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TITLE

REAR CROSSHEADER FITTING INSPECTION

B, D, and F REACTORS

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REAR CROSSHEADER FITTING INSPECTION
B, D, AND F REACTORS

INTRODUCTION

Cavitation flow has been known to exist in rear crossheader "Parker" fittings at B, D, and F Reactors for the last five or six years. Calculations showing initiation of cavitation flow as a result of high flow rates in the present fittings were verified by experimental data in 1954 (1).

A study is currently being conducted to determine the required plant modifications to obtain flow increases on the order of fifty percent above existing flows. This study and the results of preliminary tests that show nominal flow increases may be obtained by reaming rear crossheader fittings has focused attention on the condition of existing rear face piping.

To obtain an estimate of the effect of cavitation in rear crossheader fittings resulting from past and current operating conditions, twenty one fittings were examined during the period October 6, 1959 to November 30, 1959. This document reports the inspection results.

SUMMARY

Of the twenty one fittings inspected, fifteen showed evidence of cavitation. Eight of these fittings can be termed "Slightly" damaged. A saw tooth type of erosion estimated to be approximately 1/16" deep and extending about 1/8" up the inner flared portion of the fitting was evident on two fittings and has been termed potentially severe (Figure I).

Analysis of variance on the twenty one fittings (thirteen at B, three at D, and five at F) shows that for statistical purposes there is no difference between the reactors. That is, the results of a twenty one fitting examination at one reactor are not expected to vary from the results found by inspecting several fittings at each reactor with the total number equaling twenty one.

Assuming the fittings chosen for inspection have been selected in a random manner, it can be said with ninety percent confidence that the percentage of fittings having damage exceeding 0.05" in depth is between 3.9 percent and 21.4 percent. It can also be said (with ninety percent confidence) that the percentage of fittings having damage exceeding 0.100" in depth, is greater than 0.0 percent and less than 5.4 percent. It has been estimated on the basis of the twenty one fittings inspected, that 8.2 percent of the fittings have damage exceeding .05" and 0.9 percent have damage exceeding 0.100" (2).

Additional inspections are recommended to provide a better basis for a statistical approach to the problem of fitting damage and to provide a method of estimating damage rate. Twenty one fittings represents only .35 percent of the total fittings on three reactors and conclusions should therefore be verified by further inspection.

DISCUSSION

A small borescope was utilized to visually inspect the interior surface of the twenty one rear crossheader fittings. Table I shows the location of the fittings which were inspected and summarizes the type of damage noted. Efforts to obtain photographs of damage were unsuccessful.

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The damage on #1762 at B Reactor was reported to have been located in the crossheader wall adjacent the crossheader fitting⁽³⁾. Further analysis of cavitation characteristics and the fact that subsequent inspection of the remaining fittings did not show damage in this area makes the reported damage location subject to question. It is more likely that the damage on #1762 is on the inner edge of the fitting.

The nine fittings inspected at B Reactor on November 30, 1959 (Table I) were previously examined by the B Reactor Process Engineer in late 1957 or early 1958⁽⁴⁾. It is reasonable to assume that no damage was noted at that time. Rear header pressures required to prevent critical flow in crossheader fittings have been determined in the Hydraulics Laboratory⁽⁵⁾. Comparison of this data with tube flows and header pressures on fittings inspected shows that all inspected fittings have been operating under critical flow conditions during the past two years. Although the header pressure on the nine tubes inspected November 30, 1959 increased from 19 to 53 psi in July 1959, critical flow still occurred in these crossheader fittings (Table II). At present the only estimate of damage rate that can be made appears to be the slight damage and pitting which occurred on five of the nine fittings at B Reactor during the past two years. An acceptable explanation is not evident for the fact that four of the nine fittings had no evidence of cavitation damage although the tubes had similar operating experience.

The saw tooth type of erosion noted on three of the inspected fittings has been termed potentially severe on #3062-D and #3366-F. The attached sketch (Figure I) shows the three types of damage noted. Crossheader fittings at B, D, and F reactors were presumably nitrided prior to installation. This surface hardening which probably resisted cavitation attack for some time, has been removed in portions of the fittings which show the saw tooth type of erosion. Bubbles are apparently formed in the throat of the fitting and compressed as they proceed along the flared section. Upon reaching the inner edge of the fitting, the pressure has increased sufficiently to cause bubble collapse with resulting fitting damage. Other mechanisms of cavitation attack have been advanced⁽⁶⁾, which may also be contributing to the erosion type of damage. Spaces at the inner edge of the cracks in the material act as bubbles themselves and collapse with explosive force when local pressures at their outer ends are increased by bubbles collapsing in the flow. On a rough or eroded surface it is possible for highly compressed bubbles to be driven into a fissure in the material followed by explosion of these bubbles when the pressure drops in the surrounding region. Although a satisfactory estimate of damage rate is not known, at present, it is evident that once cavitation attack begins, conditions are immediately created for an increased rate of attack.

The possibility that erosion on the inner edge of the fitting may have or will in the near future progress to the point where welds are adversely effected is not the only cause for concern. Cavitation induced vibration, coupled with the work hardening effects of repeated impact from bubble collapse, may be accelerating an approach to the metal endurance limit. If such is the case, fitting failures attributed to metal fatigue are not unlikely.

To provide a basis for statistical analysis of preliminary data, the extent of damage was classified into four categories (Table III). The cases of sawtooth erosion which appeared to be 1/16" deep and 1/8" long on the inner fitting edge were classified as heavy damage. Fittings which showed evidence of the start of sawtooth erosion were classified as slight damage when the depth appeared to be about 1/32" or the inner fitting edge had rounded off by pitting. Those fittings having small pits either in the flared portion or on the edge of the fitting were termed "light" pitting. The numerical value of one mil was arbitrarily assigned to indicate no fitting damage.

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Table III summarizes the data utilized in the statistical analysis of fitting damage. It can be estimated that the probability of a given fitting having penetration exceeding 0.100" is 0.9 percent and probability of a fitting having penetration exceeding 0.050" is 8.2 percent. However, on the basis of the twenty one fittings examined there appears to be two definite categories of fittings; those with no damage (28.6 percent) and those with damage (71.4 percent). Among those with damage a log normal distribution seems to fit the data fairly well and experience has shown this to be a good practical approximation to data such as these⁽²⁾. From this distribution it can be estimated that the total number of fittings having penetration exceeding 0.100" is about 10.5 percent and the percent of fittings with damage depth greater than 0.050" is about 23.0 percent. The second method of analysis although pessimistic may be more realistic. The results of additional inspections will determine whether or not there is justification for separating the fittings into the categories of damage and no damage to draw conclusions.

F. J. Kempf
Reactor Modification Design
FACILITIES ENGINEERING SECTION

FJK/dd

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- (2) Letter - K. B. Stewart to F. J. Kempf dated December 22, 1959
- (3) Letter - F. J. Kempf to H. W. Heacock, Crossheader Fitting Inspection at B
Reactor, October 13, 1959
- (4) Personal Communication - C. M. Heeb
- (5) HW-52302 ADD - Critical Flow Conditions for B, D, and F Outlet Fittings at High
Flow Rates - E. D. Waters - January 2, 1958 - SECRET
- (6) Cavitation in Hydraulic Structures Symposium Proc. A.S.C.E., 71,999 (1945)

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Heavy Damage

Slight Damage

Light Pitting

FIGURE I

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TABLE I - INSPECTION SUMMARY

<u>Reactor</u>	<u>Fitting Inspected (Tube No.)</u>	<u>Date Inspected</u>	<u>Inspected By</u>	<u>Type of Damage</u>
B	1762	10/6/59	C. W. Harrison J. H. Hoage F. J. Kempf	*Saw tooth flow erosion on cross-header adjacent fitting ($\approx 1/32$ " deep; $\approx 1/16$ " wide)
	3389	"	"	Pitting on inner tapered surface and slight erosion of inner edge of fitting.
	3965	"	"	Shallow pitting (5 to 10 mils) on tapered surface. Slight edge erosion.
	4077	"	"	None
	1563	11/30/59	P. D. Clare F. J. Kempf	Slight pitting and erosion on inner edge of fitting $\approx 1/32$ " deep extending $\approx 1/16$ " up tapered surface.
	1566	"	"	" " " " " "
	1570	"	"	" " " " " "
	1584	"	"	None
	1666	"	"	None
	1671	"	"	None
	1674	"	"	None
	1676	"	"	Slight pitting on tapered surface (5 to 10 mils)
	1682	"	"	Slight pitting on inner edge of fitting.
	1862	11/4/59	V. R. Hill E. G. Shockey F. J. Kempf	Slight pits in rust colored inner surface of crossheader opposite fitting.
	3062	"	"	Saw tooth erosion on inner edge of fitting $\approx 1/16$ " deep and extending $\approx 1/8$ " up tapered surface.
	3885	"	"	No evidence of cavitation. Slight crud deposit on inner edge of fitting.

* Location of damage subject to question. Subsequent inspection of remaining fittings did not show damage in this area.

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TABLE I (Continued)

<u>Reactor</u>	<u>Fitting Inspected (Tube No.)</u>	<u>Date Inspected</u>	<u>Inspected by</u>	<u>Type of Damage</u>
F	3366	10/27/59	V. R. Hill F. J. Kempf	Saw tooth erosion on inner edge of fitting $\approx 1/16$ " deep and extending $\approx 1/8$ " up tapered portion of fitting.
	3457	"	"	Pin hole leak under weld (poor machining & incomplete weld penetration) Light pitting (5-10 mils) on inner edge of fitting.
	3481	"	"	Shallow crack in minimum cross-sectional area portion of fitting. Pits on tapered portion of fitting $\approx 1/32$ " deep at edge of fitting. Irregular built up deposit on crossheader wall.
	3681	10/25/59	C. W. Harrison J. H. Hoage F. J. Kempf	Shall pitting on inner edge of fitting (5-10 mils)
	3683	"	"	Pitting and surface indications of cavitation on inner edge of fitting. Pock marks $\approx 1/32$ " deep in rust colored deposit on inside of crossheader opposite fitting.

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TABLE II

Average Tube Flow, Temperature and Rear Header Pressure for the Period January 1958 through October 1959

Reactor	Tube Number	Average Flow		Average Temp.		Average HDR Press.		Damage Noted
		Before	After	Before	After	1/58 to	7/59 to	
		I&E*	I&E	I&E	I&E	7/59	10/59	
B	1563	39.6	46.0	101.6	93.6	19.2	53.2	Slight Damage
	1566	39.3	45.4	104.0	97.7	19.2	53.2	Slight Damage
	1570	39.9	46.6	102.6	94.6	19.2	53.2	Slight Damage
	1584	39.8	47.0	102.3	92.2	19.2	53.2	None
	1666	39.1	46.0	101.0	96.0	19.2	53.2	None
	1671	39.0	45.1	101.6	95.6	19.2	53.2	None
	1674	39.4	45.9	100.5	94.6	19.2	53.2	None
	1676	40.0	46.4	100.2	93.1	19.2	53.2	Slight Damage
	1682	39.7	46.5	101.3	92.0	19.2	53.2	Light Pitting
	1762	40.8	44.9	91.0	90.0	23.8	51.8	Slight Damage
	3389	40.5	48.3	90.5	87.0	17.6	54.6	Slight Damage
	3965	41.1	47.3	91.0	88.0	19.7	54.7	Light Pitting
	4077	38.8	46.2	98.0	88.5	19.1	54.1	None
<u>12/58 to 11/59</u>								
D	1862	42.4	48.3	84.0	84.8		22.6	Light Pitting
	3062	43.0	48.7	88.0	86.3		18.0	Heavy Damage
	3885	43.5	48.8	90.0	86.5		19.3	None
<u>12/58 to 9/59 to</u> <u>9/59 10/59</u>								
F	3366	39.9	47.5	103.5	96.5	25.6	15.7	Heavy Damage
	3457	41.3	48.2	84.5	78.0	21.8	16.4	Light Pitting-Leak
	3481	39.5	45.6	103.5	94.5	25.6	15.7	Slight Damage
	3681	39.8	46.7	98.0	91.5	20.5	12.1	Light Pitting
	3683	40.2	46.7	98.5	89.5	22.6	16.8	Slight Damage

*I&E refers to full element loading. Time of loading with I&E elements varied from 7/58 to 11/58.

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TABLE III

DATA UTILIZED IN STATISTICAL ANALYSIS OF FITTING DAMAGE

<u>Damage</u>	<u>Approximate Depth</u>	<u>Frequency</u>	<u>Percent of Total</u>
Heavy	0.060"	2	9.5
Slight	0.030"	8	38.1
Light Pitting	0.010"	5	23.8
No damage	0.001"	6	28.6

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