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RESULTS OF EXPERIMENTAL TESTS
SIMULATING SUPPLY PRESSURE DECREASE
IN A K PROCESS TUBE

by

K. G. Toyoda - J. F. Calkin

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PURPOSE

The purpose of this report is to present experimental data on a series of tests which were made to simulate flow reductions to a K type process tube by simulated front header pressure decreases.

INTRODUCTION

Simultaneous reduction of coolant to several or all reactor tubes raises concern not only for the adequacy of protection in the individual process tube but also of the reactor as a whole. In event of such flow reduction, the heat generation does not decrease until at least 1.4 seconds have elapsed following the accident.¹ Thus, the water temperature from each tube will rise, and result in an increase in the bulk water temperature. If the increase in bulk water temperature is such that saturation temperature at the top of downcomer is reached, pressurization may occur at that point and exceed the maximum recommended working pressure limit (approximately 1 to 2 psig).

In recent months, the Thermal Hydraulics Operation, HLO, has been engaged in a series of tests which simulated the flow reduction to an individual process tube. Results of these runs have provided a basis for evaluating the true protection afforded by the present pressure monitoring system and have permitted the relaxation of individual tube limits in several reactors. The information derived from these tests also provide some qualitative insight into transients which may result from accidents affecting several tubes simultaneously; e.g. front header pressure decrease. However, the transient behavior of the coolant in the process tubes are such that quantitative description of the process is extremely difficult to evaluate without performing actual simulated tests. For example, previously obtained test results on an individual tube accident would lead one to the conclusion that front header pressure decreases from a BPA outage will not lead to unstable tube conditions for tube temperature limits obtainable in the near future. But it is not possible to establish the water temperature-time sequence absolutely to permit analysis of the subsequent effect of higher temperatures at the top of the downcomer. However, once the outlet water temperature-time relation is established experimentally for a single tube, the results can be extrapolated to the top of the downcomer by determining the time required for the water leaving the process tube to reach the top of the downcomer. In the like manner, the effect of each reactor tube may be calculated, and the cumulative water temperature effect determined.

To provide such experimental information and to secure a broader picture of transients in general, a short series of tests simulating supply pressure decrease was desired. Flow reductions of this type may represent a potential case of BPA outage, failure of inlet water supply line on one side of the reactor, and other similar events.

SUMMARY

Transients following different rates of decrease in front header pressure were simulated for K reactor process tube assembly. Tests were made at nominal 1050 and 1250 KW tube power, nominal 100 and 125°C initial outlet water temperature, at initial front header pressure of 350 psig.

1. "Recommended Heat Output Curve for K Reactor", SS Jones, 6/26/57, Conf-Undoc.

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In the worse case of flow reduction simulated, front header was reduced from 350 psig to approximately 210 psig in about two seconds (flow reduction to about 68 per cent of initial). Scram power decay from 1225 KW initial power initiated at 2.25 seconds after start of flow decay resulted in maximum outlet water temperature rise from 125 to 154°C at time 3.4 seconds (Figure 3).² With approximately the same flow decrease characteristics, scram initiated at 2.95 seconds after start of flow decay gave a temperature rise from 128 to 160°C at 3.95 seconds (Figure 5). In neither case was flow instability encountered.

A run typical of a BPA outage with initial tube power of 1265 KW and outlet water temperature of 125°C gave a maximum temperature of 133°C at 2.7 seconds after start of flow decay when power was reduced at 2.4 seconds following accident simulation (Figure 10).

It is believed that these data should be quite useful in calculating the bulk water temperature of the whole reactor as a function of time following an incident such as a BPA outage.

DETAILS

Experimental Equipment

The experiments were performed on the electrically heated low pressure mockup located in the 189-D Thermal Hydraulics Laboratory. The test section was a prototype of the K reactor process tube assembly except that the length of the simulated active section was only 23.5 feet. The heater rod was 1.43" OD and was made of sections of cupro-nickel, copper, and brass to give a step-cosine heat generation profile. The rod was placed in a standard K process tube internally coated with 5 mil of Heresite (insulating coating). The assembly also included a standard dummy section, rear nozzle, pigtail, and rear cross-header connector.

Experimental Method

At a simulated front header pressure (pump discharge pressure) of 350 psig and a rear header pressure of 25 psig, steady-state conditions at pre-fixed tube powers (nominal 1050 and 1250 KW) and outlet water temperatures (nominal 100°C and 125°C) were obtained. At the start signal, the pump discharge pressure was reduced by manually controlling a test section bypass valve. This is in essence a control of the supply pressure to the test section. Simultaneously, the power decay control cam was actuated by a manual start. The transient traces of pressure, flow, water temperature, and tube power were recorded on high speed oscillographic recorders. Tests were halted when the outlet water temperature was shown to be decreasing on the recorder.

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2. Outlet water temperature measured at end of active section and not at the Y crossheader connector.

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Data Presented

The results of the test plotted in Figures 1 through 10 show the traces of front header pressure, flow rate, and outlet water temperature as measured at the end of the active section. A summary of pertinent information for these runs is tabulated in Table I.

Figures 1, 2, and 3 show results of tests where the flow reductions by step decrease in front header pressure was imposed as rapidly as possible. Figure 1 is a case of front header pressure drop from 350 psig to 300 psig; Figure 2 from 350 psig to 250 psig, and Figure 3 from 350 psig to 200 psig. Test results of Figures 4 through 6 represents tests with pressure reductions from 350 to 200 psig or less but where attempts were made to control pressure decrease at a rate slower than that obtained for the run shown in Figure 3.

In each case of the foregoing tests, the pressure or flow decay simulated is more severe than that which is expected to result from a BPA outage. The calculated K reactor flow decay characteristics following a BPA outage are shown for a variety of initial flows in Figure 11.³ Thus, additional tests were made where flow rates approximated these characteristics as closely as possible. Since the experimental technique relied upon the ability of the experimenters to manually duplicate a fixed curve, exact conformance to them were not possible. The tests results for these cases are shown in Figures 7 through 10.

Ideally, it was desired to reduce the tube power at one fixed time following the initiation of pressure reduction. Again the fact that manual start was utilized to actuate the power control cam resulted in actual power reductions occurring from 2.25 to 3.25 seconds after the start of the test. In Figure 12 a typical power decay characteristic from time the simulated scram became effective (i.e. 2.25 to 3.25 seconds) is shown. This characteristic is applicable to all runs in this series.

(It is interesting to note that in the tests simulating a BPA outage, the ratio of the maximum temperature rise of the water across the heated section over the initial water temperature rise is approximately equal to the initial tube flow over the flow which existed at the time scram was effected. In the cases of more rapid and severe flow reductions, the ratios of the temperature rises were less than those of the flows. Two possible occurrences may cause this effect: (1) boiling in the tube proper and/or (2) temporary storage of heat in the test heating element.)

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3. Data used was supplied by DL Condotta. Comparisons with in-reactor experimental data reported in HW-42964, "Final Report - PT 105-14-MR", 5/15/56, PC Walkup and RE Hall, show reactor experimental decay rate to be slightly slower. For example, Condotta's calculated data show flow at 5 seconds to be 82 per cent of the initial flow as opposed to 85 per cent reported in HW-42964.

K. G. Toyoda
K. G. Toyoda
Thermal Hydraulics Operation
J. F. Calkin
J. F. Calkin
Thermal Hydraulics Operation

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TABLE I

SUMMARY OF FRONT HEADER PRESSURE DECAY TESTS

Conditions: Initial Front Header Pressure - 350 psig
 Initial Rear Header Pressure - 25 psig
 Initial Inlet Water Temperature-22 to 27°C

Figure No.	Run No.	Initial Power KW	Initial Flow GPM	Time Seconds		Outlet Water Temp T _o (°C)		Description of Pressure Reduction Method
				Scram	T _o Max	Initial	Max	
1	1	1225	44.4	2.5	3.0	125	135	Step decrease to 300 psig
2	2	1225	44.2	3.0	4.0	127	147	Step decrease to 250 psig
3	3	1225	44.4	2.25	3.35	125	154	Step decrease to 200 psig
4	4	1225	43.7	3.1	3.9	127	158	Decrease to 200 psig
5	5	1225	44.2	2.95	3.95	128	160	Decrease to 200 psig
6	8	1040	53.0	2.85	4.2	96	125	Decrease to 175 psig
7	9	1040	53.3	2.35	5.15	97	110	} BPA Outage Simulation to 200 psig
8	10	1040	52.8	2.7	3.5	97	108	
9	11	1265	46.3	2.65	3.45	128	138	
10	12	1265	46.5	2.4	2.7	125	133	

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Figure 1

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 3

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 4

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 5

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 6

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 7

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 8

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 9

Experimental Process Characteristics Following Supply Pressure Decrease to a Minimum Value

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Figure 10

Experimental Process Characteristics Following Supply Pressure Decrease in a K Reactor Tube Assembly

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Figure 11

Theoretical Pump Flow Decay Curves Following BPA Outage for K Reactor

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