LIQUID METAL FUEL REACTOR EXPERIMENT

MONTHLY PROGRESS STATEMENT

SEPTEMBER, 1957

AEC CONTRACT NO. AT(30-1)-1940
B&W CONTRACT NO. AEJ-46

SUBMITTED TO THE
UNITED STATES ATOMIC ENERGY COMMISSION
BY
THE BABCOCK AND WILCOX COMPANY

LMFRE MONTHLY PROGRESS STATEMENT
No. 10 SEPTEMBER, 1957 BAW-1029

TABLE OF CONTENTS

I. SUMMARY

It was agreed at a Brookhaven National Laboratory meeting to delay the containment material suitability program.

The Cook Electric Company started preliminary welding work on Croloy 2-1/4 strip.

Comparison of the second two-dimensional calculation (using the CURE Code - LMFR06) with the equivalent one-dimensional calculation established that the latter overestimates flux in the reflector and outer core region.

The Spectral Code(P) was modified to replace the uniform inelastic scattering model with the evaporation model. A preliminary comparison indicates the contribution of inelastic scattering to k_{eff} of the reference design is 70 percent greater using the latter model.

A criticality calculation based on a clean critical concentration of $N(25)/N(Bi) = 710 \times 10^{-6}$ indicates the critical diameter for pure graphite side and end reflectors is about 45 inches.

Attempts to run a core transit case produced the same wild oscillations in core pressure as previously obtained.

The fast and slow neutron flux distribution in concrete shielding surrounding the reactor was obtained; the resulting relaxation length of thermal neutrons is about 8 cm.

A preliminary estimate of instrumentation requirements for the Critical Experiment was made and specifications for long-delivery items were sent to manufacturers. Preliminary specifications for reactor tables and drive mechanisms were prepared and cost estimates obtained from vendors.

Reference design core modifications were completed, and side reflector drawings are being revised.

The basic graphite R&D program has been altered slightly to save time and money. All test blocks for this program should be ordered by November 15.

Preparations are being made for a graphite cemented joint test program and studies to determine whether core and/or side reflector mock-ups are necessary.

Copies of a revised reference reactor drawing were distributed.

The initial U-235 concentration was determined to be about 800 ppm by weight. This concentration will require an active core diameter of 45 to 47 inches.

On August 19 the A. D. Little Company began a study phase to develop a continuous uranium monitor for the LMFRE.

A sodium-to-air heat exchanger was investigated for use in place of the steam system.

Studies on a U-Bi to air-to-air heat transport system were completed and cost comparisons made.

An air-cooled condenser was investigated for use in place of the water-cooled condenser and cooling tower scheme presented in the Reference Design Report (BAW-1019).

Complete Phase IA plant arrangement drawings were prepared.

The overhead-bridge manipulator maintenance scheme shows promise of becoming more attractive (technically and economically) than the rotating plug-cylindrical cell concept.

Development of a liquid-metal column control rod continues.

Eleven persons from Walter Kidde Nuclear Laboratories are now assigned to the project in Lynchburg.

Chemical research budget and schedule estimates were revised.

Reproducibility has been outside the limits felt necessary for the analysis of chromium in bismuth.

Erratic behavior has been experienced in Brookhaven's method for spectrographic determination of zirconium and magnesium; an investigation was initiated to develop a better method.

Testing of Croloy 1-1/4 and Croloy 2-1/4 in a liquid-metal atmosphere at 885 and 975 F, will begin the first week in October. All material ordered has been received except the Brown Recorder. Assembly work on all auxiliary equipment was completed and water and lines were installed.

At a meeting in Lynchburg, test specifications for the Materials Testing Loops were changed and the zirconium concentration reduced from 250 ppm to a maximum of 175 ppm. Two of the modified pumps were received from the Deming Pump Company and installed on the two normalized and tempered loops Loop No. 3 is now in operation and Loop No. 2 will be started about the second week of October. Fourteen more bismuth pumps were returned to Deming for modification.

Work on the statistical program progressed and sixty tests have been completed. A review of test data indicates that future tests should be run for a longer period of time because weight changes varying by small amounts affected the total loss received from short-time test periods.

Eighteen of the present 20 stations are now in operation (long-period test) with new concentration levels of 1150 ppm uranium, 350 ppm magnesium, and 175 ppm zirconium.

Solubility tests employing two levels of additives are being run in the two remaining tilting furnaces.

The Utility Loop was in continuous operation during the month. At the month's end, a total of 830 hours had been logged, 250 of these at ΔT of 135 F. Latest heat-transfer coefficient for the regenerative type heat exchanger indicates no improvement.

A seven pound lot of extruded beryllium pipe and plate has been ordered for welding experiments (reactor port thimble joints).

Continued testing for bismuth weepage through graphite indicates that bismuth oxide forms an impervious skin barrier, preventing bismuth from penetrating the graphite. The situation was cleared up by switching to argon gas and purging the pores of the graphite. This points out that weepage testing must be done in a vacuum under controlled conditions; design work is in progress to convert the screening test apparatus accordingly.

Developmental work on welding procedures enabled us to complete, to a partial degree of satisfaction, a weld in 6-1/2 in. OD x 5/8 in. wall carbon steel pipe using carbon steel wire. Welding 360 degrees for a full circumferential pass has proven difficult so an alternate method of welding 180 degrees from top to bottom is being considered now.

Equipment on order includes (1) a motorized pipe cutting and beveling machine which will be modified to carry the arc welding equipment around the circumference of a positioned pipe and (2) a constant potential adapter unit (for use with a D. C. welding generator) to improve arc control.

Welds made by induction heat without forging pressure would greatly simplify this method for remote application; this possibility will be studied in the future.

Solubility studies of fission and corrosion products in five percent inhibited HCl and fused Hooker salt indicate that most fission and corrosion products cannot be dissolved in these reagents.

Final sampler design for Radiation Test Loop No. 1 (BNL) is in process.

Test valve on-site fabrication is complete.

Final approval of the melt and dump tank has been given.

Detailed design of Radiation Test Loop No. 2 (ETR) has advanced enough to allow some component fabrication.

A Radiation Test Loop No. 3 (MTR) flux measurement made to determine suitability of MTR facility HG-5 resulted in a value of 1.36×10^{13} n/cm^2/sec.

Most of the project contracts for the 4-in. Utility Test Loop (BNL) have been renegotiated.

A sodium cold trap has been designed and fabrication started.

Completed Phase IA design for Reactor Building. A Phase IA cost estimate reduced costs for plant acquisition and construction to about one-half the Phase I estimate.

A shielding concrete study was started and various high-density concrete tests have been scheduled by the physics section.

II. ADMINISTRATION

1. Executed a contract with Arthur D. Little, Incorporated, for study of a continuous uranium monitoring instrument.

2. Met with AEC site selection committee to prepare a recommendation of a site for the LMFRE.

3. Prepared revised cost estimates and schedules for the project.

4. Secured a subcontract with Walter Kidde Nuclear Laboratories, Inc., for a study of remote maintenance procedures for the LMFRE.

III. RESEARCH & DEVELOPMENT COORDINATION (J. P. Holliday)

A. MATERIALS

1. Graphite outgassing and sump penetration preliminary test specifications were prepared. Testing will be done on small samples at B&W's Alliance Research Center beginning December, 1957.

2. Comments on reactor core specifications were submitted to the LMFRE Reactor Design group.

3. Requests for quotations on graphite samples for sump penetration tests, graphite-to-metal seal tests, alternate impregnation tests, and carbide formation tests were submitted to the Purchasing Department. Justification for purchasing this graphite from three vendors also was submitted to Purchasing.

4. The Graphite R&D program was discussed with B&W personnel in Alliance; information developed on the graphite-to-metal seal program, bismuth weepage determinations, thermal conductivity, and thermal expansion determinations. Results of these discussions have been reported.

5. Work to be done on beryllium tubes was discussed on visits to the Research Center and Brush Beryllium Company. These tubes are intended to be used for control rod liners and in-pile test thimbles in the LMFRE core. Brush Beryllium Company will quote on development of extruded tubing and the Research Center will work concurrently on mechanical seals and the welding of beryllium.

6. Information on the feasibility of plating Croloy steels with molybdenum was developed through discussions with Metals Research and Development, Inc. They believe that their electroless method of plating metals like nickel and cobalt may be applicable to molybdenum.

Information on molybdenum vapor deposition was requested from Battelle Memorial Institute and arrangements were made to discuss their methods during an October visit.

7. Selection of suitable chemical processing containment material was discussed at a BNL meeting. It was agreed to delay the material suitability program until more is known about the chemical processing system to be used.

8. A meeting was held with Research Center representatives to determine operating conditions for the first four Croloy 2-1/4 corrosion loops. Cleaning methods, additive concentrations, and preconditioning methods were discussed and selected. A letter describing these parameters was issued.

9. Samples of Croloy 2-1/4 containing a high N to Al ratio were requested from Jones-Laughlin Steel and will be forwarded to the Research Center for use in the Zr-N Film Theory Program.

B. COMPONENT DEVELOPMENT

The Powell Valve Company was visited to discuss 1-in. globe valves and a 2.5-in. dump valve. A Cook Electric Company representative discussed

Croloy 2-1/4 bellows fabrication at this meeting. Cook Electric was then sent some Croloy 2-1/4 strip and has started preliminary welding work. Powell Valve Company agreed to quote on 1-in. Croloy 2-1/4 valves with Croloy 2-1/4 bellows.

C. RESEARCH INITIATED

1. These requests for initiation of research programs were reviewed and forwarded for approval:

a. Corrosion characteristics of a Pb-Mg Eutectic.
b. Solubility of U in Bi.
c. Gas permeability of coated graphite.
d. Na-Bi reactions.
e. Rate of U-C formation.
f. Testing of valve bellows.
g. Mechanical properties, penetration, and absorption testing of a new graphite.
h. Diffusion of U into Bi-impregnated graphite.
i. Precipitation characteristics of U-Bi in heat exchanger tubes.
j. Electrolytic addition of U, Zr and Mg in Bi.

2. Objectives of U solubility research and scope of work to be done at B&W's Alliance Research Center were discussed with Alliance representatives; preliminary studies have been initiated.

3. The Research Center was asked to conduct preliminary tests on Na-Bi mixing reactions. The total program, under which all aspects of such a reaction will be analyzed, was discussed. The need for this work is based on the possibility of Na leaks in the intermediate heat exchanger.

D. UTILITY TEST LOOP

A tentative list of inspections which B&W would like to perform on components of the 4-in. Utility Test Loop was compiled and sent to B&W's BNL representative for forwarding to the BNL personnel concerned.

E. SPECIFICATIONS

Of the five specifications received this month, two were final, requiring no comments, and one already had been issued without soliciting comments. Preliminary specifications for uranium-aluminum foils and the reactor vessel were reviewed and appropriate comments prepared.

IV. LMFRE REFERENCE DESIGN STUDIES

A. PHYSICS AND MATHEMATICS (T. C. Engelder)

1. Reactor Statics

a. The second two-dimensional calculation using the CURE Code (LMFR06) was run and the results analyzed. Comparison with the equivalent one-dimensional calculation established that the latter over-estimates the flux in the reflector and outer core region.

b. The five additional two-dimensional cases described in the August Monthly Progress Statement (BAW-1028) were re-evaluated, and the preparation of input data is essentially complete.

c. Work continues on the treatment of inelastic scattering in bismuth. The Spectral Code(P) was modified to replace the uniform inelastic scattering model with the evaporation model. A preliminary comparison of these models indicates that the contribution of inelastic scattering to the k_{eff} of the reference design is 70 percent greater if the evaporation model is substituted for the uniform scattering model. For the latter model, k (inelastic scattering) = 0.05.

A hand calculation was made to compare the evaporation model to the more realistic "evaporation-discrete interval" scattering model. The evaporation model is used for neutron group energies greater than 2.6 Mev and the measured cross-sections corresponding to the discrete excitation levels in bismuth are used below 2.6 Mev. The two approaches compared favorably.

d. The positive xenon temperature coefficient was recomputed, for the case of no xenon removal, using the mean of the steady state values of the Xe-135 concentration at the core inlet and outlet. The resulting temperature coefficient is $+2.2 \times 10^{-5}$/C, or about 45 percent of the prompt negative temperature coefficient.

e. The U-235 addition necessary to over-ride fission product poisoning was checked by raising the thermal cut-off energy from 0.07 ev to 0.2 ev. This change increased the required U-235 addition by only 10 ppm. Detailed information on the resonance structure of the fission products would be necessary to refine this approach.

f. In view of recent uranium solubility data in the presence of zirconium and fission products, a criticality calculation was made on the basis of a clean critical concentration of $N(25)/N(Bi) = 710 \times 10^{-6}$. For pure graphite side and end reflectors, the critical diameter is about 45 inches, or about four inches greater than the case of $N(25)/N(Bi) = 1000 \times 10^{-6}$.

2. Reactor Dynamics

a. The re-formulated core kinetics code was completed and

and checked out. Simple test cases have been run using both the Predictor-Corrector and the more accurate Runge-Kutta method. The agreement is excellent and the saving in computer time is about 50 percent.

b. Attempts to run a core transient case produced the same wild oscillations in core pressure as previously obtained. Neither an improved equation nor modified constants eliminated this difficulty. A modification of the program is being made to improve the accuracy of the fuel temperature and density calculations since the pressure is strongly dependent on these values.

c. Work continues on a mathematical investigation of the stability of the set of core kinetics equations referred to in 2. a. The procedure is to linearize the equations, obtain the matrix elements from the coefficients of the variable terms, and obtain the eigenvalues of the matrix. The stability of the system is then inferred from the signs of the eigenvalues. A program is being written to obtain these eigenvalues.

3. Shielding Calculations

a. The fast and slow neutron flux distribution in the concrete shielding surrounding the reactor was obtained from a multi-group multi-region calculation normalized to 20 MW heat. The resulting relaxation length of thermal neutrons is approximately 8 cm.

b. Work began on a calculation of neutron flux in the concrete shielding surrounding the primary system. In this case, the neutron source will have a delayed neutron spectrum.

4. Critical Experiment

a. The neutron source requirement has been estimated to be about five curies of Po-Be on the basis of a two-group two-region diffusion calculation. To improve this estimate, efforts are being made to evaluate the thermal leakage current from a parallelepiped with a point source of fast neutrons at one face.

b. A preliminary estimate of instrumentation requirements was made, and specifications for long-delivery items were sent to manufacturers.

c. Preliminary specifications for the reactor tables and drive mechanism were prepared and cost estimates obtained from vendors. Final drawings are being made.

d. Preliminary specifications were sent to vendors for U-Al foil, core and reflector graphite, bismuth, fuel channels (aluminum or graphite), control rods, and test hole liners. Replies from the vendors of U-Al foil and reflector graphite have been received and are being evaluated.

B. REACTOR ENGINEERING (J. J. Happell)

Reference design core modifications are complete. The side reflector drawings are being revised; prints and descriptive text will be published soon.

Vendor specifications for a test block (40-in. diameter x 32-in. length) for the graphite R&D program are complete and awaiting approval. Similar specifications will be written to cover test blocks from other vendors, and all blocks should be ordered by November 15.

The basic graphite R&D program has been altered, as outlined below, to save time and money.

1. Request vendors to manufacture large blocks and submit a portion of

the block for a test program involving:

a. bismuth absorption
b. bismuth weepage
c. nuclear cross-section
d. density

2. Select the graphite for use in the LMFRE based upon these test results.
3. Request the chosen graphite vendor to submit the rest of the block for an extensive physical property test program.

The remainder of the test program (seals, cemented joints, carbide reaction rates, etc.) will be carried out as originally planned by ordering suitable samples from each vendor.

Preparations are under way for (1) a graphite cemented joint test program, and (2) studies to determine whether core and/or side reflector hydraulic mockups are necessary. Discussions will be held with members of the B&W Reactor Design Section and the Alliance Research Center.

Based upon the engineering work to date, a revised reference reactor drawing was completed and copies are being distributed.

A revised reactor principal events schedule has been completed, including R&D.

Revised fission product buildup curves were completed for cases involving various amounts of U-Bi absorbed in the core graphite. The results indicate effects are not important for 20 MW-years of operation, and that the assumption of no U-Bi absorption is the most conservative from a design fuel concentration standpoint.

Due to the reduced solubility of uranium, as reported by BNL metallurgy memo No. 696, and a re-evaluation of the solubility safety margin, the initial U-235 concentration was determined to be about 800 ppm by weight. The physics section reported that an active core diameter of 45 to 47 inches will be required at this concentration.

Shielding and dose rates were completed for ETR test loops and components.

Information is being gathered from past studies of liquid metal control rods. Calculations are also underway to determine cooling rates required for solid tantalum and molybdenum rods.

Preliminary seal test results at B&W's Alliance Research Center are encouraging. Small size graphite metal compression seals can be made using 600 psi contact stress.

Work has been initiated to determine the effects of U-Bi absorption in thick core sections with respect to reductions in the thermal conductivity of graphite.

On August 19 the A. D. Little Company began a study phase to develop a continuous uranium monitor for the LMFRE. A meeting was held September 17, 18, and 19 to discuss the applicable methods and to review the scope of the work. B&W's Alliance Research Center personnel were also in attendance since they have devoted considerable effort to the analysis of uranium in bismuth solution.

Possible methods which may be adapted to uranium monitoring and which will be investigated by A. D. Little include:

a. magnetic susceptibility
b. nuclear magnetic resonance
c. x-ray absorption
d. x-ray fluorescence
e. polarography (voltammetry)

f. electrolysis
g. electro potential methods
h. neutron absorption
i. sub-critical multiplication

This study program should be completed by December 16 at which time a comprehensive report will be issued and preliminary design of a prototype should begin.

A preliminary specification for the reactor nuclear instrumentation has been completed and should be sent to various vendors for proposals next month. This specification covers only the conventional; i.e. standard temperature detectors and instrumentation. High-temperature neutron detector development will be handled under a separate subcontract. Reactor control specifications will be issued after the control scheme has been formulated.

The systems analysis (analogue) studies contract was completed and negotiations with the selected vendor should be initiated by the Purchasing Department early next month. The initial studies have been outlined by the system analysis committee and include analysis of the primary loop and its associated components.

Selected vendors were contacted to obtain pertinent information on their proposals for high-temperature neutron detectors. The proposals and the scope of work involved are being re-evaluated with the hope that contract negotiations can be started during the last quarter of 1957.

C. SYSTEMS ENGINEERING (S. S. Waldron)

1. Coordination of R&D scheduling with LMFRE engineering schedules was investigated.
2. Negotiations continue for procurement of valves and instruments for the 3/4-in. utility test loop.
3. A purchase order for one pump was submitted for AEC approval and engineering negotiations with another supplier continue.
4. Specifications on degasser sparger plate tests were submitted for comment.
5. The following R&D initiation requests were submitted for approval:
   a. Precipitation characteristics of U-Bi in heat exchanger tubes
   b. Corrosion testing of Pb-Mg eutectic
   c. Bellows testing
6. A sodium-to-air type heat exchanger was investigated for use in place of the steam system.
7. Studies on a U-Bi to air-to-air heat transport system were completed and cost comparisons made.
8. An air-cooled condenser was investigated for use in place of the water-cooled condenser and cooling tower scheme presented in the Reference Design Report (BAW-1019).
9. A comprehensive comparison of five alternate heating and cooling schemes was initiated; final selection is expected in October.
10. Complete Phase IA plant arrangement drawings were prepared, covering important revisions for a more economical plant.

D. MECHANISMS ENGINEERING (G. R. Winders)

The overhead-bridge manipulator maintenance scheme being developed for the LMFRE shows some promise of becoming technically and economically

more attractive than the rotating plug-cylindrical cell concept presented in the Phase I and IA reports to the USAEC. Modifications of this scheme are being utilized to explore its feasibility for a full-scale LMFR central station power plant.

A liquid-metal column control rod is being developed to operate on the principal of displacement of a confined fluid up into an annulus around a plunger tube when the tube is driven down into the fluid. The fluid will be a liquid-metal alloy with sufficient neutron capture cross-section to offer effective reactor control by precise mechanical fluctuation of the column height in each of four core rod assemblies. (P)

On September 10, six persons from Walter Kidde Nuclear Laboratories (WKNL) started work on the LMFRE. Eleven WKNL personnel are now assigned to the project in Lynchburg and three more are expected soon. WKNL's basic approach to LMFRE remote maintenance and plant layout problems is to start conceptual design work with the systems of a 550 MW central station LMFR plant. After various schemes are compared, several will be extrapolated to LMFRE layouts for further development and comparison. Another work phase would then be required for final recommendations and development of maintenance equipment specifications and cost data for the scheme selected.

E. CHEMICAL PROCESSING (R. D. Pierce)

The following research specifications were sent to the Research and Development Coordination Group:

1. Revised specifications on the dissolution rate of U, Mg and Zr in bismuth
2. Electrolytic fuel make-up methods
3. Uranium solubility with additives and fission products present.
4. Uranium oxidation rates in U-Bi solutions exposed to air

A trip was made to Armour Research Foundation to discuss uranium solubility measurements; they will forward this proposal as soon as possible.

Chemical research budget and schedule estimates were revised and issued.

Meetings were held at BNL to discuss:

1. Cost of loop N components
2. Corrosion in salt systems
3. Gaseous fission product adsorption

Work being done by Horizons for BNL was reviewed.

A report on the off-gas problem in the ETR loop was issued.

V. RESEARCH & DEVELOPMENT

A. MATERIALS TESTING

1. E-1281 Chemical Analytical Methods (W. A. Keilbaugh)

Training additional technical personnel in wet chemical procedures for bismuth analyses, was emphasized. Additional personnel, sufficiently versatile to perform several types of analyses, will help reduce time between receipt and actual sample analysis.

Developmental work continues on the corrosion products, chromium and manganese. Results indicate that testing of the manganese procedure is nearly complete. Some effort was necessary to achieve reproducible results in developing satisfactory techniques for the electrolytic separation of bismuth.

The determination of chromium in bismuth has proved troublesome. Reproducibility has been outside the limits felt necessary for this analysis. Efforts to improve the procedure continue.

Erratic behavior in Brookhaven's method for spectrographic determination of zirconium and magnesium has been experienced repeatedly; therefore, an intensive investigation was initiated to determine what caused the lack of precision and to develop a better method.

2. E-1292 ZrN Theory (F. Eberle)

Samples of four representative heats of Croloy 2-1/4 were quenched from 1700 F and are now being aged for 24 hours at temperatures varying from 700 F to 1350 F. Samples from each aging temperature will be analyzed for soluble and insoluble nitrogen and aluminum to determine the amount of nitrogen available for protective film formation at the various temperatures.

3. E-1343 Miscellaneous Materials Investigations (F. Eberle)

Progress towards testing Croloy 1-1/4 and Croloy 2-1/4 in a liquid-metal atmosphere at 885 F and 975 F has reached the following status:

1. All materials ordered have been received except the Brown Recorder - this will not hold up the job.
2. Assembly work on all auxiliary equipment was completed and water and sewer lines were installed.
3. Four test assemblies are being welded in a drybox and will be completed the first week in October, when the test program will get underway.

4. E-1316 & E-1317 Materials Testing Loops (W. Markert, Jr.)

The original test specifications for these loops were changed at a meeting in Lynchburg. Two of the pumps with the latest modifications were

received and installed on the two normalized and tempered loops. Loop No. 3 is now in operation, starting its "preconditioning" run. This loop was rinsed with alcohol (not chemically cleaned). Loop No. 2, which is also normalized and tempered and chemically cleaned, will be started about the second week of October.

Fourteen more bismuth pumps were returned to the Deming Pump Company to receive the latest modifications. These are due back at the rate of one per week starting about the first week of October.

The construction of additional loops (beyond the original sixteen) is being held up pending completion of specifications on cleaning methods. Sandblasting is being considered as another variable in the cleaning methods. If used, it would have to be done before construction of the loops can begin.

The zirconium concentration for the loops, also revised at the Lynchburg meeting, was reduced from 250 ppm to a maximum of 175 ppm.

5. E-1318 Static and Capsule Tests (W. Markert, Jr.)

Work progressed on the statistical program originally outlined and sixty tests have been completed. After this work has been processed, the Analytical Section will evaluate the tabulated weight changes.

Data compiled to date has been reviewed and it was concluded that future tests should be conducted over a longer period of time. This was felt essential because weight changes varying by small amounts affected the total loss received from short-time test periods. A long-time test cycle also would balance any initial corrosion losses that might appear exceptionally inconsistent due to varying degrees of attack in the initial period of the test. Test times considered for the program are 250, 500, 1000, and 2000 hours using the original outlined metallurgical and surface preparations. To secure data in a reasonable period of time and still conduct all necessary outlined tests, material for twenty more capsule stations has been ordered.

Eighteen of the present 20 stations are in operation on the long-period test with new concentration levels of 1150 ppm uranium, 350 ppm magnesium, and 175 ppm zirconium.

Honed capsules and electropolished specimens of known surface conditions were prepared and four units are now ready for cycling in bismuth.

Solubility tests employing two levels of additives are being conducted in the two remaining tilting furnaces. These tests will be for 48, 96, and 192 hour periods at a temperature of 750 F, followed by a 48 hour isothermal treatment at 750 F prior to quenching.

Eight capsules have been hydrogen fired and are being prepared for their portion of the outlined program.

B. PROTOTYPE TESTING

1. E-1288 Utility Loop (W. Markert, Jr.)

This test was in continuous operation during the month. At the month's end, a total of 830 hours had been logged. 250 of these at a ΔT of 135 F. The latest heat-transfer coefficient for the regenerative type heat exchanger does not indicate any improvement.

The past several weeks, the loop has been operated essentially isothermally due to the "common" center electrode connector on the main

heater running red hot during ΔT operation. It is planned to increase the cross-section of the connector at the first opportunity. (This cross-section has been increased on the corrosion loops.)

2. E-1368 Reactor Port Thimble Joints (M. Christensen)

We have explored the availability of beryllium in the tubular and rolled form desired for the LMFRE reactor and have studied existing information on the joining of beryllium. Apparently, very little has been done on beryllium to beryllium fused joints and the information available is not encouraging. However, a seven pound lot of extruded beryllium pipe and plate has been ordered for welding experiments.

3. E-1370 Graphite-to-Metal Seals (W. Markert, Jr.)

A technical report, No. 7043, on graphite-to-metal seals screening tests was completed and distributed.

Continued testing for weepage through graphite uncovered some anomalies. It appears that bismuth oxide forms an impervious skin barrier, preventing bismuth from penetrating the graphite. The situation was cleared up by switching to argon gas and purging through the pores of the graphite. This points out that weepage testing must be done in a vacuum under controlled conditions. Design work is in progress to convert the screening test apparatus to meet these conditions.

Purchase orders were let by Lynchburg for large pieces of graphite which can be used to test seals and weepage in the large testing vessel. Arrival dates were given as November 25 to December 15.

4. E-1371 Dump Valves (W. Markert, Jr.)

Work on this project has been delayed. Release to go ahead was obtained subsequent to September 30.

5. E-1373 Isolation Valves (W. Markert, Jr.)

The Wm. Powell Company was visited and negotiations made toward the purchase of a number of valves for the "in-pile" loops.

C. IN-PILE TESTS

1. E-1369 In-Pile Tests (W. Markert, Jr.)

The detailed design of radiation test loop No. 2 continues. The loop instrumentation has been ordered and fabrication of the heat-exchanger melt tank and disposal tank is under way. An apparatus has been constructed for the calibration of an EM type flowmeter. A number of runs with this apparatus will be performed to determine the integrity of the flowmeter. Fabrication of a sampling apparatus is under way. Detailed design of the in-pile test section mock-up for testing in the ETR critical facility continues. The necessary construction material has been ordered and fabrication will begin on receipt of the material.

D. CHEMICAL PROCESSING

1. E-1378 Solubility in Bismuth (W. A. Keilbaugh & W. Markert, Jr.)

A literature search for applicable test procedures to determine uranium solubility in bismuth in the presence of additives and corrosion and fission products was completed. In evaluating these methods, it was felt that the data needed could be obtained best by hot centrifuging the bismuth after an initial mixing and equilibrating period. The centrifuge equipment considered could give the desired centrifugal forces at high temperatures. While the results may not give true solubility, they should be applicable to the solubility problems involving the critical experiment.

The analysis of samples from current solubility tests has started. These tests, apart from the work described above, consist of Croloy 2-1/4 capsule tests using a semi-static autoclave type apparatus from which samples are taken.

E. INSTRUMENTATION AND CONTROL

1. E-1335 Monitoring of U-235 (W. A. Keilbaugh)

Research Center representatives attended a three day conference with Lynchburg AED personnel and A. D. Little, Inc. representatives to discuss various approaches to the continuous monitoring problem. Since A. D. Little, Inc. holds a contract to develop a method for solving this problem, the Research Center agreed to furnish them samples of uranium in bismuth, and steps were taken to prepare such samples.

The bibliography compiled during our earlier activity in this area also will be forwarded to A. D. Little, Inc.

2. E-1492 Non-Nuclear Instrumentation (W. Markert, Jr. & E. E. Coulter)

A test apparatus was built to calibrate the magnetic flowmeter which has been in operation on the utility loop. Early runs were made without a successful indication from the flowmeter. Changes are now being made to the apparatus in an attempt to assure wetting of the flowmeter section by the bismuth. Operation of the apparatus otherwise appears satisfactory.

F. REMOTE MAINTENANCE

1. E-1280 Remote Welding System (M. Christensen)

Investigation of the gas-shielded metallic-arc process for automatic butt-welding of pipe continues. The equipment consists of an Auto-Arc voltage control unit for governing arc length and a D. C. motor generator set. The present jig for rotating the welding unit about a horizontal pipe has been improvised from shop equipment merely for experimental work. Developmental work on welding procedures has enabled us to complete, to a partial degree of satisfaction, a weld in 6-1/2 in. OD x 5/8 in. wall carbon steel pipe using carbon steel wire. It has been difficult to weld 360 degrees for a full circumferential pass and an alternate method of welding 180 degrees from top to bottom is now under consideration.

We are now obtaining welding information on Croloy 2-1/4 pipe of 4-1/2 in. OD x 3/8 in. wall using 1/16 in. diameter wire of equivalent analysis. Some difficulty has been experienced in arc control and weld bead oxidation. All previous work has been done using carbon dioxide gas, but lately we have noticed a general improvement by using helium and argon additions amounting to 85 percent of the gas volume. Helium and argon of equal volumes have also been tested and show very satisfactory bead deposits in both arc control and bead protection.

Equipment now on order includes a motorized pipe cutting and beveling machine and a constant potential adapter unit for use with a D. C. welding generator. The cutting and beveling machine will be modified to carry the arc welding equipment around the circumference of a positioned pipe. The constant potential is a unit to improve the arc control.

The 300 kw high-frequency alternator has been obtained and set up, and a 50-T capacity press-type welding fixture has been built to supply forging pressure. With this combination of induction heat and forging pressure, we have been making induction-forge butt welds. To date, we have worked with only one pipe size and have fabricated an inductor that produces a heat pattern in the work piece conducive to satisfactory welds. Much further experimentation and study are necessary to establish a set of parameters that will produce consistently good welds in this pipe size. Data are currently being obtained to observe the effects of variations of welding current, voltage, time, pressure, joint design, inductor design, and other pertinent factors that influence the quality of the induction weld. Future study will include welds made by induction heat without forging pressure. This would greatly simplify this method for remote application. To date only carbon steel has been used in these experiments. We have ordered Croloy 2-1/4 pipe from Beaver Falls.

2. E-1282 Cleaning and Decontamination (W. A. Keilbaugh)

Solubility studies of fission and corrosion products in five percent inhibited hydrochloric acid and fused Hooker salt are in progress and indicate that most fission and corrosion products cannot be dissolved in these reagents. Attempts to solubilize these materials continue.

VI. RADIATION LOOP TESTING (E. E. Walsh)

A. RADIATION TEST LOOP NO. 1 (BNL)

Final sampler design is complete, based on mock-up testing information, and fabrication is in process.

Main circulating pump canning has been completed and the pump installed in a testing loop.

February 1957 delivery of valves is still a problem. However, on-site fabrication of a test valve is complete and testing will coincide with the main circulating pump test.

The in-pile section is ready for assembly except for beryllium test specimens.

The regenerative heat exchanger fabrication is in process. Tube sheets, tube supports, shell return bend, shell spacers, reducers, and inlet and outlet nozzles have been fabricated. The nozzles have been welded to the shell, the welds are being radiographed, and tube-to-tube sheet attachment mock-up is under study. The pipe and Croloy 2-1/4 billets for the induction furnace are being processed for this component's assembly.

Croloy 2-1/4 pipe for the loop cooler has been finned and sand blasted. The tees have been machined and welded to the cooler shell and shell end plates and bellows containment have been fabricated.

Final approval of the melt and dump tank has been given. Fabrication of the carbon steel containment and tank support is in process.

B. RADIATION TEST LOOP NO. 2 (ETR)

Detailed design of this system has advanced and fabrication of some components started.

System instrumentation and primary system valves have been ordered.

Equipment necessary to calibrate an electromagnetic type flowmeter is being constructed.

A liquid-metal sampler mock-up is under construction.

The in-pile section mock-up design is progressing and will be installed in the ETR Critical Facility so reactivity measurements can be made.

C. RADIATION TEST LOOP NO. 3 (MTR)

A flux measurement in an adjoining vertical hole was made to determine suitability of MTR facility HG-5 for an in-pile U-Bi loop. Flux value obtained was 1.36×10^{13} n/cm^2/sec. Influence of this flux on system design and the value of an experiment at this level is under consideration.

D. 4-INCH UTILITY TEST LOOP (BNL)

Most of the project contracts have been renegotiated and should be completed soon.

Size of the furnace burners and cooler fans has been adjusted, allowing loop operation at a temperature differential of 75 C (2.5 MW) instead of 150 C (5.0 MW) as originally planned.

The control system has been revised to allow closer duplication of the thermal aspects of LMFRE operation and cost of the additional instrumentation necessary has been obtained.

A hazards review of sodium use in the system's secondary side is in progress.

Test work has started on the reaction between sodium and bismuth at loop operating temperatures.

A sodium cold trap has been designed and fabrication started.

A complete loop component inspection list has been compiled and respective vendors advised of this requirement.

VII. BUILDINGS, GENERAL SERVICES, AND SITE DEVELOPMENT (J. D. Kenney)

Phase IA design for the Reactor Building was completed. Floor plans, elevations, and two sections were made under direction of Barberton Plant engineering personnel. A Phase IA cost estimate was completed, reducing costs for plant acquisition and construction to about one-half the Phase I estimate. Schedules for building design and construction were drawn up based on latest estimates of final Site Selection and Architect-Engineer Selection.

The BAO Construction Chief visited the project and discussed Architect-Engineer Selection, economical construction materials and procedures, and unit prices for construction cost estimating.

A shielding concrete study was started and various high-density concrete tests have been scheduled by the physics section. Analysis, source, cost, and placement methods of sample mixes are being investigated.

END