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MODIFIED TUBULAR SUPPORT PATTERNS --
RIBBED AND RIBLESS PROCESS TUBES

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MODIFIED TUBULAR SUPPORT PATTERNS --
RIBBED AND RIBLESS PROCESS TUBES

INTRODUCTION

Reactor support charge designs and patterns have been numerous and varied over the past few years, the basis for acceptance of a particular support loading being determined from a consideration of fabrication costs and the hydraulic characteristics of the proposed dummy load as it applies to a particular reactor.

Since the first three or four dummy pieces downstream of the fuel column (and upstream of the column in a spline tube) are discarded after the irradiation process, it is desirable to use tubular dummies for this portion of the support charge which are less expensive to fabricate and which are easily identified during the charging-discharging process. However, there exists a remote possibility that one or more tubular pieces could be inadvertently placed in a rear nozzle resulting in a flow restriction in the process tube. These arrangements of tubular support pieces in the dummy pattern, i.e., tubulars positioned against the fuel column and/or in the process tube rear nozzles, have been hydraulically tested to determine if there is adequate and unrestricted flow at normal operating header pressures.

PURPOSE

This report extends the number of possibilities of support loading patterns covered in previous reports and applies to the C-ribbed process tube, the K-ribbed tube, and the K-ribless Zircaloy-2 tube though the results given here should apply to B and D tubes as well.

Of interest are the hydraulic characteristics of a process tube in which:

1. A tubular support charge is separated from the fuel by a five-inch perforated expendable piece.
2. A tubular column is placed against the fuel column.
3. A tubular piece is placed in the rear nozzle.
4. A tubular piece is placed against the upstream end of the fuel column in a spline tube or is positioned against the insert in the upstream portion of the spline tube.

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SUMMARY*

1. The tubular section of a support pattern (usually three tubular pieces with the associated perfs to make up the total support charge) separated from the downstream end of the fuel column by a three-inch eight-hole perforated expendable is of sufficient length to give about the same pressure drop from the end of the active section of the fuel column to the rear header (EOAS-RH) as a five-inch 12-hole piece, an eight-inch 20-hole piece, or one to four eight-inch 20-hole expendables (Figures 1 and 2).
2. Three tubulars positioned next to a fuel column will increase the ΔP of a C-ribbed tube by as much as 80 percent and the ΔP of a ribless tube by about 12 percent (Figures 1 and 3).
3. One tubular against the rear nozzle cap of C-ribbed tube will increase the EOAS-RH value by 85 percent (Figure 4) and, when placed in a K nozzle, by 5 percent. If two tubulars are placed in the K nozzle, the increase is approximately 50 percent at operating flow (Figure 5).
4. In a C-Reactor spline tube, the use of tubulars in the upstream dummy pattern does not appreciably affect the pressure drop (FN-EOAS) provided none of the tubulars are positioned against the nozzle insert or against the upstream end of the fuel column (Figure 7). When against the fuel column, the increase in ΔP at operating flow is about 5 psi (0.75 percent flow decrease) and when against the insert, the increase is about 18 psi (3.0 percent flow decrease at 50 gpm).

EQUIPMENT

The C-Reactor tube mock-up consisted of a uniform-wall ribbed process tube with a fuel load of 30 CIIN, 2 CIWM, and a "standard" downstream support charge (front-to-rear) of one eight-inch 20-hole expendable, three eight-inch tubulars, and 11 eight-inch 16-hole perfs -- the pattern being rearranged as required for additional tests.**

Standard rear hardware was used on the C-ribbed tube, the K-ribbed tube, and the K Zircaloy-2 process tube. Flow rates were measured with a 1-1/4 inch Potter flowmeter while the pressure drops were taken with a mercury manometer where feasible and with calibrated Heise gages where the ΔP exceeded 60 psi.

*Also, see Table I, page 7.

**The dummy support patterns for various reactor process tubes are given on the appropriate graphs along with the applicable curves.

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DISCUSSION AND RESULTS

1. Downstream Support Charge Pattern

A. C-Ribbed Tube (Figures 1 and 2)

Figure 1 illustrates the pressure drop associated with various loading patterns in the C-ribbed tube. Of interest are the results obtained when the three tubular pieces are placed next to the fuel column (curve 4) and when the tubulars are separated from the fuel by various lengths of perforated expendable pieces (curves 1.B, 1.C, and 2).

Curve 1 represents the ΔP (EOAS-RH) using a standard support pattern. Curve 3 represents the ΔP when the four holes of the 1-1/2 inch long expendable were reamed from 1/2- to 5/8-inch diameter to permit less resistance to the flow recovery process immediately downstream of the end of the fuel column.

Figure 2 shows the pressure drop as a function of the length of the expendable separating the tubular portion of the support pattern and the end of the fuel column, and indicates that the difference in ΔP is only about 1 psi between a three-inch and eight-inch expendable. This value may vary by ± 1.0 psi due to different positioning of the perforated piece in the nozzle barrel from one loading to the next. The short pieces were cut from a standard eight-inch long 20-hole expendable and the cut end dressed down with emery cloth.

The results indicate that the majority of the pressure recovery occurs within about two inches of the downstream of the end of the fuel column and that any additional length of perforated support charge in this region merely contributes to increased pressure drops due to the additional holes. Some improvement can be realized by oversizing the holes immediately adjacent to the fuel column though this modification should be economically justified since the ΔP recovery is small (about 2 psi for the 1-1/2 inch expendable).

However, it is apparent that a standard five-inch expendable or even a three-inch perforated piece between the fuel and tubular portion of the support charge is hydraulically satisfactory.

B. K Zircaloy-2 Tube (Figure 3)

Figure 3, which gives the ΔP (EOAS-RH) for four tubulars placed adjacent to the fuel charge in a K-ribless tube was reproduced from the undocumented report, "Flow Tests of KV Tubular Support Pieces Positioned Next to KVN Fuel in a Zircaloy-2 Process Tube," March 26, 1964, and showed a 0.4 percent flow decrease at 68 gpm.

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Additional pressure recovery probably could be gained, in the case of tubulars or perfs adjacent to the fuel column, by minimizing the fluid frictional wall stresses in the flow channels. This could be effected by designing for slightly larger annular wall-to-wall dimensions in order to optimize the channel velocities and the equivalent diameters of the central and annular regions.

2. Tubular Pieces in the Outlet Nozzle (Figures 4, 5, and 6)

A. C-Ribbed Tube (Figure 4)

The placing of a tubular support piece in a C rear nozzle results in an increase of about 85 percent in EOAS-RH (Curve 2, Figure 4). Since the tubular piece extends four inches upstream of the nozzle outlet port, the deceleration of center flow and the increased annular flow in the nozzle region accounts for the large pressure drop encountered in the C tube. When the tubular piece is placed upstream eight inches and a perf is placed against the rear nozzle cap, the effect on the ΔP (EOAS-RH), is comparable to that obtained with a standard downstream support charge since the perf now allows a direct flow path to the nozzle outlet port without large acceleration-deceleration effects.

B. K-Ribbed Tube (Figure 5)

Placing an eight-inch tubular against the nozzle cap of a K-ribbed tube does not appreciably effect the flow because the upstream portion of the tubular extends only about 1-1/2 inches upstream of the nozzle outlet port; nor is the effect appreciable when the tubular and the upstream perforated piece are interchanged (Curve 2, Figure 5).

However, when two tubulars are placed in the rear nozzle barrel, the upstream tubular end extends 9-1/2 inches upstream of the outlet port, again increasing the ΔP between the rear nozzle and the rear header (Curve 3).

C. K Zircaloy-2 Tube (Ribless) (Figure 6)

As in the K-ribbed tube, the interchanging of a single tubular and perf in the rear nozzle does not appreciably effect the flow characteristics of the system since the nozzles are of the same general configuration. Two adjacent tubulars were not tested in the Zircaloy-2 tube, but the general effect should not be much different than with the ribbed tube, except that the increased pressure drop should not exceed about 10 psi at 70 gpm. The

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self-supported elements of the Zircaloy-2 tube should allow better annular flow than that shown for the case where the tubulars are lying along the bottom of the nozzle barrel as with the K ribbed-tube nozzle.

3. Modified Upstream Dummy Pattern - C Spline Tube (Figure 7)

The substitution of three tubulars for three perforated pieces in a spline tube does not affect the pressure drop from the front nozzle to the downstream end of the fuel column (Curves 1.A, 1.B, 1.C, Figure 7), provided the tubulars are separated from the fuel column and insert by at least one five-inch perforated expendable. With the tubulars next to the fuel column, the increase of about 5 psi (FN-EOAS) at 50 gpm represents about 0.75 percent flow decrease. When the three tubulars are placed next to the insert, an increase of about 18 psi (3.0 percent flow decrease) is encountered.

A summary of the approximate pressure and flow changes with various support charges is given in the following table:

TABLE I - PRESSURE AND FLOW ASSOCIATED
WITH SUPPORT CHARGE VARIATIONS

Curve No.	ΔP (EOAS-RH) (psi)	Flow Decrease (gpm)	% Flow Decrease
Figure 1. C-Tube - Modified Downstream Dummy Pattern (50 gpm)			
1	20.0	0 (base)	0 (base)
2	21.0	0.1	0.2
3	18.5	-0.15 (increase)	-0.3 (increase)
4	37.5	1.5	3.0%
Figure 3. K-Zircaloy-2 Modified Downstream Dummy Pattern (68 gpm)			
1	35.0	0.3	0.4%
2	31.5	0 (base)	0 (base)
Figure 4. C-Tube - Tubulars in Rear Nozzle (50 gpm)			
1	20.0	0 (base)	0 (base)
2	37.0	1.5	3.0%
Figure 5. K-Ribbed Tube - Tubulars in Rear Nozzle (50 gpm)			
1	18.0	0 (base)	0 (base)
2	19.0	0.1	0.2
3	27.0	0.9	1.8%
Figure 7. C-Reactor - Upstream Spline Tube Pattern (50 gpm)			
	(FN-EOAS)		
1	260.0	0 (base)	0 (base)
2	278.0	1.6	3.0
3	265.0	0.4	0.8%

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Figure 1. Modified Downstream Dummy Pattern C-Reactor

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Figure 2. End of Active Section to Rear Header Pressure Drop as a Function of the Support Piece Length Separating Fuel Column and Tubular Pieces

Dummy Loading
Pattern (front
to rear)

All pieces
self-supported.

① 4 tubular
11 24-hole perf
(tubulars against
fuel column)

② 4 24-hole exp.
8 tubular
3 24-hole perf

Figure 3. Modified Downstream Dummy Pattern
K Zircaloy-2 Tube

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Figure 4. Tubulars in Outlet Nozzle C-Tube

Dummy Loading
Pattern (front
to rear)

- ① Standard Load
38 KIV I&E
1-8" 20-hole exp.
10-8" tubular
2-8" 16-hole perf

- ② A 1-8" expendable
9-8" tubular
1 perf
1 tubular
1 perf

- B Same, but last perf
and tubular pieces
interchanged (tub.
extends 1-1/2" up-
stream of outlet port)

- ③ Same as 1, but
with 2-8" tubular
in nozzle (tub.
extends 9-1/2" up-
stream of outlet
port)

Figure 5. Tubulars in Outlet Nozzle
K-Ribbed Tube

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Figure 6. Tubulars in Rear Nozzle K Zircaloy-2 Tube

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Upstream Dummy
Pattern (front
to rear)

- ①
 - A. Insert
12-8" 20-hole exp.
1-5" 12-hole exp.
30 CIIN + 2 CIIWM
 - B. 9 expendable
3 tub. 1/4" wall
1-5" exp.
 - C. 9 expendable
3 tub. 3/16" wall
1-5" exp.
- ②
 - 3 tubular
9 expendable
1-5" exp.
(tub. against
insert)
- ③
 - 9 expendable
1-5" exp.
3 tubular
(tub. against
fuel column)
- ④ Normal central
zone tube without
upstream support
charge or spline
cap.

Figure 7. Modified Upstream Dummy Pattern
C-Reactor Spline Tube

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