WARD-4173-2

155L
WARD-4173-2
UC-25 Metals, Ceramics, and Materials

MASTER

SODIUM TECHNOLOGY PROGRAM
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING JUNE 30, 1970

Approved by:

W. E. Ray *William E. Ray*
Principal Investigator

P. Murray
P. Murray
Project Manager

THIS DOCUMENT CONFIRMED AS
UNCLASSIFIED
DIVISION OF CLASSIFICATION
BY *J. H. Kahan*
DATE *9/17/70*

Contract AT(30-1)-4173
U. S. Atomic Energy Commission
Submitted to AEC/NYOO August 1970

This document is
PUBLICLY RELEASABLE

B. Steele

Authorizing Official

Date: *5-4-07*

Westinghouse Electric Corporation
Advanced Reactors Division
P. O. Box 158
Madison, Pennsylvania 15663

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in the United States of America

Available from

Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfiche \$0.65

TABLE OF CONTENTS

Table	Page
1 Introduction.....	1
General.....	1
Summary of Objectives.....	1
Background.....	1
Summary of Prior Work.....	2
Summary of Current Progress.....	2
2 NCAA-100 Project Administration.....	5
Objectives.....	5
Prior Work.....	5
Current Progress.....	5
3 NCAA-200 Interstitial Transport in Sodium Systems.....	6
Objectives.....	6
Prior Work.....	6
Current Progress.....	8
4 NCAA-300 Sodium Corrosion of Weldments and Brazements.....	14
Objectives.....	14
Prior Work.....	14
Current Progress.....	15
5 NCAA-400 Mechanical Properties of Structural Materials in Sodium.....	17
Objectives.....	17
Prior Work.....	17
Current Progress.....	17
6 NCAA-600 Special Components Mechanical Properties in Sodium..	35
Objective.....	35
Prior Work.....	35
Current Progress.....	35
7 Summary of Work Plan Preparation.....	38
8 List of References.....	39

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

LIST OF FIGURES

Figure	Page
1 Control Panel for CEL-1 and CEL-2.....	9
2 CEL-1 After Completion of Loop Welding Operation.....	10
3 Vacuum Distillation Unit Attached to CEL-1.....	11
4 CEL-1 Sample Tank.....	12
5 Corrosion Rate Data for Annealed Type 316 Stainless Steel....	20
6 Photomicrographs of Annealed 316 Stainless Steel Tube Sample (OD Surface) After 5049 Hours in Flowing Sodium at 1215°F (500x).....	25
7 Photomicrographs of Annealed 316 Stainless Steel Tube Samples (OD Surface) After 5049 Hours in Flowing Sodium at 1315°F (500x).....	26
8 MPS Sodium Loop with Modified #1 Cold Trap System.....	28
9 MPS Sodium Loop with Modified #2 Final Cold Trap Modification	30
10 Stress-Relaxation Curves Obtained for Annealed 316 Stainless Steel Rod at 1200°F in Flowing Sodium.....	32
11 Loading Curves for Stress-Relaxation Tests.....	33
12 Creep-Rupture Curve for Annealed Type 316 Stainless Steel at 1200°F and 43,200 PSI in Flowing Sodium (MPS-2).....	34

LIST OF TABLES

Table	Page
1 Sodium Analysis Results for Pre-Exposure Loop (PEL-1-1).....	19
2 Chemical, Metallurgical, and Tensile Evaluations to be Performed for PEL-1-1 Test Samples After 5,049 hours at 1215°F and 1315°F in Flowing Sodium.....	22
3 Bulk Interstitial Analysis of PEL-1-1 Specimens (Type 316 stainless steel, annealed).....	23
4 Sodium Analyses and Conditions for MPS Operation ^(a)	29

SECTION 1

INTRODUCTION

GENERAL

This is the second quarterly progress report on work being performed during FY-1970 under AEC Contract AT(30-1)-4173, "Compatibility of Structural Materials with Sodium," and covers the work performed from April 1, 1970 to June 30, 1970. It should be noted that the major technical effort was confined to April and May. Late in May, a request was received from the Commission to prepare new work plans in selected areas of the national sodium technology program. Since this was a priority assignment, taking precedence over current milestones, existing shop orders were closed and efforts were directed toward the preparation of the work plans. Only the construction of the Carbon Equilibrium Loops (CEL) was continued during June since this entailed equipment rather than program funds.

A brief summary of the work plan preparation effort is given in Section 7 of this report.

SUMMARY OF OBJECTIVES

The overall objective of this project is to generate a better understanding of the effect of FFTF and LMFBR sodium environments on the reference structural materials used in those systems, and translate that information into data which the designer can use to quantitatively allow for sodium-materials incompatibilities.

The project consists of one administrative and four technical tasks as follows:

NCAA-100 Project Administration

NCAA-200 Interstitial Transport in Sodium Systems

NCAA-300 Sodium Corrosion of Weldments and Brazements

NCAA-400 Mechanical Properties of Structural Materials in Sodium

NCAA-600 Special Components Mechanical Properties in Sodium

BACKGROUND

The Westinghouse Advanced Reactors Division (ARD) has maintained an expanding company-sponsored sodium technology program since 1967, with particular emphasis on sodium-materials compatibility studies. By early FY-1970, the sodium-materials compatibility portion of this program encompassed nine small pumped loops and several projects covering:

1. Demonstration plant corrosion mock-up studies
2. Carbon and nitrogen transfer in sodium systems
3. Sodium corrosions of weldments and brazements
4. Effects of sodium on mechanical properties of structural materials

During the second quarter of FY-1970 the Coolant Chemistry Branch of the AEC authorized preparation of a work program under Contract AT(30-1)-4169, which incorporated portions of the above work, together with new scope into a five-year plan of sodium-materials compatibility engineering studies. The present contract funds major portions of that plan through the balance of FY-1970.

In so doing, the contract incorporates on-going effort in certain areas detailed in the body of this report under Tasks NCAA-300 and -400. Tasks NCAA-200 and -600 represent new scope; NCAA-200 entails new facilities which are funded in part by Westinghouse and in part by the AEC.

A clear objective of this contract is to maintain constant liaison with both FFTF and LMFBR design groups to ensure that generated data will have a maximum utility to these projects. Design requirement reviews and inputs from other sources, such as the LMEC, will be continually monitored. All experimentation will be planned to facilitate extrapolation of results to full scale systems.

A major constraint in the execution of this contract is the need to monitor sodium quality by methods which can be related to other programs and reactor operations; extensive use will be made of on-line meters. Sodium analytical techniques will be coordinated with the Sodium Technology Group at ANL who are assigned responsibility for developing reference sodium analytical procedures. Although this phase of the contract effort applies to all tasks, the work will be consolidated and reported under Task NCAA-200, since it has major relevance in that area.

SUMMARY OF PRIOR WORK

All work related to the present investigation and performed prior to the present period has been fully reported in WARD-4173-1 "Sodium Technology Program Quarterly Progress Report for the Period Ending March 31, 1970."

SUMMARY OF CURRENT PROGRESS

NCAA-200 Interstitial Transport in Sodium Systems

Experimental Plans - No significant change has been made in the experimental program detailed in the previous report.

Procurement - All thin foil material for the experimental program has been received and metallurgical characterization of the alloys is nearing completion.

Construction of the CEL control panel and of the first loop (CEL-1) is also nearing completion. The status of on-line metering is as follows:

1. Two UNC carbon meter side loops have been ordered.
2. Three electrochemical carbon meters were ordered from BNL.
3. Two electrochemical oxygen meters were ordered from Westinghouse, which will use the new high purity thoria-yttria ceramic electrolyte.
4. An order was placed for a Fisher Gas Partitioner for monitoring hydrogen, and the instrument was received.
5. Voltmeters and recorders for display and readout of electrochemical meters have been procured.
6. An on-line vacuum distillation column for use on CEL-1 has been fabricated.

Sodium Sampling and Analysis - Submittal to ANL of procedures for sodium sampling and analysis is proceeding.

NCAA-300 Sodium Corrosion of Weldments and Brazements

Loop run WBTL-2, containing spot welded and brazed Type 316 stainless steel fuel pin support grid samples, was terminated after 2100 hours of operation. The samples have been weighed, but further evaluation has been halted since no funding has been provided for this task in FY-1971.

The conceptual design of WBTL-3 test section, which is to study cavitation effects in fuel rod support grids at high sodium velocities, has been completed but detailing has not progressed due to lack of funding.

NCAA-400 Mechanical Properties of Structural Materials in Sodium

Preliminary evaluation of the samples, removed from the Pre-Exposure Loop (PEL-1) after 5049 hours operation, has revealed low corrosion rates consistent with the low sodium velocities employed. However, loss of interstitial elements (C, N) had taken place, which is anticipated to have a deleterious effect on mechanical properties. Metallographic evaluation of the samples is in progress.

Thermal aging of parallel, out-of-sodium samples at 1200 and 1325°F is proceeding.

The Stress Relaxation Test System (MPS-1) and the Creep Rupture Test System (MPS-2) have been operated to continue debugging procedures. Problems corrected included: clogging of covergas systems, accumulation of entrapped covergas in the cold trap, and nonrepresentative sodium by-pass sampling.

The Strain Cycle Fatigue Test System (MPS-3) loop and test chamber have been essentially completed and will be operated independently for check out.

NCAA-600 Special Components Mechanical Properties in Sodium

In a series of meetings with FFTF design personnel most of the component areas were reviewed and some potential fractional component configurations requiring evaluation were identified.

SECTION 2
NCAA-100 PROJECT ADMINISTRATION

F. A. Brassart, W. B. Heubel, and P. Murray

OBJECTIVES

The objectives of this task are to assure that the project is successfully completed, on schedule, within budget, and to the satisfaction of the Atomic Energy Commission; to assure compliance with contracted obligations; and to coordinate this project with other AEC and Westinghouse sponsored LMFBF development projects.

Under this task, overall project direction and day-to-day administration will be provided. Plans and controls will be established and maintained, periodic reviews will be held with the Commission, correspondences and reports will be coordinated, and day-to-day technical and administrative liaison with the Commission will be provided.

PRIOR WORK

Authorization for work during FY-1970 was received from the Commission based on the work program submitted in December 1969. Although this is a new AEC sponsored program, it picks up on-going effort at ARD in certain tasks.

Internal work authorization and budgets were established.

CURRENT PROGRESS

Overall project direction and day-to-day liaison with the AEC continued. Schedule 189a/Work Plan for FY-1971 was prepared and submitted to the New York Operations Office.

Quarterly progress report (WARD-4173-1) for the period ending March 31, 1970 was prepared and distributed.

SECTION 3

NCAA-200 INTERSTITIAL TRANSPORT IN SODIUM SYSTEMS

C. Bagnall, E. C. Bishop, B. R. Grundy, S. L. Schrock and S. A. Shiels

OBJECTIVES

The objectives of this program are to provide experimental information and analytical relationships for design data, so that the rate and direction of carbon and nitrogen transfer and associated mechanical property changes of structural materials within liquid metal systems, representative of primary and secondary circuits of a LMFBR, may be predicted.

PRIOR WORK

On-going ARD Program

Westinghouse Advanced Reactors Division has an extensive Westinghouse/Utility sponsored program in progress to study the mass transfer of the major metallic elements in LMFBR structural materials. The Mass Transfer Loops (MTLs) used in that program are corrosion potential mock-ups of Westinghouse LMFBR primary and secondary systems and are run with hot leg temperatures up to 1325°F and ΔT s of up to 300°F. Type 316 stainless steel hot leg and Type 304 stainless steel cold leg materials are used in the primary systems; the secondary system materials are Type 304 stainless steel hot leg and Incoloy 800 cold leg.^[1] As part of the MTL program, selected sections of the loop piping are thoroughly examined for evidence of carbon and nitrogen transport. This is done by comparing the interstitial gradients in the exposed material with the gradients in the as-received material.

Related Work Outside Westinghouse

The current AEC sponsored interstitial transfer program is part of an overall national program on sodium technology. The work at Westinghouse interfaces with, and in some areas complements, work being carried out at WADCO, AI, ANL, BNL, and GE. Programs at MSAR and UNC, which have now been terminated, are also relevant to the Westinghouse effort.

In the important area of carbon meter calibration and operation, the Westinghouse program will benefit from past work at UNC and BNL where the meters were developed, and at MSAR where the UNC meter was used successfully in high carbon environments. The ANL program is perhaps the most extensive one outside Westinghouse. ANL personnel are concentrating primarily on relating carbon transport to chemical species and on adapting experimental meters for on-line use in EBR-II. The meter program particularly is of interest to Westinghouse.

The work at AI, where an investigation will be conducted on the effects of the carbon and nitrogen content in stainless steel on the mechanical properties of the steel, will interface with the work at Westinghouse in the area of material properties. Work related to this contract, by WADCO, is in an equipment design and installation phase.

Preparatory Work

During the first half of FY-1970 extensive preparatory work on the interstitial transport program was carried out in anticipation of the current AEC contract. This work involved a preliminary survey of the literature and identification of the key problems in defining interstitial transfer in sodium systems. An experimental approach was decided upon and a facilities design concept was originated. The program and design philosophies were embodied in the work program which was submitted in November 1969.

A preliminary state-of-the-art review of carbon diffusion data has been documented and issued as an internal memo September 1969; this documentation will be issued as an appendix in the next quarterly report.

Experimental Plans

A detailed experimental program was written for the Carbon Equilibrium Loops (CELs), covering shakedown of the loops and metering systems, carbon meter calibration and measurement, and evaluation of carbon equilibrium concentrations (C_e), and motivity or diffusion coefficient (M) values.

Facilities

The design of the CELs, including the control panels and tie in of all on-line instrumentation was completed, and a System Design Description (SDD) written. The SDD, together with the relevant detailed drawings, was submitted to the AEC, Coolant Chemistry Branch, for approval. Apart from minor modifications, the SDD was accepted.

Control of Hydrogen from the UNC Hydrogen Meter

A study of methods of hydrogen control was made. Cover gas stripping was compared with cold trapping, and allowances were made for loss of hydrogen by permeation through the loop walls. Even at low trapping efficiencies, cold trapping was found to be much more efficient than cover gas stripping, and will be used as the main method of hydrogen control. However, it will be supplemented by cover gas stripping and a gas chromatograph will be installed for cover gas monitoring.

Sodium Sampling and Analysis

During a visit by ARD personnel to ANL, an interim policy on sodium sampling and analysis was agreed to by ARD and ANL to be effective until a national policy is established.

CURRENT PROGRESS

Procurement

All thin foil material for the experimental program has now been received. The inventory includes Type 316L stainless steel, Type 304 L stainless steel, Incoloy 800, 2-1/4 Cr-1 Mo steel, and Armco Iron. Chemical and metallurgical characterization of these alloys is nearing completion.

Construction of the CEL control panel, the loop, and its auxiliary equipment, is completed except for wiring hookup, loop insulation, and installation of carbon and oxygen meters. Three electrolytic carbon meters (for CEL-1, CEL-2, and ITF) have been received from BNL after proof testing in static sodium, and a modified version of the oxygen meter is anticipated from Westinghouse Research Laboratories in the latter part of July.

The advanced structural stage of the facility is illustrated in Figures 1 through 4. Figure 1 shows the control panel for CEL-1 and CEL-2. The control and analyzing consoles for the UNC carbon meter can also be seen to the right of the control panel.

Figure 2 shows a general view of the internal layout of the loop prior to installation of thermocouples and heaters.

Figure 3 shows the vacuum distillation column attached to its own side loop and situated on top of the main loop frame so that it is readily accessible from a catwalk. The long rod extending from the top of the unit allows the sampling crucible to be lowered into the sodium through the valve and below the cooling coil, and then drawn back to the center of the glass section for distillation under vacuum. The crucible and RF heating coil are shown at the base of the distillation column.

Figure 4 shows the large sample tank (sodium capacity: 0.8 cu. ft.). The long rods extending from the top of the tank are for raising and lowering the specimen racks through the cover gas into the sodium pool.

On-Line Metering

During this period all outstanding bids and information for on-line sodium impurity metering equipment were received, enabling final choices to be made. Devices to be incorporated are as follows:

Figure 1. Control Panel For CEL-1 and CEL-2

3796-1

Figure 2. CEL-1 After Completion of Loop Welding Operation

Figure 3. Vacuum Distillation Unit Attached to CEL-1

3796-3

Figure 4. CEL-1 Sample Tank

3796-4

1. UNC diffusion carbon meter
2. BNL electrochemical carbon meter
3. Westinghouse electrochemical oxygen meter
4. Fisher Gas Partitioner (chromatograph) for cover gas hydrogen monitoring

The present status of various items is as follows:

1. Permission for purchase of two UNC carbon meter side loops was obtained from AEC, NYOO, and the order was placed immediately. The gas supply and analysis console of the UNC carbon meter now at ARD has facilities for handling one carbon meter probe. All materials and components necessary to increase readout capabilities by one or two further probes were identified. Orders were not placed because of diversion of funds into work plan preparation.
2. An order for three electrochemical carbon meters was placed with BNL. These are still laboratory prototypes, but represent state-of-the-art technology. Several improvements over early versions are incorporated.
3. An order for two electrochemical oxygen meters was placed with Westinghouse, Nuclear Instrumentation and Control Dept.
4. An order was placed and delivery taken of a Fisher Gas Partitioner, Model 29. This is a simple gas chromatograph with a thermal conductivity detector. It will be used to monitor the hydrogen content of the sample tank cover gas.

Delivery was taken of differential voltmeters and recorders for readout and display of electrochemical meter outputs; these were incorporated in the appropriate control panels.

Sodium Sampling and Analysis

As previously agreed with ANL, detailed procedures used by ARD for oxygen analysis by amalgamation and for by-pass sampling were submitted for approval; tentative approval has been received. Evaluation of carbon in sodium analysis was completed and the procedure is ready for submittal to ANL for approval. Evaluation of nitrogen in sodium analysis is also complete and the detailed procedure is being written.

SECTION 4

NCAA-300 SODIUM CORROSION OF WELDMENTS AND BRAZEMENTS

E. C. Bishop, S. L. Schrock, G. A. Whitlow, and W. L. Wilson

OBJECTIVES

The objective of this task is to provide quantitative sodium corrosion data from welded and brazed joints exposed under conditions simulating actual LMFBR sodium environment. The values of the variables of the temperature gradient (ΔT), temperature, oxygen content, and sodium flow rates will be selected so that they bear the maximum resemblance to actual service conditions; i.e., conditions under which material mass transfer would take place. In addition, the phenomenon of cavitation and cavitation damage effects will be studied under simulated service conditions.

PRIOR WORK

The available data on sodium corrosion of weldments and brazements was reviewed in detail in the previous quarterly report.^[1] In that report, program philosophy, experimental plans for this task, and the experimental facility to be used in this program (the Weldment and Brazement Test Loop, WBTL) were described. A system design description for this facility was submitted to the AEC Coolant Chemistry Branch for approval and comment. Progress on each of three loop runs in the WBTL is summarized in the following paragraphs.

WBTL-1 - Simulated fuel pin grid type samples in the Inconel 718/Microbraz 50 material combination were exposed to flowing, low oxygen sodium for 3500 hours at temperatures of 900 and 1200°F. The 1200°F samples lost weight as a result of exposure to sodium, while the 900°F samples gained weight. Weight change results were dependent on sodium velocity and position downstream from the heater, and were due to removal and deposition of nickel and phosphorus in the case of the braze, and nickel and chromium from the Inconel 718. Further evaluation was delayed due to funding curtailment.

WBTL-2 - This run logged approximately 1250 hours under operating conditions, and was primarily concerned with the examination of the behavior of spot-welded Type 316 stainless steel, grid-type samples in sodium. The behavior of welds in both annealed and cold-worked stainless steel is being examined and unwelded samples were included for comparison. In addition to these samples, a few brazed joints and simulated end-closure weld samples were included for testing. A limited number of end-closure welds contained a known defect and some of the brazed grid samples had received a post-brazing sensitization treatment prior to exposure to sodium. Since this work is in direct support of a grid design to be utilized in 37-pin, grid-type sub-assemblies to be irradiated in EBR-II, it is being charged to task OFBA-313 on contract AT(30-1)-4135 (Oxide Fuel Element Development). Control samples of the materials in this test were thermally aged in vacuum for comparison.

WBTL-3 - Discussions were held with the staff of the ARD Mechanical Development and Thermo Fluids Groups (LMFBR Project) regarding the design requirements for the next run in the Weldment and Brazement Loop (WBTL-3). Considerable interest was expressed in cavitation and cavitation damage effects, which may occur under appropriate sodium conditions in the vicinity of the fuel rod support grids. Consideration was being given to a test section design using a single 37-pin, grid-type cell, equipped with a dummy fuel pin which would be tested at sodium velocities of the order of 40 fps. Other factors such as gas entrainment in the sodium and its effects on the onset of cavitation were being considered. It seems likely that the redesigned loop system WBTL-3 will be a high velocity system with several short term replaceable test sections (or "legs") and several long-term test sections.

CURRENT PROGRESS

Work being charged to this task includes evaluation of the brazed grid samples from WBTL-1 and design of the samples and test sections for the next run, WBTL-3, which was originally scheduled to commence operation early in FY-1971.

WBTL-1 - Chemical analysis of microdrillings of the braze material from both sodium exposed and unexposed samples has been performed. The major indication confirms previous X-ray analysis findings that phosphorus is very much depleted with a corresponding apparent increase in nickel and chromium. Further work on this subject has been delayed due to higher priority projects.

WBTL-2 - The sodium corrosion loop run WBTL-2 was terminated during this period after accumulating 2100 hours of operation. This decision was made for two reasons: first, some of the loop components such as the pump and flowmeter were required for WBTL-3; and second, redesign of this system was essential to reduce downtime. This loop system has been disassembled and the samples removed, cleaned, and weighed.

The thermal aging capsules have logged 2200 hours at operating temperatures of 900 and 1200°F. Since the capsules also contain Inconel 718 samples for comparison with WBTL-1 samples, they will be run for 3500 hours, which was the length of the WBTL-1 run.

WBTL-3 - It was decided that cavitation and cavitation damage effects, which may occur under appropriate sodium conditions in the fuel rod support grids, will be the principal subject to be investigated in the next run in the Weldment and Brazement Loop (WBTL-3). A conceptual cavitation test cell, utilizing two EBR-II grid-type cells and a dummy 21-inch long fuel pin, has been designed, and preliminary drawings are in progress. The use of high temperature accelerometers to detect cavitation is under consideration. The redesigned loop system will be a high velocity system incorporating long term samples and the short term replaceable cavitation test cell mentioned above.

Work on this task has been temporarily suspended due to an AEC directive to give priority to the preparation of Coolant Technology Work Plans. When work ceased, preliminary drawings of the conceptual cavitation test cell were near completion.

SECTION 5

NCAA-400 MECHANICAL PROPERTIES OF STRUCTURAL MATERIALS IN SODIUM

E. C. Bishop, J. C. Cwynar, P. N. Flagella, R. Hundal, and S. L. Schrock

OBJECTIVES

The objective of this task is to obtain experimental mechanical property data for FFTF and LMFBR structural materials exposed to flowing sodium, such that meaningful corrosion allowance limits may be applied by the designers. Effects of sodium exposure at typical reactor conditions on the mechanical properties of the materials will be evaluated in terms of pre-exposure temperature, time, and different surface to volume ratios for the materials. Long term mechanical property tests such as stress relaxation, creep-rupture, and strain-cycle fatigue will be performed primarily in flowing sodium in order to retain the surface condition for the material developed during pre-exposure. Evaluations from this work are intended to provide base line information in support of Task NCAA-600.

PRIOR WORK

ARD has initiated an internal program to provide mainly stress-relaxation, creep-rupture, and strain cycle fatigue data in sodium on selected structural alloys. These data were to be used to evaluate the effects of a dynamic sodium system, approaching those of the FFTF and LMFBR, on the mechanical properties of structural and core materials. Some of the equipment designed and built for this program has reached the operational stage.

A sodium Pre-Exposure Loop (PEL-1) was designed and fabricated early in CY-1969. The first loop run was initiated in May 1969, and 5000 hours of pre-exposure was accumulated on the test specimens in March 1970. The test samples consisted of sheet, bar, and tubing, pre-exposed at 1200 and 1325°F with a turbulent sodium flow ($Re \approx 15,000$). The sodium purity was maintained at approximately 10 ppm oxygen by cold trapping.

The testing facilities MPS-1 and MPS-2 were designed and fabricated during CY-1969, and were ready for shakedown tests. They were designed for stress relaxation and creep-rupture testing, respectively, and the test specimens will be exposed to a turbulent sodium flow during testing. A testing facility for strain cycle fatigue (MPS-3) was designed and fabricated, and assembly of the system was underway.

CURRENT PROGRESS

Material

The initial material selected to determine the effect of a dynamic sodium environment on the mechanical properties for FFTF and LMFBR structural

materials was annealed Type 316 stainless steel in tube, sheet, and bar forms. Selection was made early in CY-1969, so that test samples were available for the Pre-Exposure Loop (PEL-1) start-up in May 1969. At that time the reference fuel cladding material for the LMFBR and FFTF was annealed Type 316 stainless steel. Test samples were also fabricated from the same heats for inert gas aging tests and unexposed long term mechanical property tests, to be run in parallel with sodium exposed samples.

After consultations with FFTF and LMFBR designers, it was decided to incorporate 20 percent cold-worked, Type 316 stainless steel cladding material into the program. A limited quantity of highly characterized cladding material was made available from the Cladding Development Program on Task SSBA 210 of Contract AT(30-1)-4135. Both 20 percent cold-worked and annealed 316 stainless steel tubing will be included in the next PEL-1 and Aging-1 runs.

Test Plans

The initial samples planned for mechanical property testing in sodium, as well as those planned for the next sodium pre-exposure run, and the inert gas aging exposures were given in Table 6-6 of Reference 1. As noted, the first stress-relaxation and creep-rupture tests performed in flowing sodium will involve unexposed (as-received, annealed) samples at 1200°F. These data will be used as a base reference to evaluate samples tested after pre-exposure to sodium for 5000 hours at 1200°F and samples aged in an inert gas for 5000 hours at 1200°F.

Due to the AEC directive late in May to prepare new work plans for the sodium technology program, further work on test plans was suspended.

Pre-Exposure Loop (PEL-1-1)

Disassembly of the Pre-Exposure Loop (PEL-1-1) was completed after 5049 hours of operation at nominal test section temperatures of 1200 and 1325°F (actual temperatures were 1215 and 1315°F respectively), a loop ΔT of 3000°F maximum, and a sodium velocity to give a Reynold's Number of approximately 15,000 (turbulent flow) over the test specimens. The loop was continuously cold-trapped at 300°F. Results of sodium analyses made during the run are in Table 1. Oxygen and carbon were maintained at less than 10 ppm and less than 20 ppm respectively. These are the reference impurity levels for the FFTF and LMFBR.

The mechanical property test specimens (Type 316 stainless steel, solution-annealed, bar, sheet, and tube) have been removed from the test sections, cleaned, and weighed. For a more complete description of the PEL-1-1 specimen inventory, refer to the previous quarterly report^[1] of this program. All specimens experienced weight losses and average corrosion rates have been calculated for tube and sheet specimens. These corrosion rates have been plotted against the L/D ratio for each specimen (where L/D is the location of the specimens in terms of the number of equivalent pipe diameters downstream from the main heater exit) and are presented in

Table 1. Sodium Analysis Results for Pre-Exposure Loop (PEL-1-1)							
Date	Loop Hours	O ₂ (a) (ppm)	C(b) (ppm)	N ₂ (c) (ppm)	H(d) (ppm)	OH(e) (ppm)	Comments
5/26/69	0	8, 7, 11	4	<2	0.9	2.1	Start-up
7/3/69	741	3, 10, 11	4	<2	0.1	0.3	-
9/12/69	1454	5, 5, 11	3	<2	-	-	Trace heater shorting to wall caused small leak. Repairs necessary.
9/23/69	1454	11(+ 1)	-	<2	-	-	Repairs completed. Loop restarted.
10/1/69	1494	15(+ 2)	3	<2	1.2	0.5	Power outage caused partial dump.
10/2/69	1494	5, 5, 5	8	<2	1.1	1.0	
12/18/69	3200	11(+ 3)	11	<2	-	-	
1/20/70	3870	17(+ 4)	-	-	-	-	Power outage caused partial dump.
1/22/70	3870	7.5(+ 0.4)	38 31	<2	0.6	1.4	
2/19/70	4427	11(+ 1)	16	<2	0.3	0.8	
3/25/70	5049	8.3(+ 1.3)	6	<2	0.2	0.2	End of loop run.
NOTES: (a) Mercury Amalgamation Method (b) Total Combustion Method (c) Kjeldahl Method (d) "Non-Hydroxide" Hydrogen (e) "Hydroxide" Hydrogen							
				by vacuum-reflux technique at controlled amalgamation temperature in dry-box			

Figure 5. The lines drawn through the data points are hand-fitted. Several observations concerning these data can be made at this time:

1. The corrosion rate decreases exponentially with distance from the main heater exit. This effect ("downstream" or "L/D" effect) is due to the saturation of the sodium with corrosion products as it flows through the relatively long (52 inches) isothermal test sections.
2. The corrosion rate at 1315°F is approximately a factor of three greater than at 1215°F.

Figure 5. Corrosion Rate Data for Annealed Type 316 Stainless Steel L/D From Heat Source

3796-5

3. The difference in the corrosion rate of tube versus sheet specimens at the same temperature can partially be attributed to the fact that the ID surface area of the tubes, exposed to essentially stagnant sodium, was not factored into the corrosion rate calculation.

Calculated curves for corrosion rates versus L/D using equations derived by GE^[2] from loop runs 8-1, 8-2, 8-3, and 9-1 are also included in Figure 5. A sodium velocity of 2.6 fps was used in the calculations and results were corrected for an exposure temperature of 1315°F. The cold trap temperatures of the GE loops (~275°F) and the PEL-1 loop (~300°F) yield essentially identical oxygen solubilities in sodium (both <5 ppm). It can be seen in Figure 5 that with the exception of loop run 8-3, the calculated curves using the GE equations and the ARD PEL-1 data for tube samples at 1315°F are in general agreement.

It is important to note that the mechanical properties of an austenitic stainless steel exposed to a liquid sodium environment (hot leg) are likely to be affected by three factors:

1. Loss of local carrying capability due to material removal caused by general corrosion
2. Alteration of mechanical properties due to metallic element depletion and the subsequent formation of a ferritic phase
3. Alteration of mechanical properties due to interstitial element depletion

Item (1) above is predictable and as such can be accounted for in design. Item (2) is a surface effect and as such is not expected to significantly alter most mechanical properties. Item (3) is presently unpredictable, occurs to significant depths in stainless steels, and is probably the most influential factor affecting the mechanical properties.

Although it is satisfying to be in agreement with other experimenters on general corrosion rates, a more important factor to consider when mechanical properties are being studied is the degree of interstitial depletion. In addition to the general corrosion rate analysis, a detailed sample characterization program has been delineated and is presented in Table 2. Because of the L/D effect, representative samples from each end of the test sections are being characterized. Samples have been submitted for bulk interstitial analyses (carbon and nitrogen), metallic gradient analysis (Fe, Cr, Mo, Mn, Ni), and metallography. The bulk interstitial analyses have been completed and results are in Table 3.

Examination of the carbon results shows that sheet samples have experienced essentially no change, while tube samples have been depleted of carbon. Because of this inconsistency, a repeat analysis was performed on a randomly selected tube and sheet specimen. Results were in general agreement with initial analysis. This anomaly will require further

investigation; however, it should be noted that the expected behavior of carbon mass transfer in all austenitic stainless steel system with a ΔT , is decarburization of hot leg specimens.

The nitrogen results appear more consistent in that both types of specimens and exhibited nitrogen depletion after pre-exposure to sodium. The degree of depletion was markedly greater at 1315°F than 1215°F, as expected.

It can be concluded from these analyses that interstitial transfer has occurred to a significant degree due to the sodium exposure and that mechanical property testing in MPS units (MPS-1,2, and 3) should proceed to determine the resultant effect on mechanical properties.

Table 2. Chemical, Metallurgical, and Tensile Evaluations to be Performed for PEL-1-1 Test Samples After 5,049 hours at 1215°F and 1315°F in Flowing Sodium					
	Analytical Test	Sample (a,b)			Determination
		tube	sheet	bar	
Prior to performing long-time mechanical property tests	Interstitial, Bulk	X	X		C, N, O, H
	Glow Discharge Emission Spectography(c)		X		Cr, Ni, Fe, Mn, Mo, gradients
	Metallography	X	X	X	Carbide, Sigma, Grain size, hardness gradient
	Microprobe, Continuous	X	X	X	Cr, Ni, Fe, Mn, Mo gradients (relative)
	Tensile, Uniaxial	X	X	X	UTS, YS, ductility
Concurrent with testing	Microprobe, Spot	X	X	X	metallic gradients (quantitative)
	Scanning Electron Microprobe	X	X	X	surface constituents (quantitative)
	Interstitial, Layer	X	X	X	C, N, gradients
(a) One sample each for 1215°F and 1315°F (no bar samples exposed at 1315°F) (b) One sample each from inlet and exit of flow leg (c) Sequential surface analysis					

Table 3. Bulk Interstitial Analysis of PEL-1-1 Specimens (Type 316 Stainless Steel)					
Specimen Type	Specimen Condition	Sample from Test Section Inlet		Sample from Test Section Outlet	
		Carbon ^(c) (ppm)	Nitrogen ^(d) (ppm)	Carbon ^(c) (ppm)	Nitrogen ^(d) (ppm)
Sheet ^(a)	As-received	606-611(608)	490	606-611(608)	490
	Exposed to 1215°F Na	643-644(644)	302-349(326)	643-654(648)	281-321(301)
	Exposed to 1325°F Na	673-685(679)	108-157(132)	664-665(664) 663-676(670)	116-137(126)
Tubing ^(b)	As-received	556-559(558)	548-563(556)	556-559(558)	548-563-(556)
	Exposed to 1215°F Na	523-542(532)	446-458(452)	504-519(512)	506-509(508)
	Exposed to 1315°F Na	433-498(466)	103-108(106)	368-382(375) 410-429(420)	138-139(138)

Vendor	Heat No.	Lot No.	Dimension
(a) Armco Steel Corp.	380233	-	0.018 in. thick
(b) Superior Tube Co.	20303	316726	0.300 in. OD x 0.012 in. wall

(c) Total Combustion Method of Analysis
(d) Kjeldahl Method of Analysis

Metallographic examination has also been initiated and all specimens have progressed through the final polishing stage. Metallographic mounts of tube specimens, pre-exposed to 1215 and 1315°F sodium, have been subjected to an etching procedure reportedly^[3] capable of distinguishing between carbides (M₂₃C₆) and sigma phase. The etching procedure is outlined below:

1. Remove any disturbed metal by repeated polishing and etching in a mild acid reagent (Vilella's reagent).
2. Etch in hydrochloric-picric acids in alcohol (Vilella's reagent) to outline carbides, ferrite, and sigma phase.
3. Repolish and etch in ferricyanide (Murakami's Reagent) at room temperature to reveal carbides only, sigma particles being faintly discernible only after longer etching times.

4. Repolish and etch electrolytically in 10 percent chromic acid, using 3 volts and 1 amp for 15 seconds or more, which eats out sigma and carbides and leaves ferrite clearly outlined.

Photomicrographs, taken after Steps (2), (3), and (4) in the etching procedure, are shown in Figures 6 and 7 for the 1215 and 1315°F tube samples respectively. By comparing Photomicrographs (a) and (b), one can identify carbides; by comparing (a) and (c) one can identify ferrite; and by elimination one can identify sigma.

It has been tentatively concluded that at 1215°F, carbides ($M_{23}C_6$) are present in the grain boundaries to within approximately one mil of the sodium exposed surface. A discontinuous ferrite phase, approximately one mil thick, exists on the surface with a high occurrence of sigma phase within it. A slight amount of sigma phase is also present in the grain boundaries.

At 1315°F there are no carbides or ferrite evident in the microstructure. There is a much higher percentage of massive sigma phase present in the grain boundaries. The grain boundaries also appear to be depleted of some constituent (possibly chromium) as evidenced by Figure 7a.

It should be noted that the foregoing conclusions are only tentative pending further metallographic examination. It is also intended to verify these conclusions by an X-ray technique developed by WRL, whereby identification of secondary phases (carbides, sigma, chi, and Laves) in austenitic stainless steels is obtained by comparing Mo/Cr and Fe/Cr ratios.

Thermal Aging

In order to determine the effect of sodium pre-exposure on the mechanical properties for the annealed 316 stainless steel sheet, tube, and bar samples run in PEL-1 at 1200 and 1325°F for 5000 hours, identical samples have been prepared for thermal aging in argon at 1200 and 1325°F for 5000 hours. The stainless steel capsulating tubes (1.0-inch dia. x 24-inches long), seven for each temperature, were first outgassed at 1000°F in a vacuum of 1×10^{-4} torr, test samples inserted, and then sealed by welding end plugs in place, using the same dry box with argon as the covergas. The capsules were then clustered into bundles of seven each, instrumented for temperature measurement, and inserted into a stainless steel containment tube (3.5-inch OD x 25-inches long). Thermal aging of the encapsulated samples was initiated at the end of this reporting period.

Mechanical Property Systems

The Stress Relaxation Test System (MPS-1) and the Creep Rupture Test System (MPS-2) have been operated as complete units. Several of the problem areas related to the sodium loop, the mechanical test system, and integration of loop and test system have been resolved in this reporting period.

(a) ETCHED, VILELLA

(b) ETCHED, MURAKAMI

(c) ETCHED, ELECTROLYTIC CHROMIC ACID

Figure 6. Photomicrographs of Annealed 316 Stainless Steel Tube Sample (OD surface) After 5049 Hours in Flowing Sodium at 1215°F (500x)

3796-6

(a) ETCHED, VILELLA

(b) ETCHED, MURAKAMI

(c) ETCHED, ELECTROLYTIC CHROMIC ACID

Figure 7. Photomicrographs of Annealed 316 Stainless Steel Tube Sample (OD surface) After 5049 Hours in Flowing Sodium at 1315°F (500x)

3796-7

A redesign of the covergas systems was performed to prevent sodium vapor from condensing, and clogging the covergas lines as experienced with a static covergas system. The sodium vapor introduced problems in the performance of mechanical property tests and also reduced the reliability of the emergency dumping system. A slow covergas bleed is being introduced to the test chamber through the extensometer tubes and discharged through a temperature-controlled vapor trap. The vapor trap does not operate at 100 percent efficiency, and a small amount of sodium dust particles is still present in the covergas after passing through the vapor trap. A 60 micron replaceable filter has been installed to intercept the sodium dust before the covergas flow-regulator valve is allowed to clog.

Two problems were experienced with the sodium cold-trapping system which affected the stability of flow in the loop, and the accuracy of the sodium sampling procedure. The turbulence of the sodium in the test chamber appeared to create a fine foam which was pulled through the loop system. This fine foam accumulated in areas of low flow velocities, such as the cold trap and the cold trap economizer. The sodium level in the cold trap was gradually lowered to a point where the cold trapping efficiency was affected, and also, release of large bubbles into the sodium stream was occurring. When the large bubbles released from the cold trap reached the pump, flow was normally disturbed or in some cases stopped, and a large and intolerable thermal instability occurred in the sodium system and in the test sample. A redesign of the cold trap loop to reduce the problem of gas accumulation has been completed for MPS-1, -2 and -3.

Concurrent with the baseline data test run, the redesign of the cold trap loop was evaluated. The flow disturbance observed with the previous cold-trap loop design has been reduced to a level where it does not affect the operation of MPS-2 (creep-rupture). For MPS-1 (stress-relaxation) which is highly sensitive to changes in the sodium flow and temperature, the redesign has not reduced the problem satisfactorily and intermittent cold trapping will be employed during a mechanical property test for this loop.

Table 4 shows the sodium sampling analysis data obtained from MPS-1 and -2, as well as the sampling conditions. The observed cold trapping efficiencies with the cold trap design used in the MPS loops have been 5 to 15 percent. Assuming 5 percent efficiency, the level of oxygen should be reduced from 2100 ppm (only measurement at loop startup) to 10 ppm in approximately thirty hours. In contrast, the actual values ranged from 29 to 50 ppm, after 90 to 259 hours of cold trapping. In interpreting these results, a layout of the cold trapping and sampling stations was examined. The loop diagram (Figure 8) shows that the sodium sample tubes were located after the economizer, and that the sodium temperature at this point was approximately 340°F. At this temperature the solubility of oxygen in sodium is in the order of 3 to 5 ppm. As long as the bulk sodium had a higher impurity level than the solubility limit for the temperature of the sample section, the impurities deposited on the tubing wall, and were included in the analysis, in addition to the bulk sodium impurity level. Sample MPS-2-G also strongly indicates that this may be the case; by flowing through the tubes with sodium at 900°F, the impurities were dissolved and put into the main loop again.

Figure 8. MPS Sodium Loop with No. 1 Cold Trap System

Table 4. Sodium Analyses and Conditions for MPS Operation ^(a)						
SAMPLE	MPS2C	MPS2D	MPS2E	MPS2F	MPS2G	MPS1D ^(b)
Date	5/8/70	5/12/70	5/15/70	5/20/70	5/20/70	6/24/70
Loop at 1200°F (hr)	1	89	161	257	265	123
Cold Trapping Time (hr)	2.5	90.5	162.5	258.5	258.5	123
Cold Trap Temp. (°F)	290	290	290	290	Not Flowing thru CT	420
Sample Time (hrs)	2.5	22	22	15	5	5
Sample Temp. (°F)	345	340	340	340	900	1000
O ₂ (ppm)	2100 $\pm$ 300	50.2($\pm$ 3.9)	38.1($\pm$ 1.6)	29.0($\pm$ 0.2)	52.4($\pm$ 0.6)	9.7($\pm$ 1.0)
C (ppm)	13 to 43	8	---	---	---	---
(a) Flow over test sample (creep-rupture) at $\sim$ 3 fps.						
(b) Sample MPS1D with sample section ahead of the cold trap economizer (latest design)						

Based on this analysis, the sodium sample section was located in front of the economizer on MPS-1, where the sodium temperature was 900 to 1100°F, as shown in Figure 9. The sodium analysis (MPS-1-D) showed, after a relative short cold trapping period, a purity level below 10 ppm. It is therefore assumed that the sodium oxygen level has been less than 10 ppm in the previous tests despite the sodium analysis indicating the contrary; and that the current baseline data test is being conducted in sodium of reactor purity. Both MPS-1 and MPS-3 loops have been modified as shown in Figure 9. MPS-2 will be modified at the earliest convenient time. Results of the stress relaxation tests in MPS-1 have given quite erratic relaxation curves. The causes of this behavior were thought to be friction in the extensometer system and a lack of sodium temperature stability at the test sample. The temperature deviations were attributed mainly to variations in line voltage during the day, and also the effect of changes in the ambient temperature on the thermal balance of the loop. A controller with automatic reset capability was substituted for the previously used manual reset controller. The friction of the extensometer system has been reduced by increasing the clearance between rods and tubes. The previous problem where sodium vapor condensed and froze the extensometer movements will be avoided by keeping the system heated above the freezing point for sodium, and the use of LVDT's capable of operating to 500°F.

The Strain Cycle Fatigue Test System (MPS-3) has been delayed due to a necessary modification to the ramp generator module on the MTS fatigue machine to be carried out by MTS. The loop part of the test system is essentially finished, and will be started up shortly to be checked out independently. The fabrication of the test chamber for MPS-3 is complete, and it will be connected to the sodium loop in the near future.

Figure 9. MPS Sodium Loop with Modified No. 2 Cold Trap System

Test Results

Results of the last stress-relaxation run in MPS-1 are shown in Figures 10 and 11. Figure 10 shows that the two relaxation curves are quite erratic, even though Run II was better than Run I. The causes for the erratic behavior are thought to be friction in the extensometer system and lack of temperature stability on the test sample. Both of these problems will be reduced substantially in the next run. Figure 11 shows the load/strain curves obtained during loading of the test sample and Young's Modulus values calculated from the elastic portions of the curves.

A short-time creep-rupture test of annealed 316 stainless steel bar (0.25-inch dia. x 1.00-inch gage length) was performed at 1200°F and 39,000 psi to determine the operation performance of the MPS-2 system. The results are presented in Figure 12. No problems were encountered except for a small displacement of the initial strain value during loading. An evaluation is being performed but the displacement appears to be related to friction in the extensometer rods and tubes.

Currently a long-term creep-rupture test is being conducted in MPS-2 with an unexposed, annealed 316 stainless steel rod sample.

Figure 10. Stress Relaxation Curves Obtained for Annealed 316 Stainless Steel Rod at 1200°F in Flowing Sodium

Figure 11. Loading Curves for Stress-Relaxation Tests (See Figure 10)

Figure 12. Creep-Rupture Curve for Annealed Type 316 Stainless Steel at 1200°F and 43,200 psi in Flowing Sodium (MPS-2)

3796-12

SECTION 6

NCAA-600 SPECIAL COMPONENTS MECHANICAL PROPERTIES IN SODIUM

E. C. Bishop, J. C. Cwynar, and P. N. Flagella

OBJECTIVE

The objective of this task is to isolate and define the effect of prolonged exposure to dynamic sodium under mass transfer conditions on the mechanical behavior of special component configurations required for fabrication of the FFTF and LMFBR demonstration plant.

PRIOR WORK

A general review of design oriented reports for the FFTF and LMFBR systems was conducted in an effort to identify fractional component configurations requiring mechanical property testing in dynamic sodium; in addition, discussions have been held with LMFBR and FFTF design engineers, and stress analysis conducted on a continuing basis with the same objective in mind. Two fractional components tentatively identified for mock-up testing in sodium are:

1. Tube-to-tubesheet weldment (FFTF and LMFBR)
2. Fuel pin support grid structure (LMFBR)

CURRENT PROGRESS

Because of the urgency connected with initiating characterization of PEL-1-1 samples in support of the NCAA-400 task, a major emphasis was placed in this area in preference to the NCAA-600 task effort during the early part of this period. The latter third of the period was spent in preparing a Sodium Technology Program work plan per AEC directive.

During this reporting period, a discussion was held with LMEC to ascertain whether any of their work would aid in achieving the objective of this task. Two contracts held by LMEC were identified as pertinent:

1. "Technical Liaison for Materials and Process Development" (189 No. 13291)
2. "Component Materials Management and Control" (189 No. 13293)

The objective of Item (1) is to determine the needs of component designer-fabricators for data on material properties, and to guide experimental programs toward satisfying those needs by monitoring the materials testing

activities. The objective of Item (2) is to provide specimens of characterized materials for all tests made to determine properties of component material and fabricated elements for LMFBR service. These contracts may also aid in fulfilling the objectives of the NCAA-400 task.

It was also suggested that ORNL be contacted concerning a contract to study structural high temperature design methods for LMFBR core structures to determine if they have identified any specific design configurations in need of testing.

A series of meetings was held with FFTF design engineers encompassing the following component areas of the FFTF reactor:

1. Core Components
 - a. Driver Fuel Assembly
 - b. Radial REflector Assembly
 - c. Radial Shield Assembly
 - d. Control Rod Assembly
2. Reactor Internals
 - a. Core Restraint Mechanism
 - b. Core Support Structure
 - c. Instrument Tree
3. Coolant Transport System
 - a. Pump
 - b. Valves
4. Heat Transfer System
 - a. Intermediate Heat Exchanger (IHx)
 - b. Dump Heat Exchanger (DHx)
5. Irradiation Testing System
 - a. Closed Loop Assembly

The purpose of these meetings was twofold:

1. Gain familiarity with, and determine the status of the current component designs.
2. Obtain the design engineers opinions concerning areas of in-sodium effects requiring experimental investigations to guarantee a reliable component design.

In the case of components listed under Items (1), (2), and (5) above, the meetings were quite successful in that preliminary design drawings and the expected environmental conditions were obtained. These drawings are being reviewed in order to identify potential problem areas associated with a sodium exposure. Once potential problem areas have been identified, review meetings will again be held with the cognizant design engineer to obtain comments. In the case of components under Items (3) and (4), designer-fabricators will be selected shortly by RDT. At that time a more complete review of the component design will be possible. Nonetheless, conceptual designs were obtained for review and will suffice, in some cases, to identify potential problem areas. An example of one such case would be the tube-to-tubesheet weld in the IHX.

SECTION 7

SUMMARY OF WORK PLAN PREPARATION

W. E. Ray

The portion of this reporting period after May 25 was devoted to preparation of a Westinghouse statement of the required national program on LMFBR coolant technology in six specified areas:

1. Out-of-Pile 304/316 Testing
2. Advanced Fuel Cladding
3. Steam Generator Materials
4. Wear and Erosion of Materials in Sodium
5. Fractional Components Testing
6. Radioactive Repair Engineering

All were prepared in accordance with a Coolant Chemistry Branch format for work plan preparation and, per directive, to an annual expenditure level not in excess of \$5,000,000.

Submittal of the work plans was made to the Coolant Chemistry Branch on July 15. Four volumes were involved, the titles of which were as follows:

- Volume 1: SODIUM TECHNOLOGY PROGRAM WORK PLAN - SUMMARY
- Volume 2: SODIUM TECHNOLOGY PROGRAM WORK PLAN - PROJECT PLANS
- Volume 3: SODIUM TECHNOLOGY PROGRAM WORK PLAN - APPENDIX A -
SUPPORTING DATA
- Volume 4: SODIUM TECHNOLOGY PROGRAM WORK PLAN - APPENDIX B -
PROPRIETARY SUPPORTING DATA

Unfortunately, it was not possible to meet the objectives identified by the Coolant Chemistry Branch Steering Committee during its meeting in San Francisco in April 1970.

In many instances, schedule and/or cost restraints necessitated abbreviated coverage of a subject area or a change in technical direction from that which was originally recommended. To illustrate, a surveillance program was identified in the 304/316 testing program which extends beyond the specified project end date of Fiscal Year 1972; and it was recommended that "alternate" rather than "advanced" fuel cladding be investigated under Project 2.

SECTION 8
LIST OF REFERENCES

1. "Sodium Technology Program Quarterly Progress Report for the Period Ending March 31, 1970," WARD-4173-1, (May 1970).
2. "Sodium Components Development Program: Mass Transfer Investigations in Liquid Metal Systems," Quarterly Progress Report No. 6, June-August, GEAP-5693, (1968).
3. E. J. Dublis and G. V. Smith, "Identification and Mode of Formation and Resolution of Sigma Phase in Austenitic Chromium-Nickel Steels," ASTM Special Technical Publication No. 110, (June 1950).

DISTRIBUTION LIST FOR REPORTS TO
BE DISTRIBUTED BY DTIC FOR CONTRACT AT(30-1)-4173

Assistant Director, RDT,
Pacific Northwest Programs
U.S. Atomic Energy Commission
Post Office Box 550
Richland, Washington 99352

Assistant Director for Reactor Technology (2)
Division of Reactor Licensing
U.S. Atomic Energy Commission
(BETH-010)
Washington, D. C. 20545

Director (2)
Division of Reactor Standards
U.S. Atomic Energy Commission
(BETH-010)
Washington, D. C. 20545

U. S. Atomic Energy Commission
Washington, D. C. 20545
Attention: Library (2)

RDT Site Office
U. S. Atomic Energy Commission
Idaho Operations Office
Post Office Box 2108
Idaho Falls, Idaho 83401

RDT Site Office
U.S. Atomic Energy Commission
Argonne National Laboratory
9800 South Cass Avenue
Argonne, Illinois 60439

RDT Site Office
U.S. Atomic Energy Commission
Post Office Box 1446
Canoga Park, California 91304

RDT Site Office
U.S. Atomic Energy Commission
310 DeGuigne Drive
Sunnyvale, California 94086

RDT Site Office
U.S. Atomic Energy Commission
Post Office Box X
Oak Ridge, Tennessee 37830

RDT Site Office
U.S. Atomic Energy Commission
Post Office Box 154
Madison, Pennsylvania 15663

RDT Site Office
U.S. Atomic Energy Commission
Post Office Box 2325
San Diego, California 92112

Director (1)
Project Manager, FFTF (5)
Pacific Northwest Laboratory
Battelle Memorial Institute
Post Office Box 999
Richland, Washington 99352

Director (4)
LMFBR Program Office
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Associate Director (5)
Engineering Research &
Development
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Director, K. Division (2)
Los Alamos Scientific Laboratory
Post Office Box 1663
Los Alamos, New Mexico 87544

Assistant Director (RDT) (2)
Oak Ridge National Laboratory
Union Carbide Corporation
AEC Operations
Post Office Box X
Oak Ridge, Tennessee 37831

Director (5)
Liquid Metal Engineering Center
Post Office Box 1449
Canoga Park, California 91304

Manager
Idaho Nuclear Corporation
Post Office Box 1845
Idaho Falls, Idaho 83401

Superintendent
Metallurgy Division
U.S. Naval Research Laboratory
Washington, D. C. 20390

Research Director
Albany Metallurgy Research Center
Bureau of Mines
U.S. Department of the Interior
Post Office Box 70
Albany, Oregon 97321

Head Metallurgy and Materials Science
Division
Department of Applied Science
Brookhaven National Laboratory
Upton, New York 11973

Office of Vice President
Atomic Power Development Assoc., Inc.
1911 First Street
Detroit, Michigan 48226

Westinghouse Electric Corporation
Tampa, Florida 33616

Foster Wheeler Corporation
100 South Orange Avenue
Livingston, New Jersey 07039

Mine Safety Corporation
Division of Mine Safety Appliances
Company
Evans City, Pennsylvania 16033

Byron Jackson Corporation
Post Office Box 2017
Terminal Annex
Los Angeles, California

Atomics International
A Division of North American
Aviation, Inc.
Office of the President
Post Office Box 309
Canoga Park, California 91304

Chief Project Manager
Fast Reactor Components Power
Generation Division
The Babcock and Wilcox Company
Barberton, Ohio 44203

The Babcock and Wilcox Company (2)
Power Generation Division
Post Office Box 1260
Lynchburg, Virginia 24505
Attention: Librarian

Associate Manager
Materials Engineering Department
Battelle Memorial Institute
Columbus Laboratory
505 King Avenue
Columbus, Ohio 43201

Combustion Engineering, Inc. (2)
Office of the Vice President
Nuclear Division
Post Office Box 500
Windsor, Connecticut 06095

Manager, Advanced Reactors
Division (3)
Westinghouse Electric Corporation
Power Systems
Post Office Box 158
Madison, Pennsylvania 15663

Gulf-General Atomic, Inc.
Office of the President
Engineering Division
Post Office Box 608
San Diego, California 92112

General Manager (3)
Breeder Reactor Development Operation
General Electric Company
310 DeGuigne Drive
Sunnyvale, California 94086

Chairman
Department of Nuclear Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Nuclear Materials and Equipment Corp.
Office of the President
Apollo, Pennsylvania 15613

Manager, Research
United Nuclear Corporation
Grasslands Road
Elmsford, New York 10523

Distribution to UKAEA under
UKAEA/USAEC Fast Reactor Exchange

Development Contracts Division (2)
U.S. Atomic Energy Commission
New York Operations Office
376 Hudson Street
New York, New York 10014