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HYDRAULIC SUPPLY AND DEMAND CHARACTERISTICS OF THORIUM

TARGET ELEMENTS IN B, C, D, AND K PROCESS TUBES

By

C. W. Angle

September 15, 1964

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HYDRAULIC SUPPLY AND DEMAND CHARACTERISTICS OF THORIUM
TARGET ELEMENTS IN B, C, D, AND K REACTOR TUBES

INTRODUCTION

In conjunction with the proposed thorium target element replacement program, hydraulic tests were performed in the Hydraulics Laboratory in 185-D building to determine the flow characteristics of 1.480-inch OD solid thorium loadings in B, C, D, and K fringe tubes. Included are supply curve data for those orifice combinations which are tentatively to be used with the thorium loads in the various fringe tubes.

In addition, predicted supply-demand characteristics are presented for a loading of 1.600-inch OD thorium solids in a K-Reactor Zircaloy-2 process tube equipped with a 0.270-inch flat-plate orifice in a K central zone double-orifice retainer union (cage), Drawing H-1-21952.

RESULTS

Table I is a listing of the operating flows and Panellit pressures to be expected in the B, C, D, and K fringe tubes at various front header pressures with different venturi or orifice combinations used in conjunction with the 1.480 nominal OD thorium loadings. These results are also shown in Figures 1 through 9.

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TABLE I.

Operating Conditions with Various Orifice and Venturi Combinations in B, C, D, and K Fringe Process Tubes -- Nominal 1.480-inch OD Thorium Target Elements*

Process Tube	Venturi or Orifice	Avg. Coolant Temp.°C	FH Press. psig	RH Press. psig	Op. Flow gpm	Op. Pan. psig	Crit. Flow gpm	Min. Pan. psig
C Uniform Wall Ribbed Aluminum 1.632-inch ID	0.385-inch ID insert with adapter. CG-558 hardware	20	380	40	33.2	312	-	<0
	0.302 primary with screen. Zone 3.	20	420	40	29.0	282	≈42	<0
		20	380	40	27.2	260	≈40	<0
		50	420	40	29.8	276	≈42	<0
B-D Uniform Wall 1.559-inch ID	0.310-inch ID Venturi	20	580	40	28.1	474	-	<0
	0.239 15° TUS primary	20	580	40	23.5	420	≈38	<0
	0.361 15° TUS secondary							
K Ribbed Aluminum 1.673-inch ID	0.339 TDS primary							
	0.398 secondary, Zone 14	20	440	40	32.2	260	45	90

*Actual measurements were 1.4765- to 1.4835-inches OD and 8.675- to 8.705-inches in length.

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The front nozzle barrel to end-of-active-section pressure drop and demand curves are given for the C tube as a function of average coolant temperature (20 and 50°C) and flow. Comparison of the experimental (FN-EOAS) pressure drop with the analytical or graphical values for frictional pressure loss at 50°C (90°C outlet temperature) as determined from HW-54590, indicates that at 20 gpm the experimental and analytical values agree. The analytical ΔP values at 50°C for higher flow rates, however, are somewhat low due to the additional energy losses of the solid face thoriums (the frictional pressure drop relationship of HW-54590 does not consider acceleration-deceleration effects). At an average temperature of 50°C, the error (FN-EOAS) at 30 gpm will not exceed about 10 psi (1.5 percent of actual flow).

At the expected average operating temperature of 35°C, the operating conditions of flow and Panellit pressure determined from HW-54590 should be sufficiently accurate to obtain Panellit operating pressures within 4 psi and flow rates within 0.75 percent in the range 25-33 gpm for all ribbed tubes.

The orifice combinations as they exist in the B, C, D, and K fringe tubes were found to meet the requirements of operating flow, Panellit pressures, and critical conditions when used with the 1.480-inch OD solid thorium loads. If different fuel diameters are contemplated, construction of new demand curves with the given orifice arrangements will dictate the new operating conditions provided the new operating point is not in the critical flow region.

Table II lists the experimental data obtained with laboratory-fabricated 0.270-inch ID orifices in the K-Reactor central zone orifice cage. These data, also shown in Figures 10, 11, and 12, represent the front header to front nozzle characteristics as obtained with a 0.270-inch flat-plate (FP) orifice with an 11/16-inch spacer downstream (SpD) with the present 0.420-inch venturi insert in place in the orifice cage. The orifice and spacer are held in place with the screen holder at the upstream end of the cage and the Panellit pressures are monitored at the 0.420-inch venturi insert throat. Placing the orifice and spacer in the cage requires removal of the screen holder, insertion of the spacer, placement of the orifice upstream of the spacer, and reassembly of the holder. No additional modifications need be made for this arrangement of orifice, spacer, and venturi.

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TABLE II.

Operating Conditions with Various Orifice and Venturi Combinations in K Zircaloy-2, 1.681-inches OD
Central Zone Process Tubes -- 20°C Average Coolant Temperature, FH = 440 psig, RH = 40 psig

Process Tube Loading	Venturi or Orifice	Op. Flow gpm	Cavit. Flow gpm	Crit. Flow gpm	Op. Pan. psig	Cavit. Pan. psig	Crit. Pan. psig	Min. Pan. psig
1.600 Nominal OD Thorium Solids	0.420 Venturi Insert	25.4	--	--	416	-	-	<0
	0.270 F.P. SpU slightly rounded edge (with venturi insert)	20.2	25.0	30.2	292	218	115	<0
	0.270 F.P. SpU square edge (with venturi insert)	19.4	19.3	27.7	266	265	80	<0
	0.270 F.P. SpD square edge (with venturi insert)	19.0	21.0	28.8	258	220	55	<0
	0.270 F.P. SpD square edge (without venturi insert)	18.6	21.0	28.5	256	220	55	<0
38 KVNS I&E Standard Rails	0.270 F.P. SpD (with venturi insert)	27.5	21.0	28.8	92	220	55	<0
52 KVE I&E Standard Rails	0.420 venturi	69.6	--	--	236	-	-	<0
	0.270 F.P. SpD	27.8	21.0	28.8	75	220	55	<0
52 KVE I&E Arch Rails	0.420 venturi	75.1	--	--	215	-	-	<0
	0.270 F.P. SpD	28.1	21.0	28.8	68	220	55	<0

NOTE: F.P. (flat plate), SpD (spacer downstream), SpU (spacer upstream)

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The demand curve of Figure 12 and the resulting operating parameters as they appear in Table II are tentative and are based on an analytically predicted pressure drop across the 1.600-inch OD thorium elements. The operating conditions will be determined experimentally when the prototype elements are received and the results will be included in an addendum to this report. In the interim, the estimated operating conditions of the thorium target load in a K central zone tube should prove sufficiently accurate to provide a basis for determining over-all reactor flow performance.

DISCUSSION

Since the Panellit gauges on K Reactor contain bourdon tubes which have soft-soldered junctions (as compared to silver-soldered B-D-Reactor Panellits), it was decided that the operating Panellit pressure should be 300 psig, or less.* Consequently, the flat-plate orifice size or configuration may have to be adjusted to compensate for differences in the analytically predicted thorium demand curve and the experimentally determined curve.

The sharp edge, no-taper flat-plate orifice tested appears to meet the minimum requirements of operating Panellit pressure and flow for the 1.600-inch thorium loading in the K Zircaloy-2 tube. However, it can be seen from Figure 11 that, though the critical flow rate is approximately 28.5 gpm, a very slight "spitting" noise is encountered at 22.0 gpm, indicating that cavitation conditions may begin to exist at this flow rate. (No noise was detected at 21.5 gpm).

With a predicted operating flow of 19 gpm, it would require a reduction in pressure drop downstream of the front nozzle of about 80 psi and a resulting Panellit pressure decrease of 40 psi to obtain a flow of 21.0 gpm. A complete rear pigtail failure would reduce the downstream pressure drop by 40 to 45 psi, depending on the position of failure and based on a rear header pressure of 40 psig. The new Panellit pressure would be approximately 240 psig, a reduction of 20 psi,

$$\left(\frac{\Delta P_{\text{pan}}}{\Delta P_{\text{RH}}} \approx 0.5 \right),$$

and the new flow would be 20 gpm, an increase of 1 gpm. Consequently, a Panellit trip would probably not be experienced nor would cavitation flow be reached with a complete rear pigtail failure.

*Conversation with P. A. Carlson, P. J. Hollifield, and S. A. Wood.

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Further ΔP results of orifice, spacer, and insert arrangements are given in Figure 10, the variation being in spacer placement and venturi insert effect on pressure drop. From Table II, it can be seen that the assembly may be operating in cavitation if the spacer is placed upstream of the orifice and should be considered as a possible consequence of improper assembly.

The shaded area of Figure 12 represents the variation in flow and front nozzle barrel pressure which can be expected with variations in fuel loading diameters and orifice finish. The top supply curve was obtained with a poorly made rounded-edge orifice and the bottom with a well-made lap-finish sharp-edge orifice. The Panellit pressure for any operating point within this area will be 4-10 psi less than the FNB pressure as determined from the applicable supply and demand curves. This will give an operating Panellit range of about 250 to 300 psig, depending on the combination of fuel loading diameter and orifice quality. With the proper orifice and fuel tolerances, it is expected that this operating "band" can be somewhat reduced.

The demand curves which describe the remaining two boundaries of the "band" are determined by a loading of thorium solids which is uniformly 0.005-inch undersize or 0.005-inch oversize. In practice, however, a loading will probably consist of various degrees of undersize and oversize elements so that the demand curve would likely approach the "average" case of the 1.600-inch OD elements.

Figure 11 represents the ΔP versus flow characteristics of standard and arch rail KVN and KVE I&E self-support elements in the K central zone tubes. For pressure drops with fuel element quantities other than those shown, the pressure drop per element can be added to or subtracted from the total ΔP given at any flow rate and a new curve constructed.

The additional curves (Figure 12) of the 0.420-inch venturi and the enriched and normal uranium loads were considered to be a possible result of neglecting to orifice a thorium-charged tube or orificing a tube which contained 38 KVNS I&E elements or 52 KVE I&E elements (standard or arch rails). The operating Panellit pressures and flows for these loads are given in Table II and are represented by the triangular symbols on the appropriate curves of Figure 12, the data being obtained with a laboratory-fabricated orifice.

Since the 0.270-inch orifice with spacer downstream represents the best characteristics of the orifice combinations tested, including smaller ID orifices and primary-secondary combinations, any improvement in operating Panellit minus cavitation Panellit pressure values (i.e., $P_{op} - P_{cav} > 40$ psi, where $P_{op} = 260$ psig) would have to be obtained by

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raising the operating Panellit pressure. This would involve using a slightly larger orifice size in conjunction with the silver-soldered gauges.

As stated previously, the results on the operating parameters of the K Zircaloy-2 central zone tube are not final. They can, however, be used in evaluating orifice performance and Panellit requirements based on the analytical demand curves of the proposed 1,600 thorium load.

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At FH = 380 psig
 Crit Flow = 40 gpm
 Crit Pan. = 130 psig
 Min Pan. = < 100

*Plotted from ΔP
 versus Flow Equations:

$$F = 2.27 \text{ (FH-PAN)} \sqrt{\frac{\Delta P}{\rho}}$$

$$F = 9.59 \text{ (FN-PAN)} \sqrt{\frac{\Delta P}{\rho}}$$

Figure 1.

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Loading - Front
to Rear

32 THO₂ Solids
4 8-inch Perfs
8 8-inch Tubulars
3 8-inch Perfs

Figure 2.

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Figure 3.

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At FH = 580 psig,
Crit Flow 38.0 gpm
Crit Pan. 120 psig
Min. Pan. < 0 psig

$$F = K(\Delta P)^n$$

$$K_p = 1.81$$

$$n = 0.504$$

$$K_s = 7.66$$

$$n = 0.493$$

*Curves taken from
data obtained 6-27-62.

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Loading Pattern
Front to Rear

32 THO₂ Solids
4 8-inch Expendables
8 8-inch Tubulars
2 8-inch Perfs
1 5-inch Perf

(0.469/0.469 ID Rear
Nozzle and Header
Fittings)

Figure 5.

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At FH = 440 psig
Crit Flow ≈ 45.0 gpm
Crit Pan = 90 psig
Min Pan = 90 psig

Flow Constants:

$$F = K(\Delta P)^n$$

$$K_s = 2.42$$

$$n = 0.500$$

$$K_s = 4.85$$

$$n = 0.513$$

Figure 7

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Loading Pattern
Front-Rear

38 THO₂ Solids
3 8-inch perfs
8 8-inch tubulars
2 8-inch perfs

Figure 8.

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Figure 9

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Flow Characteristics of 0.270-inch Orifice
in K-Reactor Orifice Cage (Drawing H-1-21952)

Figure 10.

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Hydraulic Characteristics of Standard and Arch Rail KVN
and KVE Self-Supported Fuel in a K Zircaloy-2 Process Tube

Figure 11.

Estimated Supply-Demand Curve for 1.600-inch OD Thorium
Target Elements in K Zircaloy-2 Tube

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