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ENGINEERING DEPARTMENT
OCAB-3

OYSTER CREEK NUCLEAR GENERATING STATION

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appears that these two types of microbes probably played a role in the early stages of corrosion, but are not likely the most important factor at this time influencing the corrosion rate of the most heavily wasted metal areas.

The report is attached as Appendix B.

6.6 Ground Potential Measurements

The possibility of stray currents influencing the corrosion rate was also considered. In order to provide an assessment of this, external potential measurements were conducted to check for the presence of stray currents. Potential measurements were taken between the ground and each of the five sand bed drain lines using a copper-copper sulfate reference cell. The measurements revealed no evidence of stray currents during shutdown. Similar measurements were taken during plant operation with the same results (3,4).

7.0 Conclusions

Based on the results of the analyses presented in Section 6.0, it is concluded that the corrosion damage is occurring within the sand cushion region of the annulus between the vessel shell and concrete shield.

Wetting of the sand bed may have occurred as early as initial construction. The only other documented evidence of leakage was during the 1980, 1983 and 1986 outages. Although the exact source of leakage during construction is unknown, it was reported [1] that during the application of the Firebar-D material that copious quantities of water were observed coming from the Firebar and running down the drywell presumably into the sand bed. During outages water was most likely coming from a leaking gasket in the seal plate region. This gasket was replaced during the 1986 refueling outage and the leakage appears to be stopped. On the above basis and in view of the fact that there would not be other sources of water to enter the annular region behind the drywell during operation, it has been concluded that the introduction of water was an intermittent occurrence (i.e. during outages) which may have occurred during construction but definitely occurred in 1980, 1983 and 1986. Also, it can be concluded that the sand as a result of this water introduction is contaminated with chloride, magnesium, and sulfate along with numerous metal ions as shown in Table 7, which confirms the supposition that the Firebar material is the major contaminant contributor to the corrosion process.

Sand is generally ascribed with good drainage properties which would allow for the bulk of the water which entered the sand bed to flow out of the drain lines; however, because this region is fairly enclosed with little air circulation, high humidity is believed to exist in the annular space which could result in the sand remaining moist for indefinite

periods of time. This is partially substantiated by the fact that high humidity and sweating is generally observed in the torus room where the sand bed drains exist. Above the sand bed, however, fiberglass boards and above that Firebar are applied to the exterior drywell steel which would help prevent moisture from coming directly in contact with it. In addition, during operation the average drywell air temperature is approximately 140°F which again would prevent condensation from forming on any exposed steel surfaces. The overall environmental within the annular region can therefore best be described in the following manner: Water was introduced into the sand bed possibly as early as in the late sixties containing magnesium chloride and magnesium sulfate from the Firebar. The bulk of this water would have drained off leaving moist sand behind. It is documented that the exterior of the drywell was coated with red lead primer over which Firebar and fiberglass boards were applied which would afford general protection to these steel surfaces from corrosion. Evidence that a read lead primer existed is shown in Figure 3 and Tables 7 and 12. Coating damaged areas and with time all areas within the sand bed would be expected to experience general corrosion as long as the sand remained moist or until a protective oxide film built up on the steel surface as a result of the corrosion process. It appears, however, that a completely protective film did not result most probably because of the presence of magnesium chloride. The actual metal loss which may have occurred during the time frame from initial startup until the next time water was reintroduced as a result of leakage into the cavity is unknown. The first documented incident of water intrusion following startup which would definitely initiate corrosion was

in 1980. Water samples collected and analyzed at this time for radioactivity measurement, indicated that it was refueling water and hence adds credence to the assessment that the source of the water was the leaking bellows gasket. Corrosion rates would therefore be properly based on the assumption that the corrodent was refueling quality water contaminated with chloride from the Firebar and that the corrosion process was aqueous general corrosion. The availability of chlorides from the Firebar is confirmed by the leachate analysis data presented in Table 9. Some shallow pitting is also occurring but it is considered only in view of its contribution to overall thinning.

The possibility of stress corrosion cracking and hydrogen embrittlement were also considered. However, these forms of corrosion are generally associated with high strength steels or high temperatures and not considered a damage mechanisms for the environment or material associated with the drywell. Ultrasonic examination of the welds and heat-affected zone in the wastage regions also showed no indication of cracking.

An upper bound general corrosion rate for carbon steel would be expected to be in the range of 10-20 mpy depending on the drywell plate temperature. These corrosion rates, however, if applied generally to the drywell region in contact with the sand bed are consistent with the average wall loss of .288" only if the corrosion is assumed to have occurred since 1969 which was the first possible time water could enter the sand bed drains.

In fact, however, close scrutiny of the UT thickness data indicates that corrosion was extremely non-uniform as defined above in the section on UT measurements. First, the region above the 11'9" elevation shows little or no wall loss. Then the region from 10'3" to 11'9" shows the greatest wall loss followed by the region below 10'3" which shows substantially less wall loss. Lastly, only two regions of the drywell encompassing four bays show any significant wall loss. A possible explanation for this is that due to channeling only these regions became wetted. This assumption is potentially confirmed by the observation that the sand in the minor wastage regions was dry. Also, the intimacy of the contact between the sand and the plate is a factor. If the sand had been pushed away from the drywell in certain regions due to the preoperation pressure test causing the drywell to expand; this also can result in variations in corrosion rate regardless of the moisture in the sand. The protectiveness of the red lead primer will be a function of its integrity in the various regions and again may be leading to variable corrosion rates. Lastly, differential aeration may be playing a role in where corrosion is occurring. Clearly the presence of magnetite, an oxygen deficient oxide, in some regions and hematite in other regions suggests this is occurring.

This corrosion was most likely influenced by the presence of chloride, leached from the Firebar-D, Table 9, as it was found to be incorporated within the Fe_3O_4 corrosion product, Figure 15. Bacteria are not

believed to have been a major influence on the corrosion. This latter conclusion is based on the results presented in Section 3.5. Also, there is no direct evidence that stray currents contributed to the corrosion process as discussed in Section 3.6. Therefore, the corrosion observed can be explained solely on the basis of chemical attack.

A pictorial representation of the corrosion is shown in Figure 19.

Review of the literature suggests corrosion rates can vary widely for carbon steel in aqueous environments. Rates can be as low as 1-2 mpy in high pH aqueous environments or greater than 50 mpy in acid solutions. Dr. Uhlig in his "Corrosion Handbook" (Ref. 5) lists corrosion rates for ambient temperature, seawater at approximately 1-7 mpy which at 140°F would conservatively equate to approximately 17 mpy. Uhlig further states that with the formation of corrosion products the rate of corrosion will be less than it would be if the steel were in direct contact with seawater and that the rate will stabilize and not change with time. In addition, he observed that, "specimens of steel have been exposed to seawater where sulfate reducing bacteria were known to be present, and in fact were found in the corrosion products which contained appreciable percentages of iron sulfide. The observed rates of corrosion and pitting of such steel fell within the normal range previously defined."

If we then take the 17 mpy corrosion rate and project this over the 17 year life of the plant it correlates closely with the average corrosion loss of 288 mils. However, in order to insure conservatism in the structural analysis a factor of safety should be applied to this rate. To arrive at a defendable factor it has been assumed that all corrosion occurred over the past six years as a result of the water intrusion in 1980. This would equate to a corrosion rate of 48 mpy and give a factor of safety of 2.8.

GE's prediction was similar (2). Battelle, in a report provided to EPRI, performed a literature search and concluded that the rates we predicted were reasonable (6).

Two meetings held with consultants (minutes are attached as Appendix C) resulted in conclusions that our sampling approach and analysis conclusions were adequate.

8.0 References

1. Primary Containment Design Report, The Ralph M. Parsons Company, prepared for GE.

2. F&PMT Transmittal No. 870178-003 Rev. 1, Corrosion Evaluation of the Oyster Creek Drywell, GE.