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# AEC RESEARCH AND DEVELOPMENT REPORT

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LABORATORY RECORDS  
1954

POWER PILE DIVISION

QUARTERLY REPORT

For

JUNE, JULY, AUGUST, 1948

By

E. B. ASHCRAFT

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POWER PILE DIVISION

QUARTERLY REPORT

for

June, July, August, 1948

By

E. B. Ashcraft

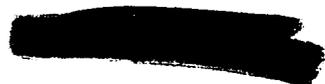
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POWER PILE DIVISION

QUARTERLY REPORT

June, July, August, 1948

I. SUMMARY

A. Design Study of Navy Pile Application

During this quarter the Navy Pile design study was continued as the major activity of the division. This subject is covered in detail in the final report on the feasibility program (ORNL-133), and will not be duplicated in this report.

Some additional work was done on Dynamic and Static corrosion testing after ORNL-133 was issued and is included in this report.

B. Materials Development and Experimental Work

The materials development and experimental work of the division continued on a more general basis than that dealing exclusively with the design study of the Navy Pile application. Development and experimental work was continued on:

Thermal Conductivity of Uranium Bearing Materials under Irradiations at High Temperatures.

Development of New Pile Sample Container

Thermal Conductivity Measurements at Room Temperature

Thermal Expansion Apparatus

High Temperature Modules Tests

Study of Sample Irradiation Techniques.

Graphite Impregnation

Simultaneous Pile Irradiation and High Temperature Creep Experiment

Instrumentation for Creep Tests

Recovery of Uranium from Graphite Fuel Units

Graphite Permeability Effect of High Temperatures

Metallurgy, Zirconium, Beryllium Alloys

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Ceramics, Beryllium

C. Miscellaneous

The transfer of Power Pile Division Personnel from Oak Ridge National Laboratory to Argonne National Laboratory is approximately half completed.

A listing of all equipment to be transferred to Chicago, including a complete description of each item, as well as identifying property numbers, was prepared for transfer of the division to A.N.L. Lists were also prepared for drawings and documents.

II. CORROSION TESTS (E. B. Ashcraft, Section Chief)

A. Dynamic Corrosion Tests (A. Amorosi, J. Perry, E. L. Kelso)

The only run not previously reported is in progress now. Zirconium, Beryllium, and Columbium are exposed to pure degassed water at temperature 250-260° C, and pressure of 1250 psi. Run time is approximately 50 hours and it is hoped the run will last several hundred hours before an equipment failure forces a shut-down.

B. Static Corrosion Tests (A. Amorosi, J. Perry, E. L. Kelso)

Run results not previously reported are shown on Fig. 1. Emphasis was placed on super-critical temperature tests. Stainless steel showed remarkable resistance in all cases and type 347 (Columbium stabilized 18:8) showed no weight change at all. Beryllium (6-1 extrusion ratio) decomposed completely. Zirconium gained from 4-15 grams per square meter surface area and samples became mottled with white oxide. Beryllium Stainless Steel couple decomposed Beryllium at 580° F.

III. MATERIALS DEVELOPMENT AND EXPERIMENTAL WORK

A. Thermal Conductivity of Uranium Bearing Materials Under Irradiation At High Temperatures. (L. P. Hunter, R. G. Berggren, H. E. Robertson, J. Kincaid).

The purpose of these measurements is to determine the simultaneous effect of irradiation damage and annealing. Previous work is reported in reports Mon N-442, ORNL-22, and ORNL-66.

The irradiation of impregnated graphite No. 1 was terminated after a total dose of 61 KWH per c.c. since the conductivity had not changed sensibly in the last 10 KWH of dosage. The value reached by the conductivity of this sample at the end of its run is about equal to the value of the thermal conductivity of a carbon body which had been molded from the usual coke-pitch mixture and baked at the operating temperature of this sample (800° C) without graphitizing. Impregnated graphite No. 3 failed after 31 KWH per c.c. total dose.

In Fig. 2 is shown a comparison between the results obtained on impregnated graphite samples No. 1 and 4. These samples were run at very nearly the same temperature and rate of damage. The discrepancy between the curves is not explained. The results obtained with sample No. 4 seem to be in better agreement with other samples, such as sample No. 3, so that the step in the curve of sample No. 1 that occurs between doses 4 and 7 KWH per c.c. is probably spurious.

In Fig. 3 is shown a comparison between the results obtained on impregnated graphite No. 3 and molded graphite No. 4. These samples were operated at 630° C and 650° C respectively throughout their runs. The much lower damage shown by the molded sample is probably due to the fact that the UO<sub>2</sub> particle size is much larger in it than in the impregnated sample. This should effect the total damage two ways. In the first place the number of

fission recoils reaching the graphite structure is much smaller since many are absorbed in the UO<sub>2</sub> particles themselves. This should be reflected in the lower initial slope of the resistivity vs. dosage curve. In the second place the larger size of the UO<sub>2</sub> particles in the molded sample allows a larger volume of graphite structure which is more than the range (5 $\mu$ ) of fission recoil fragment from the nearest UO<sub>2</sub> particle. This should be reflected in the lower final value of thermal resistivity.

In Fig. 4 is shown a comparison between the results obtained on impregnated BeO #3 and hot pressed BeO #31. Here it is the impregnated sample which shows the lower damage. This can possibly be explained by reference to the radiographs of Fig. 5. The lower radiograph is a ten diameter magnification of the structure of the hot pressed BeO - UO<sub>2</sub> mixture, the upper radiograph is a ten diameter magnification of the structure of the UO<sub>2</sub> impregnated BeO specimen. A comparison of these two structures shows that the individual UO<sub>2</sub> impregnated BeO specimen. A comparison of these two structures shows that the individual UO<sub>2</sub> aggregates are larger in the molded specimen but that there are more extensive regions in the impregnated specimen which appear to contain no UO<sub>2</sub> at all. This latter fact is probably due to the method of fabrication of the low density impregnated BeO specimen. (See ORNL-22, page 72 and Fig. 53). Since a great majority of the fission recoil fragments are probably stopped in the UO<sub>2</sub> aggregates of the hot pressed specimen (BeO #31) the initial slope of the relative thermal resistivity vs. dosage is considerably less than that for the impregnated BeO #3. However, since there is a greater volume of the body which is untouched by fission recoils in the impregnated BeO #3 the final value of the relative resistivity is considerably less than that of the hot pressed BeO #31. Another contributing factor may be that the pressed specimen is a monolithic structure, with the UO<sub>2</sub> aggregates an integral part of the body, so that any damage to them might leave an effect on the thermal conductivity of the whole body; while damage to the UO<sub>2</sub> aggregates in the impregnated specimen would presumably not affect the conductivity of the whole body since they are not an integral part of its structure. This would not account for a difference in initial slope but might help explain the difference in the final values.

#### B. Development of New Pile Sample Containers. (R. G. Berggren)

It has been decided that the variation in specimen temperature attainable by varying the atmosphere in the container is not sufficient. Therefore, two new modifications of the container are being developed, one for higher temperatures and the other for lower temperatures. To raise the temperature further, the sample was inclosed in a tight nickel jacket, (low emissivity). This did raise the temperature, although not as far as desired. Calculations indicated the sample temperature could be increased about 150° C if a thermal radiation shield of low emissivity were to be placed between the sample and the container shell.

Samples placed in containers with this modification (Fig. 6) have shown the expected temperature increase of 150° C. Fig. 6 shows:

- (1) Test sample, which is heated by the fission energy of the uranium it contains.
- (2) 0.005" nickel jacket
- (3) 0.010" nickel thermal radiation shield, (the new feature of this modification)
- (4) Lavite rings for spacing the thermal radiation shield

- 
- (5) Six Lavite cones for locating the sample in the center of the container
  - (6) Pins to eliminate end play of the radiation shield and Lavite rings
  - (7) Pins to prevent longitudinal travel of the sample
  - (8) Thermocouples
  - (9) Outer shell of container
  - (10) Plug brazed into container, sealing it.

In order to reach a lower operating temperature without changing the Uranium loading of the samples, it was decided that there must be good thermal contact between the sample and outer shell. To achieve this, while the expansion coefficients of the sample and the outer shell differed, the sample and shell are tapered and the sample pushed into the tapered shell, establishing thermal contact between the sample and shell.

The proposed apparatus is shown in Fig. 7. Numbered parts in the figure corresponds to:

- (1) Tapered sample cylinder, which is self heated
- (2) Thermocouples
- (3) Tapered shell of container
- (4) Spring pushing sample into tapered shell
- (5) Lavite plates to locate spring and prevent injury of the sample by the spring
- (6) Plug
- (7) Proposed weld for sealing the container

Spring materials tested thus far have been unsatisfactory in that they annealed at temperatures lower than that reached when the plug is brazed into the shell by methods used on previous containers. In order to eliminate the need for a spring that will withstand this temperature without annealing, a method is being investigated by which the heat of welding can be localized to the immediate region of the weld.

As shown in Fig. 8, this welding apparatus consists of a specimen holder rotating at 6 r.p.m. and a pointed carbon rod in electrical contact with the specimen, all in a hydrogen atmosphere. An electrical current is passed through the carbon rod to the specimen, the tip of the rod being heated to a high temperature because of its relatively high resistance. The temperature reached by the tip of the rod is high enough to melt the portion of the two 0.010" copper flanges in contact with the rod and welding the flanges together. As the specimen rotates under the hot carbon rod, a continuous weld is produced. Trial runs have been successful in producing welds of good

physical appearance in which the heat was localized by virtue of the high thermal resistance of the thin flanges and the large heat capacity of the copper plug and container. But, when vacuum tested, appreciable leaks were found. Further work is in progress to produce a vacuum tight weld of good physical strength. If successful, the need for a high temperature spring will be eliminated.

C. Thermal Conductivity Measurements at Room Temperature. (R. G. Berggren)

Trial runs were made with the improved apparatus, as described in the last quarterly report, (ORNL-66), but results were not reproducible. Measurements made on a copper calibration sample showed much too great a spread to be considered satisfactory. Causes of this unsatisfactory behavior are now being investigated.

The apparatus for measurement of thermal conductivity by the transient method is on hand and samples are now being fabricated for use in it.

D. Thermal Expansion Measurements. (H. E. Robertson)

The thermal expansion apparatus which was used to give the results previously reported on BeO has been adapted for use with an inert atmosphere for the measurement of specimens which would oxidize readily in air at elevated temperatures. The atmospheric envelope has been built and tested satisfactorily. The problem of measuring the sample temperature accurately has given some difficulty, since the atmosphere has, up to the present time, caused some irregular cooling of the sample. This problem is being worked out at present.

E. High Temperature Modulus Tests. (J. Giles Morgan)

Using the apparatus described in the previous quarterly report, (ORNL-66), preliminary runs have been made in order to determine the change of resonance frequency with temperature for the individual components of the three component oscillating system. The procedure followed was:

(1) Measuring the resonance frequency of a piezo-electric quartz crystal and its variation with temperature. This quartz crystal is used to drive the three component system. By use of thermal radiation shields and careful insulation the quartz temperature is kept at a minimum. The resonance frequency shows a slight decrease with increase in temperature.

(2) Using DeKhotinsky cement, a 3/16" diameter fused silica rod twelve inches in length was suspended from the quartz crystal. Resonance frequency measurements were then made on this two component system as a function of the furnace temperature. From this data and knowing the mass of the rod and crystal, the frequency of the rod alone may be calculated.

$$\text{Equation (1) } m_1 \tan \left( \frac{\pi f_0}{f_1} \right) - m_2 f_2 \tan \left( \frac{\pi f_0}{f_2} \right) = 0$$

where  $m_1$  - mass of the quartz crystal  
 $m_2$  - mass of the fused silica rod  
 $f_0$  - resonance frequency of the composite oscillator  
 $f_1$  - resonance frequency of the quartz crystal alone  
 $f_2$  - resonance frequency of the fused silica rod

Solving for  $f_2$  involves trial and error calculations. It was found that the resonance frequency of fused silica increases with temperature. It is necessary to know the number of half-wave lengths present in the silica rod and it is also desirable to have values of resonance frequency at different temperatures employing several different numbers of half-waves. The number of half-waves was found by determining two adjacent resonance frequencies and solving for  $n_1$  in the following equations:

$$\text{Equation (2)} \quad f_o = \frac{n_1}{2L_1} V$$

$$f_{o2} = \frac{(n_1 + 1)}{2L_1} V$$

$f_{o1}$  - the resonance frequency of  $n$  half-waves.

$f_{o2}$  - the next adjacent resonance frequency of  $(n_1 + 1)$  half-waves

$L_1$  - the length of the silica rod (meters)

$V$  - the velocity of propagation of the elastic wave (meters/sec.)

(3) The next step is to cement the sample onto the end of the fused silica rod and determine the resonance frequency of the three component oscillator. From this data and using an equation similar to equation 1, the resonance frequency of the sample may be calculated. As yet no reproducible data on the sample itself has been obtained. This has been partly due to experimental difficulties in obtaining a satisfactory oscillating system. It was necessary to obtain a cement which would transmit vibrations at  $1000^\circ \text{C}$  and not introduce sufficient viscous friction to suppress the desired resonance.

After investigating several methods a technique was developed using a 50-50 mixture of Alundum and Sauereisen Cement in Sodium Silicate. The sample and the rod are clamped on a V-block and a thin layer of the cement applied to the surfaces to be joined. By use of a spring to keep the ends of the two rods pressed together, the cement is allowed to dry at room temperature for 24 hours. The cemented joint is then slowly brought up through  $125^\circ \text{C}$  over a period of two hours.

Difficulty has also been encountered in the failure of the quartz to pyrex seal on the tube which enclosed the system. An all quartz tube is now being fabricated to eliminate this problem.

#### F. Sample Irradiation Techniques. (J. Giles Morgan)

In parallel with the high temperature modulus tests, bench runs are being made on the most effective method of irradiating the modulus samples in the pile. The following conditions must be met:

- (1) Irradiation at an elevated temperature.
- (2) Good heat transfer from the temperature source to the sample.
- (3) A small temperature gradient along the length of the sample
- (4) A method of introducing and withdrawing the samples from the face of the pile.
- (5) Determining the temperature obtainable during irradiation.

It is planned to irradiate these samples around a Uranium slug. Substituting a glo-bar dissipating the same amount of energy as that of the slug when in the flux of the pile, a bench model as shown in Fig. 9 was constructed. Using a taper between the Aluminum sample holder and the stainless steel glo-bar case there was found to be  $10^{\circ}$  C temperature drop from the heat source to the sample, when 250 watts were dissipated. The temperature gradient along the length of the sample varied  $8^{\circ}$  C. The most difficult problem appears to be devising a method of introducing and withdrawing the sample holder. In order to insure good thermal contact, the surface of the holder must press firmly against the surface of the slug can. However, it was found that the small taper necessary because of space limitations cause the two surfaces to bind and in order to separate the surfaces, they must be driven apart. A sample block has been designed, and is being fabricated, in which the block is split down one side so that it may be more easily removed.

G. Graphite Impregnation. (J. C. Carpenter, H. E. Robertson and I. T. Humphreys)

a. During this quarter it has been found that successful pitch impregnation of the graphite is more reliably achieved with a slight modification of the procedure than that reported before, (ORNL-66). The best procedure evolved to date is as follows: The sample and pitch are evacuated in the impregnation chamber for 15 minutes after which the temperature is raised to  $200^{\circ}$  C at which point the heat is turned off and the chamber is pressurized to 250 psi of nitrogen forcing the pitch into the submerged sample. When the temperature has dropped to  $150^{\circ}$  C the pressure is relieved and the sample is removed from the impregnation chamber. The baking and graphitizing procedures are the same as before. (ORNL-66)

b. Research was continued on the intermediate percentage impregnations with the emphasis on the determination of a real independent variable of the drying procedure such as the rate of evaporation of water at each point of the drying schedule. For this investigation a special recording potentiometer of 1 Mv range was set up to monitor the temperature difference between an impregnation specimen and its furnace surroundings during the drying procedure. Two runs were made on a given specimen at a given temperature; a "dry" run and a "wet" run. The "dry" run consisted of placing a cold dry specimen in the hot furnace which was set at a given temperature and monitoring the temperature of the specimen with time as well as the furnace temperature. The "wet" run was the same except that the specimen was impregnated with water before the heating. From the difference in these two heating curves one may calculate the rate of evaporation of the water as a function of time.

A "dry" run and a "wet" run were made on a sample at a furnace temperature of  $300^{\circ}$  C. These runs are shown in Fig. 10 where Curve "A" is the temperature of the "dry" sample versus time, Curve "B" is the furnace temperature (during the "dry" run) versus time, Curve "C" is the temperature of the "wet" sample versus time, and Curve "D" is the temperature of the furnace (during the "wet" run) versus time. Curves "A" and "B" were recorded simultaneously by using a motor driven selector switch to switch from one thermocouple to the other every ten seconds. Curves "C" and "D" were recorded in the same manner.

The rate of temperature rise in the dry sample, for a given difference in temperature between the sample and the furnace, was obtained from the slope of curve "A". From this rate of temperature rise, heat transfer

rates at each temperature difference, were calculated from the following equation:

$$Q_d = \left(\frac{\partial T}{\partial t}\right)_D (C_{pc} M_c)$$

where  $Q_d$  = Rate of heat transfer to the dry sample (cal/min)

$T$  = Temperature of sample ( $^{\circ}C$ )

$t$  = Time (min.)

$\left(\frac{\partial T}{\partial t}\right)_D$  = Rate of temperature rise in the "dry" run ( $^{\circ}C/min$ )

$C_{pc}$  = Specific heat of the graphite sample (cal/ $^{\circ}C$  gm)

$M_c$  = Mass of graphite in sample (gms)

The rate of heat transfer to the "wet" sample at a given difference in temperature between sample and furnace is assumed to be the same as the heat transfer rate to the "dry" sample at the same temperature difference because heat transfer conditions are nearly the same in both instances. The rate of heat transfer to the "wet" sample is considered the sum of three separate rates of heat transfer. These rates of heat transfer are the rate of heat transfer required to produce the observed rate of temperature rise of the graphite, the rate of heat transfer required to produce the observed rate of temperature rise of the water present in the sample, and the rate of heat transfer required to produce the rate of evaporation of water from the sample.

$$Q_d = Q_w = Q_1 + Q_2 + Q_v$$

where  $Q_w$  = Rate of heat transfer to the "wet" sample (cal/min)

$Q_1$  = Rate of heat transfer for producing the observed rate of temperature rise of the graphite (cal/min)

$Q_2$  = Rate of heat transfer for producing the observed rate of temperature rise of water present in the sample (cal/min)

$Q_v$  = Rate of heat transfer for producing the rate of evaporation of water from the sample (cal/min)

The rate of heat transfer for producing the observed rate of temperature rise of graphite and the rate of heat transfer for producing the observed rate of temperature rise of the water present can be calculated using the rate of temperature rise of the "wet" sample (slope of curve "C") in the following equation:

$$Q_1 \quad Q_2 = \left(\frac{\partial T}{\partial t}\right)_W (C_{pc} M_c) + \left(\frac{\partial T}{\partial t}\right)_W (C_{pw} M_w)$$

where  $\left(\frac{\partial T}{\partial t}\right)_W$  = Rate of temperature rise of "wet" sample ( $^{\circ}C/min$ )

$C_{pw}$  = Specific heat of water (cal/ $^{\circ}C$  gm)

$M_w$  = Mass of water present in sample at this time (gms)

The rate of heat transfer producing the rate of evaporation of water from the sample is then the difference between the total rate of heat transfer to the sample and the rates of heat transfer for producing the observed rates of temperature rise of the graphite and water present. This is shown by the following equation:

$$Q_v = Q_w - (Q_1 + Q_2)$$

The rate of evaporation of water from the sample at any given time can then be calculated from the rate of heat transfer producing the rate of evaporation of water at that time by the following equation:

$$\frac{\partial M_w}{\partial t} = \frac{Q_v}{H_w}$$

where  $\frac{\partial M_w}{\partial t}$  = Rate of evaporation of water (gms/min)

$H_w$  = Latent heat of vaporizing of water (cal/gm)

Combining the above expressions we have the following:

$$Q_w = Q_1 + Q_2 + Q_v$$

$$Q_w = \left(\frac{\partial T}{\partial t}\right)_D (C_{pc} M_c) + \left(\frac{\partial T}{\partial t}\right)_W (C_{pw} M_w) + H_w \frac{\partial M_w}{\partial t}$$

$$Q_w = Q_D = \left(\frac{\partial T}{\partial t}\right)_D (C_{pc} M_c)$$

$$\frac{\partial M_w}{\partial t} = \frac{\left(\frac{\partial T}{\partial t}\right)_D (C_{pc} M_c) - \left[\left(\frac{\partial T}{\partial t}\right)_D (C_{pc} M_c) + \left(\frac{\partial T}{\partial t}\right)_W (C_{pw} M_w)\right]}{H_w}$$

where  $\left(\frac{\partial T}{\partial t}\right)_D$  and  $\left(\frac{\partial T}{\partial t}\right)_W$  are for the same differences of sample and furnace temperatures in both "wet" and "dry" runs.

Thus: 
$$\frac{\partial M_w}{\partial t} = \frac{Q_D - (Q_1 + Q_2)}{H_w}$$

In the actual calculations, values for the various quantities were obtained from the following sources:

$\left(\frac{\partial T}{\partial t}\right)_D$  from slope of curve "A"

$\left(\frac{\partial T}{\partial t}\right)_W$  from slope of curve "C"

$C_{pc}$  from published tables

$C_{pw}$  from published tables

$H_w$  from published tables

$M_c$  by weighing the dry sample

$M_w$  Only the initial mass of water was known from weighing the

"wet" sample. The mass of water present at any given time was calculated as described below:

The "wet" run was divided into a finite number of time intervals (one minute intervals in the 300° C run) and the water evaporated in the first minute calculated. This was subtracted from the initial mass of water present, giving a new  $M_w$ . The new  $M_w$  was used in calculating the water evaporated in the second minute and the calculation repeated until  $M_w$  became zero.

In this manner the data Fig. 11 was obtained from the potentiometer record of "dry" and "wet" runs at a furnace temperature of 300° C. These data come from the runs shown in the Fig. 10. From the last column on the right in the "wet" run tabulation one may find the rate of evaporation of water at any time during the drying procedure. This is the end result of such an analysis and constitutes the true independent variable of the drying procedure which was sought.

This procedure of analysis has just been perfected and it yet remains to extend the procedure to samples impregnated with UNH rather than water and to correlate final uranium distributions with the rate of evaporation of water.

#### H. Simultaneous Pile Irradiation and High Temperature Creep Experiment

(Seagaser and Hunter)

(1) General. Work continues on the design and experimentation necessary to development an apparatus suitable for the determination of the creep-rate and limiting creep-stress of materials of construction proposed for power-pile application while exposed to simultaneous fast neutron irradiation and high temperatures. Based on experiments and field tests of the various components necessary for the successful operation of such a device, the design shown by Fig. 12 is submitted. This device incorporates all of the essential functions necessary for the determination of the creep of materials, although the apparatus necessarily differs from the construction of a conventional creep-rate apparatus as described in the A.S.T.M. Tentative Method of Test for Long-Time (Creep) High Temperature Tension Tests of Metallic Materials (E22-34T). This diversion from the standard is necessary for the pile-irradiation tests because of the very rigorous and unusual conditions under which the apparatus must function.

The requirements for the successful operation of a creep-determination device for insertion in a fuel-channel hole in the O.R.N.L. Pile are:

- (1) The over-all dimensions of the apparatus must be confined to a maximum diameter of 1.200 in. and a length of not more than 12 in.
- (2) The apparatus must be assembled from components which are themselves unaffected by irradiation. (As far as the tests are concerned).
- (3) All measurements of stress, temperature, and elongation must be made by remotely located instruments.

- [REDACTED]
- (4) The creep-apparatus must be capable of being disconnected by remote control for discharge into the storage canal.
  - (5) All connections to the device which are to be withdrawn from the loading face of the pile must be made of material which will not become excessively radioactive or which can be conveniently withdrawn into a lead container.
  - (6) A means of attaining the fast-neutron flux as well as simultaneous high temperature must be provided.

That the apparatus meets these requirements as well as the requirements ordinarily imposed by a conventional creep-apparatus may be seen by analysis of the proposed design.

(2) Stress Measurement. The required stress will be induced in the creep-specimen by means of gas pressure supplied from a high-pressure cylinder of Helium. The pressure will be regulated to the necessary value for a given wall thickness as shown by the curves of Fig. 13. This pressure will create a force on the piston head which will, therefore, be resisted by an essentially equal load on the specimen. Since the gas is retained by a flexible stainless-steel bellows, an apparatus has been designed and is currently being fabricated for the determination of the mean-effective-area of the bellows and its spring rate. This auxiliary equipment is necessary for the calibration of each of the bellows in order to determine the effect of the variation in mean-effective-area and spring-rate of the bellows on the induced stress in the specimen. Holes are drilled radially in the enlarged shoulder of the specimen in order to equalize pressure on the inside and outside of the specimen wall, such that component stresses due to unequalized pressures are eliminated. Pressure measurements will be made externally to the Pile by means of a 1000psi capacity Heise bourdon-tube pressure gauge. An  $8\frac{1}{2}$  in. diameter gauge with 500 graduations has been ordered. These gauges have a guaranteed accuracy of one-half of one per cent at points of reading above 20 per cent of scale. The accuracy for the remainder of the scale is one-fifth of one per cent of total. A certificate of accuracy covering at least 20 points on the dial is given with each gauge. The pressure system will be connected to the Pile Creep-apparatus by means of a Hansen quick disconnect coupling or equivalent for remotely discharging the device from the pile as shown by Fig. 14.

(3) Specimen Wall-Temperature and Fast Neutron Flux Determination. The temperature of the specimen wall and the required fast-neutron flux for bombardment damage will be attained by inserting a U-235 impregnated cylinder of graphite within the specimen bore. By carefully controlling the amount and distribution of uranium in the heater-element and knowing the value of the thermal neutron flux in which the apparatus is placed, the fission rate of the uranium in the heater element can be calculated, and, hence, the number of fast neutrons per square centimeter per second determined. Since the element is within the specimen, practically all of the fast neutrons generated (with the exception of those leaking from the ends) must pass through the specimen wall. The heater-element is shown in three sections in order that both a substantially constant wall temperature and flux can be maintained. A request has been submitted to the A.E.C. for 100 grams of U-235 which is estimated to be sufficient for 20 specimens.

The specimen wall-temperature will be measured by means of three iron-constantan thermocouples of No. 30 Ga. wire attached to the specimen wall at points 1 in. along its length and displaced radially by 120 degrees. A device consisting essentially of a globar unit and short length of aluminum tubing has been constructed for the purpose of determining the best methods of attachment of the thermocouple junctions to measure the true wall temperature. The leads from the thermocouples will be brought out of the high pressure shell as shown by means of three double eyelet Stupacoff hermetic seals retained against gas pressure by ring nuts and sealed with lead gaskets and solder. The output from these thermocouples will be measured by a suitable potentiometer placed adjacent to the loading face of the pile. The leads from the thermocouples will be disconnected by placement of deliberately weak links of small gauge wire at the lead-outs from the creep apparatus.

(4) Strain Measurement. Experiments have been conducted on two types of strain-measurement devices which appear to be suitable for use in the Pile creep apparatus. The first of these types is based on the pneumatic-gauge principle in which a variation in orifice size is made to vary the flow or pressure of a fluid. In application to creep-strain measurement, the variable orifice consists of a small nozzle through which is discharged a gas impinging against a plate moving perpendicularly to the orifice diameter. This device has proven very sensitive to linear motion and is expected to be very stable under pile irradiation. However, the problems involved in connecting the gauge to the apparatus and the necessity of thereby running two gas pressure leads from the pile make the second type appear to be the more feasible.

This second type of measuring device investigated is based on the differential inductance-gage principle, and is essentially a linear variable potential transformer. The device of a size suitable for mounting in the creep apparatus is commercially available and may be purchased from either the Schaevitz Mfg. Co., or the Baldwin Mfg. Co. under the trade name of Microformer. A Microformer unit from the Baldwin Co. has been tested in the O.R.N.L. Pile and the results are presented in the memorandum from C. E. Stillson to L. P. Hunter, under the subject, The Effect of Radiation on A Differential Transformer. In this test, the Microformer unit was mounted in such a manner that the Microformer core could be alternated between two fixed positions approximately 0.020 in. apart by remote control. Observations of output and resistance were made periodically during an irradiation period of 18 days with the Microformer placed within the maximum flux field of the pile. The input to the Microformer was 10 volts, 2000 cps, alternating current. The output was measured with a Hewlett-Packard Model 400-A vacuum tube voltmeter. As quoted from the memorandum, "Careful examination of the data reveals no failure or abnormal operation of the differential transformer during irradiation." The sensitivity of the Microformer was measured as 18.8 millivolts per 0.001 inch core displacement, or 0.0000532 inch per millivolt at 10 volt, 2000 cps. input. Similar tests are being planned for the Schaevitz type of Microformer. Therefore, considering its linearity of output voltage with core position, its accuracy of within one per cent under adverse conditions, the fact that it can operate at fairly high temperatures, the mechanical ruggedness and simplicity of construction, the simplicity of mounting and running the electrical connections from the pile and the elimination of friction between core and transformer, the linear variable differential transformer is recommended as a suitable device for measuring creep strains under irradiation.

[REDACTED]

(5) Fabrication Technique. Tests are planned and have been conducted on the technique of assembly of the various components of the pile creep device in order to insure success in the assembly of final apparatus. The most critical of the problems involved in assembly are those of high-temperature silver-soldering techniques in joining the various stainless-steel shells. This problem is complicated by the limited space available for fillet-welds, and the necessity of joining the shells with the creep specimen in place. Obviously, if the specimen is of low melting point alloy, such as 2S-Aluminum, there is danger of melting the specimen. Therefore, a technique of joinery based on induction heating is being investigated. It is anticipated that very close heat control can be obtained by this method, thereby offering the possibility of confining the heat to the outer shells without excessive penetration of heat to the specimen. The silver solder is applied by insertion of wires laid in grooves between the shells before assembly. The silver solder flows by capillary action to all points of the joint and, by careful control of clearances practically the full strength of the parent metal may be obtained in the joint. Several test specimens to perfect this technique are being fabricated.

(6) Bench Model Test Apparatus. The bench model of the creep-test apparatus as described in the previous Quarterly Report (ORNL-66) has been fabricated and assembled. No major difficulties of fabrication or assembly were encountered and since the pile model creep apparatus is similar in principle, no difficulties in this assembly are, therefore, anticipated. The necessary instrumentation, gas cylinders, power source, etc., are being assembled and it is expected that a preliminary creep-test on a 2S-Aluminum sample may very shortly be started.

#### I. Instrumentation for Creep Test. (C. Stilson)

In the creep test described in the previous section of this report, one end of the specimen will be fixed, another end free to move. The displacement of the free end will be measured to determine the specimen elongation during the test. Methods suggested as feasible for this application include the use of the Pneumatic Micrometer and the Linear Differential Transformer. Experiments with each method have indicated that both methods are feasible. The final selection of the instrumentation used will be based on consideration of accuracy, reliability and space limitations.

The important specifications of the instrumentation required for the creep measurement application follow.

1. Displacements up to a maximum of 0.040 inch are to be measured.
2. A minimum accuracy of 1% is desired.
3. The instrument must have long-time stability.
4. The indicating means must be located a minimum of 25 feet from the sensory means.
5. The sensory means must be unaffected by strong fission radiation fields.

6. No access to the sensory means is possible after radiation is started.

A further requirement is that the sensory instrument and connecting means should be of a minimum size and complexity because of the restricted size of the space available for the creep test device of which the sensory means is a part.

1. Pneumatic Micrometer. It was suggested that a gas inert to pile radiation could be used in connection with a fixed nozzle and the free end of the creep specimen (actuator) as a pneumatic micrometer. In the early experiments a flow-limiting orifice was used between the air supply and the nozzle, thus the nozzle pressure is a function of nozzle resistance, likewise, of creep specimen elongation.

The first experimental work was done using plain flat-ended nozzles (torch tips) with the nozzle outlet stream impinging on a flat plate. This work showed only a maximum indication of the order of 0.010 or 0.015 inch if possible in the range of plain nozzle sizes feasible for the intended instrument application. Since a measurement range of 0.040 inch is specified, a means of improving the range of indication was required. In order to increase the range of operation various types of variable area nozzles were conceived. The most promising of these was a ball-type nozzle considered from the standpoint of ease of construction with available materials. The first bench model of a pneumatic micrometer (designated "preliminary model") was constructed and tested. Fig. 15 shows a schematic of the general arrangement and a full size sectional detail of the nozzle.

Calibrations of the "preliminary model" are shown in Figs. 16 and 17. Fig. 16 shows a calibration for two different nozzle outlet areas. The addition of the second hole is an improvement over the single hole. The curve Fig. 17 shows the effect of two different operating pressures, 30 and 60 psi. These calibrations show that the indication is closely doubled for a corresponding increase in pressure indicating that the device is usable over a wide range of pressures. Adequate indication of displacement is observed over the desired 0.040 inch operating range for each curve shown.

Two disadvantages of pneumatic micrometer in this form and for this application arise from the fact that the nozzle pressure changes considerably in magnitude. At low pressures the ball which is floating between the actuator and the applied nozzle pressure has less force available to overcome possible restraints, for example during calibration sufficient force was not available at the lowest nozzle pressures to overcome the dial indicator mechanism spring load. To retain a simple form of pneumatic micrometer for the pile application it is desirable to discharge the nozzle into atmospheric pressure. Because of the forced air cooling in the fuel channels the nozzle discharge would be subject to static and dynamic pressure errors. These errors would be especially large for the less restricted, low nozzle-pressure-drop condition.

An analysis of the basic design factors showed the possibility of modifying the orifice and nozzle pressure ratios radically with considerably improved results. In the "preliminary model" it was necessary to have the orifice pressure drop and nozzle pressure drop of the same order of magnitude at some intermediate displacement condition. The improved arrangement

[REDACTED]

that was suggested by the analysis indicated the desirability of maintaining a low orifice pressure drop and a high nozzle pressure drop. This arrangement results in a large change in flow as the nozzle resistance is varied by the change in displacement of the free end of the creep specimen. These desirable pressure characteristics are easily obtained and a suitable indicating means are provided simultaneously by the replacement of the orifice used on Pneumatic Micrometer Model 1 by a flow meter consisting of a venturi throat and low range differential pressure measuring device. A suitable Flowmeter Model 1, was constructed using a crude venturi made of two sizes of copper tubing and a U-tube manometer as the differential pressure gage. A sketch showing the construction of Flowmeter Model 1 is shown in Fig. 18. The combination of Flowmeter Model 1 and the ball nozzle previously used (in the pneumatic micrometer "preliminary model") was designated as Pneumatic Micrometer Model 1. Calibrations of this model for three different pressures are shown in Fig. 19. Satisfactory operation is indicated over the 0.040 inch operating range required by the specifications stated. The performance of the Pneumatic Micrometer Model 1 was sufficiently gratifying that consideration of a refined, small design pneumatic micrometer was started. Preliminary design studies have indicated that a pneumatic micrometer suitable for this application can be built having sensory element of approximately 3/8 inch diameter by one inch long. The connecting tube between the sensory element and the flow meter can be as small as .065 inch i.d. and as long as 25 feet without severe design requirements. If necessary, it appears practical to reduce these dimensions since the lower limit has not yet been approached.

2. Differential Transformer. Differential transformers are available commercially which showed promise for application to creep measurement in the pile; therefore, testing of an available transformer in an operating pile was indicated. A differential transformer made by the O. S. Peters Co., Washington, D. C. was procured and tested. The arrangement of the test, in general, involved similar techniques to those planned or used for other experiments inserted into the fuel channels of the ORNL pile. Since the position of the differential transformer during test is approximately 25 feet from the pile face and no access to the devices is possible during or after irradiation, a necessary and sufficient radiation test of the differential transformer was considered to be the observation of the differential transformer output voltage for two definite core positions during an irradiation period exceeding the probable irradiation period of the creep test experiments. Accordingly a device to move the core of the differential transformer between two fixed locations was designed, built and tested. Resistance measurements were made periodically during irradiation to aid in diagnosis in case of malfunctioning.

The test device mechanism shown on assembly drawing Fig. 20 consists basically of a two-ended cable wrapped on two assembled grooved sheaves with an interposed eccentric cylindrical cam and an enclosing cam-follower having a linkage rod carrying the differential transformer core. The sheave and cam assembly is restricted to 180° rotation by stops to give a displacement of the core equal to twice the cam eccentricity, or a total displacement of a nominal 0.020 inch. This mechanism provides a means of positioning the core of the differential transformer in either of two fixed positions at will from the face of the pile by operating the pull wires connected to the cable on the sheave.

Bench testing consisted of making a precise measurement of actual

core motion, determining suitable electrical operating conditions, checking linearity of output voltage with position of the core, and making a pre-pile simulated test-run. Measurements indicated that the "best value" of displacement was 0.0219 inch. The reproducibility of the net core displacement was much better than expected considering machinery tolerances. Tests showed advantageous electrical operating conditions when an exciting voltage and frequency of ten volts and 2,000 or 2500 cps. were used. The output voltage was linear with respect to the core position within the accuracy of measurement.

The pile test consisted of irradiation of the test device continuously, according to the pile operating schedule, for a period of over two weeks. Readings were made periodically of the output voltage for the two positions of the core and of the coil resistance. The output voltages measured during the irradiation period are plotted on the graph Fig. 21. The net output voltages and differences in output voltages for the two core positions are plotted on the graph Fig. 22. The net output voltage corresponds to the net displacement of the core.

For comparison purposes several observations were made prior to loading the test device in the pile -- one observation after loading but before the pile was on, and the balance of readings made during the irradiation period. Several readings were made soon after the pile was brought up to power, in case failure occurred early; then, readings were made less frequently as the irradiation time increased. Observations were made over a period of 18 days -- longer than planned for creep experiments. Careful examination of the data reveals no failure or abnormal operation of the differential transformer during irradiation. At the conclusion of the test, the differential transformer test assembly was discharged from the pile into the canal.

It will be observed that Fig. 21 shows a consistent decrease in output voltages for both positions between pre-pile and in-pile readings. This consistent difference is attributed to the mechanism settling in a different sheave-shaft and bearing position since there was freedom from friction on the control wires in the pre-pile test; however, friction was present in the pile test since the control wires and electrical wires were drawn through a spiral hole in the channel shield plug. This effect is eliminated in the net output voltage curve since the effect is consistent for each core position.

The resistance measurements of the differential transformer showed no changes larger than those corresponding to the expected temperature change in the resistance of copper wire in the ambient temperature of the fuel channel cooling air of the pile. The conclusions of these tests are that the differential transformer would be suitable for measurement use in an operating pile for maximum periods and flux conditions equivalent to conditions during tests. A more complete description of conditions of test and test results are given in a confidential memorandum subject "The Effect of Radiation on a Differential Transformer" dated 8-16-48, addressed to Dr. L. P. Hunter from C. E. Stilson.

J. Recovery of Uranium from Graphite Fuel Units (L. W. Fromm and H. E. Webb)

Work this quarter was devoted mainly to the conversation of the process to the use of alternating current and to the adaption of the process for mass treatment of samples.

It had previously been shown that relatively high current densities would be required for the electrolytic process; and since high alternating currents (from large transformers) are more easily obtained than are high direct currents (from high capacity rectifiers), it was deemed desirable to find a way of using alternating current. The literature showed that the surface oxide of tantalum has the property of greater electrical resistance in one direction than in the other, and that both tantalum and its oxide are resistant to nitric acid corrosion. Experiments proved that by using a tantalum electrode with the graphite sample as the other electrode, the alternating current is rectified within the bath so the tantalum becomes the cathode and the graphite the anode. Also, by virtue of the same property of the tantalum, if the lead wire to the graphite is made of tantalum, no leakage of current directly to the bath occurs. It is necessary, however, to place a bit of platinum foil between the tantalum and the graphite to conduct the current into the graphite.

It was also found that efficiency could be multiplied by use of two tantalum cathodes in a full-wave circuit. In this circuit one cathode is connected to each end of the secondary of a transformer and the graphite sample anode is connected to the secondary center-tap. The anode is thereby subjected to the same conditions as when fed with pulsating direct current supplied by a full-wave rectifier. Two methods for mass treatment of samples were tried. The first was that of random placement of samples in a tantalum basket with a piece of platinum foil at the bottom. The experiment was unsatisfactory, since a current density of 3 to 5 amps./cm.<sup>2</sup> is required for efficient operation of the process and since the entire side surfaces of two samples were exposed to the action. With existing equipment a current density of 0.5 amps./cm.<sup>2</sup> was the maximum that could be attained in this apparatus.

In order to confine the required current for the desired current density to 10 to 15 amps., a second method was tried wherein the samples were stacked end to end and the action confined to one end of the stack. Several apparatus were designed and constructed to accomplish this. The final improved apparatus consisted of a vertical tank 2 inches in diameter and about 30 inches long attached to an external convection cooling system; in the top of the tank are mounted in a circle, 60° apart, three parallel 1/4-inch tantalum rods insulated from each other electrically by a "Lave" fitting. Two of the rods extend half-way down the tank and act as cathodes in the full-wave circuit, and the third rod runs to the tank bottom, makes a 180° bend, and extends back up along the center line of the tank, ending in a pedestal 1/8 inch thick and 0.787 inch (2cm.) in diameter about 2 inches below the cathode ends. Upon this pedestal, the top of which is covered by a disk of platinum foil, are stacked three or four 2 cm. diameter by 5 cm. long graphite samples. A glass tube equal in length to the height of the sample stack is placed surrounding the samples, supported by a glass bar hung across the top of the stack. This glass tube confines the disintegrating action to the top of the stack, and as action continues the tube moves downward so that the distance relationship between action surface, glass insulating tube, and cathodes remain constant. Tests on three stacked samples in this apparatus indicated

that at 10 amps. (3.2 amps./cm.<sup>2</sup>) complete disintegration occurred in 47 minutes, and at 15 amps. (4.8 amps./cm.<sup>2</sup>) complete disintegration occurred in 20 minutes. The underlying principle of this apparatus is easily adaptable to large scale application. An investigation as to the best method of treatment of hollow cylindrical samples was begun with a view toward the comparative testing of samples which have been impregnated and/or coated with pitch and tar, metal-plated, metal-sprayed, and otherwise treated in the course of the pore-sealing investigation of J. R. Humphreys, Jr. Very preliminary results indicate that the best method is the gradual lowering of the sample into the disintegration bath at a rate approximately equal to the rate of disintegration. An apparatus to perform this operation semi-automatically has been designed and is now under construction.

To date the graphite powders resulting from disintegration runs on uranium-impregnated samples have been refluxed in concentrated nitric acid for a total of 183 hours. Assuming that all the original uranium has now been removed and accounted for, the following results have been calculated:

Run No.	Description	Recovery Percentage	
		During Disintegration Run	During 183 Hour Reflux
EU-1	Disintegration in Boiling Bath- 1 hr.	99.76	0.24
EU-2a	Disintegration at room temp.-26 min. Then Boiled Slurry 2 1/2 hrs.	99.82	0.18
EU-2b	Same as EU-2a. Another piece of same sample.	99.81	0.19
EU-3	Disintegration at room temp.-28 min. Filtered immediately without refluxing.	99.32	0.68

K. Graphite Technology. (J. R. Humphreys and C. C. Scott)

Tests are underway to determine the effect on permeability of high temperature ageing on previously prepared bulk impermeable graphite samples. Ageing times of from 4 to 6 hours at temperatures in the range of 1000-2000° C are proposed, starting with 1000° C and recycling at progressively higher temperatures until definite permeability of the sample is observed.

The samples to be used on this test were recycled, using the pitch impregnation and reduction method until they were impermeable. The original permeability measurement tests for these samples consisted of making the tubes (1 1/8" OD x 1D x 4" L) an integral part of a 6 liter vacuum system and then measuring a leak rate over a one half hour period. A reduced volume system will be used in making permeability measurements on the tubes for the heat ageing tests in order to increase the sensitivity of the measurement.

[REDACTED]

L. Metallurgy. (H. B. Fairchild)

A broad range report on zirconium beginning with the history of the metal and covering all known physical and chemical data, nuclear physics properties, corrosion studies, methods of production, methods of fabrication, of the ductile metal, and the facts of pertinent interest is being written.

Final arrangements were made in conference between members of our Division and representatives of the Sylvania Electric Products Co. proceeding with that portion of the contract with the AEC which is of direct interest to us. This contract requests that Sylvania follow a program of three main objectives for the Navy pile studies. These are (1) the research into the production of ductile beryllium, (2) investigation of the beryllium-uranium metallurgy powder metallurgy techniques with the objective of preparing "sandwich" fuel elements with Be-U "meats" and zirconium cladding, and (3) the execution of more or less standard tests on the creep strength, thermal expansion, and thermal conductivity of zirconium.

M. Ceramics. (W. W. Galbraith)

The ceramic development program was continued at the Electrotechnical Laboratory, Norris, Tennessee, in cooperation with the U. S. Bureau of Mines. During the last quarter three phases of the program to improve the resistance to thermal rupture of beryllia bodies were studied.

Beryllia bodies containing a special shipment of fused BeO grain, crushed and screened into selected ranges of screen sizes, showed significant volume expansion after firing in gas fired kilns and small or no volume expansion after firing in the reducing atmosphere of a graphite-resistor kiln.

Beryllia bodies were fabricated into test cylinders to evaluate the resistance to thermal rupture. Variations in grain size distribution and firing conditions were studied.

Representative beryllia test cylinders were tested for resistance to thermal rupture in order to evaluate the effect of grain size distribution and firing conditions. The test results indicated that a body containing 47.5 per cent minus 10 plus 35 mesh, 19 per cent minus 35 plus 100 mesh, and 28.5 per cent minus 100 mesh dense BeO grain, bonded with 5 per cent low calcined BeO powder, and fired at 165° C for 8 hours would have good resistance to thermal rupture.

Complete data for the work are found in the May, June, and July, 1948 Electrotechnical Laboratory reports (ETL 11, 12, and 13) titled "Refractories for Atomic Power Production".

## AIR SATURATED STATIC WATER TESTS

RUN #	Sample	Sample History	Temp. °F	Time hrs.	PH	Area cm <sup>2</sup>	Wt. change g/M <sup>2</sup>	Observations
B-3	Be	6-1 Extrusion ratio	750	43.5	in 5.7 out 5.9	16	9.0	Numerous small cracks on one side- One major crack through sample localized corrosion in form of white nodules at edges
B-4	Be	6-1 Extrusion ratio	750	43.5	in 5.7 out 8.9	16	complete disintegration	
EM-1	Be-SS couple	Be 6-1 extrusion ratio SS Carpenter 20	680	41	in 5.9 out 8.0	16	Be disintegrated SS 0.2	
SS-9	Stainless Steel	Carpenter 20	750	43.5	in 5.7 out 3.85	16	-0.125	Sample reddish brown color
SS-11	"	G.T.-45	750	42	in 5.8 out 5.0	20	.005	Sample dark brown
SS-12	"	"	750	42	in 5.8 out 5.5	20	-0.15	Sample reddish brown
SS-13	"	Type 32 (Ti Stabilized)	750	64	in 6.2 out 4.1	16	-0.06	" " "
SS-15	"	Type 347 (Cb Stabilized)	750	64	in 6.2 out 6.0	16	0.0	" " "
SS-17	"	Type 316 (Mo Stabilized)	750	64	in 6.2 out 6.0	16.3	-0.4	Sample showed numerous white nodules on one side, other side tarnished
G-1	Graphite	From Untermeyer Pump	680	64	in 6.2 out 7.5	27.7	-1.62	No change in sample appearance
Z 22	Zr	Footc Mineral (source)	750	42	in 5.8 out 5.8	10	4.0	White oxide spots visible-sample malleable
Z 23	Zr	" "	750	42	in 5.8 out 6.5	10	15.3	" " " " "

FIGURE

IMPREGNATED GRAPHITE IRRADIATED AT HIGH TEMPERATURE

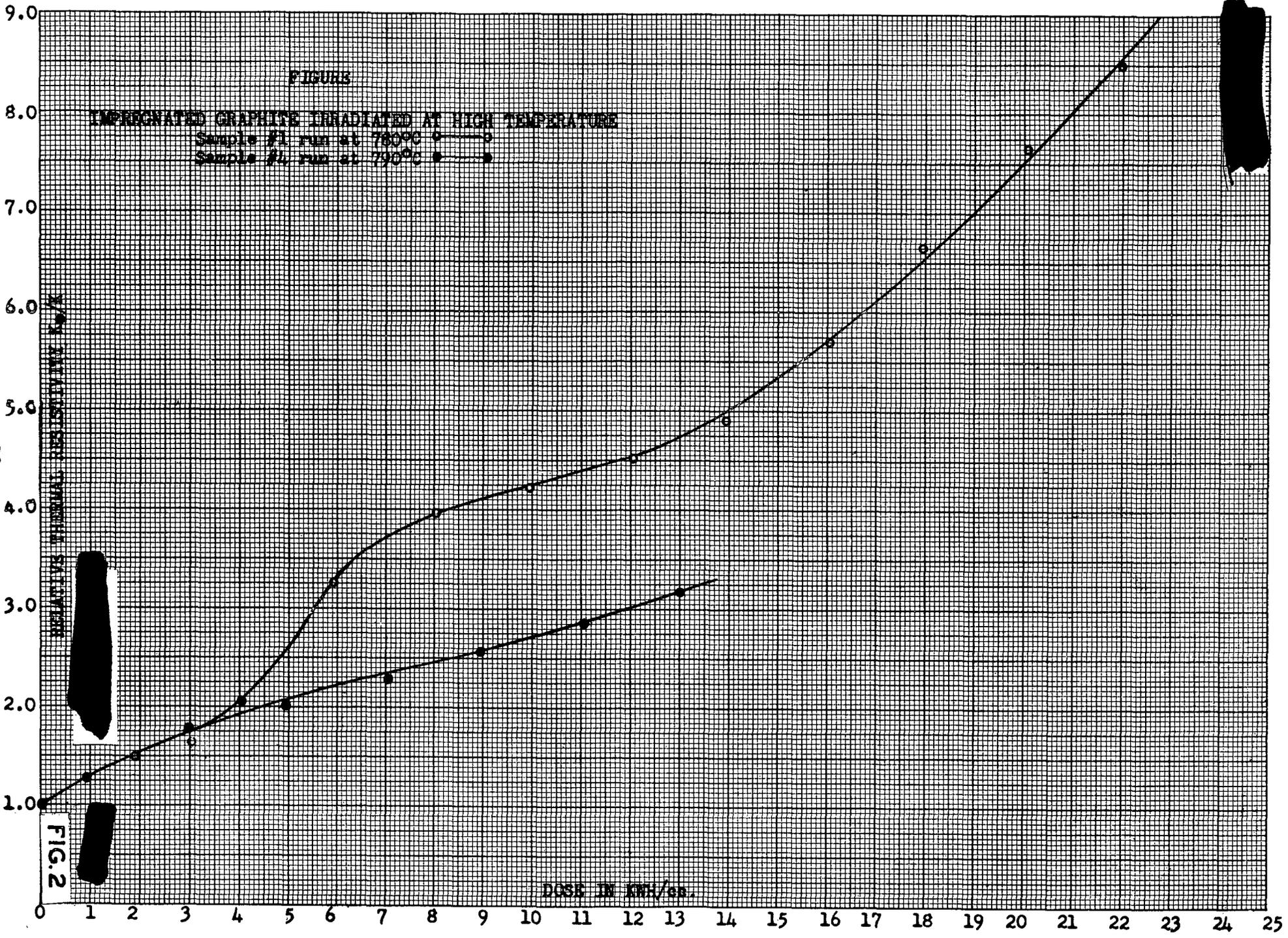
Sample #1 run at 700°C ○—○

Sample #2 run at 790°C ●—●

23  
K/g. IRRADIATED GRAPHITE  
SILVER

FIG. 2

DOSE IN KW/CS.



12

FIGURE

GRAPHITE IRRADIATED AT HIGH TEMPERATURE  
 Impregnated Graphite #3 (6300°C) ○—○  
 Molded Graphite #4 (650°C) ●—●

11

10

9

8

7

6

5

4

3

2

1

RELATIVE THERMAL RESISTIVITY (%)

DOSE IN MR/HR

FIG. 3

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36

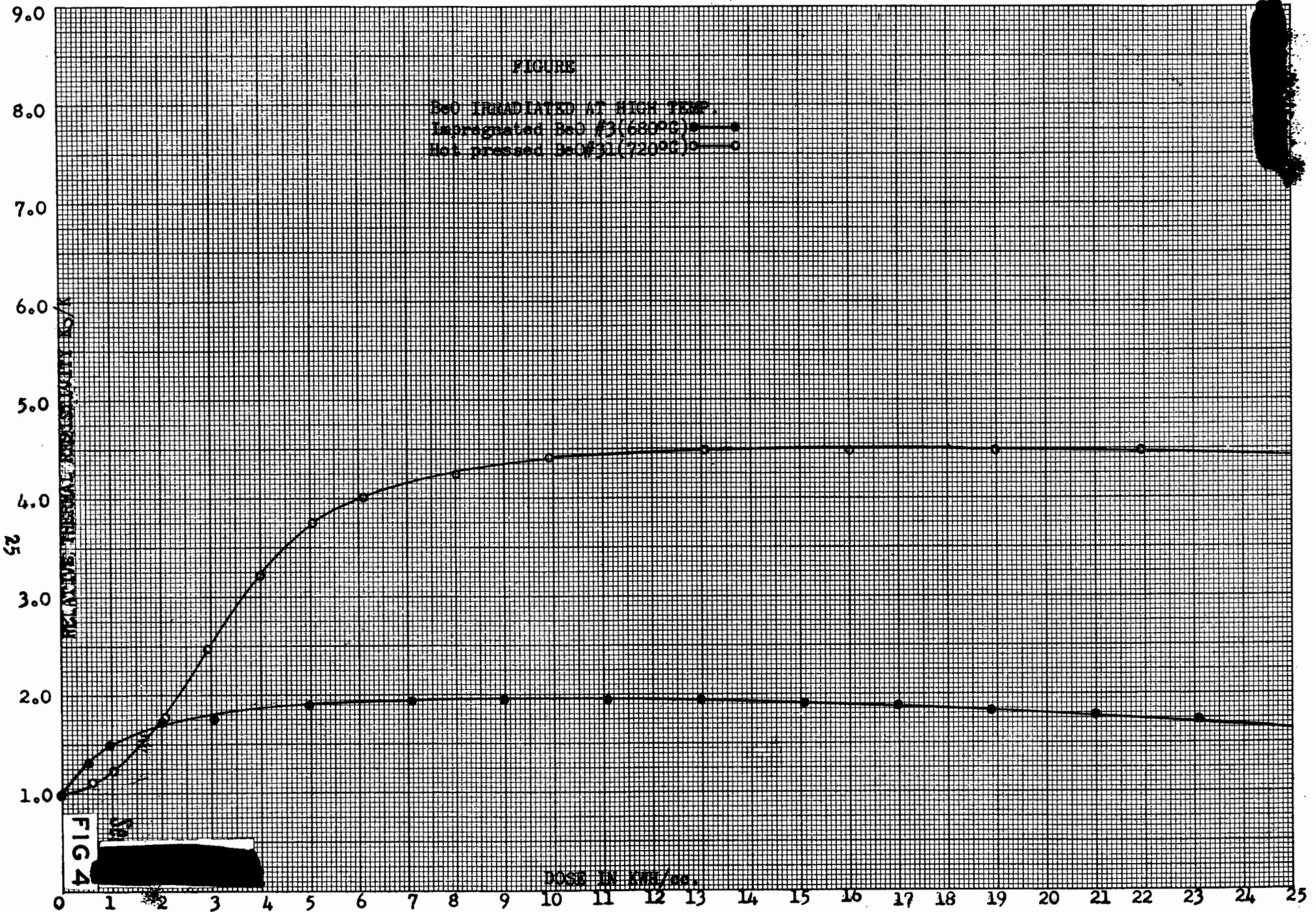
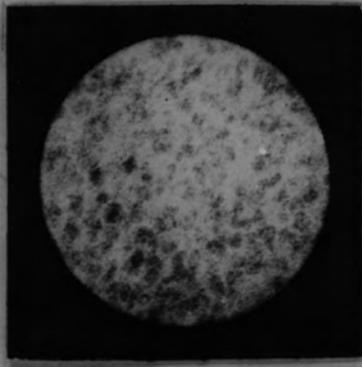


FIG 4

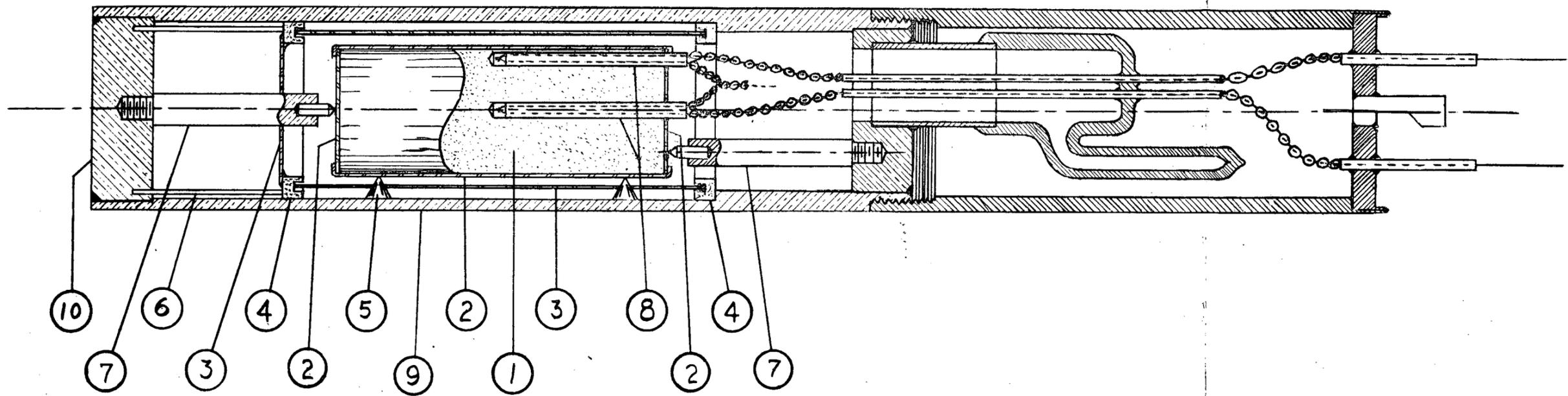


EXTRUDED  $\text{BeO}$  IMPREGNATED WITH  $\text{UO}_2$



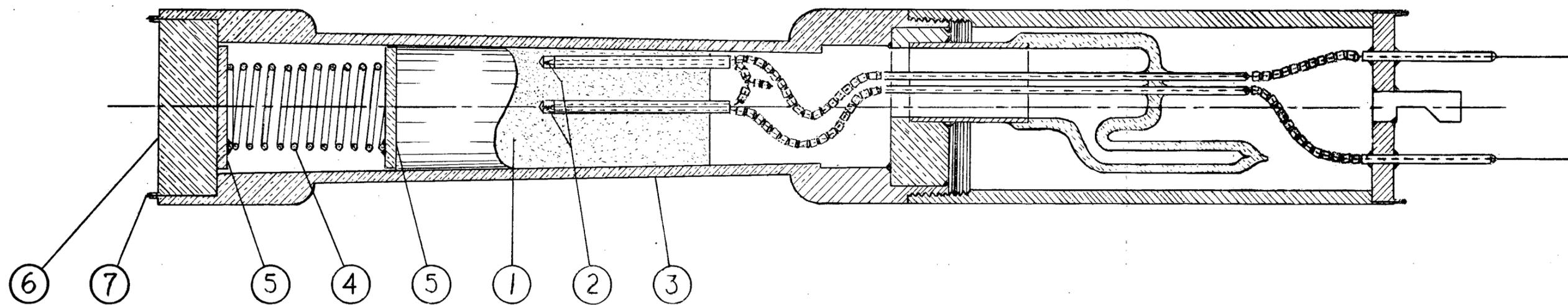
HOT PRESSED  $\text{BeO-UO}_2$  MIXTURE

$\text{BeO-UO}_2$  MIXTURES



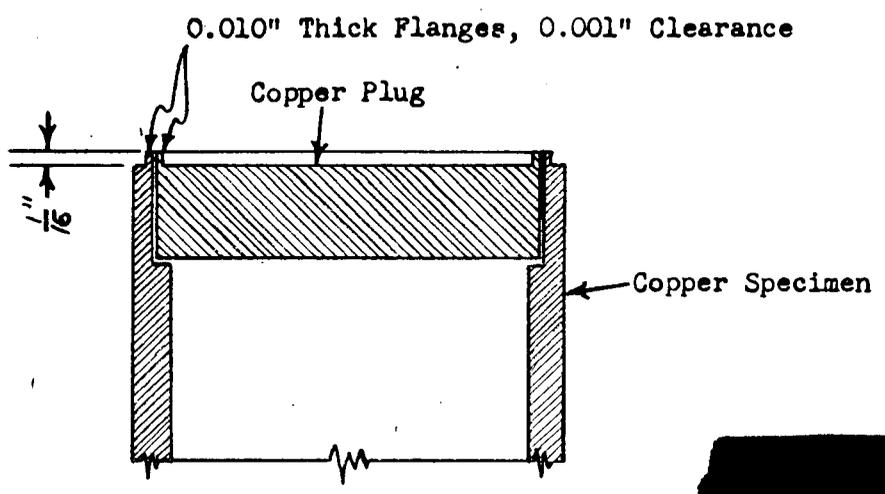
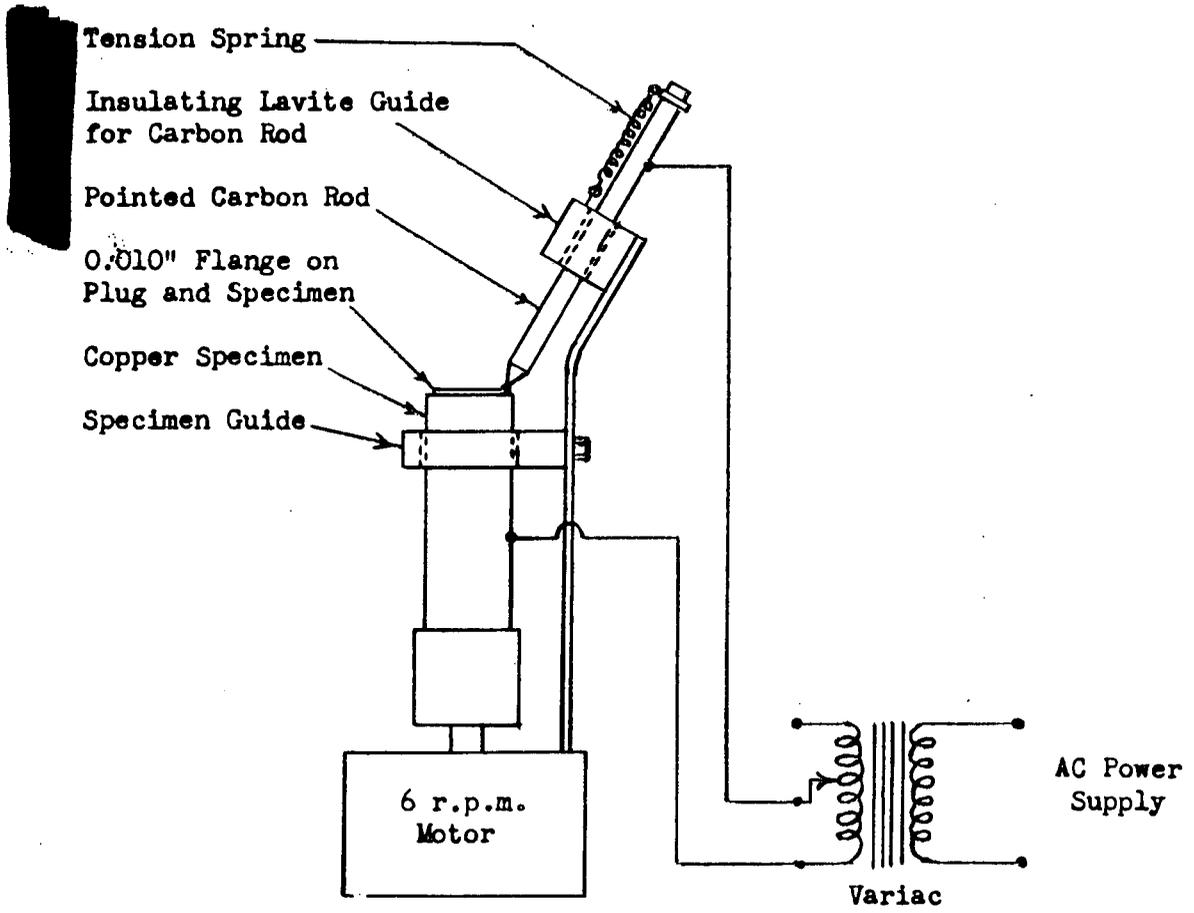
HIGH TEMPERATURE  
THERMAL CONDUCTIVITY  
PILE APPARATUS

FIG. 6



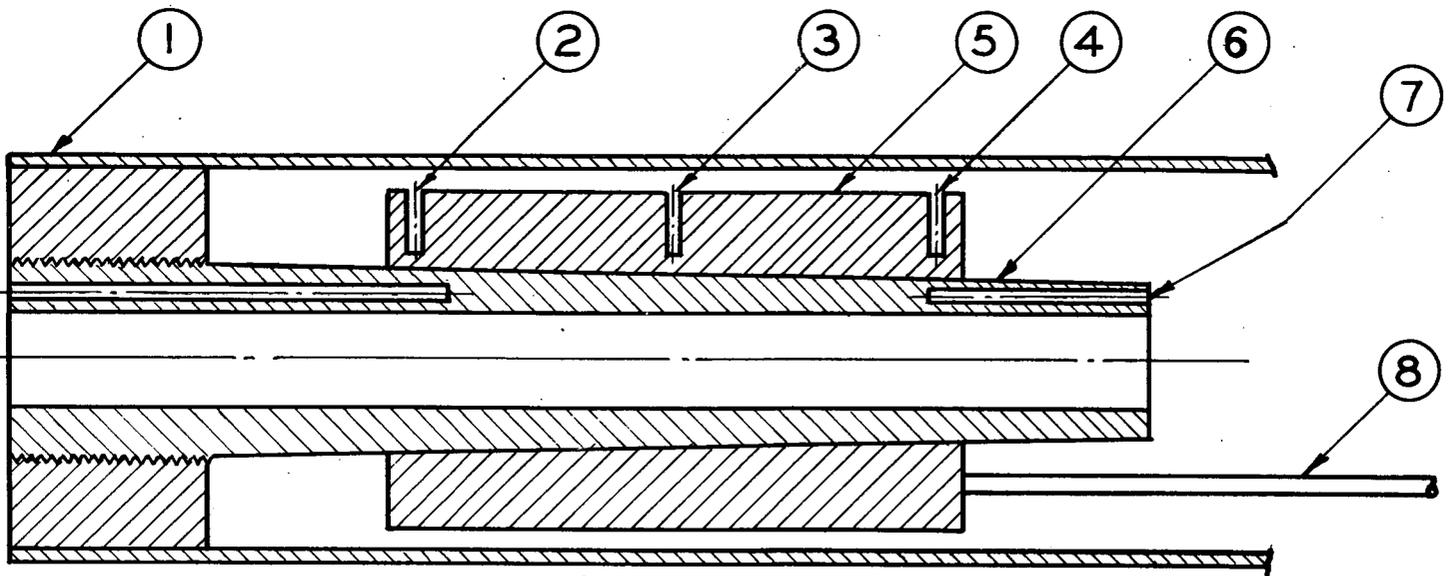
LOW TEMPERATURE  
THERMAL CONDUCTIVITY  
PILE APPARATUS

FIG. 7



WELDING APPARATUS  
 USING  
 HOT CARBON ROD METHOD  
 FIG. 8

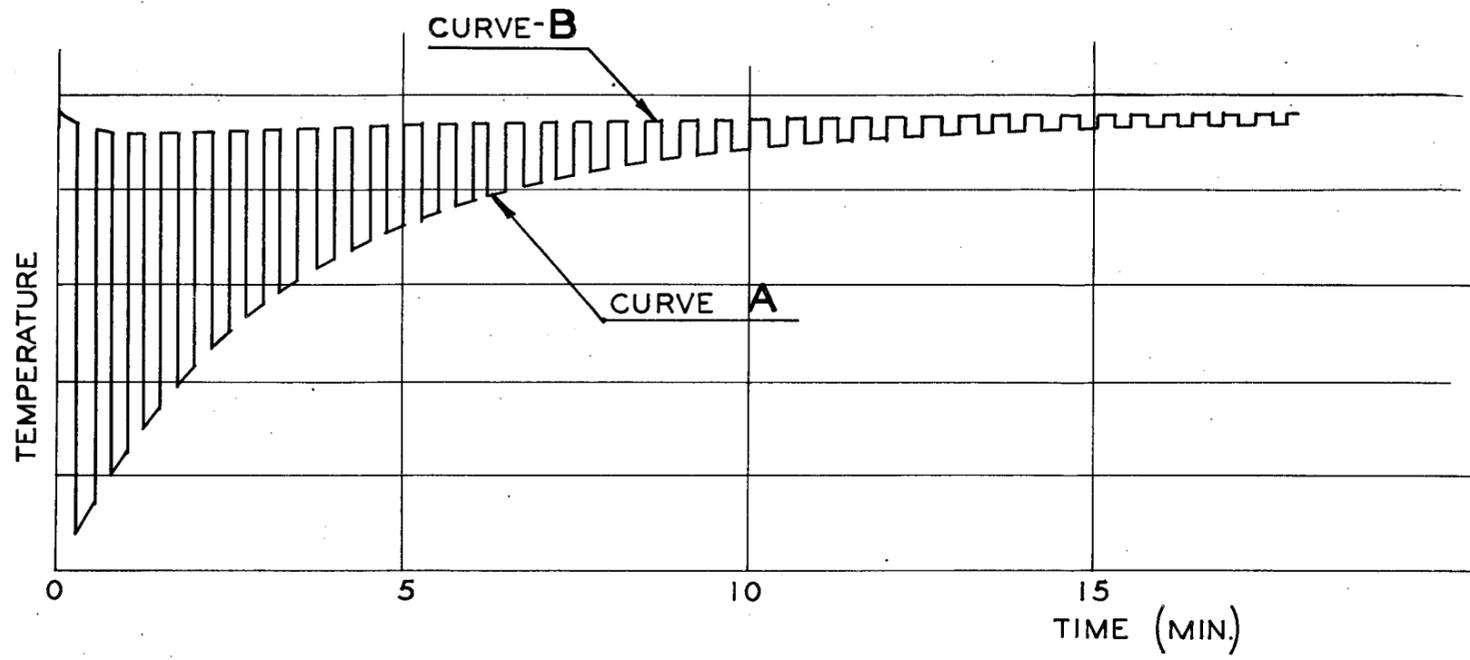
PPD-A-1466



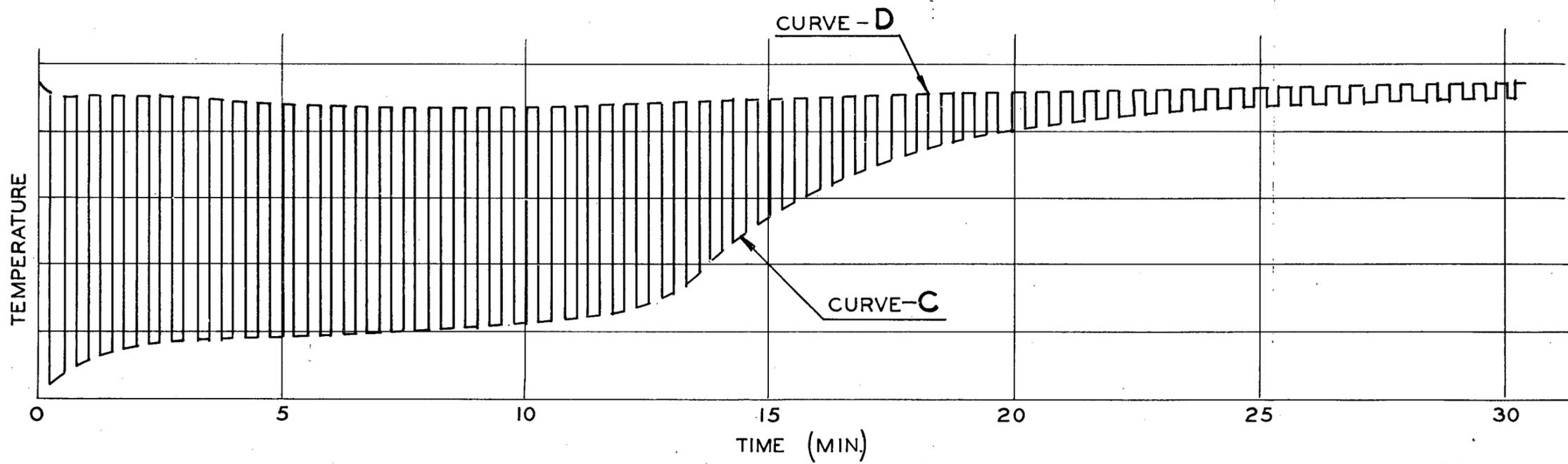
- ① 2-S ALUMINUM TUBING.
- ② ③ ④ THERMOCOUPLE HOLES DRILLED IN SAMPLE HOLDER BLOCK.
- ⑤ 2-S ALUMINUM SAMPLE HOLDER BLOCK. SAMPLES TO BE IRRADIATED WILL BE PLACED IN HOLES DRILLED PARALLEL TO THE LONGITUDINAL AXIS.
- ⑥ STAINLESS STEEL TAPERED HOLLOW CYLINDER TO ENCLOSE THE GLO-BAR. THIS CORRESPONDS TO THE SLUG CAN IN THE FINAL SET-UP.
- ⑦ TWO THERMOCOUPLE HOLES DRILLED IN BOTH ENDS OF THE GLO-BAR CASE.
- ⑧ ALUMINUM PUSH ROD TO INSERT AND WITHDRAW THE SAMPLE HOLDER.

SAMPLE IRRADIATION BENCH MODEL

FIG. 9



DRY RUN



WET RUN

IMPREGNATION SAMPLE  
 RUN AT 300°C FURNACE  
 TEMPERATURE

FIG.10  
 PG.

"DRY" RUN AT 300° C FURNACE TEMPERATURE

M<sub>c</sub> 26.6828 gms.

Time (min)	(T <sub>f</sub> -T <sub>s</sub> )* (°C)	(°C/min)	Q <sub>d</sub> (cal/min)
0	271.8	---	---
1/3	242.0	78.0	400
2/3	216.6	70.6	404
1	195.0	65.0	390
1 1/3	172.6	57.4	370
1 2/3	154.6	53.8	363
2	141.4	47.6	334
2 1/3	129.0	42.6	303
2 2/3	111.0	38.4	269
3	104.8	34.6	254
3 1/2	90.6	33.8	239
4	78.0	28.4	225
5	60.4	25.4	202
6	48.2	18.4	149
7	38.2	13.8	114
8	29.6	10.4	87

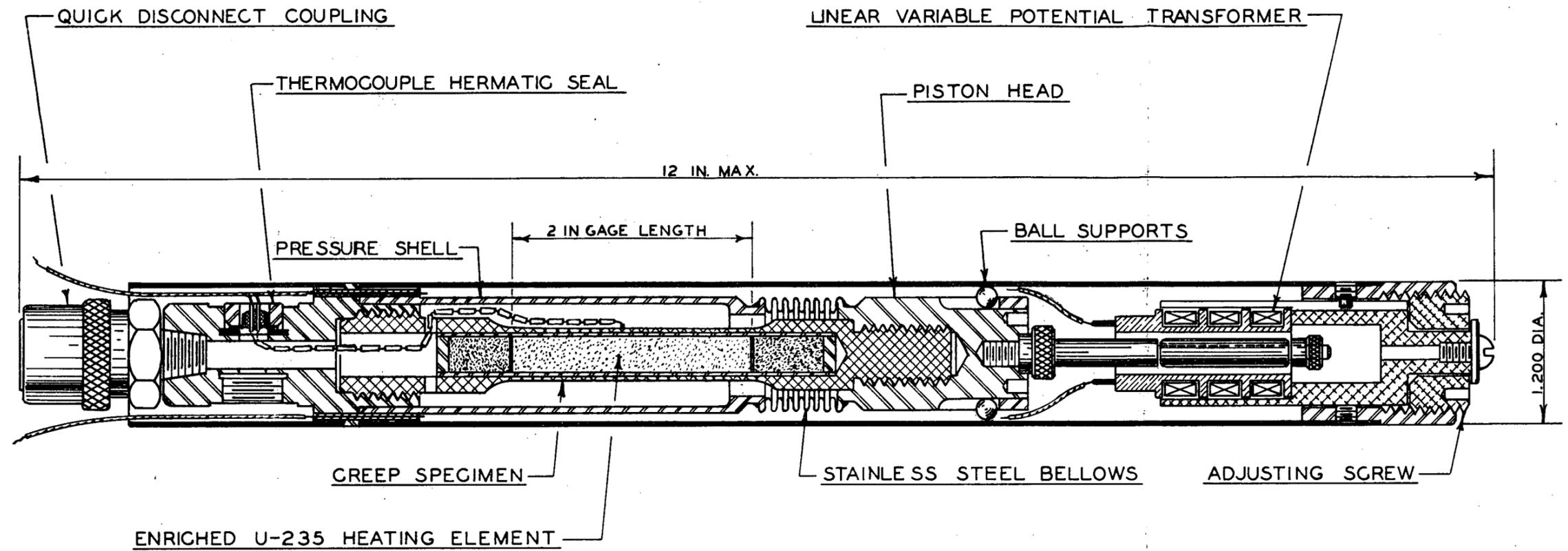
"WET" RUN AT 300° C FURNACE TEMPERATURE

M<sub>c</sub> 26.6828 gms.  
M<sub>w</sub> 6.4406 gms. (initial value only)

Time (min)	(T <sub>f</sub> -T <sub>s</sub> )* (°C)	(°C/min)	M <sub>w</sub> (gms)	Q <sub>1</sub> (cal/min)	Q <sub>2</sub> (cal/min)	Q <sub>d</sub> (cal/min)	Q <sub>v</sub> (cal/min)	(gms/min)
0	266.8	37	6.4406	175	240	415	0	0
1/2	234.4	27	6.4406	137	173	410	100	.187
1	223.0	19.2	6.3466	102	122	408	184	.343
1 1/2	212.4	13.4	6.1756	74	83	406	249	.464
2	207.8	9.6	5.9436	54	57	402	281	.524
2 1/2	204.4	7.0	5.6816	40	40	401	321	.600
3	203.4	5.0	5.3816	28	27	401	346	.645
4	198.8	3.7	5.0586	22	19	400	359	.667
5	194.4	2.6	4.3916	15	12	398	371	.673
6	192.4	1.9	3.7186	11	7	397	379	.705
7	190.0	4.2	3.0136	24	13	396	359	.669
8	185	5.4	2.3446	32	13	390	345	.645
9	182.0	5.6	1.6996	33	10	387	344	.643
10	181.0	4.2	1.0566	25	5	387	357	.662
11	177.6	7.4	0.3946	45	3	382	334	.622
12	173.0	23.8	0.0000					
13	159.6	33.6						
14	125.2	31.0						
15	99.8	24.4						

\* (T<sub>f</sub>-T<sub>s</sub>) is the difference between sample and furnace temperatures.

FIG. 11



PILE CREEP-TEST APPARATUS

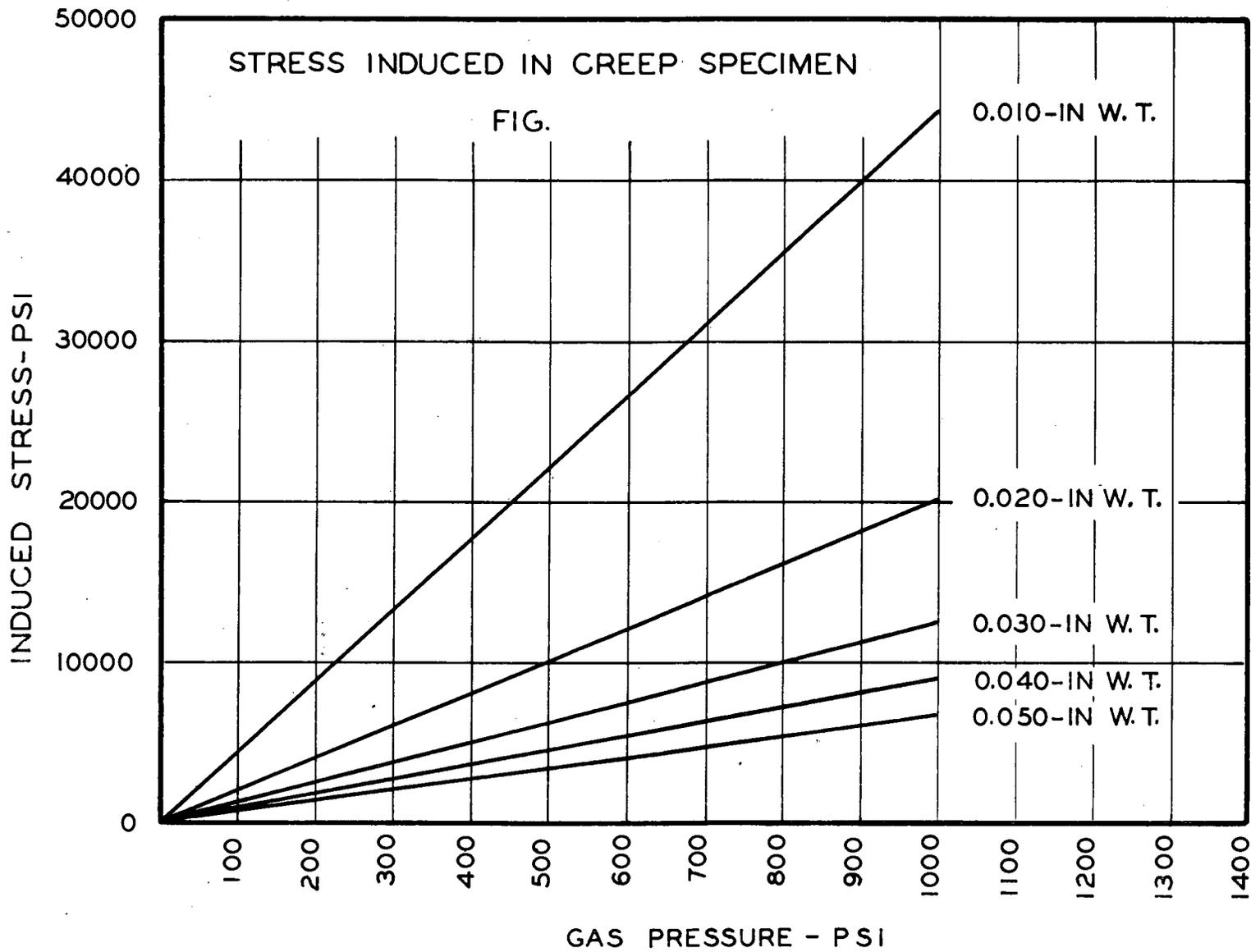
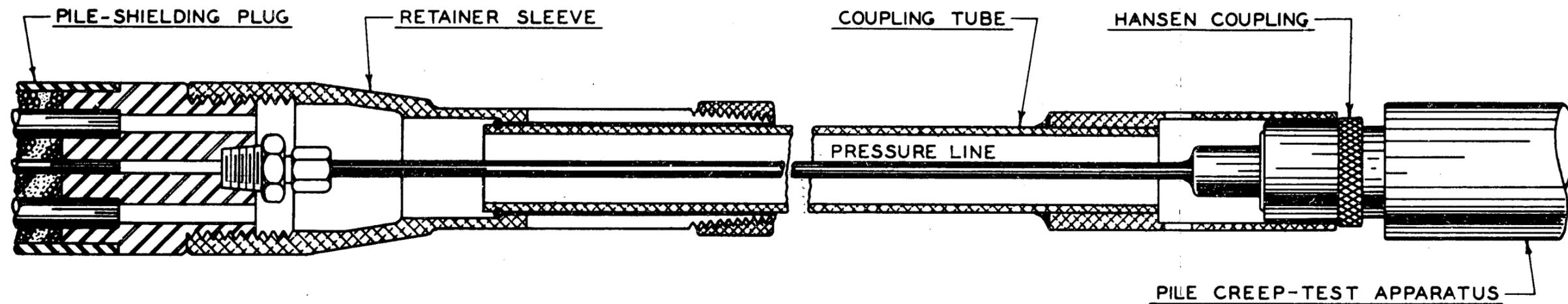


FIG.13

NOT CLASSIFIED



PILE CHARGING TUBE

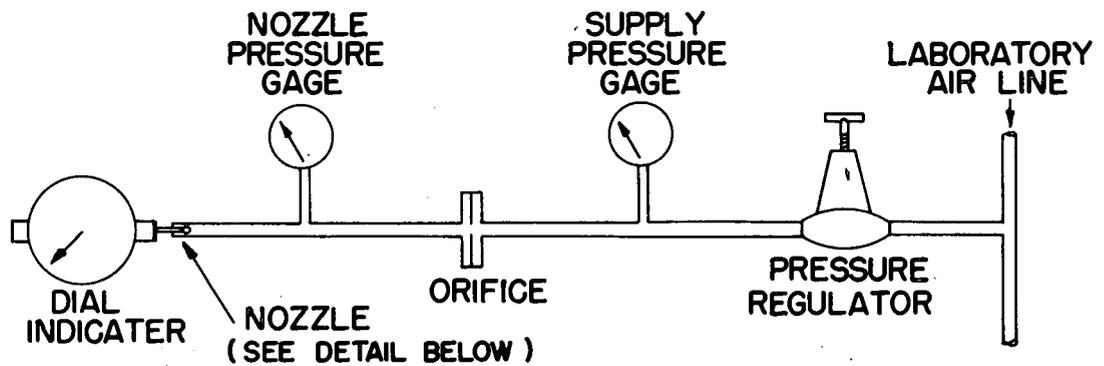
This Drawing Classified As

Per C.L.S.

FIG. 14

# PNEUMATIC MICROMETER PRELIMINARY MODEL

## SCHEMATIC:



## NOZZLE DETAIL:

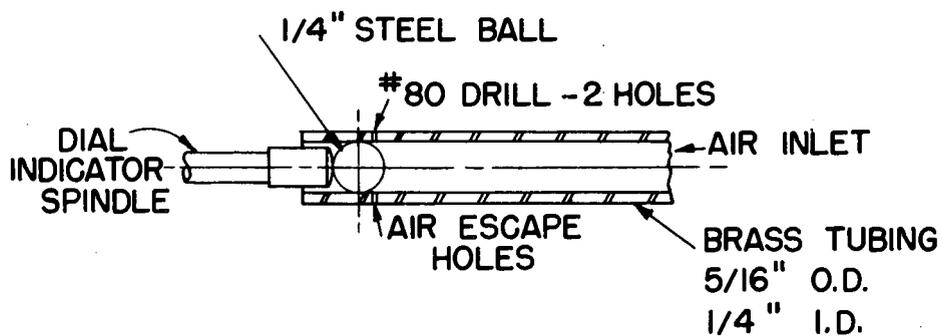
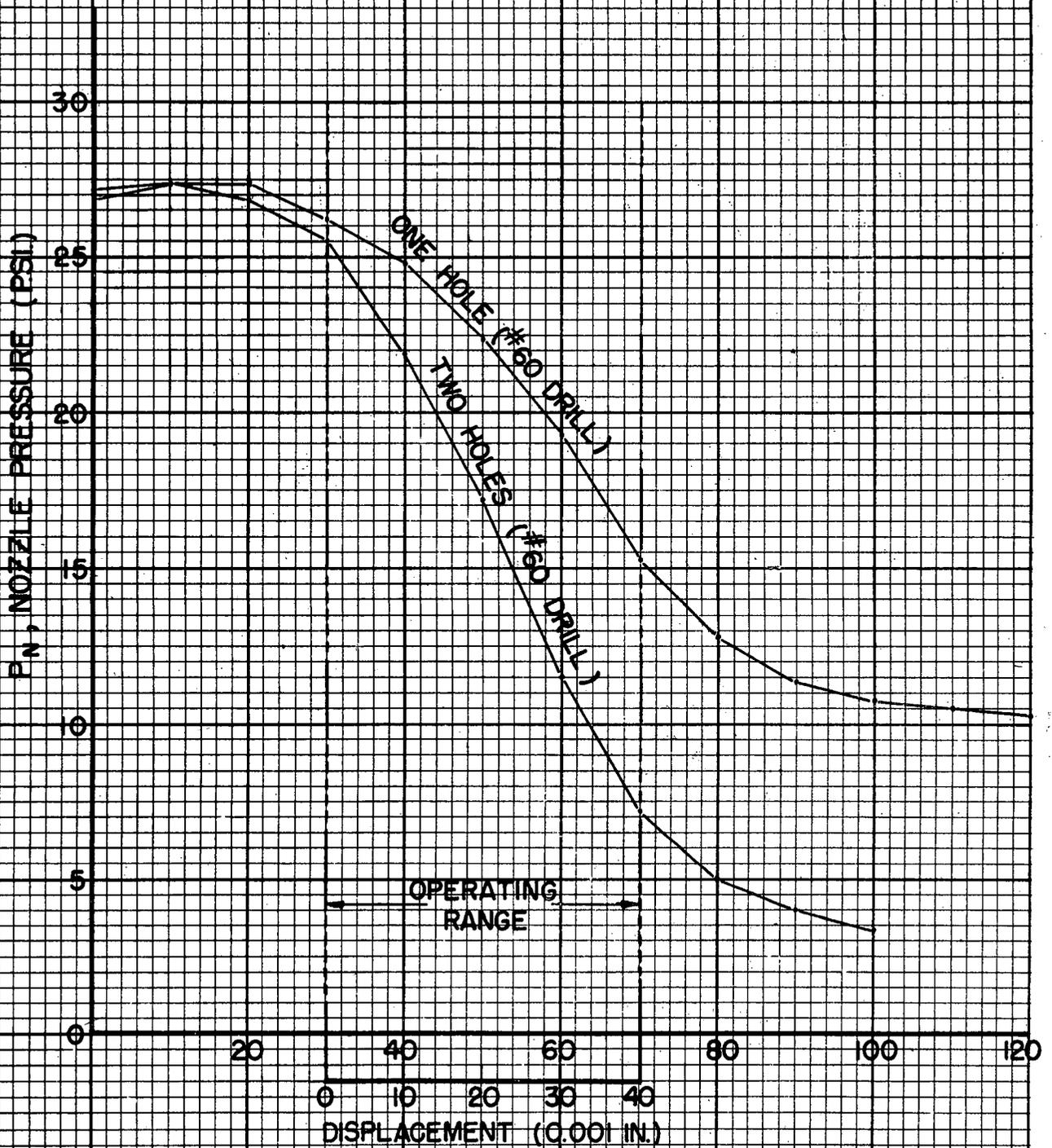


FIG.15

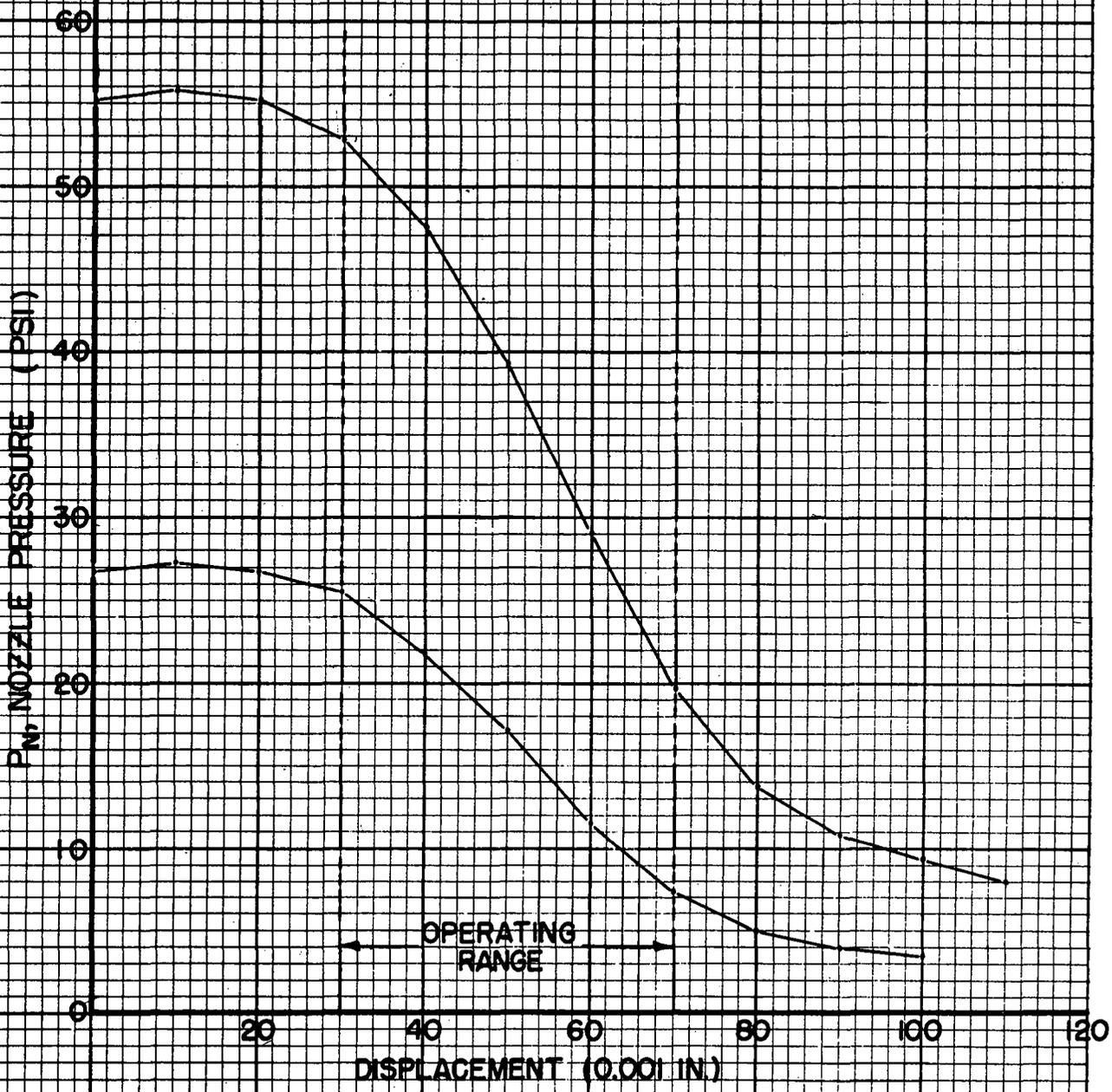
NOZZLE AREA: VARIOUS  
SOURCE PRESSURE: 30 PSI



CALIBRATION OF PNEUMATIC MICROMETER  
PRELIMINARY MODEL  
30 PSI

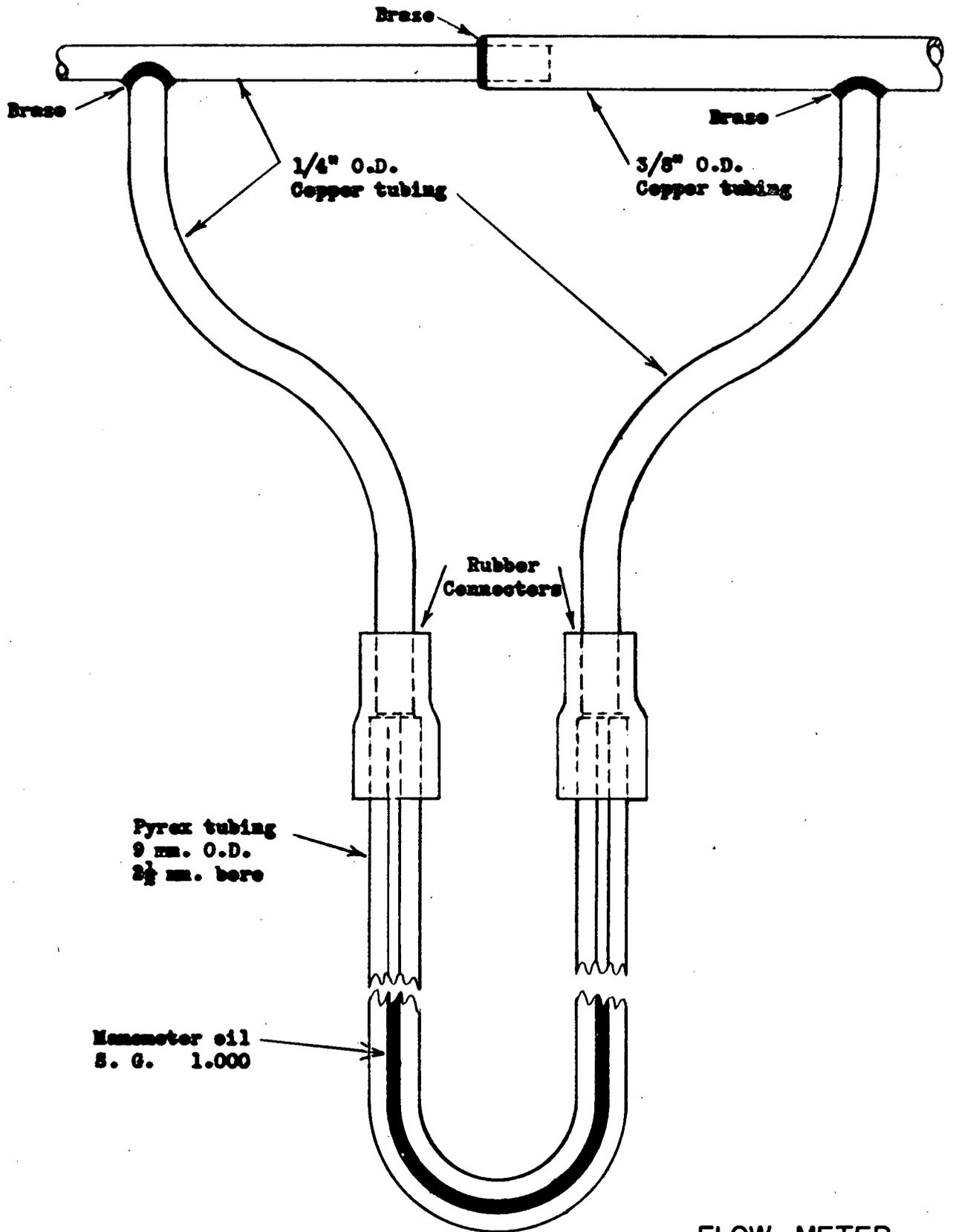
FIG. 16

NOZZLE AREA: 2 HOLES (#60 DRILL)  
SOURCE PRESSURE: 30 PSI & 60 PSI



CALIBRATION OF PNEUMATIC MICROMETER  
PRELIMINARY MODEL  
30 & 60 PSI

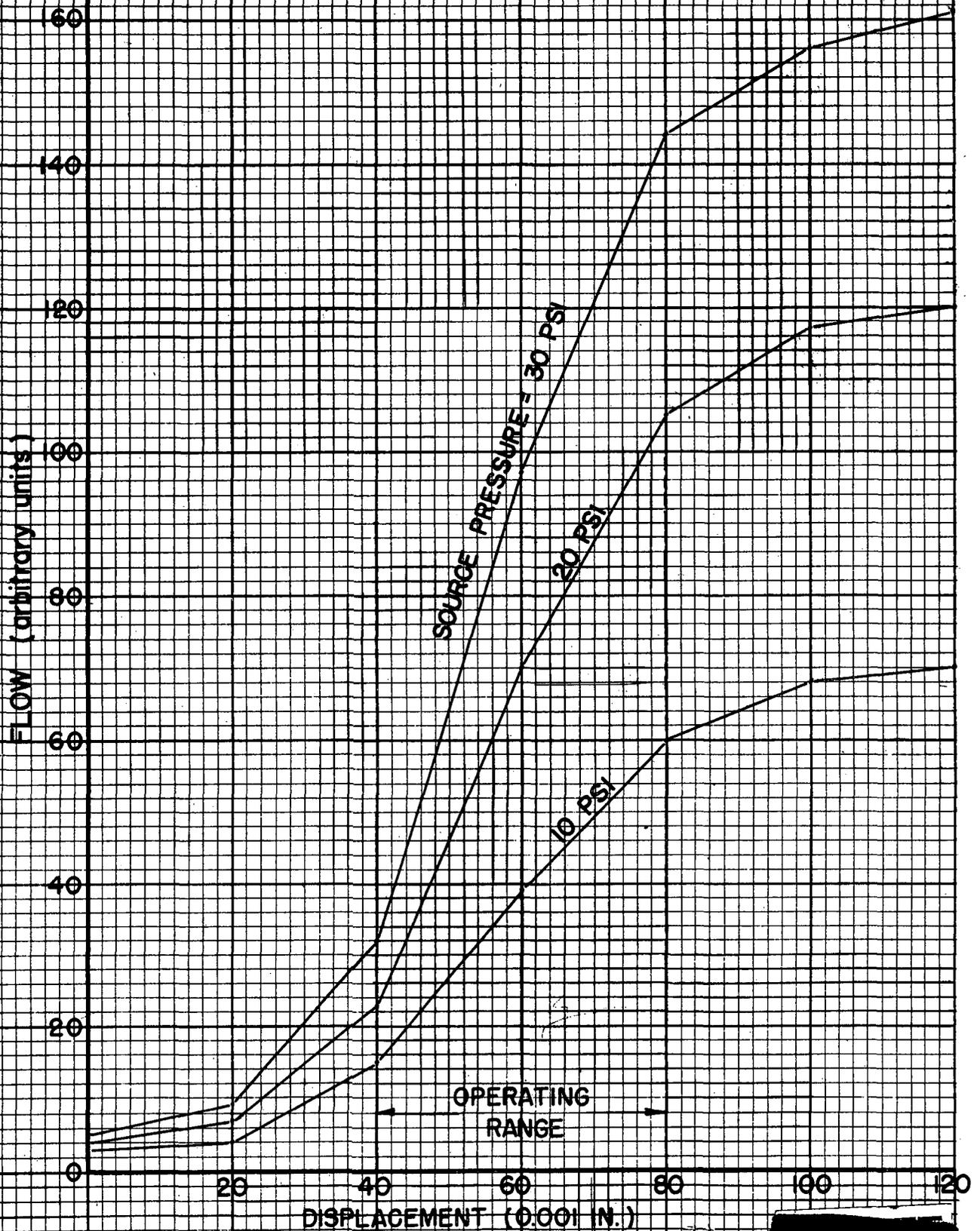
FIG. 17



FLOW METER  
MODEL-I



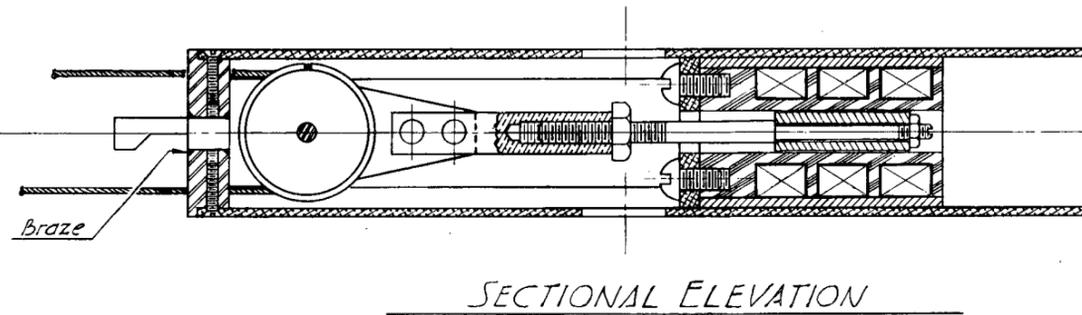
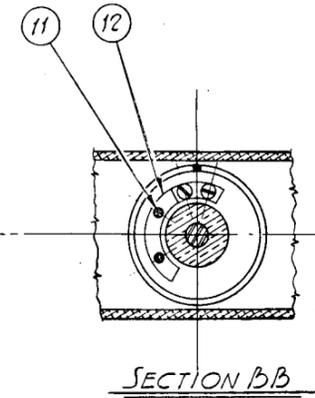
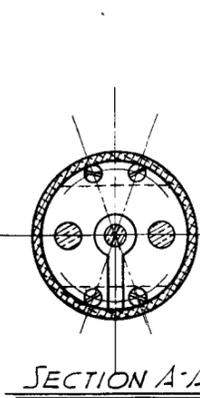
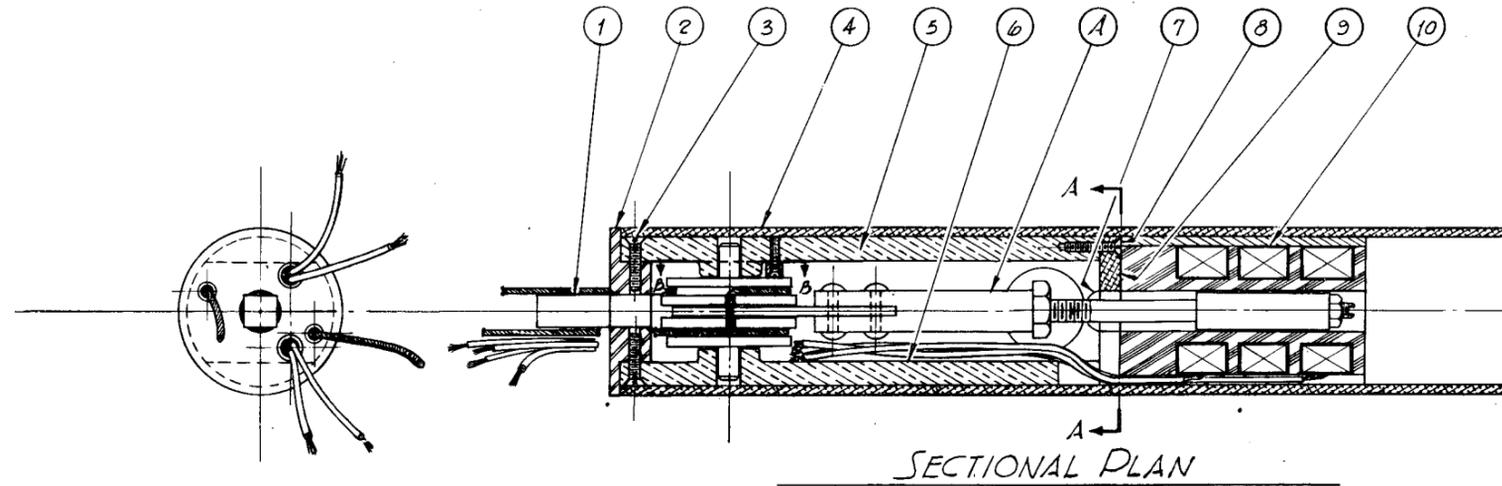
FIG. 18



CALIBRATION OF PNEUMATIC MICROMETER MODEL I

FIG. 19

PARTS LIST					
ITEM NO	DWG NO	NO REQD	NAME	FINISHED SIZE	MATERIAL
1		1	DOG	3/16 x 3/16 x 1/16	MILD STEEL
2		1	HEAD	1 DIA x 1/4	" "
3	STOCK	4	#0-80 FLAT HD. MACH. SCR.	1/16 LG.	BRASS
4		1	CASE	1 DIA TUBE 5 1/2 LG	ALUMINUM
5		1	BEARING PLATE	AS SHOWN	BRASS
6		1	" "	" "	" "
A		1	SUB-ASSEMBLY "A"	AS SHOWN	" "
7	STOCK	2	#6-32 NC-2 RND. MACH. SCR.	1/4 LG.	ALUMINUM
8	"	4	#0-80 FLAT HD. MACH. SCR.	5/16 LG.	BRASS
9		1	SUPPORT DISK	.900 DIA x 1/8	ALUMINUM
10	STOCK	1	MICROFORMER		
11	"	2	#0-80 FLAT HD. MACH. SCR.	3/16 LG.	BRASS
12		1	FIXED STOP	AS SHOWN	" "



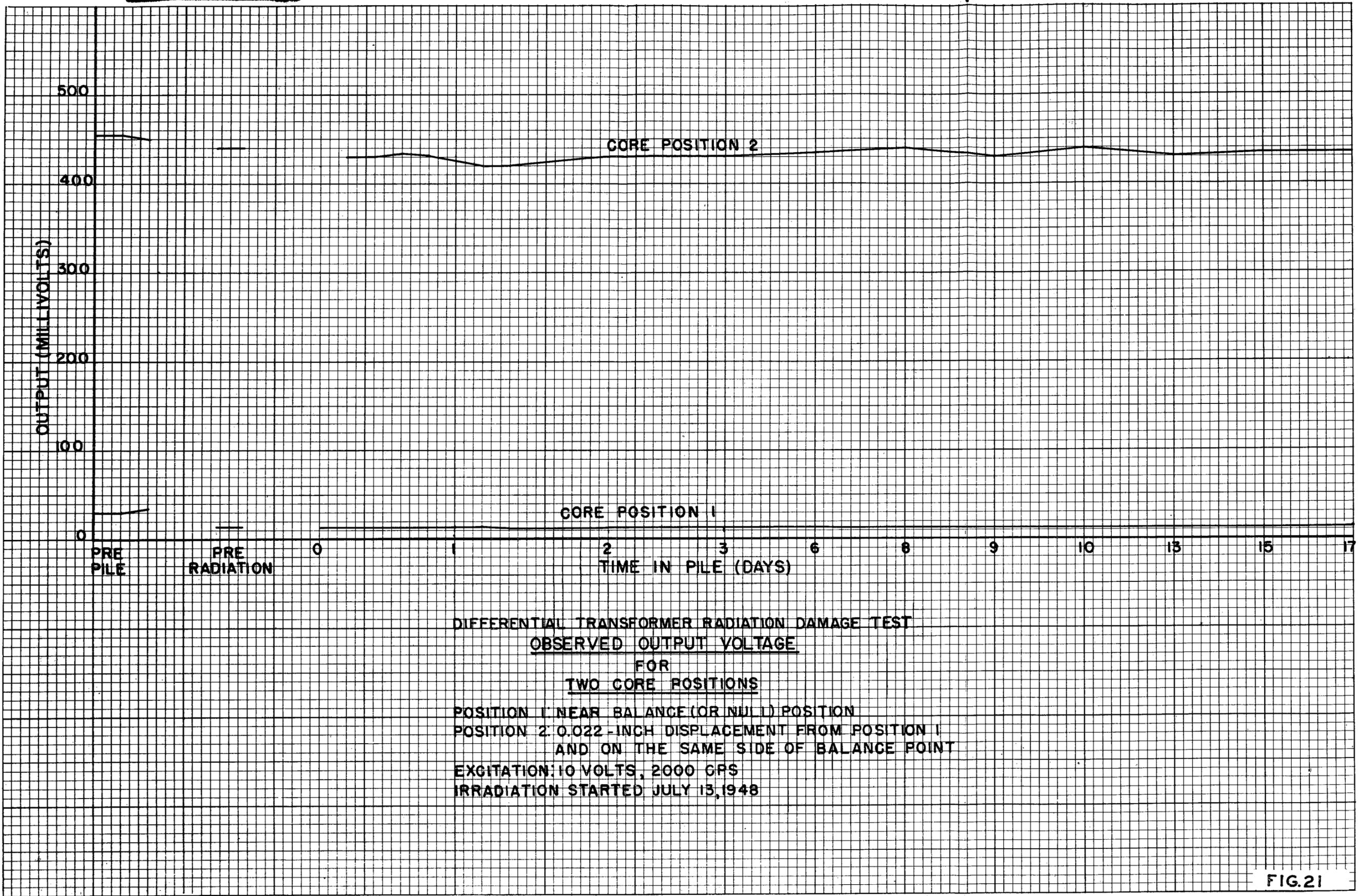
NOTE:  
Do Not Scale This Drawing

FIG. 20

SUB-ASSEMBLY "A" and DETAILS	D-4217
DETAILS	D-4216
REFERENCE DRAWINGS	DWG. NO.

THIS DRAWING HAS BEEN CLASSIFIED AS <b>NOT CLASSIFIED</b>	BLDG. 115 A
PER <i>R. Smith</i>	MICROFORMER - CALIBRATING DEVICE ASSEMBLY
LIMITS ON DIM. UNLESS OTHERWISE SPECIFIED	ENGINEERING DEPARTMENT
FRACTIONS $\pm 1/64$	OAK RIDGE NATIONAL LABORATORY
DECIMALS $\pm .005$	DIVISION OF CARBIDE AND CARBON CHEMICALS CORP
ANGLES $\pm 30'$	OAK RIDGE, TENNESSEE
SCALE 2" = 1"	SUBMITTED <i>R. Smith</i> ACCEPTED <i>R. Smith</i> APPROVED <i>R. Smith</i>
	CL-1157R
	D-4215

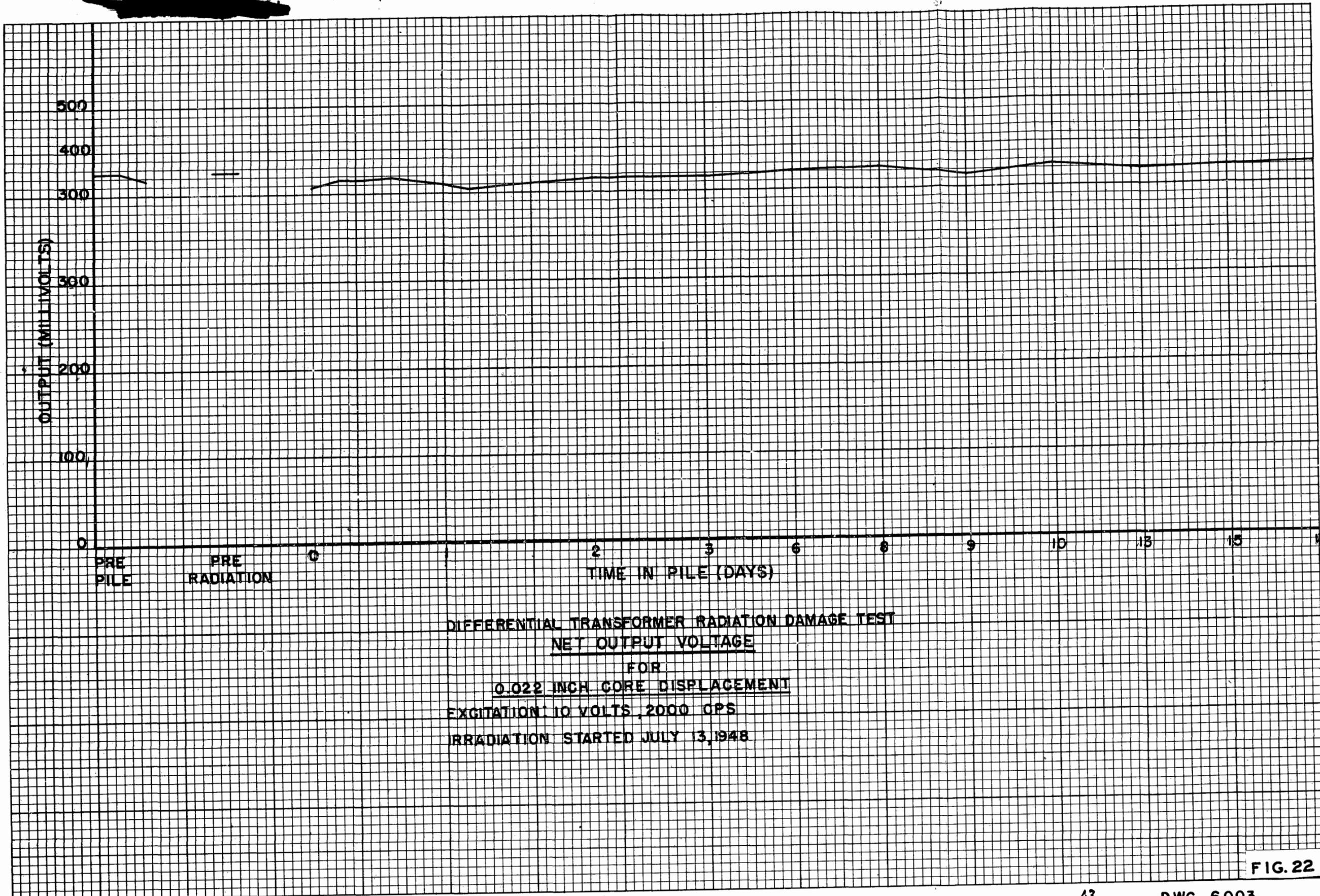
REV LTR.	REVISIONS	APPD	DATE
DRAWING NO.			
DRAWN	DATE	CHECKED	DATE
<i>Strachman</i>	5-25-48	<i>A. L. S.</i>	5-25-48
TRACED	DATE	DESIGNED	DATE
	5-25-48		5-25-48



DIFFERENTIAL TRANSFORMER RADIATION DAMAGE TEST  
OBSERVED OUTPUT VOLTAGE  
 FOR  
TWO CORE POSITIONS  
 POSITION 1 NEAR BALANCE (OR NULL) POSITION  
 POSITION 2 0.022-INCH DISPLACEMENT FROM POSITION 1  
 AND ON THE SAME SIDE OF BALANCE POINT  
 EXCITATION: 10 VOLTS, 2000 CPS  
 IRRADIATION STARTED JULY 13, 1948

FIG. 21

DWG. 6002



DIFFERENTIAL TRANSFORMER RADIATION DAMAGE TEST  
NET OUTPUT VOLTAGE  
 FOR  
0.022 INCH CORE DISPLACEMENT  
 EXCITATION: 10 VOLTS, 2000 CPS  
 IRRADIATION STARTED JULY 13, 1948

FIG. 22