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U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 6.1.1 ENGINEERED SAFETY FEATURES METALLIC MATERIALS

REVIEW RESPONSIBILITIES

Primary - Materials Engineering Branch (MTEB)

Secondary - None

I. AREAS OF REVIEW

General Design Criteria 35, 38, and 41 of Appendix A of 10 CFR Part 50 require that emergency core cooling systems, containment heat removal systems, and containment atmosphere cleanup systems shall be provided as engineered safety features.

The following areas relating to general materials considerations in the design of these engineered safety features (ESF) and the chemistry of ESF coolants are reviewed:

1. Materials Selection and Fabrication
The materials selection and fabrication procedures used in the engineered safety features are reviewed. These systems include containment heat removal systems, containment air purification and cleanup systems, emergency core cooling systems (ECCS), and other ESF specific to an individual plant, as described in Section 6 of the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. The specific areas of review and review procedures are similar to those in Standard Review Plan 5.2.3, "Reactor Coolant Pressure Boundary Materials." The basis of the review is to assure compliance with Section III of the ASME Boiler and Pressure Vessel Code (hereafter "the Code"), control of welding procedures, control of the use of sensitized stainless steels, and compatibility of materials with the specific coolants used.

2. Composition and Compatibility of Containment and Core Spray Coolants
The composition of the containment and core spray coolants must be controlled to ensure their compatibility with materials in the containment building, including the reactor vessel, reactor internals, primary piping, and structural and insulating materials. These controls must be selected to maintain the integrity of the reactor coolant pressure boundary by preventing stress-corrosion cracking of safety-related components, and to prevent evolution of excessive amounts of hydrogen within the containment in the unlikely event of a loss-of-coolant accident.

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Containment and core spray solutions containing boron for reactivity control and other additives (such as thiosulfates) for reacting with gaseous fission products must be stable under long term storage conditions and during prolonged operation of the sprays.

II. ACCEPTANCE CRITERIA

The acceptance criteria for the areas of review described in Section I of this plan are as follows:

1. Materials Selection and Fabrication

Materials for use in ESF must be selected for their compatibility with core and containment spray solutions, as described in Section III of the Code, Articles NB-2160, and NB-3120. Mechanical properties must be as given in Appendix I to Section III of the Code, or parts A, B, and C of Section II of the Code, except that cold-worked austenitic stainless steels must have a maximum 0.2% offset yield strength of 90,000 psi, to minimize the probability of stress-corrosion cracking in these systems, as described in Reference 9.

Regulatory Guide 1.44, "Control of the Use of Sensitized Stainless Steel," describes acceptable criteria for preventing intergranular corrosion of stainless steel components of the ESF. Furnace-sensitized material should not be allowed in the ESF, and methods described in this guide should be followed for cleaning and protecting austenitic stainless steels from contamination during handling and storage, for testing materials prior to fabrication, and for ensuring that no deleterious sensitization occurs during welding.

Regulatory Guide 1.31, "Control of Stainless Steel Welding," describes acceptable criteria for assuring the integrity of welds in stainless steel components of the ESF. The control of delta ferrite content of weld filler metal as specified in this guide is modified by the Branch Technical Position MTEB 5-1 (Ref. 10), which sets forth an acceptable basis for delta ferrite content of weld filler metal.

The composition of nonmetallic thermal insulation for austenitic stainless steel components of ESF (if thermal insulation is used) should be controlled as described in Regulatory Guide 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel." Concentrations of leachable contaminants and added inhibitors should be controlled as specified in position C.2.b and Figure 1 of this guide to minimize the probability of stress-corrosion cracking of these components.

2. Composition and Compatibility of Containment and Core Spray Coolants

The compositions of containment spray and core cooling water should be controlled to ensure a minimum pH of 7.0, as given in the Branch Technical Position MTEB 6-1, Reference 11, attached. Experience has shown that maintaining the pH of borated solutions at this level will inhibit initiation of stress-corrosion cracking of austenitic stainless steel components for periods of more than seven months.

Hydrogen release within the containment because of corrosion of materials by the sprays in the event of a loss-of-coolant accident (LOCA) should be controlled as described in Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident." As the pH increases over 7.5, the rate of corrosion of aluminum increases. The amount of aluminum within the containment should therefore be controlled, and the amount of hydrogen that could be generated within the containment should be calculated as recommended in Regulatory Guide 1.7.

III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case.

To ascertain that the acceptance criteria given in Section II are met, the reviewer examines each of the review areas given in Section I for the required information, using the following procedure:

1. Materials Selection and Fabrication

   The reviewer compares the mechanical properties of the materials proposed for the ESF for their compliance with Appendix I of Section III of the Code, or with parts A, B, and C of Section II of the Code. He verifies that cold-worked austenitic stainless steels used in fabrication of the ESF are in conformance with Section II.1.

   The methods of controlling sensitized stainless steel in the ESF systems are examined by the reviewer and compared with the positions listed in Regulatory Guide 1.44, especially regarding cleaning and protection from contamination during handling and storage, verification of nonsensitization of the materials, and qualification of welding procedures using ASTM A-262-70 (Ref. 3). If alternative methods of testing the qualification welds for degree of sensitization are proposed by the applicant, the reviewer determines if these are satisfactory, based on the degree to which the alternate methods provide the needed results and on MTEB positions taken on previous applications. If necessary, the reviewer asks the applicant to justify technically his departures from the MTEB positions. Alternative tests that have been accepted by the MTEB include the use of ASTM A-393 (Ref. 4), for determining the degree of sensitization of the heat-affected zones (HAZ) of qualification welds, and the use of ASTM A-262-70 as amended by Westinghouse Process Specification 84201 MW (Ref. 5), for qualifying welds and testing raw materials for sensitization.

   The methods for controlling and measuring the amount of delta ferrite in stainless steel weld deposits are examined by the reviewer and compared with Regulatory Guide 1.31, "Control of Stainless Steel Welding," and the Branch Technical Position MTEB 5-1, especially regarding the acceptance procedures for delta ferrite content of filler metal and the examination of production welds. If alternative positions are proposed by the applicant, the reviewer determines if these are satisfactory, taking into consideration positions taken on previous applications. If necessary, the reviewer asks the applicant to justify technically his departures from the acceptance criteria stated in Section II.2.

The reviewer determines whether nonmetallic thermal insulation will be used on austenitic stainless steel components of the ESF, and if it is, he verifies that the amount of leachable impurities in the specified insulation lie within the "acceptable analysis" area of Figure 1 of Regulatory Guide 1.36, as discussed in the acceptance criteria, Section II.1.

The reviewer examines the information on the compatibility of the ESF materials of construction with the proposed ESF coolants to verify that all materials used are compatible with the coolants, as required by Articles NB-2160 and NB-3120 of Section III of the Code. The reviewer considers the composition of the sprays and any mixing processes that might occur during operation of the sprays.

2. Composition and Compatibility of Containment and Core Spray Coolants
The reviewer determines that the coolant sprays will have a minimum pH of 7.0 and reviews the methods of ascertaining that the pH will remain above this minimum during the operation of the sprays. In many instances, the ESF coolant solutions are stored in more than one form (such as a boric acid solution and a sodium hydroxide solution) and mixed only when the ESF are called upon to operate during an emergency. In some plants, the coolant is stored as a boric acid solution which is neutralized by (dry) sodium phosphates mounted in baskets inside the containment after the ESF sprays are activated. Consequently, the reviewer must examine the control of pH of such coolants, to evaluate the short-term (during the mixing process) compatibility and long-term compatibility of these sprays with all safety-related components within the containment.

The applicant's estimate of the amount of hydrogen generated within the containment by corrosion of materials is evaluated by the reviewer for conformance with Section II.2. He pays particular attention to the hydrogen generated by the corrosion of aluminum if the pH of the coolant is above 7.5. The review verifies that this estimate is realistic and conservative using the calculation methods outlined in the guide.

The reviewer examines the methods of storing the ESF coolants to determine whether deterioration will occur either by chemical instability or corrosive attack on the storage vessel. The reviewer determines what effects such deterioration could have on the compatibility of these ESF coolants with both the ESF materials of construction and the other materials within the containment.

3. General
If the information contained in the safety analysis reports or the plant Technical Specifications does not comply with the appropriate acceptance criteria, or if the information provided is inadequate to establish such compliance, a request for additional information is prepared and transmitted. Such requests identify not only the necessary additional information but also the changes needed in the SAR or the Technical Specifications. Subsequent amendments received in response to these requests are reviewed for compliance with the acceptance criteria.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided in accordance with the requirements of this review plan and that his evaluation supports conclusions of the following type, to be included in the staff's safety evaluation report:

"The mechanical properties of materials selected for the engineered safety features satisfy Appendix I of Section III of the ASME Code, or Parts A, B, and C of Section II of the Code, and the staff position that the yield strength of cold-worked stainless steels shall be less than 90,000 psi.

"The controls on the pH of the reactor containment sprays and the emergency core cooling water following a postulated loss-of-coolant accident are adequate to ensure freedom from stress-corrosion cracking of the austenitic stainless steel components and welds of the containment spray and emergency core cooling systems throughout the duration of the postulated accident to completion of cleanup. The controls on the use and fabrication of the austenitic stainless steel of the systems satisfy the requirements of Regulatory Guide 1.31, "Control of Stainless Steel Welding," and Regulatory Guide 1.44, "Control of the Use of Sensitized Stainless Steel." Fabrication and heat treatment practices performed in accordance with these requirements provide added assurance that stress-corrosion cracking will not occur during the postulated accident time interval. The control of the pH of the sprays and cooling water, in conjunction with controls on selection of containment materials, are in accordance with Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident," and provide assurance that the sprays and cooling water will not give rise to excessive hydrogen gas evolution by corrosion of containment metal or cause serious deterioration of the containment. (The controls placed on concentrations of leachable impurities in nonmetallic thermal insulation used on austenitic stainless steel components of the engineered safety features are in accordance with Regulatory Guide 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel.")* Conformance with the Codes and Regulatory Guides mentioned above, and with the staff positions on the allowable maximum yield strength of cold-worked austenitic stainless steel, and the minimum level of pH of containment sprays and emergency core cooling water constitute an acceptable basis for meeting applicable requirements of General Design Criteria 35, 38, and 41."

V. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 35, "Emergency Core Cooling," Criterion 38, "Containment Heat Removal," and Criterion 41, "Containment Atmosphere Cleanup."

2. ASME Boiler and Pressure Vessel Code, Section II, Parts A, B, and C, and Section III, Articles NB-2160 and NB-3120, and Appendix I, American Society of Mechanical Engineers.

*The sentence in parenthesis is to be included only if nonmetallic thermal insulation is to be used on ESF piping.

3. ASTM A-262-70, Practice E, "Copper-Copper Sulfate-Sulfuric Acid Test for Detecting Susceptibility to Intergranular Attack in Stainless Steel," Annual Book of ASTM Standards, Part 3, American Society for Testing and Materials.

4. ASTM A-393-63, "Recommended Practice for Conducting Acidified Copper Sulfate Test for Intergranular Attack in Austenitic Stainless Steel," Annual Book of ASTM Standards, Part 3, American Society for Testing and Materials.

5. Process Specification 84201 MW, "Corrosion Testing of Wrought Austenitic Stainless Steel Alloy," Westinghouse Electric Corporation.

6. Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident."

7. Regulatory Guide 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel."

8. Regulatory Guide 1.44, "Control of the Use of Sensitized Steel."

9. Standard Review Plan 5.2.3, "Reactor Coolant Pressure Boundary Materials."

10. Branch Technical Position MTEB 5-1, "Interim Position on Regulatory Guide 1.31, 'Control of Stainless Steel Welding'," appended to Standard Review Plan 5.2.3.

11. Branch Technical Position MTEB 6-1, "pH for Emergency Coolant Water," appended.

BRANCH TECHNICAL POSITION MTEB 6-1

pH FOR EMERGENCY COOLANT WATER

A. Background

In response to a Technical Assistance Request, dated April 20, 1972, needed to establish the minimum value of pH in post-accident containment sprays for the Fort Calhoun Station, the Materials Engineering Branch, reviewed the available information and recommended the criteria listed in the Branch Technical Position, below.

The minimum pH value of 7.0 follows from the Westinghouse report (Ref. 1) conclusion that in ECCS solutions adjusted with NaOH to pH 7.0 or greater, no cracking should be observed at chloride concentrations up to 1000 ppm during the time of interest. Figure 7 of the Westinghouse report shows that time for initiation of cracking of sensitized and nonsensitized U-bend specimens of Type 304 austenitic stainless steel in solutions of 7.0 pH having 100 ppm chloride was seven and one half months and ten months, respectively. These time periods are more than ample time to allow cleanup after the hypothetical design basis accident.

The great majority of tests reported in the Oak Ridge report, Reference 2, were performed with pH of 4.5, and only two tests were conducted with pH's other than 4.5. Some cracking was observed at pH 7.5 in the sensitized 304 stainless steel U-bend specimens after two months exposure to pH = 7.5 and chloride concentration of 200 ppm. All of the 316 stainless steel specimens showed no evidence of cracking. Considering the fact that in U-bend specimens the material was sensitized, stressed beyond yield, and plastically deformed, we conclude that the reported test conditions were much more severe than the stress conditions likely to exist in the post-accident emergency coolant systems.

We agree with the Oak Ridge conclusion that absolute freedom from failure of any complex system such as a spray system can never be guaranteed, but by proper design, fabrication, and control of the corrosive environment, the probability of failure can be significantly reduced. Our recommended minimum pH of 7 is somewhat higher than Oak Ridge recommendation of a minimum of 6.5.

B. Branch Technical Position

MTEB criteria for pH level of post-accident emergency coolant water to minimize the probability of stress-corrosion cracking of austenitic stainless steel components, non-sensitized or sensitized, not stressed or stressed, are as follows:

1. Minimum pH should be 7.0.

2. The higher the pH (in the 7.0 to 9.5 range) the greater the assurance that no stress corrosion cracking will occur.

3. If a pH greater than 7.5 is used, consideration should be given to the hydrogen generation problem from corrosion of aluminum in the containment.

C. References

1. D. D. Whyte and L. F. Picone, "Behavior of Austenitic Stainless Steel in Post Hypothetical Loss of Coolant Environment," WCAP-7798-L, Westinghouse Nuclear Energy Systems, November 1971 (NES Proprietary Class 2).

2. J. C. Griess and G. E. Creek, "Design Considerations of Reactor Containment Spray Systems - Part X, The Stress Corrosion Cracking of Types 304 and 316 Stainless Steel in Boric Acid Solutions," ORNL-TM-2412, Part X, Oak Ridge National Laboratory, May 1971.

SRP 6.1.2