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March 27, 1980

Mr. D.L. Ziemann, Chief
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Division of Operating Reactors
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Dresden Station Unit 1
Chemical Cleaning Project
Consideration of Effects
of Crevice Corrosion Beneath
Stainless Steel Cladding During
Layup Conditions
NRC Docket No. 50-10

Dear Mr. Ziemann:

Questions have recently been raised by your staff and consultants concerning the potential effect of residual solvent which may be trapped within crevices, extending through the stainless steel cladding into the carbon steel base metal, throughout the layup period. We feel the following attachment adequately addresses the concerns raised and shows that the corrosion rates expected are not significant to pose a problem during the layup period.

Please address any questions you may have concerning this matter to this office.

One (1) signed original and thirty-nine (39) copies of this letter and enclosure are provided for your use.

Very truly yours,

Robert F. Janecek

Robert F. Janecek
Nuclear Licensing Administrator
Boiling Water Reactors

2618A/bmb
Attachments

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CONSIDERATION OF THE EFFECT ON POSSIBLE CRACKS IN DRESDEN-1 STAINLESS STEEL CLADDING AFTER EXPOSURE OF THEM TO CHEMICAL CLEANING

Introduction

The chemical cleaning of Dresden Unit 1 includes extensive studies of the interaction of the Solvent, NS-1, with the many metallurgical components of the primary system (1). Following the chemical operations, it is planned to "layup" the reactor for several months to carry out the examination, testing, refurbishing, and maintenance activities. The reactor pressure vessel of Dresden-1 is constructed of A302-B carbon steel, clad with 304 stainless steel on the inner surface, which is exposed to primary water (hence cleaning solvent). The worst case situation in regards to corrosion is to postulate an existing crack which has breached the stainless steel cladding layer and extends part way into the carbon steel base metal. The remainder of this discussion addresses this point.

Dilution and Temperature

The application of solvent will be followed by drains and rinses with copious amounts of demineralized water. Thus, it becomes very difficult to support a case in which the cleaning solvent is able to displace the water which originally occupied the plant, and yet not be at least partially displaced by the rinse water. A conservative approach is nonetheless taken, which assumes undiluted solvent as the basis for these cases.

Substantially all of the corrosion data of Reference 1 were gathered at or near cleaning operation temperature, which represents a more severe case than layup conditions near room temperature. At the lowest temperatures, corrosion effects are drastically reduced. The measurement of low corrosion rates is difficult during short time spans. However, one method of judging rates at reduced temperature is to apply the general principle that reaction rates are reduced by a factor of 2 for each decrease of 10^0 Centigrade. This could mean corrosion rates over 1,000 times lower at layup condition than at cleaning condition. While no quantitative data are available currently, this beneficial temperature effect should be kept in mind and considered along with the discussion to follow.

General Corrosion

General corrosion is considered from solvent which is postulated to be trapped in a pocket behind a thru-cladding crack in the reactor pressure vessel. Three subcases of this situation are clear: (1) Trapped solvent in the pocket with no other flow in or out, (2) Trapped solvent with inward diffusion of air, and (3) Trapped solvent in communication with water through the cladding crack.

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(1) DNS-D1-016. Technical Study for the Chemical Cleaning of Dresden-1. July 15, 1977.

The completely trapped pocket of solvent is an extreme case in which it must be postulated that somehow solvent can enter an assumed crack in the stainless steel cladding of the reactor pressure vessel, and fill some sort of void within the carbon steel behind the cladding. Then it must be further assumed that the cladding crack no longer functions as a channel, so solvent cannot escape or become diluted. Under these conditions, the worst case is continuing slow corrosion of the carbon steel until the ability of the solvent to accept iron is exhausted. At this point, the driving force for continuing general corrosion disappears. Rates may be more like an inorganic salt solution such as ammonium sulfate which shows less than 20 mil/yr. corrosion at 20% concentration on mild steel (2).

The second case to consider under general corrosion is one in which the solvent invades a postulated cladding crack and remains in the pocket behind the cladding, but the entry path through the cladding remains open to air during those periods when the reactor pressure vessel is drained for maintenance activity. As in the previous case, the solvent is depleted by any corrosion which initially takes place. Once the chelate capacity of the solvent has been exhausted, the corrosion behavior in the presence of air is expected to be greatly influenced by the amount of free ferric ion in solution which, in turn, is related to oxidation efficiency of any air which may diffuse through the cladding crack. This situation is not unlike the conditions which can develop from the draining of normal water during a system maintenance procedure, where experience has shown tolerable corrosion when exposed to moist air.

The third case is most realistically what would happen to a solvent-filled cladding crack with a cavity at the carbon steel interface. The exposed entry to the crack is, in this case, covered with normal reactor layup water. Within the cavity containing sequestered solvent, any corrosion will result in the depletion of solvent capacity, as in the previous cases. Replenishment of oxygen, however, can only occur by intrusion of fresh, oxygenated water from the bulk of the layup volume. The process of intrusion of fresh water must be accompanied by displacement of an equal volume of solvent, since the cavity volume changes insignificantly at any point in time. Thus, the process of oxygen renewal results in a continual dilution of trapped solvent, resulting in a situation less severe than either of those discussed above for general corrosion.

Galvanic Corrosion

Consideration must be given to effects of galvanic corrosion at the interface at the base of the postulated thru-cladding crack and the carbon steel below. Here, both macro- and micro-galvanic processes are considered.

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(2) NACE Corrosion Data Survey

From the standpoint of macro-galvanic action, the small anodic area of the carbon steel cavity may be compared with the extremely large cathodic area of the stainless steel-clad interior of the primary system. From a practical standpoint, however, this is not a valid comparison. Any crack small enough to trap solvent behind the cladding layer is small enough to provide a minimal cross section of conductive fluid. Furthermore, the resistance along this small conductive pathway is high because of the purity of the layup water (infinite resistance if the system is drained and air filled). From an overall standpoint, then, the assumed cavity "sees" a limited cathode of stainless steel and macro-galvanic effects are not operative.

The micro-galvanic effect is represented by the postulated pocket of solvent trapped in a cavity within the carbon steel behind the "cracked" 304 stainless steel cladding. In this geometric arrangement, the principle galvanic attack would be along the carbon steel/stainless steel interface, not in the direction of crack extension into the carbon steel substrate. The shape of the assumed cavity, which extends into the carbon steel, makes the anode-to-cathode surface ratio much larger than unity. Therefore, a 1:1 ratio is an outside worst case. Spent chelate would be expected to behave as an ionized salt at moderately low pH. A model for this is ammonium sulfate, already mentioned, which has equivalent conductivity at about 1% concentration. Data from a report on simulated cladding cracks (3) show that a maximum of 70 mils of corrosion occurs along the bimetallic interface during four days at 250°F. The worst expected corrosion is less than this and is in the direction transverse to crack propagation. The direction parallel to crack propagation is necessarily much less.

Through-Clad Crack Propagation

The extensive fracture mechanics corrosion test program addressing the effect of NS-1 on the propagation of through-cladding cracks on carbon and low alloy steels present in the Dresden 1 primary system has been completed and the final report is currently undergoing review prior to publication. The general conclusions of the work have been previously transmitted in the form of General Electric Company PME (Plant Materials Engineering) transmittals numbers PME 77-509-70, PME 78-509-002, PME 78-509-66, and an apparent test results report 509.ATR-77. The results of the tests, as reported in these documents, indicated no significant deleterious effect on crack propagation resulting from exposure to a simulated cleaning cycle in NS-1 followed by long-term exposure to a simulated BWR service environment.

Subsequent examination and detailed analysis of the data generated in this investigation have confirmed the conclusions drawn initially. Propagation of mechanically induced through-cladding fatigue

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(3) NEDC-24227 "Effects of Dow NS-1 on Simulated Through-Cladding Cracks on Carbon and Low Alloy Steel 1-T WOL Fracture Mechanics Specimens". To be released in the near future.

cracks in some 1-T WOL ASTM A 399 fracture mechanics specimens was observed in specimens exposed to the simulated NS-1 cleaning cycle and also in control specimens exposed to demineralized water for the time and at the temperature of the cleaning cycle. Statistical evaluations of the differences between the control specimens and the NS-1 specimens were made, both in terms of the proportions of specimens exhibiting crack propagation and in terms of the extent of propagation when it occurred. The results of these evaluations show that the differences in both comparisons were not significant at the 0.10 level, the minimum level at which one might conclude that the differences might be due to factors other than experimental error: that is, factors other than simple chance variation in the behavior of different specimens. There were no indications that exposure to NS-1 signficantly increased either the incidence of crack propagation, or the extent of crack propagation when it occurred.

The extent of undercutting of the cladding mentioned in the transmitted reports was an observation of the general mode of attack on the tested specimens, and appears to be more closely related to specimen preparation than to basic corrosion characteristics of the NS-1 solvent. Generally speaking, undercutting was observed when the machined notch penetrated through the cladding and into the base metal, as shown in Figure 1-B. In a few instances some slight undercutting was observed in specimens where the machined notch did not penetrate the base metal, as shown in Figure 1-A. The maximum undercutting observed on any specimen was only 0.07 inches. The penetration of the base metal by the machined notch was an inadvertent event, resulting from small variations in the depth of the cladding at the location of the notch. Such variations are a normal occurrence unless extreme care is taken in the deposition of the weld metal. Their presence was not of concern from the standpoint of the purpose of the investigation since they did not affect the stress intensity at the tip of the fatigue pre-crack, and it was essential that the fatigue pre-cracks penetrate into the base metal for a significant portion of their length in order to achieve the high stress intensity value chosen for these tests. The presence of such slight undercutting should cause no concern for crack propagation in a direction parallel to the cladding-substrate metal interface. In order for such propagation to occur, a high tensile stress would have to exist which was perpendicular to the plane of the interface, as shown in Figure 2. There is no apparent source for a stress of the magnitude required in the necessary direction.

To summarize the data and observations of the crack propagation study, no effects on either the incidence or the extent of crack propagation of through-cladding cracks were observed on highly stressed fracture mechanics specimens subjected to a simulated cleaning cycle in NS-1, followed by extended exposure to a simulated BWR environment. These results would lead one to expect that the presence of NS-1 solvent would have no effect on crack propagation during the relatively low temperature waiting period between the cleaning operation and startup. The possible presence of some slight undercutting of the cladding does not pose a threat to the integrity of the vessel because there appears to be no mechanism for the application of stresses in the direction necessary to propagate a crack along the cladding-substrate interface. Finally, all stresses of concern from the standpoint of crack propagation would be very low during the waiting period. In view of these observations and extrapolations, we see no reason for concern regarding the effects of NS-1 solvent on the propagation of any through-cladding cracks which might exist in the Dresden 1 primary system.

Conclusion

The possible modes of corrosion in a postulated crack through the 304 stainless steel cladding, into the A302-B carbon steel walls of Dresden -1 reactor pressure vessel have been considered. It is concluded that corrosion rates are not significantly high to pose a problem during the layup and maintenance period which is expected to follow the chemical cleaning operation. Any postulated corrosion mechanism is decreased in rate by the low layup temperature (compared to short-term cleaning conditions). Realistically, the full-strength solvent in a crevice will have been diluted during rinse cycles, further decreasing the problem.

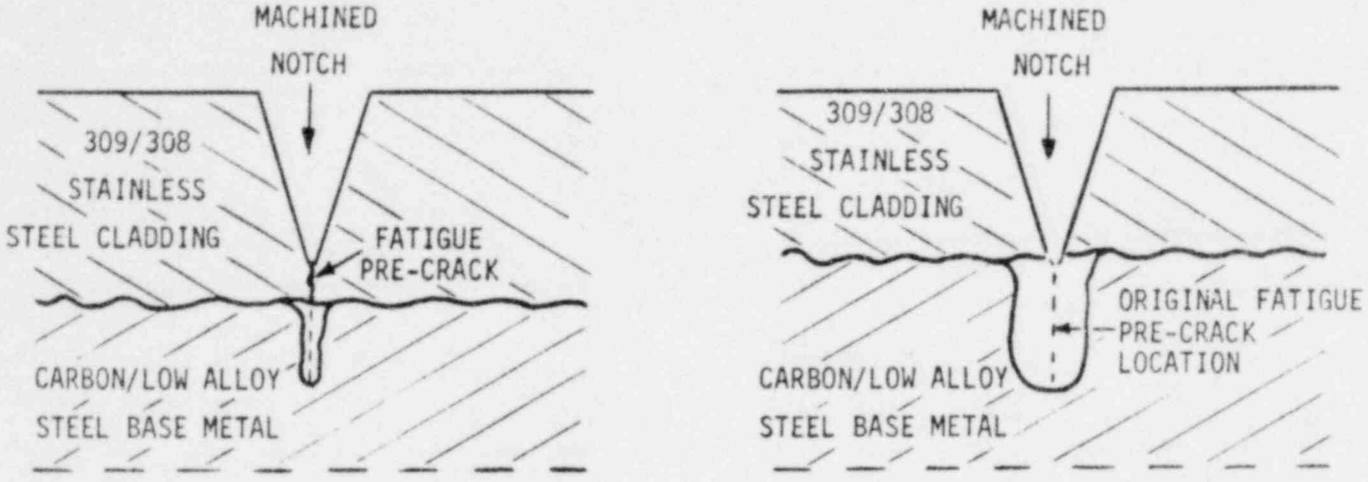

FIG. 1-A

FIG. 1-B

FIGURE 1 - IDEALIZED SKETCHES SHOWING IN-CLAD AND THROUGH-CLAD NOTCH TIP LOCATIONS IN FRACTURE MECHANICS TEST SPECIMENS.

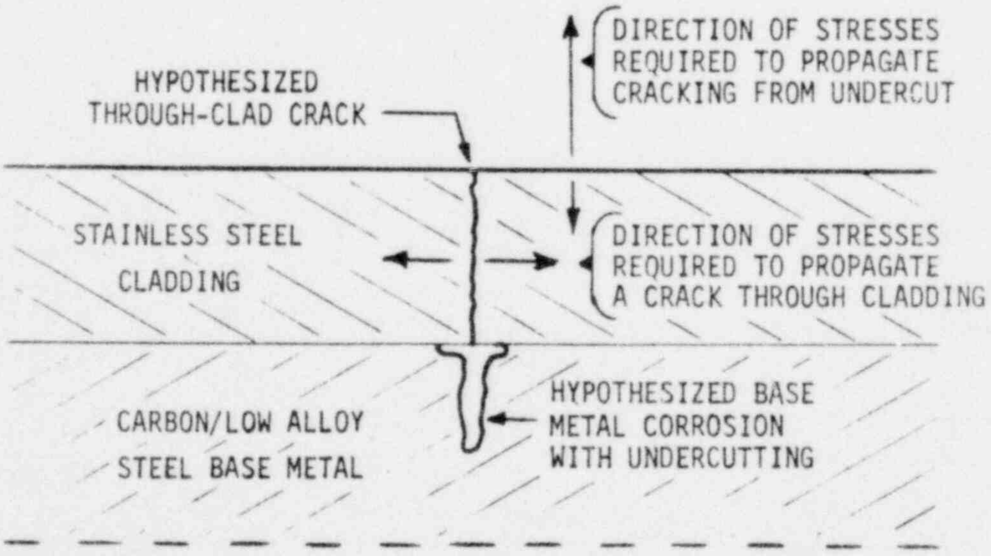

FIGURE 2 - SCHEMATIC SHOWING STRESS ORIENTATIONS REQUIRED FOR CRACK PROPAGATION