Quarterly Technical Progress Report Liquid Metal Engineering Center (LMEC)

April-June 1967

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Liquid Metal Engineering Center

Operated for

the U.S. Atomic Energy Commission by Atomics International

A Division of North American Aviation, Inc.

Contract: AT(04-3)-700

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The progress report for the
previous quarter was
NAA-SR-12416.

Program: Liquid Metal Engineering Center	
Project: AEC Assistance and Consultation	
Project Manager: R. W. Dickinson	Project Engineer: R. W. Dickinson
Reporting Period: April - June 1967	AEC Category: 04-01-61-03.1
General Order: 7693	Subaccount: 12100

I. PROJECT OBJECTIVES

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

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

A. SPECIFICATIONS AND STANDARDS TASK UNIT

A Specifications and Standards Task Unit was set up within LMEC. Seven engineers are assigned to this unit on a full-time basis with technical support provided from the entire LMEC staff as required.

A detailed work plan for the LMEC effort on LMFBR specifications and standards was completed and forwarded to the AEC. Comments were received and the program is being modified in accordance with AEC direction.

An agreement was reached with the Bechtel Corporation of San Francisco to assist LMEC in the preparation of LMFBR standards and specifications.

A series of visits was made to other installations as an initial step toward coordination of the LMFBR standards program. Visits were made to PNL, ANL, APDA, GE, and ORNL.

Draft specifications and standards were prepared for a 60,000-gpm sodium pump, component cleaning, intermediate heat exchanger, and sodium quality; drafts are currently in review. Detailed outlines and guides for preparation of standards were completed for welding, materials, and quality assurance.

Consultations were held with ORNL representatives to coordinate the LMEC effort with the overall RDT standards program administered by ORNL.

A file of standards and specifications pertinent to the LMEC standards activity was started. Documents accumulated to date include: RDT water reactor standards; a complete set of FARET specifications; PBF, LOFT, and ATR specifications; and a large number of individual specifications from other programs and facilities.

B. VALVES TASK UNIT

A memorandum was issued in which the effects of sodium impurities on austenitic-stainless and ferritic steels were reviewed and sodium purity requirements were developed.

C. PIPING TASK UNIT

Reviews of piping development programs received from RDT on LMFBR piping development work scope were accomplished.

Comments and suggestions were forwarded to the RDT-AEC Site Office (AI).

Initial steps have been taken for an engineering evaluation of HNPF main sodium piping during the HNPF retirement program.

D. PUMPS TASK UNIT

Program guidelines were prepared for development of large (60,000-gpm) pumps and valves suitable for 30-in. lines operating at 1200°F.

Estimates of dimensions and weights for 60,000- and 120,000-gpm pumps were prepared.

Assistance has been provided to RDT in their direction of the Large Sodium Pump Study Project. Work on this project to date by Westinghouse Electric Corp. (a study contractor) has been reported as a rough draft Phase I Report which was reviewed in detail for RDT. Many suggestions by LMEC for revision of this report are being incorporated in the revised draft of the document. Activity by the Byron Jackson Pump Company (the other study contractor) has yet to be described in a report.

E. INCIDENT REPORT SYSTEM TASK UNIT

The program was initiated by conducting a concerted review of DOD, NASA, UKAEA, Maritime Administration, and other malfunction and maintenance reporting systems. Their origins, methods, long-range objectives, short-range objectives, and equipment requirements were studied. Cognizance was taken of organizational problems encountered, complexity of input data requirements, cost of operation, and overall relative success of the programs. From this review, "The Outline Plan for Collection, Evaluation, and Dissemination of LMFBR Facilities Incident Report Information," was prepared and formally submitted to the Commission on March 15 for review and evaluation.

Several local visits were conducted to review other systems in operation and to determine the relative importance placed on digital computer usage, microfilm usage, microfilm logic-sorting equipment, hardcopy requirements, and/or visual review of original documents. Recordak's MIRACODE film logic-sort system was found to be popular and the most acceptable if this type of sorting function were found to be required. Visual review of original reports was needed but very little hard copy.

A preliminary EAM Card Format for recording 32 categories associated with identification of component malfunction and maintenance data was prepared.

Review of HNPf, SCTI, and SRE sodium component historical data was initiated.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT

A study was initiated to determine design and fabrication limitations of potential LMFBR configurations. A first-round identification of problem areas and design uncertainties was completed and a set of design criteria was proposed to guide future effort. The original treatments, which included consideration of both pot and piped configurations, have been modified to reflect RDT direction that the LMEC study concentrate solely on the pot or "Combined Unit Reactor Vessel (CURV)" concept.

III. PROGRESS DURING REPORT PERIOD

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

An agreement was reached with the Bechtel Corporation of San Francisco to assist LMEC in the preparation of LMFBR standards and specifications. Under the agreement, Bechtel will provide a 5-man effort over the period May 12 through September 30, 1967 to prepare draft standards on welding, materials, cleaning, inspections, and quality assurance. LMEC prepared comprehensive guides and outlines to aid Bechtel in preparation of these standards. Bechtel was also furnished copies of the appropriate water reactor standards and other background material. Bechtel completed a review of the RDT water reactor welding standard as the initial step toward preparation of a welding standard for liquid metal systems. Bechtel representatives presented results of their review at LMEC; the conference was also attended by ORNL representatives who participated in the discussions. Bechtel also started work on standards for materials and quality assurance.

Visits were made to other LMFBR program installations to discuss specifications and standards in relation to the experience and technical requirements at those facilities. A visit was made to PNL with discussions centered on FFTF requirements. At ANL, items reviewed included quality assurance, EBR-II and FARET specifications, and general liquid metal experience. At APDA, discussions were held on FERMI and other APDA specifications, quality assurance, welding, materials, and other standards and practices. A visit was made to General Electric at Sunnyvale, California to discuss SEFOR specifications and the LMFBR standards program.

Preparation of the sodium quality standard was continued. The latest draft was reviewed and some of the technical requirements are being further investigated, particularly the allowable level for oxygen. An outline was begun of the technical requirements and potential problem areas of large sodium piping and pipe supports.

At the request of PNL, LMEC reviewed the preliminary specifications for the FFTF reactor vessel and transmitted comments to PNL. In conducting the review, LMEC studied the technical requirements of the RDT water reactor standard for reactor vessels, as well as other specifications and standards.

Much of the review will be applicable to an LMFBR reactor vessel standard; an outline of the LMFBR standard was begun.

Two meetings were held with ORNL representatives on coordination of the LMEC effort with the RDT standards program. Working arrangements relative to review and release of tentative standards were discussed. ORNL provided LMEC blocks of RDT numbers to be applied to materials, equipment, and process standards issued by LMEC. It was agreed that, where possible, the LMFBR standards will follow the format of the corresponding RDT water reactor standard, since the water reactor standards do not follow a completely uniform format.

Three additional engineers were assigned on a full-time basis to the LMEC standards and specifications effort, making a total of seven personnel engaged in this activity in addition to Bechtel assistance and support from the LMEC technical staff.

Comments were received from the AEC on the program plan previously submitted by LMEC for the preparation of LMFBR standards and specifications.

B. VALVES TASK UNIT (R. B. Hinze)

SPTF design personnel from the contractor, C. F. Braun, were briefed on valve requirements unique to sodium service.

Technical recommendations for examination of HNPF sodium valves and purification equipment (among other components) were made to the AEC.

Results of a study of published literature on the effect of impurities in sodium on austenitic-stainless and ferritic steels were issued as a memorandum, "Sodium Purity Requirements (A Review and Evaluation)," NAA-SR-MEMO-12394. In this memorandum, impurities in sodium in use as a fast reactor coolant are identified and their significance discussed. Any study of sodium purity requirements must be made with reference to a particular system. Here, sodium purity requirements are developed for a coolant system constructed of austenitic-stainless steel and 2-1/4 Cr-1 Mo ferritic steel, operating at a 1200°F reactor outlet temperature (the temperature designated for the prototype LMFBR) for 30 yr. Included in the tentative conclusions of the memorandum is a 2-ppm limit on oxygen concentration, necessary for acceptable corrosion (2 mil) during the 3-yr life of fuel-element cladding when cladding temperature is 1300°F.

This conclusion is based chiefly on results of the Sodium Mass Transfer program published in GEAP-4831.* These results were extrapolated beyond test conditions using the empirical equation to predict average corrosion rates for various oxygen concentrations. To be conservative, calculated values of average rates were multiplied by a factor of five to give the approximate maximum corrosion rates which fall within the 95% confidence level, as presented in GEAP-4831. From this calculation, a 2-ppm oxygen concentration was found to limit fuel-cladding corrosion to 2 mil in 3 yr, assuming that extrapolation is appropriate and the published correlation is accurate and applicable.

Recommendations are included in the memorandum for additional development work to verify certain extrapolations and values used in the study and for work where existing information is insufficient to support a specification. Finally, it was concluded that since pertinent technology is developing, periodic review of these requirements is necessary to keep them abreast of advances in the state-of-the-art.

Proposed scope-of-work statements (RFP) for implementation of recommendations in the sodium purity requirements memorandum concerning additional mass-transfer investigations, studies relating metal-surface-carbon content to mechanical properties, and nitriding investigations were prepared.

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

In response to LMEC recommendations on HNPF Sodium Piping Post-Operation Evaluation, RDT concurred in the desirability of this effort and requested LMEC to define the required work in more specific terms. This effort was redefined; the information included the following: (1) more specifics on the measurements to be performed; (2) identification, both tubular and schematic, of specific piping sections of interest; (3) cost estimate and schedule; and (4) confirmation that adequate documentation of HNPF operating history is available.

*M. C. Rowland, D. E. Plumlee, and R. S. Young, "Sodium Mass Transfer: XV. Behavior of Selected Steels Exposed in Flowing Sodium Test Loops," GEAP-4831 (March 1965)

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

Assistance has been provided RDT in directing the Large Sodium Pump Study Project by evaluating material presented by the pump study contractors at their meetings with RDT and those organizations participating in the 1000-Mwe LMFBR, Followon Studies. These evaluations have been both general and specific in nature when necessary to redirect the study toward a pump-centered rather than a system-oriented effort. A part of the advisory effort has also resulted in a reduction of the number of possible configurations to be studied.

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

A visit was made to the Federal Aviation Agency Headquarters in Los Angeles to obtain information on their safety and reliability data collection system and compliance monitoring. The backbone of safety and reliability compliance renegotiation is review, by the FAA regulatory division, of system failure and inspection data supplied by the carrier operators and manufacturers on a weekly basis from their reliability data processing systems. From these data, subsystem inspection and maintenance schedules, as required by the FAA regulatory division, are either increased or decreased in frequency and complexity as indicated for a given airline or carrier vehicle. The Director of the maintenance and inspection compliance division emphasized the need for some form of enforcement incentive if a program of this type is to succeed. A detailed trip report on the FAA system was prepared.

Time-shared digital computer systems were investigated as a possible alternative to a microfilm logic-sorting system. Representatives from four computer companies (viz., General Electric, International Business Machines Corp., Control Data Corp., and Tymshare Inc.) visited the LMEC and presented descriptions of their computer systems capabilities. In addition, a visit was made to the computer facilities of the Control Data Corp. and Tymshare. A visit was also made to Rocketdyne's Canoga Park facility where Rocketdyne's experience with timesharing systems was discussed and a demonstration of their computer terminals in operation was witnessed.

An evaluation and recommendation was prepared on the above systems which indicated Tymshare Incorporated to best satisfy LMEC requirements on the basis of system capabilities and economics of immediately available models. A formal

recommendation will be prepared requesting the installation of a teletype Model 33 or 35 to be obtained for use at the LMEC in conjunction with the Tymshare and/or General Electric computer systems. It is intended that as new and expanded timeshare computers are installed and become available, their applicability to LMEC demands will be reevaluated and the best system made use of since 30-day commitments are all that is required. It was determined that timeshare systems are not intended to be included as ADPEquipment referred to in SAN Chapter 1801.

Historical data collection on sodium components from files at the SRE and HNPF and tabulation of all incident reports from the SCTI were completed. The tabulating format is a reduced version of the EAM card format. Approximately 125 component failures and their causes have been tabulated from the SRE. Numerous heater and thermocouple failures are listed without cause data. Most of the tabulated failures occurred in bellows seal valves and pump freeze seals as a result of improper line or component heating. HNPF sodium components data sources include AI-initiated work requests (to August, 1963), AI and CPPD monthly reports, and ROAP semiannual reports. Approximately 250 incidents have been tabulated. A visit was made to HNPF and the following reports were collected and shipped to the LMEC for review: (1) daily reports written in support of the Operations Analysis Program, (2) CPPD component files, and (3) completed work requests. The daily reports will be used to plot curves of power generation and individual coolant loop operation. The "Total Time In Service" of the equipment associated with 135 failure events recorded for the SCTI was determined.

As historic data tabulation is completed for each of the three facilities, the data will be sorted and reviewed for continuity, gaps, and clarity of logic. Where indicated, additional information will be solicited. Evaluation of the data should lead to definite information with respect to specific components and procedures.

While evaluation of the data is only just starting, certain trends are already clearly evident. The most important of these is that in spite of the existence of an apparently well managed Reactor Operations Analysis Programs, the data did not detail information in sufficient breadth for direct application to component reliability evaluation.

It has been repeatedly evident that in test facilities and pilot plants, burnin-type component failures have an equal if not more important counterpart in

burnin-type malmaintenance. This is enhanced by the common practice of teaching the new operating crews the intricacies of the new facility by having them conduct the maintenance during the shakedown or burnin period. A potentially good operator may not of necessity be a good maintenance technician; especially in instances where, for a specific component, no maintenance procedures have as yet been devised.

Many of the incident reports, etc. have been very difficult to interpret because the individuals preparing the reports tried to define descriptive terms in the format in accordance with their personnel interpretation. The stated "incident" may actually be the "effect" and the "cause" the "incident." The true cause, such as "abnormal stress due to thermal distortion," may not be recorded as related to the "incident" but under later "modifications." Consequently, preparation of preliminary formats for component malfunction reporting has been delayed in the expectation of being better able to correct some of these format deficiencies as more of the data are reviewed.

The development of formats for the evaluation of historical failure event data has been initiated. Examination and compilation of the data will take several months to complete.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT (J. E. Owens)

A program for the parallel investigation of pot-type and piped reactor configurations was developed and submitted for AEC review. Basic design criteria were set forth, problem areas and design uncertainties were identified, and comparative data were provided on LMFBR reactor plants and various plant design studies. Subsequently, in recognition of informal comments by RDT reviewers, a second draft was prepared to eliminate consideration of piped configurations and to concentrate on investigation of the CURV concept.

Following submittal of the initial study plans, effort was directed toward preparation of draft work statements for studies by potential supporting contractors. Work areas were selected which appeared to be unequivocally related to the CURV investigation. These included:

- 1) Unitized System Design Layout Study
- 2) Reactor Vessel Design Study

- 3) Unitized System Size Evaluation
- 4) IHX Design Study
- 5) Large Sodium Pump Design Study.

Formal response to LMEC submission was received from RDT in June 1967. This response clarified the objective and purpose of the CURV Study and established the required scope of work. Further discussion of the LMEC CURV Study was obtained on June 19, 1967 during a meeting between LMEC and RDT representatives. It was agreed that LMEC effort for the immediate future should be devoted to: (1) summarizing the advantages and disadvantages of potential system arrangements within the CURV concept and (2) establishing the technological limitations associated with the reactor vessel and the top closure. At the close of the report period, a list of questions was being generated for use in evaluating the merits of potential CURV systems. The reactor vessel work statement previously prepared also was being reviewed and expanded. Additionally, a program plan was being prepared to show the revised management and technical approach to the CURV Study and to develop preliminary cost information for GFY 68 and 69.

IV. EVALUATION OF EFFORT TO DATE

A. SPECIFICATIONS AND STANDARDS OF TASK UNIT

Preparation of specifications and standards is proceeding at a currently satisfactory rate. It is evident that some delay will be encountered in establishing firm technical requirements for some components and processes because of the lack of applicable experience or conclusive technical data. Areas requiring further investigation or substantiation will be noted, as appropriate, in the tentative drafts of standards and specifications.

B. VALVES TASK UNIT

The requirements for sodium purity presented in NAA-SR-MEMO-12394 represent a "best set" of impurity levels applicable to the particular system defined in the memorandum, based on published information. Subsequent to issuance of the memorandum, the LMEC has been informed that some new data and reevaluation of existing data from the Sodium Mass Transfer program, as yet unpublished, casts doubt on the applicability of the information presented in

GEAP-4831 to the development of oxygen concentration requirements as presented in the memorandum. The effect of this new information, and any other pertinent information, on the findings of the sodium purity requirements memorandum should be determined as the information becomes available.

C. PIPING TASK UNIT

Preliminary steps have been taken in a comprehensive piping development and proof test program. This program is required for the successful development of large diameter sodium piping.

The engineering evaluation of the HNPF main sodium piping, both primary and secondary, will provide information on the performance of stainless-steel piping at maximum temperatures of 945°F for times exceeding 8,000 hr, in a sodium-cooled reactor plant.

D. PUMPS TASK UNIT

The consideration of both piped and pot-type reactor concepts for the 1000-Mwe LMFBR has required evaluation of additional pump configurations. These added pumps have common shaft seal and bearing problems and generally lower NPSH requirements. Preliminary information for both contactors indicate serious problems with pump drives in the areas of heat rejection and speed range. Continued participation by LMEC in this study will help define areas where additional development work is needed and where the current state-of-the art is adequate for the foreseeable needs of the LMFBR program.

E. INCIDENT REPORT SYSTEM TASK UNIT

Direct discussions with executives of the Federal Aviation Agency, Hughes Aircraft Co., J. M. Covington Corp., and others have been particularly rewarding. Many gray areas of directional uncertainty have been partially cleared with respect to the relationship between component system reliability and the fields of maintenance, inspection, test information, regulation, safety, and close relationship with the complying contractor. Significant time savings in planning have been gained and a continuation of this type of effort is anticipated.

Review of microfilm sorting and viewing equipment, time-sharing computer equipment, and the anticipated reporting and data processing system needs has

made possible immediate determination of equipment requirements once the scope of effort will have been defined.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT

Efforts toward development of design criteria, identification of problem areas, and preparation of work statements have been productive and will serve to facilitate future investigations. However, progress has been hampered by initial misunderstanding of the scope of the program and by delayed response to LMEC submittals. The referenced direction and recent discussions with RDT representatives have resolved many LMEC questions and should help to ensure proper orientation of future effort. Similar discussions will be required as the work progresses to answer questions which currently remain unresolved. For example, a conflict appears to exist between the memorandum statement that "it is not the purpose of the CURV Study to develop a specific design or to establish a reference design for any given reactor" and its requirements for detailed analyses of the effects of fluid flow, mechanical- and flow-induced vibration, thermal transients, and dimensional variations.

V. NEXT REPORT PERIOD ACTIVITIES

A. SPECIFICATIONS AND STANDARDS TASK UNIT

LMEC will continue to determine and evaluate the needs of the various LMFBR engineering programs and facilities, relative to standards and specifications. Results of this survey will be used as the basis for the scope and schedule of the LMFBR standards program. A revised plan for standards preparation at LMEC will be submitted to the AEC by the end of the report period.

Preparation of the sodium quality standard will be continued and a tentative draft submitted to RDT and ORNL. Preliminary drafts and outlines of technical requirements will be prepared for standards on reactor vessels, piping, valves, and inert gas.

Liaison will be maintained with the Bechtel Corporation, working conferences will be held, and draft standards prepared by Bechtel will be reviewed. A major effort is anticipated on preparation of the quality assurance standard.

B. VALVES TASK UNIT

Consultation on the LMFBR valve engineering program will be provided as requested by RDT.

The impact of new data and evaluation from the Sodium Mass Transfer program at General Electric and preliminary corrosion information from high-heat flux heater tests at Atomics International on sodium purity requirements will be determined when the information is available.

C. PIPING TASK UNIT

Document review and preparation in the piping field will be conducted at the direction of RDT. Evaluation of HNPF sodium piping will also be performed at the direction of RDT.

D. PUMPS TASK UNIT

Continued discussions are anticipated with RDT, the Large Sodium Pump Study contractors, and those participating in the 1000-Mwe LMFBR followon studies. Information derived from these sources will be used to advise RDT as they guide the Pump Study Project. Additional discussions with the pump study contractors will aid in preparation of their Phase I reports, which are scheduled for completion later this year.

E. INCIDENT REPORT SYSTEM TASK UNIT

Intensive developmental effort on formats, codes, etc. continues to be deferred until such time as the expected scope of the program can be formally clarified. Current response rate to the request for review of the plan by AEC contractor organizations indicates August as a possible date for this clarification. However, an informal discussion with the Head of Reliability Engineering, Space Systems Division, Hughes Aircraft Co. indicates that their program, in operation for 5 yr and presently applied to the Surveyor program, more closely approximated LMFBR component reliability, short-range (first 3 yr) objectives than all other systems reviewed. (This is because it is a test rig and design modification program similar to that planned for LMFBR.) Some of the ideas used will be incorporated into preliminary formats during July and August for purposes of discussion and assistance in clarification of the planned objective.

Search of SRE, SCTI, and HNPF literature for additional failure event information has been temporarily postponed to permit development of evaluation formats, but is expected to be completed during next quarter.

Arrangements are being made for visits to PRDC, APDA, ANL, and EBR-II during the month of July to discuss methods for obtaining historical data on sodium system component failures from these facilities.

Processing of historical failure data will continue.

Development of mathematical models relating distribution functions of environmental effects to component reliability and design margins will be initiated.

F. COMBINED UNIT REACTOR VESSEL (CURV) TASK UNIT

The technical and managerial program plan and cost estimates will be completed and submitted for RDT review. The scheduled completion date for this information is July 24, 1967. The reactor vessel work statement will be completed, and a new work statement covering investigation of top closure design will be prepared. Initial discussions will be held at ANL concerning the 1000-Mwe followon studies, EBR-II design, and LMFBFR Program Office activities. Additionally, discussions will be arranged at the EBR-II site relative to its operating and maintenance history. The study of advantages and disadvantages of various CURV configurations will be continued at LMEC. This information will be augmented by the design, operating, and maintenance experience from EBR-II and other applicable LMFBFR plants.

Program:	Liquid Metal Engineering Center		
Project:	Data Acquisition and Processing Center Study		
Project Manager:	R. W. Dickinson	Project Engineer:	J. T. Meyer
Reporting Period:	April - June 1967	AEC Category:	04-01-61-03
General Order:	7693	Subaccount:	13100

I. PROJECT OBJECTIVES

The overall objective of this project is to perform a conceptual design study as authorized by CPAO-AEC to accomplish the following specific objectives:

- 1) Establish the basic technical requirements for LMEC data acquisition, recording, and processing as indicated by known program objectives and foreseeable needs
- 2) Establish the capabilities, specifications, and availability of existing data system equipment
- 3) Perform tradeoff studies and complete conceptual design for satisfying the requirements identified in paragraph (1) above
- 4) Prepare a final report recommending a system capable of satisfying present and known future LMEC requirements. The report will include a plan of action, proposed schedule, estimated cost for acquisition and installation of the recommended system, and criteria and specifications for the major system components.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

LMEC data processing requirements were determined and a survey of available AEC and commercial data systems was completed. Tradeoff studies were completed on major alternate approaches, and conceptual designs to accommodate LMEC data handling requirements were submitted.

The Data Acquisition and Processing Center Study was concluded with the submittal of the Task IV report. This report included a plan of action, procurement schedule, estimated costs, and performance specifications for the

procurement of the LCTL and SCTI data systems. The material submitted was based on information forwarded to Tasks I through III. SPTF data system specifications were not included in the Task IV report because of uncertainties in the SPTF Architect-Engineer's final data system requirements.

III. PROGRESS DURING REPORT PERIOD

The Task IV report was written, printed, and submitted to the AEC for review. The report included a plan of action, schedule, estimated costs, and performance specifications for LCTL and SCTI data systems. The preliminary specifications for the SPTF data acquisition system have been completed and forwarded to the SPTF Project Manager and the Architect-Engineer for their review and use.

IV. EVALUATION OF EFFORT TO DATE

A comprehensive evaluation of the LMEC data processing requirements was made and an approach was recommended that will satisfy these requirements. System conceptual designs were formulated and forwarded to the AEC for approval. A complete survey of available AEC-owned and commercial data systems was completed and the information gathered is reflected in the final report. The study was concluded with the submittal of the Task IV report. The specifications therein will provide the LMEC with data systems which will be adequate to meet present requirements and capable of expansion to meet future needs.

V. NEXT REPORT PERIOD ACTIVITIES

The LMEC data center study was completed during this report period.

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 1967	AEC Category: 04-01-04-31
General Order: 7693, 7694	Subaccount: 13200

I. PROJECT OBJECTIVES

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

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

Repair of the sodium heater was accomplished and the plant was returned to normal operation. Operation of the plant on a steaming cycle totalled 88 hr before the main steam line failed from extensive cracking. A contract was signed with Bechtel to: (1) redesign the main steam piping, (2) procure long-lead hardware required for reconstruction, and (3) review the adequacy of the steam and feedwater system. Other contracts were signed with Burns and Roe, Inc. and Battelle Memorial Institute to review the mode and cause of failure of the steam piping. Redesign of the steam system reached 66% completion.

III. PROGRESS DURING REPORT PERIOD

Negotiations were successfully concluded with the signing of a contract with Bechtel Corp. to redesign the high-pressure steam piping, to place orders for the procurement of long-lead-time equipment, and to review the steam and feedwater systems in order to make recommendations for improvements. Engineering work, which was started well in advance of the signing of the contract, has been approximately two-thirds completed; procurement activity and the review function are both approximately one-half done.

Purchase orders were placed for the principal long-lead materials required to accomplish rebuilding the steam system. Considerable difficulty was encountered

in getting a commitment for a desuperheater. The unit required is of nonstandard design; and vendors, all of whom are back-ordered on much standard equipment, were hesitant to undertake this special job. A compromise was reached by ordering two half-capacity standard desuperheater units instead of one single full-capacity (special) unit. The schedule controlling items will be the pressure reducing valves, which require a nominal 30-week delivery period. All other purchasing actions remaining are for relatively short lead-time materials. With the desuperheater problems resolved, all dimensional requirements for the system have been established. Detailed design is proceeding in an orderly fashion. Bechtel's review of the steam and feedwater system has not resulted in any radical discoveries, and apparently only minor changes will be required in this system.

A study of demineralizer requirements to accomplish full-flow condensate polishing was nearly completed. This study was undertaken because of the implications of the chloride stress corrosion failure of the high-pressure steam piping and because the existing equipment is limited in capacity to a 40% bypass flow at full load. Also, all three consulting firms independently (and so far, informally) recommended installation of full-flow condensate polishing capacity. Several potential vendors were contacted and a preliminary specification was written. Suppliers indicate a delivery time of at least 7 months for requisite components. Approval has been solicited to proceed with the preliminary design of the additions to the treated water system required to provide full-flow polishing capacity.

Contracts were also negotiated with Burns and Roe, Inc. and Battelle Memorial Institute to review the cause of the steam piping failure. Representatives of both organizations have completed an on-site review of all aspects of this incident. The task for Burns and Roe includes an evaluation of the possibility of rebuilding the steam system with austenitic steel. BMI's task is intended to identify and/or corroborate the cause and mode of piping failure. Both organizations are to submit reports by the end of FY 67, but these are not available for reference herein. Tentative conclusions, independently determined by these consultant firms indicate that: (1) the mode of failure was stress corrosion; (2) the instigating cause was repeated wetting and drying of the steam line as occasioned by the preheat and initial steaming cycle requirements; and (3) in view of the

nature of the SCTI plant and the operating conditions imposed upon the steam system, the use of a 2-1/2 Chrome - 1 Moly piping material is recommended.

Replacement of bellows expansion joints in the secondary sodium piping was completed. The replacement consisted of expansion loops which require no bellows joints. The addition of these piping expansion loops increases the volume of the secondary system; adequate sodium inventory is available to accommodate this increase. A system description of the primary sodium piping modification to remove expansion joints was prepared and transmitted to AEC-CPAO.

A one-day conference was held with representatives from General Electric, San Jose, regarding placing nine mass-transfer tab assemblies at various locations in the SCTI sodium piping. Agreement was reached on the appropriate location for each assembly and on the manner in which data will be assembled and transmitted to GE. Installation of five of these assemblies in the primary sodium piping was nearly completed.

A series of short tests were run to obtain data on leakage flow rates and valve position versus flow for three of the 10-in. butterfly valves in the primary system. The valves divert sodium flow from a constant speed primary pump into bypass lines supplying the sodium cooler and "hot shock" lines. These data were needed because of a requirement to impose some ramp flow changes in connection with the IHX vibration study. A curve (see Figure 1) includes the results. The differences between the valves shown for FRC-100V and those for TRC-100V-1 and V-2 occur because of a difference in seating conditions. Butterfly valves of the type installed at the SCTI are normally fitted with a closure ring around the periphery of the butterfly disc to assure tight shutoff. Valves TRC-100V-1 and V-2 are fitted with such rings because of a shutoff requirement; valve FRC-100V-1, however, was purposely installed without a ring because tight shutoff was not required. The difference between TRC-100V-1 and V-2 reflects different system characteristics upstream of the valves.

Another series of tests were performed to establish the gas entrainment rate from the free sodium surface in the primary pump. In these tests, data were obtained only at 100% rated flow for the pump, which is 2700 gal/min (only full-flow data were of interest at this time). Five separate test periods of varying duration yielded data with about a 20% spread and indicated a gas transport rate of 2.3 scfh.

Figure 1. SCTI Butterfly Valve Characteristics

Circulation of sodium in the primary pump continued without interruption for all but the last 3 weeks of the quarter. During the last 3 weeks of the quarter, the primary pump was shut down in order to allow the addition of a new level controller for the pump case and permit installation of the GE mass transfer tabs.

Preventive maintenance activities performed during this period included re-packing of valve stems throughout the feedwater and low-pressure steam systems and the primary sodium system, and cleaning and adjusting of all level controllers and their transmitters. Contractors finished stabilizing the soil embankment around the base of the cooling tower, resealing the catch basin apron, and repairing the berm around the apron to prevent any further deterioration of the cooling tower base. Other contractors have resumed inspection, testing, repair, and replacement actions on electrical equipment which was damaged in an electrical fire reported several months ago. Cleanup and repair of all this damaged equipment was not adequately completed immediately after the fire. Present work is intended to return all of the affected equipment to a prefire condition. Because of this investigation, several major portions of the plant equipment will be shut down for a period of about 2 weeks. Assignment of personnel to other tasks

precluded preparation of the as-built System Design Description and the last few historical incident reports.

IV. EVALUATION OF EFFORT TO DATE

Failure of the high-pressure steam line and delays encountered in resolving repair problems has created a serious hiatus in the SCTI program. Completion of design work required for reconstruction of the steam piping has been slower than anticipated. Placing of orders for long-lead-time materials permits establishment of a reasonably firm target date for return of steaming operation of April 1, 1968.

V. NEXT REPORT PERIOD ACTIVITIES

Redesign of the main steam piping will be completed; purchase orders for short-lead-time items will be placed. The as-built System Design Description will be completed for publication action. Four mass transfer tab assemblies will be added to the secondary sodium piping.

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Program: Liquid Metal Engineering Center	
Project: Liquid Metals Information Center	
Project Manager: R. W. Dickinson	Project Engineer: J. J. Droher
Reporting Period: April - June 1967	AEC Category: 04-01-61-03
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 1967

The LMIC became operational on July 1, 1966 and now has information from 5066 documents stored within the computerized search and retrieval system. The Center has responded to 325 separate requests for information from various organizations, including practically all of the major laboratories engaged in liquid metals technology. These requests have involved 1075 separate subject categories for which computerized searches were performed resulting in a total of 128,210 printouts with bibliographic data and abstracts of documents containing pertinent information.

Preparation of the initial draft of an updated version of the Liquid Metals Handbook, Sodium-NaK Supplement, was completed on schedule. The LMIC data bank, with its computerized search and retrieval capability, and LMIC file copies of pertinent documents were used extensively by the individual authors to enhance the depth of coverage and played a vital role in the timely completion of the document. Copies of the initial draft were delivered to the Commission on June 30, 1967 for distribution and comment.

III. PROGRESS DURING REPORT PERIOD

During this quarter, 146 additional documents were processed, making a total of 5066 documents in the LMIC data bank. The Center responded to 106 inquiries for information during the quarter, of which 96 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 343 different subject categories and yielding a total of 38,656 computer-produced printouts.

Work was completed on the initial draft of the updated version of the Sodium-NaK Supplement to the Liquid Metals Handbook. This initial draft is a compilation from some 50 authors and is divided into 19 chapters as follows:

1. Physical Properties
2. Chemistry
3. Effects on Materials
4. Fluid Flow
5. Heat Transfer
6. Purification
7. Sodium and NaK Systems
8. Intermediate Heat Exchangers (IHX)
9. Steam Generators
10. Heaters and Coolers
11. Radiators, Condensers, and Boilers
12. Pumps
13. Valves
14. Vessels and Piping
15. Equipment and System Accessories
16. Instrumentation
17. Handling
18. Safety
19. Applications

IV. EVALUATION OF EFFORT TO DATE

No major problem areas have been encountered in data storage and retrieval.

The LMIC has received technical guidance from the Division of Reactor Development and systems guidance from the Division of Technical Information of the U.S. Atomic Energy Commission. Information on liquid metals technology is being provided to a broad spectrum of potential users including national laboratories, other government agencies, R&D companies, and universities. Inquiries have been received at rates higher than anticipated and all indications are that the Center is performing a vital service and is fulfilling a definite mission in the Liquid Metal Fast Breeder Reactor (LMFBR) Program.

Revision of the Sodium-NaK Supplement incorporates into a single document the information on this field of liquid metals technology developed to date. During the dozen years which have elapsed since the first publication of this supplement, liquid metals technology has grown both in depth of exploration and in the size of equipment which has been developed. Coverage of the present supplement is considered adequate to perform feasibility studies and conceptual design, to size components and systems, to develop preliminary component and system descriptions, and to define basic constraints and parameters. Any finished design, however, will require more extensive research into the reference literature.

V. 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.

An extensive review of the initial draft of the updated Handbook Supplement will be performed during the next quarter. It is anticipated that incorporation of all applicable comments into the final draft will be completed by the end of calendar year 1967. Portions of the material now included in the chapter on Equipment and System Accessories will be utilized to form an additional chapter on Bearings and Seals, making a total of 20 chapters for the final draft.

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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 1967

AEC Category: 04-01-61-03

General Order: 7693

Subaccount: 13400

I. PROJECT OBJECTIVES

The objectives of this project are to: (1) complete contract negotiations for SPTF optimization studies and Titles I, II, and III work with C. F. Braun and Co.; (2) complete optimization studies; (3) provide surveillance for optimization study and Title I effort.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

The organization, conceptual engineering, cost estimate, and schedule for the SPTF by LMEC were completed on schedule. Proposals for the optimization studies and design work were received from seven Architect-Engineering (A-E) firms. These proposals were reviewed and evaluated. The Contractor Selection Board's recommendation for the winning A-E was mailed to AEC-CPAO on February 17, 1967. Approval of the Board's recommendation was received March 21, 1967 and C. F. Braun and Co. was notified that it had been selected.

III. PROGRESS DURING REPORT PERIOD

Agreement was reached between LMEC and Braun on the total estimated manhours and cost of A-E services for optimization studies and Titles I, II, and III. The contract for the optimization and Title I phases was signed on May 31, 1967. Optimization studies were scheduled to be completed by June 30, 1967; the Conceptual Systems Design Description by July 31, 1967; and Title I by October 15, 1967.

Braun prepared study task orders which define the objectives, schedule, information needs, relationship to other studies, and expected results for the following optimizations:

<u>Task No.</u>	<u>Task Area</u>
A	Sodium Loading System — New vs Existing System
B1	Main Circulating System Sodium Cooling — Method and Control
B2	Main Circulating System — Piping, Sizing, and Arrangement
B3	Flow Control — EM vs Valves
B4	Main Circulating System — Selection of Materials
B5	Main Circulating System Vortexing
B6	Materials Surveillance Station (MSS)
C	Sodium Purification and Sampling System
D	Sodium Cleaning and Disposal System
E	Fill and Drain System
F	Inert Gas and Vent System
G	Auxiliary Cooling System
H	Control and Instrumentation System
I1, 2, 3	Electrical System — Selection of Voltage and Switchgear
I4	Electrical System — Selection of Piping and Vessel Preheating Methods
J	Instrument Air and Plant Air System — Emergency Operation of Pneumatic Controls
K	Utilities — Requirements for Facility
L	Safety — General Considerations as Applied to Other Studies
M	Development of Site Information
N	Test Planning and Functional Analysis

SPTF design criteria were specified in the Overall Conceptual Systems Design Description (OCSDD), NAA-SR-MEMO-12160. During the progress of the optimization studies, some of these criteria were questioned where significant cost effectiveness advantage could be anticipated by reasonable relaxation of the criteria.

One of the criteria so considered was the temperature transient of $\pm 4^{\circ}\text{F}/\text{sec}$ for 170 sec. Calculations showed that for the thin-wall components under consideration, the peak thermal transient stress is generated after 100 sec from the beginning of the transient (see Figure 2 for 1-in.-thick wall); therefore, consideration was given to limiting the duration of the transient to the time required for peak thermal stress. Another calculation showed that the facility sodium inventory and tankage, governed by the same transient, could be cut in half if the

Figure 2. Transient Thermal Stress for 304 SS Pipe and Cylindrical Vessels

duration of the transient was held to 120 sec. The total temperature change of 480°F (4°F/sec for 120 sec) is also greater than all LMFBR primary or secondary loop ΔT 's now under consideration. The final transient design criteria will be established after completion of optimization studies and input from LMFBR study contractors. Other criteria being scrutinized are design temperature and pressure.

Four alternate conceptual arrangements of tanks, pumps, and piping were prepared by Braun. One of these was eliminated by a preliminary comparison and evaluation. The other three are shown in Figures 3, 4, and 5. Tank and pipe sizes are for 60,000-gpm flow in each loop, with full-flow transient capability as specified in the OCSDD. The sodium inventory is 93,000 gal in both Concepts 1 and 2, and 147,000 gal in Concept 4. In Concept 1, feed tanks are above grade and drain tanks below grade. In Concept 2, all tanks are below grade; in Concept 4, the feed/surge tanks are above grade and the dump tanks below grade.

Tank sizes and sodium inventories for the alternate concepts are based on flow mixing studies as determined by the specified thermal transients. Calculations were made to determine the sodium inventory for transients at various

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Figure 3. SPTF Conceptual System No. 1

Figure 4. SPTF Conceptual System No. 2

Figure 5. SPTF Conceptual System No. 4

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flow rates and time durations for ± 4 and $\pm 10^\circ\text{F}/\text{sec}$. The transient governing sodium inventory in each case is $4^\circ\text{F}/\text{sec}$ for 170 sec. Results of the calculations show that the required sodium inventory is reduced by one-half if the time duration of the transient is shortened from 170 to 120 sec. These conceptual arrangements were evaluated by LMEC. Concepts 1 and 2 appeared preferable over Concept 4. The choice between 1 and 2 will be made when sufficient detail about systems operability, flexibility, and cost is developed.

The problems related to material selection and main loop thermal transient capability were clarified. Based on preliminary calculations, Braun was predicting that single-wall 304 SS, 30-in.-diameter pipe could not be used for SPTF service; while with Incoloy-800, possibly 25 cycles of the $10^\circ\text{F}/\text{sec}$ transient could be imposed. (Thermal stress during the $10^\circ\text{F}/\text{sec}$ transient is more severe than during the $4^\circ\text{F}/\text{sec}$ transient.) This led Braun to favor Incoloy-800 over 304 SS. LMEC explained that the current fatigue life requirement was minimum 100 transients per loop and that if Braun's preliminary stress calculations were correct, a thermal barrier in the pipe would be required; if the thermal barrier was required with either 304 SS or Incoloy-800, 304 SS appeared to be the best choice of material since more data are available for it in sodium service. Calculations of fatigue life for single-wall, 30-in.-diameter, 304 SS pipe by LMEC indicated cycle life in excess of 1000. The difference between Braun's and LMEC predictions was found to be a result of Braun using the strength allowable for 304 SS at 1250°F of 3250 psi from the current issue of the piping code ASA B31.1 (to be revised this year), and LMEC using the value of 4350 psi from the Winter 1965 addenda to the Section VIII, 1965 Boiler and Pressure Vessel Code. Use of the Boiler and Pressure Vessel Code was suggested in LMEC's OCSDD. The higher strength allowable results in lower pipe wall thickness for which fatigue life is exponentially greater.

Calculations for elbows and sections with discontinuities and stress concentrations have shown that unlined elbows may provide the required fatigue life, but that discontinuities and stress concentrations may be critical. Special attention will be given to limiting these effects. Fatigue life will be drastically affected if LMFBR systems studies show that more severe thermal transients than currently considered are to be considered; the outcome might be that the entire main loop and feed/drain lines must be provided with a thermal barrier.

The potentially large difference in cost between piping systems with or without a thermal barrier points out the importance of realistically defining thermal transient conditions and SPTF transient capability.

Material tradeoff studies including cost, stress, and physical properties considerations were made by Braun. Potentially applicable design codes were evaluated. The list of candidate materials was narrowed to the 300 series steels and Incoloy-800. Fabrication methods, price information, and availability of large-diameter pipe and fittings made of 304 steel and Incoloy-800 were investigated.

Braun's preliminary optimization study report of the Main Circulating System - Materials Selection was submitted to LMEC for review. The report recommended two materials for further study. These were 304 stainless steel and Incoloy-800. LMEC comments suggested that discussion, tables, and graphs of mechanical properties, and metallurgical effects for the materials under consideration be included in the report; also that the selection of the material should be made in this phase of the work.

Various flow control methods such as different valve types, split loops, and EM brakes were investigated. Design requirements for large gate, butterfly, and globe valves were established. Inquiries to several valve manufacturers regarding these requirements were made. Fischer Valve Co. promised a response regarding the feasibility of butterfly valves for main loop flow control by June 1, 1967.

The preliminary study report of Sodium Flow Control was submitted to LMEC on June 29, 1967. Braun's recommendation, based on technical and economic factors with input from valve manufacturers, is to use butterfly valves. No additional R&D effort to develop these valves is suggested. Electric motor or electrohydraulic valve actuators are preferred over the pneumatic type. Two types of mechanical valves considered in this study are shown in Figures 6 and 7. LMEC review of this report is now in progress.

The following methods for removing pump heat from the sodium were investigated:

- 1) A full-flow sodium-to-air cooler
- 2) A sodium-to-sodium-to-air cooler

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Figure 6. 30-in. Class 5 Butterfly Valve With Limitorque Drive

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Figure 7. Y-Valve

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3) A bypass sodium cooler with two sodium-to-air coolers, one for high temperatures and one for low temperatures

4) Fins on the main loop piping.

The main problem with each method is high stress during temperature transient tests. The two most promising alternates are fins on the main loop piping and bypass sodium flow with high- and low-temperature coolers.

Braun's preliminary optimization study report of the Sodium Loading System was submitted to LMEC. It was recommended to use the sodium from the HNPF secondary drain tanks and the existing portable melt unit. LMEC comments were prepared and transmitted to Braun. More comprehensive documentation of the tradeoffs considered, including cost/schedule effectiveness, were suggested.

Heat loads for preheating of piping and components were calculated. Electrical preheating methods including resistance, induction, and direct series types were studied. Hot gas tracing or jacketing for piping preheat will also be considered.

Braun's preliminary optimization study report of the Sodium Cleaning and Disposal Systems was submitted to LMEC. The existing cleaning facility was determined to be inadequate. A new system with provisions for steam and alcohol cleaning capability was recommended. LMEC comments transmitted to Braun questioned the use of alcohol for cleaning large components and suggested cost tradeoffs as a basis for recommendation.

A safety criteria document was prepared by Braun for LMEC review. When finalized, this document will provide the safety standards for all design work and specifications of the SPTF. LMEC comments on SPTF Design Criteria were sent to Braun. Suggestions were made for definition of credible accidents, general safety criteria, and second-level design criteria to satisfy the safety criteria.

Optimization study reports of Main Cooling System, Determination of Building Height, Vortexing, and Equipment Handling were given to LMEC for review on June 29.

Visits to Westinghouse APD and ANL-Program Office by the SPTF Project Manager were made on June 8 and 9, 1967 to obtain pump information critical

to SPTF-pump interface. These visits were very useful in establishing information flow among the contractors and agencies with potential input to the SPTF effort. Subsequently, in a memo from the ANL LMFBR Program Office concerning the question of the number of pumps to be tested in the SPTF, an estimate of 16 pumps was made. Helpful preliminary data on size, weight, and types of pumps were also obtained from Byron Jackson.

A bar-type schedule for the Title I effort was submitted by Braun to LMEC on June 30, 1967.

IV. EVALUATION OF EFFORT TO DATE

All scheduled optimization study reports are planned by Braun to be submitted to LMEC by July 7, 1967. Some of these reports will be 3 to 4 weeks overdue based on the original schedule, because of the need to incorporate more detailed technical and cost documentation. Preliminary reviews of the reports submitted by Braun on the last two days of June indicate that again more detailed technical and cost information will be required with a possible further delay of up to 3 weeks for completion of optimization studies.

The Conceptual Systems Design Description is scheduled to be completed by July 31, 1967. Because of delays in the optimization studies, this document could be up to 3 weeks late.

The Title I schedule submitted to LMEC was inadequate because there was no manpower level indicated for the work tasks. After submission of an acceptable schedule, Title I work will proceed as planned.

It was pointed out in the other sections of this report that the thermal transient requirements have a significant effect on the facility design and cost. The work is proceeding based on the transients specified in the OCSDD and a minimum of 100 transients and 500 startups and shutdowns per loop. If more severe transients or a larger number than those specified are to be considered, this information must be made available to SPTF immediately.

V. NEXT REPORT PERIOD ACTIVITIES

The optimization studies will be completed, and the Conceptual Systems Design Description will be issued. Title I design effort will be continued.

Program:	Liquid Metal Engineering Center		
Project:	Sodium Pump Bearing and Seal Test Program		
Project Manager:	R. W. Dickinson	Project Engineer:	L. B. Copeland
Reporting Period:	April - June 1967	AEC Category:	04-01-61-03.1
General Order:	7693, 7694	Subaccount:	14100

I. PROJECT OBJECTIVE

The project objective is to determine, by study and experiment, the suitability of candidate bearings and seals for the large sodium pumps being designed as a part of the LMFBFR program of the USAEC. From evaluation of test data and performance characteristics to be obtained, suitability will be determined in relation to reliability, life, efficiency, and maintenance requirements.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

Program plans were prepared and submitted for AEC-RDT review. The Overall Conceptual System Design Description (OCSDD) for the Seal Test Facility was prepared and submitted to and reviewed by AEC-RDT. Design of the seal test rig was finalized and fabrication was begun.

III. PROGRESS DURING REPORT PERIOD

Design of the seal test rig (see Figure 8) was completed and detail design of components was nearly completed. All engineering analyses and studies were completed and reporting documents issued. An interface control drawing was prepared showing the maximum envelope dimensions for a seal that the test rig can accommodate, and giving dimensional data for adaptation of a test seal to the rig. A draft of a specification for assembly and adjustment of the seal test rig was prepared and a review was initiated. Design of modifications required to convert a stand obtained from salvage to an assembly and calibration stand for the seal test assembly was performed. Requested funding authorization for installation of a substation to supply seal test facility power was received and design was started.

Sodium vessel procurement was ordered and partial delivery made in June. Resolution of a problem in obtaining test vessel acceptance to Section VIII of the ASME Boiler and Pressure Vessel Code caused some delay. Due to thermal gradient stress imposed by test design requirements, the vendor's calculations were unacceptable to the state inspector. By agreement with the inspector, a thermal stress analysis was made of the affected zone of the vessel per Code Section III. This analysis was accepted by the inspector as a basis for meeting Section VIII code stamp requirements.

Delay was also encountered in procurement of bearing spindle assemblies for the seal test rigs. First, a no-bid response "because of . . . specifications, terms and conditions" was received; and second, an excessively long delivery period was quoted for spindles alone. Consequently, design of a replacement spindle was undertaken and resulted in a superior design that can be obtained in an adequately shorter period of time. Superiority was attained mainly by eliminating a secondary support housing and by making the seal-shaft adaptor-flange integral with the spindle shaft. Machining is reduced and simplified, strength and stiffness are increased, and obtaining and maintaining balance are improved. Discarding of the catalog spindle design was also influenced by a delivery quotation for spare bearings of 40 to 42 weeks. A design layout was reviewed and approved, and detail design was started. Bearings were selected, ordered (including spares), and have been received.

Procurement action for seal test rig hardware was continued and fabrication was started; 80% completion is estimated. Procurement of sodium and electrical instrumentation and controls was started and is estimated as 70% complete. Procurement of seal service supply instrumentation and controls has not been started, since information required for design finalization has not yet been obtained from the pump study contractor.

A number of items for the seal test rig were obtained from surplus and modification and rework were started. Two test stands were modified, sodium containment (drip) pans were fabricated, and modification of the assembly and calibration stand was started. Overhaul of one motor-generator set has been ordered. A request for equipment from the SRE was approved and the majority of the items received (two 50-hp dc motors, two tachometer generators, weld fittings, finned tubing, and valves). Nearly all thermal insulation and piping

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Figure 8. Na Pump Shaft Seal
Test Assembly
NAA-SR-12520

were ordered and received; pipe spooling was started. Valves were obtained, machining for modification to sodium service was completed, and welding was ordered. A sodium level gauge and probes were ordered and received. Fabrication of two primary sodium vapor traps was nearly completed. Fabrication of the sodium fill line filter assembly was started. Instruments obtained from surplus have been calibrated or are awaiting range change kits that were ordered.

A third draft of a Quality and Reliability Assurance Plan for fabrication and assembly of the seal test rig was received for review. Sample forms for recording inspection data and information and a cost estimate were also received. In the interim, quality control is being performed on an item-by-item basis.

An inquiry and request for quotation was made of possible suppliers of equipment to measure shaft journal-to-bearing radial clearance during bearing tests in 1200°F sodium. None of 31 responders could supply equipment for such service. Two corporations have recommended programs in the belief that it is possible to develop an adequate system. Other means of determining bearing performance are being considered, e. g., utilizing developed equipment with proven lower temperature capability (932°F) and extrapolating data.

Letters requesting information regarding bearings and seals from the pump study contractors were sent to AEC-NYOO and AEC-SAN. Information requested included: (1) design status, (2) design criteria and performance requirements, (3) test requirements, (4) estimated cost and procurement time for test items, and (5) schedule. Enclosures of the seal-test design layout, the P&I diagram (for a barrier-gas-type seal), and the seal-to-rig interface control drawing were included for review and comment by the contractors. A meeting was subsequently held with one contractor and, on the basis of their evaluation and the meeting discussion, the belief was expressed that the test rig design is satisfactory. No response has yet been received from the other contractor.

Comments were received from AEC-RDT regarding the OCSDD for the Seal Test Facility that had been prepared on the basis of initial information received from one study contractor. Approval was waived in favor of resolving and incorporating comments into the Preliminary System Design Description (PSDD). Evaluation and resolution of the comments and preparation of the PSDD were started. However, because of the comments and of the required content of a PSDD, completion of some sections is necessarily held in abeyance until additional information is obtained from the study contractors.

IV. EVALUATION OF EFFORT TO DATE

Preparation of the seal test rig will be completed well ahead of the receipt of test seals. It appears probably that seal service instrumentation and controls can be selected and obtained during the period in which seals are being procured. Procurement of test bearings and seals from the pump design study contractors, however, is not meeting the originally anticipated schedule of the test program. Furthermore, it is not known when procurement, or even detail design, will be initiated. A possible approach to timely procurement is to select designs that presuppose the approved Phase II designs and to negotiate separate contracts for detail design and fabrication. While there is no guarantee that finally selected and approved designs would be the same, it is highly probable that selections based upon results of current Phase I analyses being performed by the contractors would be correct.

Preparation of System Design Descriptions is also behind schedule because of the lack of detail information from the study contractors. Until this information is obtained, neither the PSDD for the Seal Test Facility nor the CSDD for the Bearing Test Facility can be completed. Although it appears that resolution may be close at hand, a schedule for SDD preparation cannot be estimated until the point in time for receiving the required information is ascertained.

V. NEXT REPORT PERIOD ACTIVITIES

Detail design of the seal test rig and component procurement will be completed and assembly continued. If required information is obtained as anticipated, seal service instrumentation and controls will be selected and procurement initiated. Also, finalization of the Seal Test Facility PSDD and the bearing test OCSDD should be started. Preparation of seal test plans, specifications, and procedures will be begun. Establishment of Bearing Test Facility design requirements will be pursued. Efforts will be made to obtain detail designs of bearings and seals from the study contractors.

Program:	Liquid Metal Engineering Center		
Project:	Precision Mechanisms in Sodium		
Project Manager:	R. W. Dickinson	Project Engineer:	W. J. Freede
Reporting Period:	April - June 1967	AEC Category:	04-01-61-03.1
General Order:	7693, 7694	Subaccount:	24100

I. PROJECT OBJECTIVES

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

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

A. TEST APPARATUS AND PROCEDURES

A first draft of a topical report, NAA-SR-12446, entitled "Self-Welding and Wear Behavior of Materials in Sodium Environments at Elevated Temperatures," was prepared which contains a description of apparatus and procedures employed for the tests concerned.

B. PROGRAM RESULTS

A proof draft of the literature/experience survey was issued for AEC review. This topical report, NAA-SR-12448, is entitled "Literature and Experience Survey Concerning Mechanical Elements in Alkali Metal Environments."

Static contact tests were completed to determine self-welding characteristics of 49 candidate material combinations in 1200°F sodium vapor and circulating, liquid, cold-trapped and hot-trapped sodium. Similar tests were initiated on 54 additional material combinations.

Experiments were conducted using sliding friction and wear test fixtures to determine coefficients of friction and wear behavior in 800 to 1200°F liquid and

vapor sodium. Information pertaining to 75 material combinations was obtained; each test involved a 200-hr run.

III. PROGRESS DURING REPORT PERIOD

Drafts of topical reports NAA-SR-12446 and -12448 were prepared for review and publishing. These were described in the previous sections.

New static contact tests in 1200°F sodium environments were initiated; involved were 54 material combinations, none of which were included in the prior test series involving 49 combinations. The first test was in cold-trapped liquid sodium with 20- to 30-ppm O₂ content; starting friction coefficient readings were obtained at ambient temperature in argon and at 1200°F in cold-trapped liquid sodium.

Sliding friction and wear tests in cold-trapped liquid sodium were completed for series L, 53, M, 57, N, 61, O, 65, P, 69, Q, 73, R, and 77 experiments. Average travel velocity was 3.33 cm/sec, rubbing pressure was 8.65 kg/cm³, and each test run was for 200 hr. Data obtained are tabulated in Table 1.

The dimension of cm³/cm-kg indicates cubic centimeter of pin material worn off per centimeter of travel, per kilogram of pressure on the test rubbing surfaces. As such, it is a recognized standard means for expressing the phenomenon of wear. Thus, in examining the data, it is noted that 17-4 PH wore excessively against Hastelloy-C. On the other hand, TZM had a low degree of wear against Hastelloy-C. Where "material buildup" is indicated, the length of rubbed pins increased instead of decreased, apparently due to welding of contact asperities.

Settlement of the labor strike at the Stellite Division of Union Carbide resulted in shipment of several key candidate test materials. These items were fabricated into specimens for future static contact and sliding friction and wear tests.

In accordance with instructions relayed through AEC-CPAO, experimental activities pertaining to this program were limited to continuance of tests in progress at the beginning of the prior quarter. Before these orders were established, procurement arrangements had been made for various bearing and gear test specimens. A number of these items were received and were placed in storage pending future guidance.

TABLE 1
DATA FROM SLIDING FRICTION AND WEAR TESTS IN LIQUID,
COLD-TRAPPED (20 to 30 ppm O₂) SODIUM

Test Number	Materials		Temperature (°F)	Beginning Coefficient of Sliding Resistance	Specific Wear on Pins (Average) (cm ³ /cm-kG)
	Pin	Plate			
L-1	Stellite-3	Stellite-6B	1200	0.35	5.73 x 10 ⁻¹¹
L-2	TZM	Hastelloy-C	1200	0.32	2.98 x 10 ⁻¹¹
L-3	17-4 PH	Hastelloy-C	1200	0.32	401.0 x 10 ⁻¹¹
53	Colmonoy-4 (HF)*	Colmonoy-75 (HF)	1200	0.71	80.5 x 10 ⁻¹¹
M-1	Stellite-1 (HF)	K-95 (WC)	1200	0.53	19.8 x 10 ⁻¹¹
M-2	Stellite-6H (HF)	K-95 (WC)	1200	0.53	34.0 x 10 ⁻¹¹
M-3	Stellite-273 (HF)	Stellite-6B	1200	0.34	14.0 x 10 ⁻¹¹
57	Stellite-273 (HF)	Stellite-1 (HF)	1200	0.33	6.79 x 10 ⁻¹¹
N-1	Stellite-6H (HF)	Stellite-6H (HF)	1200	0.46	9.74 x 10 ⁻¹¹
N-2	Stellite-273 (HF)	Stellite-273 (HF)	1200	0.40	32.5 x 10 ⁻¹¹
N-3	Inconel-718	Inconel-718	1200	0.32	7.95 x 10 ⁻¹¹
61	Colmonoy-6 (HF)	Colmonoy-75 (HF)	1200	0.41	39.2 x 10 ⁻¹¹
O-1	Stellite-1 (HF)	Stellite-6B	1200	0.39	5.73 x 10 ⁻¹¹
O-2	Inconel-718	Hastelloy-C	1200	0.31	25.25 x 10 ⁻¹¹
O-3	Hastelloy-C	Inconel-718	1200	0.28	18.56 x 10 ⁻¹¹
65	Stellite-273 (HF)	Hastelloy-C	1200	0.38	Material buildup
P-1	Inconel-718	K-95 (WC)	1200	Test incomplete; mechanical difficulties	
P-2	Stellite-1016 (HF)	K-95 (WC)	1200	Test incomplete; mechanical difficulties	
P-3	Colmonoy-4 (HF)	Stellite-6B	1200	0.33	125.6 x 10 ⁻¹¹
69	WB-49	WB-49	1000	0.31	14.0 x 10 ⁻¹¹
Q-1	Inconel-718	K-95 (WC)	1200	0.85	2.75 x 10 ⁻¹¹
Q-2	Stellite-1016 (HF)	K-95 (WC)	1200	0.62	6.55 x 10 ⁻¹¹
Q-3	Inconel-718	Stellite-6B	1200	0.21	3.87 x 10 ⁻¹¹
73	WB-49	WB-49	1000	0.34	21.25 x 10 ⁻¹¹
R-1	Molybdenum	Inconel-718	1200	0.99	Material buildup
R-2	Hastelloy-C	Stellite-6H (HF)	1200	0.39	116.1 x 10 ⁻¹¹
R-3	Colmonoy-5 (HF)	Colmonoy-75 (HF)	1200	0.31	108 x 10 ⁻¹¹ (minimum)
77	TZM	WB-49	1000	0.26	6.37 x 10 ⁻¹¹

*HF indicates hard facing material

IV. EVALUATION OF EFFORT TO DATE

Preliminary evaluation of self-welding and sliding friction and wear tests in 1200°F cold-trapped liquid sodium indicated qualified acceptable static contact and motion contact surface properties at test pressures and velocities used for a number of candidate material combinations. AISI-T1, T15, M1, M2, M3, and M43 tool steels, which exhibited good sliding friction and wear characteristics during short-term (10-hr) tests in 932°F liquid sodium (cold-trapped) conducted by other laboratories, showed excessive wear and galling when they became hot short in 1200°F liquid cold-trapped sodium. Sliding 200-hr tests conducted on the latter materials in 800°F cold-trapped liquid and vapor sodium indicated excellent wear resistance. Titanium carbide was subject to rapid oxidation attack in 1200°F cold-trapped liquid sodium, and was rendered unsuitable for any use in this environment.

Although wear rates on the best material combinations tested were much larger in 1200°F sodium environments than would be permissible for normal ambient commercial applications, galling or seizing was indicated as a greater potential problem. Limiting parameters affecting the latter remain to be investigated.

V. NEXT REPORT PERIOD ACTIVITIES

Thirty- and sixty-day static contact (self-welding) tests on the second set (54 combinations) of candidate material combinations will be completed in 1200°F cold-trapped (20- to 30-ppm O₂ content) liquid sodium environments.

Sliding contact tests in 800 to 1200°F cold-trapped liquid sodium will be continued. Similar tests in sodium vapor and hot-trapped liquid sodium will be initiated on the better material combinations as determined from tests in cold-trapped liquid sodium. Exploratory tests will be conducted to determine parameters which are critical in buildup of material on certain specimen contact surfaces.

The literature/experience survey topical report, NAA-SR-12448, pertaining to mechanisms in sodium, will be revised to reflect future AEC recommendations. The topical report on "Self-Welding and Wear Behavior of Materials in Sodium

Environments at Elevated Temperatures," NAA-SR-12446, will be printed and distributed.

Test plans will be written for testing of mechanical elements in liquid and vapor sodium environments; these will be forwarded to the AEC for approval. After AEC permission is granted, testing of mechanical elements such as gears, bearings, and gripper surfaces will begin immediately.

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Figure 9. Bellows Linear Seal Test Apparatus

NAA-SR-12520

Program:	Liquid Metal Engineering Center		
Project:	Mechanisms in Sodium		
Project Manager:	R. W. Dickinson	Project Engineer:	W. J. Freede
Reporting Period:	April - June 1967	AEC Category:	04-01-61-03.1
General Order:	7693, 7694	Subaccount:	27110

I. PROJECT OBJECTIVES

The objectives of this project are as follows:

- 1) Evaluate the use of wafer-type welded diaphragm bellows as linear seals for exclusion of contaminants from the cover gas above a sodium vessel.
- 2) Determine the reliability of a rack-and-pinion type of gear train, fabricated from Hastelloy-C, for operation as a linear actuator in liquid sodium at elevated temperatures.
- 3) Develop information concerning deposition of sodium vapor on stainless-steel surfaces at varying temperatures and oxygen contamination levels. Determine characteristics of these deposits which must be considered when designing mechanisms required to function in sodium vapor environments.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

A. TEST APPARATUS DESCRIPTIONS AND PROCEDURES

1. Bellows Linear Seal Test

Test bellows were mounted on a support housing which penetrated 12 in. into the test vessel (see Figure 9). The actuating shafts were guided above the vessel by a chevron-type seal and within the vessel by a plug guide fixed to the shaft which rode within the support housing. The test bellows served to seal the support housing, with the chevron seal acting as a backup seal in the event of a bellows failure. The shafts which cycled the bellows were driven by a gear rack assembly positioned above the vessel. Two shafts were driven simultaneously in opposite directions. Cycling was controlled by limit microswitches at the upper

end of the stroke for each drive rack. The microswitches activated thermal delay circuits which reversed the direction of drive.

Argon was provided as cover gas both within the support housing and test vessel. A constant bleed was maintained within the vessel of 1 to 2 ft³/hr. The pressure differential across the bellows was monitored by a water manometer backed up by a vapor trap. Bellows failure was sensed by an equalization of the pressures.

The test bellows were designed for a stroke of 5 in., 1 in. greater than the 4-in. test stroke, and a pressure differential of 1 psi (0.5 psi was used as test pressure). The design life was specified at 10,000 cycles and 20 yr of exposure at 1000°F in sodium vapor. The OD of the bellows was 1-3/4 in. with an ID minimum of 1/2 in. The material as specified was 347 CRS.

The test sequence to provide data on the performance of bellows as linear seals in 900°F sodium vapor was as follows:

- 1) Quality assurance test performed at ambient temperature for approximately 1500 cycles at the test stroke and cyclic rate of 4 in. and 1.1 cycles/min
- 2) High-temperature integrity test at 900°F conducted in an inert atmosphere for approximately 1500 cycles at the test stroke and cyclic rate
- 3) High-temperature performance test at 900°F performed in sodium vapor above a 1200°F sodium pool for a minimum of 27,000 cycles at the test stroke and cyclic rate
- 4) High-temperature intermittent performance test at 900°F completed in sodium vapor for a minimum of 1000 cycles at the design stroke. The cyclic rate was modified to include a 1-hr dwell period between each half cycle at the test cyclic rate of 1.1 cycles/min. This latter part of the test program was intended to approximate in-service reactor conditions where dwell periods exist.

2. Stroke Multiplier Test

The test article was a stroke multiplication gear system fabricated of Hastelloy-C with an output-to-input ratio of 4 to 1. The system utilized floating pinions rather than fixed pinions, eliminating the need for shafts and associated bearings. In the floating pinion system, a neutral or fixed rack acted to balance

the force system. The floating pinion gear train was better adapted to a sodium environment due to the degree of clearance variation possible without loss of movement sensitivity or control characteristics. Nominal wear of the gear teeth would not hinder operation or sensitivity.

The test unit was positioned within a sodium vessel suspended by a cylindrical housing (see Figure 10). The central drive rod actuated the four input racks through an adapter plate and mounting cage. The four input racks drove the smallest of the three gear surfaces (16 teeth). There were two pinion units on each side of the output rack. The central and largest of the three gear surfaces (32 teeth) positioned the output rack from both sides, which were restrained by the two fixed racks mounted on the support housing. At any instant, the center of rotation was at the fixed rack. The input axis was 0.4 in. from the center of rotation and the output axis was 1.6 in. from the center of rotation, providing the 4-to-1 amplification of motion, output-to-input.

Sodium was excluded from the upper housing region and drive rod by use of a wafer diaphragm bellows. Input motion was provided by a chain driven load bar, limited by microswitches at the upper and lower extreme of the stroke. Thermal time-delay circuitry acted to reverse the direction of travel at the extreme of each stroke.

Gear system clearances or backlash were determined during testing by making use of an elevating support platform. The platform was raised and lowered to predetermined positions of the output rack weight, allowing the weight to come to rest, unloading the system. The distance traveled from zero to full load provided the backlash. Loads were monitored by a full-bridge load cell positioned above the drive rod upper seal.

The schedule of minimum testing to provide data qualifying the described floating pinion stroke multiplication mechanism for service in 1200°F sodium was as follows:

- 1) Reference test at ambient temperature was conducted for approximately 100 cycles at the test stroke length and linear travel rate of 3 in. and 3 in./min, respectively. The initial load was established as 30 lb, one-half of the design load.

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Figure 10. Stroke Multiplier Test Apparatus
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Figure 10. Stroke Multiplier Test Apparatus
(Sheet 2 of 2)

2) Elevated temperature break-in tests were made at 800°F, then 1000°F for 100 cycles at the test stroke length and linear travel rate, with a 30-lb load. During this break-in period, backlash readings were recorded to monitor rack distortions.

3) Half-load operation tests were performed in 1200°F sodium for 10,000 cycles at the test stroke length and linear travel rate, with a 30-lb load.

4) Stroke length transition tests were conducted for a minimum of 1000 cycles at one-half the stroke length before making a transition to the normal stroke length. Effects of the transition point on movement patterns were recorded. This procedure was repeated three times.

5) Full-load operation tests were completed in 1200°F sodium for 10,000 cycles at the test stroke length, with a linear travel of 6 in. /min and a 60-lb load.

During all test phases, friction and backlash readings were taken when test conditions changed and as previously noted. These procedures were established to serve as minimum criteria for qualification of the mechanism.

3. Vapor Deposition Study

Test fixtures were as detailed in Figure 11. The inner shaft plug assembly, supported by a double O-ring seal at the upper end of the housing, provided one of the deposition surfaces. The raised area of the split housing provided the mating surface, leaving an annulus of 0.010 in. in which the deposition characteristics were studied. The test deposition surfaces were located at varying depths of penetration into each of two vessels, six per vessel. The temperature of the test deposition surfaces varied with the natural temperature gradient in each vessel. Baffle plates stabilized this gradient, providing a range between 900 and 250°F. Argon cover gas, premixed to a particular oxygen contamination level, was continually bled into each vessel through the hollow shaft on each test fixture, exhausting above the test area through ports in the housing. The convective flow which resulted carried the cover gas and vessel vapors up the annulus, providing the conditions for deposition in the annulus as well as along the housing itself. The reduced volume of the test section theoretically would fill before clogging or binding in the upper housing would occur.

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Figure 11. Sodium Vapor Deposition Test Fixture

Torque readings were taken of the plug shaft periodically during a test to record the deposition temperature shear strength of the deposit which was forming. A room temperature torque reading was also taken at conclusion of each test.

This test program pertained to investigation of sodium vapor deposition, nucleation, and examination of these precipitates under controlled conditions. Fixed conditions were: (1) sodium pool temperature at 1200°F, (2) configuration of test fixtures, and (3) the use of argon as cover gas. The natural convective flow of gas around and through each test fixture annulus, affecting deposition temperatures, was dependent on deposit formation. Controlled variables were vessel pressure, volume of cover gas introduced into each vessel per unit time, and the oxygen contamination level of the argon cover gas.

Testing was initiated under the following system conditions:

- 1) Sodium temperature was established at 1200°F with the surface level of the pool approximately 6 in. below the longest test fixture.
- 2) Flow of cover gas input to the vessel was stabilized with a premixed oxygen contamination level (100, 1000, and 10,000 ppm, depending on the test involved).
- 3) Vessel cover gas pressure was placed in steady state at the desired level.

The conditions were held for a period of 250 hr during which period torque readings were taken on each test article shaft every 25 hr. Fixture temperatures were dropped to room temperature for final torque readings. Test specimen temperatures were taken with torque readings. Flow meter readings were checked daily to monitor venting conditions.

After completion of a period of exposure, test fixtures were removed directly into a glove box positioned above these components (see Figure 12). Depositions were photographed and shear areas were determined by optical means as observed through the glove box window. Samples of deposits were removed and forwarded for analysis. X-ray diffraction techniques identified elements and compounds present, and the mercury amalgamation technique was used to provide the quantity of equivalent oxide present in each deposit (hydrides and carbonates were titrated as equivalent oxide).

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Figure 12. Sodium Vapor Deposition Test System Showing Test Vessels and Glove Box

NAA-SR-12520

B. PROGRAM RESULTS

1. Bellows Seal Test

Tests were completed on four 347 CRS bellows, two each supplied by different manufacturers. The first pair of bellows, referred to as bellows "A" and fabricated by the Belfab Company, were subjected to 30,000 continuous cycles in 900°F sodium vapor without failure. Bellows "A" were removed and cleaned after this test. Bellows "B," fabricated by the Belmetric Company, were subjected to continuous cycling in 900°F sodium vapor; both bellows failed between 1200 and 1300 cycles. The "A" bellows were reinstalled for the intermittent cycling test in 900°F sodium vapor. One of these bellows failed after 493 additional cycles. The remaining "A" bellows was removed with the failed bellows for a prefailure metallographic examination.

Sections from each of the bellows were mounted, polished, and electrolytically etched using an oxalic acid solution for photomicrographic examination. Similar sections were prepared for electron probe examination of a reaction layer on the surface of Bellows "A." Calculations were also made to approximate the operating stresses for the bellows under extension. Bellows "A," with a total of 50 convolutions, were operated at approximately 65% of the elastic limit and Bellows "B," with a total of 70 convolutions, were operated at approximately 46% of the elastic limit. All bellows failures occurred at inner diameter welds. Bellows "B" failed after 20 hr at temperature in sodium vapor even though operating stresses were below that of Bellows "A," which went a total of 1450 hr at temperature in sodium vapor. The early failure of Bellows "B" was attributable to sensitization occurring prior to testing. Figure 13 shows the degree of material deterioration present at the time of failure. Numerous cracks were formed and were propagated through the material, providing numerous failure zones. Bellows "A" represented a typical stress fatigue failure. The single failure zone (see Figure 13) shows the crack propagating through the heat-affected zone of the inner weld also in an area of stress concentration.

2. Stroke Multiplier Test

The final full-load operation phase of the test program was completed with a total of 100,000 cycles at 1200°F in sodium which included all phases. Distortions during heatup were insignificant (see Figure 14). Reference and break-in tests indicated no change in the frictional load range contributed by the gear

BELLOWS "A"

BELLOWS "B"

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Figure 13. Photomicrographs of Failure Zone
in Inner Welds of Bellows

Figure 14. Backlash Profile - Stroke Multiplier Test

teeth. System clearances (backlash) initially dropped as a result of thermal expansions. The half-load (30-lb) operational test was extended for a total of 37,000 cycles during which three stroke length transitional tests were conducted, totalling 41,000 cycles. A measurable increase in backlash occurred during the half-load test (see Figure 15). The wear rate during this period was approximately 5.5×10^{-7} in./cycle which can be stated as an equivalent individual tooth contact during any one cycle. Due to the complexity of the gear system, many teeth were in contact at any one instant. Each contact was subjected to varying static loads, so that it was difficult to state a specific wear rate per tooth contact. Any one position on the racks at which a backlash reading was taken would be contacted two times during a cycle gear tooth contact, reflecting backlash at this position, which could occur as many as five times at varying loads. An overall and general specific wear rate was indicated as 1.1×10^{-7} in. per average contact. Beyond ~40,000 cycles, the wear rate dropped essentially to zero even though this period reflected an increase in load to 60 lb and an increase in drive speed from 3 to 6 in./min input.

System loads as indicated in Figure 16 included the drive shaft seal, guide friction bellows spring load, and the gear train friction. During any one cycle, all but the gear train loads remained smooth. However, superimposed on this base load pattern were the gear system tooth loads reflected by the irregular pattern in Figure 16, Regions A and B. Figure 17 summarizes the gear train frictional loads and the steady-state load represented by gear train loads. The latter plot represented an approximate system efficiency. This efficiency averaged 86% during a major portion of the test program.

3. Vapor Deposition Study

Six tests were completed, each conducted for a period of 250 hr at operating conditions. The first three tests were conducted using commercial grade argon (approximately 10 ppm oxygen) as the cover gas. Maintained with this gas was a bleed rate of approximately $0.5 \text{ ft}^3/\text{hr}$. Modifications made to the test fixtures after each of the first three shakedown tests provided a configuration which would receive a deposit on all test sections. Tests 4 through 6 were conducted with a cover gas of argon containing approximately 100 ppm oxygen. Deposition which occurred below approximately 500°F (see Figures 18 and 19) did not wet the surface as was the case in the hotter regions to 900°F (see Figures 20 and 21).

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Figure 15. System Backlash - Stroke Multiplier Test
(Sheet 1 of 2)

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Figure 15. System Backlash – Stroke Multiplier Test
(Sheet 2 of 2)

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Figure 16. Load Components – Stroke Multiplier Test System

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Figure 17. Gear System Loads – Stroke Multiplier Test

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Figure 18. Bulk Type Nonwetting Deposit on Housing (Specimen 4)

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Figure 19. Bulk Type Nonwetting Deposit on Plug (Specimen 5)

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Figure 20. Film Type Wetting Deposit on Specimen 1

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Figure 21. Film Type Wetting Deposit on Specimen 2

This limited the shear strength data available from deposits in colder regions of the test vessel. A more massive crystalline-like deposit was observed in the colder regions as indicated by Figures 18 and 19. The bond between the deposit and the surface was superficial as shown by the manner in which the housing could be peeled from the plug, leaving a clean surface (see Figures 22 and 23). The strength of the deposit itself was high and would clog or bind a mechanism even though it did not wet the surface of the mechanism.

Shear strengths of deposits at temperature were clouded by the system frictional levels. Shear data presented (see Table 2) was measured at room temperature (approximately 90°F). Shear stresses ranging between 70 and 125 were reported, based on areas of surface contact observed as the test article was removed from the vessel within the glove box. Other values were indicated as approximate figures, as there was uncertainty regarding the area of shear. Even though both plug and housing were wetted, it was difficult to ascertain a precise shear area.

III. PROGRESS DURING REPORT PERIOD

Metallographic examinations of the failed bellows following the bellows seal tests were initiated; preliminary observations were made and reported.

The stroke multiplier test program was completed and results reported. Final dimension checking of the gears was initiated.

Six series of tests for the vapor deposition study were completed and results of the shear strength determinations were reported. Oxide content analysis of the deposits was initiated.

IV. EVALUATION OF EFFORT TO DATE

A. BELLOWS SEAL TEST

From the data available, it was concluded that various differences in manufacturing techniques produced a substantial difference in bellows service life. The Belmetrics Company bellows were received in a highly sensitized condition which resulted in numerous areas of crack propagation. Stress levels played an insignificant part in the failure mode. Conclusions regarding the effects of

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Figure 22. Clean Surface on Specimen 6 Plug Left by Nonwetting Deposit

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Figure 23. Mating Specimen 6 Housing Showing the Nonwetting Deposit

TABLE 2
SHEAR DATA FROM VAPOR DEPOSITION TESTS

Specimen Number	V ₁ S ₁	V ₁ S ₂	V ₁ S ₃	V ₁ S ₄	V ₁ S ₅	V ₁ S ₆	V ₂ S ₁	V ₂ S ₂	V ₂ S ₃	V ₂ S ₄	V ₂ S ₅	V ₂ S ₆
Test 4 10 ppm Oxygen												
Pressure - 1 in. H ₂ O												
Flow Rate - 0.42-0.53 ft ³ /hr												
Temperature Range (°F)	845	750	652	550	473	387	785	697	620	510	440	372
	800	705	610	507	420	338	760	680	580	500	433	352
Torque Variation at Temperature (in. -lb)	+2.3	+4.5	+3.9	+1.7	+1.2	+3.0	+1.4	+2.4	+0.5	+2.9	+1.8	+2.2
Torque at Room Temperature (in. -lb)	130	120	110	27	12	30	120	100	70	9	16	14
Shear Area (in. ²)	3.14	3.14	2.75	*	*	0	3.14	2.86	*	*	*	*
Shear Stress at Room Temperature (lb/in. ²)	83	76	80	*	*	0	77	70	*	*	*	*
Test 5 100 ppm Oxygen												
Pressure - 1 in. H ₂ O												
Flow Rate - 0.42-0.53 ft ³ /hr												
Temperature Range (°F)	890	800	722	600	465	353	810	695	625	452	355	337
	875	762	645	490	370	245	785	650	543	430	337	310
Torque Variation at Temperature (in. -lb)	+2.9	-6.5	+2.4	+2.4	+0.9	+1.8	+1.8	+2.3	+0.3	+1.7	+2.8	+2.2
Torque at Room Temperature (lb/in.)	145	150+	150+	150+	40	35	150+	150+	40	14	11	20
Shear Area (in. ²)	3.14	3.14	3.14	3.0	0.8	1.1	3.14	3.14	*	*	*	*
Shear Stress at Room Temperature (lb/in. ²)	92	96	96	100	110	85	96	96	*	*	*	*
Test 6 100 ppm Oxygen												
Pressure - 1 in. H ₂ O												
Flow Rate - 0.42-0.53 ft ³ /hr												
Temperature Range (°F)	870	806	715	592	430	370	820	737	698	480	466	372
	842	730	625	475	365	242	795	682	455	440	347	245
Torque Variation at Temperature (in. -lb)	+0.1	-2.0	+6.0	0	+0.1	+0.1	-0.3	+0.3	-0.3	+0.2	+4.0	+3.5
Torque at Room Temperature (in. -lb)	140	150	150	150	8	9	165	180	145	12	41	15
Shear Area (in. ²)	3.1	3.1	2.6	2.6	-	-	3.1	3.1	2.4	-	1.0	-
Shear Stress at Room Temperature (lb/in. ²)	90	97	115	115	-	-	106	116	121	-	82	-

*Deposit present but shear area uncertain or non-wetting deposit

900°F sodium vapor on the service life of Bellows "B" could not be formed. Bellows "A," manufactured by the Belfab Company, failed in a typical stress fatigue fashion, and represented a higher quality bellows. Higher stress levels under a tensile mode caused the latter to fail. This indicated that deposition of vapor at 900°F in wafer convolutions had minimal effect on the initiation of a failure. Little or no surface attack was found.

B. STROKE MULTIPLIER TEST

Testing performed indicated that the model Hastelloy-C floating pinion stroke multiplication system was reliable for service in 1200°F sodium. Wear rate dropped off after an apparent break-in period. Frictional levels within the gear train were low, contributing to an overall average unit efficiency above 85%.

C. VAPOR DEPOSITION STUDY

Testing completed to date offered preliminary values for deposit strength and the effects of deposition surface temperature on precipitation rates. Shear strength of the deposit at deposition temperatures (240 to 900°F) was low enough to be concealed by system friction levels (less than 15 in. -lb of torque).

The film-like deposit exhibited in Figures 20 and 21 provided a good shear test as it wetted both the plug and the housing. Data from these specimens was reported (see Table 2) as deposit shear strength. The massive nonwetting deposit exhibited in Figures 18 and 19 provided no usable data other than oxide content and qualitative surface interaction observations.

V. NEXT REPORT PERIOD ACTIVITIES

A final report on the bellows seal test will be prepared. A final report will also be prepared on the stroke multiplier test.

Testing for the vapor deposition study will be continued with argon cover gas oxygen contamination levels of 100, 1000, and eventually 10,000 ppm. A minimum of three tests will be conducted under each contamination condition; additional tests will be performed as required by the quality of data obtained.

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Program:	Liquid Metal Engineering Center		
Project:	Installation of B & W Steam Generator		
Project Manager:	R. W. Dickinson	Project Engineer:	R. L. Rehorst
Reporting Period:	April - June 1967	AEC Category:	04-01-61-03
General Order:	7693	Subaccount:	41310

I. PROJECT OBJECTIVES

The objective of this project is to install the B & W steam generator in the SCTI in preparation for testing.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

The Preliminary System Description for the installation of the B & W steam generator in the SCTI was completed. One technical review meeting was held between Atomics International and Babcock and Wilcox.

III. PROGRESS DURING REPORT PERIOD

Final design of the B & W installation, approval for which was received in March, proceeded at a satisfactory level. The design effort to date has been concentrated in the areas of equipment layout, sodium piping, and instrumentation. The final design of the steam and feedwater systems modifications has been delayed pending receipt of the Bechtel redesign of the existing systems. It is now anticipated that this latter work will begin in mid-July, 1967.

A piping and equipment layout drawing showing the arrangement of the steam generator, fill tanks, relief tank, and sodium piping in the SCTI steam generator pit, has been completed. Review and approval of this drawing was accomplished in June. Work to update the P&I diagram has reached 75% completion. Electrical and instrumentation work has included preparation of an instrument index, control system studies and modifications, and redesign of the plant safety shutdown system.

A review of secondary sodium system hydraulics was started. This review will investigate the effect of the replacement of the bellows expansion joints with pipe loops on the B & W steam generator installation.

No additional information was received from B & W concerning the test program. However, telephone conversations revealed that they are working on the program and expect to have the revised document completed before the end of the year.

IV. EVALUATION OF EFFORT TO DATE

The current SCTI shutdown has necessitated a delay in the start of the B & W test program. It has also prevented the final design work from meeting planned schedules. The final design has been delayed due to a "hold" that was placed on the steam and feedwater systems modification design until the contractor completed his redesign of the existing systems. This is not expected to result in increased expenditures for the B & W installation program, as the delay has been met with reduced manpower levels and concentration of effort in those areas where the steam and feedwater systems are not involved.

V. NEXT REPORT PERIOD ACTIVITIES

It is anticipated that final design of the B & W steam generator installation, final design of the required process system modifications, and preparation of an equipment removal package will be 60% completed. The system description will be updated as the design work progresses. No coordination meetings with B & W are scheduled.

Program: Liquid Metal Engineering Center	
Project: High Temperature Strain Measurements	
Project Manager: R. W. Dickinson	Project Engineer: M. M. Lemcoe
Reporting Period: April — June 1967	AEC Category: 04-01-61-03
General Order: 7693	Subaccount: 52110

I. PROJECT OBJECTIVES

The objectives of this project are to evaluate and develop suitable, reliable, high-temperature strain gages for experimental stress or strain measurements in or out of sodium, or as sensing elements in process instrumentation or force-arm applications. Commercially available gages also will be tested and calibrated to determine their limits, applicability, and reliability as analytical instruments for use in sodium component loop testing at temperatures up to 1200°F.

II. MAJOR ACCOMPLISHMENTS IN FISCAL YEAR 1967

A topical report, "Characteristics of Two Commercial High-Temperature Electrical Resistance Strain Gages," NAA-SR-12118, was completed and published. Pertinent information on the steady-state and transient characteristics of the Microdot Type SG420 and BLH Type HT 1212-5A gages is contained in that report.

A foil gage geometry-material combination has been developed which permits flame-spray bonding of foil-type gages without damage to the gage. This is regarded as a significant advancement for several reasons: (1) there are no commercial foil gages on the market that can be flame-spray bonded directly without damage; (2) foil gages offer several distinct advantages over wire gages, including greater uniformity from gage to gage and the elimination of joints within the gage itself, which results in greater gage reliability; and (3) flame-spray bonding is rapid and eliminates the need for curing the cement required for bonding commercial foil gages. This is of particular importance in the instrumentation of LMFBR components where mass and size are so large as to make field curing of the cement infeasible, or impossible. Flame-spray-bonded foil gages may be installed in the field without any curing whatsoever.

III. PROGRESS DURING REPORT PERIOD

Evaluation of the present versions of the LMEC Armour-D - platinum and all-Armour-D gages was completed; statistical analysis of the data is virtually complete. Figures 24 through 28 are sample CRT plots of the data obtained from the evaluation and the statistical analysis. All figures are for LMEC Armour-D - platinum gages, with the exception of Figures 27 and 28 which are for LMEC all-Armour-D gages (without a platinum element). Figure 24 is a plot of apparent strain vs temperature from ambient to 1200°F to ambient for three consecutive cycles. It is noted that the plots for the second and third cycles are virtually identical, indicating stabilization of the gage after only two cycles. It is further observed that the maximum apparent strain never exceeds 3600 microstrain. This compares with a maximum apparent strain of about 58,000 microstrain (1200°F) for the BLH Type HT 1212-5A gage^{*} which was evaluated earlier. In other words, the BLH gage has an apparent strain approximately 16 times that of the LMEC Armour-D - platinum gage. Figure 25 is an apparent strain-vs-temperature plot for 5 gages, along with the 95% confidence limits and 95-90% tolerance limits. The symbols represent actual data points. It is noted that the shape of the mean value curve is similar to that of Figure 24, the maximum value of apparent strain being 3600 microstrain. At 1200°F, the 95% confidence interval is about 800 microstrain which, although substantially less than that for any commercial gage, is larger than desirable for accurate strain measurements. The width of the confidence interval is a function of the variation from gage to gage - the larger the variation, the wider the confidence interval. Attention is now being focused on the use of gage fabrication techniques which will reduce this variation. Figure 26 is a plot of the average transient apparent strain (thermal shock) vs temperature for the 1st, 4th, 7th, and 10th cycles, at a heating rate of 20°F/sec. It is observed that the repeatability characteristics of the gage are quite acceptable. Figure 27 is a CRT plot of drift vs time at 1200°F. The symbols again represent actual data points. It is noted that the average drift rate over the first 1000 hr is only 1.8 microstrain/hr, which is indeed good. However, not all LMEC gages have a useful life of this magnitude, and a concerted

^{*}M. M. Lemcoe, "Characteristics of Two Commercial High-Temperature Electric Resistance Strain Gages," NAA-SR-12118

Figure 24. Average Initial Apparent Strain vs Temperature Characteristics, LMEC Armour-D-Platinum Gage

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Figure 25. Apparent Strain vs Temperature Characteristics with Confidence and Tolerance Limits, LMEC Armour-D-Platinum Gage

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Figure 26. Average Transient (Thermal Shock) Apparent Strain vs Temperature Characteristics, LMEC Armour-D-Platinum Gage

Figure 27. Drift vs Time Characteristics, 1200°F, with Confidence and Tolerance Limits, LMEC All-Armour-D Gage

7694-2548

Figure 28. Apparent Strain vs Temperature Characteristics with Confidence and Tolerance Limits, LMEC All-Armour-D Gage

effort is being made to improve the average useful life of the gages from 300 to 500 hr to well beyond 1000 hr.

Figure 28 is a CRT plot of the apparent strain vs temperature from ambient to 1200°F to ambient for 7 gages. It is noted that the apparent strain of the all-Armour-D gages, although less than that of the BLH gage, is quite large in comparison to the LMEC Armour-D - platinum gage. Nevertheless, the maximum confidence interval width of 1100 microstrain is only slightly greater than that of the LMEC Armour-D - platinum gage.

Testing and calibration of 10 Microdot Type SG 423 gages were completed and an interim report was written.

Evaluation of various joining procedures continued with major attention focused on advanced cutter-type electron beam and microcircuit capacitance discharge welding equipment. Tests of weld joints made with a Hughes microcircuit discharge welder showed no material improvement over joints made with conventional discharge welders. Weld joints made with the cutter-type E-B welder, which has a beam diameter of 1 mil, are still being evaluated.

Negotiations with a source for platinum cladding Armour-D wire and for drawing Armour-D wire to special sizes were completed; and clad and unclad wire are now being drawn down to wire as small as 2 mils in diameter. A special melt of Armour-D alloy has also been made primarily to determine whether this material can be rolled into foil and subsequently used to fabricate foil gages which can be flame-spray bonded.

The pilot gages which were "sodium-proofed" by means of chemically vapor-deposited tungsten have been received from the vendor. Preparations are now in progress for testing these gages in sodium at temperatures of about 900°F.

Design of the fixtures and sodium capsules for evaluating gages in sodium was completed and fabrication is in progress. Additional flame-spray-type foil gages have been fabricated and are presently being evaluated.

IV. EVALUATION OF EFFORT TO DATE

The additional data generated to date still indicate that the LMEC gage is the most promising gage for testing LMFBR components above 900°F. However,

the possibilities of flame-spray-bonded foil gages for use above 900°F are also being given serious consideration, because of their inherent advantages over wire type gages, as mentioned in Part II. If Armour-D can be rolled into foil of the required thickness, Armour-D foil gages may well prove to be superior to the present version of the LMEC gage.

Because of the poor performance observed on the Microdot SG 423 gages, additional evaluation of this gage will be necessary. The scope of this evaluation will be established in the near future.

V. NEXT REPORT PERIOD ACTIVITIES

Major attention will be devoted to the evaluation of gages in sodium. Tests in sodium will begin as soon as fabrication of the fixtures and sodium capsules is completed. Evaluation of the Microdot SG 425 gages in sodium will begin as soon as possible after their receipt from the vendor. Fabrication and evaluation in sodium of pilot gages "sodium-proofed" by means of chemically vapor-deposited films will also be carried out. Evaluation of weld joints made with the cutter-type E-B welder should be completed. Cladding and drawing of the Armour-D wire should be completed if difficulties are not encountered by the vendor; fabrication of gages from the clad wire will be initiated and pilot tests run. Finally, a state-of-the-art survey of high-temperature transducers utilizing strain gages or strain gage force arms to measure pressure, vibration, flow, head, etc., will be initiated.

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Program: Liquid Metal Engineering Center

Project: LMEC Laboratory Support

Project Manager: R. W. Dickinson

Project Engineer: R. K. Wagner

Reporting Period: April — June 1967

AEC Category: 04-01-61-03

General Order: 7693

Subaccount: 89110

I. PROJECT OBJECTIVES

The objectives of this project are: (1) to plan and execute a systematic metallurgical and chemical surveillance of materials and coolants used in the Liquid Metal Engineering Center, (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 1967

The major accomplishments during this fiscal year included the definition and adoption of a basic operating program; the planning, direction, and completion of laboratory facilities to support this endeavor; and the initiation of consulting services to complement the adopted program. Supplementary service work accomplished during the fiscal year included the preparation of long-range LMFBR chemical and metallurgical plans, the participation in design reviews for future LMEC operating systems, the failure analysis of the SCTI stainless-steel steam system, and the contribution of chemical and metallurgical sections to the LMEC revision of the Liquid Metals Handbook, Sodium and NaK Supplement.

III. PROGRESS DURING REPORT PERIOD

The construction and building modifications for the Chemical and Metallurgical Laboratory, initiated in April, have proceeded on schedule with completion planned for mid-July. Completed work includes: plumbing, heating, major electrical modifications, and installation of partitions and laboratory furniture and cabinets. A comparison of Figures 29 and 30 shows the extent of progress; where

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Figure 29. LMEC Laboratory During Early Stage of Modification

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Figure 30. LMEC Laboratory Nearing Completion

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Figure 29 represents an early construction phase, ducting installation; Figure 30 shows the same general area with partitions, ceiling, light fixtures, and laboratory furniture installed.

Purchase orders for operating supplies and materials for the laboratory were placed. Partial shipments of new equipment and the laboratory supplies have been received. Approval of funding for laboratory equipment not available from surplus stock was given. Purchase requisitions for these laboratory items were released for purchase action.

The laboratory facility should be available for occupancy in mid-July; however, due to delays in the procurement of some equipment items, it will not be operational until late August. To minimize the effect of these delays, installation of the laboratory equipment on hand will begin with the completion of construction.

During this period, consultation was provided to a number of LMEC programs. Major contributions included: (1) failure analysis of the SCTI steam line; (2) LMEC material, welding, and component specifications for liquid metal service; (3) review of candidate materials for SPTF and for the seal test apparatus; and (4) metallurgical evaluation of bellows failures incurred during service in sodium. For the Precision Mechanisms in Sodium Program, a summary report based on a survey of reported experience for bearings and mechanical elements operating in alkali metals was prepared for publication. In addition, the laboratory staff participated in the preparation of the revised Sodium and NaK Supplement, Liquid Metals Handbook, where drafts were submitted for the chemical and metallurgical sections.

IV. EVALUATION OF EFFORT TO DATE

With the completion of construction work to modify Building 057, one of the major objectives of the plan to establish a chemical and metallurgical laboratory has been realized. Equipment procurement and installation constitutes the major task remaining. Some delay in the procurement phase was introduced by the delayed approval of funding. The delays incurred will not obstruct the performance of the laboratory function, particularly while in this early developmental stage, since non-LMEC facilities are still available for any analyses required during the interim.

The basic plan for the Materials Surveillance Program has been completed. Initiation of work under the test plan is dependent on the operation and modification of the LMEC testing facilities such as SPTF and SCTL. However, liaison activities and familiarity with each of these systems have been developed through various services recently performed, including consultation on material selection and failure analysis.

V. NEXT REPORT PERIOD ACTIVITIES

The LMEC Chemical and Metallurgical Laboratory will become operational with a capability to accommodate the major analytical requirements of the LMEC operating and experimental programs. Technical consultation activities will be maintained with services available for all metallurgical and chemical problems.

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Program: Liquid Metals Engineering Center	
Project: Maintenance of Temporarily Idle Equipment	
Project Manager: R. W. Dickinson	Project Engineer: W. T. McSweeney
Reporting Period: April - June 1967	AEC Category: 04-01-61-03
General Order: 7693	Subaccount: 89200

I. PROJECT OBJECTIVES

Objectives of this 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 1967

Excessive material, old equipment, and other miscellaneous unusable gear were removed from the premises of the three installations now idle, i.e., Large Component Test Loop (LCTL), Core Component Test Facility (CCTF), and Auxiliary Component Test Installation (ACTI). Extensive inspection, overhaul, and repair of components and equipment have been completed to return the LCTL to a ready-to-run condition. The LCTL cold trap and plugging meter were both replaced by new units. Sodium was transferred between the various tanks and circulated in the 3-in. loop.

III. PROGRESS DURING REPORT PERIOD

Installation of a new cold trap and plugging meter in the LCTL was completed. Sodium was transferred between the three main vessels of the LCTL (i.e., drain supply and core tanks) and circulation was established in the 3-in. loop utilizing the 2- by 3-in. pump. After approximately 1-1/2 hr at 700°F, a sodium leak developed at two different elements of a 275-kw immersion heater. Replacement of the heater element is in progress. A total of five standard operating procedures were written for the LCTL.

A preliminary engineering study was performed, in connection with modifying the Auxiliary Component Test Installation (ACTI), to accommodate testing of intermediate size pumps (7000 to 20,000 gpm) and sodium system instruments in support of the LMFBR program.

IV. EVALUATION OF EFFORT TO DATE

All temporarily idle test installations at the LMEC are being adequately maintained and the LCTL has been returned to a ready-to-run condition. The objectives of the task are being satisfied.

V. NEXT REPORT PERIOD ACTIVITIES

Circulation of sodium at the LCTL will be resumed for at least 2 weeks after replacement of the immersion heater bundle in the 3-in. loop is completed. This will be followed by sodium circulation in the 6-in. loop. Preparation of standard operating procedures for use in operating the LCTL will continue. Procedures now in rough-draft form will be finalized. Routine preventive maintenance activities will be continued on a regular schedule.