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EXAMPLES OF THE CHANGES IN TEMPERATURE, PRESSURE AND FLOW
FOLLOWING A REACTOR POWER SURGE

M. R. Kreiter and J. M. Batch
June 7, 1962

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EXAMPLES OF THE CHANGES IN TEMPERATURE, PRESSURE AND FLOW
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INTRODUCTION

While it is obvious that a power surge in a Hanford reactor will result in temperature increases of the fuel and water, it is also true that there will be changes in the coolant flow rate and the pressures in each process tube. In addition, if the power increase is of sufficient magnitude, a self-induced flow reduction will occur as a result of pressure changes due to boiling within the process tube.

The relations between power, temperatures, flow and pressure following a power surge are difficult to calculate with precise accuracy. However, a knowledge of these relations is important for incorporation with physics considerations to allow prediction of maximum fuel temperatures following a power surge and to specify detection instrumentation for proper reactor control.

Fairly precise information of temperatures, flow, and pressure in a single process tube following a power surge can be obtained using an electrically heated model in the 189-D heat transfer laboratory. Obtaining such information for all possible conditions and for all the Hanford reactors would be a fairly large job. However, two cases were run with an existing full scale electrically heated model of a single column of fuel elements in a C reactor overbore process tube. These demonstrate the general relationship between temperature, pressure and flow following a power surge and provide examples of the type of experiments that are possible.

SUMMARY AND CONCLUSIONS

Electrical resistance heating of a test section representing 32 C-VI-N I&E fuel elements in a C reactor overbore process tube was used in determining the thermal hydraulic characteristics of a reactor process tube following a power surge. Pressure, temperature and flow data were recorded following a sudden induced increase in the power level. Two such experiments were completed; one in which the power was increased from 1020 KW to 1900 KW and the other in which the power was increased from 1800 KW to 3390 KW.

The case in which the power was increased from 1020 KW to 1900 KW is shown in Figure 1. The results show that about 14 seconds after the start of the power rise, the surface temperature began to increase very rapidly as the cooling mechanism changed to film boiling. During this time the outlet water temperature increased about 80 F, the Panellit pressure increased 200 psi, and the flow (not shown) decreased from 34.5 gpm to 3.5 gpm.

The case in which the power was increased from 1800 KW to 3390 KW is shown in Figure 2. For this case film boiling commenced 11 seconds after

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the start of power surge and during this time the outlet water temperature increased 120 F. The Panellit pressure increased 250 psi to the value of the front header pressure in 10.4 seconds and the flow rate (not shown) decreased to 3.0 gpm at about 13.0 seconds.

The power surges studied in these experiments do not represent a particular reactor event but were chosen to conveniently show the response of the process variables during a power surge. It might be noticed that for the two cases run, a Panellit high trip would have been realized in time to prevent fuel damage by melting.

EXPERIMENTAL EQUIPMENT

Nuclear heating of a train of fuel elements was simulated by use of electrical resistance d-c heating of a metal test section. The test section was 1.991" OD x 0.339" ID x 23.6 feet long and represented a charge of 32 C-VI-N I&E fuel pieces. Various metals were used in fabricating the test section such that a stepped cosine distribution with a maximum power to average power ratio of 1.41 was obtained. Small holes connecting the annulus and hole channels were drilled at 9 inch intervals to simulate interjunction flow characteristics of standard fuel charges. Support of the test section and electrical insulation from the 2.147 ID smooth bore zirconium process tube was accomplished by attaching ceramic spacers (0.185" wide x 0.625" long x 0.070" high) to the surface of the test section. Four ceramic spacers were positioned 90 degrees apart at six inch intervals along the test section with a total of 192 spacers being used. Outlet hardware as shown on Drawing SK-1-4781 was used.

PROCEDURE

Experimental procedures consisted of adjusting the tube flow at an initial power setting such that the outlet coolant temperature was 130 C at a rear header pressure of 50 psig. A power increase was then imposed upon the test section. The elevated power level was maintained until film boiling on the test section surface was detected at which time a 1400 i.h. power decay, based on the initial power, was imposed on the test section. Data was taken during the power increase and subsequent power decay using a high speed galvanometric recorder.

A constant front header pressure of 400 psig was maintained during the 1020 KW to 1900 KW run. This was not possible during the 1800 KW to 3390 KW excursion and therefore the Panellit pressure, which has been generalized to 200 psig using the method discussed in HW-42469-C(1)* is not shown above 450 psig. During this time the flow through the test section would be negligible. The rear header pressure varied during the experiments and reached maximum values of 58 psig during the 1020 KW to 1900 KW excursion and 85 psig during the 1800 KW to 3390 KW excursion.

*Numbers in parentheses refer to Bibliography.

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DISCUSSION

Two experiments simulating a power excursion using a C overbore geometry test assembly have been completed. The data obtained are plotted in Figures 1 and 2 as a function of time after initiation of the power excursion. Excessive surface temperatures did not occur when the power decay was initiated 15.9 seconds and 12.6 seconds after the start of the power surge for the 1020 KW to 1900 KW case and the 1800 KW to 3390 KW case respectively. In the lower tube power case, the power decay could have been delayed somewhat longer without "fuel" damage since a test section temperature of about 960 F would correspond to reactor fuel jacket melting.⁽²⁾

The data show that the time required for the Panellit pressure to increase 60 psi from an initial pressure of 200 psig for the low and high power excursion cases was 9.1 seconds and 7.8 seconds respectively. Assuming a combined time of 3 seconds for Panellit response and full insertion of the VSR's the total time elapsed from the initiation of the excursion until scram would be 12.1 seconds and 10.8 seconds for the low and high power cases respectively. If then, the maximum time in which a scram can be initiated safely are 15.9 seconds and 12.6 seconds, it appears that the Panellit system set for a 60 psi span would afford adequate protection against fuel element damage from melting in both cases studied.

The value of T_{outlet} may be somewhat misleading in that the thermocouple, which was located at the rear header connector, extended approximately 6 inches into the pigtail. It was not possible to measure the pressure at this point and thus the thermocouple was probably indicating the saturation temperature of the water during the latter portion of the transient. This points out an important consideration in contemplating use of a temperature monitor in a "detection-scram" system when the temperature monitor is located near the rear header and the outlet water temperature prior to the excursion is at or near the saturation value.⁽³⁾ The pressure drop between the temperature monitor and the rear header would be small and the static pressure at the monitor during an excursion would be essentially constant. With the coolant temperature being at or near the saturation temperature corresponding to the pressure at the monitor location little or no temperature increase in the coolant would be experienced. It would then appear questionable whether a trip would be obtained.

An interesting facet of the 1020 KW to 1900 KW excursion is that the experimental time at which initiation of a power decay was necessary is very near that obtained for film boiling to commence using previously reported C Overbore upstream plugging transient data for 1790 KW and a plugged flow rate corresponding to the initial experimental flow of 34.5 gpm.⁽²⁾

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NOMENCLATURE

- F - Flow as measured at inlet of test section, gpm
- Pan - Pressure at Panellit tap, psig
- T_o, T_{outlet} - Temperature of water near rear header connector, °F
- T_{EOAS} - Temperature of water at end of the active heated section (end of fuel charge), °F
- FH - Front heater pressure, psig
- RH - Rear header pressure, psig
- TI - Tube inlet pressure, psig

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