Charles R. Pierce
Regulatory Affairs Director

Southern Nuclear
Operating Company, Inc.
40 Inverness Center Parkway
Post Office Box 1295
Birmingham, AL 35242

Tel 205.992.7872
Fax 205.992.7601

SOUTHERN COMPANY

June 12, 2015

Docket Nos.: 50-366 NL-15-1032

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555-0001

Edwin I. Hatch Nuclear Plant – Unit 2
Inservice Inspection Program
Owner's Activity Report for Outage 2R23

Ladies and Gentlemen:

Enclosed is the ASME Section XI Code Case N-532-4 OAR-1 Owner's Activity Report for the 2R23 Refueling Outage. Table 1, "Items with Flaws or Relevant Conditions that Required Evaluation for Continued Service," lists evaluations performed for continued service. Repair/Replacement activities did occur during Cycle 23 and during the 2R23 Refueling Outage and are addressed in Table 2, "Abstract of Repairs, Replacement or Corrective Measures Required for Continued Service." Per ASME Section XI, Subarticle IWB-3100, the evaluation of the shroud crack-like indications is provided in Enclosure 4. Please note that information deemed proprietary to EPRI has been redacted, but can be provided to the Nuclear Regulatory Commission upon request.

This report is for the second period of the 4th Interval ISI activities (Interval 4, Period 3, Outage 2).

This letter contains no NRC commitments. If you have any questions, please contact Ken McElroy at (205) 992-7369.

Respectfully submitted,

C. R. Pierce

C. R. Pierce
Regulatory Affairs Director

CRP/RMJ/lac

Enclosures:
1. 2R23 Form OAR-1 Owner's Activity Report
2. 2R23 Form OAR-1 Owner's Activity Report, Table 1, Items with Flaws or Relevant Conditions that Required Evaluation for Continued Service
3. 2R23 Form OAR-1 Owner's Activity Report, Table 2, Abstract of Repairs, Replacement or Corrective Measures Required for Continued Service
4. SNC and SI Evaluation Core Shroud Axially Oriented Flaw

cc: Southern Nuclear Operating Company
Mr. S. E. Kuczynski, Chairman, President & CEO
Mr. D. G. Bost, Executive Vice President & Chief Nuclear Officer
Mr. D. R. Vineyard, Vice President – Hatch
Mr. M. D. Meier, Vice President – Regulatory Affairs
Mr. D. R. Madison, Vice President – Fleet Operations
Mr. B. J. Adams, Vice President – Engineering
Mr. G. L. Johnson, Regulatory Affairs Manager - Hatch
RTYPE: CHA02.004

U. S. Nuclear Regulatory Commission
Mr. V. M. McCree, Regional Administrator
Mr. R. E. Martin, NRR Senior Project Manager - Hatch
Mr. D. H. Hardage, Senior Resident Inspector – Hatch

Edwin I. Hatch Nuclear Plant – Unit 2
Inservice Inspection Program
Owner's Activity Report for Outage 2R23

Enclosure 1

2R23 Form OAR-1 Owner's Activity Report

FORM OAR-1 OWNER'S ACTIVITY REPORT

Report Number 2-4-3-2 (Unit 2, 4th Interval, 3rd Period, 2nd Report)

Plant Edwin I. Hatch Nuclear Plant, P.O. Box 2010, Baxley, Georgia, 31513

Unit No. 2 (if applicable) Commercial service date 09/05/79 Refueling outage no. 2R23

Current inspection interval 4th (1st, 2nd, 3rd, 4th, other)

Current inspection period 3rd (1st, 2nd, 3rd)

Edition and Addenda of Section XI applicable to the inspection plans 2001 Edition with 2003 Addenda

Date and revision of inspection plans Volume 1: 12/17/14 Rev. 5.0; Volume 2: 12/22/14 Rev. 4.0; Volume 3: 1/9/15 Rev. 4.0, Volume 4: 1/12/15 Rev. 6.0, Volume 5: 12/18/14 Rev 5.0, Volume 6 12/17/14 Rev. 7.0

Edition and Addenda of Section XI applicable to repair/replacement activities, if different than the inspection plans Same

Code Cases used: N-460, N-663, N-532-4, N-513-3, N-586-1 (if applicable)

CERTIFICATE OF CONFORMANCE

I certify that (a) the statements made in this report are correct; (b) the examinations and tests meet the Inspection Plan as required by the ASME Code, Section XI; and (c) the repair/replacement activities and evaluations supporting the completion of 2R23 (refueling outage number) conform to the requirements of Section XI.

Signed Anthony Giancatarino (Owner or Owner's Designee, Title) Date 6/9/2015

CERTIFICATE OF INSERVICE INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and the State or Province of Georgia and employed by HSB Global Standards of Hartford, CT have inspected the items described in this Owner's Activity Report, and state that, to the best of my knowledge and belief, the Owner has performed all activities represented by this report in accordance with the requirements of Section XI.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the repair/replacement activities and evaluation described in this report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Robert Allen (Inspector's Signature) Commissions NB 13626, GA 856, A, N, I (National Board, State, Province, and Endorsements)

Date 6-9-15

Edwin I. Hatch Nuclear Plant – Unit 2
Inservice Inspection Program
Owner's Activity Report for Outage 2R23

Enclosure 2

2R23 Form OAR-1 Owner's Activity Report, Table 1, Items with Flaws or Relevant Conditions that Required Evaluation for Continued Service

ITEMS WITH FLAWS OR RELEVANT CONDITIONS THAT REQUIRED EVALUATION FOR CONTINUED SERVICE

UNIT 2 Cycle 23 TABLE 1

Examination Category and Item Number	Item Description	Evaluation Description
B-N-2 (B13.40)	During IVVI (VT-3 and EVT-1), crack like indications were reported at various locations on the Core Shroud.	Evaluated as acceptable for continued service using attached evaluation 1500270.301NP.R0 and Section XI supplement.
D-B(D2.10)	After shutdown for the 2R23 outage, leakage was identified on 8" PSW line feeding the Unit 2 "C" EDG.	Evaluated per N-513-3 for continued operation. Leak was repaired later in the same outage, and is further described on Table 2 of this report.
F-A(F1.30)	RHR Piping Supports (5) failed post maintenance VT-3 due to discrepancies between drawing tolerances and those found in the field.	Evaluated as acceptable per RERs SNC585423 and SNC592495 produced by Hatch Design Engineering.

Edwin I. Hatch Nuclear Plant – Unit 2
Inservice Inspection Program
Owner's Activity Report for Outage 2R23

Enclosure 3

2R23 Form OAR-1 Owner's Activity Report, Table 2, Abstract of Repairs, Replacement or Corrective Measures Required for Continued Service

ABSTRACT OF REPAIRS, REPLACEMENT OR CORRECTIVE MEASURES REQUIRED FOR CONTINUED SERVICE

UNIT 2 Cycle 23 TABLE 2

Code Class	Item Description	Description of Work	Date Completed	Repair/Replacement Plan Number
1	"A" FW Check Valve	Replaced parts within the F010A FW Check Valve after failed LLRT.	3/2/2015	WO SNC637638
1	3" Piping Welds	Flapped welds 2B21-1MS-3-8 and 2B21-1MS-3-20 on the Main Steam system to identify possible material porosity after ISI indications were reported.	3/5/2015	WO SNC638234
1	12" FW Weld Overlay	Full Structural Weld Overlay installed on Feedwater weld 2B21-1FW-12AA-8. This weld overlay was required due to inspection coverage requirements.	3/8/2015	WO SNC545024
3	8" PSW Piping to 2C EDG	Replaced section of 8" PSW line that was leaking due to a small hole. This piping feeds the Unit 2 "C" Emergency Diesel Generator.	3/25/2015	WO SNC636435
3	3" PSW line	RHR and Core Spray room cooler PSW return line was isolated and repaired after leaking pipe near 2P41F006A was identified.	4/27/2014	WO SNC569457

ABSTRACT OF REPAIRS, REPLACEMENT OR CORRECTIVE MEASURES REQUIRED FOR CONTINUED SERVICE

UNIT 2 Cycle 23 TABLE 2

3	2" PSW line	During an ISI pressure test for the PSW system, a leak was identified on the discharge piping coming from the "A" Control Rod Drive room cooler. The leak immediately upstream of the 2P41F002A valve was isolated and repaired.	1/16/2014	WO SNC533953

Edwin I. Hatch Nuclear Plant – Unit 2
Inservice Inspection Program
Owner's Activity Report for Outage 2R23

Enclosure 4

SNC and SI Evaluation Core Shroud Axially Oriented Flaw

Southern Nuclear Operating Company — **INF-Form-002-A**

Indication Notification Form — **INF # I15H2006**

Part 1 Findings

Exam Date:	NDE Method:	Instruction/Rev/Dev.:
02-24-2015	UT ☐ PT ☐ MT ☐ ET ☐ RT ☐ VT X Other ☐	NMP-ES-024-206/11.1

Comments:

During IVVI of the Core Shroud, crack like indications were reported at the following locations. See attached INR's for additional details. Reference CR 10031730.

2B11 IVH13, Shroud Vertical Weld 320° Weld V-4 from ID (EVT-1). INR H2R23-IVVI-15-07

2B11 IVH15, Shroud Vertical Weld 230° Weld V-6 from ID (EVT-1). INR H2R23-IVVI-15-04

2B11 IVH120, Shroud Interior Surfaces from Top Guide Support Ring. 35°- 45° (Cell 42-47) (VT-3) INR H2R23-IVVI-15-03.

2B11 IVH121, Shroud Interior Surfaces from Top Guide Support Ring. 45°- 55° (Cell 44-43) (VT-3) INR H2R23-IVVI-15-06.

2B11 IVH130, Shroud Interior Surfaces from Top Guide Support Ring. 135°- 145° (Cell 42-07) (VT-3) INR H2R23-IVVI-15-05.

Signature – Engineering Programs NDE Level III:		Date:
Kevin White *Kevin White*		3-02-2015
Signature - Engineering Programs Engineer / Date: DeLisa S. Pournaras *DeLisa Pournaras*	Signature - Engineering Programs Supervisor: Rebecca Retherford *[signature]*	Date: 3-02-2015

Part 2 - Acknowledgement

Notification Acknowledged By:	Title:	Date:
Andrew Gordon / *Andrew Gordon*	SITE BWRVIP ENGINEER	3/4/2015

Part 3 - Disposition by Project/Site

Comments:

Please see attached BWRVIP and Section XI evaluations for further details.

Corrective Action:

No corrective action required, please see attached evaluations for details.

Signature:	Title:	Date:
Andrew Gordon / *Andrew Gordon*	SITE BWRVIP ENGINEER	4/15/2015

Part 4a - Re-Examination After Corrective Action

N/A

Signature - Examiner: N/A	SNT Level: N/A	Date: N/A

Part 4b - Additional Examinations (Scope Expansions)

No scope expansion required. Please see attached evaluations for details.

Part 4c - Successive Examinations (Future Exam Requirements)

Please see attached evaluations for details.

Signature - Engineering Programs Engineer:	Date:
DeLisa S Pournaras	4/17/15

Part 5 - ANII Review

	Date:
Robert Adams *Robert Adams*	5-14-15

Part 6 - INF Final Review/Closeout

	Date:
Kevin White *Kevin White*	5-20-2015

Figure 1

BWRVIP EVALUATION

TE # CAR255483 Component Core Shroud

Applicable NMG NMP-ES-010-GL02 BWRVIP Guideline # BWRVIP-76, Rev. 1

INF/INR # I15H2005

Condition:

During 2R23 Hatch performed significant shroud visual exams from both the interior and exterior shroud surfaces. Core Shroud interior surfaces at cells (42-47), (46-43), (42-07), (06-11) and (10-47) were examined per ASME Section XI B-N-2 exam rules which call out a VT-3 inspection. Vertical welds V-3, V-4, V-5, V-6, V-7 and V-8 were examined [redacted] with [redacted] EVT-1 exams from both the OD and ID surfaces. Five GEH INRs document the findings from these shroud inspections:

1. INR 15-03 - VT-3 exam of cell lane (42-47) identified five total axially oriented flaws measuring a maximum of 1.65". One of these flaws crosses the entire H-4 weld.
2. INR 15-05 - Shroud lane (42-07) identified four total flaws in the vicinity of the V-3/H-4 intersection, the largest of which was 6.3" running somewhat parrellel to the V-3 weld and passing completely through th H-4 weld.
3. INR 15-06 - Two flawed areas were identified during examinations of cell lane (46-43), both of which were outside of weld heat affected zones. Two indications measuring a maximum of 1.9" were found roughly 3" CCW from V-5 and 12" inches above H-5. These indications are axially oriented and located in an area showing signs of heavy surface grinding. Two additional axially oriented indications (0.88" maximum) were found just below the H-5 weld and slightly CW of V-5.

   The flaws described in the above 3 INRs were initially identified via the ASME section XI VT-3 exam but upon discovery were further evaluated with the EVT-1 method. The flaws listed in the 2 INRs below were identified via BWRVIP prescribed EVT-1 exams.

4. INR 15-04 - EVT-1 exams performed on vertical weld V-6 noted two axially oriented indications with a maximum length of 3.1". One of these indications starts on the CCW side of the V-6 weld toe and extends upward, through the H-4 weld and beyond the heat affected zone above H-4. It should be noted that the previously noted V6 indication that was tracked during 1R18 and reinspected 2R19 was determined to be non-relevant during 2R23, although the non-relevant

indication seemed to end where the 2R23 indication begins at the CCW weld to of V-6. The other 2R23 indication at this location branches off of the first 3.1" indication just above V-6 on the upper edge of H-4 and runs axially away from H-4 for roughly 1.1".

5. INR 15-07 - EVT-1 examination of weld V-4 noted a 3.5" axially oriented indication running from above the H-4 weld roughly 1.5" CW of V-4 to a location roughly 0.92" below H-4.

Disposition:

Structural Integrity Associates was contacted during the 2R23 outage to help Hatch evaluate the referenced condition. SIA calculation 1500270.301-R0 conservatively assumes all identified flaws are through-wall in depth. It then evaluates a single bounding flaw (6.3" flaw at V-3/H-4), having shown that parallel flaws are bounded by a single flaw. This evaluation calculates the maximum allowable flaw length to be 46.02". It confirms a 10-year interval for re-inspection to be structurally acceptable. However, current fluence projections for the Unit 2 Shroud indicate that welds H-4, V-3, V-4, V-5 and V-6 will exceed the [redacted] fluence threshold [redacted] during Cycle 27. [redacted] Therefore prior to 2R26 startup, flaw evaluations associated with these welds must be either re-evaluated assuming all weld ligament above this fluence is flawed, or the existing evaluation submitted to the NRC.

Basis for Disposition:

All axially oriented indications identified during 2R23 are bounded by the 6.3" flaw which was determined acceptable in SIA calculation 1500270.301-R0. While INR H2R23-IVVI-15-03 and 15-05 do identify horizontal indications along the H-4 weld, the tie rods installed on the shroud structurally replace the horizontal welds which mitigate horizontally oriented flaws. The above referenced calculation establishes that an operating interval of 44 years is structurally acceptable with the flaws identified during 2R23. [redacted] It is important to note that ASME Section XI rules for re-inspection will also apply to many of these indications, and that additional [redacted] limitations [redacted] limit the use of this inspection interval.

Scope Expansion (ref. NMI step 4.6.9)

[redacted] no scope expansion is required as all vertical welds have established intervals for re-inspection. Horizontal welds to not require examination due to installed tie rods. See attached document for justification against ASME Section XI scope expansion.

Follow-on or Supplemental Examinations (ref. NMI step 4.6.10)

The above-referenced structural evaluation justifies a 10-year re-inspection interval, however due to additional evaluation limitations which will be applicable after 2R26, re-examination of V-4, V-6, and flaws reported at lanes 42-47, 46-43(V-5), and 42-07(V-3) are recommended for reinspection during 2R26 to apply up to date inspection results for re-evaluation. In addition, the flaws seen in cells 46-43, 42-07 and 42-47 that are not associated with either vertical or horizontal welds will be dealt with using the rules within ASME Section XI. Because of these ASME code rules, shroud ID lanes (42-47), (42-07) and (46-43) must be examined using the VT-3 method in each of the three ISI periods in the 5th ISI interval beginning 1 January 2016. See attached document for ASME Section XI re-examination frequency discussion.

References (ref. NMI step 4.7.1)

INR H2R23-IVVI-15-03 Core Shroud ID from 42-47

INR H2R23-IVVI-15-04 Core Shroud Vertical Weld V-6

INR H2R23-IVVI-15-05 Core Shroud ID from 42-07

INR H2R23-IVVI-15-06 Core Shroud ID from 46-43

INR H2R23-IVVI-15-07 Core Shroud Vertical Weld V-4

SIA document 1500370.301 Rev. 0, HNP2 Core Shroud Axially Oriented Flaw Calculation

Review and Approval (ref. NMI Step 4.7)

Responsible Engineer: Andrew Gordon / Andrew Gordon Date: 04/01/2015

Independent Review: DeLisa Pournaras / DeLisa Pournaras Date: 4/7/2015

Supervisor Approval: Dale Willyard Dale Willyard Date: 4-8-15

Edwin I. Hatch Nuclear Plant – Unit 2 Technical Justification Regarding Scope Expansion of ASME Code Section XI B-N-2 Components

On February 21, 2015, inspection personnel performing scheduled visual VT-3 examinations of the Edwin I. Hatch Nuclear Plant – Unit 2 Core Shroud reported new crack-like indications not associated with a horizontal or vertical weld. The indications were reported to SNC via INR H2R23-IVVI-15-03,-05 and -06 and are located at 40°, 45° and 140° azimuths and in the areas of and between horizontal welds H4 and H5.

The two indications detected at 40° from cell location 46-43 were measured to be 1.7" and 1.9" in length. These indications were located roughly 3" ccw from the V-5 weld and 12" above the H-5 weld. As noted in INR 15-06, inspection personnel noted evidence of heavy surface grinding in the area.

An additional indication extending beyond the H-4 HAZ was identified at 45° during inspection of cell lane 42-47. Horizontal indications were noted within the weld HAZ, although one indication branches axially outside of the HAZ. This indication branches up and away from H-4 extending a distance of 1.65" beyond the toe of H-4. Four other indications were noted within INR 15-03 but in all instances these other indications are associated with the H-4 weld.

The final indications are noted within INR 15-05 at roughly 140° near the V-3 / H-4 intersection seen in cell 42-07. The major indication noted here is 6.3" in length which runs roughly parallel to V-3. This indication starts roughly 1" CW of V-3 in the base metal and terminates below H-4, still approximately 0.75" CW of V-3. Two additional axial indications measuring 0.9" and 1.4" are seen below the H-4 weld but outside of its HAZ. A fourth indication of 1.3" in length is seen branching axially below the toe of H-4.

These examinations were performed to comply with ASME Section XI Code Table IWB-2500-1, Category B-N-2 Item Number B13.40 "Core Support Structures" requirements and therefore the rules of IWB-2420 "Successive Inspections" and IWB-2430 "Additional Examinations" apply. This Technical Justification Regarding Scope Expansion for Examination has thus been prepared to lay the requirements and logic for compliance with these requirements.

Successive Inspections

The applicable rule for compliance regarding successive examinations is IWB-2420(b) which requires that "*the areas containing the flaws or relevant conditions shall be reexamined during the next three inspection periods listed in the schedule of the inspection program of IWB-2400.*" IWB-2420(c) prescribes that "*If...the flaws or relevant conditions remain unchanged the component examination may revert to the original schedule of successive inspections.*" The 2R23 refueling outage is the last outage of Period 3 of ISI interval 4. Compliance thus dictates that follow-up examinations be conducted during an outage in each of the three periods of the 5th interval.

Additional Examinations

IWB-2430(a) states that in part

"Examinations performed in accordance with Table IWB-2500-1 that reveal flaws or relevant conditions exceeding the acceptance standards of Table IWB-3410-1 shall be extended to include additional examinations during the current outage. The additional examinations shall include an additional number of welds, areas, or parts, included in the inspection item, equal to the number of welds, areas, or parts, included in the inspection item that were scheduled to be performed during the present inspection period. The additional examinations shall be selected from welds, areas, or parts of similar material and service."

The original Code Section XI requirement for B-N-2 Item B13.40 is "Accessible Surfaces" employing visual VT-3 examination techniques.

In order to assess potential locations for scope expansion the original examination requirement must be assessed. The inner diameter of the core shroud is considered a B-N-2 component in its entirety. Thus all accessible surfaces would require examination during each 10-year ISI interval and are scheduled accordingly. The shroud surfaces which are considered "always" accessible are those surfaces which can be examined from the outer diameter of the shroud because the only obstructions are permanent ones such as jet pumps or tie rods. These items are scheduled throughout the interval by lanes corresponding to azimuths. Unlike the outer diameter, the inner diameter of the shroud along with any surfaces below the core plate do not normally become accessible for VT-3 surface examination. However, scheduled fuel cell evacuations along the periphery of the core permit some azimuths of the inner diameter to be accessible for VT-3 surface examination and they are scheduled appropriately. The inner diameter surfaces are also scheduled by azimuthal lanes corresponding to the fuel cells which are evacuated during the outage. The 2R23 outage scope contains those azimuthal lanes that were to be evacuated. In total, five fuel cells were made available for inspection, and all were inspected. It is not an ASME Code Section XI requirement to evacuate fuel cells or remove other components to "make" surfaces accessible.

Basis for sufficiency – The indications detected were in base metal material not associated with any horizontal or vertical shroud weld. Indications that were noted in exam reports to be associated with welds are handled within appropriate, approved BWRVIP guidance. Axial indications noted within this document were evaluated within Structural Integrity Associates calculation 1500270.301 Rev 0. This calculation demonstrates the structural acceptability of all indications for at least 10 years. Those indications noted to be associated with surfaces and not welds, will be scheduled for successive examination in each of the 3 Periods within the 5th ISI Interval in accordance with the Section XI code.

Based on this assessment additional visual VT-3 examinations are not warranted to meet Code requirements.

Extent of Condition

Extent of condition exams should be discussed by the BWRVIP Technical Team, with input from ISI personnel. Based on the recommendation from this discussion, additional surface examinations in base material, particularly in areas that have not been examined during the 10-year ISI interval may be scheduled. TE 916111 has been issued to ensure further discussion of this topic at the next opportunity.

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1500270.301NP

Project No.: 1500270

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
HNP2 Shroud Flaw Evaluation

CONTRACT NO.:
Purchase Order: SNG 19354-0012, Rev. 0

CLIENT:
Southern Nuclear Operating Company, Inc.

PLANT:
Edwin I. Hatch Nuclear Plant, Unit 2

CALCULATION TITLE:
Hatch Nuclear Power Plant Unit 2 Core Shroud Axially Oriented Flaw

NOTE: This document is the non-proprietary version of SI Calculation No. 1500270.301, Rev. 0. The EPRI and Southern Nuclear proprietary information has been redacted.

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 18	Initial Issue	Daniel V. Sommerville 05MAR2015	**Responsible Engineer** Heather F. Jackson 05MAR2015 **Responsible Verifier** Fabien Hsu 05MAR2015

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1.0 INTRODUCTION

Multiple reportable indications were detected in the Hatch Nuclear Plant, Unit 2 (HNP2) core shroud during the Spring 2015 (2R23) refueling outage planned inspections [1].

The 2R23 inspections [2] consisted of:

- Visual examinations (VT) of the inside and outside surfaces of vertical welds V3, V4, V5, V6, V7, and V8,
- Shroud exterior surface VT examinations from top guide to core plate at azimuths of 35 to 65°, 125 to 155°, 215 to 245°, and 305 to 335°,
- Shroud interior surface VT examinations from top guide to core plate from azimuths 90 to 270°.

Several axially oriented indications were reported on the inside surface of the core shroud in the vicinity of the core shroud circumferential welds H4 and H5 and in the base metal near the vertical weld V5 intersection with circumferential weld H5 [1].

Figure 1 illustrates the HNP2 core shroud configuration and weld locations, while Figure 2 illustrates the locations and sizes of reported indications, based on 2R23 inspection results [1].

2.0 OBJECTIVES

The objectives of the work documented in this calculation package are to:

1. Perform a flaw evaluation for all of the axially oriented indications reported during the Spring 2015 HNP2 refueling outage (2R23).
2. Perform a flaw evaluation of the base material indications in accordance with the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI rules for inservice inspection of light water reactors.

Circumferentially oriented indications or the circumferential component of indications are not evaluated in this calculation package since the tie rod shroud repair installed at HNP2 structurally replaces the circumferential welds [2]. By extension, a circumferentially oriented flaw elsewhere in the core shroud is not structurally significant since the tie rods provide the load-carrying capacity for lateral loads.

3.0 METHODOLOGY

The methodology used for the flaw evaluation and leakage calculation is discussed below.

3.1 Flaw Evaluation

Evaluation of the axially oriented flaws is performed using methods consistent with those presented in BWRVIP-76, Revision 1 [3]. The following process is used:

1. Characterize location and dimensions of all reportable indications, using the most recent shroud inspection data,
2. Select applicable material properties and failure modes,
3. Apply inspection uncertainty as appropriate for the method and delivery system used,
4. Add crack growth for the applicable evaluation interval and growth mechanisms,

5. Evaluate stability of the indications using the fracture mechanics methods appropriate for the material type and environmental conditions.

It is important to note that the flaw evaluation methods provided in Reference [3] are based on the rules of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI IWB-3600 and Nonmandatory Appendix C. Material-specific crack growth rates, tensile and fracture toughness properties, and inspection uncertainties, which are not provided in ASME XI, are used in this evaluation since they are applicable to the environment, material, and inspection methods. All aspects of this methodology have been reviewed and accepted by the U.S. Nuclear Regulatory Commission (NRC) with respect to inspection and evaluation of the Boiling Water Reactor (BWR) core shroud [3].

Each step of the process is described separately below.

3.1.1 Characterize Flaws

The number, orientation, and dimensions of the reported indications are obtained from the inspection notification reports (INRs) provided by General Electric Hitachi Nuclear Energy Americas, LLC (GE-H) [1]. The INRs are also used to infer the likely initiation and growth mechanism for the reportable indications which is necessary in order to identify which crack growth mechanisms to consider in the flaw evaluation.

Several indications are reported on the core shroud inside surface [1]. All of the indications on the shroud inner surface are conservatively treated as through-wall flaws. A single bounding flaw is selected for evaluation rather than individually evaluating each of the indications reported. See Assumptions 1 and 5 below.

3.1.2 Material Properties

BWRVIP-100, Revision 1 [4] is used to identify the failure modes appropriate for the level of fluence in the core shroud material. Tensile properties will be selected at a temperature and fluence level such that the allowable flaw sizes and plastic zone size are bounding. BWRVIP-100, Revision 1 [4] and the ASME Code, Section II, Part D [5a] are also used to select the appropriate tensile properties for the fluence level and temperature. BWRVIP-100, Revision 1 [4] is used to select the appropriate fracture toughness for the shroud fluence. The results of this procedure are described in Section 7.0.

The peak fluence on the shroud at the end of life, which is reported to be 50.1 effective full-power years (EFPY) and corresponds to the year 2038 [6] is conservatively used for this evaluation.

3.1.3 Inspection Uncertainty

Inspection uncertainties provided in the inspection method demonstration documentation, appropriate to the inspection method and delivery system, are applied to the length of all reportable indications [7].

3.1.4 Crack Growth

Consistent with the methods provided in BWRVIP-76, Revision 1 [3] and the clarifying guidance given in References [8, 9] intergranular stress corrosion crack growth (IGSCC) is calculated for the evaluation interval and added to each end of each reportable indication. Fatigue crack growth is not a relevant mechanism for the core shroud; therefore, IGSCC is the only relevant crack growth mechanism.

The IGSCC length crack growth rate provided in BWRVIP-76, Revision 1 [3] and BWRVIP-14-A [8] is used for all flaws:

da/dt = {{ }}

Each tip of each flaw will grow by 4.38 inches during the 10-year interval as shown below:

{{( )}} (10 years) (365.25 days/year) (24 hours/day) = 4.38 inches / flaw tip

3.1.5 Fracture Mechanics

Stability of the core shroud is assessed by performing both limit load and linear elastic fracture mechanics (LEFM) calculations, based on the material properties established in Section 4.0. The limit load calculations evaluate stability of the core shroud structure; whereas, the LEFM calculations evaluate stability of the crack.

The limit load method provided in ASME B&PV Code, Section XI, Nonmandatory Appendix C [5b] for through-wall axial flaws is used since the method provided in BWRVIP-76, Revision 1 [3] assumes that the circumferential welds on either end of the vertical weld are cracked through-wall. For the present situation, some of the flaws to be evaluated are at, or passing through, a circumferential weld. Therefore, the assumption of a finite height cylinder is not well suited. Consequently, the ASME B&PV Code Section XI, Nonmandatory Appendix C solution is considered a more appropriate solution. The following equation is specified in Section XI C-5410 for through-wall axial flaws [5b]:

$$l_{allow} = 1.58 \cdot \sqrt{R_m \cdot t} \cdot \sqrt{\left(\frac{\sigma_{flow}}{\sigma_{Hoop}}\right)^2 - 1} \qquad (1)$$

Where
l_{allow} = 2a, allowable flaw length, inch
R_m = Shroud mean radius, inch
t = Shroud wall thickness, inch
σ_{flow} = Flow stress, ksi
σ_{Hoop} = Hoop stress, ksi

To remain consistent with the intent of ASME Section XI [5b] and based on guidance in the technical basis documentation [14], a Structural Factor (SF) for the appropriate Service Level condition is applied to hoop stress. Service Level D is the limiting condition, and an SF of 1.39 is used as recommended in BWRVIP-76, Revision 1 [3, Appendix D.5].

LEFM solutions published in Reference [10] are selected for this evaluation, as described below. The solutions used for this evaluation are consistent with those suggested in BWRVIP-76, Revision 1 [3]. The following LEFM solutions are used:

- Single through-wall axial flaw in an internally pressurized cylinder (See Figure 3) [10, pg. 485],
- Infinite array of parallel through-wall flaws in a plate subjected to a membrane load (See Figure 4) [10, pg. 256],
- Plastic zone size correction [10, pg. 16].

The LEFM solution for a single through-wall axial flaw in an internally pressurized cylinder is a good representation of a single axial flaw in the core shroud. The LEFM solution for an infinite array of parallel through-wall flaws in a plate provides means of understanding the interaction between multiple parallel flaws. This solution is used to show that treating a single flaw by itself provides a bounding treatment of the driving force at the tip of the axial flaw. In other words, review of the LEFM solution for an array of parallel axial flaws shows that adjacent flaws tend to "shield" each other and reduce the resulting driving force at the crack tip.

The radius of the plastic zone size is added as an additional crack length at each end of each flaw. The plastic zone size correction is estimated, for conditions of small scale yielding, using the following equation [10, pg. 16]:

$$r_y = \alpha \cdot \left(\frac{K_I}{\sigma_y} \right)^2 \qquad (2)$$

Where α is used to adjust for plane strain or plane stress conditions at the crack tip, where:

Plane Strain: $\alpha = 1/6\pi$

Plane Stress: $\alpha = 1/2\pi$

σ_y is yield stress, ksi

For this calculation the allowable fracture toughness, K_{IC}, and the plane stress adjustment is used with Eq. (2) above to obtain a bounding estimate of the plastic zone size for the flaw stability calculations, regardless of end of interval flaw size.

4.0 DESIGN INPUTS

The design inputs used for this calculation are identified below:

Geometry:

The shroud geometry is taken from Reference [11]:

- Shroud ID: 174.5 inch [11a, for elevations between top guide and core plate]
- Shroud Thickness, t: 1.5 inch [11b]

Loads and Through-wall Stress Distributions:

The upper shroud RIPD values are taken from Reference [2], and are summarized as follows:

- Level A RIPD: 7.81 psi
- Level B RIPD: 11.72 psi
- Level C RIPD: 29.5 psi
- Level D RIPD: 29.5 psi

IGSCC Crack Growth Rate:

The IGSCC length crack growth rate provided in BWRVIP-76, Revision 1 [3, page F-1] and BWRVIP-14-A [8, page 6-2] is assumed at each crack tip.

This crack growth rate in the axial direction is (( )) [3, 8].

Reactor Coolant Water Chemistry:

HNP2 implemented hydrogen water chemistry (HWC) in September 1991, Noble Metal Chemical Addition (NMCA) in March 2000, and began On-Line NobleChem (OLNC) in November 2011 [2, 12]. Under HWC conditions and OLNC, the shroud horizontal welds H3, H4 and H5 are considered mitigated, and the vertical welds between these horizontal welds (shown in Figure 1 and Figure 2) are also considered mitigated [13, Table 4-1]. However, crack growth based on normal water chemistry is conservatively assumed in this calculation. See Assumption 6 below.

Shroud Fluence:

The peak shroud fluence along the entire core shroud height at the end of design life at 50.1 EFPY (2038) is conservatively used for this evaluation, per Assumption 2 below. The bounding fluence at 50.1 EFPY is (( )) [6].

Material Type:

The shroud material is SA-240 TP304L stainless steel [11a].

Material Properties:

For fluence values greater than (( )) but lower than (( )), LEFM analysis should be used to determine the structural stability of flaws in the core shroud, based on a static initiation, plane strain, mode I fracture toughness. Consequently, the following toughness value is used for this evaluation:

- (( )) [4]

The material flow stress and yield stress both increase with fluence [4]. However, it is conservative to use un-irradiated materials properties since this will result in a larger plastic zone size and a smaller allowable flaw size. Consequently, un-irradiated tensile properties are used [5a]:

- σ_u (un-irradiated, 550°F): 57.2 ksi [5a, Table U]
- σ_y (un-irradiated, 550°F): 15.9 ksi [5a, Table Y-1]
- σ_f (un-irradiated, 550°F): 36.6 ksi (taken as the average of σ_u and σ_y)

Initial Flaw Distribution:

The flaw lengths and configurations are taken from the 2015 INRs [1]. Since several indications are reported, and many have been detected using a VT-3 inspection technique (accuracy of sizing is uncertain), no attempt is made to evaluate every indication in this calculation package; rather a bounding approach to flaw evaluation is taken as discussed in the methodology section.

Inspection Uncertainty:

Evaluation factors to account for inspection uncertainties for the visual (EVT-1 and VT-3) inspection data are taken from the applicable demonstrations for the inspection technique identified in the INRs [1]. The evaluation factors are taken from BWRVIP-03 [7, Section 3.1]. No depth evaluation factors are used since all flaws are treated as through-wall.

The applicable length evaluation factor associated with VT and measurement of flaws with a ruler is (( )) [7, Section 3.1]. This factor is applied at each axial crack front of the evaluated configuration, per Assumption 7 below.

Operating Cycle Duration:

HNP2 is on a 2 year operating cycle [2].

5.0 ASSUMPTIONS

The following assumptions are used in this evaluation.

1. All flaws are assumed to be through-wall for the structural evaluation.

   This assumption is bounding and necessary since the inspection technique reported in Reference [1] is visual inspection (VT) and is not capable of detecting flaw depth. This assumption provides a bounding flaw evaluation for all flaws.

2. The 50.1 EFPY peak shroud fluence is used to determine the fracture toughness for all flaws.

   This assumption is conservative because it applies the bounding fluence projected at the end of design life to all locations. The current refueling outage is 2R23 and the end of design life is reported to be 50.1 EFPY, which corresponds to the year 2038 [6].

3. A 100% capacity factor is assumed for crack growth.

   This assumption is conservative because it uses the maximum number of hours possible, each year, for crack growth.

4. Flaws are allowed to grow through the horizontal welds.

   Inspection data from the HNP2 core shroud shows evidence of flaws growing through the horizontal weld H4 [1]; therefore, this assumption is considered appropriate.

5. A single bounding flaw is evaluated in this calculation package which is defined to bound the length reported for all axial indications.

   Rather than evaluate all axially-oriented indications separately, a single flaw evaluation is performed of the single largest flaw. It is shown in this calculation that parallel flaws are bounded by a single flaw; thus, this approach bounds all reported flaw lengths and configurations (single or multiple parallel flaws).

6. Normal water chemistry is used.

   The use of normal water chemistry is conservative since it assumes the fastest crack growth rate.

7. A length evaluation factor of [[ ]] is used when evaluating flaws.

   This assumption is conservative since no adjustment to measured flaw length is required for the purpose of flaw evaluation. This assumption is applicable to flaw lengths obtained using VT and measurement with a ruler, and when the RMS value of flaw length measurement errors during performance demonstration is less than 0.75 inch, as cited in BWRVIP-03, Revision 17, based on documentation in BWRVIP letter 2004-426 [7, note 3 to Table 3.1-1].

6.0 CALCULATIONS

All calculations are performed using an Excel spreadsheet, and flaw stability is assessed by performing bounding calculations for all reported indications, as follows:

1. The bounding shroud fluence at 50.1 EFPY is applied for all shroud elevations resulting in a lower-bound fracture toughness for all flawed locations.

2. Review of the LEFM solution shown in Figure 4 illustrates that the crack driving force for parallel flaws in a plate is reduced compared to the case of a single flaw in a plate, as shown by observation of the F_{II} curve for s→0 which corresponds to a single flaw. Consequently, multiple aligned flaws can be bounded by treating each as a separate flaw.
3. The longest flaw reported near the H4/V3 intersection is selected for evaluation and clearly bounds all flaw lengths reported. This flaw is assumed to be a single continuous flaw passing through the H4 weld. The initial flaw size considered, before addition of uncertainty and crack growth, is 6.3 inches [1c].

7.0 RESULTS

Table 1 summarizes the applicable failure mode and analysis method based on the end-of-interval fluence.

The allowable flaw size for an axially oriented flaw in the HNP2 core shroud, considering the lower-bound fracture toughness of (( )) and un-irradiated yield strength (conservative) is:

LEFM: **46.02 inches**

Limit Load: **275.40 inches**

Table 2 presents the results of the axial flaw LEFM evaluation. The 10-year, end of interval, bounding flaw size is **15.5 inches**. This flaw bounds all reported axially oriented indications. The final flaw size is determined by adding to the reported flaw size the inspection uncertainty and projected 10-year crack growth at each crack tip:

End-of-interval flaw size = 6.3 inches + 2(0.20 inch) + 2(4.38 inches) = **15.5 inches**

The calculated allowable **operating interval** for the reported indications is approximately **44 years** using the bounding IGSCC crack growth rate. No re-inspection interval greater than 10 years is currently allowed in BWRVIP-76 [3].

After 10 years of operation from the Spring 2015 inspections, the core shroud **structural margin,** on fracture toughness, **is 3.96** (Table 2). The **required structural margin is 1.39.**

8.0 CONCLUSIONS

The results of flaw evaluations show that the axially oriented indications reported in the HNP2 core shroud during the 2R23 outage are acceptable as-is for a **10-year** inspection interval.

The calculated inspection interval for all axially oriented flaws is greater than 10 years; however, the required re-inspection interval is as defined by the applicable re-inspection requirements provided in the ASME B&PV Code Sec. XI (Code year and addenda as approved for the current operating interval for the plant) [5] or BWRVIP-76, Revision 1 [3], as appropriate, depending on whether the flaws are located in the base material or adjacent to the core shroud welds. In any case, flaw evaluation results support a 10-year inspection interval.

9.0 REFERENCES

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   c. INR H2R23 IVVI-15-05 – Shroud ID Surface from Top Guide Cell 42-07
   d. INR H2R23 IVVI-15-06 – Shroud ID Surface from Top Guide Cell 46-43
   e. INR H2R23 IVVI-15-07 – Shroud ID Vertical Weld V04
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10. Tada, H., Paris, P., Irwin, G., The Stress Analysis of Cracks Handbook, 3rd. Ed., ASME Press. 2000.

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    a. Southern Nuclear Company Drawing No. 2-BN-6-6, Revision 3, "Core Shroud Weld Section and Details," SI File No. 1500270.203.
    b. Southern Nuclear Company Drawing No. 2-BN-6-4, Revision 1, "Shroud (Side View)," SI File No. 1500270.203.
    c. Southern Nuclear Company Drawing No. 2-BN-6-5, Revision 6, "Core Shroud Weld Identification Roll Out (Inside View)," SI File No. 1500270.203.
12. Water Chemistry:
    a. Southern Nuclear Company Nuclear Management Guideline, NMP-CH-005-GL01, Version 7.0, "E. I. Hatch Water Chemistry Strategic Plan," November 2014, SI File No. 1500270.206.
    b. Southern Nuclear Company 4th Quarter 2014 Mitigation Health Report for Hatch Nuclear Plant Units 1 and 2, SI File No. 1500270.206.
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Table 1. HNP2 Core Shroud Evaluation Fluence and Failure Modes

50.1 EFPY Fluence, n/cm^2 [6]	Failure Mode [4]	Analysis Method [4]
[[ ]]	Non-Ductile Fracture	LEFM with [[ ]]

Table 2. HNP2 Shroud Bounding Axial Flaw Evaluation Results

Axial Flaw at H4 with bounding length at end of 10-year interval = 15.5 in	Evaluation Method	Service Level A/B		Service Level C/D		Acceptable for 10 Years (Y/N)
		Results	Acceptance Criterion	Results	Acceptance Criterion	
	LEFM	$K_I = 5.0$ $SF = 9.9$	$K_I < 50$ $SF > 2.77$	$K_I = 12.6$ $SF = 3.9$	$K_I < 50$ $SF > 1.39$	Y

Note: K_I in ksi-in$^{0.5}$.

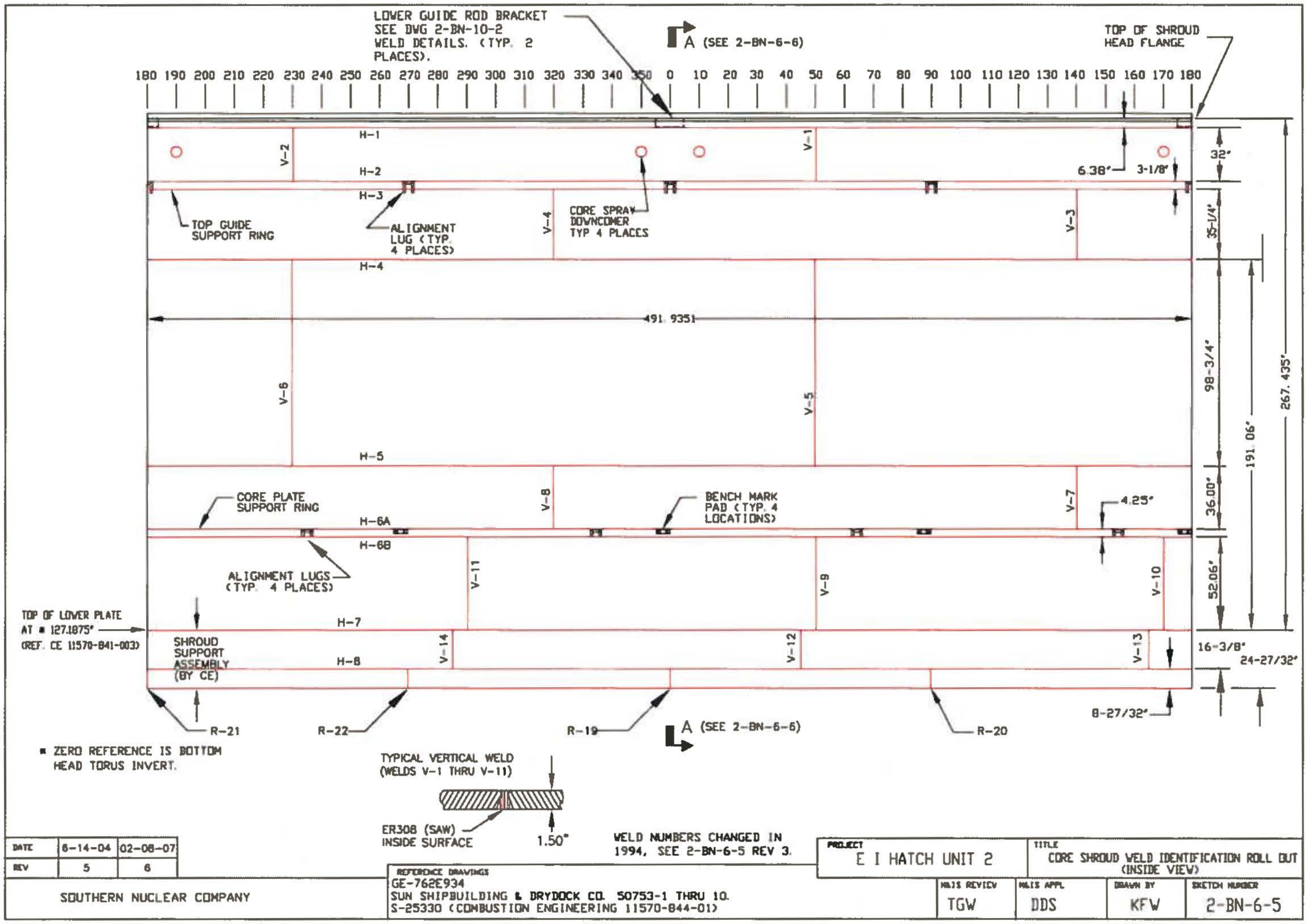


Figure 1. HNP2 Core Shroud Configuration [11]

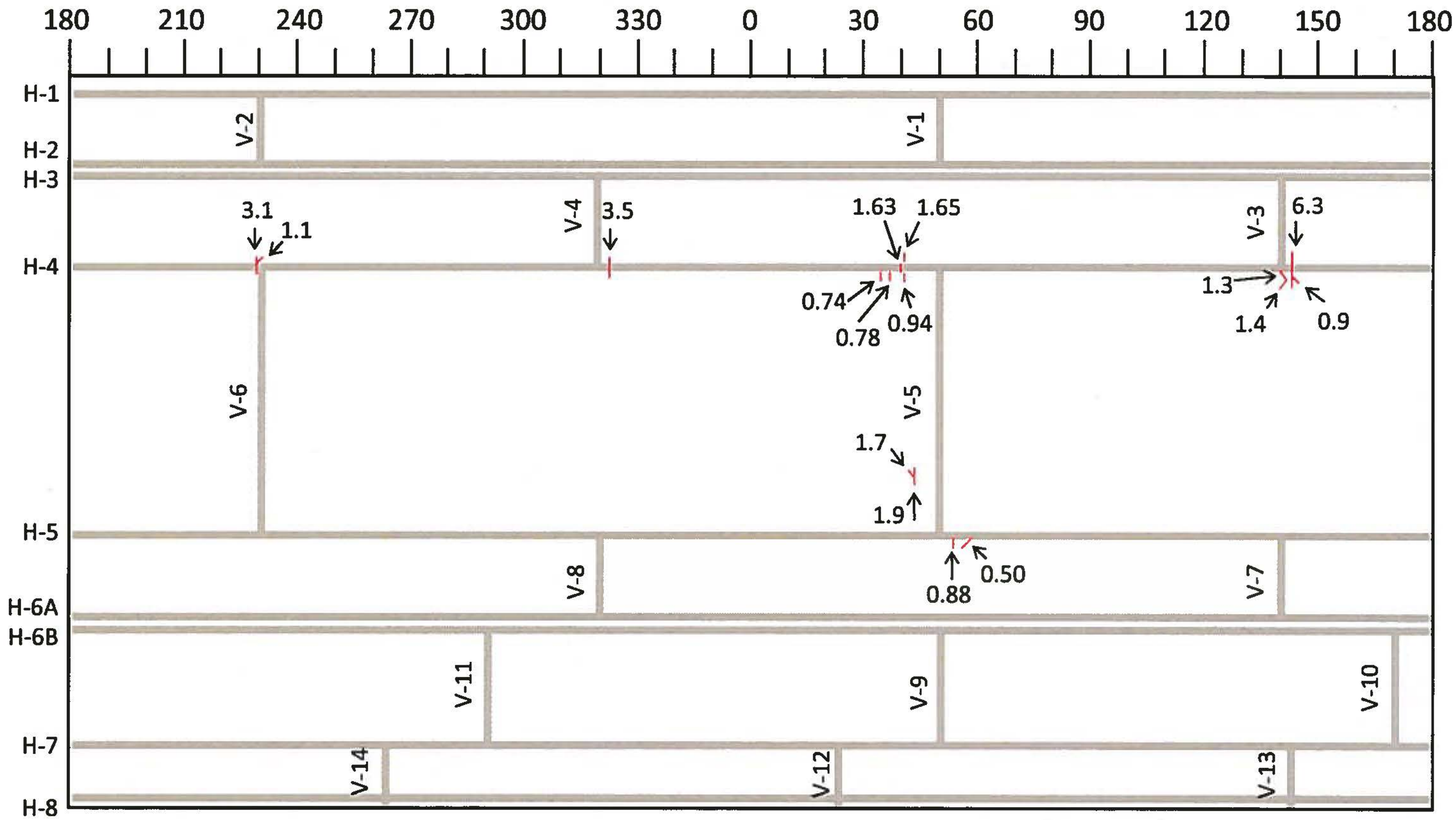
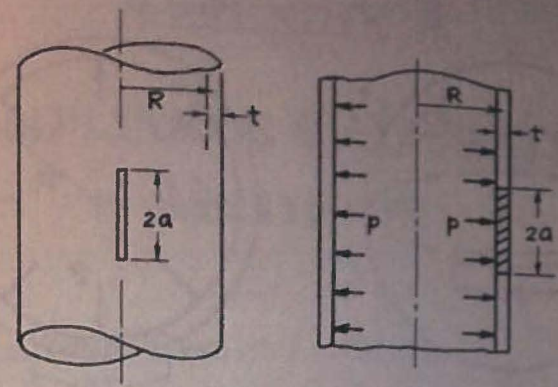


Figure 2. Map of HNP2 core shroud ID indications based on 2R23 inspection results [1]. Annotations show approximate location, orientation, and length in inches.



$$\sigma = p\frac{R}{t}$$

$$\lambda = a/\sqrt{Rt}$$

$$K_I = \sigma\sqrt{\pi a} \cdot F(\lambda)$$

$$F(\lambda) = (1 + 1.25\lambda^2)^{1/2} \qquad 0 < \lambda \le 1$$

$$= 0.6 + 0.9\,\lambda \qquad 1 \le \lambda \le 5$$

Crack Opening Area:

$$A = \frac{\sigma}{E'}(2\pi Rt) \cdot G(\lambda)$$

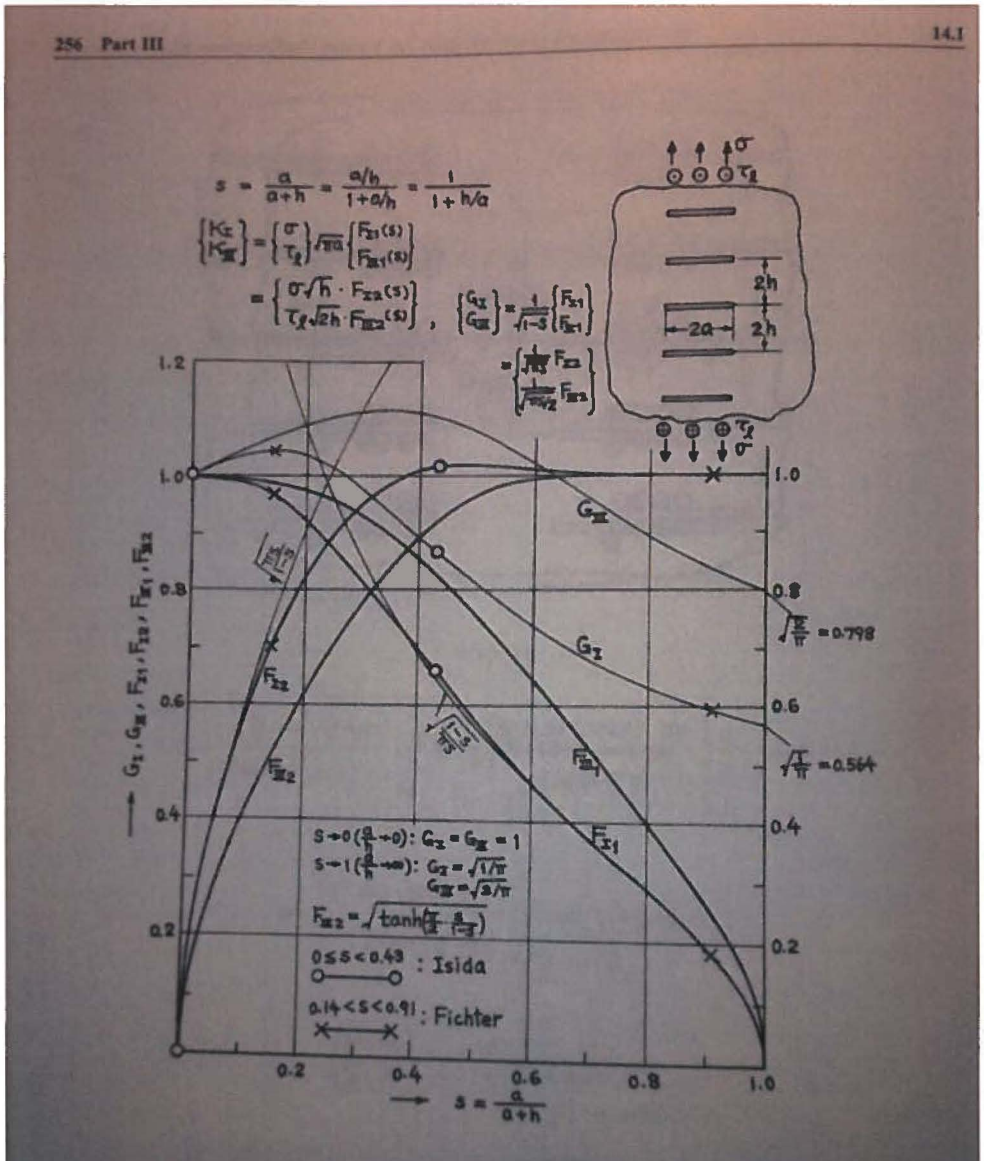
$$G(\lambda) = \lambda^2 + .625\lambda^4 \qquad 0 < \lambda \le 1$$

$$= .14 + .36\lambda^2 + .72\lambda^3 + .405\lambda^4 \qquad 1 \le \lambda \le 5$$

Methods: K Integral Transform; A Paris' Equation (see **Appendix B**)
Accuracy: K_I 1%; A 2%
References: **Folias 1965; Erdogan 1969; Tada 1983a**

NOTE: As $a \to \infty$, $K_I \to \sigma\sqrt{R}\left(\frac{\sqrt{27\pi}}{2} \cdot \frac{R}{t}\right)$ **(Harris 1997)**

Figure 3. LEFM Solution for a Single Through-wall Axial Crack in an Internally Pressurized Cylinder [10]



Method: K_I Fourier Transform (Fichter), Expansions of Complex Potentials (Isida), Asymptotic Approximation (polynomial of degree ten) (Benthem)
K_{II} Stress Concentration Factor (Neuber), Westergaard Stress Function (Tada)
Accuracy: K_I Estimated at 1%
K_{II} Exact
References: Fichter 1967; Isida 1971a; Benthem 1972; Neuber 1937; Tada 1973

Figure 4. LEFM Solution for an Infinite Array of Through-wall Cracks in a Plate with a Membrane Load [10]