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Current Status

Second Generation Process Tube Internal C...

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CURRENT STATUS

SECOND GENERATION PROCESS TUBE INTERNAL CORROSION

Seven water leaks during the past year because of internal corrosion of second generation process tubes have emphasized the need for additional corrosion information. Numerous out-of-pile and probolog examinations have been made to determine the nature of the corrosion, and mixer fuel elements currently are changed in central zone tubes in order to reduce the corrosion rates. This document presents the data obtained to date as a general description of the tube condition at the time when the mixer elements were adopted and outlines future action necessary to determine when the second generation tubes must be replaced because of internal corrosion. No attempt is made to explain the mechanism of the corrosion since that is covered adequately elsewhere.⁽¹⁾

Summary and Conclusions

Out-of-pile examinations show that many second generation tubes at the 100 B, F, and DR Reactors have corroded preferentially toward the top such that the tops now are thinner than the bottoms. In direct contrast, the top corrosion rate of

(1) HW-62464, "Status Report on the TOA Corrosion Problem," N. R. Miller, December 9, 1959.

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100 F and H tubes (which were installed at the same time as the 100 B, D, and DR tubes) has been low enough that the bottoms of most tubes are thinner than the tops. And to further complicate the picture the corrosion rate of tubes with the same temperature history (corrosion index) varies as much as three to one, corresponding to an observed current wall thickness range as large as from 25 to over 50 mils.

Measurements show that approximately five percent of the second generation tubes at 100 B, D, DR, and H have minimum wall thicknesses less than 35 mils and that some of these are potential leakers right now. Since no calculation has been found for determining the minimum wall thickness of the individual tube, these potential leakers can be found only by probologing all tubes. Calibration shows that the probolog accuracy is the usual $\frac{1}{3}$ mils at 100 B, D, and DR. Additional calibration of the probolog for 100 F and H is desirable since only five data points are available and those are about a year old. The 100-F tubes still are thick enough that probologing solely to determine the amount of internal corrosion currently is not necessary.

The majority of the second generation tubes have minimum wall thicknesses over forty mils so that large scale tube replacements shouldn't be necessary for several years if the thinner tubes are found and replaced.

Very high corrosion rates have been observed in tubes installed during 1959. Since two already have leaked because of this corrosion, emphasis should be placed on probologing all 1959 tubes.

Efforts should be directed toward determining the corrosion rate of the tubes with mixer charges. Enough should be examined out-of-pile and with the probolog this fall (after about one year experience) to permit determination of the mixer effectiveness and if there are any deleterious effects. An accurate corrosion equation must be found so that satisfactory tube replacement forecasts will be possible.

Discussion

A. Historical

The second generation process tubes* were installed primarily between September 1955, and June, 1957, at 100 B, D, and H and during 1958 at 100-DR, when the approximately 900 central original tubes were replaced at each reactor because the bottoms had corroded thin. Since those periods replacement of the surrounding rings of tubes and of a small number (50 to 100 per reactor) central tubes.

* Second generation tubes are defined as those tubes installed in the reactors since January 1, 1955. As a general rule they are the second tube installed in a channel, but some are the third or even fourth tube.

continued at a relatively slow rate (0 to 200 tubes per year). At 100-F over 1500 original tubes were replaced between September, 1955, and June, 1957, and installations have continued since primarily in the bottom fringe and the central region at about 300 tubes per year. Because essentially all tubes still are original at 100 C, KE, and KW, no discussion of the tubes at those reactors will be included in this document.

During 1957 and 1958 the few second generation tubes examined out-of-pile showed a tendency toward more rapid corrosion of the top than of the bottom, but the total corrosion of a given tube was so small that no definite conclusion could be made that the tubes were corroding in a different manner than the original tubes. It was expected that the tops would corrode faster than the bottoms at first, but eventually as the ribs wore down, the corrosion would shift to the bottom. Probolog examinations showed no unusual corrosion rates, and, of course, could not be used to determine whether the corrosion were at the top or the bottom.

In January, 1959, one of two 100-D tubes removed to determine the nature of the corrosion of second generation tubes provided the first clear evidence of rapid top-of-tube corrosion; the top had corroded approximately 28 mils while the bottom had corroded only nine. Efforts began immediately to determine the nature of the corrosion in order that the proper time for tube replacement could be determined. To date, approximately eighty additional tubes have been examined out-of-pile, and over 700 have been probologed. Included in the out-of-pile examinations are seven tubes that have leaked since May, 1959, because of excessive corrosion of the tops.

B. Out-of-Pile Tube Examinations

Out-of-pile examinations of the second generation tubes have revealed that not only are the tops corroding very rapidly, but that there also is no apparent correlation between the corrosion rates of different tubes: the corrosion rates of tubes with essentially identical operating conditions may vary by as much as three to one.

Historically, tube corrosion has been correlated with the corrosion index, which essentially is a measure of the temperature history of the tube.⁽²⁾ The total corrosion of the bottoms of the original 100 B, D, F, and H central tubes was computed with reasonable accuracy by multiplying the corrosion index by an empirical relative corrosion (rc) factor between 0.75 and 1.00 in accordance with the experience at the particular reactor. The rc factor for corrosion of the tops of the tubes was equal or slightly less than that for the bottom, and since the top of the new tube was ten mils thicker than the bottom, the top wall thickness had no effect on tube replacements.

(2)

EW-43945, "An Improved Basis for Scheduling Removal of Corroded Process Tubes," D. R. deHallas, June 27, 1956.

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Correlation of corrosion of second generation tubes with the corrosion index shows a radical change for both the top and the bottom of the tube. For the bottom the rc factor now varies from 0.5 to 1.5 (see Figure I), and at the top the rc varies from one to eight (see Figure II). The effect of these high corrosion rates on the tubes is shown on Figure III: whereas the tops of the original tubes rarely were thinner than the bottoms, the tops of the majority of the second generation tubes examined were thinner than the bottoms.

Detailed study of Figures I to III also reveals that rapid corrosion of the tops occurs primarily at 100 B, D, and DR and that the tops of 100 F and H tubes generally are corroding at a lower rate. However, even at 100 F and H there is evidence of some tubes corroding very rapidly at the top.

The most disconcerting conclusion obtained from analysis of these figures is the large scatter of the data. The corrosion index appears useless for determining the minimum wall thickness of an individual tube.

Attempts to find another variable for correlating the corrosion have been unsuccessful except for a fair correlation with the tube installation date. In general, the rc factor for the top of the tube decreases with increased age of the tube as shown on Figure IV. This would be expected because as the top corrodes, additional flow at the top reduces the water temperature and the corrosion rate. However, the large difference in the correlation lines on Figure IV for 1959 and 1960 cannot be attributed solely to this; adoption of the mixer charge late in 1959 also should have reduced radically the corrosion rate of the tops of the tubes. It should be noted that on Figure IV the rc for the top of the tube still varies by as much as a factor of three for a given installation date.

The rapidity of top-of-tube corrosion of new tubes is emphasized by the high rc factors for 1959 tubes on Figure IV. Two of the data points represent tubes that had been penetrated after only seven and nine months operation, and both tubes had a mixer charge for about three months. Corrosion rates of five to ten mils per month are common for new tubes without mixers. Because of this high corrosion rate, all central tubes installed during 1959 should be probologed as soon as possible so that any additional thin tubes can be located and replaced.

C. Probolog Data

Because of the high cost of out-of-pile examinations, it is more economical to use the probolog to obtain a description of the corrosion of the typical tube. Also, analysis of the data from out-of-pile examinations has revealed no practical method for calculating the wall thickness of the individual tube. Since out-of-pile examinations and water leaks have proved that many tubes are potential leakers, a program of probologing all second generation central tubes at 100 B, D, and DR has been started in order that the current individual tube wall thicknesses can be determined and any thin tubes identified and replaced. At 100-H it is planned to probolog a large enough sample of tubes so that the need for probologing all second generation tubes can be determined. Such a program is not necessary at 100-F because most tubes are probologed periodically during the continuous search for external corrosion.

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Calibration of the probolog for top-of-tube corrosion has been accomplished by use of the data from out-of-pile examinations for 100 B, D, and DR, which represent the worst cases of this type corrosion. In general, the probolog is accurate within the usual $\frac{1}{3}$ mils, which is adequate for determining tube condition and replacement date (see Figure V). The top-of-tube calibration has not been used as yet for 100 F and H because the bottom-of-the-tube calibration still appears adequate for most tubes.

The probolog results for 100 B, D, and DR in general show (1) the same scatter of wall thicknesses observed with the out-of-pile examinations, and (2) that the tubes are not as thin as one would conclude from the out-of-pile examinations (see Figures VI to VIII). This latter result would be expected since the tubes chosen or available for out-of-pile examination usually were representative of the worst cases of top-of-tube corrosion whereas the probolog results represent the typical tube. The average second generation tube in the 100 B, D, and DR Reactors is 44 mils thick and the observed distribution of wall thicknesses is as follows:

Wall Thickness	Percent of Tubes		
	100-B	100-D	100-DR
30 mils or less	0	2	0
35 mils or less	4	5	5
40 mils or less	17	29	15
45 mils or less	57	71	50
50 mils or less	90	99	94
55 mils or less	100	100	99

Not enough 100 F and H tubes have been probologed to date to permit an accurate determination of the distribution.

The above data show that probologing all 100 B, D, and DR second generation tubes is necessary to locate the small percent of tubes that are potential leakers and that most tubes still have considerable remaining useful life. The cost of the current probolog program is small compared to permitting numerous water leaks to occur later in the five percent of the tubes that are less than 36 mils thick now.

The probolog results for 100-F Reactor show that the 1955 and 1956 tubes are corroding at about one-third the rate of the 100 B and D tubes. The 1957 to 1959 tubes are corroding at a faster rate than the older tubes, but the total corrosion to date is too small for most tubes examined to permit definite conclusions (see Figures IX and X).

100-H tubes show mixed conditions. The majority appear to be corroding at the same rate as the original central tubes (rate = 1.00), but a small percent also are corroding at a much higher rate. Not enough tubes have been probologed to permit determination of this percent, but finding two thin tubes in sixty-three probologed is ample evidence to justify probologing all central tubes (see Figure XI).

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D. Future Corrosion Monitoring Program

Future activities should emphasize determining the current tube condition and corrosion rates. Probologing should continue at 100 B, D, DR, F and H until the wall thickness is known for all second generation tubes. The probolog should be calibrated for 100 F and H since only five data points for the two reactors are available and these are almost a year old.

The nature of the corrosion prior to the use of mixers has been described adequately. The major objective of out-of-pile tube examinations now should be to determine the location and rate of corrosion with mixers. By next fall there will be a year's experience so that any significant changes due to mixers should be apparent. At least 100 tubes should be reprobloged after six months to one year experience with mixers so that the current corrosion rate can be determined.

Acknowledgement

The data of this report were obtained from the recent probolog and out-of-pile tube examination reports of D. E. Strege of the Component Testing Operation.

JRY:ng

J. Young
Operations Analysis
Production Operation

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Figure I
BOTTOM WALL THICKNESS
SECOND GENERATION TUBES

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Figure II

TOP WALL THICKNESS
SECOND GENERATION TUBES

Figure III

SECOND GENERATION TUBE CORROSION

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Figure IV

RELATIVE TOP-OF-TUBE CORROSION
SECOND GENERATION TUBES

Figure V
PROBOLOG ACCURACY
TOP-OF-TUBE CORROSION

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Figure VI

TYPICAL 100-B TUBE CORROSION
SECOND GENERATION TUBES

Minimum Top Wall Thickness - Mils

Figure VII
TYPICAL 100-D TUBE CORROSION
SECOND GENERATION TUBES

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Figure VIII
100 DR TUBE CORROSION
SECOND GENERATION TUBES

Figure 1A

100-F TUBE CORROSION
1955 AND 1956 TUBES

Corrosion Index .

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Figure X
100-F TUBE CORROSION
1957 TO 1959 TUBES

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Figure XI

100-H TUBE CORROSION SECOND GENERATION TUBES

Minimum Wall Thickness - Mils

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