U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 5.4.2.1 STEAM GENERATOR MATERIALS

REVIEW RESPONSIBILITIES

Primary - Materials Engineering Branch (MTEB)

Secondary - None

I. AREAS OF REVIEW

General Design Criteria 14, 15, and 31 of Appendix A of 10 CFR Part 50 require that the reactor coolant pressure boundary (RCPB) must have an extremely low probability of abnormal leakage and must be designed with sufficient margin to assure that the design conditions are not exceeded during normal operation and anticipated operational occurrences, and that the probability of rapidly propagating failure of the RCPB is minimized.

A review is made of the following areas, reported in the applicant's safety analysis report (SAR). These are all related to the ASME Boiler and Pressure Vessel Code (hereafter "the Code") Class 1 and 2 materials of pressurized water reactor (PWR) steam generators, including all components that constitute part of the reactor coolant pressure boundary.

1. Selection and Fabrication of Materials

The materials selected for the steam generator are reviewed.

Materials for components of the steam generator are divided into two classes: Class 1, which includes material for those parts exposed to the primary reactor coolant, and Class 2, which includes materials for parts exposed to the secondary coolant water.

Class 1 component materials include the following:

Inconel 600 Tubing	-	ASME SB-163, Ni-Cr-Fe, Annealed
Carbon Steel Tube Sheet	-	ASME SA-533, Grade A, weld-clad with Inconel 600 on the primary coolant side
Channel Head Casting or	-	ASME-SA-216, Grade WCC, Class 1, weld-clad with austenitic stainless steel
Channel Head Plate	-	ASME - SA-533, Grade A, B, or C
Forged Nozzles	-	ASME SA-503, Class 2

Class 2 component materials include the following:

Shell Pressure Plates	-	ASME - SA-533, Grade A, B, or C, Class 2
Bolting	-	ASME SA-193, Grade B-7
		ASME SA-540, Grade B 23 or B 24

The Inconel-600 tubes are commonly welded to the tube-sheet cladding and expanded into the tube sheet by rolling or explosive-expanding (explanding). Full depth expansion is the preferred design, especially for "U"-tubed steam generators.

The adequacy and suitability of the ferritic materials are reviewed. The fracture toughness properties and requirements for Class 1 and Class 2 ferritic components are reviewed.

2. Steam Generator Design

The extent of crevice areas in the design of the steam generator is reviewed.

3. Compatibility of the Steam Generator Components with the Primary and Secondary Coolant

The possibility of stress-corrosion cracking and wastage of the tubes as determined by the chemistry of both the primary and secondary coolants are reviewed. The methods to be used in monitoring and maintaining the chemistry of the secondary coolant within the specified ranges are reviewed. The compatibility of ferritic low alloy steels and carbon steels with the primary and secondary coolants is reviewed.

II. ACCEPTANCE CRITERIA

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

1. Selection and Fabrication of Materials

The mechanical properties of the materials selected for the steam generator components must meet the Code requirements given in Appendix I of Section III and Parts A, B, and C of Section II. The corrosion-resistant weld-deposited cladding on the tube sheet must be made and inspected according to the requirements given in Article QW-214 of Section IX of the Code. The tubes in U-tubed steam generators must be rolled or "explanded" for the full depth of the tube sheet to avoid the presence of a deep crevice between the tube and tube sheet, as recommended in the Branch Technical Position MTEB 5-3, "Monitoring of Secondary Side Water Chemistry in PWR Steam Generators" (Ref. 7), appended. Onsite cleaning and cleanliness control should be in accordance with the position given in Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants" (Ref. 4), and in ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components For Nuclear Power Plants" (Ref. 3). The welds between the tubes and the tube sheet must meet the requirements of Section III and Section IX of the Code. Any materials designed to code-case requirements must meet the requirements given in Regulatory Guide 1.85, "Code-Case Acceptability-Materials" (Ref. 5).

The fracture toughness of ferritic materials used for Class 1 components in the steam generator must meet the requirements of Article NB-2300 of Code Section III, and Appendix G, Paragraph G-2000.

The fracture toughness properties of the ferritic materials selected for Class 2 components in the steam generator must meet the requirements of paragraph NC-2310 of the Summer 1972 Addenda to Section III of the Code, which state that the test requirements and acceptance standards for Class 2 components must be the same as specified for Class 1 components. Paragraph NB-2332(b) states that for Class 2 components greater than 2 1/2 in. wall thickness, the lowest service temperature must not be less than the nil-ductility transition reference temperature, RT_{NDT}, plus 100°F, unless a lower temperature is justified by methods similar to those contained in Article G-2000 of the Summer 1972 Addenda to Section III.

2. Steam Generator Design

The steam generators must be designed to avoid extensive crevice areas where the tubes pass through the tube sheet, and where the tubes pass through tubing supports, as indicated in Branch Technical Position MTEB 5-3 (Ref. 7).

3. Compatibility of The Steam Generator Tubing with the Primary and Secondary Coolant

The acceptance criteria for primary coolant chemistry are given in Standard Review Plan 5.2.3, "RCPB Materials." The secondary coolant purity should be monitored as described in Reference 7.

III. REVIEW PROCEDURES

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

For each area of review, the following review procedure is followed:

1. Selection and Fabrication of Materials

The reviewer examines the materials and fabrication procedures as given in the SAR for Class 1 and Class 2 components of the steam generators, to determine the degree of conformance with the acceptance criteria stated in Section II.1. The reviewer verifies that the tubes are properly welded and expanded into the tube sheet, that proper care is taken to maintain cleanliness during fabrication, assembly, and installation of the unit, and that information relative to impact tests is in conformance with the acceptance criteria stated in Section II.1.

2. Steam Generator Design

The reviewer examines the design of the steam generators to verify that tight crevice areas where tubes pass through the tube supports are minimized, as discussed in Section II.2.

3. Compatibility of the Steam Generator Tubing with the Primary and Secondary Coolant

The reviewer examines the controls to be placed on the composition of the primary and secondary coolants to determine that they meet the acceptance criteria cited in Section II.3.

4. 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 need for 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 is 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 materials used in Class I and Class 2 components of the steam generators were selected and fabricated according to codes, standards, and specifications acceptable to the staff. The onsite welding and cleanliness controls during fabrication conform to the recommendations of Regulatory Guide 1.37, "Cleaning of Fluid Systems and Associated Components during the Construction Phase of Nuclear Power Plants." The controls placed on secondary coolant chemistry are in agreement with established staff technical positions. Conformance with applicable codes, standards, staff positions, and Regulatory Guides constitutes an acceptable basis for meeting in part the requirements of General Design Criteria 14, 15, and 31."

V. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary," Criterion 15, "Reactor Coolant System Design," and Criterion 31, "Fracture Prevention of The Reactor Coolant Pressure Boundary."

2. ASME Boiler and Pressure Vessel Code, Part A of Section II, Appendix I of Section III, and Section IX, American Society of Mechanical Engineers.

3. ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components For Nuclear Power Plants," Draft 2, Revision 0, November 15, 1973, American National Standards Institute.

4. Regulatory Guide 1.37, "Quality Assurance Requirements of Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants."

5. Regulatory Guide 1.85, "Code Case Applicability-Material."

6. Standard Review Plan 5.2.3, "RCPB Materials."

7. Branch Technical Position MTEB 5-3, "Monitoring of Secondary Side Water Chemistry in PWR Steam Generators," appended.

BRANCH TECHNICAL POSITION MTEB 5-3

MONITORING OF SECONDARY SIDE WATER
CHEMISTRY IN PWR STEAM GENERATORS

A. BACKGROUND

In view of the extensive history of stress corrosion or wastage of steam generator tubing in operating PWR's, we recommend the following criteria.

B. Branch Technical Position

1. Crevices between the tubing and the tube sheets or tubing supports should be minimized to prevent concentration of impurities or solids in these areas. Steam generators incorporating Inconel 600 tubes should be designed and built to achieve this goal.

2. The methods utilized for control of secondary side water chemistry should be described. In plants having more than one steam generator, additives to each steam generator should be controlled separately. Records should be made of the following items, and summaries of the data should be available for report as requested by the Commission.

   a. For plants utilizing volatile chemistry:
      (1) The composition, quantities, and rates of addition of additives should be recorded initially and whenever a change is made.
      (2) The electrical conductivity and the pH of the bulk steam generator water and feedwater should be measured continuously.
      (3) For once-through steam generators, the pH and electrical conductivity at the coolant inlet should be measured continuously.
      (4) Free hydroxide concentration and impurities (particularly chloride, ammonia and silica) in the steam generator water should be measured at least three times per week (daily if serious condenser leakage is occurring).
      (5) The electrical conductivity of the condensate should be measured at least once weekly (daily if serious condenser leakage is occurring).
      (6) The condenser leakage should be measured at least daily in freshwater-cooled plants, and continuously in seawater-cooled plants.

   b. For older plants still utilizing phosphate treatment:
      (1) The composition, quantity, and rate of addition of each additive should be recorded initially and whenever a change is made.
      (2) The Na/PO_4 molar ratio of the secondary coolant should be recorded initially and whenever a change is made.
      (3) The electrical conductivity and pH of the bulk steam generator water and feedwater should be measured continuously.
      (4) The concentration of suspended/dissolved solids and impurities (particularly free caustic, chloride, silica, and sodium) in the steam generator water should be measured daily.

(5) The concentration of dissolved solids (particularly sodium and phosphate) in the blowdown liquid should be measured once each week.

(6) The rate of blowdown should be recorded initially and whenever a change in rate is made.

(7) The hideout and reverse hideout of phosphate should be recorded. The phosphate concentration in each steam generator (or in one steam generator if this is shown to be representative of all) and in the blowdown liquid should be measured before and after each planned power level change of 10% or greater, and should be measured after each unplanned power level change of 20% or greater.

(8) The condenser leakage should be measured at least daily in freshwater-cooled plants and continuously in seawater-cooled plants.

SRP 5.4-6