the opinion that the static and sliding contact tests to date have been extremely helpful in the selection of materials for their specific applications. As for immediate needs, initial materials recommendations for fuel duct wear applications must be made by December 1968. Sliding tests of the most promising material couples with greater parameter variation should be in progress and fretting tests should begin as soon as possible to provide information input to these fuel duct materials decisions. Rolling contact tests should begin immediately in support of the vertical core duct guide, oscillator rod, fuel-handling gripper, and control-rod drive. In addition, PNL stated that the vapor deposition studies are in direct design support of all FFTF mechanisms having to operate in a sodium vapor environment.

Specific test requests received from FFTF are discussed in the following paragraphs.

1. Materials Interface Effects in Sodium

The objectives of these tests are: (1) to provide materials wear compatibility information for application to mechanical element design; (2) to evaluate materials with respect to surface wear mechanisms such as static, fretting, sliding, rolling, and impact wear in sodium and sodium vapor; and (3) to evaluate other applicable characteristics such as galling, brinelling, surface fatigue, ductility, and ability of material to accommodate thermal stresses arising from differences in thermal expansion.

Initial materials recommendations for fuel duct wear applications must be made by December 1968; therefore, sliding tests should be continued and fretting tests should begin as soon as possible. In support of the vertical core duct guide, basic rolling contact tests should be initiated.

Initial fretting tests should be conducted on the following materials couples:

- 1) Stellite-6B on Haynes-273
- 2) Inconel-718 on itself
- 3) Inconel-718 on Haynes-273
- 4) Inconel-718 on Type 304 SS.

The temperatures at which the wear resistant materials in sodium must operate range from about 550°F to about 1050°F for the initial FTR operating conditions; while for maximum operating conditions, some materials may be subjected to temperatures above 1200°F in special applications.

2. Sleeve Bearing Tests

The objective is to evaluate the performance of sleeve bearings in sodium and sodium vapor for various speeds, loads, and clearances. This information is required for FFTF bearing applications such as the oscillator rod and the fuel-handling gripper rack and pinion.

Specific test requirements are tabulated as follows:

<u>Parameter</u>	<u>Oscillator Rod</u>	<u>Fuel-Handling Gripper Rack and Pinion</u>
Na Environment	Liquid and vapor to 1200°F	Liquid and vapor to 800°F
Speed	50 to 1500 rpm	1 to 20 ft/min.
Size	Shaft diameter of 2 in.	Pitch diameter of 3 in.
Loads	Radial	Push to 1400 lb
	Thrust	Pull to 5000 lb

Test data are of immediate use for sleeve-vs-roller bearing design decisions.

3. Ball and Roller Bearing Mechanism Tests

The objective is to evaluate performance of ball and roller bearing mechanisms in sodium and sodium vapor at various speeds and loads. This information is required for FFTF bearing applications such as the oscillator rod and the control-rod drive systems.

Specific test requirements are tabulated as follows:

<u>Parameter</u>	<u>Vertical Core Duct Guide</u>	<u>Roller Bearings</u>		<u>Ball Bearings</u>
		<u>Oscillator Rod</u>	<u>Fuel-Handling Gripper Rack and Pinion</u>	<u>Control Rod Drive</u>
Sodium Environment	Liquid to 1200°F	Liquid & vapor to 1200°F	Liquid & vapor to 800°F	Vapor to 1200°F
Speed	10 ft/sec scram	50 to 1500 rpm	1 to 20 ft/min	?
Size	To be determined by test	Shaft diameter of 2 in.	3-in. pitch diameter pinion	1-in. inner race 1-1/2-in. outer race
Load	1500 lb	Radial Thrust	Push to 1400 lb Pull to 5000 lb	Axial 125 lb

4. Ball and Screw Mechanism Tests

The objective is to evaluate the performance of a roller nut mechanism (if ball bearing tests conducted in 1 and 3 are promising) for the FFTF control-rod drive mechanism in sodium vapor. Evaluate performance of lead-screw operators in sodium valve service.

Specific test requirements are tabulated as follows:

<u>Parameter</u>	<u>Roller Nut Mechanism</u>	<u>Lead Screws</u>
Na Environment	Vapor to 1200°F	To be determined
Speed	To be determined	
Size	1-1/2-in.-diameter Acme thread 1-in. inner race 1-1/2-in. outer race	
Load	Axial force to 1000 lb on Acme screw thread	
Other	Reverse operation	

5. Lifting Device Tests

The objective is to evaluate performance of candidate lifting mechanisms for the FFTF fuel-handling machine such as chains and sprockets, cables and drums, and tapes and drums. Specific test requirements known at this time are:

1) Na Environment	Liquid and vapor to 800°F
2) Speed	1 to 20 ft/min feed.

6. Seal Tests

The objective is to evaluate candidate sealing mechanisms for FFTF control-rod drive system and the fuel-handling machine. Specific test requirements known at this time are:

1) Seal Type	Labyrinth
2) Na Environment	Vapor to 1200°F
3) Purge Gas Flow	10 ft ³ /min
4) Seal Diameter	2-1/4 to 3 in.
5) Type of Motion	Vertical sliding.

7. Springs and Bellows

The objective is to evaluate performance of springs and bellows in FFTF applications. Springs may be utilized in the FTR control mechanism to accelerate poison into the core when required. Possible bellows applications exist in the safety control-rod drive system and the fuel-handling gripper mechanism. Steady-state and cyclic tests would be required. Specific test requirements known at this time are tabulated as follows:

<u>Parameter</u>	<u>Springs</u>	<u>Bellows</u>
Na Environment	Liquid and vapor to at least 1200°F	Vapor to 800°F
Size	0.7-in.-diameter 4-in. coil mean diameter	1 to 4 in. ID x type
Stroke	-	1/2 to 1-1/2 in.
Material	S-816, A-286, Inconel-X750, Inconel-718	SS
Stress	30,000-psi shear	To be determined

Additional test requests being drafted include:

- 1) Lifting device tests
- 2) Gear tests
- 3) Seal tests
- 4) Springs and bellows.

IV. NEXT REPORT PERIOD ACTIVITIES

Wear rates of Ampco-18 HT13 vs Stellite-6B, Type 304 SS, and hard-chrome-plated Type 304 SS at temperatures between 700 to 900°F in cold-trapped liquid sodium will be reported in LMEC-TDR-68-14.

Vapor deposition tests will be initiated to establish the nature, control, and removal of sodium films. These tests will be in direct design support of all FFTF mechanisms having to operate in a sodium vapor environment.

Work will continue on documentation of the experience history relating to mechanisms at Fermi.

Data analysis will continue to refine correlations related to wear performance and material properties. A trade-off matrix will be prepared to rank the various material combinations from overall considerations (friction, wear, mechanical and thermal properties, composition, availability, cost, fabricability, etc.). The sliding contact tests will continue with the more promising material couples and the testing will be performed with variations of the following parameters: load, velocity, and temperature.

Some static contact tests may be required with the latest superalloys such as Udimet-630, LTZ, and TZC, as they become available and providing they show promise from the sliding wear tests.

Basic rolling friction and wear tests will be initiated in support of FFTF mechanisms.

Basic fretting and impact wear tests will be initiated to enable FFTF personnel to decide on materials for fuel duct wear applications by December 1968.

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

Liaison with manufacturers will also be on a continuous basis in support of the design and fabrication of mechanical elements such as roller and journal bearings, spur gears, and ball bearings for 900°F tests in support of FFTF.

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: April-June 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. Within the overall objective is a trade-off study of LMFBR test requirements matched to specific facilities, primarily to identify deficiencies in test facility accommodations. 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.

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.

The final System Design Description of the Hallam Pump Test Loop (future ACTI) has been prepared to serve as a basis for future facility modification.

The FFTF flowmeter position test has been completed. The results show that a usable flow signal is obtained when a permanent magnet type flowmeter is mounted adjacent to a pipe elbow.

III. PROGRESS DURING REPORT PERIOD

The draft of the HNPF Pump Test Loop Final System Design Description has been completed and is ready for publication processing. The following drawings have been included:

- 1) P&I Diagram — Loop I and II
- 2) Loop I Piping — Isometric
- 3) Loop II Piping — Isometric
- 4) Electrical Single — Line Diagram
- 5) Loop I Piping Heaters and Thermocouples
- 6) Loop II Piping Heaters and Thermocouples.

The FFTF flowmeter position test on the SCTI has been successfully completed. The following observation can be made concerning the test flowmeter output signal:

- 1) The flowmeter position with respect to pipe elbows (even next to the elbow) does not appear to have a significant effect on the percentage of noise signal content up to about 2700 gpm in a 10-in. pipe (~ 11 ft/sec).
- 2) The percentage of noise is greatest at low flows, reduces to a minimum at mid-range flows, and increases at higher flows.
- 3) The test flowmeter consistently had a higher noise content in the output signal than the reference flowmeter.
- 4) The dc component of the signal was decreased up to 16% by the presence of conventional steel pipe clamps near the electrodes and magnet.

Seven alternate piping arrangements and cost estimates utilizing the existing piping at the HNPF Pump Test Loop for the ACTI have been prepared. The cost savings amount to less than 10% over the cost of new piping. The use of the existing piping is not recommended, since it is not suitable for 1200°F. The ACTI should be built with all new piping.

IV. NEXT REPORT PERIOD ACTIVITIES

This project is not presently funded in FY 1969.

Program: Liquid Metal Engineering Center

Project: Instrumentation Testing, Evaluation, Calibration, and Standardization

Project Manager: R. W. Dickinson

Project Engineer: J. T. Meyer

Reporting Period: April-June 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 1.4, Section 4, of the LMFBR Program Plan.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1968

State-of-the-art reports have been written and distributed on sodium flow, level, temperature, pressure, and impurities measurement. These studies were made and the reports were written specifically to provide information for the preparation of sodium instrumentation standards. The writing of these standards has been initiated and is continuing as a joint effort with the Codes and Standards Task Unit.

The LMEC instrumentation maintenance, repair, and calibration effort was initiated and is proceeding on a firm, well-planned basis. Excess equipment has been procured to equip the laboratory. Laboratory requirements were presented to RDT to provide guidance in determining which facility should be assigned to LMEC to house the instrument maintenance function.

The LMFBR instrumentation functional testing and test facilities requirements study was submitted to RDT. This document provides a basic plan on which to build LMFBR instrumentation facilities.

Vendor proposals were received from seven sources for the Sodium Components Test Installation-Data Acquisition System (SCTI-DAS). These proposals were evaluated and recommendations were made to RDT as to vendor qualifications and selection.

III. PROGRESS DURING REPORT PERIOD

Documentation of vendor selection for the SCTI-DAS was completed and forwarded to AEC-RDT. The vendor recommended by LMEC was selected and procurement was approved. The procurement negotiations were entered into and the necessary paper work was disposed of. The funding for the system was approved and transferred to LMEC on June 18, 1968. Contract negotiation and preparation could not be accomplished before the end of FY 1968. The necessary paper work was completed to obligate the funding and the procurement is proceeding. The required operational date for the system makes the utmost expediency in procurement necessary.

Upon completion of the state-of-the-art studies, work was begun on the preparation of instrument standards. The establishment of a format for these standards is still of some concern and is, at present, still being worked out between the Codes and Standards Task Unit and the Instrumentation Task Unit. A sample outline was prepared by the Codes and Standards Task Unit and an attempt is being made to follow this particular outline. Problems are being encountered following this format and these are being resolved by conferences between the two task units. Certain task unit personnel have had to be reassigned to other higher priority tasks and the preparation of these standards is being accomplished at a reduced level.

The study to define specific functional testing and test facilities requirements was forwarded to RDT. Further study has been done on LMFBR functional testing and test facilities requirements with emphasis being placed on FFTF and SPTF near-term needs. Meetings were attended with RDT personnel to discuss the input to this report.

Priorities were established for acquiring test facilities based on Section 4 of the LMFBFR Program Plan requirements and these have been recommended to RDT in a cover letter. RDT has subsequently directed that certain trade-off and option studies be performed on the recommended facilities. These studies, involving the Temperature and Pressure Test Chamber (TPTC), the Sodium Components Test Loop (SCTL), the Sodium Instruments Test Tower (SITT), and the In-core Flowmeter Test Insert (IFTI) have been initiated. Parameters under investigation in these studies are facility cover gas pressures, operating temperature, sizes (height, diameter, total volume), interconnection possibilities, multiple test capabilities, transient capabilities, and costs for the various trade-offs. Trips have been made to PNL and the LMFBFR Program Office and consultations have been held with FFTF personnel to further define in-core instrument test requirements. One of the major byproducts of these meetings has been the realization that a concerted effort will be required on the part of all concerned parties to provide test facilities in time to perform significant testing on FFTF instrumentation. Considerable effort has been expended in the studies to determine the maximum level to which existing facilities can be used for this testing pending the modification and construction of completely adequate test facilities. Trip reports have been written detailing discussions entered into on these visits. This work is not proceeding at a satisfactory rate because of the urgency of other work and the assigning of personnel to these other tasks. Because of the urgency in acquiring and providing proper test facilities for instrumentation for the FFTF and LMFBFR programs, additional personnel are being selected and assigned to this task.

The evaluation of areas of uncertainty associated with SPTF instrumentation is continuing, and recommendations for required design support and/or development will be submitted to RDT by July 15, 1968. This work has been continued and somewhat delayed because of uncertainties in the accuracy of pressure measuring devices, the uncertainties being primarily between what is advertized or claimed and what might actually be true. Visits are planned to the various manufacturers and users to determine the present state-of-the-art in these pressure measuring devices. At the conclusion of these visits, a report will be written and forwarded to RDT with LMEC's recommendations for this further development work.

Flowmeter position testing, requested by FFTF project, has proceeded at a quite satisfactory rate. The results of this testing have been written up and will be published as a letter enclosure by July 12. The preliminary results indicated that further testing should be done utilizing noise analysis techniques. This work has been done, and the results are currently being written.

The LMEC operating procedure for instrumentation calibration and maintenance has been approved by the director, LMEC, and is now in effect at LMEC. Work has continued on the preparation of instrument maintenance and calibration procedures for use by the LMEC instrumentation and standards laboratory. This unit has been separated from the instrumentation testing, evaluation, calibration, and standardization project and is now being operated under a separate subaccount (17200).

A major effort has been expended toward the end of this reporting period in the preparation of a Schedule 189 for FY 1969. The work previously included under project 17100 was divided into two projects and will be covered by two Schedule 189's, 17100 and 17200. The work separated under project 17200 includes all of the LMEC instrumentation and standards laboratory function including test engineering. In addition, the LMEC strain gage program has been integrated into the overall LMEC instrumentation program. For simplification of costing and scheduling, it will continue to be covered by a separate Schedule 189. This 189 (subaccount 52110) will, in addition to strain gages, cover special purpose instrumentation being tested for the LMFBR program.

The LMEC has been directed to consider as an extension of its scope of work the technical management of LMFBR neutron detector development tasks. This activity has been assigned to the LMEC Instrumentation Task Unit and the LMEC instrumentation Project Engineer. A work outline and a form 189 for FY 1968 has been prepared for this activity.

The physical facility for housing the LMEC instrumentation maintenance, calibration, and standards laboratory has not yet been transferred to LMEC. This facility is urgently needed so that LMEC can supply the quality of instrument maintenance and calibration required by the LMFBR Program Plan and as directed

by RDT. To satisfactorily meet the schedule previously submitted to AEC, this facility was needed by March 1, 1968. This would have enabled an operational date for the program of July 1, 1968. It must be realized that it would take a period of approximately 3 months for this program to become completely operational and for all LMEC instrumentation to be functioning under a planned program of schedule preventive maintenance and routine calibration. Pending receipt of the physical facility, LMEC instrument maintenance and calibration laboratory personnel are proceeding with the writing of maintenance and calibration procedures.

IV. NEXT REPORT PERIOD ACTIVITIES

The effort to procure the SCTI-DAS will be continued. It is expected that during this next report period, the contract negotiations will be completed, the contract will be signed, and design review meetings will be conducted with the vendor.

The work on LMFBR instrumentation standards preparation will be continued with the completion of the standards for sodium level and sodium impurities measurement instrumentation. Comments on the LMFBR standard RDT-905 will be forwarded to the LMEC Codes and Standards Task Unit. An alternate procedure has been prepared as an enclosure with the comments. This enclosure is being forwarded as a more positive approach to the need for a standard.

Additional studies for sodium instrumentation and calibration facilities will be continued. This effort will be continued on a top-priority basis because of the urgency for these facilities.

A major effort during the next report period will be the staffing up of this activity to adequately handle the increased work load indicated by recent assignments. This increased work load is clearly outlined in the Schedule 189's associated with the instrumentation task at LMEC.

Program: Liquid Metal Engineering Center

Project: High-Temperature Strain Measurements

Project Manager: R. W. Dickinson

Project Engineer: M. M. Lemcoe

Reporting Period: April-June 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 LMFBF 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 and fabrication of component parts for a facility were 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 and SG425 strain gages and gage components were completed. Causes of the poor performance and premature failure of these gages were established.

Development effort on the present version LMEC Armour-D - platinum wire gage was completed.

Evaluation of the LMEC clad Armour-D gages has 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 LMFBR sodium components. 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 clad gage concept.

III. PROGRESS DURING REPORT PERIOD

Six special Microdot gages, with Armour-D filaments, are being evaluated at 900°F. Their drift characteristics to date vary between 0.4 and 0.7 micro-strain/hr, which is outstanding to excellent (see Table 4, Gages MD1-1 through MD3-2). At the end of 500 hr of soak, the gages will be thermally shocked, and the procedure repeated. Each time the procedure is repeated, the temperature will be increased 100°F. It is the purpose of these tests to determine whether Microdot gages with Armour-D alloy for the filaments are superior in performance to the Microdot SG420 or SG425 gages in the temperature range of 950 to 1200°F.

Pilot tests were completed on eight Microdot SG420 strain gage assemblies with intermediate shims to determine whether there was a change in gage calibration resulting from chiseling the assemblies from the calibration bar and rewelding them to the test article. The results from these tests show that there is a significant change in gage factor and apparent strain, unless the gages are post-stabilized by load and temperature cycling, after installation on the test component. Figure 19 shows, for a typical gage, the error in gage factor which will result if the gages are not post-stabilized. This figure is a plot of gage output vs the central deflection in a constant-moment beam calibration fixture at 900°F.

TABLE 4
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	13th series appar- ent strain pending	1200	3607	3.8	2.3	120	120	120	Outstanding life with excellent drift characteristics
D23-1	Armour-D-Pt wire	4th series elevated temperature; load test pending	1200	896	4.2	7.8	30	30	30	Excessive drift
D23-2	Armour-D-Pt wire	Same as above	1200	896	4.2	8.0	30	30	30	Same as above
D25-1	Armour-D wire, Pt foil leads	4th apparent strain test pending	1200	915	4.0	7.7	30	30	30	Same as above
D25-3	Armour-D wire, Pt foil leads	Same as above	1200	915	2.2	13.7	20	20	20	Gage failed during 1st cycle at 10°F/sec
D26-1	Armour-D wire, Pt tabs	Out	1200	310	1.6	1.6	0	0	0	Same as above
D26-2	Same as above	Out	1200	310	1.5	1.5	0	0	0	Same as above
D27-1	Same as D26 with Pt tabs reversed	Out	1200	310	2.9	2.9	0	0	0	Same as above
D28-1	Armour-D-Pt wire	2nd series soak in progress	1200	357	1.5	1.5	10	10	10	Very good drift characteristics
D28-2	Same as above	Out	1200	310	1.5	1.5	10	0	0	Gage failed during 1st cycle at 20°F/sec
D28-3	Same as above	2nd series soak in progress	1200	357	1.6	1.6	10	10	10	Very good drift characteristics
D28-4	Same as above	Same as above	1200	357	1.4	1.4	10	10	10	Same as above
D29-1	Armour-D-Pt wire	Same as above	1200	342	0.6	0.6	10	10	10	Excellent drift characteristics
D29-2	Same as above	Same as above	1200	342	0.8	0.8	10	10	10	Same as above
D29-3	Same as above	Same as above	1200	342	1.4	1.4	10	10	10	Very good drift characteristics
D29-4	Same as above	Same as above	1200	342	1.1	1.1	10	10	10	Same as above
D31-1-3	All Armour-D wire	2nd apparent strain test pending	900	294	0.1	0.1	10	10	10	Gages on half-bridge excellent drift characteristics
D31-2-4	All Armour-D wire	Same as above	900	294	0.2	0.2	10	10	10	Same as above
D32-1	Armour-D-Pt wire	Same as above	1200	312	2.6	2.6	10	10	10	Good drift characteristics
D32-3	Same as above	Same as above	1200	312	2.8	2.8	10	10	10	Same as above
D33-1	Same as above	Same as above	1200	312	2.2	2.2	10	10	10	Same as above
D33-2	Same as above	Same as above	1200	312	3.0	3.0	10	10	10	Same as above
D33-3	Same as above	Same as above	1200	312	3.0	3.0	10	10	10	Same as above
D34-1	Same as above	Same as above	1200	312	2.8	2.8	10	10	10	Same as above
D34-3	Same as above	Same as above	1200	312	2.8	2.8	10	10	10	Same as above
D34-4	Same as above	Same as above	1200	312	2.5	2.5	10	10	10	Same as above

TABLE 4
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	Out	1200	2687	7.7	2.9	97	90	90	Outstanding life, failed 8th cycle 10°F/sec
DEN4-2	Same as above	5th series elevated temperature load test pending	1200	1200	3.2	3.2	40	40	40	Good drift characteristics
DEN4-3	Same as above	Same as above	1200	1200	3.0	3.2	40	40	40	Same as above
DEN4-4	Same as above	Same as above	1200	1200	3.0	2.7	40	40	40	Same as above
DEN8-1	LMEC Composite	3rd series thermal soak pending	1200	607	1.6	1.8	20	20	20	Very good drift characteristics
DEN8-2	S700-Pt	Same as above	1200	607	1.6	1.8	20	20	20	Same as above
DEN8-3	Same as above	Same as above	1200	607	1.7	1.9	20	20	20	Same as above
DEN8-4	Same as above	Same as above	1200	607	1.9	2.0	20	20	20	Same as above
DEN9-1	All S700 Alloy	4th series soak test pending	1200	905	2.1	2.0	30	30	30	Same as above
DEN9-2	Same as above	Same as above	1200	905	2.5	2.3	30	30	30	Same as above
DEN9-3	Same as above	Same as above	1200	905	2.2	2.1	30	30	30	Same as above
DEN9-4	Same as above	Same as above	1200	905	2.4	2.3	30	30	30	Same as above
DEN10-2	Same as above	4th series apparent strain test pending	1200	917	2.7	3.2	30	30	30	Good drift characteristics
DEN11-1	Same as above	Same as above	1200	917	2.7	3.1	30	30	30	Same as above
DEN11-2	All S700 Alloy	Same as above	1200	917	2.7	3.1	30	30	30	Same as above
DEN12-1	Fe-Cr-Al	3rd series thermal shock test pending	1200	894	2.3	3.3	20	20	20	Same as above
DEN12-2	Same as above	Out	1200	587	1.6	1.9	10	10	10	Gage failed in 1st cycle 10°F/sec
DEN12-3	Same as above	3rd series thermal shock test pending	1200	894	2.3	3.3	20	20	20	Good drift characteristics
DEN12-4	Same as above	Same as above	1200	894	2.0	3.1	20	20	20	Same as above
(Microdot Gages)										
MA1-1	SG423	8th series shock test pending	950	1599	1.7	0.8	70	70	70	Very good drift characteristics
MA1-2	Same as above	Same as above	950	1599	2.0	1.3	70	70	70	Under 750 microstrain mechanical load (4th series)
ML1-1	SG420	Test completed	900	209	1.8	1.8	10	10	10	Very good drift characteristics
ML1-2	Same as above	Same as above	900	209	1.6	1.6	10	10	10	Same as above
ML2-1	Same as above	Same as above	900	209	0.9	0.9	10	10	10	Under 750 microstrain mechanical load. Excellent drift characteristics
ML2-2	Same as above	Same as above	900	209	0.8	0.8	10	10	10	Same as above

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TABLE 4
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	
ML1-1	SG420	Test completed	950	192	2.0	2.0	10	10	10	Good drift characteristics
ML1-2	Same as above	Same as above	950	192	3.5	3.5	10	10	10	Satisfactory drift characteristics
ML2-1	Same as above	Same as above	950	192	2.1	2.1	10	10	10	Under 750 microstrain mechanical load. Good drift characteristics
ML2-2	Same as above	Same as above	950	192	1.8	1.8	10	10	10	Very good drift characteristics
ML1-1	Same as above	Same as above	1000	192	5.2	5.2	10	10	10	Power failure — excessive drift
ML1-2	Same as above	Same as above	1000	192	4.1	4.1	10	10	10	Same as above
ML2-1	Same as above	Same as above	1000	192	4.6	4.6	10	10	10	Same as above
ML2-2	Same as above	Same as above	1000	192	-	-	10	10	10	Recording instrument failed
ML1-1	Same as above	Same as above	1050	198	1.6	1.6	10	10	10	Very good drift characteristics
ML1-2	Same as above	Same as above	1050	198	0.8	0.8	10	10	10	Excellent drift characteristics
ML2-1	Same as above	Same as above	1050	198	1.2	1.2	10	10	10	Very good drift characteristics
ML2-2	Same as above	Same as above	1050	198	5.8	5.8	10	10	10	Excessive drift characteristics
ML1-1	Same as above	Same as above	1100	200	1.9	1.9	10	10	10	Very good drift characteristics
ML1-2	Same as above	Same as above	1100	200	0.8	0.8	10	10	10	Excellent drift characteristics
ML2-1	Same as above	Same as above	1100	200	1.2	1.2	10	10	10	Very good drift characteristics
ML2-2	Same as above	Same as above	1100	200	1.8	1.8	10	10	10	Same as above
ML1-1	Same as above	Same as above	1150	216	9.9	9.9	10	10	10	Excessive drift
ML1-2	Same as above	Same as above	1150	216	4.8	4.8	10	10	10	Same as above
ML2-1	Same as above	Same as above	1150	216	7.8	7.8	10	10	10	Same as above
ML2-2	Same as above	Same as above	1150	216	8.7	8.7	10	10	10	Same as above
MS1-1	SG425	Out	900	130	0.3	0.3	0	0	0	Gage failed in 1st thermal soak
MS1-2	Same as above	2nd series appar- ent strain	900	208	0.3	0.3	10	10	10	Outstanding drift characteristics
MD1-1	Armour-D filaments	1st thermal soak in progress	900	336	0.6	-	0	0	0	Excellent drift characteristics
MD1-2	Same as above	Same as above	900	336	0.5	-	0	0	0	Same as above
MD2-1	Same as above	Same as above	900	336	0.7	-	0	0	0	Same as above
MD2-2	Same as above	Same as above	900	336	0.7	-	0	0	0	Same as above
MD3-1	Same as above	Same as above	900	336	0.5	-	0	0	0	Same as above
MD3-2	Same as above	Same as above	900	336	0.4	-	0	0	0	Same as above

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Figure 19. Change in Gage Factor Characteristics

Cycles 1, 2, and 3 show the strain-deflection characteristics before the strain gage assembly is removed from the calibration bar by chiseling. Cycles 4, 5, and 6 show the same characteristics after the assembly has been chiseled off and rewelded to the calibration bar. It is noted that there is a 155-microstrain zero shift out of 615 microstrain on Cycle 4, which corresponds to an error of 25%. Cycle 4 readings would correspond to the first readings taken with the strain gages after installation on the test article. Only after at least one additional load cycle is this error essentially zero.

Figure 20 shows the error in apparent strain which will result if the gages are not temperature-cycled after installation. This figure is a plot of apparent strain vs temperature on a mechanically unstressed bar for a typical gage. Cycles 1, 2, and 3 represent the apparent strain vs temperature characteristics before the strain gage assembly is removed by chiseling. Cycles 4, 5, and 6 represent the same characteristics after the assembly has been chiseled off and rewelded to the calibration bar. It is noted that at 500°F there is a 250-microstrain difference between Cycle 4 and Cycles 5 and 6. This corresponds to an error of 250 out of 1100 microstrain, or nearly 23%. Only after at least one additional temperature cycle is this error essentially zero.

The need for post-stabilization (load and temperature cycling) after installing the gages on the test article is clearly evident.

Evaluation of two early version Microdot SG425 gages was initiated. These two gages, designated MS1-1 and MS1-2, were subjected to a maximum test temperature of 900°F. One gage failed at the end of 160 hr because of cracks in 2 of the 3 copper leadwires at the weld joint with the gage shanks. The other gage is still under test. After 208 hr of soak, the gage is still performing quite satisfactorily, with an average drift rate of only 0.3 microstrain/hr.

Evaluation of eight of the latest version SG425 was also initiated. Data obtained to date are shown in Table 4.

The fifth thermal soak is in progress on LMEC clad Armour-D gages, which have been subjected to 1208 hr of exposure at 1200°F and 120 thermal shocks. Performance continues to demonstrate the feasibility of the gage concept.

Evaluation of other LMEC gages continued (see Table 4 for results). It is noted that Gage D-13 (all Armour-D wire) is still operating after being subjected

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Figure 20. Change in Apparent Strain Characteristics

to 3607 hr of soak at 1200°F and 330 thermal shocks, with a drift rate of only 2.3 microstrain/hr. It is also noted that the "flame-spray" foil gages, DEN4-2, -3, and -4, are still performing satisfactorily, with a drift rate between 2.7 and 3.2 microstrain/hr, after 200 hr at 1200°F, and after being subjected to 120 thermal shocks.

Inspection of the Microdot SG420 gages to be used in conjunction with the pending Alco/BLH steam generator and IHX tests has been completed. All gages were found to have a resistance to ground of at least 200 megohms at 950°F, which is excellent.

Data reduction, statistical analysis, and preparation of CRT plots continues for the gages listed in Table 4. This information, which is being compiled concurrently with the gage evaluation, will be incorporated in reports, upon the completion of each evaluation.

Five all-nickel sheathed gages fabricated by Microdot were received and are being reserved for the development of "sodium-proof" gages, as a part of the industrial strain gage program.

Room temperature checkout of the axial load calibration facility continues. The calibration bar was instrumented with 12 room-temperature strain gages to determine uniformity of strain distribution on all four faces of the bar along its entire length. Bending was found to be undetectable, since the variations from point to point were found to be within the accuracy of measurement; i. e., less than 1%. Correlation of results obtained with the strain gages and those obtained with a DCDT (direct-current differential transformer) was found to be within 5% (see Figure 21). Correlation of the results and those obtained with a Tuckerman optical strain gage is pending. If the Tuckerman gage confirms the accuracy of the strain gages, then steps will be taken to improve the accuracy of the DCDT measuring system.

Application of the second block of thermal shocks to the B&W huts, immersed in sodium, has been completed with no malfunctioning of the facility to date. The huts were subjected to 1000 hr of exposure at 900°F and 60 thermal shocks at a heating rate of 15°F/sec. No leaks were detected in the huts.

Several new soak furnaces and an 8-channel tape punch, with interfacing accessories for the Gerber data reduction system, are being installed to expedite strain gage evaluation and data reduction. One of these furnaces (split-type)

will be used in conjunction with the above-mentioned axial load gage calibration facility.

Extruded Armour-D bar, approximately 1 in. in diameter, has been received from the vendor; it will also be reserved for use on the industrial strain gage program.

IV. NEXT REPORT PERIOD ACTIVITIES

Major attention will be focused on: (1) facilities development, including a facility for evaluating and calibrating gages under simulated transient heating and cooling conditions, and completion of the axial calibration facility; (2) evaluation of Microdot SG425 gages, Microdot gages with Armour-D filaments, and other special gages now under test (see Table 4); (3) tests to determine the differences, if any, in tensile and compressive gage factor of Microdot gage assemblies incorporating an intermediate shim; (4) evaluation of Microdot SG420 gages at maximum test temperatures of 800 and 1050°F, which correspond to maximum temperatures anticipated in the Alco/BLH steam generator and IHX performance tests, respectively; (5) other preparations for the Alco/BLH steam generator and IHX performance tests, including gage precalibration; and (6) performing whatever additional tasks, presently under discussion, that are authorized by RDT.

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Figure 21. Comparison of Strain Gage and DCDT Readings

Program: Liquid Metal Engineering Center

Project: LMEC Laboratory Support

Project Manager: R. W. Dickinson

Reporting Period: April-June 1968

General Order: 7693

Project Engineer: R. K. Wagner

AEC Category: 04-01-61-03.8

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 chemical and metallurgical 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 a 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

Analytical requests from LMEC projects indicate that the laboratory is adequately equipped to satisfy most analytical and test requirements. However, requests for some sophisticated analyses, particularly during the last half of the fiscal year (since January 19, 1968) have revealed a major deficiency. The absence of x-ray fluorescence and electron beam microprobe equipment imposes

an analytical limitation in the areas of diffusion zones, wear products, compositional gradients, and rapid quantitative analyses of inorganic compounds and alloys. When required, these analyses were performed in other facilities available to LMEC. Estimates of current and near-term demand indicate that the existing arrangement will not become unwieldy until FY 1970.

In an effort to derive maximum benefit and flexibility from the equipment currently in the laboratory, the potential of the flame spectrophotometer was investigated. With this equipment, standard curves have been prepared to determine oxygen in sodium by flame photometry. Development of this method provides an alternate procedure to the volumetric method in current use.

A detailed series of calibration and check analyses indicated a lack of reproducibility in the performance of the carbon train. After completion of several procedure and equipment modifications to eliminate carbon contamination, proof-testing of the carbon train for consistent performance was completed. Results of these analyses indicate that the modifications were effective. A significant reduction in carbon blank values was produced from 20 to 5 micrograms. Further improvement is indicated by the results of analyses performed on samples from sodium used in the second USAEC carbon-in-sodium round robin. An initial value, prior to modification, of 105 ppm C was measured. In two subsequent determinations, values of 15 and 21 ppm were measured. The latter results compare very favorably with the round-robin values reported (ranging between 11 and 53 ppm).

Steps taken to reduce carbon contamination which apparently caused the high initial value included:

- 1) Installation of a cold trap in glove box transfer chamber to eliminate backstreaming of oil vapor from vacuum pump
- 2) Relocation of O-ring seals and maintenance at room temperature to avoid their outgassing
- 3) Improved sample homogeneity by melting for removal from capsule rather than employing mechanical methods.

A number of oxygen analyses were performed on sodium samples obtained from various operating systems. For most systems, oxygen values were normally relatively low - 12 to 15 ppm. For some samples, however, oxygen values

to 225 ppm were measured. Because the sampling procedure was suspect, a retest was performed with substantially lower values measured. This experience again demonstrates that the adoption of sound sampling methods is mandatory before analytical results are meaningful.

A brief effort to evaluate existing oxygen solubility in sodium data was completed. The summary was prepared for presentation at a recent meeting of a technical society. Data evaluated were selected from all known sources and included an expression* derived from the results of six different investigations where either the amalgamation or vacuum distillation method was used to measure oxygen concentration.

Numerous analyses were performed on a variety of materials in support of the Seal Test and LCTL Programs. Verification analyses were performed on materials (Type 304 SS flanges and SS weld rod) used to modify the seal test vessels. Concern over the presence of chlorides in compounds to be used on these vessels prompted a number of chlorine analyses. A graphite-base heat transfer material used to attach cooling coils was found to contain chlorine at the 1000-ppm level. No chlorine was detected in a second sample of modified composition, where aluminum oxide was substituted for graphite. Other chlorine analyses performed on insulating materials for LCTL (EM pump) application indicated relatively low levels; 100 and 50 ppm were measured. All of these determinations were made by means of x-ray fluorescence.

B. METALLURGICAL LABORATORY

In support of the Seal Test Program, a group of ten Type 304 SS bolts, coated with a graphite-base heat transfer cement, were examined for evidence of corrosion after various conditions of exposure - time, temperature, and moisture level. Two of the ten bolts examined were in the as-received condition. Prior to metallurgical preparation, dye penetrant examinations were performed with negative results. Metallurgical examination indicated that various degrees of pitting had occurred under the cement. Pit depths from 2 to 8 mils were measured where the maximum penetration occurred for moistened cement at 300°F and 100 hr. During exposure, each bolt had been loaded in tension to approximately 35,000 psi.

* $\log S(\text{ppm oxygen}) = 6.239 - 2447/T(^{\circ}\text{K})$, where S represents the solubility of oxygen in sodium; as described by R.L. Eichelberger, Atomics International, in a report to be published, "The Solubility of Oxygen in Liquid Sodium - A Recommended Expression," AI-AEC-12685 (1968)

Weight changes were determined for two stainless steels (18-18-2 and Type 304) after a 3400-hr exposure in 1200°F static sodium. The stress-corrosion-resistant 18-18-2 experienced an average gain in weight of 5.6 mg/cm² while the weight of the Type 304 specimens increased an average of 4 mg/cm². This comparison is consistent with the weight change previously observed, after a 1000-hr exposure, where the average weight gain for 18-18-2 exceeded that for Type 304 by approximately 10%.

Routine metallurgical services and consultation were provided to various LMEC programs as requested.

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.

Program: Liquid Metal Engineering Center	
Project: Maintenance of Temporarily Idle Equipment	
Project Manager: R. W. Dickinson	Project Engineer: D. K. Darley
Reporting Period: April-June 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 secure the lower end of the LCTL core tank replacing the shackle and turnbuckle assemblies formerly used.

A new differential pressure cell used to determine supply tank sodium level was installed and put into service. Process piping, electrical, preheat panel, and control panel drawings of the LCTL were updated to reflect the present as-built conditions. Procedures for preheating, filling, and operating the 6- and 3-in. sodium loops and for operation of the purification system were completed. The 6-by-8 and 2-by-3 sodium pumps were cleaned, inspected, and refurbished.

A rotary EM pump designed by AI and used for pumping liquid metal at up to 900 psi at 600°F was received at LCTL and is being refurbished for use in support of FFTF testing.

III. PROGRESS DURING REPORT PERIOD

The calibration of the level indicators for the core tank, supply tank, and drain tank at LCTL was checked out by pumping sodium between the three tanks and comparing the sodium level indicator in the control room with the actual

sodium level measured, using a manual level probe in each tank. The remote level indicators will require calibration before accurate level readings can be made in the control room.

A rotary EM pump previously used to pump liquid potassium was received at LCTL and is being refurbished for use in support of FFTF testing. The pump rotor was rewound. The pump structure will be modified for operation at temperatures up to 950°F; it will deliver 50 gpm at 150 psig ΔP .

A "Microsen" sodium pressure transducer from HNPF was cleaned and is being calibrated for use on the discharge of the 2-by-3 circulating pump at LCTL.

Work continued on preparation of maintenance and operating procedures for LCTL. Preparation of as-built drawings was reactivated; drawings of the preheat and process panels and one line electrical and control schematics were released.

Preventive maintenance of all equipment was performed according to schedule.

IV. NEXT REPORT PERIOD ACTIVITIES

Modifications, installation, and performance checkout will be completed on the rotary EM pump that will be used in support of FFTF testing at the LCTL.

The preventive maintenance program will be continued.

The 2-by-3 and 6-by-8 LCTL sodium loops will be operated for checkout. The plugging temperature of the sodium at LCTL will be determined and the cold trap will be operated as required to clean up the system.

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