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reply to: Dr. R. W. Staehle
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18 May, 1970

Mr. Harold R. Denton, Chief
Technical Support Branch
U. S. Atomic Energy Commission
Division of Compliance
Washington, D. C. 20545

Subject: Course of Action on Repairs for Dresden -2 and Nine Mile Point

Dear Harold:

On May 14 you requested my recommendations for a course of action to be taken for the repair of safe ends on the reactor vessels of Dresden -2 and Nine Mile Point. The purpose of this letter is to transmit these recommendations together with their justification. In addition to these recommendations I have included suggestions for measures to be taken to reduce the likelihood of spurious cracking.

Primary Recommendations

The recommendations here are contingent upon the kind of "failure" which the AEC wishes to avoid:

1. For example, if it is desired to avoid the incidence of any transgranular stress corrosion cracking, then it is necessary to replace all stainless steel piping with either a higher nickel alloy, a ferritic stainless steel or a duplex alloy. In my opinion this is an unreasonable criterion in view of the economic implications. However, it must be kept in mind that incidences of transgranular cracking are always likely in austenitic stainless steel systems and extreme care must

be exercised to avoid this phenomenon.

2. If it is desired to avoid only the type of cracking observed in the first failure of the safe end at Nine Mile Point, then a different course of action is appropriate. It is my operating assumption, and I think it is the only reasonable one, that the cracking which was observed could have lead to a large rupture during a thermal transient. However, it is not appropriate here to comment on the consequences of the large rupture. Your interpretation of this is much more expert than mine. It is my contention that such a failure can result and that there is a reasonable possibility its initial stages would not be detected. Thus, it may not leak sufficiently for it to be detected before the major failure occurs.

If the AEC considers that such a failure must be avoided, then I recommend that:

a. The intergranular mode of sensitized SCC be considered as leading to the extensively penetrated cracking of the type observed at NMP and LACBWR.

b. The AEC should require that all safe ends be replaced either with solid sections or weld overlayed inside and outside.

c. The AEC should require that a condition for replacement is that the licensee demonstrate (by test results) the adequacy of the replacement material and procedure through agreed upon tests. Incidentally, some of these tests may be already completed. These tests should demonstrate (1) that the new material will resist SCC in the form used in the replacement and (2) that the configuration used will not be subject to premature failures as a result of thermal shock, fatigue, or other appropriate mechanical requirements.

d. The most reasonable replacement material is probably Type 308L weld deposited material since this has had wide use as weld overlay material. Acceptable materials would also include Incoloy-800 and Inconel-600 providing that other defects are not introduced. The 308L has the disadvantage relative to the other two materials of a ready susceptibility to transgranular SCC in chloride environments. The uncertainties in the latter two materials involve their behavior in the weld sensitized condition with respect to intergranular SCC in the water $-O_2$ environments.

e. Following the repairs the system must be hydrostatically tested.

I believe that in its regulatory capacity the AEC has no choice but to require repair of all safe ends. The pattern of occurrence of failures contains elements of frequency and unpredictability which cannot be denied. Regardless of the detailed rationalization of the cracking and attempts by various parties to obfuscate the issues, the fact remains that this cracking is occurring with great frequency (NMP, LACBWR, Oyster Creek) in sensitized stainless steel, that the cracking is extensive, and that it was not predicted. From a management point of view one must conclude that, regardless of the stress analysis or any other intermediately ameliorating fixes or calculations, there is a high probability of failures occurring again; further, there is the reasonable probability that one of the failures may be the open ended type.

Secondary Recommendations

There are a number of other recommendations which should be considered at this time. While they are not as immediately critical as the primary recommendations above, I believe that they should be seriously considered and should form the basis for action taken in the near future.

1. Consideration should be given to the development of improved alloys for service in reactor vessels and piping. Those presently available continue to exhibit problems. Two areas in which work might be undertaken are the duplex alloys and the high purity ferritic alloys.

2. Consideration should be given to shot peening inside and outside surfaces of stainless steel. This would prevent the initiation cracking. While there are always questions about coverage of shot peening the probability of SCC is greatly lowered.

3. Consideration should be given to an exterior coating which would inhibit SCC from the outside in.

4. The criteria for leaks of valves, fittings, etc. in operating plants should be reviewed and tightened. In my opinion there should be no dripping water of any kind anywhere near the reactor or its components.

5. The AEC should conduct a program to determine the effect of crack extent (depth + circumferential distribution) on the mode of mechanical failure under appropriate loading schemes. This is addressed to the question: "How and under what conditions would the SCC crack propagate under mechanical loads expected during service."

6. There is a reasonable incentive to determine the extent of the transgranular SCC on the internal surface observed by BNWL in examining the interior surface of the second core spray nozzle.

Comments and Justification in Support of Primary Recommendation

1. The first question in my mind is whether the AEC will consider that a complete break of any safe end is sufficiently serious to pose a threat to safety. If there is no threat, then there is no point in promulgating any required repair action.

2. I believe that there is a reasonable possibility that the intergranular cracking of the type observed at NMP and LACBWR can lead to a complete severance or substantial yawning of the pipe. Such an assertion is based on the fact that in both cases the cracks were penetrated 50-100% of the wall over 1/3 of the circumference. That such a defect can occur before leaks are found was a great surprise and also a cause for substantial concern.

3. The critical questions here relative to the causative parameters are the levels of oxygen and stress which are critical. For example there is the reasonable possibility that the cracking may have occurred in the gas phase where radiolytically produced oxygen had accumulated and which would be saturated with water. However, for various reasons I believe this to be an unreasonable assumption. For example, the deposition of copper in the LACBWR case suggests that water was in the crevice for a protracted period of time. I suggest that it is, practically speaking, unreasonable to associate these failures exclusively with these gasified regions.

With respect to the variable of stress; I believe, along with with others, that a higher stress may be required to propagate the intergranular cracks than in the case of transgranular cracks. However, I believe it is unreasonable to cut this effect too fine with respect to deciding which safe end should be repaired. Despite the fact that stress analyses are being conducted on as-built pipes there is no clear certainty that these analyses are sufficiently accurate with respect to what really exists.

Further, there is no basis for confidence which suggests that these stresses will stay the same during operation. They may either increase or decrease.

4. A possibly causative factor may be considered the fluoride ion. Despite the paper by Ward, Mathis and myself showing the virulence of this contaminant in causing SCC of sensitized material, there is no basis for suggesting that it was uniquely causative in the wide range of cases observed. It must be concluded for the present that fluoride (as well as chloride) is undesirable but that it is not uniquely causative for cracking of the heavily sensitized material.

5. There is the additional issue concerning whether the smaller cracks will propagate later. This matter is conjectural. However, from the point of view of public safety it is reasonable to assume that existing cracks will propagate, but at a slower rate. This is the approach often used in the chemical industry when scheduling the reordering of replacement materials. Naturally, it is tempting to conclude otherwise depending on ones economic prejudices or on one's aversion for political infighting.

There were two instances at NMP where specimens were taken to assess the effects of stress: The flared region of the first safe end and the second safe end. In both cases cracks were observed. These were not so deep but were clearly of the propagating type as opposed to the "disk geometry" associated with the external "strawberry" examined. Thus there was no evidence for these additional cracks at the other two locations to be "running out of gas." The possibility that the cracks in the flared region of the first safe end were related positively to oxygen concentration must be rejected in view of the narrowness of the crevice, i.e. the high surface to volume ratio for the solution would permit the oxygen to deplete rapidly.

The observation of the longitudinal crack in the second core spray nozzle from the GE investigation suggest that the residual stresses may be unpredictable and significant.

6. The strong incentive for repair at the present time is related also to the fact that repairs later will be increasingly difficult owing to the accumulation of radioactivity. A failure several years hence will be increasingly difficult to repair and will result in greater risks to personnel than performing the repair immediately. While this point is obvious, it should be considered relative to the very high probability that <u>failures will occur</u> unless repairs are made.

7. I do not believe that a program of interium inspection is sufficient to prevent the occurrence of a serious crack. The initial cracks observed at NMP occurred within three months. It is reasonable that a cracking system which starts slowly and remain undetected early could, within a short time, begin propagating at a very rapid rate.

8. There is no basis for the fact that the reactor system must be dynamic (i.e. heating, cooling, or otherwise contorting) for cracks to propagate. The components can be essentially still, and the residual stresses would be sufficient for cracks to initiate and propagate.

9. The significance of the transgranular cracks starting from the inside of the safe end of the second core spray nozzle at NMP is not clear. They were clearly caused by simultaneous presence of chloride ions and oxygen at the 1-10 ppm level. However, it is not clear at what time chloride was present. The natural question here is why was more extensive transgranular not observed in other parts of the system, i.e. in the other core spray nozzle. This problem could be reasonably associated with only this second core spray line. However, this issue is not clear. There is an incentive for pursuing this matter further.

10. Some of the protection against the propagation of transgranular cracks from the outside despite the reasonability of occasional contamination probably results from the fact that the metal surfaces when hot are dry and when cool and wet are not sufficiently warm for cracks to propagate.

Concluding Remarks

The stress corrosion problem is characterized by its incredibility. After all, the material is "stainless" and does not corrode. It may occur once but, after all, an individual failures does not ~~respect~~ represent an epidemic.* This subconcious belief has anesthetized both technical perspective of experts and the practical judgment of engineering management. I believe it is time for the AEC to publish a decisive instruction that all sensitized stainless steel must be eliminated. Unless such action is taken summarily, the reactor industry jeopardizes itself in terms of a major failure. That such a failure would be grevious not only to the AEC but also the country's already deficient electrical power goes without saying.

While the above paragraph as well as the entire letter is not constructed in quantitative terms and is rhetorical in place, it portrays the seriousness with which the problem must be considered acted upon. It is never possible to have anywhere near sufficiently quantitative information to make such engineering decisions.

I urge you to implement these recommendations without delay.

Sincerely,

R. W. Staehle
Consultant

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* This is in jest but represents, unfortunately prevailing opinion.