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PHYSICS DIVISION
QUARTERLY PROGRESS REPORT FOR
PERIOD ENDING JUNE 15, 1950

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PHYSICS DIVISION

A. H. Snell, Director
E. O. Wollan, Associate Director

QUARTERLY PROGRESS REPORT

for Period Ending June 15, 1950

DATE ISSUED: AUG 10 1950

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INTRODUCTION AND SUMMARY

The following report covers classified work for the interval March 15 - June 15, 1950. The unclassified section of the Quarterly Report appears separately (ORNL 782).

Refinements and extensions of the measurements of electrical resistivity and density changes produced in U-Al alloys under pile irradiation are herein described. Samples containing 15 and 30 percent U (93.3 percent enriched) show a saturation in the density change (which amounts to about 3 percent) after an irradiation nvt of 0.5×10^{20} cm^{-2}. The electrical resistivity of the same alloys, however, shows no saturation up to an nvt of 2×10^{20} cm^{-2}. These observations are interpreted as indicating that the density change arises mainly from lattice defects which can be healed, and which therefore reach an equilibrium; the resistivity change on the other hand arises mainly from the accumulation of fission products.

Thermal conductivity measurements of ZrU and BeU while under irradiation in the ORNL reactor have not yet yielded dependable results, because of experimental difficulties.

For the irradiation creep experiment an oven has been built and tested such that the temperature is uniform over the length of the specimen. Methods of applying the load are now being tested.

[redacted]

RADIATION STABILITY OF URANIUM-ALUMINUM ALLOYS FOR MTR

L. C. Templeton S. E. Dismuke
M. A. Bredig

A preliminary discussion of the radiation stability of uranium alloys for the Materials Testing Reactor appeared in the last Physics Division quarterly report.[1] Additional measurements have been made in the meantime on specimens of both Series II (rods) and Series III ("sandwiches").

Series II, Rods. As shown in Fig. 5 of the previous quarterly report, one specimen containing 30 percent of natural uranium had given an unexpectedly large density change, of -3.4%, after six months of Hanford irradiation. The post-irradiation measurement has been repeated twice with no significant change in the result. Since the large volume change obtained for this specimen is not in agreement with the other data on this particular alloy composition, which are of the order of 1% for both the three and the 12 months exposures, a possible error in the preirradiation measurement is assumed to account for the entirely unreasonable deviation of the six months specimen.

Figure 5 of the previous quarterly report also indicated that for specimens containing 30 percent uranium, 93.3% enriched, there is no further volume increase beyond approximately 3 percent after an integrated slow neutron flux, of nvt = 0.5×10^{20} cm^{-2}, in the adjacent ton of metal. On the other hand, specimens containing 5% uranium, 93.3% enriched, had not reached a maximum with a volume increase of 3.5% at a slow neutron dose of 2.0×10^{20} cm^{-2}. Density measurements on additional specimens after exposure to the higher dose (one year) agree with these previous data. It has been pointed out previously that the early attainment of the smaller volume change, of 3 percent, in the 15 and 30% alloys is most likely connected with the self-healing process occurring in these alloys in which the temperature during pile exposure must have been higher than in the 5% alloy. The 3 percent maximum change in the 15 and 30 percent alloys then would seem to correspond to a saturation with lattice defects (holes, interstitial atoms, "foreign" atoms in lattice positions) having higher activation energies of "healing" than some of the defects

(1) Templeton, L. C., Dismuke, S. E., Bredig, M. A., "Radiation Stability of Uranium-Aluminum Alloys for MTR," *Physics Division Quarterly Progress Report for Period Ending March 15, 1950*, ORNL 693, 14 (May 18, 1950).

in the 5% alloys, which at a dosage of 2×10^{20} n/cm^2 still continued to be produced at an almost constant rate.

The electrical resistivity measurements have shown a somewhat different situation (Fig. 4, ORNL 693). Not only was no maximum reached in any of three alloy compositions, even with 2×10^{20} n/cm^2 in the adjacent metal, so that resistivity was still increasing at a relatively rapid rate, but the effect observed was also roughly proportional to the concentration of fissionable atoms. The more recent measurements, on the 12 months specimens, confirm this finding. The difference in the effects on volume and on electrical resistivity may be connected with the greater sensitivity of the electrical properties to the concentration both in the crystal lattice, and at the grain boundaries, of impurity atoms such as the fission fragments. Their amount is assumed to continue to increase beyond one year of irradiation at Hanford (~ 25% burn-up) at a fairly constant rate, and is far less subject to "healing" than the number of holes and interstitial atoms.

Series III, Sandwich-type. Figure 10 of the earlier report showed considerable scattering of the density measurements. Specimens giving exceptionally low density values exhibited scale formation on their surfaces due to corrosion. The corroded specimens were cleaned remotely with a brush, and their density was again measured. The data after cleaning do not scatter as widely, *i.e.* hardly more than the precision of readings would lead one to expect. They follow within the limits of accuracy the curves drawn in Fig. 10 which had reached, with an integrated flux of 1×10^{20} cm^{-2}, a volume change of 2.25% in the alloy core, but no maximum. This diagram also seemed to indicate that the class III alloy, 28.9% uranium depleted of U-235, attained a maximum volume increase of 0.5% in the alloy core after three months of irradiation. The more recent data (after cleaning) rather suggest that this alloy increased in volume continuously, similarly to, but at a more rapid rate than, the alloy of class IV, 14.4% uranium depleted. In both these cases, however, the total effect observed hardly exceeds the present limits of accuracy of measurements.

THERMAL CONDUCTIVITY OF URANIUM BEARING MATERIALS[1]

R. G. Berggren J. Redman[2]
W. Primak[3]

Several attempts[4] have been made to study the effect of irradiation on the thermal conductivity of uranium alloys using the apparatus previously developed by Hunter *et al.*[5] for studying the effect of irradiation on the thermal conductivity of impregnated graphite samples. In all of these attempts the "low temperature apparatus" was used. The measurement showed peculiar fluctuations which are not completely understood. Similar fluctuations appeared in data gathered by Hunter *et al.*[6] Since the changes observed in the case of graphite were some 400-5000 percent, 10-20 percent variations in the measurements were not important. With the metal samples the fluctuations were large enough to mask any changes in the thermal conductivity.

A ZrU sample placed in the reactor showed cyclic daily fluctuations in the temperature drop from interior to rim (ΔT) as shown in Fig. 1. It would seem that this must be related to the neutron flux at the sample. Since the pile is controlled according to instruments placed in positions remote to the samples and since control of the pile involves changing the flux distribution in the pile, the neutron flux can vary in ways that are not proportional to the pile power records kept by the Operations Division. In addition, the loading of the experimental holes nearby would produce changes in the neutron flux which would make difficult the comparison of data taken over longer periods of time. An attempt is being made to compare the fluctuation of the ΔT for the ZrU sample with the pile operation data for this period to try to find the factors responsible for the fluctuation. It is further intended to load some of the nearby experimental holes and study the effect on the ΔT. A flux monitor to be inserted with each sample is currently being designed.

The fluctuations in the ΔT for a BeU sample placed in the reactor were more random and are shown in Fig. 2. Since the ΔT was small, it was suspected

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(1) Sponsored by Argonne National Laboratory.

(2) Née Kincaid.

(3) Consultant from Argonne National Laboratory

(4) Berggren, R. G., Kincaid, J. M., and Primak, W., "Thermal Conductivity of Uranium-Bearing Materials," *Physics Division Quarterly Progress Report for Period Ending March 15, 1950*, ORNL 693, 30 (May 18, 1950).

(5) Hunter, L. P., "Thermal Conductivity of Uranium-Bearing Material Under Irradiation at High Temperatures," *Journal of Metallurgy and Ceramics*, TID 66, No. 2, 41-53 (Jan., 1949).

(6) *Ibid*, Fig. 5, p. 49.

[redacted]

DWG. 9175

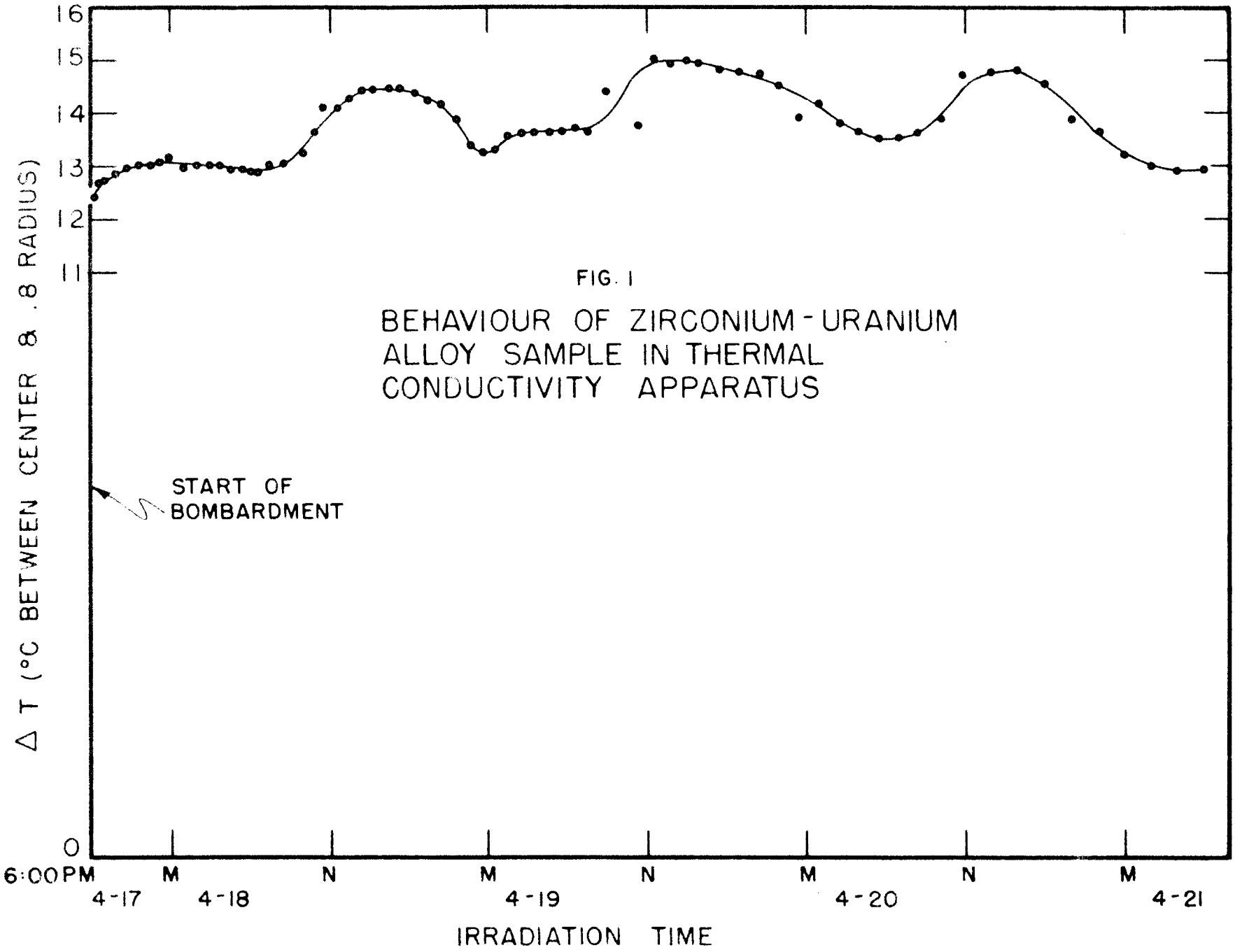

FIG. 1

BEHAVIOUR OF ZIRCONIUM-URANIUM ALLOY SAMPLE IN THERMAL CONDUCTIVITY APPARATUS

[redacted]

DWG. 9176

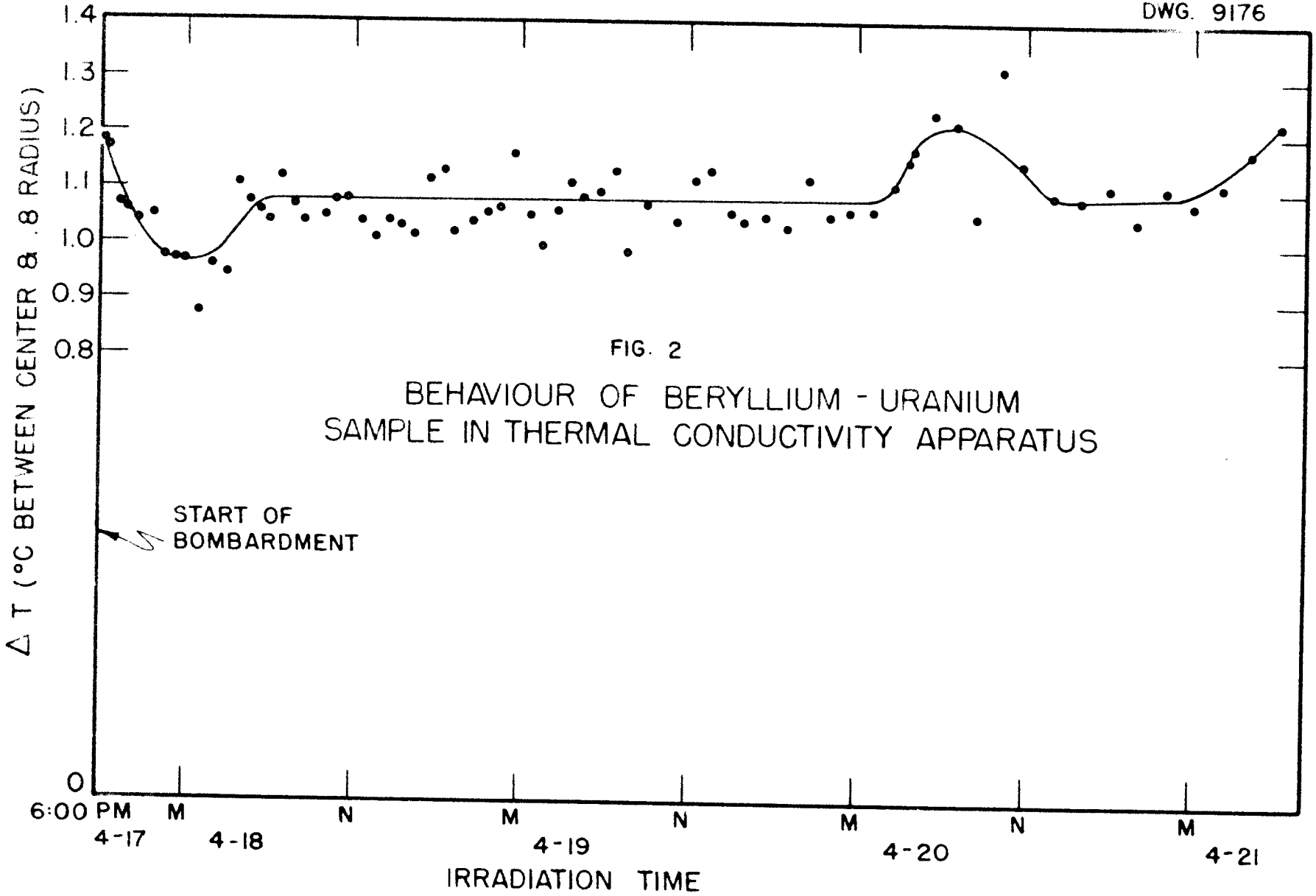

FIG. 2

BEHAVIOUR OF BERYLLIUM - URANIUM
SAMPLE IN THERMAL CONDUCTIVITY APPARATUS

that random emf's were responsible. Accordingly, facsimiles of the parts of the various thermocouple circuits were tested for spurious emf's. These were found at the points where the thermocouples entered the torpedoes (soldered through Kovar) at the cold junctions (formerly placed in the fuel channels but now placed in a stirred ice bath on the pile face), and at the terminal strips. The torpedoes are being redesigned to lessen the possible temperature gradients across the soldered Kovar seals. The terminal strips will be placed in boxes to cut down temperature gradients and solid copper posts will be used. It does not seem practicable at the present time to reduce the spurious emf's below several microvolts. It would seem desirable, therefore, to measure ΔT's of at least 50 degrees. This is not possible for cylindrical metal samples using radial heat flow employed for the graphite. For these samples the advantages of eliminating radiation and convection losses secured by the radial heat flow are small compared to the other errors of the experiment. An arrangement which will measure the axial conductivity and which will give a larger ΔT is now being assembled.

Equipment for measuring the thermal conductivity changes of ZrU alloy on irradiation in W reactors is currently being designed. Here even the radial heat flow cannot be used because the ΔT would be too great. The use of a flat plate is indicated, and these are currently being fabricated for test.

No significant additional data on the behavior of graphite has been obtained during this period.

There has been no observable change in the thermal conductivity of (6 weight percent, 93% enriched) ZrU alloy during two months irradiation in the X-10 reactor. Likewise, there has been no observable change in the BeU sample during two months irradiation in the X-10 reactor. However, the emf's which have been measured in this latter sample are only 40 microvolts, and it is not certain that this may be taken to represent the sample temperature.

The following correction, of an error appearing in the previous Quarterly Report,[7] should be noted where it should read: "-----and 0.029 for ZrU alloy ----- The latter result may be compared with a result, 0.030-----."

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(7) Berggren, R. G. *et al.*, *op. cit.*, ORNL 693, p. 31.

[redacted]

IRRADIATION CREEP EXPERIMENT[1]

W. E. Brundage W. Primak[2]

The creep experiment outlined in the previous quarterly progress report[3] is being designed, and parts are under construction and test.

Temperature control was tested using facsimiles of the creep apparatus in which no load was applied. A hollow tube which could be probed with a thermocouple was used in place of a specimen. It was not found possible to obtain a uniform temperature using the heating arrangement planned. Conduction from the ends of the specimen was sufficient so that a temperature peak was obtained in the region between the central and end heaters. This might have been overcome by winding a non-uniform heater over the central portion, but it was decided that the design difficulties might have been too great. Instead, it was decided to place a heater over the whole length of the apparatus, extending beyond the ends. This would have the advantage of keeping the microformer and its connecting bars at constant temperature. A facsimile of the oven for such a unit was constructed as shown in Fig. 1. When tested, the temperature distribution shown in Fig. 2 was obtained. Calculations were made to determine the power requirements for a non-uniform heater to give a constant temperature over the length of the furnace and it was found to involve only a 10% increase in the power at each end. It seemed likely that introducing an additional short, uniformly wound heater at each end might be a close enough approximation. This was tried and the results shown in Fig. 3 were obtained. This furnace arrangement will probably be satisfactory for the tests.

Methods for applying the load are now being tested.[4] Cable was tested, and it was found to twist very badly under load. Steel tape is now being tried. Two methods of altering the direction of the load are now being studied. The first, a ball bearing, was found in a preliminary test to give about 3/4 lb starting friction with a 550 lb load. Further tests will be performed. The second, a knife edge, has not yet been tested.

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(1) Sponsored by Argonne National Laboratory.

(2) Consultant from Argonne National Laboratory.

(3) Brundage, W. E. and Primak, W., "Irradiation Creep Equipment," *Physics Division Quarterly Progress Report for Period Ending March 15, 1950*, ORNL 693, 31 (May 18, 1950).

(4) We are indebted to R. W. Holmes and C. Bullinger (ANL) for assistance in design and test of load application.

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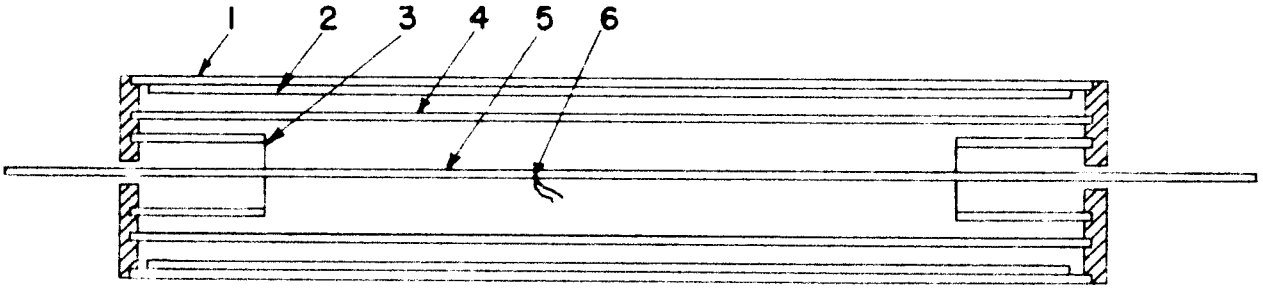
DWG. 9177

CREEP UNIT FURNACE
FIG. 1



(1) OUTER SHELL
(2) ASBESTOS PAPER
(3) END HEATER (HICHROME WIRE WOUND ON MICA WRAPPED ALUMINUM TUBE)
(4) MAIN HEATER (SIMILAR TO END HEATER)
(5) 1/8" O.D. STEEL TUBING
(6) CONTROL THERMOCOUPLE

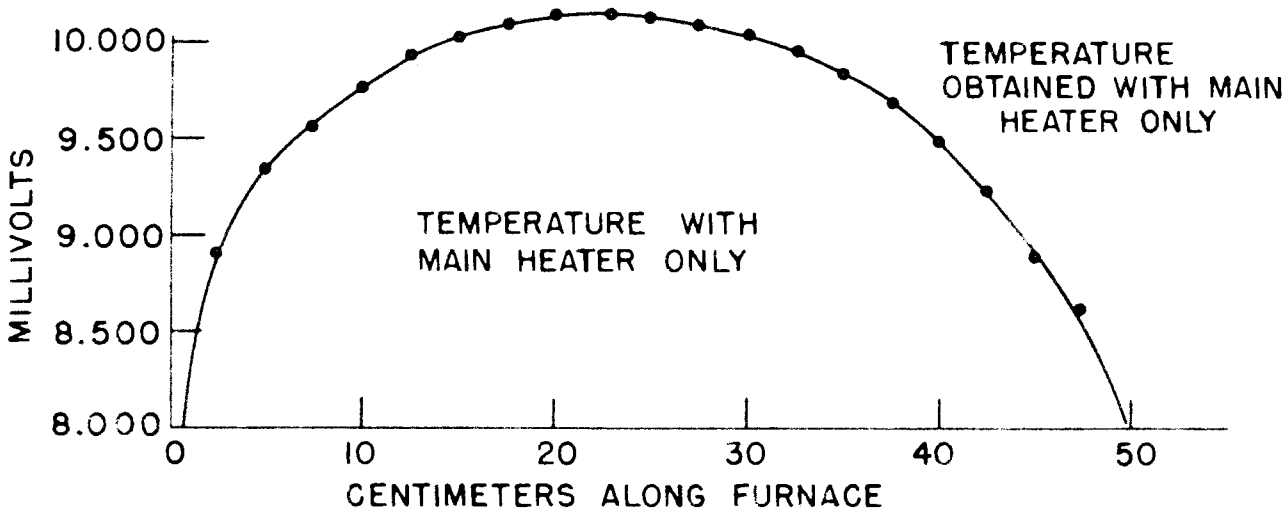


FIG. 2

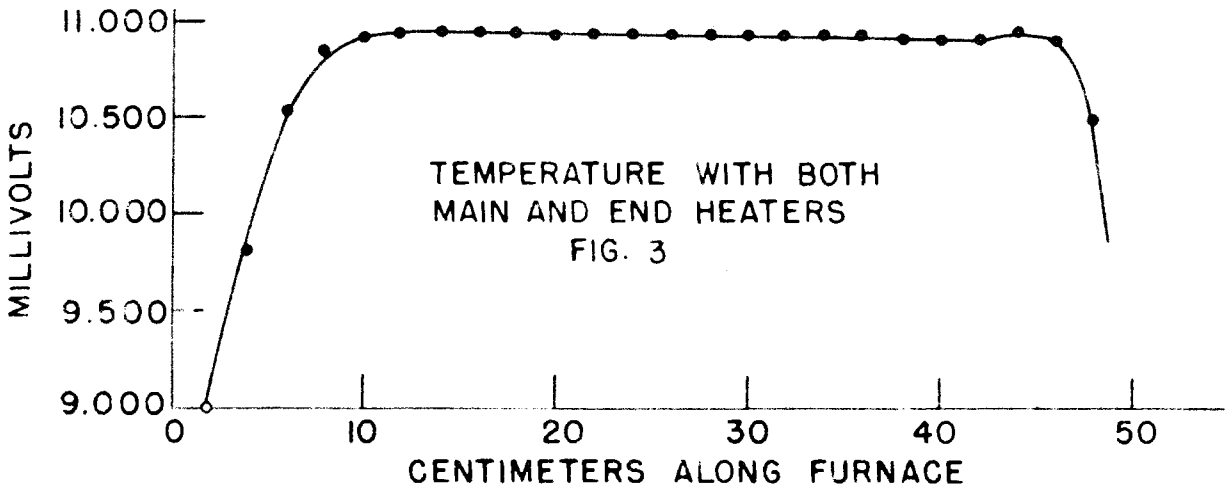


FIG. 3