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FLOW CONDITIONS AT OUTLET FITTINGS
OF EXISTING HANFORD REACTORS

AUTHOR

D. W. McLenegan

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FLOW CONDITIONS AT OUTLET FITTINGS
OF EXISTING HANFORD REACTORS

By: D. W. McLenegan
Design Engineering
Construction Engineering & Utilities Operation

November 12, 1959

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FLOW CONDITIONS AT OUTLET FITTINGS
OF EXISTING HANFORD REACTORS

I PURPOSE OF REPORT

This report records the basis underlying the decision already reached to recommend a change of process tube fittings at B, D, F, DR and H reactors, and also proposes for consideration a change in the devices for monitoring effluent water temperature.

In studying higher operating conditions (flow and temperature) for the existing reactors, it becomes apparent that the present rear-face fittings will impose limitations in performance. This report

- a) summarizes the conditions of flow and temperature which are being studied,
- b) estimates the pressures required at the outlets of the process tubes and at the rear cross-headers to avoid critical flow, and
- c) recommends new fittings for some reactors, as well as the corresponding rear cross-header pressures required,
- d) discusses the possibility of changing to external-type water temperature detectors.

Data to support these recommendations has been read directly in some cases, and estimated in others, from tests performed and reported by HAPO engineers in documents which are referenced in the following.

This report amplifies and supersedes the findings covered by HW-62180, which is being withdrawn.

II OPERATING CONDITIONS TO BE STUDIED

The conditions of Table I are being studied for Reactors B, D, DR, F, H and C. The study does not include KE and KW reactors.

TABLE I
B, D, F, DR AND H REACTORS

Flow and Injection Study Conditions

<u>Study Condition</u>	<u>Reactor Flow</u>	<u>Reactor Bulk Effluent Temp. °C</u>	<u>Injection Water</u>	<u>Total Flow</u>	<u>Effluent Temp. of Total Flow °C</u>
1. Existing	85,000**	95°	None	85,000	93°
2. 95	95,000	95	None	95,000	95
3. 105A	105,000	105	*17,000	*122,000	95
4. 105B	105,000	120	*37,000	142,000	95
5. 120A	120,000	105	*17,000	137,000	95
6. 120B	120,000	120	*42,000	162,000	95
7. 150A	150,000***	105	*21,000	171,000	95
8. 150B	150,000***	120	*53,000	203,000	95

* These quantities include 10% allowance for inefficiencies in mixing.

** 95,000 gpm at C reactor.

*** Only B reactor is being studied for 150,000 gpm.

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III CONCLUSIONS AND RECOMMENDATIONS

1. Even at the vena contracta of the outlet fittings, the static pressure of the water must be substantially above the saturation pressure corresponding to the water temperature; (1)(2) with some downstream recovery, the static pressure in the rear crossheader must be still higher. Therefore the rear crossheaders will need to be pressurized for all outlet temperatures near or above 100° C. In addition, a margin of pressure must be reserved to prevent boiling during power level surges.
2. To avoid critical flow conditions, the rear crossheader pressure should be determined by the flow and outlet temperature of the maximum power tubes, rather than by the bulk outlet temperature.
3. For the B, D, DR, F and H reactors, the present fittings are already being subjected to extremely high flow velocities, and evidences of flow erosion have been reported. (3)
4. For any flows beyond present levels at B, D, DR, F and H, the use of 1" fittings and pigtails (I.D. = 0.870") is recommended. These larger flow channels will conserve pressure which may be needed to obtain the higher flows, reduce the required pressurization of rear crossheaders, and reduce the likelihood of flow-excited vibrations. This recommendation is still subject to confirmation as regards the functioning of Panellit or other flow monitoring devices.
5. Even if the present fittings (B, D, F, etc.) were reamed to 0.600" ID, the higher flows contemplated in this study would require unduly high rear-face and crossheader pressures. (Since these fittings are understood to be nitrided, we question whether grinding might be needed rather than reaming.)
6. For the C reactor, the present fittings are of larger size, and do not constitute a major bottleneck. (4) Therefore no change of these fittings appears necessary.
7. The front-face fittings might well be changed to match those proposed for the rear faces of B, D, DR, F and H. On the front faces, however, there is little likelihood of vapor formation; the objectives would therefore be to conserve a valuable part of the pressure generated by the process pumps and to reduce the velocity, turbulence and possible vibration at the higher flows.
8. Reduction of the pressure required in the rear crossheader is important not only to conserve pumping power but also from the standpoint of avoiding excessive turbulence and possible vibration. As an example, a flow of 100,000 gpm with 50 psi pressure drop in the rear crossheaders and risers represents an energy dissipation of 2800 HP, all of which is a potential source of vibration troubles.
9. Wherever the rear fittings and pigtails are replaced by larger sizes, it would be well to consider changing also to external ("wrap-around") thermocouples, to eliminate the thermocouple wells which are potential sources of flow-excited vibrations.

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IV TECHNICAL DISCUSSION

For the B, D, F, and DR reactors with the present small outlet fittings, Waters and Batch (5) have shown the relationships between

Flow per Tube
Water Temperature
Rear Nozzle Pressure
Rear Crossheader Pressure

which are needed to prevent critical flow. Some of these data, plus extrapolations, have been combined into Table II. Analysis of the data showed these approximate relationships:

- a) Rear nozzle pressure = (Saturation Pressure + $3.1 P_v$)
where P_v = velocity head through fittings, in psi
- b) Rear crossheader pressure = (Saturation Pressure + approximately $1.15 P_v$)

Thus the loss through the rear-face fittings and pigtails is approximately two velocity heads. Note also that the crossheader pressure must exceed the saturation pressure by about 1.15 velocity heads, to insure against critical flow.

Tables II, III and IV do not include the margin of pressure needed to prevent boiling during power surges. In HW-52793, this margin is described as + 12°; (6) in the temperature range contemplated here, this corresponds to a pressure margin requirement of approximately 10 psi.

If these small fittings were to be retained in the B, D, F and DR Reactors for the higher flows now being studied, Table II shows that rear-face pressures above 300 psi would be needed. Such pressures would not only represent an unwarranted waste of pump capacity but would also require that crossheaders, risers and downcomers be designed for unreasonably high pressures.

These empirical relationships are used in this report as approximations for estimating rear nozzle and crossheader pressures required with larger fittings, where specific test data are lacking.

Table III shows approximate rear nozzle and rear crossheader pressures (B, D, DR, F) if the present fittings were to be enlarged to 0.600" by reaming or grinding. For the higher temperatures and flow-per-tube values, the required pressures are still excessive.

Table IV shows corresponding pressures (again for B, D, DR, F reactors) if 1" fittings (.870" ID) are used. Here the velocities through the fittings are very reasonable (example: 40 ft./sec. at a flow of 70 gpm/tube). The pressures required are not much greater than the saturation pressures, except at the highest flows, where there will be 15-20 psi loss through the pigtails and fittings. Unless some question arises regarding the detection of abnormal flow conditions, this size of fittings is recommended to conserve pump power and to minimize turbulence and vibration. The lower pressures permitted by these large fittings will also simplify the problem of downstream pressure dissipation.

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TABLE II
B-D-F-DR REACTORS
REAR NOZZLE BARREL AND CROSSHEADER PRESSURES
REQUIRED WITH PRESENT FITTINGS, (0.469" ID)

Flow, GPM = F	$P_v = .0244 F^2$	3.1 P_v	Temp.- Max. Tube °C	P_s	Approximate	
					$P_s \div 3.1 P_v$ = Rear Nozzle Pressure	Rear Cross- Header Pressure Required = $P_s \div 1.15 P_v$
36	31.6	98	120	14	112	50
			135	31	129	64
			150	54	152	90
48	56.2	174	120	14	188	79
			135	31	210	97
			150	54	228	119
56	76.0	236	120	14	250	103
			135	31	267	122
			150	54	290	141
64	100.0	310	120	14	324	?
			135	31	341	
			150	54	364	
70	120.0	372	120	14	386	?
			135	31	403	
			150	54	426	

Cross-section area of fitting = $\frac{\pi}{4} (.469)^2 = .173 \text{ sq.in.} = .0012 \text{ sq.ft.}$

Water velocity = $\frac{\text{GPM per tube}}{7.5 \times 60 \times .0012} \times \frac{62.4}{59.0} = 1.96 \times \text{GPM}$

Velocity pressure (psi) = $P_v = \frac{59.0 \times V^2}{2g \times 144} = \frac{59.0 \times (1.96 \times \text{GPM})^2}{64.4 \times 144} = .0244 (\text{GPM})^2$

With small fittings, very high rear-face pressures are needed; from HW-52302, loss through fittings and pigtail is approximately 2 velocity heads.

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TABLE III
B-D-F REACTORS
REAR NOZZLE BARREL AND CROSSHEADER PRESSURES
REQUIRED WITH PRESENT FITTINGS REAMED

Assume tube and
fitting bore = 0.600"

Flow, GPM = F	$P_V = .0092 F^2$	$3.1 P_V$	Temp. - Max. Tube °C	P_S	Approximate	
					Rear Nozzle Pressure = $P_S + 3.1 P_V$	Rear Cross- Header Pressure Required = $P_S + 1.15 P_V$
36	11.9	37.0	120	14	51	28
			135	31	68	45
			150	54	91	68
48	21.2	66.0	120	14	80	38
			135	31	97	55
			150	54	120	78
56	28.8	89.0	120	14	103	47
			135	31	120	64
			150	54	143	87
64	37.6	117.0	120	14	131	57
			135	31	148	74
			150	54	171	97
70	45.0	140.0	120	14	154	66
			135	31	171	83
			150	54	194	106

$$\text{Cross-section area of fitting} = \frac{\pi}{4} (.600)^2 = .282 \text{ sq. in.} = .00196 \text{ sq.ft.}$$

$$\text{Water velocity} = \frac{\text{GPM per tube}}{7.5 \times 60 \times .00196} \times \frac{62.4}{59.0} = 1.20 \times \text{GPM}$$

$$\text{Velocity pressure (psi)} = P_r = \frac{59.0 \times V^2}{2g \times 144} = \frac{59.0 \times (1.2 \times \text{GPM})^2}{64.4 \times 144} = .0092 (\text{GPM})^2$$

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TABLE IV
B-D-F-DR REACTORS
REAR NOZZLE AND CROSSHEADER PRESSURES
REQUIRED WITH 1" FITTINGS (.870" ID)

Flow GPM = F	P _v (psi)	3.1 P _v	Temp. - Max. Tube °C	P _s	Approximate	
					Rear Nozzle Pressure = P _s + 3.1 P _v	Rear Header Pressure = P _s + 1.15 P _v
36	2.7	8.4	120	14	22.5	17
			135	31	39.5	34
			150	54	62.5	57
48	4.8	15.0	120	14	29	19.5
			135	31	46	36.5
			150	54	69	59.5
56	6.5	20.0	120	14	34	21.5
			135	31	51	38.5
			150	54	74	61.5
64	8.5	26.4	120	14	40.4	24
			135	31	57.4	41
			150	54	80.4	64
70	10.1	31.5	120	14	45.5	25.5
			135	31	62.5	42.5
			150	54	85.5	65.5

$$\text{Cross-section of fitting} = \frac{\pi}{4} (.870)^2 = .600 \text{ sq. in.} = .0041 \text{ sq.ft.}$$

$$\text{Water velocity} = \frac{\text{GPM per tube}}{7.5 \times 60 \times .0041} \times \frac{62.4}{59.0} = 0.57 \times \text{GPM}$$

$$\text{Velocity pressure} = P_v = \frac{59.0 \times V^2}{2g \times 144} = \frac{59.0 (.57 \text{ GPM})^2}{64.4 \times 144} = .00207 (\text{GPM})^2$$

(psi)

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For the C reactor, which has larger fittings, it seems unnecessary to include in this report any extensive tabulation of rear-face pressures. Outlet flow conditions for this reactor have been studied thoroughly by E. D. Waters in HW-56142. The following representative values, extracted from his report, indicate that only moderate rear-face pressures are required, to avoid critical flow, even at high flow and outlet temperature:

Flow per Tube (GPM)	Temperature °C	Saturation Pressure Ps	Rear Nozzle Pressure Required
36	120	14	22
	140	38	43.5
48	120	14	30
	140	38	51.5
56	120	14	37
	140	38	58.5
64	120	14	46
	140	38	66.0

Since the required rear nozzle pressures are not greatly above the saturation pressures, little advantage would be gained by changing to still larger fittings on the C reactor.

If the recommendations re larger fittings are put into effect on B, D, F, DR, and H reactors, an opportunity is offered to simplify the monitoring of outlet water temperatures. All these reactors (as well as C) use thermocouples, one per tube, immersed in wells which project into the water streams. Even if maximum water velocities through the rear-face fittings are reduced to 35-40 ft./sec., these transverse projections can give rise to Karman vortices downstream which are potential sources of vibration. As possible replacements, thermocouples are available in a form which can be held firmly against the outer surface of a pigtail by a clamping ring, and which offers a junction protected against moisture. The read-out instrument(s) would not be affected by such a change. Also, it is believed that the response time obtainable with a thermocouple mounted externally can be at least as rapid as is obtained with a well; subject to specific investigation this estimate is substantiated by experience with "wrap-around" vs. immersion-type resistance temperature detectors.

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- (1) HW-32029 - Cavitation in the Outlet Fittings at the B, D, F Piles,
by H. H. Greenfield
- (2) HW-50104 - Study of Water Pressure Requirements at Outlets of B, D,
and F Reactors, by E. F. Smith and D. W. McLenegan
- (3) Letter, F. J. Kempf to H. W. Heacock, November 2, 1959
- (4) HW-56142 - Effectiveness of Outlet Water Temperature Monitors and
Critical Flow Conditions for Outlet Fittings, C Reactor,
by E. D. Waters
- (5) HW-52302 and HW-52302 ADD. - Critical Flow Conditions for B, D, F,
and DR Outlet Fittings, by E. D. Waters and J. M. Batch
- (6) HW-52793 - Reactor Bulk Outlet Temperature Limits, by S. S. Jones

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