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FORECAST REACTOR WATER LEAKS

Reactor water leaks cause outage time for locating and eliminating the leaks and for repairing damage caused by the water that enters the reactor. The justification for equipment and process changes necessary for reducing the number of leaks and the resultant outage time is dependent on the number of leaks expected. This document presents an estimate of the future reactor water leak frequency and the average outage time charged to each leak. A water leak is defined as any entry of water into the reactor moderator during operation.

SUMMARY AND CONCLUSIONS

Future water leaks are expected to result primarily from Van Stone flange failures and miscellaneous causes such as mechanical damage, fuel ruptures, and transverse cracks. It is assumed that continuous emphasis will be placed on corrosion monitoring to determine the tubes that must be replaced to prevent leaks because of internal and external corrosion.

The number of water leaks is expected to average between 80 and 100 per year in the future. The normal range of the number of leaks probably will be between 60 and 120 per year as a result of normal variation in the process tube physical condition.

The number of outage hours charged per leak is expected to continue at the past average rate of approximately twelve hours per leak.

DISCUSSION

Water leaks cause reactor outage time for locating and eliminating the leaks and for correcting reactor damage by the water released in the reactor. The total outage time charged to leaks is dependent primarily on the number of leaks and the average outage time per leak.

A. The Future Number of Water Leaks

Water leaks can be classified under three general titles: internal corrosion, Van Stone flange failures, and miscellaneous causes. These categories will be discussed separately, but it must be remembered that they are interrelated. In particular, internal corrosion weakens the tube and increases the probability that other types of leaks will occur.

1. Internal Corrosion Leaks

Internal corrosion leaks are defined as those leaks which occur primarily because a process tube wall has corroded internally to less than twenty-five mils thickness. Final penetration usually is by splitting because of the coolant pressure. However, failures occasionally occur because of pinholes, scratches, or other secondary causes of weakening.

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Internal corrosion failures can be essentially eliminated by replacement of all tubes at a wall thickness high enough to assure that essentially no tubes ever have a minimum wall thickness below twenty-five mils. At present, the necessary information for determining the replacement wall thickness is obtained by frequent probologging to determine the current wall thicknesses and corrosion rate. The tubes then are replaced in accordance with the following equation:

Wall thickness at replacement =

25 mils minimum permissible wall thickness + 3 mils probolog error + maximum expected corrosion before the next tube replacement opportunity.

The twenty-five mils minimum permissible wall thickness is based on the observation that the frequency of internal corrosion leaks increases rapidly as the wall thickness decreases below twenty-five mils. This may be represented schematically as follows:

The number of internal corrosion leaks is expected to be small in the future (one to three leaks per old reactor per year and zero at the K Reactors). This expectation is based on the assumption of a continuing effort to determine the corrosion rate and the current wall thickness of the tubes. Adoption of 6.6 pH process water and continued use of mixer fuel elements in central tubes is expected to reduce the corrosion rate enough that the accelerated internal corrosion rates of the past (rates as high as 100 mils per year) will be reduced to a maximum of 10 to 20 mils per year. Ample time should be available to identify a tube with accelerated corrosion before it leaks and without the high outage time cost currently required for probologging suspect tubes approximately twice per year.

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2. Van Stone Flange Failures

Van Stone flange failures are defined as any failure of that portion of a process tube altered during flange fabrication, including the portion altered by rib removal.

The primary causes of flange failures appear to be improper fabrication and excessive forces because of stuck or reluctant gunbarrels. All recent examinations of failures have shown transverse cracking or shearing at the curvature or adjacent to the curvature.

No general correlations of flange failure frequencies with tube condition or operating history have been found. Correlations have been made for specific groups of tubes after enough failures have occurred in a group of tubes to permit calculation of failure rates. No method has been found for predicting the failure rate of a group of tubes before failures occur.

Considerable effort has been expended since late in CY-1961 to assure proper fabrication of flanges. Analysis of flange failure data shows that flanges fabricated since the spring of CY-1962 have a lower failure frequency than have flanges installed during the previous three years. Approximately one-half of the tubes currently in the six older reactors were installed with these better flanges, and the percent of tubes with these better flanges will increase as additional tubes are replaced.

The number of stuck gunbarrels is expected to increase gradually with time. There is no known economical method for permanently freeing the gunbarrels, and the severity of the conditions causing stuck gunbarrels is expected to increase. There are no plans to install new tube hardware that permits Van Stone flange movement independent of the gunbarrel movement.

Correlation of the number of Van Stone flange failures with time shows a gradual increase in number with time (see Figure 1). The above discussion shows that this increase probably will be retarded because of recent better flange fabrication. The future failures probably will average about fifty per year.

3. Miscellaneous Water Leaks

Miscellaneous water leaks result from the following general causes: rupture damage, transverse cracking, external corrosion, loose nozzles, mechanical damage, and miscellaneous other causes. The frequency of these leaks varies widely from year to year in accordance with the operating conditions and the intensity of efforts to eliminate such leaks. It is assumed in the analysis of this document that the current high level of effort to eliminate such leaks will continue.

Continuation of current efforts to prevent leaks is particularly important for prevention of leaks caused by external corrosion and transverse cracks. Failure to continuously monitor and evaluate the leak

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situation could result in a severalfold increase in the frequency of these types of leaks before the severity of the situation is recognized.

The most recent published analysis of water leak causes showed the causes of water leaks during fiscal years 1959 and 1960. The frequency of leaks due to miscellaneous causes was as follows:¹

Table I
Reactor Water Leak Experience
FY-1959 and 1960

<u>Type Leak</u>	<u>No. Leaks Per Year</u>
External Corrosion	18
Mechanical Damage	6
Rupture Damage	10
Pin Hole	1
Transverse Crack	3
Leak Not Found	4
Gasket	52
Miscellaneous	1
Total	95

The frequency of external corrosion, rupture and gasket leaks is expected to be lower in the future than shown above. Continued emphasis on locating and replacing tubes with external corrosion should reduce the frequency of external corrosion leaks by at least fifty percent. Reduction of the number of ruptures in comparison to FY-1959 and 1960 (an average of 120 per year) is expected to reduce the frequency of leaks caused by ruptures by at least fifty percent. This reduction in ruptures is expected to result from the anticipated adoption of 6.6 pH process water. The number of gasket leaks should be essentially zero in the future. Use of Van Stone seal inserts at 100-B, D and F has essentially eliminated such leaks at those reactors. A significant number of gasket leaks at other reactors could be prevented by use of seal inserts.

No significant change in the number of leaks due to mechanical damage, pin holes, and other miscellaneous causes is expected. Currently, these leaks appear to occur in a random manner as a result of infrequent events or operating conditions. No change in these frequencies is expected.

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1. HW-66468, "Reactor Process Channel Water Leak History, FY-1959 and 1960", J. R. Young, August 17, 1960.

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The frequency of transverse crack failures probably will increase in the future. At present, one can only speculate the future frequency of failures because the operating conditions causing cracks have not been correlated with the frequency of cracks. Past experience indicates that cracks rarely occur during the first three years of central tube residence and that cracks occur primarily in central tubes and at 100-H. Because essentially all current old area central tubes were installed within the last eighteen months, no cracks are expected for another eighteen months. Then when the cracks occur, the frequency probably will increase gradually. When the frequency for a group of tubes with similar history reaches five failures per thousand tubes in six months, all tubes in the group should be replaced. Future transverse cracks are expected to occur first at 100-H. The experience at 100-H should permit determination of proper preventive action at the other reactors before large numbers of failures occur. Past experience indicates that the crack leak experience at 100-H probably will be as follows:

- a. The reactor central tubes will operate for at least three years with no failures.
- b. The failure rate will gradually rise to five per thousand tubes per six months.
- c. Replacement of the central tubes will eliminate the problem for another three years.

The 100-H transverse crack experience indicates that the frequency of failures rises rapidly enough after the first failure occurs in a group of tubes with similar history to justify replacing all tubes in the group two years after the first crack occurs. During this two-year period, approximately ten failures per thousand tubes occur.

A reasonable forecast of transverse crack failures at 100-H appears to be ten failures every five years. The central tube residence cycle would consist of three years with no crack failures followed by a two year period when the frequency of failures would increase gradually until replacement of the tubes can be justified.

The frequency of crack failures at the other reactors is expected to be less than at 100-H because past experience has shown a significantly lower frequency. Since insufficient information is available to permit determination of the frequency at the other reactors, the forecast total frequency of crack failures is 2 to 12 failures per year. This covers the range of frequencies from zero up to the frequency at 100-H. No crack failures are expected at 100-K.

4. Forecast Number of Water Leaks

Based on the above discussion, the forecast number of water leaks per year is:

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Table II
Forecast Water Leak Frequency

<u>Type Leak</u>	<u>No. of Leaks</u>
Internal Corrosion	6 to 18
Van Stone Flange Failures	50
Miscellaneous	
External Corrosion	9
Mechanical Damage	6
Ruptures	5
Transverse Crack	2 to 12
Gasket	0
Other	6
Total	84 to 106

Essentially all leaks are expected to occur at the six older reactors. Installation of zirconium tubes at 100-K is expected to essentially eliminate leaks at those reactors.

The actual frequency of water leaks will vary in accordance with reactor operating conditions, the amount of leak prevention effort, and the condition of the reactor tubes. The expected range of frequencies is 60 to 120 leaks per year.

It should be noted that approximately one-half of these leaks are Van Stone flange failures. The amount of water entering the reactors from these failures will depend on the amount of use of Van Stone seal inserts and the frequency of full shear failures, which the seal inserts do not always seal.

B. Outage Time Caused by Water Leaks

Past experience with water leaks has been as follows:

Table III
Reactor Water Leak Experience

<u>Calendar Year</u>	<u>No. Leaks</u>	<u>Hours Outage Time Charged</u>	
		<u>Total</u>	<u>Per Leak</u>
1957	90	1060	11.8
1958	82	950	11.6
1959	84	1080	12.9
1960	92	1090	11.9
1961	265	2690	10.2
1962	161	2210	13.7
Total	774	9080	11.7

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The outage time charged per leak probably will continue to be approximately twelve hours per leak. Anticipated improvements in water leak detection procedures may reduce the average time charged per leak by one to two hours; however, not enough experience with the improved techniques has occurred to permit determination of the effect on reactor outage time. No reduction is forecast for that portion of the charged outage time for reactor cooling, reactor startup, and replacing the leaking tubes.

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Figure 1
Van Stone Flange Failure History

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