DP - 435

Reactors - Power

AEC Research and Development Report

HEAVY WATER MODERATED POWER REACTORS

PROGRESS REPORT
October 1959

Technical Division

Wilmington, Delaware

November 1959

E. I. du Pont de Nemours & Co.
Explosives Department - Atomic Energy Division
Technical Division - Wilmington, Delaware

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REACTORS - POWER
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HEAVY WATER MODERATED POWER REACTORS

Progress Report
October 1959

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Power Reactor Studies
Wilmington, Delaware

Compiled by R. R. Hood and L. Isakoff

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ABSTRACT

Continued progress is reported on the design and construction of the Heavy Water Components Test Reactor; 78% of the firm design and 17% of the construction were complete at the end of October 1959. Approximately 15% of the firm design for the isolated coolant loops of the HWCTR was also complete. The results of further fabrication tests and irradiation tests of fuel tubes of natural uranium metal are reported. One of the metal tubes failed under irradiation, while other irradiations of metal fuels progressed satisfactorily.

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HEAVY WATER MODERATED POWER REACTORS

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INTRODUCTION

A study of the production of electric power from atomic reactors that are fueled with natural uranium and moderated with heavy water was undertaken by du Pont in November 1956 at the request of the Atomic Energy Commission. This report reviews the progress of the study during October 1959. A complete review of the du Pont program and its specific objectives were given in DP-425. Earlier progress is recorded in the following reports:

DP-232	DP-375
DP-245	DP-385
DP-265	DP-395
DP-285	DP-405
DP-295	DP-415
DP-315	DP-425
DP-345	

Progress in November will be reported in DP-445.

SUMMARY

At the end of October 1959, construction of the Heavy Water Components Test Reactor was about 17% complete; firm design about 78% complete; and design of the isolated coolant loops for special irradiation tests about 15% complete. The progress of construction during October is shown in Figures 2 and 3. Early 1961 is still the goal for startup of the facility, in spite of the steel strike; however, continuation of the strike may cause the startup to be delayed.

Several functional tests of equipment and materials for the HWCTR were in progress during October. Pressure testing of a typical section of the concrete to be used for the containment building showed that leakage to the outside atmosphere through the concrete, in case of the "maximum credible accident" with the internal pressure at 24 psig, can be limited to well below 1% of the contained volume per day. Cyclic testing of the control rod and safety rod drive packages and of the gripper mechanism of the fuel transfer coffin revealed no faults to date. Flow testing of a prototype test fuel assembly continued satisfactorily. Irradiation testing of an enriched driver fuel assembly began in a Savannah River reactor.

Experimental work on the coextrusion of Zircaloy-clad tubes of uranium metal for irradiation tests was continued at Nuclear Metals, Inc. The last of a group of five tubes of unalloyed uranium clad with Zircaloy-2 failed in a 3-hour autoclave test at 345°C; only one of these five tubes

proved suitable for irradiation. Two full-size tubes with core compositions of U - 1 w/o Si and U - 1.5 w/o Mo were extruded and are being evaluated as irradiation candidates. An exploratory study was initiated to determine the feasibility of producing an alloy of uranium that will retain the beta phase under irradiation conditions. Such an alloy may offer improved dimensional stability because the creep strength of the beta phase of uranium is higher than that of the alpha phase.

A coextruded tube of U - 2 w/o Zr clad with Zircaloy-2 failed in a Savannah River reactor after modest exposure at relatively low temperature. The low temperature irradiation of another tube of U - 2 w/o Zr and a tube of unalloyed uranium continued without incident. Both of these tubes also are being irradiated at the Savannah River Plant. Four slugs of U - 2 w/o Zr were discharged from a Savannah River reactor after irradiation at temperatures in the range contemplated for a D_2O-moderated power reactor. Dimensions of these slugs, which are clad with Zircaloy-2, will be measured to supplement earlier data (DP-395) on the effect of cladding restraint on the dimensional stability of this alloy.

DISCUSSION

I. HEAVY WATER COMPONENTS TEST REACTOR (HWCTR)

The HWCTR is a test reactor in which a significant number of fuel elements will be irradiated under conditions of temperature, pressure, and neutron flux that are representative of typical D_2O-moderated power reactors. A description of the reactor was presented in DP-383[1] and in earlier progress reports. Construction of the facility was authorized by the Atomic Energy Commission in November 1958; the goal for startup is early 1961. The total cost of the facility, which is designed for a thermal output of 61 MW, is estimated to be $8,700,000, including $1,000,000 for two isolated coolant loops in which special fuel assemblies can be irradiated. A cutaway perspective of the HWCTR building is shown in Figure 1.

A. STATUS

1. Construction

At the end of October, construction of the HWCTR was approximately 17% complete. Erection of the inside and outside forms and reinforcing steel for the outer shell of the underground portion of the containment building is now nearly complete. Shoring has been installed for support of the concrete slab at the zero level floor. Pilasters for the post-tensioning cables of the concrete shell were also placed in position. The pouring of the shell is expected early in November. The progress of construction during October is shown by the photographs in Figures 2 and 3.

The steel strike is expected to delay completion of the concrete portion of the building because of delays in the delivery of the tensioning cables and their associated fittings and of the high strength bolts that are required for fastening the steel shell to the concrete. Steel plate for the building and for the reactor vessel has also been delayed considerably by the strike. The estimated date for turning the HWCTR over to the operating group is now rather uncertain; however, early 1961 may still be a reasonable date, provided steel deliveries are not further delayed.

2. Design

The following parts of the detailed design of the HWCTR were completed and approved by the Atomic Energy Commission in October: (1) all of the process piping and instrument diagrams for the reactor, (2) instrument diagrams for the flow, temperature, and activity monitoring systems of the reactor, (3) instrument diagrams for the

(1) DP-383, Preliminary Hazards Evaluation of the Heavy Water Components Test Reactor. D. S. St. John, et al., May 1959.

radiation and nuclear incident monitoring systems, and (4) instrument diagrams for the reactor nuclear instrumentation. In addition, detailed flow diagrams of part of the secondary cooling system for the reactor were issued. At the end of October firm design was approximately 78% complete.

3. Isolated Coolant Loops

During October, quotations were solicited on the cost of the bayonet pressure tubes for the two isolated coolant loops of the HWCTR. The design details of the heavy-walled Zircaloy bayonet tubes and of the other loop equipment were discussed in the last monthly report, DP-425. A program of fabrication and flow testing of a mockup of the bayonet and its associated piping was initiated during this report period at the Savannah River Laboratory. The primary purpose of the mockup tests is to determine whether or not the flow of coolant will produce any serious vibration of bayonet components. These tests are particularly important for the boiling loop, where large quantities of steam-water mixture will be flowing at high velocity. Pressure drop data for the steam-water system will also be obtained. These data are needed for confirmation of the piping design for the boiling loop.

Design effort on the isolated coolant loops was directed primarily toward completion of the final process flow diagram, completion of the process piping and instrument diagrams, and preparation of the drawings and specifications needed for procurement of critical equipment items such as pumps, heat exchangers, and the Zircaloy bayonets.

At the end of October, approximately 15% of the firm design work on the isolated coolant loops was complete.

B. COMPONENTS TESTING

1. Permeability of Concrete

Pressure testing of concrete specimens showed that the concrete part of the HWCTR building can be made sufficiently gas-tight that the leakage to the atmosphere will be within the design objective. These tests, which were conducted by the Construction Division of the Engineering Department, are described in this article.

Four concrete blocks were poured for permeability tests. One block (6 feet long, 6 feet wide, 18 inches thick) was chosen as being representative of a typical section of the exterior wall of the building. The concrete mix used for this block was the same as that specified for the wall; that is, the concrete reached a strength of 5000 psi 28 days after pouring, and contained "Plastiment" retarder and 4% entrained air. A 6-inch-diameter sleeve, similar to those that will penetrate the wall at points of piping entry, was included in the test block. In addition, the reinforcing steel in the test block approximated that which is being used in the wall of the building. Three other test blocks somewhat similar to the one just described were also manufactured, but were not considered to be representative of the concrete that will be poured for the HWCTR. Some of the findings on these nonstandard concrete blocks are also included in the following discussion. The apparatus for the permeability tests is shown schematically in Figure 4, and photographs of the apparatus are presented in Figure 5.

One of the design objectives for the HWCTR building is a maximum leakage rate of less than 1% per day of the free volume at an internal pressure of 24 psig. The representative sample, test block No. 4, exhibited a leakage at 24 psig that was equivalent to 0.25 to 0.93% per day. This test proved that the design of the penetration through the concrete provides a satisfactory air seal. The testing of the other test blocks showed that care must be exercised in the pouring of the concrete for the wall structure. Undesirable segregation of the aggregate occurred when the concrete mix was too wet or was vibrated excessively. This segregation increased the porosity of the concrete. However, leakage rates were reduced substantially by impact application of a surface layer of concrete (e.g., the "Gunite" process). In addition, the seals between the penetration sleeves and the concrete were destroyed when impact wrenches were used to affix connections to the sleeves.

2. Safety Rod Prototype

Testing of the prototype safety rod package at the design pressure of 1500 psig and the design temperature of 285°C was started in the shops of Alco Products, Inc. This test is to consist of 500 scram cycles and 1000 normal drive cycles. The majority of both types of cycling test were completed by the end of October, and no faults had developed in the drive to that date.

A mockup is being assembled at the Savannah River Plant of part of the control and safety rod drive platform and the associated drive mechanisms. The purposes of this mockup are to determine the ease of fit and the accessibility of this equipment, and to develop procedures for its installation and maintenance.

3. Prototype Gripper Mechanism

Extended cycling tests of the prototype gripper mechanism for the fuel discharge coffin were in progress throughout October. A number of modifications were made to overcome minor difficulties. A total of 750 cycles were completed with the chuck-actuating mechanism and three different chucks were tested in picking up various reactor components. Limited cycling of the gripper mechanism over its range of vertical travel was also accomplished after installation of a modified lifting bar for the gripper head. This modified lifting bar eliminates bowing of the drive chains. A rough mockup of the water supply system for cooling fuel elements in the coffin was built at the Mechanical Development Laboratory of the Engineering Department. The basic suitability of this coolant system was established. After some further refinements, the coolant system will be tested along with the prototype gripper assembly at the Savannah River Plant.

4. Flow Test of Fuel Assembly

A mockup of an HWCTR test fuel assembly with a spiral shield muff was undamaged by 62 days of flow testing in neutral deionized water at 260°C. A flow of 300 gpm, corresponding to velocities of 17 and 24 feet/sec in the annular and axial cooling channels, respectively, was provided to the test assembly. The assembly consists essentially of a natural uranium fuel tube clad with Zircaloy-2 and a straight-ribbed housing tube, also of Zircaloy-2. Because of excessive friction losses in the spiral shield muff, the muff design was changed to provide straight flow passages (see DP-425). The flow test of the spiral muff assembly was therefore terminated, and a muff of the new design was substituted in the test assembly. As reported previously, the friction loss across the muff with the straight passages was significantly lower than that across the spiral muff.

C. MATERIALS - DRIVER FUEL ELEMENTS

1. Fabrication

Among the variables that must be controlled carefully in the fabrication of driver fuel tubes for the HWCTR is the spatial distribution of the uranium in each tube. This distribution cannot be measured directly, but must be inferred from uranium analyses of the extrusion billet and from measurements of the core length and external dimensions of the coextruded tube. The results of an evaluation of ring sections that were cut from two prototype tubes of natural uranium showed that this indirect technique is adequate for definition of the uranium distribution.

Four rings of 1/4-inch thickness were cut from the core sections of each of the prototype tubes, and the total weight of uranium in each section was derived from chemical analysis of the sections. The "measured" weight so obtained was compared with the weight computed from the billet analyses and the measured core dimensions of the sections. The measured weights were 0.2 to 2.2% higher than the computed weights, but all measured weights were within the tolerance limits allowed by the specifications (±5% of normal weight). The estimated ±1% uncertainty in the chemical analysis could be responsible for some of the disparity between measured and computed weights.

2. Irradiation

An enriched driver fuel tube was inserted into a Savannah River reactor for irradiation testing. The purpose of this irradiation test is to verify the dimensional stability of the fuel during irradiation to high burnup of the U^{235}. The tube, which was produced by a coextrusion process at Nuclear Metals, Inc., has an enriched uranium core alloyed with zirconium and is clad with Zircaloy-2. The core has a nominal composition of 9.3 w/o total uranium of 93% enrichment, which amounts to 108 grams of U^{235} per linear foot. The tube is in an assembly that contains eleven target slugs of 3.1 w/o lithium. The assembly is shown in Figure 6. Dimensional measurements and visual inspection of the tube were made prior to loading in the reactor. No pits, depressions, or bumps of any consequence were noted. The inner and outer diameters of the tube were well within the specified tolerances.

D. PHYSICS SUMMARY REPORTS

Several papers concerning the nuclear physics of the HWCTR were compiled in a single report, DP-413, for a convenient reference. These papers were presented by personnel of the Savannah River Laboratory at the meeting of the American Nuclear Society in Gatlinburg, Tennessee, on June 15-17, 1959. A list of the papers and a brief description of each are given below. Except for the first paper, which describes the physical facilities of the HWCTR, the papers cover some of the physics studies that were undertaken to provide information for the Preliminary Hazards Evaluation of the HWCTR, DP-383, and for engineering design. The subject matter covered by these papers is still under investigation and more complete and detailed reports will be issued at later dates.

1. The Heavy Water Components Test Reactor (HWCTR), L. M. Arnett - describes the physical facilities of the reactor.

2. Neutron Economy in a Critical Mockup of the HWCTR, N. P. Baumann, W. E. Graves, and G. F. O'Neill - discusses some nuclear measurements made in a full-scale mockup of the HWCTR constructed in the Process Development Pile.

3. Flux Distributions in a Critical Mockup of the HWCTR, W. E. Graves and E. J. Hurley - presents further discussion of measurements made in the mockup described in Paper 2.

4. Calculations of Physics Parameters of the HWCTR, J. W. Wade - describes calculations of reactivity transients and reactivity coefficients.

5. Power Excursions in the HWCTR, D. Randall and D. S. St. John - presents calculations of power, temperature, and pressure transients for a variety of postulated accidents.

II. TECHNOLOGY OF FULL-SCALE REACTORS

A. REACTOR FUELS AND MATERIALS

The chief objective of the program on reactor fuels and materials is the development of a low cost natural uranium fuel, of oxide or metal, that can withstand the exposures and temperatures contemplated for D_2O-cooled-and-moderated power reactors. The work on uranium metal tubes is being conducted at Nuclear Metals, Inc., where the immediate emphasis is on the coextrusion of Zircaloy-clad tubes of various core compositions for irradiation tests. The major effort on oxide fuel is at the Savannah River Laboratory, where experimental studies of a cold-swaging process for direct mechanical compaction of Zircaloy-clad elements of oxide are underway. The progress of these programs is reviewed in this section.

1. Uranium Metal Tubes for Irradiation Tests

a. Unalloyed Tubes

As was discussed in DP-395, a group of five Zircaloy-clad tubes of unalloyed uranium were coextruded for irradiation tests with the objective of comparing the dimensional stability of unalloyed uranium with that of U - 2 w/o Zr. One of these tubes passed all of the evaluation tests and is being irradiated in a Savannah River reactor. Two of the other four tubes were defective as extruded (DP-405); the third tube was rejected because it did not meet specifications on minimum cladding thickness (DP-425); and the outer cladding of the fourth tube failed in a three-hour autoclave test at 345°C. The cause of the cladding failure has not been determined yet.

Two problems that were encountered in the fabrication of these five tubes were (1) fluctuations in cladding thickness, and (2) thinning of the cladding at the end seals. Small-scale experimental tubes are being fabricated and evaluated in an effort to solve these problems. Two tubes were extruded to the desired fine-grained structure. For these tubes, the uranium cores were beta treated and quenched three times, and were then alpha extruded with a reduction of 2:1. Thinning of the clad at the core ends was about the same as in the best of the original five experimental tubes. Autoradiographs of the uniform core sections, however, showed the cladding thickness to be more uniform than in the earlier tubes.

An attempt was made to apply these favorable results to the fabrication of tubes of unalloyed uranium of 3% enrichment. Such tubes are desired for irradiation testing in the Vallecitos Boiling Water Reactor. Howeve in fabricating cores for the necessary prototype tubes of natural uranium, the castings, which were larger than those used for the reduced scale experiments, cracked during quenching from the beta phase.

b. New Alloy Systems for Fuel Tube Cores

Inasmuch as the performance under irradiation of U - 2 w/o Zr cores has not been satisfactory, cores of alternative compositions are being fabricated for irradiation testing. Two full-scale tubes with cores containing respectively 1 w/o silicon and 1.5 w/o molybdenum were extruded during this report period. Another tube that contained, in tandem, short cores of each of these compositions was extruded for destructive examination to characterize the full-length tubes.

Sections cut from the short silicon alloy tube revealed only very slight thinning of the outer cladding at the rear end of the core. Therefore, the corresponding full-length tube will be beta treated to provide the random crystallographic structure and then processed in the usual way as an irradiation candidate.

Severe thinning of the inner cladding of the short molybdenum alloy tube occurred at the rear end of the core. This result was unexpected because the end shapes of the extrusion billet had yielded satisfactory results in a reduced-scale tube with a molybdenum alloy core. The cladding thickness of the full-length tube will be measured carefully to form a basis for deciding whether the tube should be recommended as an irradiation candidate. Concurrently, heat treatment studies with extruded rod sections of this alloy are in progress with the objective of discovering a practical treatment that will provide a structure similar to that observed in as-cast slugs. Good irradiation behavior has been reported for specimens of this type that were prepared at another site.

c. Stabilized Beta-Phase Uranium Alloys

Work was started recently on another possible route to a uranium metal fuel element with improved irradiation behavior. Because the creep strength of the beta phase of uranium is higher than that of the alpha phase, it is postulated that an alloy that retains the beta phase under irradiation conditions should have improved dimensional stability. The literature was searched for references to uranium-base alloys that retain the metastable beta phase at room temperature. For a selected list of such candidates, small arc-melted buttons were prepared for heat treatment studies and for structure determination by metallography and X-ray diffraction. A number of the most promising compositions were selected for a test of stability at 500°C for 23 hours. In this severe test, most of the alloys were converted nearly completely to the alpha phase. Twelve-pound castings of the two compositions least degraded by this heat treatment (0.3 w/o Cr, and 0.4 w/o Si - 0.4 w/o Al), and of two compositions developed in another program (0.4 w/o Si - 0.3 w/o Cr, and 0.3 w/o Cr - 0.3 w/o Mo), were prepared by induction melting in vacuum. The castings will be used for further studies of heat treatment and phase retention, and to obtain information concerning fabricability.

2. Fabrication of Oxide Fuel Elements

Data reported previously (DP-425) on the effect of fines on the density of swaged elements containing crushed, fused UO_2 suggested that the density might be increased slightly by reducing the fines content of the UO_2 powder before swaging. To obtain further information on this subject, additional specimens that contain various distributions of particle size were prepared and are being evaluated. The specimens were prepared by swaging 5/8-inch rods to a final diameter of 0.465 inch; the cladding was stainless steel of 0.020-inch thickness. Variations in particle size distribution were obtained by adding up to 10% of UO_2 particles in three sieve fractions (-70 to +120 mesh, -120 to +200 mesh, and -200 mesh) to particles that were -20 to +70 mesh, -20 to +120 mesh, and -20 to +200 mesh.

B. IRRADIATION TESTS

1. Metallic Fuel Elements

One of the principal uncertainties of the du Pont designs of D_2O-moderated power reactors is whether fuel elements of uranium metal can be developed with adequate dimensional stability to withstand the necessary exposure conditions in such reactors. Information that will aid in resolving this uncertainty is being obtained from irradiation tests of uranium metal at the Savannah River Plant and in the Vallecitos Boiling Water Reactor. These tests are reviewed in the following paragraphs.

a. Uranium Tubes

A coextruded tube of U - 2 w/o Zr was irradiated in the as-extruded condition in a Savannah River reactor and failed after modest exposure at a coolant temperature of about 50°C. The tube, which was clad with 0.015-inch-thick Zircaloy-2, had a 2.06-inch OD, 1.47-inch ID, and 34-inch length. The failure developed slowly, with detectable release of radioactivity of the D_2O moderator for a period of four days; the coolant flow past the fuel tube decreased 1.5% during the last eight hours of irradiation. The failure was confirmed by analysis of the water in the container in which the fuel assembly was stored after discharge from the reactor. The activity in the water increased by a factor of 800 in 1.5 hours, and short-lived isotopes of iodine were detected in the water.

Another tube of U - 2 w/o Zr reached a somewhat lower exposure at the same coolant temperature without incident. In contrast to the tube that failed, this tube received a diffusion heat treatment prior to irradiation. The tube is being moved to a region of higher flux to increase the maximum temperature of the uranium.

One tube of unalloyed uranium clad with 0.030-inch-thick Zircaloy-2 was irradiated without incident to a modest exposure in a Savannah River reactor. This tube was discharged from the reactor for dimensional measurements. The tube may be reinserted into the reactor for further irradiation, inasmuch as it is the only Zircaloy-clad tube of unalloyed uranium presently available (see Section II-A,"Reactor Fuels and Materials").

Battelle Memorial Institute initiated metallographic examination of a section of the U - 2 w/o Zr tube that failed several months ago in a Savannah River reactor (see DP-385 and DP-415). Initial attempts to define the core structure were not successful, nor was it ascertained whether the volume changes produced during irradiation are the result of microcracks or gas formation. Examination of the cladding surface that was in contact with coolant revealed precipitation of zirconium hydride at grain boundaries to a depth of less than 0.001 inch. The source of the hydrogen is not known, but it may have come from corrosion of the Zircaloy-2 surface by D_2O coolant. The initial hydrogen content of the Zircaloy was less than 25 ppm. No cracking of the core-cladding interface was detected.

Because of a shutdown of the Vallecitos Boiling Water Reactor, no progress was made during October in the high temperature irradiation of a U - 2 w/o Zr tube at that site. Except for 3.06% enrichment, this tube has the same general specifications as the other metal fuel tubes extruded by Nuclear Metals, Inc. The results of the last inspection of this tube, after an average exposure of 772 MWD/T, were reported in DP-395. The exposure to date is about 1500 MWD/T.

b. Slugs of U - 2 w/o Zr

Four capsules, each containing a slug of U - 2 w/o Zr clad with Zircaloy-2, were discharged from a Savannah River reactor after irradiation at high temperature; disassembly of the capsules is in progress preparatory to examination of the slugs. The high temperature was attained by irradiating each slug in a matrix of lead, which served as thermal insulation.

These capsules were irradiated as part of a program to obtain data on the effect of cladding thickness and exposure on the dimensional stability of the U - 2 w/o Zr alloy when irradiated at temperatures comparable to those expected in D_2O-moderated power reactors. Dimensional changes that were observed in another group of four slugs irradiated previously were presented in DP-395. Four slugs remain in the reactor and are being irradiated further. Explicit data on the operating conditions in these irradiations will be presented in a forthcoming classified report.

2. Uranium Oxide Rods (MTR)

The four rods of uranium oxide that were irradiated in the Materials Testing Reactor (MTR) to about 4000 MWD/T (DP-375, DP-415) were removed from their housings and now await shipment to the Savannah River Laboratory (SRL) for postirradiation evaluation. These rods, which were the first oxide elements irradiated in the du Pont program, were fabricated by cold swaging fused UO_2 to 90% of theoretical density within a stainless steel sheath 0.030 inch thick.

The postirradiation evaluation of the oxide rods will consist of visual inspection, measurement of length and diameter, gamma scanning to determine the variations in exposure along the length of each rod, measurement of the fission gas release when the cladding is pierced, photography of sections of the rods, and chemical analyses of the burnup. With the exception of apparatus for measuring the release of fission gas, the necessary equipment for evaluation of the rods has been installed in high level caves at SRL. Preliminary proof tests of the fission gas apparatus were made, but further testing in a cave mockup will be required before the cave installation can be completed.

3. Relaxation of Stresses in Stainless Steel During Irradiation

An experimental program is in progress at the Savannah River Laboratory to ascertain the effects of irradiation on stress relaxation and creep in stainless steel. Initial results (DP-395) demonstrated that irradiation causes stresses to relax at a temperature (less than 100°C) that is much lower than is otherwise required to induce stress relaxation. To apply these results, it is necessary to distinguish between relaxation of shear stresses and relaxation of normal stresses, since the two types of stress exist in various proportions in reactor structures. Therefore, preparations are being made for a second experiment, differing from the first in that the stainless steel specimens will be irradiated while loaded in torsion rather than tension. In the first experiment, the maximum tensile stress was twice the maximum shear stress, but in the second experiment these stresses will be equal. The combined results of the two experiments should indicate which of the two types of stress governs the relaxation.

The design of the torsion specimens is shown in Figure 7. Each specimen is a seamless tube of 0.200-inch OD and 0.125-inch ID. The specimen is inserted in a stainless steel holder, is deformed a predetermined amount in torsion by a loading device, and is held in the loaded position within the holder by means of set screws that bear on a flat at each end of the specimen. After irradiation, the specimen is disassembled, and the angular offset of the two flats is measured. The difference between this offset and the offset before irradiation will be a measure of the relaxation that occurs during irradiation.

C. BOILING HEAT TRANSFER

As was reported last month, experimental programs were initiated at Columbia University and at the Savannah River Laboratory (SRL) to obtain heat transfer and hydraulic data for forced circulation of boiling water at conditions applicable to power reactors. Suitable experimental equipment for this purpose is being obtained by both sites. At Columbia, an existing loop is being modified for operation with boiling water preparatory to study of heat transfer in full-size mockups of the complicated fuel assemblies that are typical of power reactors. A new loop is to be installed at SRL for more basic data on two-phase flow, e.g., pressure drop and flow stability. Design of the SRL loop has been completed, and orders were placed for equipment. Construction of the loop is expected to start in November.

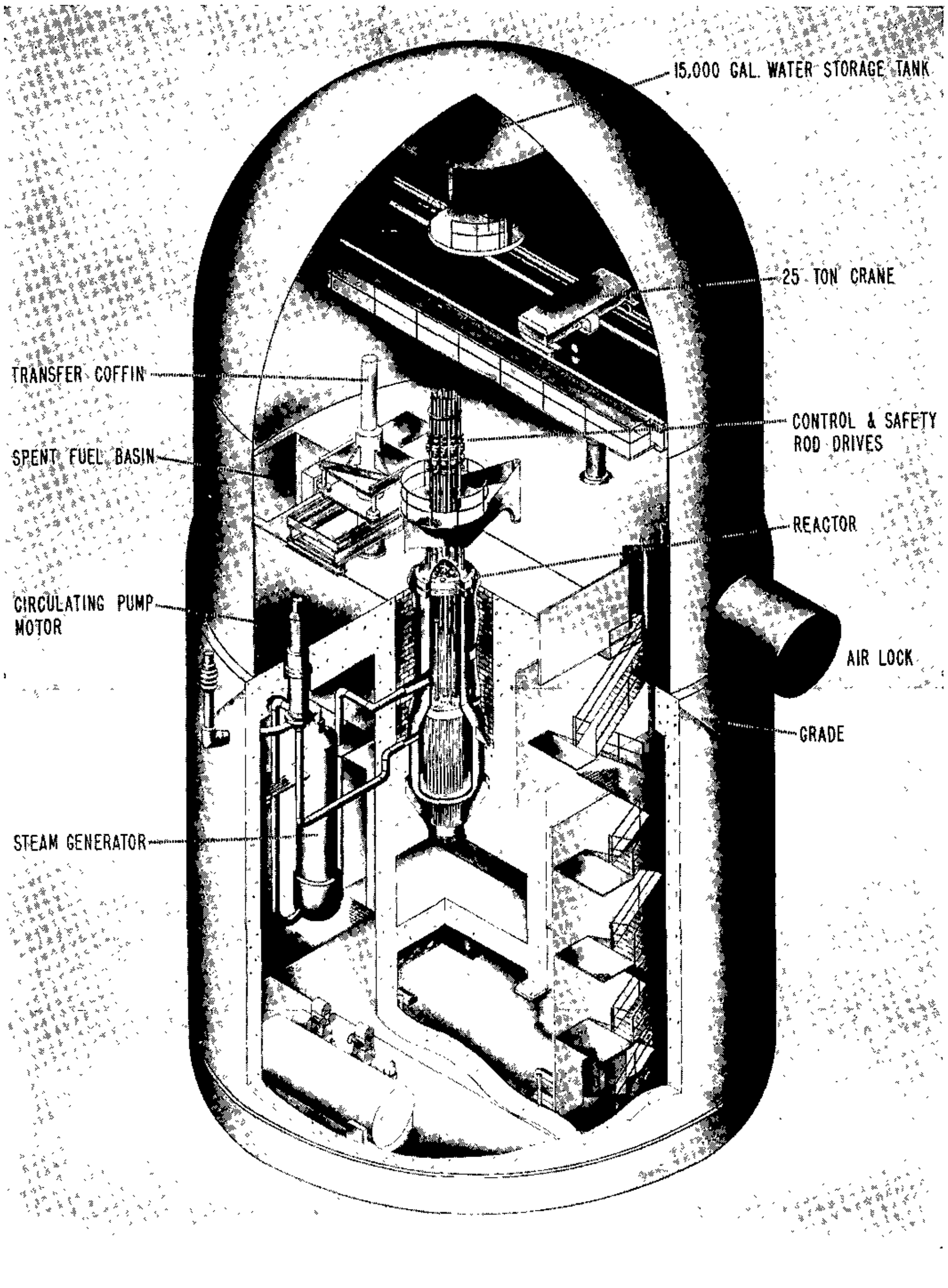


FIGURE 1 – CUTAWAY PERSPECTIVE OF THE HWCTR BUILDING

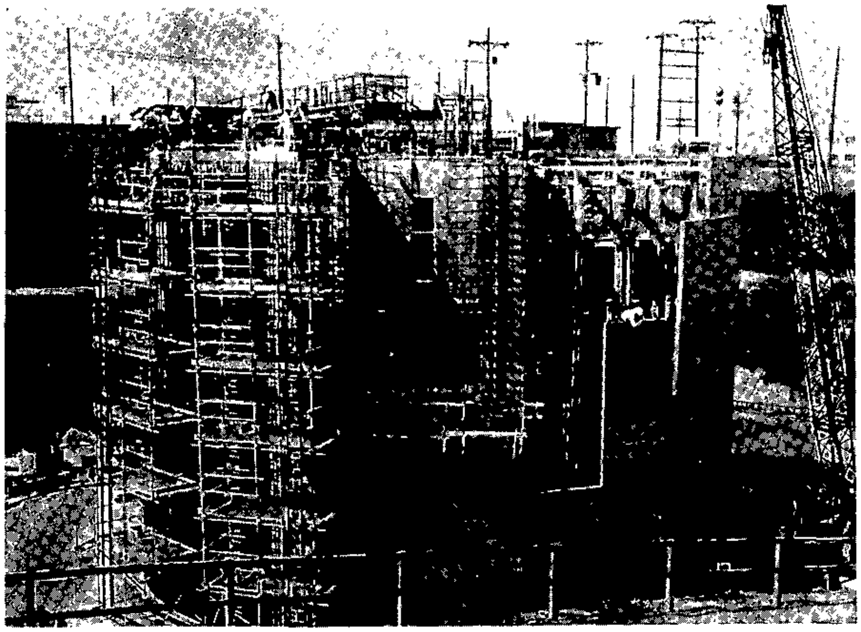


FIGURE 2 – STATUS OF HWCTR CONSTRUCTION
September 30, 1959

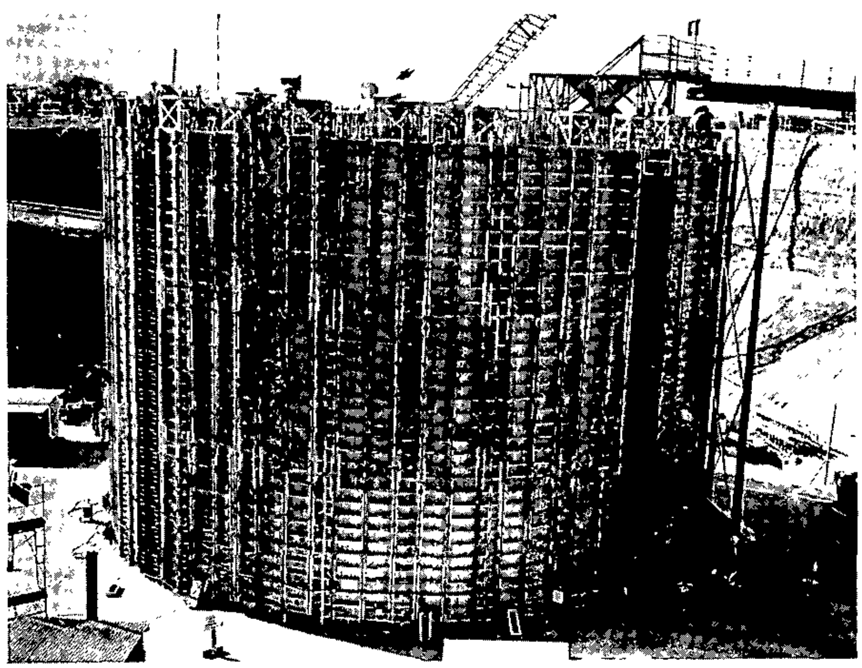
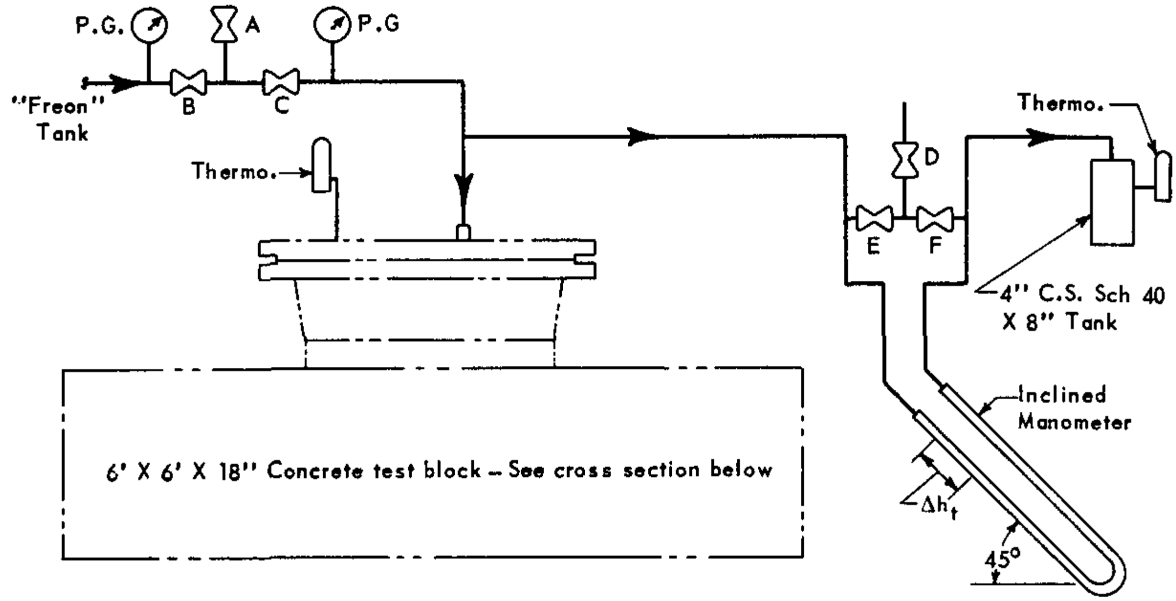
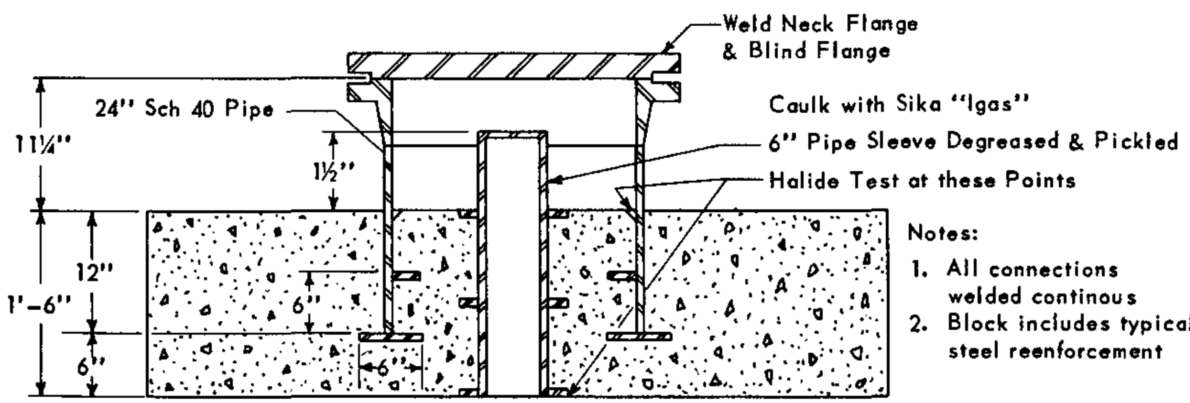


FIGURE 3 – STATUS OF HWCTR CONSTRUCTION
End of October 1959



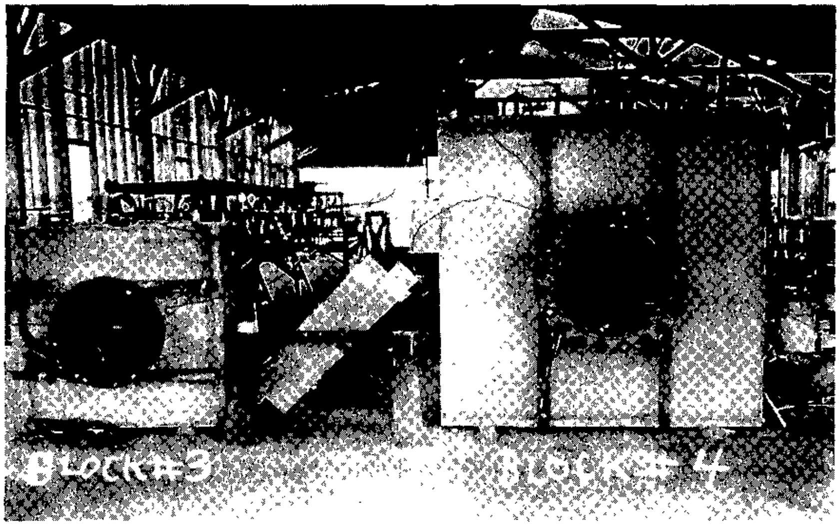
Notes:

1. All valves, connections, welds, and assemblies "Freon" tested prior to actual pressure test
2. Pressure test conducted at 24 psig
3. Valves "A" & "D" closed, remaining valves opened, and test pressure applied to system. Valves "B, C, E, & F" closed and then valves "A & D" opened
4. Manometer readings, pressure gage readings and temperature readings recorded over a period of several hours



Test Block No. 4

FIGURE 4 – SCHEMATIC DIAGRAM OF EQUIPMENT FOR CONCRETE PERMEABILITY TESTS



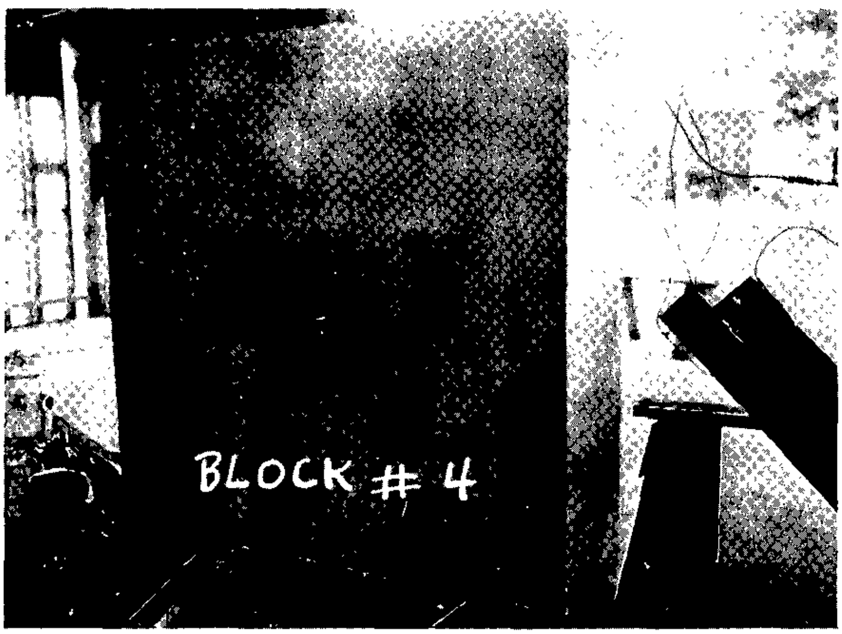


FIGURE 5 – EQUIPMENT FOR CONCRETE PERMEABILITY TESTS

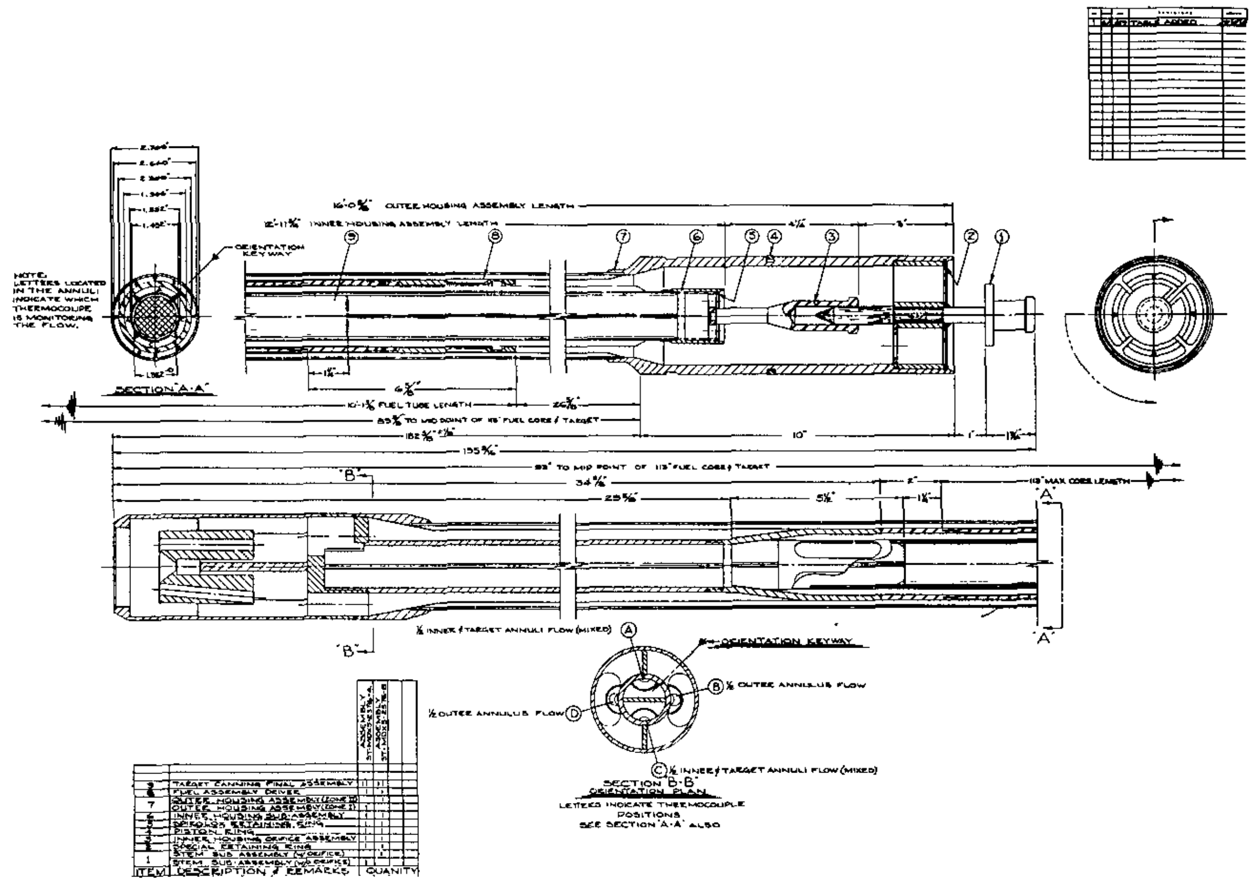


FIGURE 6 – HWCTR DRIVER ELEMENT FOR SRP IRRADIATION

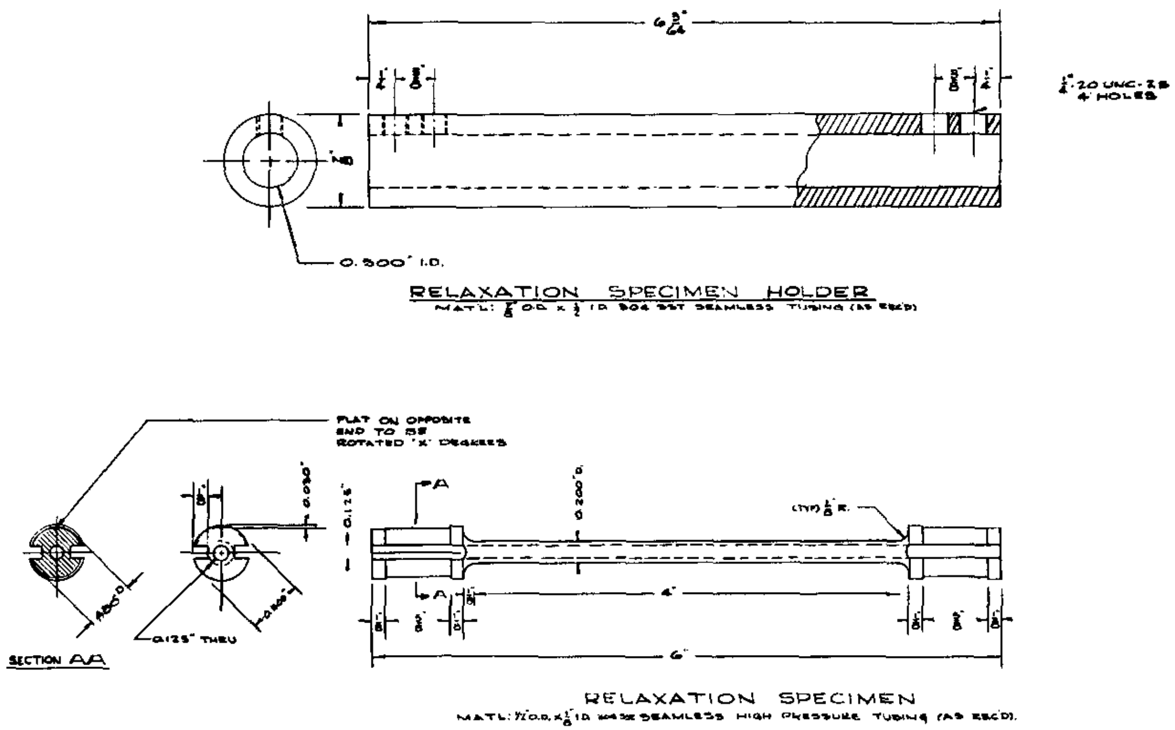


FIGURE 7 – IRRADIATION SPECIMEN FOR STUDIES OF RELAXATION OF STAINLESS STEEL IN TORSION