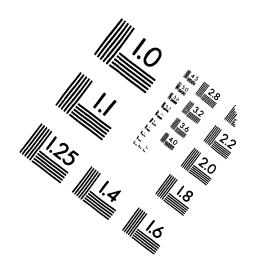
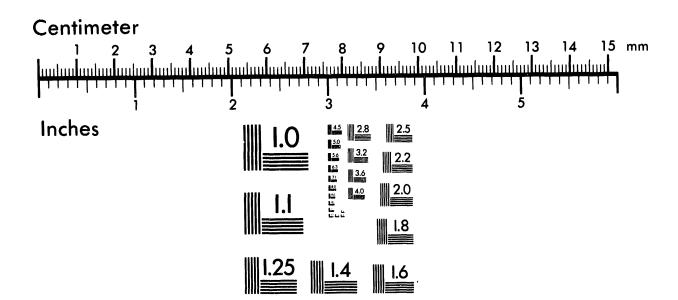


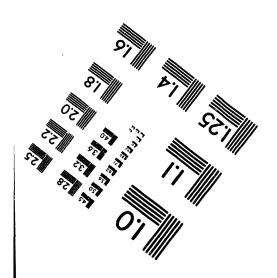


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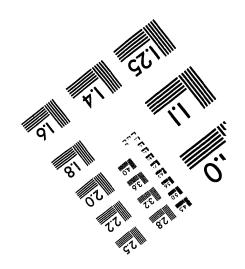
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E. D. Waters

J. M. Batch

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EXPERIMENTAL BOILING BURNOUT CONDITIONS FOR HANFORD PRODUCTION REACTORS

E. D. Waters and J. M. Batch September 20, 1961

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PURPOSE

The purpose of this report is to present some experimental data concerning boiling burnout and to discuss briefly the significance of these data in relation to the Hanford production reactors.

INTRODUCTION

Of prime importance in the design and operation of any nuclear reactor is assurance that fuel temperatures always will be maintained low enough to prevent reactor damage. As a consequence, careful consideration is given to avoiding those process conditions which result in boiling burnout* and the associated high fuel temperatures.

For the Hanford production reactors, most flow decreases or power surges that could cause boiling burnout first result in a hydraulic instability condition. This condition, in turn, results in a self induced flow reduction which almost invariably leads to boiling burnout. Therefore, in setting the the maximum operating conditions for the Hanford production reactors, first consideration has been given to defining and detecting hydraulic instability conditions and only secondary considerations have been given to defining the exact conditions of boiling burnout.

During the past several years a large amount of information regarding hydraulic instability conditions for the Hanford production reactors has been obtained in the heat transfer laboratory. During the experiments, conditions often extended beyond hydraulic instability into the region of boiling burnout. Heretofore, these boiling burnout data have been reported only indirectly in the documents concerning hydraulic instability.

Since avoidance of boiling burnout (or more specifically, the high temperatures associated with boiling burnout) is one of the safety criteria for the Hanford reactors, the available experimental boiling burnout data were gathered and are reported here. This has been done in order to demonstrate the relation between operating conditions of the reactors and the boiling burnout conditions resulting in high fuel temperatures.

SUMMARY AND CONCLUSIONS

Boiling burnout data for the Hanford production reactor were gathered from the results of laboratory investigations of hydraulic instability conditions. These burnout data, shown in Figure 1, were obtained with full scale electrically heated test sections representing a full charge of fuel elements in a single process tube. Also shown in Figure 1 are the normal operating

^{*} Definition: Boiling burnout is defined as the point at which the boiling process changes from nucleate boiling to film boiling. During film boiling the resistance to flow of heat is much greater than during nucleate boiling and higher surface temperatures are required to transfer the same amount of heat. In some cases, the increase in surface temperature with a change from nucleate to film boiling can be sufficient to cause melting of the heat transfer surface; therefore, the term 'boiling burnout' has been used to define this change.

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conditions at 130 C outlet temperature for the various reactors and the conditions at which a reactor shutdown would be initiated by the Panellit system following a flow reduction.

It may be seen from Figure 1 that in general, a reduction in flow of at least 50% or roughly a 100% increase in power level would be necessary to reach film boiling from reactor operating conditions of 130 C outlet water temperatures. It has been shown in laboratory experiments that even if such a flow reduction were to occur, the existing instrumentation would start a reactor shutdown in time to prevent fuel element melting. (1) The data in Figure 1 apply when the fuel elements are situated in their normal position close to the center of the process tubes.

The effects of displacing the fuel elements toward a wall of the process tube are shown in Figure 2. These boiling burnout data were obtained with a test section representing eccentrically placed fuel elements in a K reactor process tube. It may be seen that if the fuel elements are approximately 80 to 90% eccentric, film boiling conditions can be expected to exist. For the Hanford fuel elements, the resulting surface temperatures would not necessarily be high enough to cause melting of the aluminum cladding of Hanford fuel elements but rapid corrosion could result.

Experimental Equipment

The experiments were conducted with the 189-D Heat Transfer Apparatus. A general description of the laboratory and apparatus is given in reference (4). Nuclear heat is simulated by d.c. electrical resistance heating in metal test sections which simulate reactor fuel charges. Specific descriptions of the various full charge length test sections are given in the reports which originally presented the experimental data(1)(2)(3)(6) and will not be repeated herein.

The test section for the short test section experiments consisted of a 24-inch long metal cylinder (1.457 inch OD by 1.157 inch ID) placed inside a 1.681 inch ID tube. Thermocouples were attached to the inside surface of the metal cylinder to monitor the temperature of the heater surface. Data were obtained for two flow conditions of cooling water through the annulus which approximated conditions for a central zone and a fringe zone tube annulus at K reactor.

DISCUSSION

The experiments which are discussed in this report are of two general types; one type employed test sections which were full length simulations of reactor fuel charges and the second type employed short test sections which simulated the non-axial placement (cocking) of a few fuel elements within a reactor process tube. Since the purpose and results of the experiments were different for the two cases, they will be discussed separately.





Full Length Test Section Experiments

The boiling burnout data which were obtained with the full length test section are essentially a by-product of experiments which were conducted to determine the adequacy of present Panellit instability limit procedures. In these experiments, a constant heat input rate was maintained while the coolant flow rate through the test apparatus was reduced by small increments. Pressures, flow rate, test section temperatures, and coolant temperatures were recorded after each flow reduction. The flow was decreased in this manner until film boiling conditions were indicated by large increases in the test section (simulated fuel) surface temperatures. This condition was regarded as the incipient burnout condition; the data were recorded, and the test was then terminated.

The resultant pressure and flow rate data from such tests are commonly presented and referred to as constant power hydraulic demand curves. Such data are presented in references (1), (2), (3) and (6). In the past these curves have been compared with the Panellit protection instability model (5) to determine the adequacy of the Panellit protection procedure in assuring a shutdown in case of flow stoppages. Little attention has previously been given to the terminal or boiling burnout condition of the experiments, but it is this condition which is being considered in the present report.

The film boiling or incipient boiling burnout condition has been plotted in Figure 1 for several different simulated reactor geometries. These data plot quite nicely and show good agreement, especially among those points which utilized similar 'fuel' designs. There does appear to be a definite difference between the boiling burnout flow rate for normal I&E 'fuel' and the C-overbore 'fuel' assembly.* The reason for this is not definitely known at the present time. However, there are indications from the experimental work that with self-supported fuel, the flow patterns are such that heat transfer rates are reduced downstream of each self support. This would especially be true with low flow rates and with vapor formation.

Two additional curves have been included in Figure 1. One shows the flow rate which would be necessary to give an outlet water temperature of 130 C** for the corresponding tube power. Since most tubes on the reactor operate at outlet water temperatures below 130 C, the majority of actual operating points would be to the right of this curve. The other curve shows the flow rate which would assure a Panellit pressure trip if the initial outlet temperature were 130 C. Likewise, as most normal operating points are to the right of the 130 C curve, most Panellit trip limits would occur before the flow rate is as small as indicated by the Panellit trip limit curve of Figure 1. Figure 1 then makes the relation between normal flow, trip limit flow, and boiling burnout flow very apparent.

The conservatism of the Panellit limit protection procedures has been further demonstrated by transient heat transfer experiments. Such experiments,

^{** 130} C is the present maximum allowed outlet water temperature.



^{*} The word 'fuel' is used although the experimental test section which simulates the fuel is actually meant.



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involving sudden coolant flow reductions by plugging, have consistently shown that the power decrease (reactor scram) could be delayed until the flow rate is less than that shown by the steady state film boiling conditions of Figure 1 without resulting in excessive fuel temperatures during the ensuing shutdown.

Short Test Section Experiments

Experiments have been conducted with a short length test section to determine the effect on burnout heat flux of the non-concentric placement of fuel elements with respect to the process tube. A test section which simulated approximately 3 eight inch fuel elements was positioned within a process tube such that the annulus width was greater at the bottom of the tube than at the top. This would simulate fuel elements which were cocked or misaligned toward the top of the process tube. The degree of non-axial placement is referred to as eccentricity, defined as the percentage of the normal annulus thickness by which the fuel element is displaced from a coaxial position toward the wall of the process tube.

In these experiments, the flow rate, pressure and inlet water temperature were held constant while the power input was increased by small increments. When large increases in the test section surface temperature were noted, signifying the initiation of film boiling conditions, the test was terminated.

Such non-axial placement will reduce the heat flux at which film boiling or boiling burnout occurs as compared to a test section which is placed concentrically within the tube. This is because of the unbalance of heat transfer surface area and fluid flow area. Results of such experiments corresponding to conditions in a K reactor are presented in Figure 2. One might observe that the normal heat flux for a K reactor central zone tube would allow an eccentricity of about 80 per cent before reaching film boiling conditions; for a fringe zone tube, an eccentricity of about 90 per cent would be necessary to cause film boiling conditions. As far as application to the reactor is concerned, it must also be stated that the inception of film boiling does not necessarily preclude that the surface temperature would be above the aluminum melting temperature. Film boiling may result in rapid corrosion due to high metal temperatures without actual jacket melting.

Two points of clarification should be made with regard to these data obtained with the short test section. First, it can be argued that the data are conservative (i.e. burnout occurred at a lower heat flux than would result in reactor fuel pieces) because they were obtained with a thin walled test section and with annulus flow only. With annulus and hole flow in a thick walled test section, there could be a significant shift of the radial heat flow pattern as burnout was approached and higher tube powers would be required to produce a burnout heat flux at the top of the fuel. Second, the data were obtained with a short test section and the validity of extrapolating the data to a long train of fuel elements in the reactor has not yet been checked.





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Even with these limitations, it can be concluded from the data that temperatures high enough to cause fuel damage can result from gross misalignment of the fuel pieces in a process tube.

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BIBLIOGRAPHY

- (1) HW-67139 "Laboratory Data for Review of Outlet Water Temperature Limits for BDF Type Reactors", E. D. Waters and D. E. Fitzsimmons, 12/11/60.
- (2) HW-64398-1 "Hydraulic Demand Curves for BDF Geometry with Enlarged Outlet Fittings 25 psig Rear Header Pressure", E. D. Waters and D. E. Fitzsimmons, 5/15/61.
- (3) HW-64029 "Extended Hydraulic Demand Curves for K Geometry Tubes With I&E Fuel Elements", G. M. Hesson, D. E. Fitzsimmons, and M. F. Kenninen, 2/25/60.
- (4) HW-65722 "Description of the Thermal Hydraulics Laboratory at Hanford", J. M. Batch and K. G. Toyoda, 6/20/60.
 - (5) HW-53379 "Method for Empirical Calculation of Instability Limits", K. W. Hess and S. M. Graves, 11/12/57.
 - (6) HW-71075 "Results of Heat Transfer Experiments for the C-Overbore Assembly", E. D. Waters and M. R. Kreiter, (to be issued).

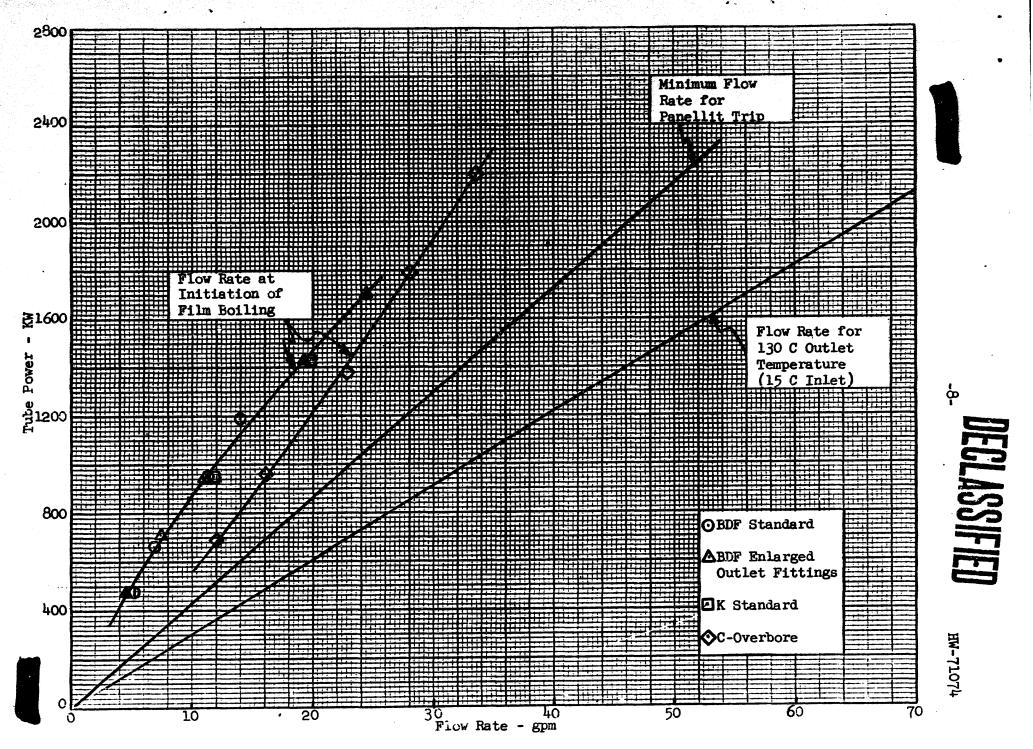


Figure 1 - Experimental Burnout Conditions for Hanford Reactors.

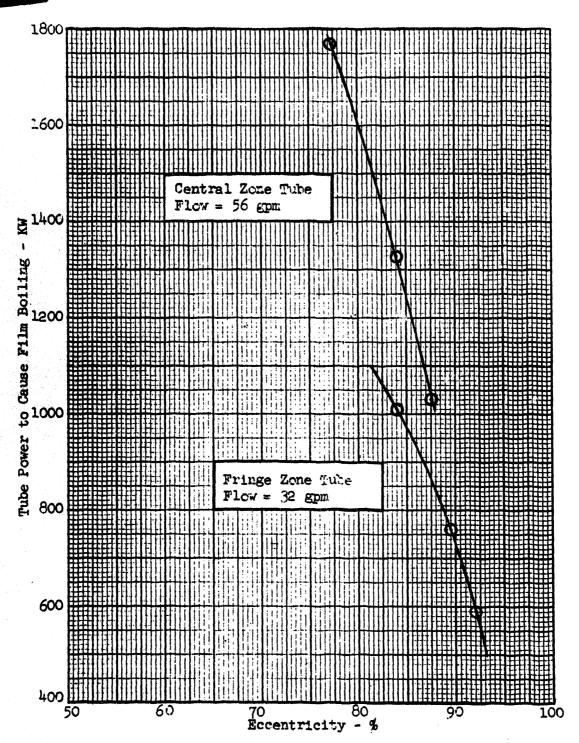


Figure 2 - Effects of Non-Axial Fuel Placement - K Reactor

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