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ORIFICE SIZES FOR K-REACTOR FRINGE ZONES WITH I&E FUEL

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ORFICE SIZES FOR K-REACTOR FRINGE ZONES
WITH H&E FUEL

E. D. Waters and J. F. Calkin

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PURPOSE

The purpose of this report is to describe orifice combinations which can be utilized in Zone 2, 3, and 4 of the K reactors while using K-IV I&E fuel elements and to present working data to describe the calibration and critical flow characteristics of initial prototypes of these orifice combinations.

A discussion is included concerning the minimum flow rates attainable by front face orificing while avoiding critical flow conditions.

INTRODUCTION

The solid fuel elements used in the fringe zones of the present production reactors will soon be replaced with I&E (internally and externally cooled) fuel elements as the production of solid fuel elements is discontinued. Since I&E fuel elements have a lower flow resistance than solid elements, it is desirable to re-orifice the fringe tubes in order to achieve maximum reactor orificing efficiency or water use efficiency.

The new orifices should take a greater pressure drop to compensate for the smaller pressure drop of the I&E fuel charge. However, there is a limit as to how much pressure drop can be taken across an orifice assembly without attaining a condition of self-limiting or choking flow which is referred to as critical flow. Operation in a condition of critical flow is to be avoided since it could result in not attaining a Panellit trip on failure of a front nozzle cap or inlet connector or it could result in actual damage to the inlet connector by cavitation and vibration. To avoid operation of reactor tubes in critical flow, experimentally determined relationships are used as a basis for establishing reactor operating standards.

Orifice sizing studies have been undertaken to determine whether present K reactor fringe zone orifices would be suitable for use with I&E fuel, and if not, to determine new orifice combinations which would be suitable. This report presents the results of these studies.

SUMMARY

At the K reactors it is desirable to have at least an 85 psi difference between normal Panellit pressure and the Panellit pressure which is associated with either incipient critical flow, pigtail failure or nozzle cap failure. This difference would not exist if the present Zone 2, 3, and 4 orifice assemblies were used with K-IV I&E fuel elements at present front header pressures as shown by data in Table I, page 6.

Three new orifice assemblies are described which will result in the desired 85 psi difference while providing normal flow rates of 51.7 gpm (zone 2),

38.1 gpm (zone 3), and 34.2 gpm (zone 4). These assemblies will use only one orifice size (and shape) which is different from those presently in use. Calibration and critical flow data are presented in Table II, page 8, for these assemblies.

Although the new zone flow rates are greater than were originally desired, the discussion points out that it is not feasible to attain a zone flow rate lower than about 34 gpm without adding flow resistance downstream of the orifice assembly. Outlet fitting orificing was considered but was rejected because the small advantages were offset by possible introduction of temperature monitor and piping vibrating problems.

Basis of Design

The following conditions were selected as the bases for the selection of suitable orifice combinations:

- (1) Fuel charge - 38 K-IV I&E fuel pieces - 1.459" O.D. x 0.385" I.D. (Since no pressure drop data were available, a pressure drop across the fuel charge equal to 60 psi was assumed at 30 gpm; this is about 3 psi lower than for 1.461" O.D. K-III I&E's as per page 5 of HW-56989.)
- (2) Standard downstream support charge with data from HW-54590, page 18.
- (3) Standard outlet fitting assembly with data from HW-54146, page 15.
- (4) Rear header pressure = 30 psig.
- (5) Front header pressure = 360 psig.
- (6) Normal Panellit pressure approximately mid-way between front header pressure and rear header pressure.
- (7) Minimum difference of 85 psi between normal Panellit pressure and the Panellit pressure which is associated with either critical flow, pigtail failure, or nozzle cap failure.
- (8) Desired zone flow rates of 39 gpm, 33 gpm and 29 gpm. (These values were eventually modified to 52, 39, and 34 gpm as discussed later.)
- (9) Use present K reactor orifice holder, pigtail, and front nozzle assembly.

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DISCUSSION

It is not difficult to determine an orifice assembly which will meet all of the above conditions except condition 7. This condition concerns the critical flow characteristics of the orifice assembly. Recall that present type orifice assemblies exhibit a choking flow phenomenon such that for pressure drops which are larger than a certain value, the flow rate is no longer proportional to the pressure drop. In fact, the flow rate remains constant while the pressure drop becomes larger and larger as the downstream pressure is reduced. The Panellit pressure which is associated with incipient critical flow is called the critical Panellit pressure, P_c . The P_c value depends on the particular orifice combination and the front header pressure and can be characterized by a constant, R , as discussed in HW-47197.

Also associated with an orifice assembly is a minimum Panellit pressure, P_m , which is the Panellit pressure which results when the front nozzle barrel pressure equals 0 psig. This condition might be visualized as the result of a front pigtail or front nozzle cap failure. P_m is not easily characterized and may vary widely from one orifice size combination to another. Although it is the result of a critical flow condition, P_m is greatly dependent upon the relative size, shape, and location of the two orifices of the combination.

The effects of critical Panellit pressure and minimum Panellit pressure become important in this study because of the following. When the fuel charge resistance is small, large pressure drops are desired across the orifices to achieve low tube flow rates. However, the maximum useable pressure drop for an orifice assembly must be less than that at critical flow. Hence, the pressure drop at critical flow, as defined by the orifice constant R , becomes very important.

To avoid sustained operation in critical flow and to assure Panellit low trip on sudden pigtail or cap failure, condition 7 was established as follows for K reactors*: the maximum possible accumulative error in laboratory data, orifice variation, and Panellit gage low trip set-up is estimated at 35 psi. Thus, the Panellit gage low trip setting would be specified as at least 35 psi above experimentally determined P_c or P_m , whichever is higher. In addition, it would be desirable that the Panellit pressure of the average normal tube should be at least 50 psi greater than the minimum allowable low trip setting. (This would allow for operation in corroded tubes, etc., which may have a lower than normal Panellit pressure.) Thus the design basis would be to have $35 + 50 = 85$ psi between the experimentally determined P_c or P_m and the average normal tube Panellit pressure, P_{an} , as determined by laboratory experiment and calculation.

$$P_c + 35 + 40$$

* With concurrence of P. A. Carlson, W. R. Smit, and N. E. Fuller, IPD, Research & Engineering.

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With the bases then fixed, the present zone 2, 3, and 4 orifice assemblies were investigated to determine their normal operating conditions with K-IV I&E's by use of the usual supply and demand analysis illustrated in the following sketch.

Sketch A

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The normal operating conditions were compared with desired conditions and with experimental P_c and P_m values as shown in Table I. From this comparison it was concluded that the present assemblies would normally operate too close to critical flow conditions and would be unsuitable for use with the K-IV I&E fuel.

TABLE I
OPERATION OF PRESENT K ORIFICES WITH K-IV I&E FUEL

Orifice Assembly	Normal Operating* Flow gpm	Panellit (Pan)psi	Critical Panellit (P_c) psi	Critical Flow Constant (R)	Minimum Panellit for Cap or Noz. Fail. (P_m) psi	Pan- P_c	Pan- P_m
Zone 2							
0.316 pri. only**	44.3	173	131	0.61	0	42	173
Zone 3							
0.290 pri.**	37.2	179	128	0.62	75	51	104
0.398 LB sec.							
Zone 4							
0.272 pri.**	33.4	166	130	0.61	85	36	81
0.371 LB sec.							
Desired values						= 85	= 85

50
35

Next, some calculations were performed to determine the feasibility of finding suitable orifice combinations to meet all of the design bases at the low flow rates desired. (There is a limit as to how low a tube flow rate can be attained by front face reactor orificing while still avoiding critical flow conditions by a specified Panellit pressure difference. The theory concerning the determination of this lowest feasible flow rate is discussed as an Appendix of this report, page 11. It may be stated that the lowest feasible flow rate is essentially determined by the critical flow constant, R, the specified Panellit pressure difference between normal and critical flow and the front nozzle barrel pressure demand characteristics.) Using the relations derived in the appendix, it was found that about 39.0 gpm would represent a practical lower limit for orifices with critical flow characteristics similar to the present K Reactor assemblies. However, it was felt

* With conditions as given in the 'Basis of Design' conditions 1 thru 5.
** Normal K Reactor orifice.

that the critical flow characteristics could be improved and that 34 to 35 gpm represented a practical low flow rate limit.

Orificing of the process tube outlet fittings was briefly investigated as a means of raising the front nozzle barrel demand pressures and thus attaining lower flow rates. However, it was found that a 0.469" I.D. orifice in the rear pigtail outlet parker fitting would result in a flow rate reduction of less than 1.5 gpm (at 34 gpm) compared to the standard outlet assembly. Such an orifice might increase the rear face vibration, increase the failure rate of temperature monitor elements (RTD's), and cause temperature reading errors. Hence, the use of outlet orificing did not appear desirable.

For these reasons, the design flow rates were changed after mutual agreement with the IPD Research and Engineering personnel concerned. It was agreed that zone 4 should be 34 gpm, zone 3 should be 39 gpm and zone 2 should utilize the present K Reactor zone 4 secondary as a single primary orifice if a suitable Panellit operating margin and a reasonable (~ 50 gpm) flow rate would result. With these changes, the orifice pattern would necessarily begin nearer the center of the reactor.

New orifice assemblies with high critical flow constants were then developed for zones 3 and 4 and the operating characteristics of suitable assemblies were determined as in Table II below. A zone 2 flow rate of 52 gpm resulted with the present K Reactor zone 4 secondary being utilized as a single primary orifice. For economic reasons, this orifice was accepted as the zone 2 assembly. For zones 3 and 4, it was necessary to depart from use of present type K reactor orifices (which would more accurately be described as flow nozzles) and go to the thin plate type orifice shown in Figure 1, page 14. The thin plate orifices are much more resistant to critical flow; they exhibit higher values for the critical flow constant, R.

The geometric configuration to be used and the operating characteristics of the new orifice assemblies are presented in Table II; also, information is included to show the operating characteristics of the new orifice assemblies at a greatly reduced front header pressure. For convenience, calibration curves are shown in Figure 2, page 15. As far as could be determined in the laboratory, the assemblies should give satisfactory operation on the reactor. There seemed to be a slight bit more Panellit pressure oscillation with the zone 3 and 4 assemblies than with the zone 2 assembly or with a K Reactor venturi. It is suggested that this may be a result of the lower operating flow rates rather than the particular orifice assembly. That is, the Panellit pressure change with flow rate, psi/gpm, is much greater at the low flows than for high flows. Hence, a ± 0.3 gpm fluctuation in the laboratory system flow rate would cause a much greater Panellit oscillation at 34 gpm than a ± 0.3 gpm fluctuation at 60 gpm.

The data of Table II are representative of a limited sample of on-site fabricated prototypes. The finally procured orifices may vary

* Supplied by N. E. Fuller and W. R. Smit, IPD, Research and Engineering

TABLE II

Calibration Table for corresponding pressure drop

DESCRIPTION AND OPERATING CHARACTERISTICS OF NEW K REACTOR PRINCE ZONE ORIFICES

$\Delta P, \text{psi} = K(F, \text{gpm})^n$ (experimental average of 3 or 4 orifices of each combination)
 $\Delta P, \text{psi} = C(F, \text{gpm})^2$ (where C is determined at operating flow rate)

$$F = \left(\frac{1}{K}\right)^{\frac{1}{n}} (\Delta P)^{\frac{1}{n}}$$

Calibration Curves are Shown in Figure 2

Zone	Orifices	Primary (FH-Pan)				Secondary (Pan-FNB)			
		K	n	C	Deviation*	K	n	C	Deviation*
2	.370-LB pri. only (present zone 4 sec.)	.0717	2.004	.0728	± 8 psi	.01904	2.023	.01979	± 0.5 psi
3	.339-TP 45° TU SpU pri.:.398-LB sec. (present zone 3 sec.)	.1123	2.029	.1164	± 1.5 psi	.0406	1.951	.0380	± 3 psi
4	.339-TP 45° TD SpU pri.:.398-LB sec. (present zone 3 sec.)	.1745	1.984	.1701	± 2.5 psi	.0406	1.951	.0383	± 2.5 psi

$$F = 2.75(\Delta P)^{\frac{1}{n}}$$

* The deviations shown represent the deviation at operating flow rate among the three or four orifice assemblies of each type which were tested.

	Normal** Flow Fn,gpm	Panellit Pressure			Pan-Pm Δm psi	Pan-Pc Δnc psi	Critical Constant R	-8-
		Normal	Critical	Minimum				
		Pan, psi	Pc,psi	Pm,psi				
<u>FH = 360 psig</u>								
Zone 2	51.5	167	<0	<0	>167	>167	.980	
Zone 3	38.1	191	103	103	88	88	.685	
Zone 4	34.2	161	71	70	91	90	.769	
<u>FH = 260 psig</u>								
Zone 2	42.9	128	<0	<0	>128	>128	.980	
Zone 3	31.7	144	72	72	72	72	.685	
Zone 4	28.3	122	50	50	72	72	.763	

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** Normal flow assuming 38 K-IV I&E fuel elements (i.e. 1.459" O.D. x 0.385" I.D.); standard dummy pattern; 30 psig rear header pressure.

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slightly in operating characteristics due to slight differences in fabricating tolerances or finishes. It is suggested that the flow characteristics be checked for a few orifices randomly selected from the final procurement items.

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BIBLIOGRAPHY

- HW-47197, "Approximate Method of Correlating Panellit Pressure With Front Header Pressure at the Critical Flow Point in Reactor Orifice Assemblies," E. D. Waters, December 12, 1956.
- HW-54146, "Critical Flow Conditions for K Reactor Outlet Fittings," E. D. Waters, December 12, 1956.
- HW-54590, "Standard Laboratory Hydraulic Pressure Drop Characteristics of Various Solid and I&E Fuel Elements," E. D. Waters, G. R. Horn, January 20, 1958.
- HW-56989, "Hydraulic Characteristics of I&E Slugs for K Reactor (Models K-III-N and K-III-E)," E. D. Waters, August 5, 1958.
-

NOMENCLATURE

c (subscript) = critical

C = constant in the equation $\Delta P = CF^2$

F = gpm = flow rate

FH = psig = front header pressure

FNB = psig = front nozzle barrel pressure

K = constant in the equation $\Delta P = KF^n$

LB = long barreled

m (subscript) = minimum

n = constant in the equation $\Delta P = KF^n$

n (subscript) = normal

$\Delta_{nc} = P_{an} - P_c$

P_{an} = psig = panellit pressure

P_c = psig = critical panellit pressure

P_m = psig = minimum panellit pressure

ΔP = psid = pressure difference

$R = \Delta P_c / (FH + 15) =$ critical pressure constant

RH = psig = rear header pressure

SpU = spacer upstream

TD = taper downstream

TU = taper upstream

APPENDIX

Concerning the Minimum Flow Rates Attainable by Front Face Orificing While Avoiding Critical Flow Conditions

As discussed in HW-47197, the common Hanford process tube orifice assemblies exhibit a condition referred to as critical flow. The point of incipient critical flow can be characterized by a critical flow constant, R, defined as

$$R = \frac{\Delta P_c(FH - P_{an})}{FH + 15}$$

where ΔP_c is the pressure drop at incipient critical flow for a given front header pressure, FH. An experimentally determined R value allows the calculation of ΔP_c for various values of FH pressure. Experience has shown that R is chiefly dependent upon orifice shape, orifice holder geometry, and slightly dependent upon orifice size. From the above relation, it follows that incipient critical flow can be characterized by a critical Panellit pressure, P_c , once the R value is known and the FH pressure is specified.

It is necessary to take as much pressure drop across the orifice as possible in order to achieve low normal flow rates. However, critical flow conditions must be avoided during normal operation for reasons of reactor safety. It has been agreed that design studies should provide that the normal operating Panellit pressure, P_{an} , should be greater than the critical Panellit pressure, P_c , by an amount equal to 35 psi plus the Panellit gage trip span. This operating margin between normal and critical flow conditions, designated $P_{an} - P_c = \Delta_{nc}$, would equal 85 psi for the K reactors.

Also associated with reactor safety considerations is the minimum Panellit pressure, P_m , which would exist for a nozzle cap or pigtail failure. It is obvious that a Panellit trip must occur for Panellit pressures equal to or greater than P_m . With no secondary orifice, the P_m value will be essentially zero psig. In an effort to attain low flow rates, a secondary orifice is used. Its size is reduced relative to the size of the primary orifice until the pressure drop through the secondary just equals the critical Panellit pressure at the time of incipient critical flow in the primary orifice. That is, for nozzle cap failure the FNB pressure equals zero psig and

$$\Delta P_{\text{secondary}} = (P_{an} - FNB)_{\text{at failure}} = (P_{an} - 0)_{\text{at critical}}$$

But P_{an} at critical equals P_c , so

$$\Delta P_{\text{secondary at cap failure}} = P_c$$

and hence

$$P_m = P_c$$

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Of course if the secondary orifice were made too small, P_m would still equal P_c but R would be reduced and the maximum possible pressure drop in the primary orifice could not be realized. Hence, there can be a delicate balance between the size of the primary and secondary orifices. And of course this assumes that both primary and secondary orifices are behaving as normal ideal orifices ($\Delta P = K F^2$) right up to the point of incipient critical flow.

The pressure drop across the primary orifice at incipient critical flow is

$$\Delta P_{\text{pri-crit}} = \Delta P_c$$

and the maximum pressure drop available under normal flow conditions is

$$\Delta P_{\text{pri-norm}} = \Delta P_c - \Delta P_{nc}$$

The ratio of the pressure drop under these two conditions could be written as

$$\frac{\Delta P_{\text{pri-norm}}}{\Delta P_{\text{pri-critical}}} = \frac{\Delta P_c - \Delta P_{nc}}{\Delta P_c}$$

But since orifice sizes were selected so that both orifices behave as ideal orifices at the time of incipient critical flow, then the pressure drop across the entire orifice assembly must have the same ratio when comparing conditions of normal and critical flow. That is,

$$\frac{(FH-FNB)_n}{(FH-FNB)_c} = \frac{\Delta P_c - \Delta P_{nc}}{\Delta P_c}$$

where FNB is front nozzle barrel pressure.

But for incipient critical flow and for cap failure

$$(FH-FNB)_c = FH$$

so that

$$(FH-FNB)_n = \frac{FH(\Delta P_c - \Delta P_{nc})}{(\Delta P_c)}$$

or

$$FNB_n = FH \left(1 - \frac{\Delta P_c - \Delta P_{nc}}{\Delta P_c} \right)$$

By use of the definition of R the above equation reduces to

$$FNB_n = \frac{\Delta P_{nc}}{R} \left(\frac{FH}{FH + 15} \right)$$

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Conditions have now been specified to attain the minimum possible FNB pressure at normal flow conditions and hence the lowest possible normal flow rate. This final equation shows that the minimum attainable flow rate is influenced by the Panellit operating margin, Δ_{nc} the critical constant of the orifice assembly, R, the front header pressure, FH, and of course the FNB pressure demand curve (the geometry downstream of the front nozzle). The relation shows, however, that the FH pressure has little effect

since $\left(\frac{FH}{FH + 15} \right)$ is nearly equal 1.0. Hence, the minimum theoretical flow rate is essentially fixed by Δ_{nc} , R, and the FNB demand curve.

The only one of these variables which is really a variable in an orifice sizing study is R. Furthermore, the minimum normal flow rate (or FNB pressure) defined by the above relations can only be approached but not completely attained by use of present type orifice arrangements. One reason for this is that the primary orifice is relatively near the secondary orifice and when incipient critical flow occurs in the primary orifice, it 'upsets' the flow path to the secondary orifice causing it to behave non-ideally. As a consequence, it is necessary to make the secondary orifice a little larger and take slightly less pressure drop under normal flow conditions than would be desired. In other words, we have not been able to approach the theoretical minimum flow rate closer than about 2 gpm using the present orifice holder arrangement.

Using the above developed relation and a FNB demand curve for the K-IV I&E fuel, the minimum feasible flow rates were calculated for K reactor as follows, assuming the listed FH, R and Δ_{oc} values:

FH (psig)	360	360	360	360	360	260	260
R	0.62	0.72	0.72	0.769	0.769	0.72	0.78
Δ_{oc} (psi)	85	85	115	85	90	85	85
Min FNB (psig)	132	113	153	106	112	112	103
Min Flow (gpm)	37.2	33.5	41.0	32.0	33.3	33.3	31.3

By comparison, the thin plate orifices developed in this study for zone 4 with an R value of 0.769 only attained a flow rate of 34.2 gpm or about 2 gpm higher than the predicted minimum. The new zone 4 assembly has an operating margin of 90 psi rather than 85 psi, but even taking this into the calculations, the minimum achieved flow rate is slightly higher than the predicted minimum flow rate. This probably reflects the non-ideal behavior or flow stream interaction between the two orifices of the assembly.

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Thin Plate Orifice

Note: This orifice is described elsewhere as:

.339 TP 45° TD SpU

where

.339 = the orifice diameter

TP = thin plate

45° = angle of taper

TD or TU = taper opening downstream or upstream

SpU = spacer upstream

Spacer Cylinder

Figure 1 - Thin Plate Orifice.
(Not to scale)

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Figure 2 - K Reactor Fringe Zone Orifice Calibrations
(See Table II for numerical equations of these lines.)

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