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MIXER PLACEMENT AT H REACTOR

INTRODUCTION

A study was made to determine possible changes in mixer placement at H reactor because of the change from an enriched core load to a natural load and to evaluate movement of metal charges 8 inches downstream. Also studied was the effect of short charging on tube life and mixer position. Special consideration was given to the fact that H reactor will be shut down in approximately seven months.

SUMMARY

Top-wall corrosion in the older central-zone tubes is expected to be the major problem between now and May, 1964. Placement of mixer fuel elements in the tenth position from the rear of 32-piece natural charges, 34-piece enriched charges, and 30-piece natural charges should provide maximum protection in the top annulus of most tubes. Mixer fuel elements should continue to be placed in the thirteen-from-rear position of 43-piece enriched charges.

No advantage is gained by displacing metal charges 8 inches downstream. Much better control can be had by skewing the flux. In general, skewing the flux upstream will increase tube life and reduce fuel rupture potential. However, top-wall failures are more likely to occur. Skewing the flux downstream will decrease tube life and increase fuel rupture potential. Also, bottom-wall failures are more likely to occur. The best compromise is probably zero skewing with negative peaking.

Short charging (30 pieces of natural fuel) will increase tube life about 100 operating days, assuming a 4° decrease in outlet temperature (base temperature = 112°C) and a flow increase of one gallon per minute. Short charging should only be necessary in a very few tubes during the October, 1964 outage; and no more than 50-60 tubes should require short charging in January, 1964. These numbers can be determined better from WTG results obtained during the January outage. Spike enrichment needed to support short charges should be charged in relatively new tubes that have operated their full life with mixer fuel elements.

DISCUSSION

Review of Tube Corrosion Status

Prior to making a detailed study of mixer placement, data from the Alternate Tube Corrosion Monitor Program were reviewed to determine the status of tube corrosion at H reactor. Table 1 is a summary of minimum-wall thickness and "corrosion index" (CI) for each central-zone monitor group as of July, 1964. Figure 1 is a summary of bottom-wall measurements made on central-zone tubes that were removed and examined by Component Testing.

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This data of Figure 1 were obtained on H reactor tubes that were installed and operated between 1950 and 1963 while H reactor coolant pH was at 7.0. The data show that CI is an important parameter and can be used to predict when bottom-wall corrosion will become a problem. Since H reactor is now operating at 6.6 pH, the "worst-case" line drawn on Figure 1 is considered to be very conservative. A conservative estimate of the worst-case line for operation at 6.6 pH is shown by the dotted line on Figure 1. The dotted line represents the worst-case relationship between bottom-wall thickness and corrosion index for tubes that operated at 7.0 pH from the time they were installed until they reached 12 corrosion index and were then operated at 6.6 pH from 12 corrosion index onward.*

The main conclusion to be drawn from this information is that bottom-wall corrosion will not be a serious problem between now and April, 1965. Our best estimates indicate that no more than two central-zone tubes having high corrosion index are likely to be potential bottom-wall failures (25 mils) by April, 1965; and no tubes will be potential bottom-wall failures by December, 1964.

By far the majority of central-zone tubes are top-thin, and this is to be expected for several reasons:

1. Mixers were not used between March and October, 1962.
2. Top-wall corrosion can be very unpredictable due to such factors as fuel misalignment, growth and warp, and graphite distortion of process tubes.
3. Enriched core loads at H reactor have resulted in higher outlet temperatures for many central-zone tubes.
4. We expect all central-zone tubes between 55 and 45 mils minimum-wall thickness, as indicated by the WTG, to be top-thin tubes.

Because the top annulus in the downstream half of the fuel charge is now as large or larger than the bottom annulus, R-top values are very near to 1.0 on the average, and top-wall corrosion rates are low; especially so for operation at 6.6 pH.** Our best estimates indicate that no more than 34 central-zone tubes are likely to be potential top-wall failures (25 mils) by April, 1965; and possibly one tube will be a potential top-wall failure by December, 1964.

Because top-wall corrosion is expected to be more of a problem than bottom-wall corrosion during the next seven months, mixer placements suggested in this report were selected to provide maximum protection in the top annulus. Special treatment of central-zone tubes (such as short charging) should be considered primarily from the same viewpoint.

Tube Life Simulations

Tube 3366-H was installed during January, 1962 and removed and examined out-of-pile during September, 1963[†]. The minimum dimensions at removal were 2.00"

*Assuming tube corrosion is only a factor of two less at 6.6 pH than at 7.0 pH.

**Recent results from the pH production tests at D reactor indicate tube corrosion rates are a factor of three less at 6.6 pH than at 7.0 pH.

[†]See Storage, Actual Tube Wall Thickness Measurements, H Reactor, October 10, 1963, HW-79217, Confidential Undocumented.

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top-wall, 0.055" bottom-wall, and 0.131" rib-plus-wall and the corrosion index was 12.1. January 1962 tubes (group C-2 in Table 1) are now estimated to have an average minimum-wall thickness of 42.7 mils and an average CI equal to 14.1 (July 1964). The initial dimensions of the new tube were about 0.064" top-wall, 0.063" bottom-wall, and 0.146" rib-plus-wall. The operating conditions for tube 3366 are summarized below.

<u>Metal Cycle</u>	<u>Charge Date</u>	<u>Discharge Date</u>	<u>Fuel</u>	<u>Mixer</u>	<u>Average Outlet Temperature</u>
1	2/62	5/62	Nat.	Yes	106°C
2	5/62	10/62	Nat.	No	107°C
3	10/62	1/63	Nat.	No	103°C
4	1/63	5/63	E-N	Yes	105°C
5	5/63	9/63	E-N	Yes	109°C

This tube is typical of most central-zone tubes having thin top walls and relatively thick bottom walls. The top-wall, bottom-wall, and rib-plus-wall corrosion profiles were used as input to the TUBE-3 code²; and continuing corrosion, to a replacement-wall thickness of 30 mils, was simulated using different mixer positions, charge positions, and axial flux. Some of the TUBE-3 input operating conditions are given in Table 2.

Table 3 gives tube life estimates for a 32-piece natural charge operating at 112°C outlet temperature with different mixer positions and axial flux. Axial flux has a significant effect on tube life and mixer position. When the flux is skewed upstream, maximum life is obtained; but more top-wall failures would occur. Similar results are shown in Table 4 for the 34-piece enriched charge. The optimum mixer position varies between six- and ten-from-rear, depending on the flux.

Of significance is the fact that at least 300 operating days of tube life can be expected. Of course, tubes operating at outlet temperatures higher than 112°C for long periods would have shorter life. But it is doubtful that very many tubes will fail in the next seven months.

Downstream Movement of Metal Charges

The TUBE-3 code was used to simulate the effect of moving metal charges 8 inches downstream. Operating conditions were the same as Table 2 and 3 except the distance from the rear of the charge to the outlet flange was reduced 8 inches. Also, it was assumed that no significant change in axial flux would occur. The results indicate there would be no significant difference in tube life or mixer position.

Short Charging

Tube life simulations were made to determine mixer position and tube life for a 30-piece natural charge. The dimensions of tube 3366 were used as input data, and the tube was operated at the conditions given in Table 2. The results are

²RD Jensen, TUBE-3 Fortran Program, Technical Description, November 4, 1963, HW-79518, Secret.

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shown in Table 5 for outlet temperatures of 112°C, 109°C, and 106°C. Cosine flux was used in all cases. Comparison with Table 3 shows that tube life is about the same as the 32-piece natural charge at 112°C. At 109°C, tube life is about 70 operating days longer than the 32-piece charge (at 112°C). At 106°C, tube life is about 160 days longer than the 32-piece charge (at 112°C). Since changing from a 32-piece charge to a 30-piece charge would decrease outlet temperature about 4°C, approximately 100 operating days of additional tube life would be expected. However, short charging may require additional supporting enrichment; and the enrichment should be charged in relatively new tubes that have operated their full life with mixer fuel elements.

The question arises as to which tubes should be short charged. It is my understanding that current plans call for short charging all spline-cap tubes (from 120 tubes) and about 77 additional tubes that are adjacent to graphite stringers and air channels. To be perfectly frank, this does not make much sense. Table 6 shows a breakdown of wall thickness by monitor group for all central-zone tubes and for tubes scheduled for short charging. There are about 380 central-zone tubes that have remaining wall thickness less than 45 mils. The majority of these tubes will last another year before failure as indicated in previous sections of this report. Of these 380 tubes, 56 are scheduled for short charging, which may be reasonable. But there are other tubes less than 45 mils that have corrosion indices greater than 18 that are not scheduled for short charging. Furthermore, there are 141 tubes greater than 45 mils that are scheduled for short charging. Even if all tubes were corroding at the rate of 2 mils per month for the next seven months, we would not expect any tube greater than 45 mils to fail.

During the October 1964 outage, we estimate that no more than 6 tubes will require short charging. By December, 1964, we expect additional tubes will require short charging. Details can be obtained from the area Process Engineer.

Conclusions

Based on recent evaluations of tube corrosion status at 4 reactor, top-wall corrosion in the older central-zone tubes will continue to be the major problem between now and May, 1964. This is primarily due to the fact that most of these tubes operated without mixers for one or two metal cycles and because fuel misalignment, growth, and warp can cause top-wall corrosion to be severe, stable and rapid. In no case, however, do we expect corrosion to be higher than two mils per month at 60 p.p.m. Our best estimates indicate that no more than two tubes are likely to be potential top-wall failures by May, 1964; and none will be potential bottom-wall failures by May, 1964. Also, no more than 24 tubes are likely to be potential top-wall failures by May, 1964; and possibly one tube will be a potential top-wall failure by December, 1964.

Mixer fuel elements should be charged in the ten-from-rear position in both 32-piece natural charges, 34-piece natural charges, and 34-piece short charges. While eight-from-rear is probably a better choice for the 34-piece short charge, ten-from-rear provides almost the same protection and allows for simplification in charge makeup. Placement of the mixer in the tenth position should provide maximum protection in the top annulus of most tubes and will not seriously affect those tubes that have the highest annulus temperatures between the ribs.

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Central-zone tubes to contain 43 pieces of enriched fuel should be charged with the mixer in the twelve-from-rear position as determined in an earlier study³. The current thirteen-from-rear position may be continued if desired, since there is very little difference between the two positions.

No advantage is gained by displacing the charges 8 inches downstream. Much better control can be had by skewing the flux. In general, skewing the flux upstream will increase tube life and reduce fuel rupture potential. However, top-wall failures will occur when the flux is skewed forward. Skewing the flux downstream will decrease overall tube life and increase fuel rupture potential. Also, downstream skewing will result in bottom-wall failures. At H reactor, the best compromise is probably zero skewing with negative peaking. In general, flux peaking increases rupture potential and decreases tube life.

Short charging should be necessary only in a very few tubes during the October outage, and no more than 50-60 tubes should require short charging in January, 1965. These numbers can be determined better by WTG results obtained during the January outage. Spike enrichment needed to support short charges should be charged in relatively new tubes that have operated their full life with mixer fuel elements.

Process Analysis Unit
Process Technology Subsection
Research and Engineering Section

CG Hough:cmw

³CG Hough, Mixer Position For Enriched Columns at H Reactor, April 19, 1964,
Confidential-Undocumented.

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FIGURE 1

**Tube Examination Data.
Bottom-Wall Thickness
Versus Corrosion Index.**

- 1962 Tubes
- 1960-1961 Tubes
- × 1956-1959 Tubes

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TABLE 1

Tube Corrosion Status - H Reactor
Alternate Tube Corrosion Monitor Program
Effective 7/7/64

<u>Monitor Group Code</u>	<u>Date Installed</u>	<u>No. of Tubes Remaining</u>	<u>Average CWT</u>	<u>Average CWT of Thinnest 10 per cent</u>	<u>Average Corrosion Index (CI)</u>	<u>Average CI of Thinnest 10 per cent</u>
C1	Pre 1962	26	43.0	37.0	13.4	17.8
C2	1/62	70	42.7	37.0	14.1	18.2
C3	3/62	108	44.6	38.7	13.1	15.9
C4	5/62	132	43.0	37.8	13.2	16.7
C5	9/62	246	46.4	39.7	11.1	14.3
C6	1/63	290	50.2	44.7	12.1	14.4

TABLE 2

Tube-3 Input Operating Conditions

Fuel	03N	03E	03N
No. of Pieces	32	34	30
pH	6.6	6.6	6.6
Tube Flow (gpm)	47	50	48
Tube Outlet Temperature (°C)	112	112	112, 109, 106
Replacement Wall Thickness (Mils)	30	30	30
Distance From Rear of Charge To Outlet Flange	110"	142"	119"

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TABLE 3

32 Pieces - 03N
Additional Tube Life Vs. Mixer Position and Axial Flux
Tube Outlet Temperature = 112°C

<u>Mixer Position</u>				
<u>No. of</u>	<u>Feet</u>	<u>Tube Life</u>		<u>Failure Location</u>
<u>Pieces</u>	<u>From</u>	<u>Days at</u>	<u>Type</u>	<u>Feet From</u>
<u>From</u>	<u>Outlet</u>	<u>100% TOE</u>	<u>Failure*</u>	<u>Outlet Flange</u>
<u>Rear</u>	<u>Flange</u>			
<u>Axial Flux:</u> Skewing = 3 upstream, peaking = +5 per cent				
None	--	406	BW	10.7
2	9.9	425	BW	10.7
4	11.4	445	BW	11.4
6	12.8	416	TW	11.4
8	14.3	435	TW	11.4
→ 10	15.8	464	TW	11.4
12	17.3	450	BW	10.7
14	18.9	435	BW	10.7

Axial Flux: Skewing = 0, peaking = 0

None	--	348	BW	9.9
2	9.9	370	BW	10.7
4	11.4	406	BW	11.4
6	12.8	406	TW	11.4
→ 8	14.3	421	BW	9.9
10	15.8	406	BW	9.9
12	17.3	392	BW	9.9
14	18.9	377	BW	9.9

Axial Flux: Skewing = 3 downstream, peaking = +5 per cent

None	--	307	BW	9.9
2	9.9	326	BW	10.7
4	11.4	363	BW	11.4
→ 6	12.8	392	BW	9.9
8	14.3	370	BW	9.9
10	15.8	348	BW	9.9
12	17.3	336	BW	9.9
14	18.9	325	BW	9.9

*TW = top wall, BW = bottom wall

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TABLE 4

34 Pieces - 03E
Additional Tube Life Vs. Mixer Position and Axial Flux
Tube Outlet Temperature = 112°C

<u>Mixer Position</u>		<u>Tube Life</u> Days at 100 % TOE	<u>Type</u> Failure*	<u>Failure Location</u> Feet From Outlet Flange
<u>No. of</u> <u>Pieces</u> <u>From</u> <u>Rear</u>	<u>Feet</u> <u>From</u> <u>Outlet</u> <u>Flange</u>			

Axial Flux: Skewing = 3 upstream, peaking = +5 per cent

None	--	364	BW	13.0
2	12.4	390	BW	13.0
4	13.5	399	BW	14.0
6	14.6	416	BW	14.6
→ 8	15.7	451	TW	11.9
10	16.8	433	BW	13.0
12	17.9	424	BW	13.0
14	18.9	407	BW	13.0

Axial Flux: Skewing = 0, peaking = 0

None	--	318	BW	13.0
2	12.4	338	BW	13.0
4	13.5	355	BW	13.5
6	14.6	399	BW	14.6
→ 8	15.7	399	BW	12.4
10	16.8	372	BW	12.7
12	17.9	364	BW	13.0
14	18.9	351	BW	13.0

Axial Flux: Skewing = 3 downstream, peaking = +5 per cent

None	--	286	BW	12.4
2	12.4	295	BW	13.0
4	13.5	320	BW	13.5
→ 6	14.6	364	BW	12.4
8	15.7	347	BW	12.4
10	16.8	325	BW	12.4
12	17.9	312	BW	12.4
14	18.9	305	BW	12.4

*TW = top wall, BW = bottom wall

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TABLE 5

30 Pieces - 03N
Additional Tube Life Vs. Mixer Position
Axial flux: Skewing = 0, peaking - 0

<u>Mixer Position</u>		<u>Tube Life</u> Days at 100% TOE	<u>Type</u> <u>Failure*</u>	<u>Failure Location</u> <u>Feet From</u> <u>Outlet Flange</u>
<u>No. of</u> <u>Pieces</u> <u>From</u> <u>Rear</u>	<u>Feet</u> <u>From</u> <u>Outlet</u> <u>Flange</u>			
<u>Tube Outlet Temperature = 112°C</u>				
None	--	358	BW	10.7
2	10.6	380	BW	11.4
4	12.1	389	TW	10.7
6	13.6	415	TW	10.7
8	15.1	415	TW	10.7
→ 10	16.6	397	BW	10.7
12	18.1	384	BW	10.7

Tube Outlet Temperature = 109°C				
None	--	422	BW	10.7
2	10.6	449	BW	11.4
4	12.1	467	TW	10.7
6	13.6	495	TW	10.7
→ 8	15.1	495	BW	10.7
10	16.6	477	BW	10.7
12	18.1	458	BW	10.7

Tube Outlet Temperature - 106°C				
None	--	504	BW	10.7
2	10.6	532	BW	11.4
4	12.1	574	TW	10.7
6	13.6	588	TW	10.7
→ 8	15.1	588	BW	10.7
10	16.6	560	BW	10.7
12	18.1	541	BW	10.7

*TW = top wall, BW = bottom wall

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TABLE 6

Remaining Wall Thickness Distribution - H Reactor
Effective July, 1964

Remaining Wall Thickness	Total No. of Tubes at Indicated Wall Thickness								No. of Tubes Scheduled for Short Charging							
	C1	C2	C3	C4	C5	C6	C7	CU2	C1	C2	C3	C4	C5	C6	C7	CU2
33-35	0	1	0	0	0	0	0	0								
35-37	2	4	0	0	0	0	0	0	1	1						
37-39	7	18	9	19	8	0	0	0		2	1	2	1			
39-41	3	13	15	21	14	3	0	0	1	2	4	3	1	1		
41-43	2	11	13	23	35	1	13	0	2	1	2	3	5	1	4	
43-45	3	7	32	24	52	13	14	0		1	3	5	5	2	2	
45-47	4	8	18	16	34	28	16	0		1	1	2	6	13	4	
47-49	1	6	8	20	39	50	7	1				2	2	15	1	
49-51	1	4	10	3	43	105	3	7			1		8	24	1	5
51-53	1	2	2	3	11	59	4	18						6		3
53-55	2	4	3	3	9	28	5	16					1	5	2	1
55-57	0	0	1	0	0	3	11	9							4	2
57-59	0	0	0	0	0	0	0	35								9
59-61	0	0	0	0	0	0	0	84								15
61-63	0	0	1	0	0	0	0	25								7
63-65	0	0	0	0	0	0	0	3								
65-67	0	0	0	0	0	0	0	0								
67-69	0	0	0	0	0	0	0	1								
TOTAL	26	78	112	132	245	290	73	199	4	8	12	17	29	67	18	42

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