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Richland, Washington
November 16, 1949

Atomic Energy Commission
Hanford Operations Office
Richland, Washington

Attention: Mr. R. C. Hageman

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INFORMATION FOR REACTOR SAFEGUARD COMMITTEE

Reference: Your letter PPE:PGH dated October 7, 1949 (GEH-15,483)

The specific information requested in the reference letter is attached hereto. Although the information was originally desired by October 13, it was agreed in verbal conversation that the timing of contemplated increases in power level would permit reasonable delay on our part in complying with your request.

Your request that we expand upon our reasons for concern over the verticals thimble aluminum creep problem is being answered in a separate letter.

Very truly yours

W. H. Woods

WK Woods

File Technology Division

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INFORMATION FOR REACTOR SAFEGUARD COMMITTEE

I. Reactivity - Temperature Coefficient for Hanford Piles

1. With water in the process tubes

Graphite coefficient 0.75 $\text{ih}/^\circ\text{C}$ at 280°C maximum central graphite temperature
0.65 $\text{ih}/^\circ\text{C}$ at 350°C maximum central graphite temperature

Metal coefficient - 0.3 $\text{ih}/^\circ\text{C}$ at 40°C average central zone metal temperature

*Assuming
constant temp
checked*

The 350°C graphite temperature and the 40°C metal temperature are both near the maximum permissible temperatures at Hanford.

2. Without water in the process tubes

Graphite coefficient - 0.2 $\text{ih}/^\circ\text{C}$ at 40°C max. central graphite temp.

Metal coefficient - 0.4 $\text{ih}/^\circ\text{C}$ at 50°C max. central metal temp.

There have been no experiments at this site to indicate the behavior at higher temperatures.

II. Methods used to obtain reactivity coefficients

The reactivity coefficients are determined by producing temperature transients in the pile by an abrupt change in power level. A comparison of reactivity transients and temperature transients then yields values for the coefficients.

In the case of the pile with water in the process tubes, the determination is made by operating at constant power until equilibrium conditions are reached; that is, the graphite temperature, metal temperature, and xenon concentration have reached steady values. The power is then lowered suddenly by about 25 MW, and the new power level is maintained until the graphite and metal temperatures again reach an equilibrium. The first step in the coefficient analysis is then to plot two curves of reactivity change as a function of time. The first of these is the calculated xenon transient, and the second is the observed reactivity transient based on rod position data and appropriate calibration curves. After the new temperature equilibrium has been reached, these two curves should be parallel, and the difference in reactivity shown by the displacement of these two parallel curves should be the sum of the graphite and metal temperature effects, or over-all reactivity contribution of the power change. Since the metal

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reaches its temperature equilibrium in a much shorter time than the graphite, their effects can be separated by noting the variation in reactivity during the time that the metal is at equilibrium but the graphite temperature is still undergoing an exponential fall to its new value. The relaxation time for the metal is a few seconds while that of the graphite is greater than one hour.

Dividing the graphite contribution by the graphite temperature change involved then gives the graphite temperature - reactivity coefficient given in paragraph I. The metal contribution is the over-all contribution minus the graphite contribution. When this quantity is divided by the metal temperature change involved, the metal temperature - reactivity coefficient given in paragraph I. is obtained. The graphite temperatures are obtained from thermocouples in the graphite and the metal temperatures are computed from cooling water temperatures. These computations have been checked experimentally by some thermocouple measurements in a metal slug.

The graphite coefficient has been verified by observation of the reactivity effect of variations in central graphite temperature at constant power. This condition occurs when the composition of the circulating gas is changed during equilibrium operation, to one of different thermal conductivity.

The metal coefficient has been roughly verified by performing coefficient tests at two different rates of cooling water flow.

The temperature - reactivity coefficients for the dry lattice were determined in a different manner. The power level of a dry reactor was brought to an undetermined low value and held constant until the central metal temperature had risen 25°C. The metal temperature was then held constant as the graphite warmed up. By comparing the rate of reactivity change to the rate of graphite temperature change, a graphite temperature - reactivity coefficient was obtained. When the graphite temperature had risen about 15°C, the power was reduced to a very low level, and the pile was kept critical at this low level by means of control rod movement. Analysis of this rod movement in terms of reactivity change, corrected for the graphite effect already determined yielded the metal temperature - reactivity coefficient. The metal temperature changes were monitored by means of special thermocouples installed in metal pieces placed in the center of selected process tubes. Other thermocouples imbedded in the graphite filler blocks were used to monitor graphite temperature changes. The reactivity variations were determined from the movement of the control rod which has been calibrated under the proper loading conditions by means of reactivity periods. The results were felt to be reliable for the temperature range involved.

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III. Comments on the Stored Energy Problem

The storage of energy in the graphite of the piles has been a problem of some concern because of the possibility that a rapid rise in graphite temperature in the pile above a previously established or steady state level might release sufficient stored energy to initiate and sustain a dangerous and uncontrollable temperature surge. As a precaution against such surges, certain restrictions were placed upon pile operating procedures to limit the maximum rate of rise of graphite temperature above the previously established level, and the operating times necessary to establish a new level were prescribed. These recommendations were based upon the experimental evidence on stored energy available at that time and on the theoretical treatment by J. A. Wheeler and J. J. O'Connor, Interim Report on Production Test No. 105-1-P, Doc. 7-3020-B, 11-9-45, which gives a complete analysis of the recommended operating limits. A simplified and somewhat expanded statement of the operating restrictions to cover all ordinary conditions was given by J. J. O'Connor, Interim Report on Production Test No. 105-1-P, Doc. 3-3585, 7-17-46.

Continued experimentation on the storage of energy has indicated that the present operating restrictions are conservative and no further restrictions appear to be necessary at this time. The following data and discussion, which indicate that an uncontrolled release of energy is very improbable under the present operating restrictions, will clarify the present status of our information on the storage of energy.

Stored energy has been monitored at Hanford by the Sykes tempering method, which gives essentially the rate of release of energy as a function of temperature to about 600°C, and by the heat of combustion method which gives the total stored energy.

1. Rate of Energy Storage

For samples exposed at a constant low temperature ($< 50^{\circ}\text{C}$) the stored energy rises rapidly with exposure to about 200 MD/CT, and then continues to increase linearly at a lower rate with longer exposure. Values over 500 cal/gm have been obtained in this manner, which are probably equivalent to the most badly damaged pile graphite.

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2. Temperature Effect

Irradiation of samples at a temperature comparable to the present filler block temperatures results in very little stored energy. After 370 MD/CT, an irradiation at 30°C produces about 230 cal/gm; at about 250°C, only 11 cal/gm were obtained. Thus, the storage of energy in the filler blocks is probably low enough to be discounted. Other technical data indicate that the filler blocks have not been damaged to any great extent, and that the major portion of the graphite damage has occurred in the tube blocks.

3. Pile Annealing Effects

Continued irradiation at about 275°C of graphite previously irradiated at low temperatures indicates that a major portion of the stored energy can be annealed over long periods of time. This supports the conclusion that the filler blocks have sustained relatively little damage and consequently have small amounts of stored energy.

4. Activation Energy of Damage

The amount of stored energy released in the Sykes test (up to 600°C) remains practically constant after a minimum exposure of about 200 MD/CT, although the total stored energy increases linearly with longer exposures. Thus, the activation energy of the damage appears to shift to higher values on continued exposures; because this apparent shift to higher activation energy values has continued with very long exposures, the possibility of releasing this energy has become less probable.

5. Stored Energy in Tube Blocks

Because of the temperature gradient in a tube block from bore to edge, the damage sustained at each point lies along a similar gradient. The maximum value of stored energy obtained to date was 568 cal/gm on graphite scraped from the bore of a tube block which contained metal for its entire life. This value may be near the upper limit for stored energy at any point in the pile. The release of energy in the Sykes test for this tube block graphite starts at about 150°C; this is about 50°C higher than for samples exposed in a cooled test hole at about 30°C. This indicates that the bore of the tube block operates at a temperature higher than the cooling water temperature with the result that the total stored energy is considerably less than would be expected for a test hole sample with comparable exposure. For samples irradiated at 275°C, the Sykes experiment begins to release energy at about 400°C.

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6. Thermal Wave Experiments

Experiments designed to favor the uncontrolled release of stored energy in samples exposed in cooled test holes have been unsuccessful. It was impossible to develop a rapid, self-sustaining thermal wave in a test sample by heating one end to $>1200^{\circ}\text{C}$ in a time period of about 7 seconds. The low thermal conductivity of graphite after a long exposure probably inhibits the rapid flow of energy necessary to sustain a wave.

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