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SCHWENCER,A. Licensing Branch 1

SEE RPT.

SUBJECT: Forwards response to NUREG-0313,Revision 1,"Technical Rept on Matl Selection & Processing Guidelines for BWR Coolant Pressure Boundary Piping." Mods to reduce occurrence of intergranular stress corrosion cracking have been made.

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September 2, 1981
G02-81-268

Docket No. 50-397

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Mr. A. Schwencer
Licensing Branch No. 1
Division of Licensing

Subject: WPPSS NUCLEAR PROJECT NO. 2
HARDSHIP EXEMPTION REQUEST FOR
IMPLEMENTATION OF NUREG-0313, REV. 1

RECEIVED
SEP 14 1981
U.S. NUCLEAR REGULATORY COMMISSION

Ref.: NRC letter, D.G. Eisenhut to Holders of Construction Permits and Applicants for Operating Licenses (BWRs), dated February 26, 1981, Subject Implementation of NUREG-0313, Rev. 1.

Dear Mr. Schwencer:

Please find enclosed the attached report "WNP-2 Response to Revised NRC Guidelines on Intergranular Stress Corrosion Cracking." This report documents the WNP-2 response to NUREG-0313, Revision 1, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping."

The Supply System has, where possible, made changes at WNP-2 which will reduce the occurrence of intergranular stress corrosion cracking. These include elimination of stainless steel from some systems, the use of corrosion-resistant cladding on the inside of pipes near critical welds, and change-out of the ten reactor recirculation system inlet line safe-ends. However, because construction at WNP-2 was approximately 85% complete and the following lines and safe-ends were installed at the time of receipt of the subject NUREG, hardship exemptions are requested for them in accordance with paragraph II B of the NUREG:

B001
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1/1

1) Those ASME Code Class 1 lines and safe-ends listed in Table III and IV of the attached report.

2) The ASME Code Class 2 lines listed in Table I of the attached report.

3) All ASME Code Class 3 piping.

In accordance with paragraph II B of this NUREG, additional measures have been taken per the guidelines of Section IV of the NUREG for the service sensitive and nonservice sensitive nonconforming lines. These additional measures are described in Section V and summarized in Table V of the attached report. With the implementation of these additional measures, WNP-2 complies with the requirements contained in NUREG-0313, Rev. 1.

The Supply System cannot comply with paragraph 4.0.6, as written, of the model technical specifications transmitted with the reference letter. These technical specifications do not relay the intent of NUREG-0313, Rev. 1. Specifically, they require all ASME Class 1, 2, and 3 lines to conform to the guidelines stated in the NUREG. But the NUREG in the Abstract allows for varying degrees of inservice inspection where the material selection, testing, and processing guidelines are not fully complied with.

In summary, the Supply System has complied with the guidelines of NUREG-0313, Rev. 1, where practical. When not practical, an augmented inservice inspection program has been committed to which is in accordance with the requirements of this NUREG.

Very truly yours,

G. D. Bouchey

G. D. BOUCHEY, Director
Nuclear Safety

GDB:TFH:nm

Enclosure

cc: J. A. Forrest, B&R
O. K. Earle, B&R (RO)

8109150476

WNP-2 RESPONSE TO REVISED NRC GUIDELINES ON INTERGRANULAR STRESS CORROSION CRACKING

(NUREG-0313, REV. 1)

by

R. A. Moen
and
T. F. Hoyle

May, 1981

WPPSS Mechanical Engineering

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LIST OF APPENDICES

I. SUMMARY

The WNP-2 plant has taken advantage of many of the technological advancements and innovations to substantially reduce the propensity for intergranular stress corrosion cracking (IGSCC) of piping systems and safe ends. These include elimination of stainless steel from some systems and the use of properly heat-treated austenitic stainless steels and corrosion-resistant cladding on the inside of pipes near critical welds in the majority of remaining systems. This report documents the metallurgical condition of the various piping systems addressed by Nuclear Regulatory Commission NUREG-0313 (Rev. 1)(1). It also describes the inservice inspection and leak detection program which will be implemented for WNP-2 to further guard against failures caused by IGSCC. The inservice inspection and leak detection program at WNP-2 complies with the requirements included in NUREG-0313, Rev. 1.

II. INTRODUCTION

Intergranular stress corrosion cracking is a generic problem facing the boiling water reactor (BWR) industry. The problem is most acute with those plants now operating and those nearing the end of construction because the combination of materials and environmental conditions causing the problem is difficult to correct. For those plants such as WNP-2, still in the construction phase, it has been feasible to make some changes that significantly reduce possibilities for the problem.

A. Purpose

The purpose of this report is to document the status of WNP-2 with respect to IGSCC prevention and to provide a basis for responding to Rev. 1 of NUREG-0313(1). This NUREG directs utilities to re-evaluate and revise, if necessary, their leak detection and inservice inspection programs in view of the presence of "conforming" and "nonconforming," "service sensitive" and "nonservice sensitive" lines.

B. Scope

The evaluation will be limited by the following constraints:

- Only austenitic stainless steels are addressed (cracking problems with carbon steel and Inconel 600 are separate issues not addressed in this report).
- Only piping/safe ends greater than 1 inch in diameter within the reactor coolant pressure boundary (RCPB) are addressed. Stainless steel piping outside of the RCPB is of concern to WPPSS, but is not addressed by this report.
- Only piping/safe ends that have failed previously (or have a chance of failing because of conditions similar to those that have led to service failures in other systems) will be addressed. These lines are termed "service sensitive."

C. Organization

The report which follows first addresses general background information relative to IGSCC in BWR's. This section is followed by a presentation of information specific to WNP-2 piping and safe ends. The NRC guidelines are then applied to this information to identify nonconforming service sensitive and non-service sensitive items. The last section of this report addresses Project plans for leak detection and/or inservice inspection of these items, in compliance with NUREG-0313, Rev. 1.

III. BACKGROUND

The problem of IGSCC has been around for many more years than nuclear reactors have been generating power. This portion of the report will: 1) address those aspects of IGSCC that now make it a unique generic problem for the BWR industry; and then 2) describe some of the activities to date at WNP-2 that have dealt with the problem.

A. Intergranular Stress Corrosion Cracking

Much has been written on this subject, yet most of the causes remain to be quantified. Basically, there are three essential ingredients that must be present to some extent before IGSCC occurs. These are:

- A susceptible material such as sensitized Type 304 stainless steel.
- A stress approaching the yield strength of the material.
- A corrodent that will, in the presence of a susceptible material and an applied stress, cause the cracking process to proceed.

The following addresses these three essential variables from the standpoint of the BWR.

1. Susceptible Materials

Austenitic stainless steels, when used in the solution heat-treated conditions, are essentially immune to IGSCC in low-chloride environments. When these materials become sensitized during welding or stress relieving, they quickly become susceptible to IGSCC.

Sensitization occurs when these materials are slow cooled through the temperature range of 800-1600 F. This may occur in a furnace (or outside of the furnace on the way to the quench tank) or during welding (in the heat-affected zone/HAZ). The time in the critical temperature range, the amount of prior working, and the carbon content of the material determine the severity of sensitization.

Fortunately, there are materials that are not susceptible to sensitization. These are listed in NUREG-0313[1] as:

- o Ferritic steels
- o Nuclear grade wrought austenitic stainless steels (low carbon, with nitrogen added to meet the strength requirements of the standard grades)
- o Low carbon wrought austenitic stainless steels
- o Cast austenitic stainless steels (CF3, CF3M, CF8, and CF8M)
- o Low carbon weld wire/rods with at least 5% ferrite (Type 308L and others)

These materials along with properly solution heat-treated standard-grade wrought austenitic stainless steels are considered by NRC to be "conforming" materials. Conversely, wrought austenitic stainless steels containing any degree of sensitization in the weld heat-affected zone are considered by NRC to be "nonconforming" materials.

2. <u>Applied Stress</u>

The IGSCC process is time dependent to the extent that high stresses cause almost instantaneous cracking given the right combination of susceptible material and corrodent. As the stress is lowered, the cracking kinetics diminish, taking longer for a crack to initiate and grow.

Stress available to promote IGSCC may be comprised of a combination of several stress elements including:

- o Primary membrane
- o Secondary (thermal expansion)
- o Residual from forming, welding, machining, and grinding

General Electric has developed a stress rule index that may be used to predict when stresses are such that IGSCC might be expected. This effort is in the developmental stage and is used simply as a "warning flag" at this time.

3. <u>Corrodent</u>

There is no single BWR environment. Rather, there are many BWR environments that are characterized by the oxygen-temperature combination. When a BWR is cold and open to the

atmosphere, the coolant is air-saturated high-purity water which contains about 8 ppm of dissolved oxygen. Under steady-state operating conditions, the environment consists of high-purity water at 550°F containing about 0.2 ppm of dissolved oxygen (plus a stoichiometric amount of dissolved hydrogen - 0.0125 ppm).

Oxygenated water increases the susceptibility of austenitic stainless steels to IGSCC when other contributing factors such as stress and sensitization are present. Of the three factors contributing to IGSCC, the environment of the BWR is essentially fixed--other than minor improvements in purity and de-aeration effects during startup. Therefore, most attention is directed toward other variables.

B. Problem in Perspective

Failure by IGSCC is not the ultimate fate of every piece of austenitic stainless steel in a BWR system. Years of BWR operating experience have shown that a very small percentage of austenitic stainless steels have failed as the result of IGSCC--and that in those instances of failure, no harm was brought to the health and safety of the public. This record has been achieved and is expected to be maintained by a "defense-in-depth" approach to reactor safety.

Defense in depth begins with the fact that austenitic stainless steels are very tough materials in which cracks can grow to very large sizes before unstable crack growth occurs. This characteristic allows one to take advantage of the "leak-before-break" principle. In other words, leaking coolant can be detected and the plant safely shut down before a major pipe rupture occurs. Carrying on with the defense-in-depth argument, the plant is additionally designed to safely shut down, even with a major pipe rupture. To maintain the defense-in-depth principle for WNP-2 requires the prevention and/or early detection and repair of intergranular stress corrosion cracks, should they occur.

C. History of BWR IGSCC

September, 1974, marked the beginning of what was identified as IGSCC in BWR piping systems. During the time following, a number of piping leaks were traced to IGSCC. This led to establishment of the NRC Pipe Crack Study Group. They reviewed factors such as metallurgy, coolant water chemistry, mode of plant operation, and pipe configuration/support. Their findings were published in NUREG-75/067[2] and this was followed by a series of guidelines and recommendations in the form of NUREG-0313[3].

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Between 1974 and 1978, a number of additional piping failures occurred in both BWR's and pressurized water reactors (PWR's). This situation, with its deepening implications, led to activation of a new NRC Pipe Crack Study Group. Their final report, NUREG-0531(4), reiterated that the recommendations were not made in the context of a major safety problem; rather, they were made because such actions would: 1) enhance plant reliability; 2) reduce personnel exposure resulting from increased nondestructive testing and repair operations; and 3) enhance the defense-in-depth approach. A summary of the six technical recommendations from NUREG-0531 is found in Appendix A.

These recommendations provided the basis for a revision to NUREG-0313. Such a revision was issued in draft form in October, 1979, and in final form in July of 1980, and it is the final revision that now serves as the basis for WPPSS's response on WNP-2.

The major differences between the original and revised NUREG, in the context of our BWR/5 plant, were found to be as follows:

- The revised NUREG now lists specific materials that may be used in the as-installed conditions. The remaining guidance on acceptable materials is about the same as stated in the original issue.

- The listing of service sensitive lines was expanded in the revised NUREG to include recirculation system riser lines and inlet lines at safe ends. Examples of service sensitive lines identified in NUREG-0313, Rev. 1(1) include the following:

  Core spray lines
  Recirculation riser lines
  Recirculation bypass lines
  CRD hydraulic return lines
  Isolation condenser lines
  Recirculation inlet lines at safe ends
  Shutdown heat exchanger lines

- The criteria for establishing service sensitive lines was expanded in the revised NUREG to include material condition and high oxygen coolant conditions.

D. WNP-2 Previous Response to NRC

WPPSS's response to NUREG-0313(3) is shown in its entirety in Appendix B. This response documented conformance of WNP-2 to positions stated in the NUREG. For those areas where conformance could not be achieved because of plant construction status, WPPSS provided rationale to support operation of the plant in its as-constructed condition with proper monitoring through leak detection and in-service inspection.

E. WNP-2 Plant Modifications

In August, 1978, the BWR vendor, General Electric, told WPPSS that certain actions had been completed on recirculation piping for WNP-2. Details of these actions are described in Section IV-B-1. Much of this work had been in progress or even completed when WPPSS provided its initial response to NRC on NUREG-0313. Another plant improvement made at this time, to improve the plant stance against IGSCC, was deletion of the CRD hydraulic return line.

Shortly thereafter, Iowa Electric's Duane Arnold Nuclear Plant experienced a series of cracking problems associated with recirculation inlet safe ends. Since these were very similar in design to WNP-2 safe ends, a study was undertaken by WPPSS to assess the implications for WNP-2. A decision was reached in February, 1979, to replace the safe ends during the construction phase rather than to risk having to replace them after the plant had operated. Actual work was initiated in late April, 1979, and the job is now completed. The materials selected for the new safe ends/thermal liners and the processes by which they were installed are discussed later in this report.

During this same time frame, the WNP-2 project also evaluated the potential benefits of adding deaeration equipment. A decision was made to not add such equipment because of uncertainties associated with its effectiveness in preventing IGSCC. A recent report by Failure Analysis Associates (5) supports that decision by concluding that "there is not sufficient data to accurately determine the effectiveness of deaeration" at this time.

F. Revised NRC Guidelines

Revision 1 of NUREG-0313 provides the following implementation guidelines for WNP-2:

> "For plants that have been issued a construction permit but not an operating license, all ASME Code Class 1, 2, and 3 lines should conform to the guidelines stated in Part III unless it can be demonstrated to the staff that implementing the guidelines of Part III would result in undue hardship. For cases in which guidelines of Part III are not complied with, additional measures should be taken for Class 1 and 2 lines in accordance with the guidelines stated in Part IV of this document."

Part III of NUREG-0313 describes the materials that are acceptable to NRC for installation in BWR piping systems. These are tabulated in Section III-A-1 of this report. Part III of NUREG-0313 goes on to state that, for new installation, tests should be made on all regular grade austenitic stainless steels to be used in ASME Code Class 1, 2, and 3 piping systems to demonstrate that the material was properly annealed and is not susceptible to IGSCC. With construction progress on WNP-2 at 85% complete and all critical piping installed, this particular requirement is nonapplicable.

The NUREG permits the limited use of corrosion-resistant cladding to qualify lines as conforming items. Other processes for reducing residual stresses and IGSCC in stainless steel weldments such as Induction Heating Stress Improvement (IHSI) and Heat Sink Welding (HSW) have not been accepted by NRC as standard methods for producing conforming lines.

WPPSS, in complying with the guidelines of the revised NUREG-0313, will first identify those lines that are to be addressed. According to Part III of NUREG-0313, these would include all ASME Code Class 1, 2, and 3 pressure boundary piping. Then these lines will be categorized as "service sensitive" or "nonservice sensitive" according to the following NRC criteria.

Service sensitive lines are:

- o Those lines that have experienced cracking of a generic nature.
- o Those lines that are considered to be particularly susceptible to cracking because of a combination of:

  High local stress
  Material condition (sensitized)
  High oxygen content in the relatively stagnant, intermittent, or low-coolant flow.

Any lines or welds that conform with one of the acceptable materials listed in Section III-A-1 of this report will be exempted from coverage by this report. The balance of the nonconforming service sensitive and nonservice sensitive lines will be addressed within Section V of this report. The resulting leak detection and inservice inspection plans will be compared with the guidelines provided in NUREG-0313 to determine if any relief will be requested.

IV. WNP-2 PIPING SYSTEMS INFORMATION

A. Stainless Steel Piping/Safe Ends

Tables I and II identify the austenitic stainless steel piping and safe ends, respectively. Included in the tables is the ASME Code Class for each item. Piping line numbers ending in "S", such as "4S", refer to Type 304 stainless steel. Note that pipe sizes under 1.5 inches are exempt from volumetric and surface examinations per the exemption requirements contained in ASME Section XI. These lines will receive visual examination only during pressure/hydrostatic tests.

Copies of the ISI drawings identified in Table I are reproduced in Appendix C.

TABLE I

Stainless Steel Piping
in WNP-2 Greater than 1" NPS

System	Line Designation	ASME Code Class	Ref. ISI Drwg.	Line Description
Class 1				
RRC	2" RRC(6)-4S	1	RRC-110 & -111	RRC drain for loops A & B
RRC	4" RRC(4)-4S	1	RRC-108 & -109	RWCU intertie to loops A & B
RRC	4" RRC(8)-4S	1	RRC-101-1 & -2; -102-1 & -2	RRC loops A & B decon-tamination connections
RRC	12" RRC(1)-4S	1	RRC 101-4, -5, -6, -7, & -8; -102-4, -5, -6, -7, & -8	RRC loops A & B (riser pipes)
RRC	12" RRC(7)-4S	1	RRC-106 & -107	RHR shutdown cooling return to loops A & B
RRC	16" RRC(1)-4S	1	RRC-101-3 & -102-3	RRC loops A & B manifolds
RRC	20" RRC(6)-4S	1	RRC-105	RHR shutdown cooling suction intertie with RRC loop A
RRC	24" RRC(1)-4S	1	RRC-101-2; -102-1 & -3	RRC loops A & B discharge
RRC	24" RRC(2)-4S	1	RRC-101-1 & -102-1	RRC loops A & B suction
RHR	12" RHR(1)-4S	1	RHR-105 & -106	RHR shutdown cooling return loops A & B
RHR	20" RHR(2)-4S	1	RHR-104	RHR shutdown cooling suction (safe end)
JP	4" Penetration Fitting	1	RPV-115	Jet pump instrumentation fitting (304L) N9A

TABLE 1 (Cont'd)

System	Line Designation	ASME Code Class	Ref. ISI Drwg.	Line Description
Class 1				
JP	4" Penetration Fitting	1	RPV-115	Jet pump instrumentation fitting (304L) N9B
SLC	1-1/2" SLC(2) -4S	1	ISI-222	SLC pump discharge to reactor vessel
Class 2				
SLC	3" SLC(1)-1S	2	ISI-222	SLC storage tank to SLC pump
SLC	4" SLC(1)-1S	2	ISI-222	SLC storage tank to SLC pump
SLC	1-1/2" SLC(2) -3S	2	ISI-222	SLC pump discharge to reactor vessel
SLC	1-1/2" SLC(3) -3S	2	ISI-222	SLC return to test tank
SLC	3" SLC(5)-1S	2	ISI-222	SLC test tank supply to SLC pump
SLC	3" SLC(5)-1S	2	ISI-222	SLC test tank supply to SLC pump
SLC	3" SLC(56)-1S	2	ISI-222	SLC suction line drain
SLC	1-1/2" SLC(56) -3S	2	ISI-222	SLC discharge line drain
DW	2" DW(11)-1S	2	ISI-217	Demineralized water containment penetration

Class 3

No Class 3 stainless steel piping within the reactor coolant pressure boundary..

TABLE II

Stainless Steel Safe Ends in WNP-2 Coolant Pressure Boundary

System	Location	Safe End Material	Liner Material	ASME Code Class
RPV	N1A-Recirc. suction	304	None	1
RPV	N1B-Recirc. suction	304	None	1
RPV	N2A-Recirc. return	316L	316L	1
RPV	N2B-Recirc. return	316L	316L	1
RPV	N2C-Recirc. return	316L	316L	1
RPV	N2D-Recirc. return	316L	316L	1
RPV	N2E-Recirc. return	316L	316L	1
RPV	N2F-Recirc. return	316L	316L	1
RPV	N2G-Recirc. return	316L	316L	1
RPV	N2H-Recirc. return	316L	316L	1
RPV	N2J-Recirc. return	316L	316L	1
RPV	N2K-Recirc. return	316L	316L	1
RPV	N9A-Jet Pump Inst.	304	None	1
RPV	N9B-Jet Pump Inst.	304	None	1
RHR	Between RHR-V-9 and field weld on RHR-V-113	316	None	1
RHR	Between RHR-V-50A and field weld on 12" RHR(1) 4S (RHR-851-17)	304	None	1
RHR	Between RHR-V-50B and field weld on 12" RHR(1)-4S (RHR-899-48)	304	None	1
RRC	Between RWCU-V-100 and field weld on 4" RRC(4)-4S	316	None	1
RRC	Between RWCU-V-106 and field weld on 4" RRC(4)-4S	316	None	1

B. Identification of Nonconforming Items

Nonconforming items are established on the basis of materials and/or processes used in fabricating the item. In order to make this determination, it was necessary to review construction records to ascertain what was used and how it was used. The following is more detailed information on each of the items identified in Tables I and II.

1. Reactor Recirculation System (RRC)

The RRC system is comprised of two loops, each consisting of a number of shop-fabricated spools and field welds joining the spools. Piping within the two loops is as follows:

- Loop A

  Pump suction (nozzle N1A to pump RRC-P-1A)

  Pump discharge (pump RRC-P-1A to manifold), including decontamination connection

  Manifold, including cross, reducer and end caps

  Riser pipes (5) (manifold to nozzles N2A through N2E)

  RHR shutdown cooling suction intertie with RRC

  RHR shutdown cooling return to RRC

  RWCU intertie to RRC

  RRC drain

- Loop B

  Pump suction (nozzle N1B to pump RRC-P-1B)

  Pump discharge (pump RRC-P-1B to manifold), including decontamination connection

  Manifold, including cross, reducer and end caps

  Riser pipes (5) (manifold to nozzle N2F through N2K)

  RHR shutdown cooling return to RRC

  RWCU intertie to RRC

  RRC drain

Again, diagrams of these piping runs are found in Appendix C.

All portions of the RRC system are ASME Code Class 1 and the entire piping system utilizes Type 304 stainless steel piping and fittings. Specifications used were:

o	Piping	- SA-312	Seamless and welded austenitic stainless steel pipe
		SA-358	Electric fusion welded austenitic chromium nickel alloy steel pipe for high temperature service
		SA-376	Seamless austenitic steel pipe for high temperature central station service
o	Fittings	- SA-403	Wrought austenitic stainless steel pipe fittings

Because of prior problems in the BWR industry, certain portions of the WNP-2 RRC system received special treatment. The balance of the system was fabricated and assembled by conventional methods. All portions of the RRC system are described below:

a. Riser Pipes

The riser pipes, as originally installed, were conforming items because:

- The welds between the 12-inch riser pipes and the 90^{o}LR elbows were solution heat treated, removing any sensitization that might have occurred as the result of welding.
- The ends of the spools were corrosion-resistant clad so that subsequent field welds between the riser pipes and manifold and riser pipes and nozzle safe ends did not leave sensitized base metal exposed on the inside of the piping.

Subsequently, however, it was necessary to remove all riser pipes during the Safe End Modification Program (discussed later). Removal was accomplished by making two cuts--one through the center of the original weld joining the riser pipe spool to the safe end (thus preserving the original corrosion-resistant cladding), and one between the vertical elbow weld and the original riser pipe to manifold sweepolet weld. The final closure welds between the riser pipes and safe ends (now Type 316L) were made by first using an ER308L consumable

insert (carbon content 0.020% and a ferrite level of 11%) and completing the weld with ER308L weld wire. Because of fitup problems, the lower ends of the spools were built up with E308L-16 weld metal before the final closure welds were made (using the same filler metals used on the upper end). Welding of these two joints on each spool was sequenced to minimize welding residual stresses.

Per NRC criteria on "conforming" materials, the field welds between the vertical riser pipe sections are nonconforming service sensitive welds. On ISI drawings (Appendix C), these are identified as:

12 RRC(1) - N2A - 1A	Loop A
12 RRC(1) - N2B - 1A	Loop A
12 RRC(1) - N2C - 1A	Loop A
12 RRC(1) - N2D - 1A	Loop A
12 RRC(1) - N2E - 1A	Loop A
12 RRC(1) - N2F - 1A	Loop B
12 RRC(1) - N2G - 1A	Loop B
12 RRC(1) - N2H - 1A	Loop B
12 RRC(1) - N2K - 1A	Loop B
12 RRC(1) - N2J - 1A	Loop B

b. Manifolds

These were among those spools receiving special treatment during shop fabrication. The welds joining the four sweepolets to each manifold, and one of the welds joining the manifold halves to the cross fitting were solution heat treated. These welds therefore, comply with NRC criteria for conforming materials. The welds joining the end caps to the manifolds, the other manifold to cross fitting welds, and the sweepolet to riser pipe welds are nonconforming nonservice sensitive items per NRC criteria. The sweepolet to riser pipe welds are nonconforming service sensitive because corrosion-resistant cladding was applied only to the original ends of the riser pipes and not the sweepolets.

c. Bypass Lines

These lines were found to be among those experiencing the highest frequency of failure within the operating system. Since their function can be performed by alternate means, GE recommended[6] that the lines be removed and the sweepolet connections capped. This was done using corrosion-resistant cladding per FKE No. 021/113050. Therefore, these capped connections are conforming items and will not be further addressed.

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2. Residual Heat Removal (RHR) System

Austenitic stainless steel (Type 304) is used in only a limited portion of each loop of the RHR system, the balance being carbon steel (SA-106 Gr B). Stainless steel is used in the following:

- o Shutdown cooling return loop A (between valve RHR-V-112A and valve RHR-V-50A safe end.)
- o Shutdown cooling return loop B (between valve RHR-V-112B and valve RHR-V-50B safe end.)

These spools are considered by NRC to be service sensitive lines. Because of the material used as base material and the fact that no post-welding solution heat treating was performed, these two spools are nonconforming service sensitive lines.

3. Control Rod Drive System

The one line in this system that has been subject to cracking problems is the hydraulic return line. As part of an earlier effort to improve the overall plant stance against IGSCC, this line was eliminated and nozzle N10 capped with an SA-508 carbon steel cap.

4. Other NRC-Designated Service Sensitive Lines

NRC designated the core spray lines and isolation condenser lines among their listing of service sensitive lines. The high and low pressure core spray lines on WNP-2 are fabricated from carbon steel, hence they fall outside of the scope of this study. WNP-2 has no isolation condensers, so those lines are not appropriate for consideration by this study.

C. Identification of Nonconforming Items - Safe Ends

Austenitic stainless steel safe ends in use within the reactor coolant pressure boundary were tabulated in Table II. These will be discussed further in the following sections.

1. Reactor Recirculation System Inlet Line Safe Ends

The 10 safe ends and companion thermal liners joining recirculation system riser pipes to the reactor pressure vessel nozzles/jet pumps were replaced during the recent Safe End Modification Program. Type 316L stainless steel was used for both the safe ends and the thermal liners. All weld filler metals used in the joining of the riser pipes to the

safe ends, thermal liners to safe ends, and thermal liners to the jet pump risers have carbon contents between 0.017% and 0.026%. These articles now conform to NRC's listing of acceptable materials.

2. Reactor Recirculation System Suction Nozzle Safe Ends

NRC does not consider these lines to be service sensitive, since they have performed satisfactorily to date. These nozzle safe ends are fabricated of standard grade Type 304 stainless steel, hence they are nonconforming nonservice sensitive lines.

3. Reactor Water Cleanup System Valve Safe Ends

There are two safe ends within the reactor recirculation system on valves designated RWCU-V-100 and RWCU-V-106. Both safe ends are fabricated from Type 316 stainless steel, thus are nonconforming nonservice sensitive lines.

4. Residual Heat-Removal System Safe Ends

The three safe ends used on valves within the RHR system are constructed from either Type 304 or Type 316 stainless steel as shown on Table II. The lines are considered by NRC to be service sensitive, thus these safe ends are nonconforming, service sensitive items.

5. Jet Pump Instrumentation Nozzle Safe Ends

NRC does not consider these lines to be service sensitive since they have performed satisfactorily to date. These nozzle safe ends are fabricated of standard grade Type 304 stainless steel, hence they are nonconforming nonservice sensitive lines.

D. Summary of Plant Conditions

One of the intermediate objectives of this study involved the determination of the degree of conformance of both service sensitive and nonservice sensitive lines and safe ends within the reactor coolant pressure boundary. The preceding paragraphs described the various systems and lines. A summary of that information is provided in the following tables:

1. Nonconforming Service Sensitive Items

Table III summarizes the nonconforming service sensitive lines and safe ends within the WNP-2 reactor coolant pressure boundary fabricated from austenitic stainless steels.

TABLE III

WNP-2 Nonconforming
Service Sensitive Lines and
Safe Ends

System	No. of Welds	Lines/Safe Ends
RRC	10	Riser pipes (new field welds only) 12 RRC(1) - N2A-1A through 12 RRC(1) - N2J-1A
RRC	10	Manifold side of riser pipe to manifold sweepolet welds 12 RRC(1) - N2A - 1 through 12 RRC(1) - N2J - 1
RHR	4	Loop A shutdown cooling return section between valve RHR-V-112A and valve RHR-V-50A safe end
RHR	3	Loop B shutdown cooling return section between valve RHR-V-112B and valve RHR-V-50B safe end
RHR	2	RHR shutdown cooling section safe end between RHR-V-9 and field weld on RHR-V-113
RHR	1	Shutdown cooling return loop A safe end between RHR-V-50A and field weld on 12" RHR(1)-4S
RHR	1	Shutdown cooling return loop B safe end between RHR-V-50B and field weld on 12" RHR(1)-4S

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2. <u>Nonconforming Nonservice Sensitive Items</u>

Table IV summarizes the nonconforming nonservice sensitive lines and safe ends within the WNP-2 reactor coolant pressure boundary fabricated from austenitic stainless steels.

TABLE IV

WNP-2 Nonconforming
Nonservice Sensitive Lines and
Safe Ends

System	No. of Welds	Lines/Safe Ends
RRC	3	Manifold to end cap welds and one weld per manifold where the cross fitting is welded to the other manifold half.
RRC	24	Pump suction lines (nozzle N1A to pump RRC-P-1A and nozzle N1B to pump RRC-P-1B) including decontamination connection.
RRC	22-26	Pump discharge lines (pump RRC-P-1A to loop A manifold and pump RRC-P-1B to loop B manifold) including decontamination connection.
RRC	9	RHR shutdown cooling suction intertie with loop A.
RRC	12	RHR shutdown cooling return to RRC, loops A and B.
RRC	21	RWCU intertie to RRC, loops A and B.
RRC	11	RRC drain, loops A and B.
RRC/RPV	2/4	RRC suction nozzle safe ends N1A and N1B.
RRC	1	Safe end between RWCU-V-100 and field weld on 4" RRC(4)-4S.
RRC	1	Safe end between RWCU-V-106 and field weld on 4" RRC(4)-4S.
RPV/JP	4	Jet pump instrumentation nozzle safe ends N9A, N9B.

V. LEAK DETECTION/INSERVICE INSPECTION COMMITMENTS

Tables III and IV define a number of lines and safe ends that are not in compliance with NRC's listing of acceptable materials, Therefore, this section describes the degree of compliance to NUREG-0313, Rev. 1, Part IV, "Inservice Inspection and Leak Detection Requirements for BWR's with Varying Degrees of Conformance of Material Selection, Testing, and Processing Guidelines." Table V is a summary cross reference between the findings of this report and the augmented requirements contained in Section IV of NUREG-0313. WNP-2 complies with the intent of NUREG-0313, Rev. 1, however, some alternative approaches and minor exceptions have been taken.

A. Leak Detection for all Nonconforming Lines

1. The reactor coolant leakage-detection system is described in the FSAR in Section 5.2.5 and 7.6.1.4. As described therein, this system meets the intent of this NUREG by providing "sufficiently diverse leak-detection methods with adequate sensitivity to detect and measure small leaks in a timely manner and to identify the leakage sources within the practical limits." (re: Part IV, B.1.a.(1).)

2. The compliance with Regulatory Guide 1.45 is discussed in Appendix C.2 pp C.2-39 through C.2-41 of the FSAR. Therein it states that the WNP-2 plant design complies with the Regulatory positions by alternate approach. (re: Part IV, B.1.a(1).)

3. WNP-2 plans to comply with the unidentified leakage limits specified in the model Technical Specification transmitted in NRC Generic Letter 81-03, with the exception of Parts 3.4.3.2.d and 4.4.3.2.2. These two parts concern valve seat leakage within the pressure boundary of a system. The Supply System feels that 3.4.3.2.d and 4.4.3.2.2 are not applicable to through-wall leakage resulting from IGSCC. Therefore, compliance with these parts is not necessary to meet the intent of NUREG-0313, Rev. 1.

   The WNP-2 leak detection system consists of temperature, pressure, and flow sensors as well as drywell air samplers. Each of these variables is continuously monitored and they all have alarms associated with them. The leak detection system is fully capable of monitoring flowrates of one gallon per minute and, thus, is in compliance with Regulatory Guide 1.45 and NUREG-0313, Rev. 1 (re: Part IV, B.1.a(2).)

4. WNP-2 concurs with the definition of unidentified leakage except for Parts 3.4.3.2.d and 4.4.3.2.2 of the Model Technical Specification (81-03) as described in (3) above. With respect to this, it should be noted that the drywell

floor drain flow monitoring system collects leakage from the drywell diaphram floor seals. This leakage is not expected to be significant, however, and thus the floor drain system meets the intent of being the primary containment air cooler condensate flow-rate monitoring system, as stated in the model Standard Technical Specification. (re: Part IV, B.1.a(3).)

B. Augmented Inservice Inspection

1. (a) Class 1

An augmented inservice inspection program will be implemented for all ASME Code Class 1 piping and components which are:

(1) Subject to examination requirements specified in ASME Section XI; and

(2) communicate with reactor coolant; and

(3) fabricated from austenitic stainless steel which does not meet the requirements specified in Part III of NUREG-0313, Rev. 1.

(b) Class 2

There are parts of two systems (identified in Table I) at WNP-2 that are Class 2 and fabricated from austenitic stainless steel. The Class 2 portions of these systems are exempt from volumetric and surface examination by the exemption criteria found in Section XI, paragraph IWC-1220. These systems will be visually examined for evidence of leakage during system pressure and hydrostatic tests per Section XI.

(c) Class 3

In accordance with the guidelines established in Part IV B of NUREG-0313, Rev. 1, no additional inservice inspection beyond the Section XI visual examination will be performed.

2. The following is a description of the criteria which will be used by the Supply System to develop the augmented inservice inspection program. The augmented program developed pursuant to this report will be part of the WNP-2 Inservice Inspection Program Plan.

(a) Nonconforming Nonservice Sensitive (Table IV)

(1) Dissimilar Metal Welds (III, B.1.b.(1).): Will be examined at least once in no more than 80 months. (There are no dissimilar metal internal attachment welds at WNP-2.)

(2) Code Class 1 Pipe Welds (III, B.1.b.(2).): The following nonconforming nonservice sensitive welds will be examined at least once in no more than 80 months:

- o All welds at terminal ends of pipe at vessel nozzles
- o All welds having a designed combined primary plus secondary stress range of 2.4 Sm or more
- o All welds having a design cumulative fatigue usage factor of 0.4 or more
- o Sufficient additional welds with high potential for cracking to make the total equal to 25% of the welds in each piping system

(3) In the event the examination described in (1) and (2) above find the piping free of unacceptable indications during the first 80 months, the examination frequency thereafter will revert to 120 months as prescribed in Section XI of the ASME Boiler and Pressure Vessel Code.

(b) Nonconforming Service Sensitive (Table III)

(1) Dissimilar Metal Welds (III, B.2.b.(2).): Will be examined at each reactor refueling outage for three successive outages. There are no dissimilar metal internal attachment welds at WNP-2.

NOTE: The Supply System will not plan to perform augmented examinations more frequently than every refueling outage, which will take place at approximately one-year intervals.

(2) Class 1 Pipe Welds (III. B.2.b.(3).): Will be examined at each reactor refueling outage subject to the same conditions in (b)(1) above. The welds to be examined will be determined using the sampling system described in IV B.2.(a)(2).

(3) In the event the examinations described in (1) and (2) above find the piping free of unacceptable indications for three successive inspections, the time between successive examinations will be extended to each 36-month period (plus or minus as much as 12 months) coinciding with a refueling outage. In the event these 36-month period examinations reveal no unacceptable indications for three successive inspections, the frequency of examinations will revert to 80-month periods.

C. Nondestructive Examination (NDE) Requirements (III B)

The method of examination, volume of material to be examined, the allowable indication standards, and examination procedures will comply with the requirements set forth in the applicable Edition and Addenda of the ASME Code, Section XI.

The preservice examinations for conforming and nonconforming lines have been done using ultrasonic procedures supplied by Lambert, MacGill, Thomas, Inc. (LMT), and approved by the Supply System. These procedures have been successfully used by LMT to detect IGSCC at many operating plants. All examinations have been recorded on strip chart recorders. These recorders record the UT data at much lower signal amplitudes than required by the Section XI Code (about 15% of full screen height at scanning gain). This low signal amplitude baseline information can be compared with the inservice results and will help the evaluator distinguish between signals from geometry and those from IGSCC.

TABLE V

WNP-2 Compliance with NUREG-0313, Rev. 1

NUREG-0313 Requirement Section	Corresponding Section of This Response	Compliance
IV. B.1 Non conforming - Nonservice Sensitive		
A. Leak Detection	V.A.3	Yes
(1) Description, Reg. Guide 1.45	V.A.2	Yes, Alternative Approach
(2) Requirements, limits		
(3) Unidentified leakage (a)	V.A.3	Yes
(b)	V.A.4	Yes
B. Augmented ISI		
(1) dissimilar metal welds	V.B.2.(a)(1)	Yes
(2) Pipe welds, Class 1	V.B.2.(a)(2)	Yes
(3) Pipe welds, Class 2 ECCS	V.B.1.(b)	N/A
(4) Pipe welds, Class 2 non ECCS	V.B.1.(b)	N/A
(5) Examination frequency	V.B.2(a)(3)	Yes
(6) Other sampling plans		N/A
IV.B.2 Non conforming - Service Sensitive		
a. Leak Detection	V.A	Yes
b. Augmented ISI		
(1) Listed Class 1 welds	V.B.2(b)(1) & (3)	Yes
(2) Dissimilar metal welds	V.B.2.(b)(1)	N/A
(3) Other Class 1 welds	V.B.2.(b)(2)	Yes
(4) Internal Attachment welds	V.B.2.(b)(3)	N/A
(5) Frequency	V.B.2.(b)	Yes
(6) Frequency - Class 2	V.B.1.(b)	N/A
IV.B.3 NDE Requirements	V.C.	Yes

LIST OF REFERENCES

1. "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," NUREG-0313, Rev. 1, published July, 1980.

2. "Investigation and Evaluation of Cracking in Austenitic Stainless Steel Piping of Boiling Water Reactor Plants," NUREG-75/067, dated October, 1975.

3. "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," NUREG-0313, dated July, 1977.

4. "Investigation and Evaluation of Stress Corrosion Cracking in Piping of Light Water Reactor Plants," NUREG-0531, dated February, 1979.

5. E. D. Eason, "The State of Knowledge on Deaeration as a Remedy for Intergranular Stress Corrosion Cracking in BWR Piping", FAA-81-2-1, March 1981.

6. Letter from F. A. MacLean to WNP-2 Project Manager, "Intergranular Stress Corrosion Cracking Countermeasures for the Hanford Recirculation System," GEWP-2-78-762, dated August 17, 1978.

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APPENDICES

APPENDIX A

Recommendations from NUREG-0531, "Investigation and Evaluation of Stress Corrosion Cracking in Piping of Light Water Reactor Plants"

- The future use of regular grades of Types 304 and 316 stainless steel in BWR piping systems should be avoided. If these materials are used, steps should be taken to ensure that IGSCC cannot occur. Such measures may include solution annealing, weld cladding, or other measures that have been demonstrated to eliminate sensitization and reduce residual stresses. Consideration should be given to techniques now under development such as Induction Heating Stress Improvement (IHSI), Heat-Sink Welding (HSW), Solution Heat Treatment (SHT) of weldments, and Corrosion-Resistant Cladding (CRC). In addition, tests such as electrochemical potentiokinetic reactivation should be run on each heat of piping to ensure that heats susceptible to IGSCC are not used, and to qualify welding procedures, heat-treatment procedures, or other thermal events that occur in the temperature range of concern.

- The presence of oxygen should be minimized in BWR's through the operating cycle.

- Specific procedures should be incorporated in the ASME Code covering improvements in ultrasonic detection and evaluation methods that have been developed to date. These should be issued in the form of a Regulatory Guide pending either a Code change or an enabling Code Case to make them applicable.

- Advanced nondestructive detection and evaluation methods are being developed under several industry and NRC programs. It is recommended that those particularly useful for examining austenitic materials for IGSCC be pursued as actively as possible. Ultrasonic signal processing techniques should be advanced, ultrasonic probes and acoustic parameters should be developed and tested.

- Investigations should be expanded to determine the effects of actual BWR operating stress and thermal loading on IGSCC.

- Based on the incidence of IGSCC in recirculation riser piping in Japan, an augmented inservice inspection program should be developed for these lines if they do not meet the guidelines stated in Part III of NUREG-0313. We recommend that the augmented inservice inspection program conform to that described for nonconforming service sensitive lines in NUREG-0313.

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APPENDIX B

WPPSS's Response to NUREG-0313,
"Technical Report on Material Selection
and Processing Guidelines for BWR Coolant
Pressure Boundary Piping"