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April 24, 1953 COPY 1 OF 1, SERIES M.A.

SLUG CENTRAL TEMPERATURES - HANFORD TYPE

Documents are listed chronologically, the most recent first. Abstracts are included for those documents not authored, in part at least, by H. H. Greenfield, D. Amos or S. S. Jones. Documents of these authors have, however, been listed. Documents marked with an asterisk (*) possibly contain pertinent information but a copy was not available for my inspection.

HW-26615; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies; (1-10-53).

HW-26565; Greenfield, H. H. and T. W. Ambrose; Some Heat Transfer Aspects for New Fuel Element Development; (12-15-52).

HW-26713; Carlson, P. A. and E. A. Eschbach; Status of Fuel Element Development at Hanford; (12-1-52).

A thermocouple slug assembly was charged into a production pile in October. Very preliminary results show that at a specific power of about 21 kw/t and a local water temperature of 57°C, the slug axial temperature is about 27°C. This is somewhat higher than calculated values.

HW-26715; Jones, S. S.; Measurement of Pressures from Film and Shroud

down to 10°C in the core of the reactor as compared to the design value of 10°C (0.5 in. 10°C) (0.5 in. 10°C)

Shroud (0.5 in. 10°C)

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HW-25380; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies - August; (9-10-52).

HW-25053; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies - July 1952; (8-12-52).

HW-24833; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies; (7-10-52).

HW-23392; Jones, S. S.; Measurement of Pressure Drop Film and Shut-down Heat Generation Effects on Uranium Slug Temperatures (P. T. 105-411-P, Suppl. A); (7-2-52).

HW-24791; Amos, D. E.; Temperature Distribution in a Slug; (6-24-52).

HW-24598; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies - May 1952; (6-2-52).

HW-23934; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies - March 1952; (4-1-52).

GEH-19,712; Coffin, L. F., Jr.; Rupture of Hanford Slugs; (3-1-52).

A possible mechanism for the rupture of fuel slugs at Hanford concerns the development of cyclic thermal stresses in the uranium slug and aluminum can due to large variation in the center of the slug between reactor operation and shutdown. Analysis for thermal stresses in the fuel can and slug is shown. The ultimate solution would be to determine the maximum allowable temperature gradient in the fuel can and slug to avoid rupture. This would require a study of the thermal stresses in the fuel can and slug during reactor operation and shutdown.

*ANL-4790; Untermeyer, S. and J. T. Weills; Heat Generation in Irradiated Uranium; (2-25-52).

HW-23448; Carbon, M. W.; Technical Activities Report - Heat Transfer Studies - January 1952; (2-1-52).

HW-22611; Alexander, W. K.; Technical Activities Report - Heat, Water and Mechanical Studies - October 1951; (11-1-51).

HW-22346; Alexander, W. K.; Technical Activities Report - Heat, Water and Mechanical Studies; (10-4-51).

HW 22283; Woods, W. K.; Thermal Stresses in Slugs; (9-28-51).

Representative temperatures in present slugs at current maximum heat generation rate: slug axis excluding end effects, 330°C.

HW-22189; Greenfield, H. H.; Slug Temperature and Thermal Conductivity Calculations; (9-19-51).

HW-21343; Alexander, W. K.; Technical Activities Report - Heat, Water and Mechanical Studies; (6-1-51).

HW-21027; Jones, S. S.; Method for Correlation of Uranium Slug Central Temperature for Production Test 105-41-P; (5-7-51).

HW-21092; Alexander, W. K. and H. L. Mars; 100 Areas Technical Activities Report - Engineers - April 1951; (5-1-51).

HW-21014; Alexander, W. K. and H. L. Mars; 100 Areas Technical Activities Report - Engineers - April 1951; (5-1-51).

HW-20618; Jones, S. S.; Applications of Thermocouple Slugs in the Study of Factors Limiting Power Level; (3-27-51).

HW-19936; Jones, S. S.; Measurement of Pressure Drop Film and Shut-Down Heat Generation Effects on Uranium Slug Temperatures (P. T. 105-411-P); (1-10-51).

HDC-1385; Isbin, H. S.; Design Staff Monthly Report for August, 1950; (8-29-50).

This document carries an attachment entitled "Permissible Slug Center Temperatures" - Present data indicate slug center temperatures upto 700°C are permissible. The limiting factor appears to be grain growth; above this temperature it could be prohibitive and result in slug blistering. Limitations found were due to lack of experimental knowledge.

HDC-949; Burda, E. J.; Determination of Slug Temperatures for Various Power Levels; (1-5-49).

The method of calculation is discussed with regard to assumptions and limitations. Sample calculations are given for the 275 MW level. Results are given in tabular form. For power levels of 275, 400, and 500 MW slug axial temperature above inlet water temperature is calculated to be 284.3, 402.2, and 496.4 $^{\circ}\text{C}$ respectively.

Power Level	Lattice Spacing	Axial Temperature of Slug Above Surface Temperature of Uranium
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275 MW	700	284.3
400 MW	700	402.2
500 MW	700	496.4

HW-10558; Woods, W. K. and S. S. Jones; Measurement of Slug Temperature (Final Report P. T. 105-80-P); (7-27-48).

CF-48-7-31; Kies, J. A. and W. A. Johnson; Thermal Stresses and Strains in Hanford Slugs; (7-1-48).

Develops mathematical expressions for the temperature distribution in Hanford slugs. Calculates the temperatures expected for D. C. heating. Concludes that it is unnecessary to make separate calculations of stress and strain for the Hanford slug and the D. C. heating experiment. Develops expressions for; thermal stresses in Hanford slugs and in slugs heated by D. C.; elastic and plastic strains in Hanford slugs; wrinkling or blistering.

HW-7-6254; Woods, W. K.; 100 Areas Technical Activities Report - Engineering; (5-21-47).

HW-7-5837; Woods, W. K. and S. S. Jones; Measurement of Slug Temperature (P. T. 105-80-P, Suppl. A); (2-20-47).

HW-7-5565; Jones, S. S.; Measurement of Operating Slug Temperature (Interim Rpt. P. T. 105-80-P); (2-30-46).

HW-7-5367; Woods, W. K.; Measurement of Slug Temperature (P. T. 105-80-P); (11-12-46).

Basis and procedure for determining the axial temperature of a slug during pile operation. Includes a method to measure any variation in temperature along the length of a slug.

MT-197 (contd.)

(a) The radial temperature drop $\Delta_o = q_{\text{av}} r^2 / 4 K_o$ is first computed for the case of a uniform heat source density, equal to the average value q_{av} of the actual heat source density distribution, and a constant conductivity $K_o = 0.063$ c. g. s. units.

(b) This is corrected for the heat source distribution by multiplying it by $(1 - \beta/4)$ where β is the ratio of the difference in the values of q at the surface and the center of the rod to q_{av} .

(c) The result is again corrected for the variation of heat conductivity with temperature by reading off the attached graph the value of the actual central temperature T_{max} corresponding to the value of $\phi_{\text{max}} = T_{\text{surface}} + \Delta_o (1 - \beta/4)$ which would be the value of T_{max} for constant conductivity K_o .

HW-3-2460; Worthington, Hood; Temperature Measurement of a Pin in an Operating Unit (P. T. 105-18-P); (5-23-45).

HW-3-2347; Kircher, C. E.; Temperature Measurement of a Pin in an Operating Unit (Final Rpt. P. T. 105-18-P); (5-5-45).

Design features of a heavy metal slug, containing an internally mounted thermocouple, to be used for measurement of the axial metal temperature of an active slug in an operating unit.

CE-2554; Lyon, R. N.; Temperature Relationship between the Center of an X-Type Slug and the End of its Jacket (12-21-43).

CE-2442; Stoll, E. J.; A Method for Determining the Temperature of a Slug in an Operating Unit (12-21-43).

*HW-3-899; Drew, T. B.; Characteristics of a Standard Tube; (9-30-44).

Derivation of general formula for the temperature at any point of a slug; characteristic curves of standard tube at standard water rate, and values and location of maximum temperature.

Du-H-1507; Weekly Progress Report - Technical Division for Period Ending June 10, 1944; (6-13-44)

The central temperature of the hottest slug, instead of having the value of 340°C will have a value of the order of 470°C . The possible problems incident to this higher central temperature are reviewed.

CP-1173 (A-1654); Newson, H. W.; Physics Research - Report for Month Ending December 28, 1943;

(This data is for the Clinton Pile)

In order to distinguish the metal coefficient from the overall coefficient the change in reactivity of the pile was observed at three shutdowns when the metal temperature dropped from its operating value to that of its surrounding graphite. The following table shows the data for these experiments:

Operating Central Metal Temp. $^{\circ}\text{C}$	Central Metal Temp. after Shutdown $^{\circ}\text{C}$	Loss in Reactivity Δk	Metal Temp. Coefficient $\Delta k / ^{\circ}\text{C}$
150	100	15	40%
151	100	18	28%
150	100	17	45%

Du-H-10,245; Drew, T. B.; Temperature of the W-Slugs Aluminum Jackets; (4-22-43).

On the axis of the pile the temperature of the metal at the axis of a slug exceeds the local temperature of Al coating on its sides by $269 \cos \left(\frac{X}{12.72} \right) \left(\frac{\pi}{2} \right) ^\circ \text{C}$ if X = distance in feet from the mid-plane of the pile. The maximum metal temperature is about 340°C . It occurs only slightly beyond the mid-plane of the pile.

Du-H-10,013; Worthington, Hood; Discussion of Heat Transfer in Power Plants with T. H. Chilton; (1-22-43).

Gives a table showing the temperature relations at the center of the pile under certain conditions that can easily be imagined.

	<u>Scale Surface Temp</u>	<u>Metal Surface Temp</u>	<u>Internal Metal Temp</u>
Liquid film coefficient 8850, no scale	-	100	500
Film coefficient 4000, no scale	-	122	522
Scale coefficient 2007 film coefficient 8850	100	193	593

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