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TITLE

PRESSURE DROP CHARACTERISTICS OF SOLID
ALUMINUM DUMMY PATTERNS IN
K ZIRCALOY-2 PROCESS TUBE

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February 16, 1965

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PRESSURE DROP CHARACTERISTICS OF SOLID ALUMINUM DUMMY
PATTERNS IN K ZIRCALOY-2 PROCESS TUBE

INTRODUCTION

Pressure drop tests were performed in the 189-D Hydraulics Laboratory to determine the number of K-Reactor solid aluminum pieces (SAs) required to throttle the tube flow of a 46-piece KVE and a 38-piece KVN arch-rail I&E fuel charge to that of a corresponding bridge-rail charge.

In addition, the effects on Panellit pressure and tube flow were determined for the cases in which:

- 1) the SAs were positioned next to the fuel column;
- 2) the SAs were over the rear nozzle outlet port;
- 3) perfs were used to isolate the SAs from the tubular portion of the support charge;

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- 4) SAs and perforated elements were used exclusively in the support charge (no tubulars), and
- 5) The SAs were "cocked" or misaligned with the longitudinal axis of the process tube.

EQUIPMENT

The laboratory prototypical mock-up assembly consisted of:

- 1) K Zircaloy-2 process tube (1.724-inch ID).
- 2) Standard rear hardware and fittings.
- 3) An extruded K front nozzle with a 0.420 venturi and the associated pigtail and front hardware.
- 4) A fuel charge of 46 KVE I&E arch-rail elements.
- 5) A fuel charge of 38 KVN I&E arch-rail elements.
- 6) Several K SAs (bridge rail, 1.435-inch body OD, 1.635-inch OD with rails, eight inches long) with the proper number of self-supported perfs, expendables, and tubulars to make up the balance of the support charge.

The pressures obtained at various flows and with different support charge patterns included the front nozzle barrel (FNB), the end of active section (EOAS), and the rear header (RH).

RESULTS

The graphical results of the tests are contained in Figures 1 through 5 for various loading patterns and SA positions in the fuel charge.

A) Figure 1

Curves 1, 2, and 3 were obtained with six, four, and two SAs, respectively, positioned next to two, four, and six tubular support elements, respectively. The dashed line of Curve 1 represents the (EOAS-RH) ΔP at 50°C with solid elements contained in the dummy pattern as given. Curve 4 is the ΔP versus flow curve for a standard pattern consisting of perfs, expendables, and tubulars. Curve 5 indicates the rear nozzle to rear header (RNB-RH) pressure drop to be expected when perfs are over the rear nozzle exit port.

B) Figure 2

Figure 2 illustrates the comparative effects on pressure drop by rearranging SAs, perfs, and tubulars in the support charge pattern (Curves 2 and 3). The cocking of one pair of SAs by offsetting the

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adjacent ends of 2 SAs and tack welding the two together, is given in Curve 1. The offset (eccentricity of the center axis) was equal to approximately 1/8-inch.

C) Figure 3

Curve 1 represents the FNB-EQAS ΔP curve when the solids are placed against the downstream KVN I&E fuel element. The effect is much like center plugging of the fuel element hole, though it is less severe due to the intermixing of the annular and center hole fluid streams at the interfacial junctions between the I&E elements.

Curve 2 is the normal ΔP to be expected with a standard dummy charge. The pressure differential obtained with all holes plugged, as obtained from HW-84477, is also included.

D) Figure 4

Figure 4 represents two dummy loading patterns which can be used in conjunction with the arch-rail elements to obtain FNB-RH pressure drop that would be nearly equivalent to the ΔP of a corresponding bridge rail and standard dummy charge. The addition of another SA to the KVE arch-rail column, i.e., four perfs, eight SAs, three perfs, would more nearly match the KVE bridge-rail ΔP at 70 gpm (Table IV of Summary).

E) Figure 5

Demand Curves 1 through 6 were included to illustrate the effects on Panellit pressure and tube flow rate by varying the support charge pattern and fuel charges as given in the introduction. The tabular results of Panellit pressure and operating flow are given under the summary portion of this report.

DISCUSSION OF RESULTS

1) Effect of Support Charge Elements on Pressure Drop

Tests of this nature which cover various support charge loadings may not include all of the possible configurations of dummy pattern arrangements. However, based on previous tests and on the results of the current tests using solid aluminum elements as an integral part of the support charge, the pressure drop of each portion of the support charge has been determined.

The frictional pressure drop across the partially plugged tubular portion of the support column (when SAs and tubulars are adjacent), the frictional ΔP for each SA, and the SA "end" effect are found

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from Figures 1 and 2. The relative position of tubulars and SAs, if used simultaneously in a pattern, is immaterial provided they are immediately adjacent to one another. This information is shown in Table I for a coolant temperature of 8°C.

TABLE I.

Flow (gpm)	EOAS-RH Standard Charge (psi)	ΔP_f /tubular (Adjacent to SA) (psi)	ΔP_f /SA	ΔP_e
40	13.2	0.62	2.37	0.42
70	40.0	1.50	6.50	1.10

Using the standard dummy charge as a base; i.e., four expendables, eight tubulars, and three perfs, the total EOAS-RH ΔP can be expressed as $\Delta P_{ST} + m(\Delta P_f/\text{tubular}) + n(\Delta P_f/\text{SA}) + \Delta P_e$, where ΔP_{ST} = EOAS-RH for a standard dummy charge, m = number of tubulars positioned next to the SAs, $\Delta P_f/\text{tubular}$ = frictional pressure drop per tubular, n = number of SAs in the column, $\Delta P_f/\text{SA}$ = frictional drop per SA, and ΔP_e = acceleration-deceleration loss associated with the flow transition at the two ends of the SA column.

When the tubulars and SAs are separated by perfs, the tubulars are assumed to contribute no additional ΔP to the column and the $m(\Delta P_f/\text{tubular})$ term would be omitted in the computation of the total pressure differential.

As an example, the ΔP , (EOAS-RH), for a dummy pattern of four expendables, six SAs, two tubulars, and three perfs at 70 gpm and 8°C would be:

$$40.0 + 2 \times 1.50 + 6 \times 6.50 + 1.10 = 83.1 \text{ psi,}$$

which agrees closely with the experimental value of 83.0 psi as given in Figure 1. Likewise, the ΔP for seven SAs with no tubulars is 86.6 psi at 70 gpm.

The front nozzle barrel to rear header demand curves are given in Figure 4 for these two support charges when used in conjunction with either the 46 KVE arch-rail fuel or the 38 KVN arch-rail fuel charge.

2) Temperature Correction

The effect on the pressure drop and, consequently, flow rate at temperatures other than 8°C can be determined by applying the temperature correction over the end of active section to rear nozzle barrel portion of the charge.

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3) SAs in the Nozzle - Figure 2, Curve 3A

Positioning four SAs in the rear nozzle of the process tube had little effect on pressure drop from the end of active section to rear header. This can be explained by the fact that the EOAS-RNB pressure drop has decreased by an amount equivalent to the ΔP associated with the length of the SAs measured from the nozzle exit port to the rear nozzle cap (seven inches) and which are now out of the main flow stream. Conversely, the RNB-RH pressure drop has increased by a similar amount due to the slight flow restriction at the nozzle port.

4) Misaligned SAs - Figure 2, Curve 1

By misaligning two adjacent SAs, an increase of 4 psi in EOAS-RH pressure drop was noted at 70 gpm. Whether the eccentricity of these two SAs affected the alignment of the adjacent SAs, perfs, and tubulars is unknown; however, assuming the additional solids could be similarly misaligned in the reactor process tube, the total ΔP increase for six SAs can be estimated at 24 psi at 70 gpm.

It is unlikely that the pressure drop increase would exceed half this amount since in the many tests performed at the 189-D laboratory, the deviation from one run to the next without regard to self-support orientation or misalignment has never exceeded about 2 or 3 psi. To exceed a pressure differential increase of about 12 psi (assuming cocked SAs), the most severe condition would require that each SA, with respect to the adjacent one, be misaligned a maximum amount.

5) SAs Next to Fuel Column - Figure 3, Curve 1

When a solid aluminum element is placed against the downstream end of the KVN I&E fuel column, the hole plugging action produces an increase in pressure drop of 171 psi at 70 gpm. When comparing this case of a partially plugged downstream fuel element and the case of a totally plugged fuel column (Figure 4 and document HW-84477), the effective annular/hole flow ratio becomes 7.10 at a ΔP of 300 psi (FN-EOAS). If the holes are considered to be completely plugged by the SA (hole flow = 0), the annular to hole ratio would be ∞ . If there were no effect due to the adjacent SA, the ratio would become 2.03 which is the annular/hole flow value when the fuel column hole is completely unplugged.

Expressed in tabular form, the results at 8°C coolant temperature are as follows:

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Charge	ΔP , FN-EOAS (psi)	Total Flow (gpm)	Annular Flow (Holes Plugged) (gpm)	Hole Flow (gpm)	Ann Hole Ratio
38 KVN I&E (arch rail) with standard dummy charge	300	73.0	48.9	24.1	2.03
Same fuel, but one 8-inch SA is posi- tioned against fuel column	300	55.8	48.9	6.9	7.10

At a pressure differential of 300 psi between the front nozzle and end of the fuel charge active section, the hole flow has been reduced from 24.1 gpm to 6.9 gpm by placing a solid dummy element against the downstream fuel element and the total flow has been reduced from 73.0 gpm to 55.8 gpm. The hole flow value obtained with the SA against the fuel column does not necessarily represent the flow through each I&E because of interchannel mixing at the junctions of the elements. Though the flow split was not determined for the KVE arch-rail charge, it is expected that the ratio will be about the same since the ratio at operating conditions with a standard dummy pattern for this charge is not significantly different from the arch-rail KVN fuel.

SUMMARY

The supply-demand curves for the various loadings are given in Figure 5. The following table identifies the demand curve number, type of fuel and dummy charge, and the Panellit pressure and process tube flow associated with each type of charge:

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TABLE III.

Curve No.	Fuel Charge	Dummy Charge	Comments	Operating Flow	Operating Panellit
				8°C (gpm)	Pressure (psig)
1	38 KVN I&E (Bridge Rail)	4 exp, 8 tub, 3 perfs	"Standard" dummy charge	66.1	266
	38 KVN I&E (Arch Rail)	4 exp, 2 tub, 6 SAs, 3 perfs, or 4 exp, 7 SAs, 4 perfs			
2	38 KVN I&E (Arch Rail)	4 exp, 8 tub 3 perfs	"Standard" dummy charge	70.3	244
3	38 KVN I&E (Arch Rail)	7 SAs, 8 perfs	SAs against fuel column	55.2	315
4	38 KVN I&E (Arch Rail)	4 exp, 7 SAs 4 perfs	1 to 6 SAs assumed to be severely cocked	64.0-65.8	277-268
5	46 KVE I&E (Bridge Rail)	4 exp, 8 tub 3 perfs	"Standard" dummy charge	71.2	238
	46 KVE I&E (Arch Rail)	4 exp, 1 tub, 7 SAs, 3 perfs or 4 exp, 8 SAs, 4 perfs			
6	46 KVE I&E (Arch Rail)	4 exp, 8 tub 3 perfs	"Standard" dummy charge	76.3	208

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Attachments: Figures
1 thru 5

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Pressure Drop of Downstream Dummy Charges
Containing Bridge-Rail Solid Aluminums (SAs)
In a K Zircaloy-2 Process Tube

Fuel Loading - 46 KWE Arch Rail 13E

Figure 1.

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Pressure Drop for Various Arrangements of
Solid Aluminums in Downstream Dummy
Pattern in a K Zircaloy-2 Process Tube

Fuel Loading = 38 KVN Arch-Rail 1&E

Downstream Dummy Pattern
Front-to-Rear
(All Elements are Eight
Inches in Length)

① 4 perfs
4 tubulars
4 SAS

② 3 perfs
3 SAS
(2 SAS eccentric in case)

③ 4 perfs
4 tubulars
4 SAS

④ 4 perfs
4 tubulars
4 SAS

⑤ 4 perfs
4 tubulars
4 SAS

⑥ 4 perfs
4 tubulars
4 SAS

⑦ 4 perfs
4 tubulars
4 SAS

⑧ 4 perfs
4 tubulars
4 SAS

⑨ 4 perfs
4 tubulars
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⑩ 4 perfs
4 tubulars
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⑪ 4 perfs
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⑱ 4 perfs
4 tubulars
4 SAS

⑲ 4 perfs
4 tubulars
4 SAS

⑳ 4 perfs
4 tubulars
4 SAS

㉑ 4 perfs
4 tubulars
4 SAS

Flow, gpm, Measured at 8°C

Figure 2.

Standard Pattern

4 expandables

8 tubulars

3 perfs

(Solids isolated by perfs)

2 perfs

4 solids

1 perf

4 tubulars

4 perfs

4 perfs

Figure 3.

See also FN-EOAS curve 1.

(SAS next to fuel column)

3 perfs

4 tubulars

4 perfs

4 SAS

B. 4 SAS

(SAS in rear nozzle)

4 SAS

3 perfs

4 tubulars

4 perfs

A. 4 perfs

3 perfs

4 SAS

4 tubulars

4 perfs

4 tubulars

4 perfs

3 perfs

4 SAS

4 tubulars

4 perfs

4 perfs

4 perfs

4 perfs

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Fuel Column Pressure Drop with SAs
Adjacent to Downstream Fuel Piece

Dummy Pattern
Front-to-Rear

- ① 4 eight-inch SAs
4 eight-inch expendable
4 eight-inch tubular
3 eight-inch perfs
(SAs next to fuel column)
- ② FN-ECAS for all other
dummy charges in which
solids and tubulars
are separated from fuel
column by expendables

Figure 3.

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FN-RH Comparison of KV Arch-Rail and Standard-Rail Fuel Charges with SA and Standard Dummy Charges

Figure 4.

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Supply and Demand Curves for
38 KVN I&E and 46 KVE I&E Fuel Charges
using Various Support Charges

FH = 440 psig
0.420 VT Insert

RH = 40 psig
8°C Coolant Temp.

See Summary for Demand Curve Identification

Figure 5.

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END