MEMORANDUM FOR: R. H. Vollmer, Director
Division of Engineering

FROM: J. Halapatz
Materials Engineering Branch

SUBJECT: DIFFERING PROFESSIONAL OPINION RELATED GENERICALLY TO SENSITIZATION OF BWR STAINLESS STEEL WELDMENTS

Reference: Memorandum, Pawlicki to Vollmer, dated April 14, 1981, Subject, "DIFFERING PROFESSIONAL OPINION RELATED GENERICALLY TO SENSITIZATION OF BWR STAINLESS STEEL WELDMENTS"

This memorandum addresses the reference memorandum. The undersigned, the originator of the DIFFERING PROFESSIONAL OPINION of interest, finds the reference memorandum inaccurate and misleading. The undersigned, in the following, presents his rebuttal of each individual opinion attributed in the reference to Messrs. Hazelton, Gustafson, Turovlin and Pawlicki:

Opinion 1. Sensitization of stainless steel is not the only factor contributing to stress-corrosion cracking of stainless steel welds. Environment and stress are others. Lab tests for stress corrosion are not the ultimate answer. Field experience is more important.

Rebuttal 1. BWR pipe cracking experience is characterized in NUREG-0679 (August 1980), "Pipe Cracking Experience in Light-Water Reactors" which states:

"2.1 <u>Boiling Water Reactors</u>

Stress corrosion cracking in BWR piping and safe ends and cracking found in miscellaneous small lines will be discussed and summarized in this section.

2.1.1 Intergranular Stress Corrosion Cracking in Piping

A primary cause of failure in BWR piping made of austenitic stainless steel has been intergranular stress corrosion cracking (IGSCC). IGSCC is a condition of brittle cracking along grain boundaries of metals caused by a combination of high stresses and a corrosive environment. Although a number of corrodents such as chlorides, fluorides, hydroxides, and sulfates are known to cause IGSCC in stainless steel, in the BWR cases the corrodent has been reported to be dissolved oxygen in high-purity primary coolant water. The oxygen level will vary from approximately 8 parts per million (ppm) when exposed to air at room temperature to approximately 0.2 ppm during reactor operation. The latter is an equilibrium level resulting from oxygen being continuously generated by radiolysis and removed by deaeration. Even the lower limit of 0.2 ppm has been demonstrated to cause IGSCC at BWR conditions in the laboratory.

IGSCC has occurred in BWRs and in the BWR environment in the laboratory only when the stainless steel pipe is in the "sensitized" condition. In this condition, the material adjacent to grain boundaries has been depleted of chromium because of the precipitation of chromium carbides in the grain boundaries and has become subject to accelerated corrosion. Sensitization may result from heat treatment, welding, or any other process that keeps the austenitic stainless steel in the temperature range of roughly 800°F-1600°F for a period of time.

The primary cause of sensitization in BWR piping has been welding. In these cases, sensitization occurs only in an area of the pipe next to the weld commonly referred to as the heat-affected zone (HAZ) of the weld. Welding also causes very high residual stresses in that part of the pipe that includes the HAZ. These residual stresses also contribute to the IGSCC."

"IGSCC at the HAZ of austenitic stainless steel welds is still occurring in operating BWRs in such systems as the recirculation bypass, core spray lines, reactor water cleanup (RWCU) lines, and the control rod drive (CRD) return lines. Several cases of IGSCC in cold-worked pipe have also been reported (Nine Mile Point and Humboldt Bay). The piping in these systems ranges in size from 1 to 10 inches. IGSCC has been reported in larger pipe sizes in foreign countries (Ref. 5). Such cracking has occurred in 14-inch-diameter Type 304 stainless steel pipe in recirculation risers in Japanese BWRs and in a 24-inch-diameter Type 304 stainless steel recirculation loop pipe in German."

"4. SUMMARY

(3) IGSCC in austenitic stainless steel piping in BWRs is a recurring problem caused by a combination of conditions, including (a) sensitization of the metal by welding, (b) high residual stresses due to welding, and (c) dissolved oxygen in high-purity water coolant. As of October 1979, 191 cases of IGSCC have been reported. These have all occurred in the HAZ of welds, primarily in Type 304 stainless steel pipe. A Pipe Crack Study Group formed by the NRC to evaluate the problem has issued reports that include discussions of the cause, extent, and safety implications of IGSCC and recommendations for corrective action. In addition, NRC staff has issued reports implementing the recommendations. These include the use of more corrosion-resistant materials for plants in the construction stage and the instituting of augmented inservice inspection in IGSCC-sensitive lines in operating plants."

NUREG-0679, in citing such unfavorable field cracking experience, implicates environment and stress as IGSCC conducive factors which are unavoidable in boiling water reactor plants, with mitigation of IGSCC available only through control of the welding process and the use of more corrosion-resistant materials.

Opinion 1 is further rebutted by NUREG-0313, Rev. 1, (July 1980), "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," which recommends testing of materials and welding controls to minimize IGSCC.

"III. SUMMARY OF ACCEPTABLE METHODS TO MINIMIZE CRACK SUSCEPTIBILITY - MATERIAL SELECTION, TESTING, AND PROCESSING GUIDELINES

B. Testing of Materials

For new installation, tests should be made on all regular grade stainless steels to be used in the ASME Code Class 1, 2, and 3 piping systems to demonstrate that the material was properly annealed and is not susceptible to IGSCC. Tests that have been used to determine the susceptibility of IGSCC include Practices A* and E** of ASTM A-262, "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels" and the electrochemical potentiokinetic reactivation (EPR) test. The EPR test is not yet accepted by the NRC. If the EPR test is used, the acceptance criteria applied must be evaluated and accepted by the NRC on a case-by-case basis.

C. Processing of Materials

Corrosion-resistant cladding with a duplex microstructure (5% minimum ferrite) may be applied to the ends of Type 304 or 316 stainless steel pipe for the purpose of avoiding IGSCC at weldments. Such cladding, which is intended to (a) minimize the HAZ on the pipe inner surface, (b) move the HAZ away from the highly stressed region next to the attachment weld, and (c) isolate the weldment from the environment, may be applied under the following conditions:

1. For initial construction, provided that all of the piping is solution annealed after cladding.

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*Practice A - Oxalic acid etch test for classification of etch structures of stainless steels.

**Practice E - Copper-copper sulfate-sulfuric acid test for detecting susceptibility to intergranular attack in stainless steels.

acceptable only on the portion of the pipe that has not been

2. For repair welding and modification to in-place systems in operating plants and plants under construction. When the repair welding or modification requires replacement of pipe, the replacement pipe should be solution-annealed after cladding. Corrosion-resistant cladding applied in the "field" (i.e., without subsequent solution annealing of the pipe) is removed from the piping system. Other "field" applications of corrosion-resistant cladding are not acceptable.

Other processes that have been found by laboratory tests to minimize stresses and IGSCC in austenitic stainless steel weldments include induction heating stress improvement (IHSI) and heat sink welding (HSW). Although the use of these processes as an alternate to augmented inservice inspection is not yet accepted by the NRC, these processes may be permissible and will be considered on a case-by-case basis provided acceptable supportive data are submitted to the NRC."

Opinion 2. We do not doubt that some heats of type 304 can become sensitized enough by some welding processes using heat inputs of 110,000 Joules/inch to make them fail ASTM A262 and/or ASTM A393. This fact alone does not mean that they will fail in most BWR applications.

Rebuttal 2. This opinion is rebutted by NUREG-0679 which identifies welding as the primary cause of sensitization in BWR piping and NUREG-0313, Rev. 1, which recommends testing of materials and welding process controls to minimize IGSCC. NRC endorsement of these NUREGs indicates that a sufficient number of IGSCC failures have occurred to warrant an official acknowledgement that a IGSCC problem exists.

Opinion 3. Issuance of NUREG-0313 and NUREG-0313, Rev. 1 reports, which implement the Pipe Crack Study Group's recommendations, have in effect made the current R.G. 1.44 obsolete. The updating of R.G. 1.44, which was first proposed some time ago, should be now accorded high priority.

Opinion 4. NUREG-0313, Rev. 1 will be implemented on Class 1, 2, and 3 piping in all BWRs. It is clear that protection from problems with IGSCC in BWR piping is being provided by compliance with NUREG-0313, not compliance with every regulatory position of R.G. 1.44. In fact, R.G. 1.44 is not even mentioned in NUREG-0313, Rev. 1.

Rebuttal 3 & 4. The memorandum, Noonan to Tedesco, dated February 18, 1981, subject, "Compliance with NUREG-0313, Rev. 1, for BWR Operating License and Construction Permit Reviews", (Attached), stated that until an applicant demonstrates compliance with NUREG-0313, Rev. 1, the evaluation of the potential for intergranular stress corrosion cracking in BWR coolant pressure piping would be an open item in the plant safety evaluation report. The memorandum provided the input to be included in the SER to identify and describe the issue. This position, however, is not being implemented. The Shoreham SER, dated April 1980, for example, states in Section 4.5.1, "Control Rod System Structural Materials", Section 4.5.2, "Reactor Internal and Core Support Materials," and Section 5.2.6.4, "Fabrication and Processing of Austenitic Stainless Steel", that the intent of the recommendations of Regulatory Guide 1.44, have been met. This statement, then, seriously challenges the credibility of the SER. The credibility of the SER is further challenged by the fact that the Shoreham applicant has not, as yet at this date, responded to NUREG-0313, Rev. 1.

Opinion 5. Both the Shoreham and La Salle plants have made physical changes to their systems and have made commitments to do augmented inservice inspection in other areas. The staff has determined that Shoreham and La Salle are in compliance with the recommendations of NUREG-0313.

Rebuttal 5. The Shoreham and LaSalle applicants have yet, at this date, to respond to NUREG-0313, Rev. 1. Opinion 5, on this basis, is at best, ambiguous and inaccurate if interpreted within the context of NUREG-0313, Rev. 1 since there is no basis to conclude that Shoreham and La Salle are in compliance with the recommendations of NUREG-0313, Rev. 1.

The undersigned, in his expression of DIFFERING PROFESSIONAL OPINION, dated April 7, 1981, recommended that the matter addressed above be identified in BWR SER inputs as an open item until more definitive information is developed. At this time, he reiterates the recommendation.

In accordance with rights granted by NRCM 4125, the undersigned, the originator of the Differing Professional Opinion, requests that it be presented to an impartial RES peer review group for review, evaluation and comment.

Joseph Halapatz

cc: S. Pawlicki, MTEB