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November 20, 1959

SINGLE TUBE FLOW RATES AT LOW HEADER PRESSURES
WITH NOZZLE CAPS REMOVED - ALL REACTORS

By E. D. Waters

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SINGLE TUBE FLOW RATES AT LOW HEADER PRESSURES WITH NOZZLE CAPS REMOVED - ALL REACTORS

By E. D. Waters

INTRODUCTION

At certain stages of the reactor charge-discharge operations, the front and/or rear nozzle caps of a process tube may be removed and thus the coolant flow past the fuel elements may be altered or even stopped. Although this has been done in the past without apparent adverse effects, the combination of desired changes in operational procedure and ever increasing residual nuclear heat generation rates makes it desirable to secure quantitative data concerning flow rates and flow splits for various conditions of nozzle cap removal. Also, it was desired to know the effect on flow rate of having a standard downstream support charge pre-inserted upstream of the fuel charge as may be done during some pre-charging operations. This report then presents the results of an experimental study to furnish such data.

SUMMARY

Laboratory data of flow rate versus header pressure were obtained for various conditions of nozzle cap removal from C, K and BDF single tube mockups of central zone tube assemblies using I&E slug charges. The data are presented in Figures 1 through 3. Suggestions are made on page 4 for applying the data to DR and H reactors.

In general, the effect of a pre-inserted support charge on the flow rate is small, especially with the front nozzle cap on.

It should be noted that pre-insertion of an entire (117 inch long) support charge and subsequent front cap replacement is impossible in either a BDF tube with 34 fuel elements or a C tube with 32 fuel elements simply from a length standpoint.

EQUIPMENT AND PROCEDURE

The equipment used in these experiments consisted of the prototypical reactor process tube, header and nozzle assemblies of the 189-D Hydraulics Laboratory. Flow rates were measured with turbine type flow meters except for flow rates less than about 0.5 gpm which were measured by flask and stop watch. Standleg manometers were used to measure front and rear header pressures.

The BDF tube assembly included the following: CG-558 Venturi reamed to 0.310 inch ID, CG-558 front pigtail and nozzle, a charge of 34 0-II I&E fuel elements, a standard downstream support charge* and standard BDF rear fittings with a helical pigtail.

The C tube geometry included the following: helical front pigtail, standard 0.385 inch C venturi in a C front nozzle, a charge of 32 C-II I&E fuel elements, a standard

* A standard downstream support charge for all reactors except K consists of three 8-inch expendable perfs, nine 8-inch tubulars, one 5-inch expendable perf, and two 8-inch expendable perfs as reviewed from upstream to downstream of the support charge.

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downstream support charge, and standard C rear fittings including a 1 inch OD aluminum pigtail.

The K tube geometry included the following: K venturi reamed to 0.410 inch, 1 inch flexible front pigtail, standard front and rear nozzles, 38 K-III I&S fuel elements, a standard K downstream support charge**, and a 1 inch OD stainless steel rear pigtail with 0.870 inch ID adapter fittings.

DISCUSSION OF RESULTS

C-Tube

Data are presented on Figure 1 for the C-tube assembly with various conditions of nozzle cap removal as indicated by the symbols and legend. The pressures are referenced to the header centerline elevations. Since C front headers are below the process tube, then front header pressure would extrapolate to a value of about 4 inches pressure at zero flow rate through the front pigtail with the front or the rear cap off. Since C rear headers are above the process tube, then rear header pressures would extrapolate to a value of about minus 13 inches for zero flow rate through the rear pigtail with rear cap on, front cap off and no flow through the front pigtail. (If there were flow through the front pigtail, then the rear header pressure value would extrapolate to a value greater than minus 13 inches, say minus 8 to 12 depending on the back pressure due to flow from the front pigtail.)

Curve F on Figure 1 also presents data for the C-tube assembly. It shows the pressure drop from the front header to rear header due to flow as measured by a ΔP gauge or a U-tube manometer with both front and rear caps on. The use of a ΔP gauge or U-tube manometer corrects automatically to a common elevation and thus measures only the energy loss due to flow. If two separate pressure gauges are used on the headers, the readings must be corrected to a common elevation before subtraction of the readings for comparison to curve D.

Data points are shown on Figure 1 for the cases with and without a new downstream support charge pre-inserted into the front nozzle. For flow through the tube with the front cap on or for reverse flow through the tube from the rear header, the pre-inserted support charge has negligible effect. However, the effect of the pre-inserted support charge on the flow from the front header and out the front nozzle is not negligible.

It should be noted that although it is possible to pre-insert an entire 117 inch long support charge in the C-tube with 32 fuel elements and the normal support charge, it is necessary to remove one 8-inch piece from the front nozzle in order to replace the front nozzle cap.

For the case of both front and rear nozzle caps removed, the coolant flow past the fuel elements from the front header is less than 0.25 gpm for all front header pressures shown on Figure 1.

K-tube

Data are presented on Figure 2 for the K-tube assembly and various conditions of nozzle cap removal. Again, the pressure coordinate is referenced to the elevation of the

** A standard K support charge consists of three 8-inch expendable perfs, nine 8-inch tubulars and two 5-inch expendable perfs, front to rear.

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center of the header and hence it would require a negative pressure to stop the flow whenever a nozzle cap is removed.

A pre-inserted support charge rests with the upstream perf about two feet downstream of the front nozzle inlet so that there should be no problem inserting the entire support charge. Furthermore, since there is not then a perf in the front nozzle, there is negligible effect on flow due to the pre-inserted support charge. It was determined that if an 8-inch perf is placed in the front nozzle, a flow of about 10 gpm will start the perf to move out of the nozzle and a flow of about 15 gpm would move the perf out of the nozzle.

Simultaneous removal of both front nozzle and rear nozzle caps will result in very small coolant flow rates past the fuel elements. With both nozzle caps off, the flow past the fuel elements from the front header was only 0.39 gpm with 107 inches of water front header pressure and 0.25 gpm with 47 inches of water front header pressure.

BDF-Tube

Figure 3 presents similar data for a central zone BDF-tube assembly and various combinations of cap removal. Since some BDF process tubes are above the headers and some are below the headers, the pressure ordinate on Figure 3 is referenced to the process tube centerline. Hence, the header center line pressure required for a given flow rate would be 4 inches greater than that indicated by the curves if the header is below the process tube and 4 inches less if the header is above the process tube.

With a 34 fuel element charge in a BDF tube, it is necessary to leave out two 8-inch pieces of the pre-inserted support charge in order to replace the front nozzle cap. The pre-inserted support charge did change the flow characteristics for flow out the front nozzle as indicated by data on Figure 3.

Again, flow past the fuel elements is very low when front and rear nozzle caps are off. With 143 inches front header pressure, the flow past the fuel was 0.34 gpm and with 60 inches, the flow was 0.19 gpm past the fuel elements from front to rear.

DR-Reactor

Data on Figure 3 (for BDF-tube assembly) should be entirely adequate for use with a DR assembly since the only difference is in the downstream bevel of the outlet header Parker fitting which would cause negligible difference at the low flow rates involved.

H-Reactor

The only reason that the data on Figure 3 would not be valid for an H-tube assembly is because of the increased flow resistance in the outlet header fittings of an H assembly. Figure 4 is included to show the pressure drop increase across the rear header fittings for an H assembly over a BDF assembly due to the different outlet header fitting. Thus, while Curves L, M and N on Figure 3 are directly applicable to an H-tube assembly, the rear header pressure requirements for a given flow rate on Curve P must be increased by the value on Figure 4 corresponding to the particular flow rate. For example, if Curve P shows a rear header pressure of 52.5 inches is required for 2 gpm flow from the rear header on the BDF assembly, then 52.5 plus 5.9 inches or 58.4 inches of water pressure would be required at 2 gpm due to the restrictive H header fittings. Likewise, the $\Delta P_{(RH - RH)}$ could be approximated for H-reactor by adding the value from Figure 4 to the value shown on Curve R, Figure 3.

E. D. Waters

THERMAL HYDRAULICS OPERATION

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FIGURE 1 - C-TUBE ASSEMBLY
VENTURI ZONE - 32 C-II I&E FUEL ELEMENTS

A - $\square$ - no pre-inserted support charge
B - $\odot$ - pre-inserted support charge
Front cap off - rear cap on. Flow rate through front pigtail and out front nozzle versus pressure at front header centerline.

C - $\odot$ - with and without pre-inserted support charge. Front cap off - rear cap on. Flow through the tube from rear versus pressure at rear header centerline.

D - $\diamond$ - no pre-inserted support charge
E - $\odot$ - pre-inserted support charge
Front cap on - rear cap off. Flow through the tube from front header versus pressure at front header centerline.

F - $\diamond$ - with and without pre-inserted support charges. Front and rear caps on. Flow through the tube versus $\Delta P(FH-RH)$ due to flow. (See page 3).

Pressure - Inches of Water at Header Centerline - Curves A, B, C, D, E
Pressure Drop Due to Flow - Inches of Water - Curve F

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FIGURE 2 - K-TUBE ASSEMBLY
VENTURI ZONE - 38 K-III 2AE FUEL ELEMENTS

Pre-inserted Support Charge has Negligible Effect

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FIGURE 3 - BDF-TUBE ASSEMBLY, CG-558 VENTURI ZONE - 3/4 O-II I&E FUEL ELEMENTS

1 - ○ - no pre-inserted support charge
1 - ○ - with pre-inserted support charge
Front cap off - rear cap on. Flow from front header out front nozzle versus F. header pressure at process tube centerline elevation.

N - □ - with and without pre-inserted support charge. Front cap on - rear off. Flow from front header through tube versus F. header pressure at process tube centerline elevation.

P - ▽ - with and without pre-inserted support charge. Front cap off - rear cap on. Flow from rear header through tube versus R. header pressure referenced to process tube centerline elevation.

R - ◇ - with and without pre-inserted support charge. Front and rear caps on. Flow through the tube versus $\Delta P_{(FH-RH)}$ due to flow.

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FIGURE 4 - CORRECTION OF FIGURE 3 FOR H-REACTOR
(See Page 4 for discussion.)

Additional Header Pressure Required for Flow Through H-Reactor Rear Fittings
Compared to EDF Rear Fittings
Inches of Water

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