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December 16, 1998

Ms. Lora Polley
Northern States Power Company
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
Welch, MN 55089

Dear Ms. Polley:

Subject: Evaluation of the Effects of Borated Water Leaks on Concrete, Reinforcing Bars, and Carbon Steel Plate of the Containment Vessel - **UNIT 2**

Automated Engineering Services Corp. (AES Corp.) has evaluated the effects of borated water leaks on the containment concrete, reinforcing steel, and carbon steel plate of the containment shell. The attached report summarizes the results of this evaluation and provides recommendation for future action.

We will be glad to provide any additional information or clarification that you may desire. We thank you for the opportunity to be of service to NSP and Prairie Island.

Sincerely,

A.V. Setlur

A.V. Setlur, PE MN # 21678
President

Attachment

cc: Gerald Gore, NSP
Mark McKeown, NSP
Marc Meyers, NSP
Robert Cole, AES

# REPORT ON THE EFFECT OF BORATED WATER LEAKS ON CONTAINMENT CONCRETE, REINFORCING STEEL, AND CONTAINMENT STEEL PLATE

**Prepared by**

**A.V. Setlur**

December 16, 1998

## 1.0 PURPOSE

The purpose of this report is to evaluate the short term and long term effects of borated water leaks on structural components of the Reactor Building observed during the current (Fall 1998) Unit 2 outage at the Sump B location and in the vicinity outside the Reactor Coolant Drain Tank (RCDT) cubicle.

## 2.0 BACKGROUND

During the current Unit 2 outage, water leaks were observed in the vicinity outside the RCDT cubicle and in the grouted area around the pipe sleeve of the suction piping in the Sump B as shown in the attached sketch. These leaks were observed after the Refueling Pool was flooded for fuel shuffling and was found to stop shortly after the pool was emptied. The rate of flow and the amount of water collected on the basement floor (El. 697'-6") of the Reactor Building near the RCDT and in Sump B area were very small as explained below.

The water from these leaks was tested for boron concentration, chloride content, and pH. The Sump B area leak contained boron with a concentration of approximately 2700 PPM, a chloride content of 7 PPM, and a pH level of 7.8 (alkaline). The RCDT area leak had boron concentration of 5329 PPM on the basement floor, a chloride content of 7.25 PPM, and a pH level of 7.0 (neutral). Note that the boron content of the refueling pool water was measured at 2700 PPM and a pH of 5.2 (acidic). The increase in pH from the refueling pool water to those found in the leaks could be attributed to the acidity being neutralized by the carbonates and other minerals in the concrete. The higher boron content in the RCDT area leak was attributed to its concentration due to evaporation of the water on the basement floor.

The following NSP and AES staff members inspected the subject areas between 10 a.m and 10:30 a.m. of December 4, 1998: Lora Polley, Mark McKeown, Marc Meyer, and Robert Cole. The water leaks were observed and later mopped up around 11:15 a.m. that day to facilitate further observation at a later time. The mop up was confirmed by Marc Meyer during his 11:45 visit to the RCDT area. Also, evidence of dried white residue staining the concrete along the vertical joint between the RCDT outer wall edge and the sloping concrete wall was clearly seen. Marc Meyers, Laura Polley and Mark McKeown also observed dried white deposits (like miniature stalactites) on the ceiling of the cavity under the Refueling Pool. The stalactites were due southeast of the reactor and about three feet from the outside surface of the cavity wall.

From 11.45 a.m. to 12:30 p.m., Marc Meyer stayed in the RCDT area to observe how fast the water was seeping. His observation was that the leak did not increase during his 45 minutes stay in the RCDT area. Later that afternoon (around 5:30 p.m.), Marc Meyer revisited the RCDT area and observed that the leak was primarily coming from the horizontal construction joint between the sloping (curved) wall and the basement floor as shown in the attached sketch (Section C-C). He observed that the puddle of water at 5:30 p.m. was about 1/16" depth, about 2" wide at its narrowest point and flared out to about 12" wide for a distance of 24 inches in two opposite directions along the wall. Based on this, it is estimated that the volume of water collected during the 5 hours between observations was approximately 21 cubic inches. Therefore, the rate of flow is calculated at approximately 0.02 gallons/hr. As noted above, the leak stopped shortly after the refueling pool was drained down. The Sump B area leak was estimated to be about 0.5 gallons/hr. during the same five hour period (12:30 p.m. to 5:30 p.m.)

Based on the above information, the following observations can be deduced:

a. The leaks can be attributed to the refueling pool filling and possible leak in the pool liner or in the transfer canal. Efforts were being made to determine if and where this breach in the liner has occurred. This report does not address the liner investigation.

b. The flow of water to Sump B is possibly through the horizontal and vertical construction joints in the interior concrete structure, most probably between the 4th and 5th concrete pours for the horizontal travel path and up through the vertical joint between the containment steel and the adjacent sloping (curved) concrete wall. The flow to the RCDT area could possibly be through the joint between the internal concrete wall and the steel containment shell and then through the horizontal construction joint between the wall and the floor slab (Pour 5) as shown in Section C-C of the attached sketch.

c. The leaks may have occurred during previous outages and could have gone unnoticed because of the small amount of water associated with these leaks. This observation is made because of the dried out deposits seen at various locations described above.

d. The flow paths are primarily between concrete layers at the construction joints. These construction joints do not have reinforcing steel across them. They are either keyed (tongue and groove joints formed during the concrete pours) or have the previous pour surface is roughened and coated by a bonding compound prior to the installation of the next pour. Therefore, reinforcing steel is not subjected to any adverse action of the borated water.

e. The carbon steel containment shell did not show any signs of corrosion or pitting when portions of the grout surrounding the pipe sleeve of the suction lines in Sump B were removed.

f. The period of wetting of the concrete and the steel shell is about 15 days during the time when the refueling pool is flooded. This wetting could possibly have occurred every outage (18 months) for the past few outages. At other periods when the unit is in operation, the source of water was not present and the joints and surfaces should have been dry.

In the following each of the three affected components (concrete, reinforcing bars, and the containment shell) of the Reactor Building structure are examined for adverse impact of the borated water leaks.

## 3.0 EFFECT OF BORATED WATER LEAKS ON CONCRETE

Many studies have been conducted on the effect of acid rain on concrete. Laboratory studies have been conducted [Ref. 1,2] utilizing accelerated test program for effects of sulfuric acid solutions with pH ranging from 2 to 5 for periods ranging from 30 days to 100 days. Concrete samples with strengths varying from 3000 psi to 9000 psi were studied. The studies revealed the surface deterioration of the concrete increased as the strengths increased due to higher cement content in stronger concrete samples. It also increased with increasing acidity of the solution.

However the corrosive effect of borated water (boric acid) is less than that of sulfuric acid at the same acidity levels. Reference 3 shows that boric acid has negligible effect on concrete whereas the same reference indicates that sulfuric acid will rapidly disintegrate concrete. Discussions with Portland Cement Association (Mr. Robert Shuldes) confirmed that the effect of borated water will have negligible effects on concrete especially since the surface is wetted only for a short time duration (about 15 days every outage). The lack of deterioration of the concrete surfaces where white deposits were seen further reinforces the observation that borated water does not have any appreciable effect on concrete.

Based on the above, we can safely conclude that the internal concrete surfaces at the construction joints and in the flow paths of the leaks would not have any deterioration. There is no safety significance of the borated water leaks on concrete surfaces since the concrete structure would not have deteriorated and should be capable of performing its intended function.

## 4.0 EFFECT OF BORATED WATER LEAKS ON REINFORCING BARS

Since the borated water does not affect the concrete surface, the reinforcing bars would be fully protected inside the concrete. Note that the chloride content of the leaking water is small and will have no effect on the reinforcing bars. Also there is no evidence that the concrete surfaces have cracked thereby providing a path to the seepage of acidic water directly to the reinforcing bars. The likelihood of any corrosion of the reinforcing bars in this situation is very remote.

Based on this observation, there is no reason to suspect the corrosion of the reinforcing bars. Therefore, the strength of the reinforced concrete material is not compromised by the borated water leaks.

## 5.0 EFFECT OF BORATED WATER LEAKS ON THE CONTAINMENT SHELL PLATE MATERIAL

It is known in the nuclear industry that borated water in the form of boric acid can be corrosive to components fabricated from carbon and low alloy steels [Ref. 4]. However, most of the studies conducted involved reactor coolant at high concentration (13,000-15,000 PPM of boron with small amounts of lithium) and at high temperatures (> $200^0$ F). Reference 4 concludes that the maximum corrosion rates occurred where moisture can be replenished by a flowing solution, keeping a wet/dry interface between the solution and the dry boric acid crystals. It was also seen that when the boric acid dries out and is not significantly re-wetted, the corrosion levels are much lower.

As a precaution, NSP removed a portion of the grout material adhering to the steel plate around the pipe sleeve in the Sump B. The exposed steel surface did not show any signs of corrosion or surface pitting. This provides strong evidence that the boric acid solution was weak enough and was not constantly wetted for a long enough period of time to cause any deterioration of the steel plate surface. The same argument can be extended to other plate surfaces which are not exposed and which may be in the leak paths.

Based on the above, it is believed that the containment shell is not affected by the observed leaks and has the capability to perform its intended function.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

As a result of this evaluation, the following conclusions can be made:

1. The effect of borated water leaks on structural material inside the Reactor Building is in the worst case very minimal and does not affect the capability of the structure to perform its intended function. Therefore, the observed leaks do not have any safety significance.

2. It is prudent to investigate, determine, and fix the area where the leaks occur so that future leaks do not occur. There is a remote possibility that several cycles of wetting and drying could concentrate the boric acid solution to the extent that a strong solution could corrode the containment steel plate and compromise its pressure retaining capability. This has to be avoided at all costs.

3. It is recommended that periodic observation of the leak areas and of the exposed steel plate where the grout was removed in Sump B should be made when containment entry is feasible. This will provide additional information that can be used to validate or correct the conclusions reached herein.

## 7.0 REFERENCES

1. Hendrik L. Kong and James G. Orbison, "Concrete Deterioration Due to Acid Precipitation," ACI Materials Journal, Title No. 84-M13, March-April 1987.
2. Nijad I. Fattuhi and Barry P. Hughes, "Ordinary Portland Cement Mixes with Selected Admixtures Subjected to Sulfuric Acid Attack," ACI Materials Journal, Title No. 85-M50, November-December, 1988.
3. Portland Cement Association Concrete Information, "Effects of Substances on Concrete and Guide to Protective Treatments," IS001, 1997.
4. C.A. Campbell, S. Fyfitch, and D.T. Martin, "Boric Acid Corrosion of Carbon and Low Alloy Steels," Corrosion 94, The Annual Conference and Corrosion Show Sponsored by NACE International.