UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20055

January 25, 1988

TO ALL LICENSEES OF OPERATING BOILING WATER REACTORS (BWRS), AND HOLDERS OF CONSTRUCTION PERMITS FOR BWRS

Gentlemen:

SUBJECT: NRC POSITION ON IGSCC IN BWR AUSTENITIC STAINLESS STEEL PIPING (Generic Letter 88-01)

Intergranular stress corrosion cracking (IGSCC) near weldments in BWR piping has been occurring for almost 20 years. Early cases were in relatively small diameter piping. In early 1982, cracking was identified in large-diameter piping in a recirculation system of an operating BWR plant in this country. Since then, extensive inspection programs have been conducted on BWR piping systems. These inspections have resulted in the detection of significant numbers of cracked weldments in almost all operating BWRs.

A number of domestic and foreign BWR owners have replaced or plan to replace piping systems that have experienced IGSCC with more resistant material. Other owners are implementing countermeasures such as Stress Improvement (SI) or Hydrogen Water Chemistry (HWC) to reduce the susceptibility of the piping to IGSCC. In many cases, cracked weldments have been repaired by reinforcing them with weld overlay.

Substantial efforts in research and development have been sponsored by the BWR Owners Group for IGSCC Research. The results of this program, along with other related work by vendors, consulting firms, and confirmatory research sponsored by the NRC, have permitted the development of revised Staff Positions regarding the IGSCC problems.

The technical bases for these positions are detailed in NUREG-0313, Rev. 2 "Technical Report on Material Selection and Process Guidelines for BWR Coolant Pressure Boundary Piping." This revision to NUREG-0313 was a major task in the staff long range plan to deal with BWR pipe cracking that was presented to the Commission in SECY 84-301. This revision includes the relevant recommendations of the Piping Review Committee Task Group on Pipe Cracking issued as NUREG- 1061, Vol. 1, "Report of USNRC Piping Review Committee", and consideration of public comments on that document. NUREG-0313, Rev. 2 describes the technical bases for the staff positions on materials, processes, and primary coolant chemistry to minimize and control IGSCC problems. Inspection schedules and inspection sample sizes are based on the susceptibility of weldments to initiation and propagation of IGSCC. Inspection schedules are comparable to those specified in Section XI of the ASME Boiler and Pressure Vessel Code in cases where the piping material is IGSCC resistant. Varying amounts of augmented inspections are specified for piping with a greater susceptibility to cracking, where there is less certainty about the effectiveness of mitigation measures used, or in cases where repairs have been performed. When improved water chemistry control with hydrogen additions is implemented, less augmentation of inspection schedules is required.

The purpose of this Generic Letter is to seek information regarding

implementation of the new staff positions covering these technical areas. This Generic Letter supersedes Generic Letter 84-11, "Inspection of BWR Stainless Steel Piping."

This Generic Letter applies to all BWR piping made of austenitic stainless steel that is four inches or larger in nominal diameter and contains reactor coolant at a temperature above 200xF during power operation regardless of Code classification. It also applies to reactor vessel attachments and appurtenances such as jet pump instrumentation penetration assemblies and head spray and vent components.

This Generic Letter does not apply to piping made of carbon steel classified as P-1 by the ASME Boiler and Pressure Vessel Code.

Staff Positions have been developed covering the following subjects:

1. Staff Position on Materials
2. Staff Position on Processes
3. Staff Position on Water Chemistry
4. Staff Position on Weld Overlay Reinforcement
5. Staff Position on Partial Replacement
6. Staff Position on Stress Improvement of Cracked Weldments
7. Staff Position on Clamping Devices
8. Staff Position on Crack Characterization and Repair Criteria
9. Staff Position on Inspection Methods and Personnel
10. Staff Position on Inspection Schedules
11. Staff Position on Sample Expansion
12. Staff Position on Leak Detection
13. Staff Position on Reporting Requirements

These Staff Positions are fully delineated in Attachment A to this letter.

The staff continues to believe that replacing susceptible piping with IGSCC resistant materials will provide the greatest degree of assurance against future cracking problems. Licensees may follow Generic Letter 84-07, "Procedural Guidance for Pipe Replacements at BWRs"; the staff encourages programs to replace degraded piping so as to reduce the potential for cracking and to minimize the need for augmented inspections. However, the staff recognizes that, if the staff positions of this Generic Letter are implemented, adequate levels of piping integrity and reliability can be achieved. The staff believes this Generic Letter, together with the revision to NUREG-0313, will be of use to licensees in making sound decisions regarding IGSCC. Each weldment can be evaluated considering its material, heat treatment history, stress level, chemical environment and surveillance program. This will provide a basis for a reasonable judgment regarding the long-term acceptability of that weldment. Considering that each piping system has many weldments and each plant has many piping systems, the entire problem must be evaluated in an integrated way.

The Commission has determined that, unless appropriate remedial actions are taken, BWR plants may not be in conformance with their current design and licensing bases, including 10 CFR 50, Appendix A, General Design Criteria 4, 14, and 31.

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Accordingly, pursuant to 10 CFR 50.54(f), you, as a BWR operating reactor licensee or construction permit holder, are requested, to furnish, under oath or affirmation, your current plans relating to piping replacement, inspection, repair, and leakage detection. Your response should indicate whether you intend to follow the staff positions included in this letter, or propose alternative measures. This information is needed for the Commission to determine whether an operating license should be issued, or if you hold an operating license, whether it should be modified or revoked.

An acceptable response to this letter would include the following specific items:

1. Your current plans regarding pipe replacement and/or other measures taken or to be taken to mitigate IGSCC and provide assurance of continued

long term piping integrity and reliability.

2. An Inservice Inspection (ISI) Program to be implemented at the next refueling outage for austenitic stainless steel piping covered under the scope of this letter that conforms to the staff positions on inspection schedules, methods and personnel, and sample expansion included in this letter.

3. A change to the Technical Specifications to include a statement in the section on ISI that the Inservice Inspection Program for piping covered by the scope of this letter will be in conformance with the staff positions on schedule, methods and personnel, and sample expansion included in this letter (see enclosed model BWR Standard Technical Specification). It is recognized that the Inservice Inspection and Testing sections may be removed from the Technical Specifications in the future in line with the Technical Specifications Improvement programs. In this case, this requirement shall remain with the ISI section when it is included in an alternative document.

4. Confirmation of your plans to ensure that the Technical Specification related to leakage detection will be in conformance with the staff position on leak detection included in this letter.

5. In accordance with 10CFR50.55a(o), your plans to notify the NRC of any flaws identified that do not meet IWB-3500 criteria of Section XI of the Code for continued operation without evaluation, or a change found in the condition of the welds previously known to be cracked, and your evaluation of the flaws for continued operation and/or your repair plans.

Licensees and construction permit holders for BWR plants are requested to respond to this generic letter within 180 days of receipt of this letter. NRC review of your submittal of information in response to this letter is not subject to fees under the provisions of 10 CFR 170. However, should you, as part of your response or in a subsequent submittal, include an application for license amendment or other action requiring NRC approval, it is subject to the fee requirements of 10 CFR 170 with remittance of an application fee of $150 per application (Sections 170.12(c) and 170.21) and subsequent semi-annual payments until the review is completed or the ceiling in Section 170.21 is reached.

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This request for information was approved by the Office of Management and Budget under clearance number 3150-0011 which expires December 31, 1989. Comments on burden and duplication may be directed to the Office of Management and Budget, Reports Management Room 3208, New Executive Office Building, Washington, D.C. 20503.

Sincerely,

Frank J. Miraglia, Jr.
Associate Director for Projects
Office of Nuclear Reactor Regulation

Enclosures:
1. Staff Positions on IGSCC In BWR Austenitic Stainless Steel Piping
2. Model BWR Standard Technical Specification for Item 3 of this Generic Letter
3. NUREG-0313, Revision 2

(ATTACHMENT A)

STAFF POSITIONS ON IGSCC IN BWR AUSTENITIC STAINLESS STEEL PIPING

Scope

These Staff Positions apply to all BWR piping made of austenitic stainless steel that is four inches or larger in nominal diameter and contains reactor coolant at a temperature above 200xF during power operation

regardless of Code classification. It also applies to reactor vessel attachments and appurtenances such as jet pump instrumentation penetration assemblies and head spray and vent components.

This Generic Letter does not apply to piping made of carbon steel classified as P-1 by the ASME Boiler and Pressure Vessel Code.

Staff Position on Materials

Materials considered to be resistant to sensitization and IGSCC in BWR piping systems are:

(1) Low carbon wrought austenitic stainless steel, which includes types 304L, 304NG, 316NG and similar low carbon grades with a maximum carbon content of 0.035%. Type 347, as modified for nuclear use, will be resistant with somewhat higher carbon content, the usual maximum of 0.04% is adequate. These materials must be tested for resistance to sensitization in accordance with ASTM A262-A or -EI or equivalent standard.

(2) Low carbon weld metal, including types 308L, 316L, 309L and similar grades, with a maximum carbon content of 0.035% and a minimum of 7.5% ferrite (or 7.5 FN) as deposited. Low carbon weld metal especially developed for joining modified type 347 Is also resistant as deposited.

Welds joining resistant material that meet the ASME Boiler and Pressure Vessel Code requirement of 5% ferrite (or 5 FN) but are below 7.5% ferrite (or 7.5 FN) may be sufficiently resistant, depending on carbon content and other factors. These will be evaluated on an individual case basis.

(3) Piping weldments are considered resistant to IGSCC if the weld heat affected zone on the inside of the pipe is protected by a cladding of resistant weld metal. This is often referred to as corrosion resistant cladding (CRC).

(4) Cast austenitic stainless steel with a maximum of 0.035% carbon and a minimum of 7.5% ferrite (or 7.5 FN). Weld joints between resistant piping and cast valve or pump bodies that do not meet these requirements are considered to be special cases, and are covered in the Staff Position on Inspection Schedules below.

(5) Austenitic stainless steel piping that does not meet the requirements of (1) above is considered to be resistant if it is given a solution heat treatment after welding.

(6) Other austenitic materials, including nickel base alloys such as Inconel 600, will be evaluated on an individual case basis. Inconel 82 is the only commonly used nickel base weld metal considered to be resistant.

It is the staff position that no austenitic material is resistant to cracking in the presence of a crevice, such as formed by a partial penetration weld, where the crevice is exposed to reactor coolant.

Staff Position on Processes

The processes considered to provide resistance to IGSCC in BWR piping welds are:

(1) Solution Heat Treatment (SHT)

(2) Heat Sink Welding (HSW)

Either of these two processes will upgrade non-resistant material to IGSCC Category A (see Table 1)

(3) Stress Improvement (SI)

Either of the following processes will upgrade non-resistant material to IGSCC Category B or C (See Table 1)

a. Induction Heating Stress Improvement (IHSI)
b. Mechanical Stress Improvement Process (MSIP)

Last pass heat sink welding (LPHSW) is not considered to be fully effective.

Staff Position on Water Chemistry

The use of hydrogen water chemistry, together with stringent controls on conductivity, will inhibit the initiation and growth of IGSCC. However, the responses of BWRs to hydrogen injection differs from plant to plant, and the development and verification of a generic HWC specification is not yet complete. For these reasons, reductions in piping inspection frequencey based on the use of HWC will be considered on an individual case bases at the present time. Staff criteria for evaluating the effectiveness of water chemistry improvements are under development, and will be available prior to general use of the HWC option. If fully effective HWC is maintained, a factor Categories B, C, D, and E weldments. (See Table 1)

Staff Position on Weld Overlay Reinforcement

Cracked weldments that are reinforced with weld overlay are acceptable for short-term operation, and may be considered for longer term operation provided:

(1) The overlayed weldments are in conformance with the criteria of IWB 3600 of Section XI of the 1986 Edition of the ASME Boiler and Pressure Vessel Code, and

(2) they are inspected in conformance with the Staff Position on Inspection Methods and Personnel, by UT examiners and procedures qualified to inspect overlayed welds.

Staff Position on Partial Replacement

If portions of cracked piping are replaced in the course of repair, the replaced portions will be subjected to inservice inspection requirements that will depend on the materials and processes used. All relevant staff positions of this Generic Letter will apply.

Staff Position on Stress Improvement SI of Cracked Weldments

Stress Improvement is also considered to be an effective mitigation process when applied to weldments with short or shallow cracks. Specifically, welds with cracks that are no longer than 10% of the circumference, and are no deeper than 30% of the wall thickness will be considered to be mitigated by SI.

SI is only considered to be effective if it is followed by a qualified UT examination, and if cracks are found, they must be sized both in depth and length, by procedures and personnel qualified to perform sizing evaluations:

Staff Position on Clamping Devices

Clamping devices may be used for temporary reinforcement of cracked weldments. Each case must be reviewed and approved on an individual basis.

Staff Position on Crack Evaluation and Repair Criteria.

Methods and criteria for crack evaluation and repair should be in conformance with IBW-3600 of Section XI of the 1986 Edition of the ASME Boiler and Pressure Vessel Code.

Evaluation of cracks for continued operation without repair requires that crack growth calculation be performed. As some details are not yet provided in the Code, the following will be acceptable to the staff.

The crack growth rate (da/dt) selected for use by the staff is expressed as:

da/dt = 3.590 x 10E-8 x K(I)**2.161 inches per hour

where

K(I) is the applied stress intensity factor (Ksi * SQRT(in))

Linear elastic solutions for KI are required for crack growth calculations. Any standard method is acceptable, for example, those described in the ASME Boiler and Pressure Vessel Code, Section XI, Appendix A. The axial residual stress distribution considered acceptable by the staff for large diameter pipes (12 inches and larger) is described by the following nondimensional expression.

e/e(i) = SUM(from j=0 to j=4) of e(j) E**j

where

eo = 1.0
e1 = 6.920
e2 = 8.687
e3 = 0.480
e4 = -2.027
E = x/t
e(i) = stress magnitude at E = 0 (inner surface)

The above formula permits calculation of the residual stress value at any point (x) through the vessel wall thickness (t) as a function of the peak residual stress value at the inside diameter (ID), e(i).

Technical basis and additional discussion related to evaluation and repair are given in NUREG 0313 Revision 2.

Staff Position on Inspection Methods and Personnel

Examinations performed under the Scope of this letter should comply with the applicable Edition and Addenda of the ASME Code, Section XI, as specified in paragraph (9), "Inservice Inspection Requirements" of 10CFR50.55a, Codes and Standards, or as otherwise approved by the NRC.

In addition, the detailed procedure, equipment and examination personnel shall be qualified by a formal program approved by the NRC such as that being conducted in accordance with the NDE Coordination Plan agreed upon by NRC, EPRI, and the Boiling Water Reactor Owners Group for IGSCC Research, being implemented at the EPRI NDE Center in Charlotte, North Carolina.

A summary of the Staff Position on Inspection Schedules is given in Table 1. Additional details and definitions are provided below. NUREG-0313, Rev. 2, Section 5 provides background information and technical bases.

(1) Welds of resistant material, IGSCC Category A, shall as a minimum be examined according to an extent and frequency comparable to that specified in applicable provisions of Section XI of the ASME Boiler and Pressure Vessel Code, as reflected in Table 1, attached. The selection of specific welds to be included in this sample is the responsibility of the Licensee, and should include considerations of stress levels, piping configurations, weld details, etc, and should represent his best judgement regarding selection of a representative and meaningful sample.

The provisions of 10CFR50.55a, (b),(2),(ii) may be invoked if it is determined necessary to use the 1974 edition of the Code to permit a meaningful sample selection.

(2) Although castings with higher carbon content than 0.035% are not considered to be resistant to sensitization, welds joining such castings (in the form of pump and valve bodies) to piping have been relatively free of IGSCC. This may be attributed to a favorable residual stress distribution, as calculations have indicated. For this reason, welds joining resistant material to pumps and valves will be considered to be resistant welds, and included in IGSCC Category A. If extensive weld repairs were performed the residual stress may be unfavorable, in which case such welds should be included in Category D.

(3) Welds that have been treated by SI or reinforced by weld overlay that are classified as IGSCC Category F because they do not meet the applicable staff positions may be upgraded to Category E if no adverse change in crack condition is found after 4 successive examinations.

Staff Position on Sample Expansion

If one or more cracked welds in IGSCC Categories A, B, or C, are found by a sample inspection during the 10 year interval, an additional sample of the welds in that category shall be inspected, approximately equal in number to the original sample. This additional sample should be similar in distribution (according to pipe size, system, and location) to the original sample, unless it is determined that there is a technical reason to select a different distribution. If any cracked welds are found in this sample, all of the welds in that IGSCC Category should be inspected.

If significant crack growth or additional cracks are found during the inspection of an IGSCC Category E weld, all other Category E welds should be examined.

a) Significant crack growth for overlayed welds is defined as crack extension to deeper than 75% of the original wall thickness, or for cracks originally deeper than 75% of the pipe wall, evidence of crack growth into the effective weld overlay.

b) Significant crack growth for SI mitigated Category E welds is defined as growth to a length or depth exceeding the criteria for SI mitigation (either 10% of circumference in length or 30% of the wall in depth).

Staff Position on Leak Detection

Leakage detection systems should be in conformance with Position C of Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems," or as otherwise previously approved by the NRC.

1. Plant shutdown should be initiated for inspection and corrective action when, within any period of 24 hours or less, any leakage detection system indicates an increase in rate of unidentified leakage in excess of 2 gpm or its equivalent, or when the total unidentified leakage attains a rate of 5 gpm or equivalent, whichever occurs first. For sump level monitoring systems with fixed-measurement-interval methods, the level should be monitored at approximately 4-hour intervals or less.

2. Unidentified leakage should include all leakage other than:

(a) leakage into closed systems, such as pump seal or valve packing leaks that are captured, flow metered, and conducted to a sump or collection tank, or

(b) leakage into the containment atmosphere from sources that are both specifically located and known either not to interfere with the operations of unidentified leakage monitoring systems or not to be from a through wall crack in the piping within the reactor coolant pressure boundary.

3. For plants operating with any IGSCC Category D, E, F, or G welds, at least one of the leakage measurement instruments associated with each

sump shall be operable, and the outage time for inoperable instruments shall be limited to 24 hours, or immediately initiate an orderly shutdown.

If any cracks are identified that do not meet the criteria for continued operation without evaluation given in Section XI of the Code, NRC approval of flaw evaluations and/or repairs in accordance with IWB 3640 and IWA 4130 is required before resumption of operation.

TABLE 1

SUMMARY OF INSPECTION SCHEDULES FOR BWR PIPING WELDMENTS

DESCRIPTION OF WELDMENTS	NOTES	IGSCC CATEGORY	INSPECTION EXTENT & SCHEDULE
Resistant Materials		A	25% every 10 years (at least 12% in 6 years)
Non-resistant Matls SI within 2 yrs of operation (1)	(1)	B	50% every 10 years (at least 25% in 6 years)
Non-resistant Matls SI after 2 years of operation	(1)	C	All within the next 2 refueling cycles, then all every 10 years (at least 50% in 6 years)
Non-resistant Matls No SI	(1)	D	All every 2 refueling cycles
Cracked Reinforced by weld overlay or mitigated by SI	(1)(2)	E	50% next refueling outage, then all every 2 refueling cycles
Cracked Inadequate or no repair	(2)	F	All every refueling outage
Non-Resistant Not Inspected	(3)	G	All next refueling outage

Notes:

(1) All welds in non-resistant material should be inspected after a stress improvement process as part of the process. Schedules shown should be followed after this initial inspection.

(2) See recommendations for acceptable weld overlay reinforcements and stress improvement mitigation.

(3) Welds that are not UT inspectable should be replaced, "sleeved", or local leak detection applied. RT examination or visual inspection for leakage may also be considered.

(Attachment B)

Model BWR Standard Technical Specification
for Item 3 of Generic Letter 88-01

APPLICABILITY

SURVEILLANCE REQUIREMENTS

4.0.1 Surveillance Requirements shall be met during the OPERATIONAL CONDITIONS or other conditions specified for individual Limiting Conditions for Operation unless otherwise stated in an individual Surveillance Requirement.

4.0.2 Each Surveillance Requirement shall be performed within the specified time interval with:

a. A maximum allowable extension not to exceed 25% of the surveillance interval, but

b. The combined time interval for any 3 consecutive surveillance intervals shall not exceed 3.25 times the specified surveillance interval.

4.0.3 Failure to perform a Surveillance Requirement within the specified time interval shall constitute a failure to meet the OPERABILITY requirements for a Limiting Condition for Operation. Exceptions to these requirements are stated in the individual Specifications. Surveillance requirements do not have to be performed on inoperable equipment.

4.0.4 Entry into an OPERATIONAL CONDITION or other specified applicable condition shall not be made unless the Surveillance Requirement(s) associated with the Limiting Condition for Operation have been performed within the applicable surveillance interval or as otherwise specified.

4.0.5 Surveillance Requirements for inservice inspection and testing of ASME Code Class 1, 2, & 3 components shall be applicable as follows:

a. Inservice inspection of ASME Code Class 1, 2, and 3 components and inservice testing of ASME Code Class 1, 2, and 3 pumps and valves shall be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel Code and applicable Addenda as required by 10 CFR 50, Section 50.55a(g), except where specific written relief has been granted by the Commission pursuant to 10 CFR 50, Section 50.55a(g) (6) (i)

b. Surveillance intervals specified in Section XI of the ASME Boiler and Pressure Vessel Code and applicable Addenda for the inservice inspection and testing activities required by the ASME Boiler and Pressure Vessel Code and applicable Addenda shall be applicable as follows in these Technical Specifications:

ASME Boiler and Pressure Vessel Code and applicable Addenda terminology for inservice inspection and testing activities	Required frequencies for performing inservice inspection and testing activities
Weekly	At least once per 7 days
Monthly	At least once per 31 days
Quarterly or every 3 months	At least once per 92 days
Semiannually or every 6 months	At least once per 184 days
Every 9 months	At least once per 276 days
Yearly or annually	At least once per 366 days

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APPLICABILITY

SURVEILLANCE REQUIREMENTS (Continued)

c. The provisions of Specification 4.0.2 are applicable to the above required frequencies for performing inservice inspection and testing activities.

d. Performance of the above inservice inspection and testing activities shall be in addition to other specified Surveillance Requirements.

e. Nothing in the ASME Boiler and Pressure Vessel Code shall be construed to supersede the requirements of any Technical Specification.

f. The Inservice Inspection Program for piping identified in NRC Generic Letter 88-01 shall be performed in accordance with the staff positions on schedule, methods, and personnel and sample expansion included in this generic letter.

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