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July 24, 2007

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555-0001

Subject: Duke Power Company LLC d/b/a Duke Energy Carolinas, LLC (Duke)
McGuire Nuclear Station, Unit 1
Docket No. 50-369
Relief Request 07-MN-001
Relief Request from Immediate ASME Code Flaw Repair of
Charging Pump Discharge Line Valve 1NV-240

Pursuant to 10 CFR 50.55a(a)(3)(ii), Duke requests relief from the 1998 Edition, through the 2000 Addenda, of the ASME Section XI Code requirement as stipulated in Paragraph IWC-3122.2 on the basis that compliance with the specified requirements would result in a hardship or unusual difficulty without a compensating increase in the level of quality and safety. Accordingly, please find attached Relief Request 07-MN-001. This relief request is submitted because a through-wall flaw was discovered in a Chemical & Volume Control (NV) System, 3-inch cast stainless steel valve body located in the Auxiliary Building. A subsequent inspection of both units' NV accessible piping from charging pump suction to the containment isolation valves did not identify any other through-wall leakage. The NRC was informed of this problem by telephone conference calls on June 21, 22, and 25, 2007.

This flaw was not found during the performance of an ASME Section XI Code inservice inspection; therefore, Section XI requirements do not technically apply until repair/replacement activities are conducted to correct the flaw. However, using conservative decision making and for flaw evaluation review expediency, Duke is pursuing NRC acceptance of our system operational position through the formal relief request process.

This relief request contains the following regulatory commitments:

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1. Operations personnel shall observe and measure the valve flaw leakage rate and record a value in a retrievable format once every shift to ensure early detection of an increased leak rate and to ensure the assumptions used in the component operability evaluation remain valid.

2. Non-Destructive Examination personnel shall conduct a "best effort" ultrasonic volumetric examination of the flaw location every 90 days until the valve is repaired.

3. A Code repair shall be performed during the next scheduled refueling outage, 1EOC19 RFO, which is currently scheduled to begin in September 2008. If a condition leads to a forced outage of sufficient duration before 1EOC19 RFO, the repair will be performed during this forced outage.

Duke is requesting that the NRC review and approve this relief request at your earliest convenience. Please direct questions pertaining to this request to P. T. Vu of Regulatory Compliance at (704) 875-4302.

Sincerely,

G. R. Peterson

Attachment

xc w/attachment:

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ATTACHMENT

RELIEF REQUEST NO. 07-MN-001

McGuire Nuclear Station – Unit 1

Relief Request Number 07-MN-001

Relief Requested
In Accordance with 10 CFR 50.55a (a)(3)(ii)

-- Compliance with the Specified Requirements of this Section Would Result in a Hardship or Unusual Difficulty Without a Compensating Increase in the Level of Quality and Safety --

1. **ASME Code Component(s) Affected**
The component is a Class 2, manually-operated, 3-inch cast stainless steel, flex-wedge, gate valve manufactured by Walworth (Duke Energy valve number 1NV-240). The valve body is made of SA351, CF8M cast stainless steel material.

The valve is a component within the Chemical & Volume Control (NV) System which has a design pressure and temperature of 2,735 psig and 189°F, respectively. The valve is situated within the common charging header downstream from the Reciprocating Charging Pump. Both the valve and pump are located outside of containment in the Auxiliary Building. The valve provides piping system isolation for maintenance, but it does not provide any active safety-related function.

2. **Applicable Code Edition and Addenda**
ASME Section XI Code, 1998 Edition through the 2000 Addenda.

3. **Applicable Code Requirement**
ASME Section XI Code, subsection IWC, "Requirements for Class 2 Components of Light-Water Cooled Power Plants", subparagraph IWC-3122.2, "Acceptance by Repair/Replacement Activity".

4. **Reason for Request**
Active leakage from two small pinhole defects located on the valve body neck was found. The pinholes are in close proximity in a weld repair area. The pinholes appear to be located at small depressions. More careful inspection of the valve suggests that the flaw may actually be associated with a small thumbnail-shaped defect interconnecting the two primary leak sites. Subsequent examinations determined that the leak is located near the center of a 2.5 inch diameter circular-shaped weld repair. This weld repair area was one of numerous documented weld repair areas performed on the valve body.

The following NDE examination methods were performed to locate and characterize the flaw. An eddy current exam revealed nine areas on the valve body where the base metal had been repaired by welding. A computed radiography exam with the source placed in two different positions revealed no large voids. Also, "best effort" ultrasonic scans using four (4) beam angles from four (4) directions (2 axial and 2 circumferential) were made of each valve body weld repair area without revealing any planar flaws. Recognizing the particular

component limitations affecting each examination method, no flaws of significant size were detected.

Performing a Code repair/replacement activity now to correct flaws that have such a minor leak rate (< 0.01 gpm) would create a hardship based on the following overriding concern: the potential risks associated with unit cycling and emergent equipment issues incurred during shutdown and startup evolutions.

No compensating increase in the level of quality and safety would be gained by immediate repair of the flaws. Engineering calculations and judgment provide the basis to state that the NV system valve body is very robust and capable of performing its design function through the end of the current fuel cycle.

5. **<u>Proposed Alternative and Basis for Use</u>**

<u>Alternative</u>: Referencing ASME Section XI Code subparagraph IWC-3122.3, "Acceptance by Analytical Evaluation", Duke Energy Corporation proposes to temporarily accept the as-found relevant condition (i.e. through-wall flaw) to allow continued service (operation through the current unit run cycle) instead of performing immediate flaw correction by a repair/replacement activity described in Code subparagraph IWC-3122.2, "Acceptance by Repair/Replacement Activity". This proposed alternative is based on Duke performing the following actions.

1. Operations staff addressed the potential extent of condition issue by conducting a thorough inspection of both trains of both units' NV piping from the suction of the pumps to the containment penetrations for the normal charging header, the Reactor Coolant (NC) System seal supply headers, and the NV cold leg injection headers. All accessible components, including cast valves were inspected. No through-wall leakage was identified during these inspections.

2. Operations personnel shall observe and measure the valve flaw leakage rate and record a value in a retrievable format once every shift to ensure early detection of an increased leak rate and to ensure the assumptions used in the component operability evaluation remain valid.

3. NDE personnel shall conduct a "best effort" ultrasonic volumetric examination of the flaw location every 90 days until the valve is repaired.

4. A Code repair shall be performed during the next scheduled refueling outage, 1EOC19 RFO, which is currently scheduled to begin in September 2008. If a condition leads to a forced outage of sufficient duration before 1EOC19 RFO, the repair will be performed during this forced outage.

<u>Basis</u>: Please reference Enclosure 1, "Operability Evaluation – Valve 1NV-240" as the basis for considering the valve Operable But Degraded/Non-conforming to ASME Section XI requirements. The Operability Evaluation and its referenced documents, provided as attachments, present the basis for the requested relief from Code requirements.

6. Duration of Proposed Alternative

The requested Code relief shall be used until Code repair/replacement activities are performed on the valve body either during 1EOC19 RFO or during a forced outage of sufficient duration before 1EOC19 RFO.

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001

ENCLOSURE 1
Operability Evaluation – Valve 1NV-240

1. Statement of Problem

Active through-wall pinhole leakage was identified on the body of valve 1NV-240 (UNIT 1 SEAL WATER INJ FLOW CONTROL INLET ISOL) (WR 927504). The purpose of this evaluation is to evaluate the integrity of this valve body as an ASME Class B pressure boundary with respect to ECCS operability, NC pressure boundary and radiological dose limits.

The initial (pre-cleaning) through-wall leak-rate was determined to be 1 drop every minute & 55 seconds. Nominal leakage has subsequently remained stable at one drop every 40-50 seconds.

2. Relation to QA Condition

1NV-240 is an ASME Class II component, and the valve pressure boundary serves to support the Emergency Core Cooling System function. Thus the evaluation is QA condition 1.

3. Applicable codes, Standards, Regulations

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a) ASME Section III, Subsection NC, 1971 Edition, W'71 addenda.
b) ASME Code Section XI, Division 1 ASME XI, 1998 Edition, 2000 Addenda (IWC-3000 & IWA-4000).
c) NRC Generic Letter 90-05.
d) General Design Criterion 19 - Control Room

4. Evaluation Inputs/Methods Used

Flaw characterization was performed using the results of RT and UT examinations.

Fracture mechanics analyses were performed to determine the limiting crack size, and predicted flaw growth size. The flaw evaluation is based on the criteria prescribed in Section XI, Appendix C assuming the valve body neck may be modeled as a pipe and using a flaw depth to wall thickness ratio of unity (similar to the ASME Code Case N-513-1 approach). Allowable flaw sizes were determined using Limit Load criteria specified in Article C-5000 in both the axial and circumferential directions. Flaw growth evaluation considering fatigue as a possible mechanism is performed using the methodology in ASME Code Section XI, Appendix C for stainless steel components.

5. Other Evaluation Criteria

5.1 Radiological dose limits are evaluated based on comparison of total ECCS Auxiliary Building leakage and the input assumptions in the dose calculation of record.

6. Applicable Licensing References

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a) Technical Specifications: 3.4.13 (RCS Operational Leakage), 3.5.2, 3.5.3 (ECCS Operability)
b) UFSAR 6.2.4.2 (Containment Isolation Systems System Design)
c) UFSAR 6.3 Emergency Core Cooling System
d) UFSAR 9.3.4 Chemical and Volume Control System
e) UFSAR 15.4.6 Boron Dilution Event
f) UFSAR 15.6 Decrease in Reactor Coolant Inventory
g) UFSAR 3.9.2 ASME Code Class 2 and 3 Components
h) SLC 16.5.9 (RCS Structural Integrity)
i) SLC 16.9.9, 16.9.11, 16.9.12, 16.9.14 (Boration Flowpath, Sources)
j) SLC 16.9.7 (Standby Shutdown System).

7. Assumptions

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a) Service Level A/B safety factors are conservatively applied.
b) 1NV-240 valve body neck is modeled as a pipe and using a flaw depth to wall thickness ratio of unity (similar to the ASME Code Case N-513-1 approach). The pipe assumption model is justified because:
    i) there is minimal bending stress contribution,
    ii) the flaw is remotely located from any structural discontinuities and/or end restraints, therefore localized stresses do not appreciably affect the flaw region,
    iii) there is no appreciable thermal stress contribution.

8. References

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a) MCS-1554.NV-00-0001, Rev. 17 (NV DBD)
b) MCFD-1554-03.00 (Rev. 9), -01.02 (Rev. 10), -03.01 (Rev. 17) (NV Flow Diagrams)
c) MCM-1205.00-1186-001, Rev. DD (Valve Drawing for Duke Item 04J-017)
d) MCC-1206.02-83-0018, Rev. 9, NVA Stress Analysis Calculation Pipe Stress Results (Problem NVA) for Valve 1NV-240).
e) MCM 1205.00-0577, "Walworth Seismic Analysis No. 180 and Design Stress Report No. W/AN-24-76" Revision 3.
f) MCC-1227.00-00-0048, Rev. 10, Chapter 15 LOCA Offsite Dose Analysis
g) MCC-1227.00-00-0095, Rev. 1, Calculation of Post LOCA Radiation Doses for Operability of Control Room Unfiltered Leakage.
h) MCC-1227.00-00-0094, Rev. 1, Radiological Consequences of Design Basis LOCA 15.6.2.3.
i) Structural Integrity Calculation, MNS-05Q-301, Rev. 0, "Flaw Evaluation of Charging System Valve Pinhole Leak."
j) NRC RIS 2005-20, Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and On Operability
k) NRC Inspection Manual, Part 9900 Technical Guidance, Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety

l) June 22, 2007 Email from Mc Ardle III, James J, TO: Alley, Charles T Jr; Pyne, Mark A; Arey, Melvin L Jr.
m) ASME Section XI, Division 1, Code Case N-513-1, "Evaluation Criteria or Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping.
n) Structural Integrity Calculation, MNS-05Q-302, Rev. 0, "Flaw Evaluation of Charging System Valve Pinhole Leak."
o) MCS-1108.00-00-0002, Rev. 9, Specification for the Response Spectra and Seismic Displacements for Category I Structures.

9. Calculation/Evaluation

This evaluation will evaluate the integrity of 1NV-240 valve body as an ASME Class B pressure boundary with respect to ECCS operability, LOCA dose limits, and Reactor Coolant System Operational leakage limits

SSC DESIGN & FUNCTIONS

1NV-240 is a 3 inch, manual operator, flex-wedge gate valve manufactured by Walworth (Duke Item # 4J-017). 1NV-240 has a SA351 CF8M cast stainless steel valve body. The valve is located in the Aux Bldg 716 Mechanical Penetration Room. 1NV-240 has a design pressure and temperature of 2890 psig and 189°F. The system design pressure & temperature are 2735 psig and 189°F. The minimum wall thickness is 0.638 inches in the body neck region.

This valve provides isolation for outage maintenance, but does not provide any active safety-related functions. 1NV-240 is located on the common charging header downstream of the charging flow control valve (1NV-238). It remains normally open to provide charging flow & enable operation of NCP seal injection backpressure control valve (1NV-241). This valve is located upstream of the outboard charging header Containment Isolation Valves (1NV-244A & -245B). 1NV-240 is a Class 2 pressure boundary component. Since 1NV-240 is outside containment, not part of the containment isolation system, and is not a Class I pressure boundary, this valve is not part of the Tech Spec defined Reactor Coolant Pressure Boundary. Thus, the requirements of Tech Spec 3.4.13 (RCS Operational Leakage) Reactor Coolant Pressure Boundary Leakage are not applicable.

1NV-240 is in the flow path typically credited for Boration Flowpath requirements per SLC 16.9.9 & 16.9.12. 1NV-240 pressure boundary also functions to support ECCS operability. Specifically, any external leakage from 1NV-240 could result in ECCS flow diversion, and further contribute to post-LOCA dose consequences.

RCS/ECCS/Dose Analysis Leakage Limits:

The current licensing basis allows 0.35 gpm leakage into the Auxiliary Building (Reference 8.f); however, the future Alternate Source Term licensing basis will limit Auxiliary Building leakage to 0.25 gpm (reference 8.h). Thus, to maintain the assumptions of the LOCA dose analysis valid, the overall ECCS system leakage inclusive of 1NV-240 external leakage must be maintained below 0.25 gpm. The current Unit 1 ECCS system total leakage, inclusive of 1NV-240 thru wall leakage is <<0.05 gpm. Thus, the allowed LOCA dose analyses limits are not currently challenged.

1NV-240 current external leakage rates are insignificant with-respect to the flow-rates necessary to degrade ECCS and boration flow-path capability. External leakage rates necessary to challenge RCS Operational Leakage, ECCS and boration functions would be significantly higher than that allowed by the LOCA dose analysis.

Flaw Initiation Failure Mechanisms for 1NV-240:

Valve 1NV-240 normally operates with a nominal internal pressure of 2500 psi (borated water). Operating temperature is normally below 120°F as it is upstream of the regenerative heat exchanger. The valve has likely been in service for 30 years or longer (i.e., since plant startup).

The leakage is from two small pinhole defects, located on the valve body neck. The pinholes are in close proximity in a weld repair area. The pinholes appear to be located at small depressions. More careful inspection of the valve suggests that the flaw may actually be associated with a small thumbnail-shaped defect interconnecting the two primary leak sites. Subsequent examinations determined that the leak is located in near the center of a 2.5 inch diameter circular-shaped weld repair. Per the Certified Mill Test Report (CMTR) for 1NV-240, the weld filler material used for the repair was E316-16. This weld repair area was one of numerous documented weld repair areas performed on the valve body.

The flaw appears to be curved and discontinuous where it is breaking the OD surface of the valve body. This is not consistent with a mechanically initiated crack. Furthermore, the process application is not prone to cyclic pressure pulsations/cycles, and the body neck stresses are very low relative to code allowables. The valve stress analyses documented that under 4g seismic acceleration, the valve stresses were ~20% of the code allowable stresses (Reference 8.e). This acceleration force readily envelopes the Safe Shutdown Earthquake (Reference 8.h). This valve is located on the charging header, which is not subject to high vibration. Thus, the likelihood of fatigue cracking is remote.

Although the presence of a weld repair would increase the localized residual stresses, and potentially increase sensitization in the weld heat affected zone (HAZ), stress corrosion cracking (SCC) also seems improbable due to the low susceptibility of this material in a deoxygenated, low temperature borated water process. Additionally, the materials are welded and cast austenitic stainless steel, both of which contain a small percentage of delta-ferrite in their microstructure; this structure is inherently more resistant to SCC than wrought materials.

The valve is constructed of cast stainless steel (SA-351, CF-8M) which has high ductility and is not prone to brittle fracture.

1NV-240 is not subject to water hammer, as the system is maintained water solid during normal operation, and there is no possibility of steam formation.

Based on the shape and surface morphology of the defect, as well as being located in near the center of a weld-repaired area, the most likely cause of the leak is a weld flaw. The weld flaw may also have been influenced by the presence of a pre-existing casting flaw. Possible weld and/or casting flaws include shrinkage cracks, hot tearing, porosity,

and/or entrapped slag/inclusions – alone or in combination. Based on review of the CMTR, the weld procedure and filler material used for the valve repair were appropriate. Due to the geometry of the valve body, complexity of the cast microstructure, roughness of the casting surface and other factors, detection of such flaws can be difficult, if not impossible.

Although the repair may have been leak tight following the weld repair, through repeated pressure and temperature cycles over time, and slow removal of any entrapped slag or oxidation products within the defect, a tortuous leak path was eventually created. This type of flaw is consistent with the very low observed leak rate, and would also be unlikely to develop into a rapid increase in leak rate.

The rust staining observed on the exterior of the valve body is most likely a result of dissolved iron (e.g., soluble iron hydroxides) contained in the leaking borated water which re-precipitated out upon cooling and drying on the OD valve surface.

Flaw Evaluation Method:

There is not an ASME Code Case to evaluate flaws in a Class 2 valve body, therefore ASME XI Appendix C (Evaluation of Flaws in Austenitic) and Code Case N-513-1(Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping Section XI, Division 1) will be used as a guide to perform the valve body flaw evaluation.

Summary of NDE Performed:

After the discovery of two-pin hole leaks in the valve neck, a straight beam ultrasonic examination was performed in the area of the leak. This examination did not reveal any flaw indications but only the back surface of the valve. The back surface was confirmed at several locations on the valve.

A surface Eddy Current examination using a pencil probe was performed which located nine areas where the base material had been repaired by welding. One such area was at the leak location. The locations of the repairs were recorded on a roll-out drawing on the valve neck.

Informational radiography was performed using Computed Radiography (CR) technology on valve 1NV-240 using an Ir-192 source of 25.1 curies. The source was positioned in 2 directions (90 and 190 degrees) in relation to the leak point visible on the neck of the valve; making 2 exposures each. Due to material thickness of the valve neck, gate thickness and water inside the valve resulting equivalent thickness that the energy from the source has to penetrate was estimated to be ~4.50" of steel. This thickness is at or above the upper limits for Ir-192. The radiographs did not record any large voids in the area of interest.

A second ultrasonic examination using an angle beam technique was performed after the radiography. The angle beam scanning covered nine base metal weld repair areas in various locations that were mapped using Eddy Current inspection. Each weld repair area was scanned with four angle beams from four directions (2 axial and 2 circumferential). In addition to the four scan directions, the area at the leak site received

a radial scan 360° around the location. No planar flaw indications were detected. The largest through-wall planar flaw that could have gone undetected would reasonably be expected to be no greater 1/3 the valve neck thickness and no greater than 1.5" length.

There is reasonable assurance that the ultrasonic examination techniques used are capable of detecting planar flaws once they grow beyond the inner 1/3 material wall thickness and have a measured length of 1.5" or greater.

These examinations represent the best nondestructive examination technology that can be applied to detect cracking without disassembly of the valve.

1NV-240 FLAW EVALUATION:

Analysis 1

Structural Integrity Associates (SIA) performed a fracture mechanics analysis to determine the limiting allowed crack size (MNS-05Q-301, Attachment 4). The analysis determined the allowable length of a 100% through wall planar flaw in both the axial and circumferential directions. Allowable flaw sizes were determined using ASME safety factors against failure for Service Levels A/B, and included a safety factor of 2.77 and 3.0 for the circumferential and axial, respectively. (Levels A/B are Normal/Upset. The safety factors for Levels A/B are higher than for Levels C/D, Emergency/Faulted.)

The geometry model used was an infinitely long pipe to represent the affected section of the valve body and the crack evaluation was performed with a limit load analysis as specified in ASME Section XI Appendix C. Stainless steel piping is not subject to the same brittle fracture as carbon steel reactor vessels, hence a different methodology is used to assess margin to failure.

Analysis 1 Results

Based on the cast material, a design thickness of 0.875, 2500 psi operating pressure and a nominal mechanical load stress (representing seismic), the analysis shows the allowable flaw sizes are:

- 3.9 inch long 100% through wall axial flaw or
- 5.4 inch long 100% through wall circumferential flaw

Analysis 2

Structural Integrity performed a second fracture mechanics analysis to determine the limiting allowed crack size (MNS-05Q-302R0, Attachment 7) for different conditions.

In this second analysis, the design pressure of 2735 psig, design temperature of 189F, a reduced nominal wall thickness of 0.8125 inches, and the weaker of either the cast material or the weld material was used.

In this case, the limiting flaw sizes were determined using not just a single axial or circumferential 100% through wall crack, but a compound crack. That is, for various assumed depths of 360 degree (full circumferential) ID initiated cracks (corresponding to

the deepest undetectable full circumferential ID cracks), allowable lengths of a 100% through wall circumferential crack were determined. Again, Section XI, Appendix C methodology was used.

For the axial crack, an analogous but different problem was solved. There is no closed form solution methodology to allow for compound axial flaws (two flaws superimposed, one part through wall, one 100% through wall), so for various assumed amounts of 360 degree (full circumferential) ID wall thinning (corresponding to the deepest undetectable full circumferential ID cracks), allowable lengths of a 100% through wall axial crack were determined. A methodology similar to that used in Code Case N-513-1 was employed.

Also in this analysis, a crack growth evaluation was performed to determine the largest allowable presently existing axial flaw that would not grow to exceed the allowable size within 100 cycles of 0 to 2735 psig, many more than expected for one fuel cycle. This analysis was made only for the axial flaw (not subject to seismic stresses) since it was the controlling (smaller) size from the above described analyses. Seismic stresses were not considered, as the associated stresses would not be transmitted to the valve body neck region. The fatigue crack growth rate for austenitic steels exposed to water environments was used.

Analysis 2 Results

The following tables are quoted from the SIA calculation:

Table 1: Allowable Through-wall Flaw Lengths

Case	Description	Axial (in)	Circumferential (in)
1	Through-wall assuming NDE through entire thickness	3.95	> 6
2	Through-wall assuming NDE through 66% of wall thickness	1.64	> 6
3	Through-wall assuming NDE through 60% of wall thickness	1.17	> 6
4	Through-wall assuming NDE through 55% of wall thickness	0.78	> 6
5	Through-wall assuming NDE through 50% of wall thickness	0.06	> 6

Table 2: Critical Through-wall Flaw Lengths

Case	Description	Axial (in)	Circumferential (in)
1	Through-wall assuming NDE through entire thickness	13.50	> 9
2	Through-wall assuming NDE through 66% of wall thickness	7.21	> 9
3	Through-wall assuming NDE through 60% of wall thickness	6.11	> 9
4	Through-wall assuming NDE through 55% of wall thickness	5.32	> 9
5	Through-wall assuming NDE through 50% of wall thickness	4.56	> 9

The difference between Table 1 and 2 is that Table 1 includes a safety factor of 2.77 and 3.0 for the circumferential and axial, respectively. Table 2 terms the failure sized crack as "critical". The size ratios between the two tables is neither 2.77 nor 3.00 because the relationship between safety margin and flaw size is not linear when using limit load criteria.

In both cases, it is seen that for a co-existing up to 50% through wall 360 degree ID initiated circumferential flaw (corresponding to being able to detect flaws in only the outer 50% of the wall), the allowable/critical length of a 100% through wall circumferential flaw exceeds 6 inches for allowable and 9 inches for critical.

For an axial crack (most limiting), up to an ID wall thinning of 33% (corresponding to being able to detect flaws in only the outer 2/3 of the wall), the allowable length of a 100% through wall flaw is 1.64 inches, and the critical length is 7.21 inches. These sizes drop as more of the inner wall is assumed un-inspectable.

Figure 1 below, taken from the SIA calc, shows that the fatigue crack growth is negligible for any credible size flaw. (An initial axial flaw length of 4 inches is used.) Thus the allowable present flaw size is nearly or is equal to the allowable flaw sizes given above in Table 1, as shown in the below Table 3, taken from the SIA calc.

Figure 1.

Typical Crack Growth Evaluation Results

(Axial Flaw with Full Thickness)

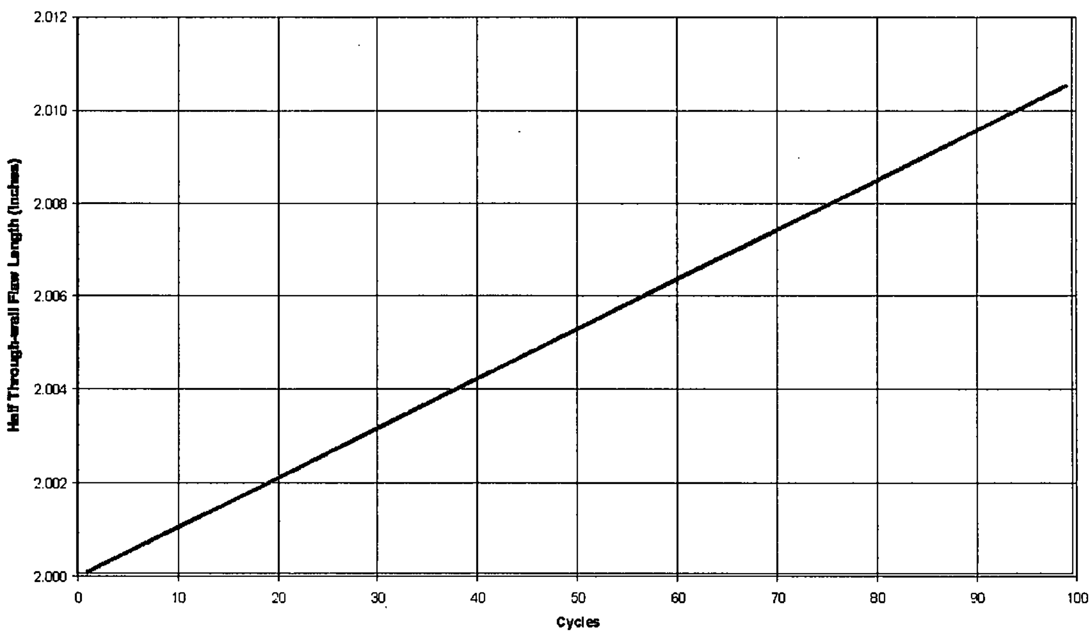


Table 3:
Typical Crack Growth Evaluation Results (Axial Flaw with Full Thickness)

Case	Description	Axial (in)
1	Through-wall assuming NDE through entire thickness	3.93
2	Through-wall assuming NDE through 66% of wall thickness	1.64
3	Through-wall assuming NDE through 60% of wall thickness	1.17
4	Through-wall assuming NDE through 55% of wall thickness	0.78
5	Through-wall assuming NDE through 50% of wall thickness	0.06

Summary of Fracture Mechanics Evaluations:

Structural Integrity Associates fracture mechanics analysis demonstrated with reasonable confidence that the critical flaw size exceeds the expected NDE detectable flaw size. The analysis utilized appropriate factors of safety, and conservative design parameters.

1NV-240 Periodic Inspections:

Periodic leakage inspections will be performed within the Boric Acid Corrosion Program, and frequent monitoring will also be performed to monitor 1NV-240 leak-rate. Additionally, periodic volumetric inspections will be performed to detect unexpected flaw growth. These actions will be addressed by the corrective action program.

10. Compensatory Actions Required for Operability

No compensatory actions are required to maintain operability.

11. Conclusions

The evaluation concluded that 1NV-240 is Operable But Degraded/Non-Conforming to ASME Section XI requirements. 1NV-240 body thru-wall leakage is non-conformance with IWC-3000 for acceptable flaw characteristics, and IWA-4000 for acceptable repair/replacement requirements.

The fracture mechanics analysis demonstrated with reasonable confidence that the critical and allowable flaw size exceeds the expected NDE detectable flaw size. The potential failure modes were evaluated with-respect to the cause of the valve body leakage, and it was concluded that the leakage likely resulted due to a weld repair flaw, and possibly a casting flaw may have been an additional contributor. The probability of a catastrophic body failure is not deemed credible, based on the following:

- The fracture mechanics analyses included significant safety factors, and overly conservative pressure cycles allowances.
- 1NV-240 body casting and weld repair materials have high fracture toughness.
- A localized weld/casting flaw would not be expected to experience a rapid increase in leakage.
- No credible failure mechanisms were identified, which could propagate a pre-existing crack.
- The surface appearance of the flaw does not appear crack-like, and thus would not be expected to be prone to rapid propagation.
- 1NV-240 was originally hydrostatically tested to 5625 psig.
- The valve stress report documented that under 4g seismic acceleration, the valve stresses were ~20% of the code allowable stresses

1NV-240 body leakage does not constitute Reactor Coolant Pressure Boundary leakage as defined by Tech Spec 3.4.13, as the valve is located upstream of the charging header containment isolation valves. The ECCS and boration flowpath capability are fully OPERABLE. Similarly, the assumptions of the LOCA dose analyses remain valid, based on total ECCS Auxiliary Building leakage (including 1NV-240 body external leakage) being substantially less than 0.25 gpm. Routine Reactor Coolant System Leakage surveillances and the ECCS Auxiliary Building Leakage Program provide assurance of continued operability. It is further concluded that the NV system is capable of fulfilling all its credited functional requirements as stated in the UFSAR and Technical Specifications.

Prepared By: Bryan D. Meyer Date: 6/25/07

Checked By: Robert W. Kirk Date: 6/25/07

Reviewed By: Victor J. Thompson Date: 6/25/07

Approved By: Scott H. Karriker Date: 6/25/07

ATTTACHMENTS:

1) 1NV-240 UT Results, 6/20/07
2) 1NV-240 UT Results, 6/21/07
3) 1NV-240 Body Neck UT Thickness Mapping, 6/22/07
4) Structural Integrity Calculation, MNS-05Q-301, Rev. 0, "Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping."
5) 1NV-240 Vendor Drawing, MCM-1205.00-1186-001.
6) Valve 1NV-240 Ultrasonic Examination Report, 6/24/07.
7) Structural Integrity Calculation, MNS-05Q-302, Rev. 0, "Compound Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping."
8) Metallurgical Report, Nuclear Generation Materials Engineering & Lab Services, "Speculated Failure Mode for MNS 1NV-240."

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 1
1NV-240 UT Results
6/20/07

DUKE POWER COMPANY
ULTRASONIC THICKNESS MEASUREMENT REPORT

FORM NDE-940B
REVISION 1

Station:	McGuire Nuclear Station	Unit:	1	Date:	6-20-07	Sheet Number:	1 of 1
Procedure:	NDE 940 Rev.: 2	F/C:	N/A	Couplant:	ULTRAGEL-2	Batch No:	06125
Examiner:	Russel E. Jones	Level:	III	Calibration Block ID:	*	Pyrometer S/N:	N/A
Examiner:	Lonnie Cochran	Level:	III	Calibration Block Temp:	AMBIENT	Cal.Due:	N/A

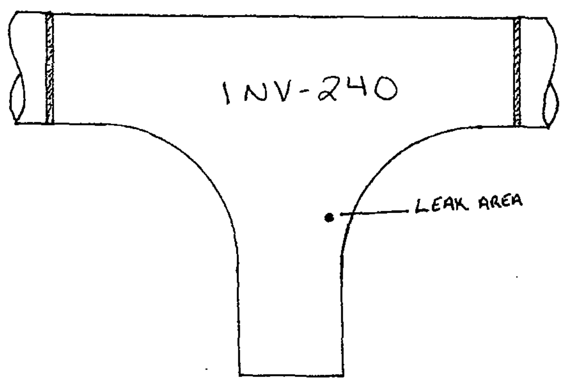
INSTRUMENT

Model No: USN 60
Serial No: 011MBT
Manufacturer: KRAUTKRAMER

TRANSDUCER

Type: Single ☐ Dual ☒ Frequency: 4.0 Mhz Size: .3.5 X 10
Manufacturer: KBA Serial No: 57462-8558

SKETCH OF EXAMINED ITEM



LOOKING EAST

DRAWING NOT TO SCALE

ACCEPTANCE STANDARD: PER ENGINEERING

RESULTS:

UT READINGS CAN NOT BE COMFIRMED 100 PERCENT ACCURATE DUE TO CAST STAINLESS STEEL MATERIAL NOT BEING COMPATIBLE WITH UT TECHNIQUES. READINGS IN AREA OF LEAK RANGED FROM .773" TO .903". SUSPECT READINGS TO BE BACKWALL INDICATION (ID OF PIPE).

* STAINLESS STEEL CAL BLOCK 03-7088 USED IN LIEU OF CAST STAINLESS STEEL CAL BLOCK. NO CAST STAINLESS STEEL CAL BLOCK AVAILABLE.

CABLES

RG62 ☐
RG174 ☒
Length: 6 ft.

Initial Calibration Time: 1850

Cal Checks

Time	Initials
1930	LDC

REMARKS: WORK ORDER 01757969-02

Component/Item No: MC 1 NV VA 0240 VALVE : INVESTIGATE LEAK

Sheet 1 of 1

REVIEWED BY: [signature] LEVEL: II DATE: 6/20/07

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 2
1NV-240 UT Results
6/21/07

DUKE POWER COMPANY

ULTRASONIC THICKNESS MEASUREMENT REPORT

FORM NDE-940B
REVISION 1

Station: McGuire Nuclear Station	Unit: I	Date: 6-21-07	Sheet Number: 1 of 1
Procedure: NDE 940 Rev.: 2 F/C: N/A		Couplant: ULTRAGEL-2	Batch No: 06125
Examiner: Lonnie Cochran LDC Level: III		Calibration Block ID: *	Pyrometer S/N: N/A
Examiner: N/A Level: N/A		Calibration Block Temp: AMBIENT	Cal.Due: N/A

INSTRUMENT	TRANSDUCER
Model No: USN 60	Type: Single ☐ Dual ☒ Frequency: 4.0 Mhz Size: .3.5 X 10
Serial No: OOTJXY	
Manufacturer: KRAUTKRAMER	Manufacturer: KBA Serial No: 57462-8558

SKETCH OF EXAMINED ITEM

SEE ATTACHED SKETCH FOR AREA LOCATIONS AND UT RESULTS.

ACCEPTANCE STANDARD: PER ENGINEERING

RESULTS:

UT READINGS CAN NOT BE COMFIRMED 100 PERCENT ACCURATE DUE TO CAST STAINLESS STEEL MATERIAL NOT BEING COMPATIBLE WITH UT TECHNIQUES. READINGS TAKEN IN AREAS IDENTIFIED BY EDDY CURRENT. READINGS RANGED FROM .612" TO .919". SUSPECT READINGS TO BE STAINLESS STEEL TO CAST STAINLESS STEEL INTERFACE AND/OR BACKWALL INDICATION (ID OF PIPE).

* STAINLESS STEEL CAL BLOCK MFB005 USED IN LIEU OF CAST STAINLESS STEEL CAL BLOCK. NO CAST STAINLESS STEEL CAL BLOCK AVAILABLE.

CABLES

RG62 ☐

RG174 ☒

Length: 6 ft.

Initial Calibration Time: 1905

Cal Checks

Time	Initials
2127	LDC

REMARKS: WORK ORDER 01757969-18

Component/Item No: MC 1 NV VA 0240 VALVE : INVESTIGATE LEAK

Sheet 1 of 3

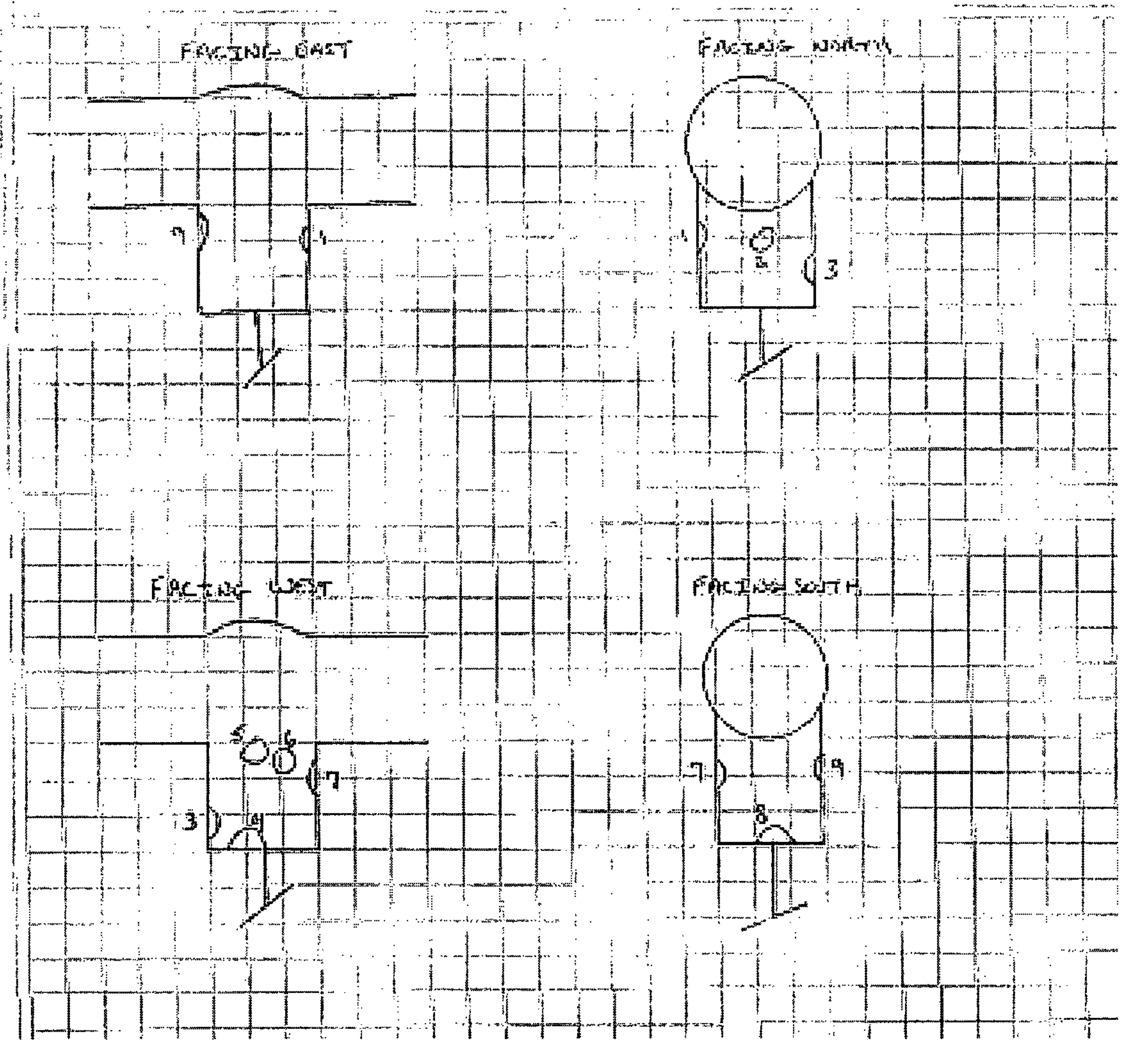
REVIEWED BY: [signature] LEVEL: III DATE: 6-21-07

Station MNS Unit 1 Rm. File No. Sheet 2 of 3

Subject AREA LOCATION MARKED BY EDDY CURRENT

VALVE: 1NV-240 By Date 06-21-2007

Prob No. Checked By Date

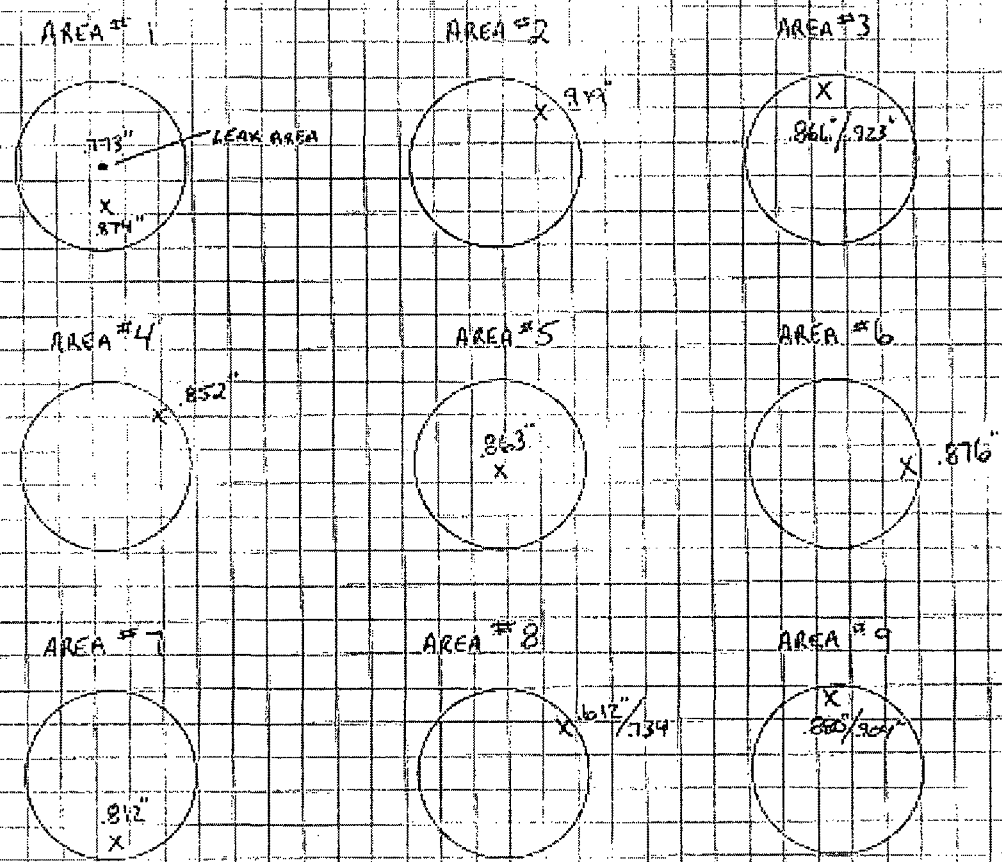


Station MNS Unit 1 Rev. File No. Sheet 3 of 3

Subject VALVE : 1NV-240

By [signature] Date 06-21-2007

Prob No. Checked By Date

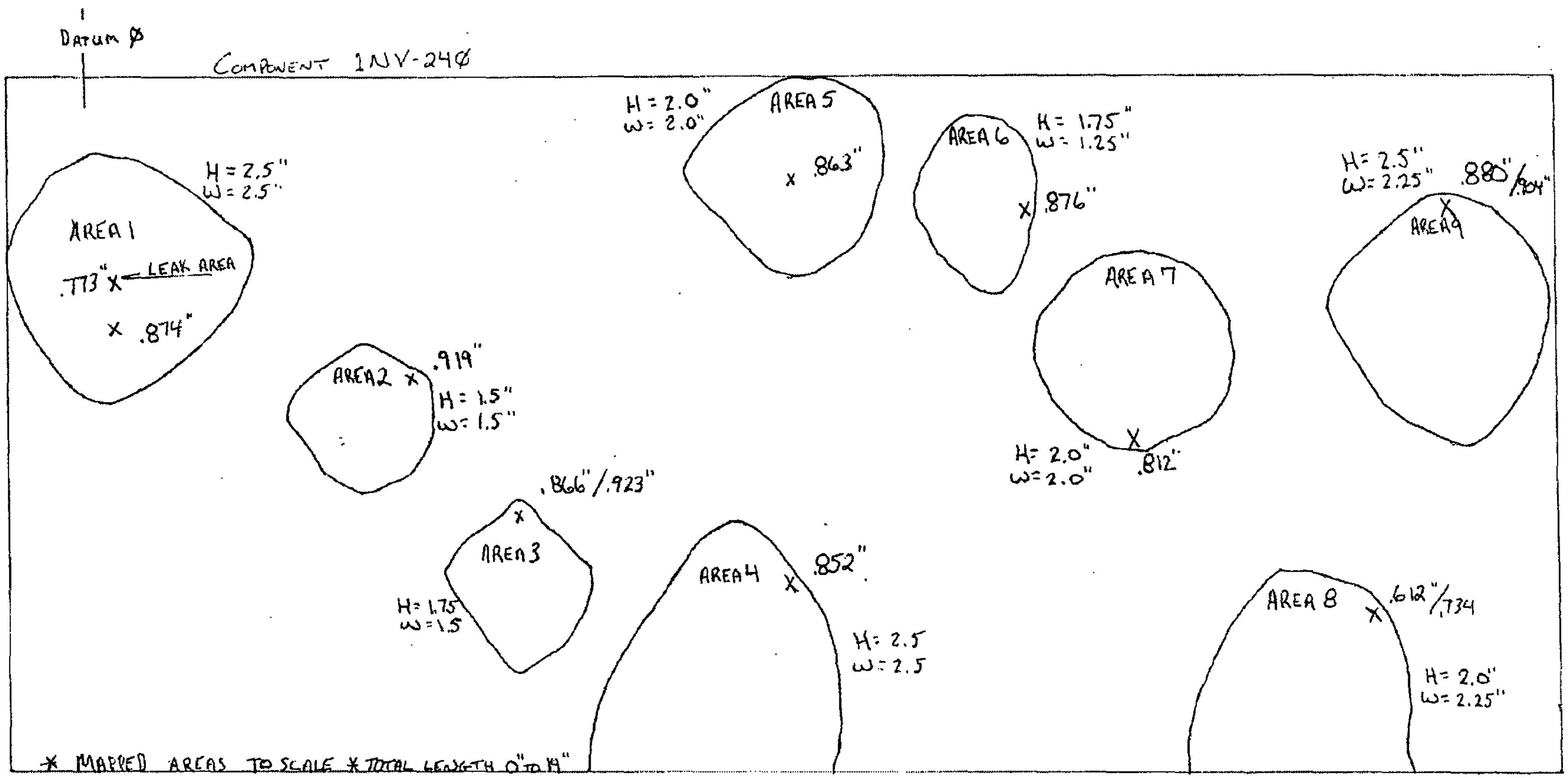


INSPECTION AREA DEMENSIONS

AREA	HEIGHT	WIDTH	AREA	HEIGHT	WIDTH
1	2.5"	2.5"	6	1.75"	1.25"
2	1.5"	1.5"	7	2.0"	2.0"
3	1.75"	1.5"	8	2.0"	2.25"
4	2.5"	2.5"	9	2.5"	2.25"
5	2.0"	2.0"			

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 3
1NV-240 Body Neck UT Thickness Mapping
6/22/07



L. Cochran III 06-22-2007

Russel Jones III 6-22-07

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 4

Structural Integrity Associates, Inc.
File Number: MNS-05Q-301, Rev. 0
Calculation Title: "Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping"

Structural Integrity Associates, Inc.	CALCULATION PACKAGE	File No.: MNS-05Q-301 Project No.: MNS-05Q

PROJECT NAME: Flaw Evaluation of Charging System Valve Pinhole Leak

Contract No.: 00091090

CLIENT: Duke Energy	**PLANT:** McGuire

CALCULATION TITLE: Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-10 A1 – A3 Computer File	Original Issue	Robert O. McGill Robert McGill 06/21/07	Robert O. McGill Robert McGill 06/21/07 [signature] Nat Cofie 06/21/07 [signature] Soo Bee Kok 06/21/07 (Checker)

SI Form F2001R2a

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1 INTRODUCTION

A pinhole leak was discovered in manual isolation valve 1NV-240. This valve is located in the Class 2 segment of the Chemical and Volume Control System (CVCS) supply line. The leak is near the bonnet closure in the cast stainless steel portion of the valve. The location of the leak is shown in Figure 1 [1]. The operating temperature of the system is 100 to 110°F with an operating pressure of 2500 psi.

Although a formal root cause evaluation has not been completed, it is believed that this defect is a fabrication defect associated with the casting. Possible degradation mechanisms such as stress corrosion cracking and localized corrosion mechanisms such as pitting and microbiologically influenced corrosion (MIC) are considered very unlikely due to the combination of the material of the valve and the operating conditions. Hence it is believed that there are no active degradation mechanisms that could have initiated the flaw and that the most likely cause of the leak is a fabrication defect.

The objective of this calculation is to determine allowable flaw sizes in both the axial and circumferential directions modeling the affected section of the valve body neck as a pipe to demonstrate structural stability. A flaw growth analysis considering fatigue is also performed to predict the flaw size at the end of the current cycle.

2 METHODOLOGY

The flaw evaluation is based on the criteria prescribed in Section XI, Appendix C [2] assuming the valve body neck may be modeled as a pipe and using an flaw depth to wall thickness ratio of unity (similar to the ASME Code Case N-513-1 [3] approach). Allowable flaw sizes will be determined using Limit Load criteria specified in Article C-3000 [2] in both the axial and circumferential directions. Flaw growth evaluation considering fatigue as a possible mechanism is performed using the methodology in ASME Code Section XI, Appendix C for stainless steel components.

3 ASSUMPTIONS / DESIGN INPUTS

The following assumptions are made for the analysis:

1. Service Level A safety factors are conservatively applied.
2. Dead weight and thermal loading are assumed negligible. Both a zero and conservative bending stress of 10 ksi (assumed for seismic OBE loading) is used in the analysis.

The following design inputs are used for the analysis (material properties are taken at the given operating temperature):

1. The valve material is SA-351 Grade CF8M cast austenitic stainless steel [4].
2. Operating pressure = 2500 psig [4].
3. Operating temperature = 110°F [4].
4. Valve body neck ID = 4.313 inches [5].

5. Valve body thickness at neck = 0.875 inch [5].
6. Design stress intensity, S_m = 20 ksi [6, p. 316].
7. Code yield strength (interpolated), S_y = 29.5 ksi [6, p. 506].
8. Code tensile strength, S_u = 70.0 ksi [6, p. 438].

4 CALCULATIONS AND RESULTS

4.1 Allowable Flaw Size Determination

Since the defect is a pinhole leak, the ASME Section XI allowable through-wall flaw size is determined in both the axial and circumferential directions in order to determine the limiting case.

4.1.1 Circumferential Flaw

The material of the valve body is Type F316, Grade CF8M cast austenitic stainless steel. Therefore, the net section collapse methodology described in Reference 7 and implemented in ASME Code Section XI, Appendix C [2] is used in this evaluation. The technical approach consists of determining the allowable flaw size (circumferential extent and through-wall depth) in the pipe that will cause the flawed pipe section to collapse.

Based on equilibrium of longitudinal forces and moments about the pipe axis, the relation between the applied loads and flaw size at incipient plastic collapse is given by:

$$P'_b = \frac{2\sigma_f}{\pi}\left(2\sin\beta - \frac{a}{t}\sin\alpha\right) \qquad (1)$$

where the angle, β, defining the location of the neutral axis is:

$$\beta = \frac{1}{2}\left(\pi - \frac{a}{t}\alpha - \pi\frac{P_m}{\sigma_f}\right) \qquad (2)$$

α	=	half flaw angle
t	=	pipe thickness
a	=	flaw depth
P_m	=	primary membrane stress
P'_b	=	bending stresses corresponding to plastic collapse
σ_f	=	flow stress at net section plastic collapse ($3S_m$).

For longer flaws penetrating the compressive bending region where $(\alpha+\beta)>\pi$, the relation between the applied loads and the flaw depth at incipient plastic collapse is given by:

$$P'_b = \frac{2\,\sigma_f}{\pi}\left(2 - \frac{a}{t}\right)\sin\beta \qquad (3)$$

where:

$$\beta = \frac{\pi}{2 - \frac{a}{t}}\left(1 - \frac{a}{t} - \frac{P_m}{\sigma_f}\right) \qquad (4)$$

An iterative process is used to calculate the critical flaw size using Equations 1 through 4. The above equations were solved for a through-wall flaw (a/t = 1). Details of the analysis are provided in Appendix A and the results are presented in Table 1.

4.1.2 Axial Flaw

The allowable axial through-wall flaw length, l_{all}, is determined using the relationship form Reference 8 which is given as:

$$l_{all} = 1.58\sqrt{Rt}\left[\left(\frac{\sigma_f}{SF\,\sigma_h}\right)^2 - 1\right]^{\frac{1}{2}} \qquad (5)$$

where:

R	=	mean pipe radius
t	=	pipe thickness
σ_f	=	material flow stress = $(S_y+S_u)/2$
SF	=	safety factor = 3.0
σ_h	=	hoop stress = $pD_o/2t$, where p = operating pressure and D_o = outside diameter.

The above expression is also used in Code Case N-513-1 for the evaluation of axial through-wall flaws.

Using the assumptions and design inputs described above an allowable flaw size is calculated in both the axial and circumferential directions per Section XI, Appendix C (see Appendix A for details). Calculation details are provided in the Excel file: *MNS-05Q Analysis.xls* (included with the project computer files). Table 1 summarizes the output.

Table 1: Allowable Flaw Sizes Calculated

Flaw Direction	Allowable Flaw Size (in)
Axial	3.89
Circumferential	9.88*
Circumferential	5.36**

* Applying no bending stress.
** Applying a bending stress of 10 ksi.

4.2 Flaw Growth Analysis

In this section, a conservative fatigue analysis is performed by assuming an initial through-wall flaw with a length of 0.25 inches. This is a very conservative assumption since the defect is a pinhole leak. An axial flaw was considered in this evaluation since it is bounding. The material of the valve body is cast stainless steel. As such, the fatigue crack growth evaluation is performed using the methodology in ASME Code Section XI, IWC-3640 for stainless steel components using the QA software package **pc-CRACK** [9].

Since the defect is through-wall, the end of life flaw size due to fatigue crack growth is calculated using the fatigue crack growth rate for austenitic steels exposed to water environments. Per Reference 7, the fatigue crack growth rate for austenitic steel in air environment along with an environment factor of 2.0 for PWR water environment can be used.

From Subarticle C-3200 of Reference 2, the fatigue crack growth rate for austenitic steel in air environments is given by:

$$\frac{da}{dN} = C_o(\Delta K_I)^n \qquad (6)$$

where,

ΔK_I	=	stress intensity factor range (K_{max} - K_{min})
n	=	3.3
C_o	=	C x S

where, C is a scaling parameter to account for temperature and is given by:

$$C = 10^{\left[-10.009+8.12x10^{-4}T-1.13x10^{-6}T^2+1.02x10^{-9}T^3\right]}$$

where, T is the metal temperature in °F (for T ≤ 800°F), and S is a scaling parameter to account for R ratio and is given by:

$$\begin{aligned} S &= 1.0 && R \leq 0 \\ &= 1.0 + 1.8R && 0 \leq R \leq 0.79 \\ &= -43.35 + 57.97R && 0.79 \leq R < 1.0 \end{aligned}$$

with,

$$R = K_{min} / K_{max}$$

The maximum operating metal temperature of 110°F is used in the calculation of the scaling factor C. At a temperature at 110°F and for R ≤ 0 as assumed in this case, C_0 was calculated as $1.17x10^{-10}$ for an air environment. A value of C_0 of $2.34x10^{-10}$ was, therefore, used for the PWR water environment to determine crack growth.

At the location of the flaw, there are no thermal transients other than heat-up and cooldown cycles. Hence the evaluation is performed by assuming 500 heat-up and cooldown cycles which is conservative relative to the time that this flaw is expected to be in service.

The results of this fatigue crack growth evaluation are shown in Figure 2. Assuming an initial through-wall flaw length of 0.25 inches, the crack growth after 500 cycles is less than 1 mil with a maximum final crack depth of approximately 0.26 inch. This final crack depth is significantly below the allowable flaw depth of 3.89 inches calculated above for an axial flaw. These results indicate that the valve body exhibits a very high flaw tolerance and should be acceptable for continued operation for at least one cycle.

5 CONCLUSIONS

- The allowable flaw size at the location of the defect is at least 5.36 inches in the circumferential direction and 3.89 inches in the axial direction.
- Flaw growth assuming a conservative initial flaw size of 0.25 inch is less than 1 mil resulting in a maximum final flaw size of 0.26 inch, which is well below the allowable flaw sizes in either the circumferential or axial direction.
- Based on the above, it is concluded that the defect in the valve is acceptable for continued operation for at least one cycle.

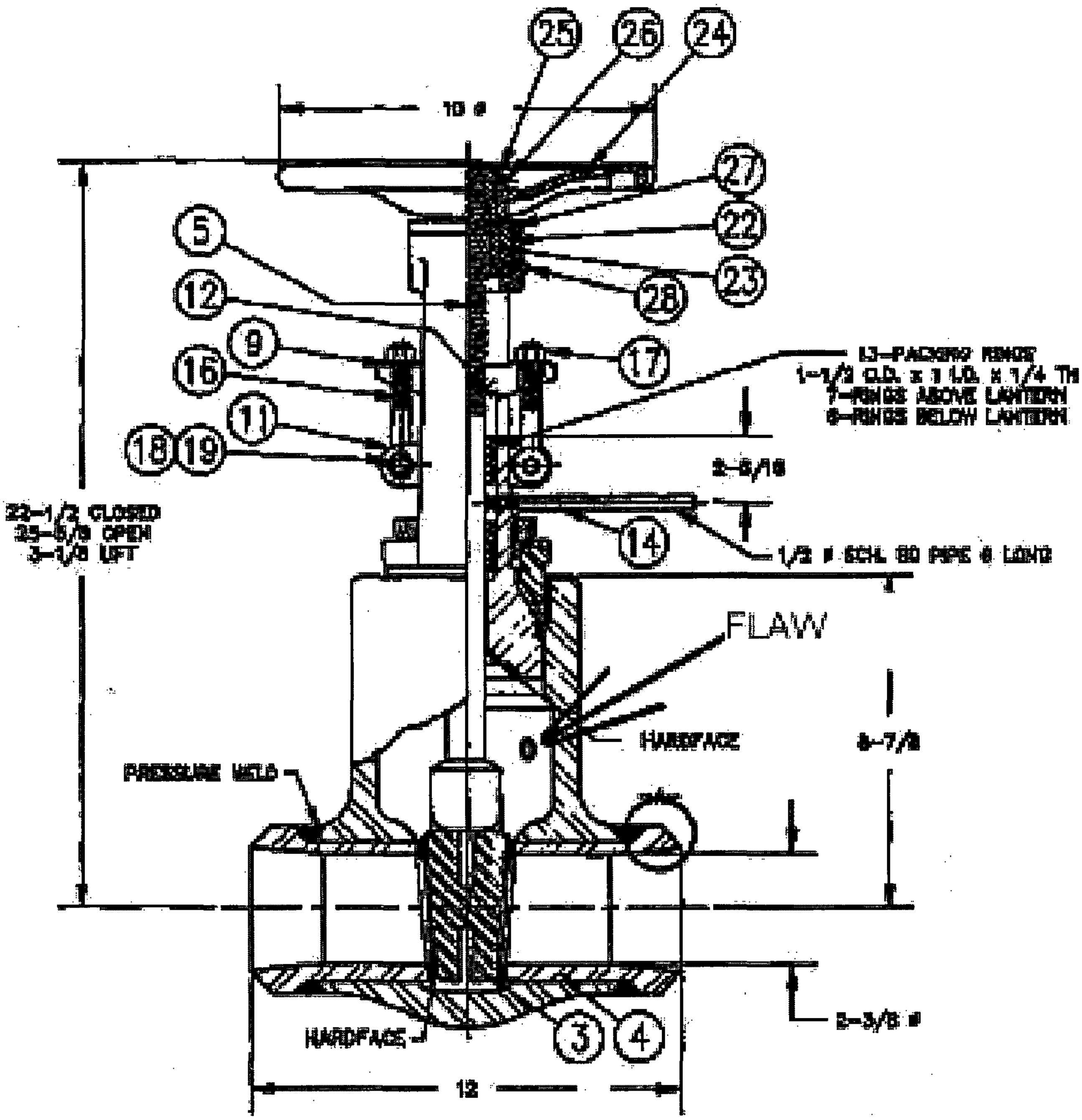


Figure 1: Location of Flaw in Valve 1NV-240

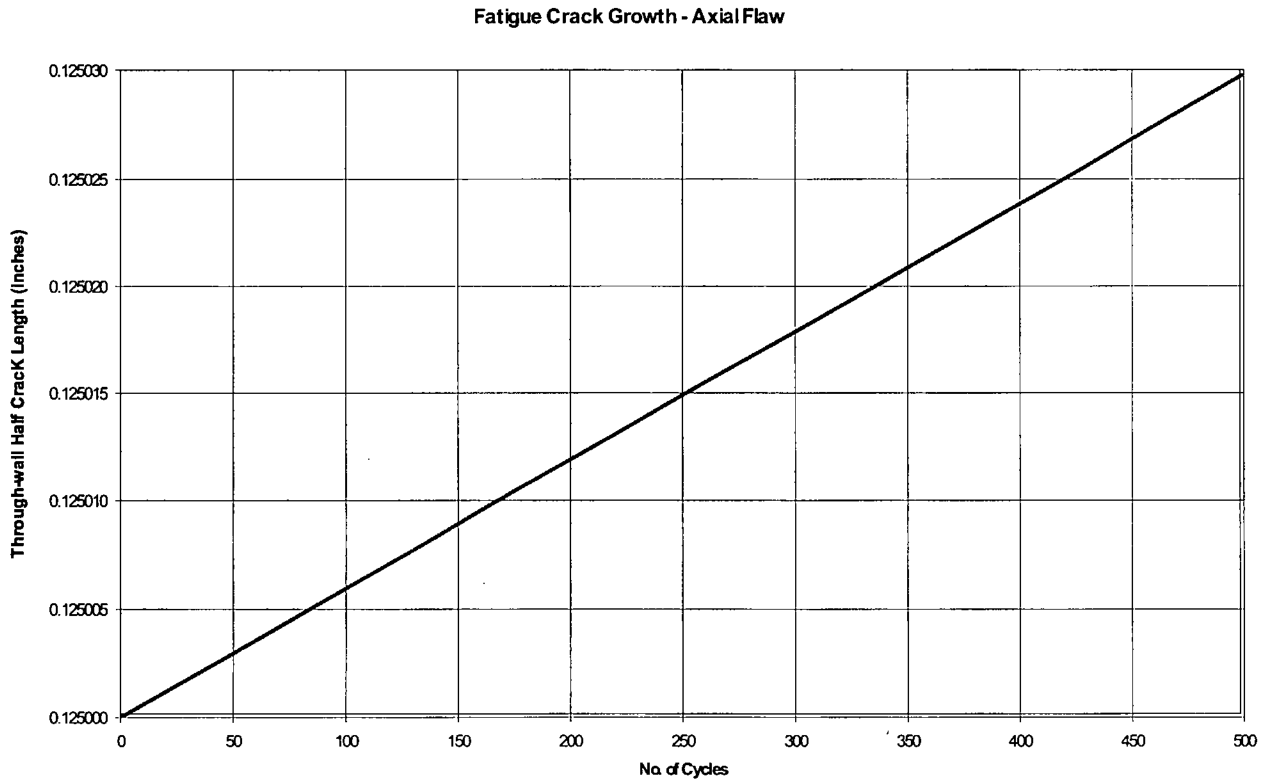


Figure 2: Crack Growth Evaluation Results

6 REFERENCES

1. Email attachment "1nv240.bmp," from Bryan Meyer (Duke) to Bob McGill (SI), "Subject: Valve Vendor Drawings – 1NV-240 with flaw location," dated Wednesday, June 20, 2007, 7:12PM, SI File No. MNS-05Q-202.

2. ASME Boiler and Pressure Vessel Code, Section XI, 1998 Edition (2000 Addenda).

3. ASME Code Case N-513-1, "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or Class 3 Piping Section XI, Division 1," Cases of ASME Boiler and Pressure Vessel Code, March 28, 2001.

4. E-mail from Robert Kirk (Duke) to Bob McGill (SI), "Subject: RE: P.O Issuance for Structural Integrity-Fracture Mechanics evaluation for 1NV-240," dated Thursday, June 21, 2007, 10:42AM, SI File No. MNS-05Q-203.

5. Email attachment "0577.pdf," from Robert Dixon (Duke) to Bob McGill (SI), "Subject: FW: 0577," dated Wednesday, June 20, 2007, 7:12PM, SI File No. MNS-05Q-201.

6. ASME Boiler and Pressure Vessel Code, Section II, Part D – Properties, 1998 Edition (2000 Addenda).

7. ASME Section XI Task Group for Piping Flaw Evaluation, 'Evaluation of Flaws in Austenitic Steel Piping,' Journal of Pressure Vessel Technology, Vol. 108, August, 1986.

8. "Evaluation of Flaws in Austenitic Steel Piping," EPRI NP-4690-SR, Electric Power Research Institute, July 1989.

9. Structural Integrity Associates, Inc., "**pc-CRACK™** Fracture Mechanics Software," Version 3.1 – 98348, 1998.

APPENDIX A

AXIAL AND CIRCUMFERENTIAL PLANAR FLAW CALCULATION DETAIL

Description of Solution Methodology:

The through-wall flaw is evaluated as two independent planar through-wall flaws: one oriented in the axial direction and one oriented in the circumferential direction. For the axial planar analysis using the inputs provided, the hoop stress and material flow stress are calculated from Reference [8] and then used in the allowable flaw length equation from Reference [8]. For the circumferential planar analysis using the inputs provided, ASME Section XI Appendix C (1998) [2], Section C-3320 is used. An iterative approach is used on theta (half crack angle) to determine the allowable flaw size conforming to the allowable pipe bending stress and allowable pipe membrane stress.

AXIAL ANALYSIS

Flow Stress = 49,750 psi $\sigma_f = (S_y + S_u)/2$ Reference []

Hoop Stress = 8,661 psi $\sigma_h = pD_o/2t$ Reference []

Safety Factor = 3 Section XI Appendix C, Section C-3420

Allowable Flaw Length = 3.89 in $l_{all} = 1.58\sqrt{Rt}\left[\left(\frac{\sigma_f}{SF\,\sigma_h}\right)^2 - 1\right]^{\frac{1}{2}}$ Reference []

CIRCUMFERENTIAL ANALYSIS

Theta + Beta = 2.27 radians $\sigma_b^c = \frac{2\sigma_f}{\pi}\left[2\sin\beta - \frac{a}{t}\sin\theta\right]$ C-3320 Equation 3 used when $(\theta + \beta) \le \pi$

$$\beta = \frac{1}{2}\left(\pi - \frac{a}{t}\theta - \pi\frac{\sigma_m}{\sigma_f}\right)$$

Design Stress Intensity, S_m = 20,000 psi

Primary Membrane Stress = 4,331 psi $P_m = pD_o/4t$ Section XI Appendix C, Section C-3310 (points to NB-3652, Equation 9)

β = 0.64 radians

P_b' = 7,665 psi Theta adjusted until failure bending stress equals equation below

$P_b' = SF(P_m + P_b) - P_m$ Section XI Appendix C, Section C-3320 (Equation 5)

Safety Factor = 2.77 Section XI Appendix C, Section C-3320 (normal operating conditions)

Piping Bending Stress = 0 psi

Failure Bending Stress = 7,665 psi

Allowable Flaw Length = 9.88 in $l_{all} = \theta D_o$

CIRCUMFERENTIAL ANALYSIS (10 ksi Bending)

Theta + Beta = 1.90 radians $\sigma_b^c = \frac{2\sigma_f}{\pi}\left[2\sin\beta - \frac{a}{t}\sin\theta\right]$ C-3320 Equation 3 used when $(\theta+\beta) \le \pi$

$$\beta = \frac{1}{2}\left(\pi - \frac{a}{t}\theta - \pi\frac{\sigma_m}{\sigma_f}\right)$$

Design Stress Intensity, S_m = 20,000 psi

Primary Membrane Stress = 4,331 psi $P_m = pD_o / 4t$ Section XI Appendix C, Section C-3310 (points to NB-3652, Equation 9)

β = 1.02 radians

P_b' = 35,365 psi Theta adjusted until failure bending stress equals equation below

$P_b' = SF(P_m + P_b) - P_m$ Section XI Appendix C, Section C-3320 (Equation 5)

Safety Factor = 2.77 Section XI Appendix C, Section C-3320 (normal operating conditions)

Piping Bending Stress = 10,000 psi

Failure Bending Stress = 35,365 psi

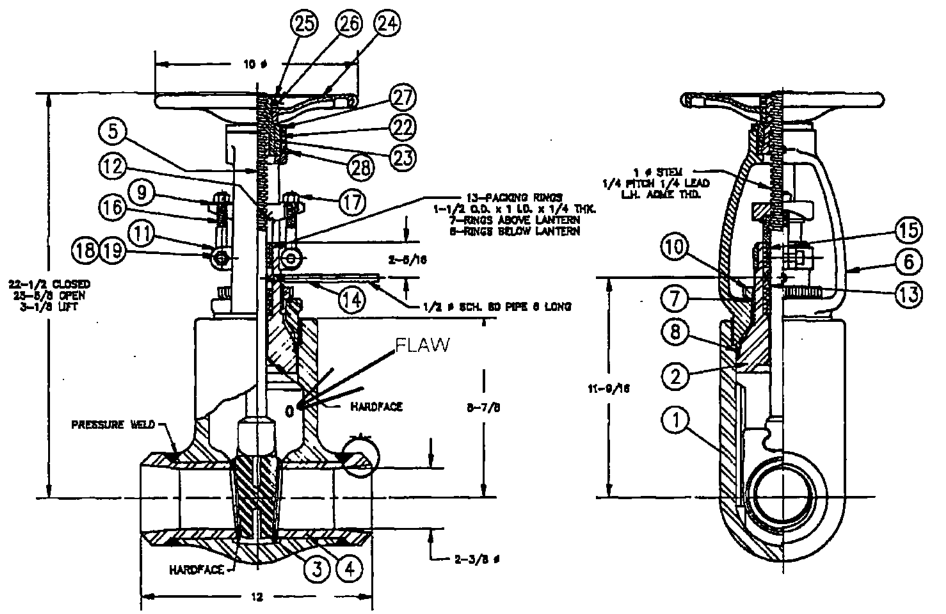
Allowable Flaw Length = 5.36 in $l_{all} = \theta D_o$

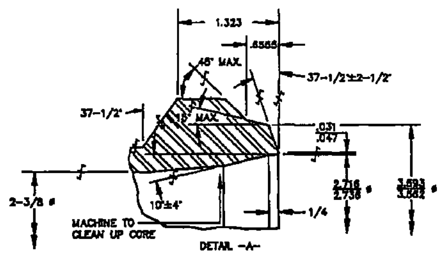
McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 5
1NV-240 Vendor Drawing
MCM-1205.00-1186-001

DPCO ~~ITEM~~ NO.	ITEM CODE	MINIMUM WALL THICKNESS	CV	DESIGN PRESSURE	DESIGN TEMPERATURE	APPROX. DRY WT.	PIPE SCH.	BASE MATERIAL	VALVE LIST NO.	NUCLEAR STATION	CUSTOMER ORDER NO.	OEM ORDER NO.	JOB NO.
~~04-017~~	6-5262-57-030-00N	.625 IN.	376 GPM	2890 PSIG	189°F	135 LB.	160	SA351 GR CF8M	MC-1500-4	MC GUIRE	A-13376	SE 28129	28129
04J-047													

DD





DETAIL -A-
WELDING END FOR USE WITH SCHEDULE 160 PIPE IN ACCORDANCE TO DUKE POWER CO. DWG. NO. MC-1576-1.0 DETAIL "C".

ERN: MC003U21

ITEM	DESCRIPTION	QTY	REMARKS
1	BODY, BW-SCHD 160	1	
2	BONNET [illegible]	1	
3	WEDGE, FLEXIBLE (•)	1	•
4	SEAT RING INSERT (•)	2	•
5	STEM	1	•
6	YOKE	1	
7	BONNET CLAMP WASHER	1	
8	BONNET GASKET	1	•
9	GLAND PLATE	1	
10	BONNET CLAMP	1	
11	EYE BOLT CLAMP HALF	2	
12	GLAND	1	
13	LANTERN	1	
14	LEAKOFF NIPPLE, 1/2 SCHD 80 x 6 LG	1	
15	PACKING	13	•
16	5/8-11 UNC-2A x 3-1/2 LG. EYE BOLT	2	
17	5/8-11 UNC-2B, HEAVY HEX NUT	2	
18	7/16-14 UNC-2A x 2-1/4 LG. HEX BOLT	2	
19	7/16-14 UNC-2B, HEX JAM NUT	2	
20	MARKING PLATE	1	NOT SHOWN
21	MARKING PLATE SPECIAL	1	NOT SHOWN
22	YOKE BUSHING	1	
23	YOKE NUT	1	•
24	HANDWHEEL	1	
25	HANDWHEEL NUT	1	
26	1/4-20 UNC-2A x 3/8 LG FP, SOC HD SET SCR	1	
27	5/16-18 UNC-2A x 3/4 LG FP, SOC HD SET SCR	1	
28	GREASE FITTING 1/8	1	

• RECOMMENDED SPARE PART
(•) WITH HARDFACING

FOR OEM PART NUMBERS AND MATERIALS FOR PARTS REPLACEMENT SEE CRANE-ALOYCO DATABASE BM NO. 00405.

THIS DRAWING WAS DEVELOPED FROM WALWORTH DWG. #A-9552-M-155 REV. E AND DUKE DOCUMENT NO. MCM-1205.00-15

CAUTION: IN AN INSTALLATION OF A FLEXIBLE WEDGE GATE VALVE WITH THE STEM HORIZONTAL OR BELOW HORIZONTAL, WHERE CONDENSATE OR OTHER LIQUID CAN BE TRAPPED IN THE BODY NECK AND THE CLOSED VALVE SUBSEQUENTLY HEATED, PROVISION SHOULD BE MADE TO PREVENT OVER-PRESSURIZATION OF THE BODY NECK.

DD — DUKE ITEM 4J-047 IS IDENTICAL TO 4J-017 EXCEPT FOR 30° PRESSURE SEAL MOD. (SEE MCM-1205.00-0015 SHT 16 PER MM-5703)

QA CONDITION 1

MCM 1205.00-1186 001

NO.	REVISION	DRN	DATE	CK'D	DATE	APP	DATE
DD	REVISED PER MM 3703	[illegible]	4-22-93	[illegible]	8-11-93	[illegible]	0/12/93

LTR	ECN	DATE	BY	DATE	BY
C	1556	11-19-91	AG	11-22-91	AJW
B	1339	01-01-91	DA	01-15-91	BWH
A	796	04-27-89	DA	06-23-89	JEK
REVISION				ENGR. APP.	

FIGURE NO: 5282PS
VALVE SIZE: 3"
PRESSURE CLASS: 1500LB
ASME SECTION III CLASS: 2

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.

CONFIDENTIAL

CRANE-ALOYCO, INC.
SCALE: N.T.S. ROMEOVILLE, IL DATE: 04-27-89

GATE VALVE-PS-HW

DWN. DA CHK. SMN
APP. JEK

CA00405

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 6
Valve 1NV-240 Ultrasonic Examination Report

McGuire Unit 1 Valve 1NV-240

Ultrasonic Examination Report

INTRODUCTION

Ultrasonic examinations were performed to investigate a through wall leak in the stainless steel valve body. The initial ultrasonic examination was performed by Duke Energy NDE personnel using a 4 Megahertz, 10 mm diameter straight beam search unit. Subsequent ultrasonic examinations were performed using 2 Megahertz dual element refracted longitudinal wave (RL) probes and OD Creeping waves. As there is no qualified procedure for cast stainless steel examination, guidance for the angle beam technique was sought from the available documents listed below:

EPRI Report TR-107481, "Status of the Ultrasonic Examination of Reactor Coolant Loop Cast Stainless Steel Materials" Table 4-1. This table indicates that RTD 60°, 70° and Creeping wave search units produced the highest signal-to-noise ratio when detecting a through-wall crack.[1]

Structural Integrity Associates, Inc. "Review of Draft White Paper: Current Inspection Capabilities for Cast Austenitic Stainless Steel Piping", Prepared by L.D. Nottingham, R.A. Hermann, A. J. Giannuzzi and N.G. Cofie.

Inspection From Outside of the Pipe

"In spite of the limitations posed by current available UT techniques, the general feeling is that large circumferential flaws (about 25% to 50% through-wall) could probably be found from the OD inspections. However, it is felt that detection of axial defects from the OD would be difficult. Axial flaws are not limiting. Large axial flaws though can be tolerated without exceeding the Section XI safety margins." [2]

USNRC Safety Evaluation for Catawba Relief Request 04-CN-001, (docket Nos. 50-413 and 50-414). This SER states that inspection of the outer 2/3 of the cast stainless steel piping material using RTD 60°, 70° and Creeping wave search units provides reasonable assurance of structural integrity.

A review of research to date indicates that planar flaws initiating at the inside surface and having through wall extents no greater than 1/3 of the wall thickness have a low probability of detection while planar flaws which have grown beyond this limit have a higher probability of detection.

CALIBRATION and EXAMINATION

The 45°, 60° and 70° beam angles were calibrated with a Krautkramer USN-60. As no cast stainless steel calibration block was available a SA-240 stainless steel plate with a 2 mm diameter side drilled hole at a depth of 1.0" was used to calibrate for the 45°, 60° and 70° beam angles. The Creeping Wave probe was calibrated using a 1/16" diameter side drilled hole at a

[1] These search units were used to inspect cast piping welds at CNS under Relief Request 04-CN-001 which is also referenced.
[2] This paper deals with cast austenitic piping inspection

depth of 0.2". Reference sensitivity was established using the applicable hole signal set at 80% full screen height. Scanning was performed at + 12dB over reference sensitivity for the 45° probe and +6dB over reference sensitivity for 60° and 70° probes. The scanning gain for the Creeping wave probe was set to reference sensitivity due to excessive front surface noise at higher gain levels. With the 45° scan it was possible to monitor the inside surface noise level at 10% full screen height assuring that some sound energy was reaching the ID. There was little internal noise indicating grain sizes on the order of one wave length or larger were not present.

As there was no qualified procedure, detection and length sizing of the flaw would be challenging and dependent on variations in grain structure within the casting. Length measurement of suspected flaws was determined by past experience with similar materials indicating that true crack lengths can be longer than that which can be seen on an ultrasonic display. Therefore any indication determined to be a flaw would have been conservatively length sized from peak amplitude down to the baseline and in no case measured less than least twice the search unit width (1.5").

ULTRASONIC EXAMINATION RESULTS

The thickness of the valve in the area of the leak measured 0.773" to 0.874". Using the maximum thickness of 0.874" the ultrasonic examination was designed to interrogate the valve body starting at 0.600" deep to within 0.1" of the outside surface.

The following RL probes were used:[3]

Manufacturer	Model	Size (mm)	Frequency (MHz)	Focal Distance (mm)
RTD	45° TRL2-Aust	2(8x14)	2	27
RTD	60° TRL2-Aust	2(7x10)	2	25
RTD	70° TRL2-Aust	2(7x10)	2	20
RTD	TRCr2-Aust	2(6x13)	2	10

The straight beam examination revealed only the back wall of the valve body and no other indications. The angle beam scanning covered nine base metal weld repair areas in various locations that were mapped using Eddy Current inspection. Each weld repair area was scanned with four angle beams from four directions (2 axial and 2 circumferential). In addition to the four scan directions, the area at the leak site received a radial scan 360° around the location. The examiners were able to maintain the inside surface reflection with the 45° search unit even while scanning over the cast base material. No planar flaw indications were detected.

The recording criteria were based on prior experience with other cast stainless steel materials and with planar flaws in general. Typically the indication would only be recorded if they have a 3:1 signal to noise ratio, planar characteristics such as indication movement in the through wall direction and a length greater than the width of the search unit in order to avoid a false call. No signals with these characteristics were found.

[3] Similar but larger search units were used at Catawba.

CONCLUSIONS

The ability to detect planar flaws in cast austenitic material is dependant on the shape, size and orientation of the grains. This was a "best effort" examination because of the absence of a qualified procedure and a calibration block of cast stainless steel and does not purport to be a Code acceptable examination. Use of the 45° beam enabled monitoring of the ID surface while all ultrasonic displays were relatively noise free. The 4 MHz straight beam search unit showed similar low noise levels. Therefore a relatively small, uniform grain size can be assumed. Because of these conditions there is reasonable assurance that the ultrasonic examination techniques used are capable of detecting planar flaws once they grow beyond the inner 1/3 volume of material and have a measured length of 1.5" or greater.

Investigations in the area of the leak and other eight weld repair areas did not show any evidence of a planar flaw.

Prepared By: James J. Mc Ardle III/Principal NDE Level III UT Date: 6/24/07
Verified By Russel E. Jones / NDE Level III UT Date: 6/24/07

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 7
Structural Integrity Associates, Inc.
File Number: MNS-05Q-302, Rev. 0
Calculation Title: "Compound Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping"

Structural Integrity Associates, Inc.	CALCULATION PACKAGE	File No.: MNS-05Q-302 Project No.: MNS-05Q

PROJECT NAME: Flaw Evaluation of Charging System Valve Pinhole Leak

Contract No.: 00091090

CLIENT: Duke Energy	**PLANT:** McGuire Unit 1

CALCULATION TITLE: Compound Flaw Evaluation of Class 2 Isolation Valve 1NV-240 Pinhole Leak in Charging Supply Piping

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-16 A1 – A13 B1 – B26 C1 – C2 Computer File	Original Issue	Robert O. McGill Robert McGill 06/24/07	Robert O. McGill Robert McGill 06/24/07 Nat Cofie 06/24/07 Marcos Herrera 06/24/07 (Checker)

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1 INTRODUCTION

A pinhole leak was discovered in a manual isolation valve 1NV-240 at McGuire Nuclear Station, Unit 1. This valve is located in the ASME Class 2 segment of the Chemical and Volume Control System (CVCS) supply line. The leak is near the bonnet closure in the cast stainless steel portion of the valve and its location is shown in Figure 1 [1].

Although a formal root cause evaluation has not been completed, it is believed that this defect is a fabrication defect associated with the casting. Possible degradation mechanisms such as stress corrosion cracking (SCC) and localized corrosion mechanisms such as pitting and microbiologically influenced corrosion (MIC) are considered very unlikely due to the combination of the material of the valve and the operating conditions. Hence, it is believed that there are no active degradation mechanisms that could have initiated the flaw and that the most likely cause of the leak is a fabrication defect.

The objective of this calculation is to determine allowable and critical flaw sizes in both the axial and circumferential directions modeling the affected section of the valve body neck as a pipe to demonstrate structural stability. A flaw growth analysis considering fatigue is also performed to predict the flaw size at the end of the current cycle. Design conditions are used for the evaluation.

2 METHODOLOGY

Non destructive examinations of the affected area of the valve were performed using ultrasonic techniques. Because of the difficulty in ultrasonically inspecting cast material, these inspections could only penetrate the valve body to a certain distance through the valve thickness. Hence in this evaluation, a compound flaw is assumed consisting of the through-wall pinhole leak and a portion of the valve body that could not be inspected. This approach to modeling the pinhole leak will bound the actual flaw.

The flaw evaluation is based on the criteria prescribed in Section XI, Appendix C [2] assuming the valve body neck may be modeled as a pipe and using an flaw depth to wall thickness ratio of unity for the pinhole leak (similar to the ASME Code Case N-513-1 [3] approach). In addition, a flaw is assumed for the inner portion of the valve body that could not be inspected. Allowable flaw sizes will be determined using Limit Load criteria specified in references 8 and 2 for both the axial and circumferential directions, respectively. Flaw growth evaluation considering fatigue as a possible mechanism is performed using the methodology in ASME Code Section XI, Appendix C for stainless steel components. No other mechanisms are deemed to be possible at this location.

3 ASSUMPTIONS / DESIGN INPUTS

The following assumptions are made for the analysis:

1. Service Level A/B safety factors are conservatively applied for the allowable flaw lengths.
2. Dead weight and thermal loading are assumed negligible.

3. The flaw growth evaluation is conservatively based on 100 full pressure cycles (0 to design pressure) since there are no thermal transients other than pressure cycles.
4. The valve body neck thickness is assumed to be 0.8125 inch.

The following design inputs are used for the analysis (material properties are taken at the given design temperature):

1. The valve material is SA-351 Grade CF8M cast austenitic stainless steel [4].
2. Design pressure = 2735 psig [4].
3. Design temperature = 189°F [4].
4. Valve body neck ID = 4.313 inches [5].
5. Design stress intensity, S_m = 20 ksi [6, p. 316].

Note that the cast austenitic stainless steel has an equivalent design stress intensity to that of the weld filler metal E316-16 SFA 5.4 [11]. The analysis presented herein applies to either material.

4 CALCULATIONS AND RESULTS

4.1 Determination of Stresses

4.1.1 Circumferential Flaw

For a circumferential flaw, the stresses of interest are the axial stresses resulting from internal pressure and the bending stress resulting from seismic loads. The axial stress resulting from pressure is given by:

$$\sigma_{hoop} = \frac{PD_o}{4t} = 5.0 \text{ ksi}$$

where: P = design pressure = 2735 psi
D_o = outside diameter = 5.938 inches
t = thickness = 0.8125 inches.

The bending stress (σ_b) is calculated as:

$$\sigma_b = \frac{M_R}{S} = 1.14 \text{ ksi}$$

where: S = section modulus = $\frac{\pi\left[D_o^4 - (D_o - 2t)^4\right]}{32D_o}$ = 14.83 in^3

M_R = 16.87 in-kips = resultant moment conservatively calculated by applying an assumed 5g load at the end of the valve in the lateral direction with a moment arm of 25 inches and valve weight of 135 lbs. Note that the moment arm length and valve weight were taken from Reference 1 (marked-up drawing) and assumed accurate.

4.1.2 Axial Flaw

For an axial flaw, the stress of interest is the hoop stress resulting from pressure loading. This is given by the expression:

$$\sigma_{hoop} = \frac{PD_o}{2t}$$

The thickness of the valve is varied corresponding to the NDE threshold for detection in determining the allowable and critical flaw sizes in the axial direction. For the full thickness of the valve, 0.8125", the hoop stress is 10.0 ksi.

4.2 Allowable Flaw Size Determination

Since the defect is a pinhole leak and the flaw cannot be characterized with accuracy through the wall, the ASME Section XI allowable through-wall flaw size is determined in both the axial and circumferential directions in order to determine the limiting case.

4.2.1 Circumferential Flaw

The material of the valve body is SA-351 Grade CF8M cast austenitic stainless steel. Therefore, the net section collapse methodology described in Reference 7 and implemented in ASME Code Section XI, Appendix C [2] is used in this evaluation. The technical approach consists of determining the allowable flaw size (circumferential extent and through-wall length) in the pipe that will cause the flawed pipe section to collapse.

For a more generalized case of a compound flaw, a closed form solution is not possible and as such, an iterative solution must be used. This iterative solution for solving the net section plastic collapse equation for a compound flaw has been incorporated in SI QA computer software Arbitrary Net Section Collapse (ANSC) [10]. Two cases are evaluated in the software: Case 1 for when the crack face will not take compression (on the compressive side of the neutral axis when a bending moment is present) and Case 2 for when the crack will take compression. The solution approach for Case 1 is as follows:

1) Based on a thin shell formulation (consistent with Reference 7), the area of the undegraded cylinder (remote from a flawed section) and the degraded cylinder (at the flawed section) as shown in Figure 2 are determined:

$$A_{nondegraded} = 2\pi r t_n \qquad (1)$$

$$A_{degraded} = \int_0^{2\pi} r t(\theta) d\theta \qquad (2)$$

where:

r = mean radius of cylinder
t_n = thickness of nondegraded cylinder

$t(\theta)$ = thickness degraded cylinder as a function of angle
θ = angle from reference point, radius.

2) The area of metal at the degraded section which is in tension and the area that is in compression are determined:

$$A_{tension} = A_{degraded} - A_{compression} \tag{3}$$

$$A_{tension} = 0.5 \, x \left[\frac{\sigma_m \, A_{nondegraded}}{\sigma_f} + A_{degraded} \right] \tag{4}$$

where:
σ_m = axial membrane stress in remote unflawed section,
σ_f = flow stress, see Figure 2.

After this is determined, an axis across the cylinder section, above which tension exists and below which compression exists, may be determined for any arbitrary angle as shown in Figure 2.

3) By changing the angle of the tension-to-compression axis (α), the moments about both the x-axis and the y-axis (or x'-axis and y'-axis) that will produce the state of stress may be determined. These may be combined to yield a resultant moment (M_r) that may be in a direction different than that of the tension-to-compression axis:

$$M_{x'} = \int_0^{2\pi} S \, r^2 \cos(\theta - \alpha) \, t(\theta) d\theta \tag{5}$$

$$M_{y'} = \int_0^{2\pi} S \, r^2 \sin(\theta - \alpha) \, t(\theta) d\theta \tag{6}$$

$$M_r = \sqrt{M_{x'}^2 + M_{y'}^2} \tag{7}$$

$$\lambda = \tan^{-1}\left(\frac{M_{y'}}{M_{x'}}\right) \tag{8}$$

where:
λ = angle of direction of resultant moment from the x'-axis,
S = $+\sigma_f$ above the tension-to-compression axis, and
$-\sigma_f$ otherwise.

4) The maximum bending stresses in the remote unflawed section may be determined. As in Reference 7, thin shell theory is used to solve all equations.

$$P_{b,x'} = \frac{M_{x'}}{\pi r^2 t} \tag{9}$$

$$P_{b,y'} = \frac{M_{y'}}{\pi r^2 t} \tag{10}$$

$$P_{b,\max} = \frac{M_r}{\pi r^2 t} \tag{11}$$

In ANSC, for a specified P_m and a given geometry and set of flaws, $P_{b,x'}$, $P_{b,y'}$ and $P_{b,\,max}$ are calculated, where $P_{b,max}$ is equal to the limiting bending stress at a point remote from the flawed section.

For the case where the section below the neutral axis, which may be flawed, is assumed to take compression, the determination of the position of the compression-to-tension axis must be iteratively determined. Otherwise, the solution technique is identical.

5) To determine the position (δ) of the tension-to-compression axis from x', the following equation must be iteratively solved:

$$\int_{-[(\pi-\beta)-\alpha]}^{(\pi-\beta)-\alpha} rt(\theta)\,d\theta = 2\int_{(\pi-\beta)-\alpha}^{\pi-\alpha} rt_n\,d\theta + \frac{\sigma_m}{\sigma_f} A_{nondegraded} \tag{12}$$

where:

β = angle to x' axis from bottom

$$\beta = \cos^{-1}\left(\frac{\delta}{r}\right) \tag{13}$$

6) The moment equations are identified, except that it must be recognized that the effective thickness below the tension-to-compression axis is the full nondegraded thickness.

Using ANSC, five compound flaw configurations were considered:

- Case 1 – Through-wall flaw of 6 inches (flaw angle = 116°) assuming NDE through entire thickness of remaining circumference
- Case 2 – Through-wall flaw of 6 inches (flaw angle = 116°) assuming NDE through 66% of wall thickness for remaining circumference
- Case 3 – Through-wall flaw of 6 inches (flaw angle = 116°) assuming NDE through 60% of wall thickness for remaining circumference

- Case 4 – Through-wall flaw of 6 inches (flaw angle = 116°) assuming NDE through 55% of wall thickness for remaining circumference
- Case 5 – Through-wall flaw of 6 inches (flaw angle = 116°) assuming NDE through 50% of wall thickness for remaining circumference

The results are presented in Tables 1 and 2. Table 1 presents the allowable through-wall flaw cases with an ASME Code safety factor of 2.77 for service levels A/B (note that service levels A/B bounds service levels C and D for this location). Table 2 presents the results of the critical through-wall flaws. A separate Case 6 ANSC run was performed similar to the limiting Case 5 except with a through-wall length of 9 inches. This resulted in a safety factor of greater than unity. Longer critical flaws would be expected for the other cases. Details of the analysis are provided in Appendix A.

4.2.2 Axial Flaw

The allowable and critical axial through-wall flaw lengths, l_{all}, are determined using the relationship from Reference 8 which is given as:

$$l_{all} = 1.58\sqrt{Rt}\left[\left(\frac{\sigma_f}{SF\,\sigma_h}\right)^2 - 1\right]^{\frac{1}{2}} \qquad (14)$$

where:

R	=	mean pipe radius
t	=	pipe thickness
σ_f	=	material flow stress = $3S_m$
SF	=	safety factor = 3.0 for allowable flaw size and 1.0 for critical flaw size
σ_h	=	hoop stress = $pD_o/2t$, where p = design pressure and D_o = outside diameter.

The above expression is also used in Code Case N-513-1 for the evaluation of axial through-wall flaws. For the compound flaw, the above equation is used and the hoop stress is calculated using the thickness corresponding to the depth that the NDE can interrogate. The five case considered for the circumferential flaw were also considered for the axial flaw and the results are presented in Tables 1 and 2 for the allowable and critical through-wall flaw lengths, respectively. Details of the calculations are provided in the Excel file: *MNS-05Q-302 Analysis.xls*.

4.3 Flaw Growth Analysis

In this section, a conservative fatigue analysis is performed to determine the beginning of cycle through-wall flaw length that will not reach the allowable through-wall flaw length in one operating cycle. An axial flaw was considered in this evaluation since it is bounding. The material of the valve body and weld filler metal are stainless steel. As such, the fatigue crack growth evaluation is performed using the

methodology in ASME Code Section XI, Appendix C [2] for stainless steel components using the QA software package **pc-CRACK** [9].

Since the defect is through-wall, the end of life flaw size due to fatigue crack growth is calculated using the fatigue crack growth rate for austenitic steels exposed to water environments. Per Reference 7, the fatigue crack growth rate for austenitic steel in air environment along with an environment factor of 2.0 for PWR water environment can be used.

From Subarticle C-3200 of Reference 2, the fatigue crack growth rate for austenitic steel in air environments is given by:

$$\frac{da}{dN} = C_o(\Delta K_I)^n \qquad (15)$$

where:

ΔK_I	=	stress intensity factor range (K_{max} - K_{min})
n	=	3.3
C_o	=	C x S.

C is a scaling parameter to account for temperature and is given by:

$$C = 10^{\left[-10.009+8.12x10^{-4}T-1.13x10^{-6}T^2+1.02x10^{-9}T^3\right]}$$

where, T is the metal temperature in °F (for T ≤ 800°F), and S is a scaling parameter to account for R ratio and is given by:

$$\begin{aligned} S &= 1.0 && R \le 0 \\ &= 1.0 + 1.8R && 0 \le R \le 0.79 \\ &= -43.35 + 57.97R && 0.79 \le R < 1.0 \end{aligned}$$

with,

$$R = K_{min} / K_{max}.$$

The maximum design metal temperature of 189°F is used in the calculation of the scaling factor C. At a temperature at 189°F and for R ≤ 0 as assumed in this case, C_0 was calculated as $1.29x10^{-10}$ for an air environment. A value of C_0 of $2.58x10^{-10}$ was, therefore, used for the PWR water environment to determine crack growth.

At the location of the flaw, there are no thermal transients other than pressure cycles. Hence, the evaluation is performed by assuming 100 full pressure cycles (0 to 2735 psig) which is conservative relative to the time that this flaw is expected to be in service.

Typical results of this fatigue crack growth evaluation are shown in Figure 3 for the case where the entire thickness is assumed in the evaluation. Assuming an initial through-wall half flaw length of 2.0 inches (or total flaw length of 4.0 inches), the crack growth after 100 cycles is approximately 0.011 inch with a

maximum final half crack length of approximately 2.011 inches. This crack growth (0.022 inches on the total flaw length) should be subtracted from the allowable flaw length of Case 1 in Table 1 to determine the beginning of cycle flaw length. Crack growth evaluations were performed for all five cases in Table 1 and Table 3 shows the beginning of cycle allowable axial flaw lengths for each of the five cases. Appendix B provides the **pc-CRACK** output for each case.

5 CONCLUSIONS

- The allowable flaw sizes at the location of the defect are as shown in Table 1. Based on the inspection capabilities in the depth direction, the allowable flaw length can be determined from this table.

- The critical flaw sizes at the location of the defect are as shown in Table 2. Based on the inspection capabilities in the depth direction, the critical flaw length can be determined from this table.

- The beginning of cycle allowable axial flaw sizes at the location of the defect are as shown in Table 3. Based on the inspection capabilities in the depth direction, the allowable flaw length can be determined from this table.

- The allowable, critical and beginning of cycle through-wall flaw lengths listed in Tables 1, 2 and 3 are conservative in view of many conservative assumptions made in the evaluation:

    - The valve wall that could not be inspected was assumed to be completely flawed,
    - Design conditions were used in the analysis in lieu of operating conditions as is typically done in ASME Section XI flaw evaluation, and
    - A conservative bending stress associated with seismic load was used in the analysis based on 5g lateral acceleration.

Table 1: Allowable Through-wall Flaw Lengths

Case	Description	Axial (in)	Circumferential (in)
1	Through-wall assuming NDE through entire thickness	3.95	> 6
2	Through-wall assuming NDE through 66% of wall thickness	1.64	> 6
3	Through-wall assuming NDE through 60% of wall thickness	1.17	> 6
4	Through-wall assuming NDE through 55% of wall thickness	0.78	> 6
5	Through-wall assuming NDE through 50% of wall thickness	0.06	> 6

Table 2: Critical Through-wall Flaw Lengths

Case	Description	Axial (in)	Circumferential (in)
1	Through-wall assuming NDE through entire thickness	13.50	> 9
2	Through-wall assuming NDE through 66% of wall thickness	7.21	> 9
3	Through-wall assuming NDE through 60% of wall thickness	6.11	> 9
4	Through-wall assuming NDE through 55% of wall thickness	5.32	> 9
5	Through-wall assuming NDE through 50% of wall thickness	4.56	> 9

Table 3: Beginning of Cycle Allowable Axial Through-wall Flaw Lengths

Case	Description	Axial (in)
1	Through-wall assuming NDE through entire thickness	3.93
2	Through-wall assuming NDE through 66% of wall thickness	1.64
3	Through-wall assuming NDE through 60% of wall thickness	1.17
4	Through-wall assuming NDE through 55% of wall thickness	0.78
5	Through-wall assuming NDE through 50% of wall thickness	0.06

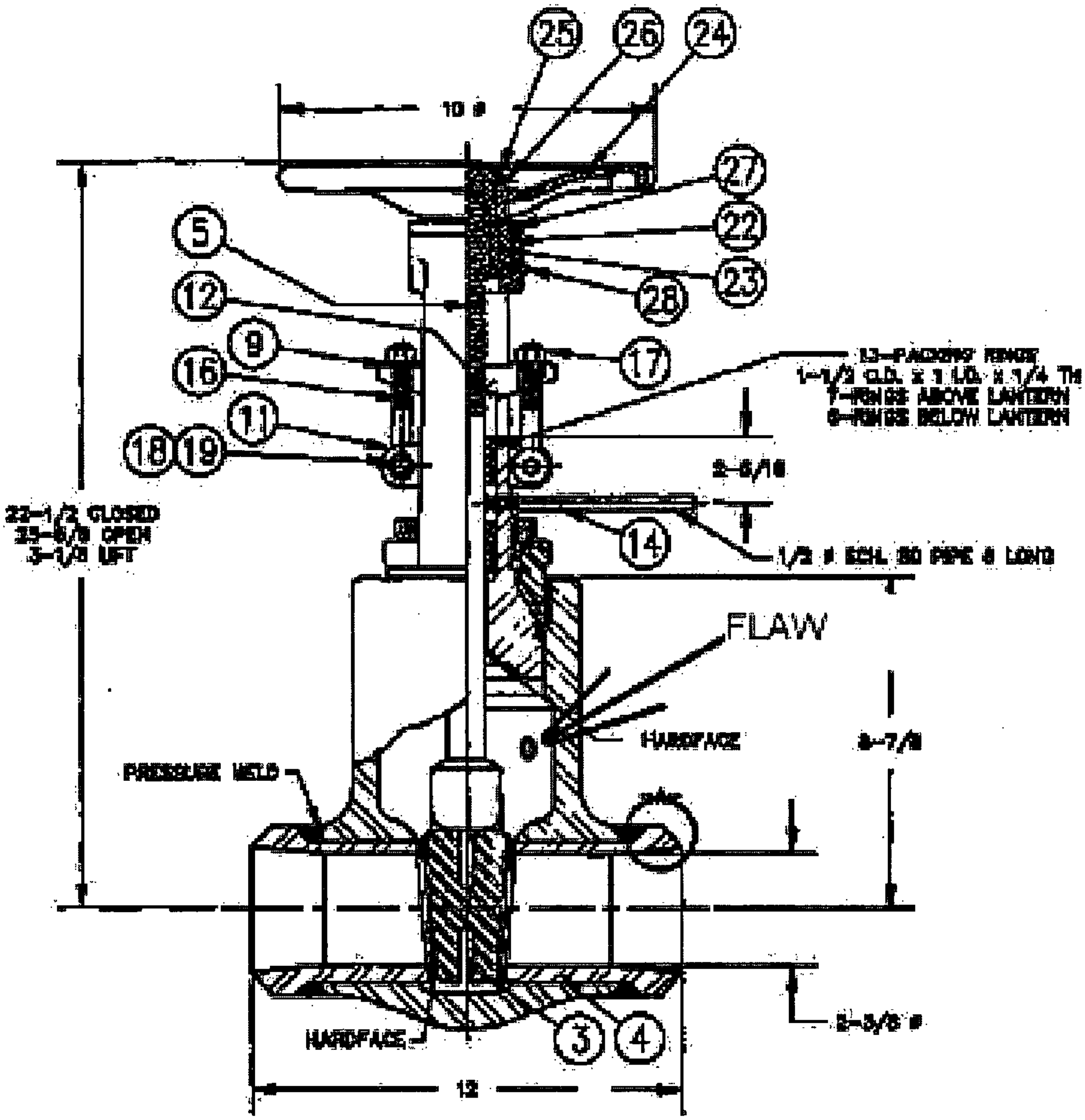

Figure 1. Location of Flaw in Valve 1NV-240

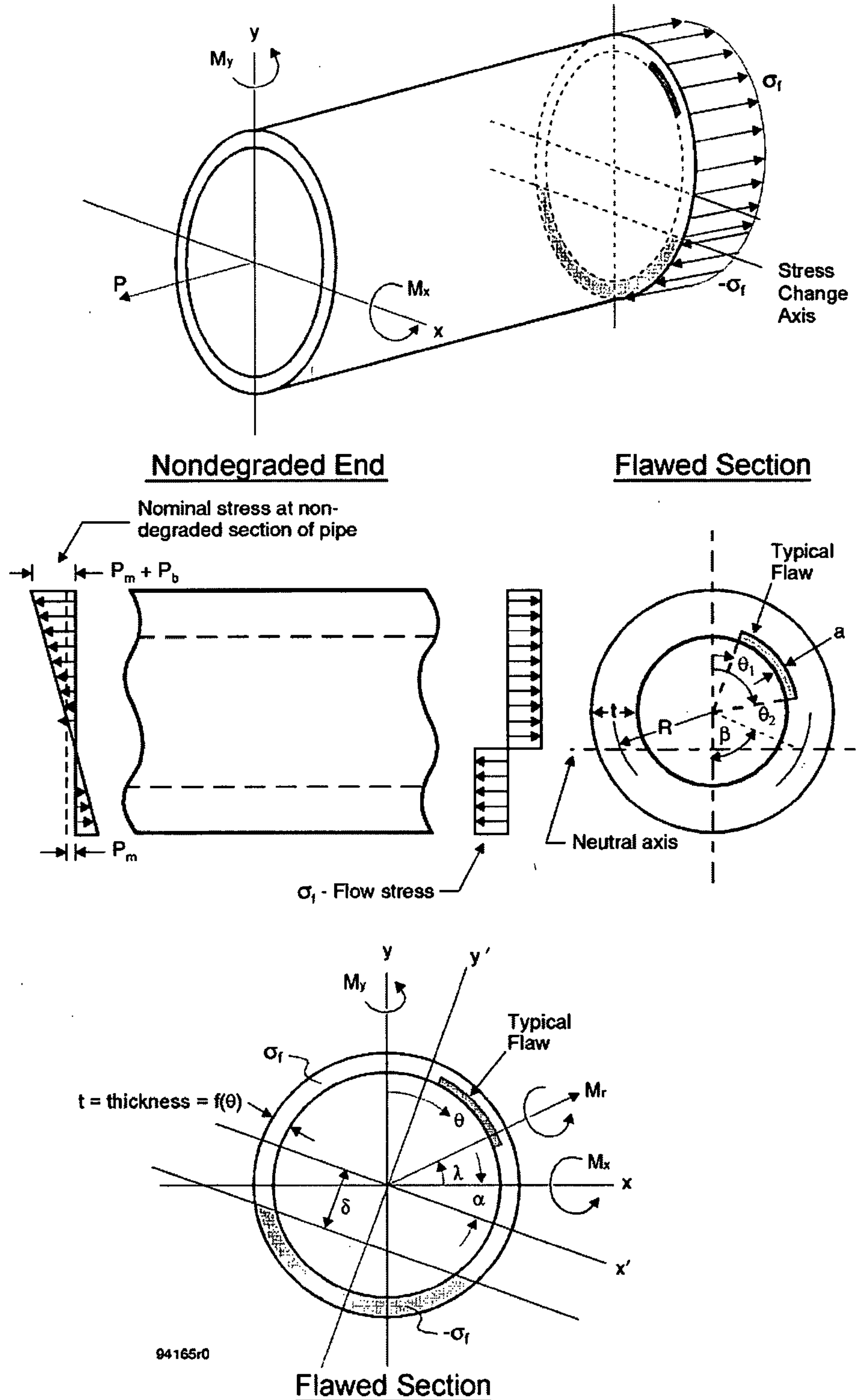

Figure 2. Loading and Stress Distribution of a Cylindrical Section at Net Section Collapse

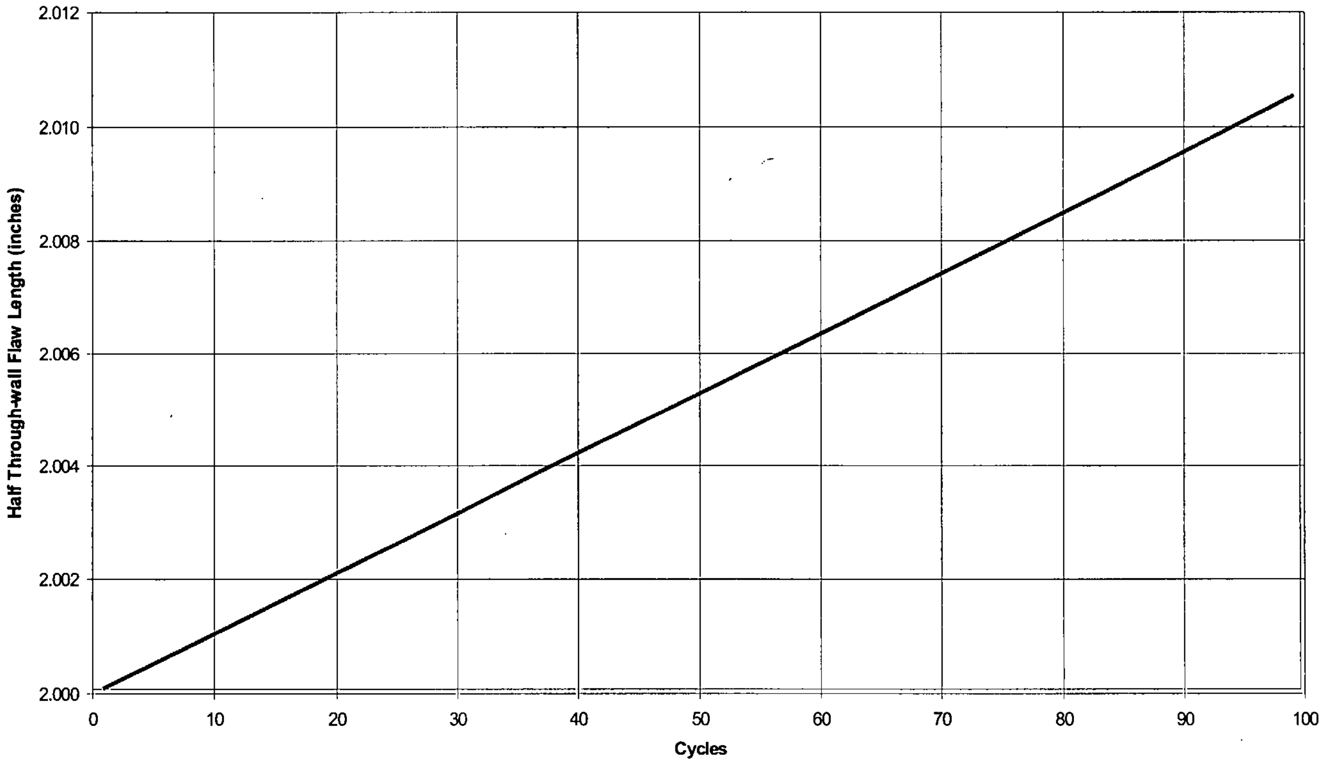

Figure 3. Typical Crack Growth Evaluation Results (Axial Flaw with Full Thickness)

6 REFERENCES

1. Email attachment "1nv240.bmp," from Bryan Meyer (Duke) to Bob McGill (SI), "Subject: Valve Vendor Drawings – 1NV-240 with flaw location," dated Wednesday, June 20, 2007, 7:12PM, SI File No. MNS-05Q-202. [This reference was unverified by Duke Energy and assumed accurate.]

2. ASME Boiler and Pressure Vessel Code, Section XI, 1998 Edition (2000 Addenda).

3. ASME Code Case N-513-1, "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or Class 3 Piping Section XI, Division 1," Cases of ASME Boiler and Pressure Vessel Code, March 28, 2001.

4. E-mail from Fred Setzer (Duke) to Bob McGill (SI), "Subject: RE: P.O Issuance for Structural Integrity-Fracture Mechanics evaluation for 1NV-240," dated Thursday, June 21, 2007, 12:08PM, SI File No. MNS-05Q-203. [Provided in Appendix C]

5. Duke Energy File Number MCM 1205.00-0577, Document Control Date August 4, 1981, SI File No. MNS-05Q-201.

6. ASME Boiler and Pressure Vessel Code, Section II, Part D – Properties, 1998 Edition (2000 Addenda).

7. ASME Section XI Task Group for Piping Flaw Evaluation, 'Evaluation of Flaws in Austenitic Steel Piping,' Journal of Pressure Vessel Technology, Vol. 108, August, 1986.

8. "Evaluation of Flaws in Austenitic Steel Piping," EPRI NP-4690-SR, Electric Power Research Institute, July 1989.

9. Structural Integrity Associates, Inc., "**pc-CRACK™** Fracture Mechanics Software," Version 3.1 – 98348, 1998.

10. SI Computer Program ANSC, Version 2.0, SI QA File QA-1900, April 1994.

11. Chemical and Mechanical Test Report for Gate Valve 1NV-240, Walworth Company, 1976, SI File No. MNS-05Q-204.

APPENDIX A

ANSC OUTPUT FOR CIRCUMFERENTIAL COMPOUND FLAW EVALUATION

```
Arbitrary Net Section Collapse ANSC 2.0 (4/26/94)
 06-23-2007   11:39:48
 Page  1

 DESCRIPTION:
    Case 1 MNS-05Q Valve Body - 1NV-240
     Pipe with 116 degree thru-wall crack, Pm=5ksi
     Crack not assumed to take compression


 WARNING:
   RADIUS TO THICKNESS RATIO < 10
   THIN SHELL THEORY NOT A GOOD REPRESENTATION

 RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

  TENSION STRESS          =    5.000 KSI
  MATERIAL FLOW STRESS    =   60.000 KSI


 ANGLE FOR MOMENT ITERATION =  10

 FLAWS DEFINED  =  1    (AS FOLLOWS)
    1 ANGLES:    0.0000 TO  116.0000  (DTHETA =  116.000) DEPTH (IN) =
0.813

 TOTAL AREA (IN2)                     =  15.15701
 REMAINING DEGRADED SECTION AREA (IN2) =  10.27308
   (APPROX. DEGRADED METAL AREA  =  10.27334 )

 AREA IN TENSION     =  5.768211
 AREA IN COMPRESSION =  4.504871

 Program Output:
    Angle = Angle that tension-to-compression axis x' is rotated
        t = Thickness in wall at position corresponding to angle
    delta = Distance from center to tension-to-compression axis
    Pb,x' = Bending stress due to moment about tension-to-compression
axis
    Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
   Pb,max = Maximum bending stress due to total limit moment
 Anglemax = Angle for total limit moment relative to original Y axis
```

Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.406	1.766	44.243	-27.419	52.051	328.21
10.00	0.000	1.766	39.733	-24.021	46.430	338.84
20.00	0.000	1.766	35.882	-19.892	41.027	351.00
30.00	0.000	1.766	32.807	-15.156	36.139	5.20
40.00	0.000	1.766	30.601	-9.959	32.181	21.97
50.00	0.000	1.766	29.331	-4.457	29.667	41.36
60.00	0.000	1.766	29.035	1.182	29.059	62.33
70.00	0.000	1.766	29.723	6.786	30.488	82.86
80.00	0.000	1.766	31.374	12.186	33.658	101.23
90.00	0.000	1.766	33.938	17.217	38.055	116.90
100.00	0.000	1.766	37.336	21.726	43.197	130.20
110.00	0.000	1.766	41.466	25.578	48.720	141.67
120.00	0.813	1.766	46.202	28.654	54.365	151.81
130.00	0.813	1.617	51.285	27.114	58.011	157.86
140.00	0.813	1.160	55.205	17.802	58.004	157.87
150.00	0.813	0.668	57.447	7.950	57.995	157.88
160.00	0.813	0.155	57.944	-2.144	57.984	157.88
170.00	0.813	-0.362	56.680	-12.173	57.973	157.88
180.00	0.813	-0.868	53.695	-21.832	57.963	157.87
190.00	0.813	-1.088	49.404	-24.013	54.931	164.08
200.00	0.813	-1.088	45.554	-19.884	49.704	176.42
210.00	0.813	-1.088	42.478	-15.148	45.098	190.37
220.00	0.813	-1.088	40.272	-9.950	41.483	206.12
230.00	0.813	-1.088	39.002	-4.449	39.255	223.49
240.00	0.813	-1.088	38.706	1.190	38.725	241.76
250.00	0.813	-1.088	39.394	6.795	39.976	259.79
260.00	0.813	-1.088	41.045	12.194	42.818	276.55
270.00	0.813	-1.088	43.609	17.225	46.888	291.55
280.00	0.813	-1.088	47.007	21.735	51.789	304.81
290.00	0.813	-1.088	51.137	25.586	57.180	316.58
300.00	0.813	-0.668	55.091	18.093	57.986	318.18
310.00	0.813	-0.155	57.396	8.253	57.986	318.18
320.00	0.813	0.362	57.957	-1.839	57.986	318.18
330.00	0.813	0.868	56.757	-11.875	57.986	318.18
340.00	0.813	1.348	53.833	-21.551	57.986	318.18
350.00	0.813	1.766	49.275	-29.982	57.679	318.68

MINIMUM STRESS (Pb,x') = 29.035 AT 60.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 29.059 AT 62.33 DEGREES

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DESCRIPTION:
   Case 2 MNS-05Q Valve Body - 1NV-240
    Pipe with 116 degree thru-wall crack, Pm=5ksi
    Crack not assumed to take compression


WARNING:
  RADIUS TO THICKNESS RATIO < 10
  THIN SHELL THEORY NOT A GOOD REPRESENTATION

RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

 TENSION STRESS          =    5.000 KSI
 MATERIAL FLOW STRESS    =   60.000 KSI


ANGLE FOR MOMENT ITERATION =  10

FLAWS DEFINED  =  2    (AS FOLLOWS)
   1 ANGLES:    0.0000 TO  116.0000  (DTHETA =  116.000) DEPTH (IN) =
0.813
   2 ANGLES:  116.0000 TO  360.0000  (DTHETA =  244.000) DEPTH (IN) =
0.271

TOTAL AREA (IN2)                    =  15.15701
REMAINING DEGRADED SECTION AREA (IN2) =  6.849143
  (APPROX. DEGRADED METAL AREA  =  6.849338 )

AREA IN TENSION     =  4.056211
AREA IN COMPRESSION =  2.792933

Program Output:
   Angle = Angle that tension-to-compression axis x' is rotated
       t = Thickness in wall at position corresponding to angle
   delta = Distance from center to tension-to-compression axis
   Pb,x' = Bending stress due to moment about tension-to-compression
axis
   Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
  Pb,max = Maximum bending stress due to total limit moment
Anglemax = Angle for total limit moment relative to original Y axis
```

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Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.271	1.918	27.429	-18.315	32.982	326.27
10.00	0.000	1.918	24.422	-16.050	29.224	336.69
20.00	0.000	1.918	21.854	-13.297	25.582	348.68
30.00	0.000	1.918	19.804	-10.140	22.249	2.89
40.00	0.000	1.918	18.333	-6.674	19.510	19.99
50.00	0.000	1.918	17.486	-3.006	17.743	40.24
60.00	0.000	1.918	17.289	0.753	17.306	62.49
70.00	0.000	1.918	17.748	4.489	18.307	84.20
80.00	0.000	1.918	18.849	8.090	20.511	103.23
90.00	0.000	1.918	20.558	11.444	23.528	119.10
100.00	0.000	1.918	22.824	14.450	27.013	132.34
110.00	0.000	1.918	25.577	17.018	30.721	143.64
120.00	0.542	1.918	28.734	19.069	34.486	153.57
130.00	0.542	1.918	32.200	20.540	38.193	162.53
140.00	0.542	1.507	35.306	14.765	38.270	162.69
150.00	0.542	1.040	37.341	8.406	38.275	162.69
160.00	0.542	0.541	38.240	1.791	38.282	162.68
170.00	0.542	0.026	37.978	-4.789	38.279	162.81
180.00	0.542	-0.490	36.562	-11.311	38.271	162.81
190.00	0.542	-0.905	34.057	-16.050	37.650	164.77
200.00	0.542	-0.905	31.490	-13.297	34.182	177.11
210.00	0.542	-0.905	29.440	-10.140	31.137	190.99
220.00	0.542	-0.905	27.969	-6.675	28.754	206.58
230.00	0.542	-0.905	27.122	-3.007	27.288	223.67
240.00	0.542	-0.905	26.925	0.753	26.935	241.60
250.00	0.542	-0.905	27.384	4.489	27.749	259.31
260.00	0.542	-0.905	28.484	8.089	29.611	275.85
270.00	0.542	-0.905	30.193	11.444	32.289	290.76
280.00	0.542	-0.905	32.459	14.450	35.530	304.00
290.00	0.542	-0.793	35.175	15.113	38.284	313.25
300.00	0.542	-0.285	37.265	8.776	38.284	313.25
310.00	0.542	0.233	38.222	2.172	38.284	313.25
320.00	0.542	0.743	38.019	-4.498	38.284	313.25
330.00	0.542	1.231	36.660	-11.031	38.284	313.25
340.00	0.542	1.682	34.188	-17.230	38.284	313.25
350.00	0.542	1.918	30.783	-20.024	36.723	316.96

MINIMUM STRESS (Pb,x') = 17.289 AT 60.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 17.306 AT 62.49 DEGREES

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DESCRIPTION:
   Case 3 MNS-05Q Valve Body - 1NV-240
    Pipe with 116 degree thru-wall crack, Pm=5ksi
    Crack not assumed to take compression


WARNING:
  RADIUS TO THICKNESS RATIO < 10
  THIN SHELL THEORY NOT A GOOD REPRESENTATION

RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

 TENSION STRESS          =    5.000 KSI
 MATERIAL FLOW STRESS    =   60.000 KSI


ANGLE FOR MOMENT ITERATION =  10

FLAWS DEFINED  =  2    (AS FOLLOWS)
   1 ANGLES:    0.0000 TO  116.0000  (DTHETA =  116.000) DEPTH (IN) =
0.813
   2 ANGLES:  116.0000 TO  360.0000  (DTHETA =  244.000) DEPTH (IN) =
0.325

TOTAL AREA (IN2)                     =  15.15701
REMAINING DEGRADED SECTION AREA (IN2) =  6.16385
  (APPROX. DEGRADED METAL AREA  =  6.164037 )

AREA IN TENSION     =  3.713561
AREA IN COMPRESSION =  2.450289

Program Output:
   Angle = Angle that tension-to-compression axis x' is rotated
       t = Thickness in wall at position corresponding to angle
   delta = Distance from center to tension-to-compression axis
   Pb,x' = Bending stress due to moment about tension-to-compression
axis
   Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
  Pb,max = Maximum bending stress due to total limit moment
Anglemax = Angle for total limit moment relative to original Y axis
```

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Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.244	1.967	24.030	-16.453	29.123	325.60
10.00	0.000	1.967	21.324	-14.415	25.739	335.94
20.00	0.000	1.967	19.013	-11.937	22.450	347.88
30.00	0.000	1.967	17.168	-9.096	19.428	2.08
40.00	0.000	1.967	15.844	-5.977	16.934	19.33
50.00	0.000	1.967	15.082	-2.676	15.317	39.94
60.00	0.000	1.967	14.905	0.707	14.921	62.72
70.00	0.000	1.967	15.317	4.070	15.849	84.88
80.00	0.000	1.967	16.308	7.310	17.871	104.14
90.00	0.000	1.967	17.846	10.328	20.619	120.06
100.00	0.000	1.967	19.885	13.034	23.776	133.24
110.00	0.000	1.967	22.363	15.345	27.121	144.46
120.00	0.488	1.967	25.205	17.190	30.509	154.30
130.00	0.488	1.967	28.323	18.514	33.838	163.17
140.00	0.488	1.617	31.247	14.206	34.325	164.45
150.00	0.488	1.160	33.234	8.568	34.320	164.46
160.00	0.488	0.668	34.210	2.669	34.314	164.46
170.00	0.488	0.155	34.147	-3.311	34.307	164.46
180.00	0.488	-0.362	33.047	-9.190	34.301	164.46
190.00	0.488	-0.843	30.944	-14.407	34.134	165.03
200.00	0.488	-0.843	28.634	-11.929	31.019	177.38
210.00	0.488	-0.843	26.789	-9.088	28.288	191.26
220.00	0.488	-0.843	25.465	-5.969	26.155	206.81
230.00	0.488	-0.843	24.703	-2.668	24.846	223.83
240.00	0.488	-0.843	24.525	0.715	24.536	241.67
250.00	0.488	-0.843	24.938	4.078	25.270	259.29
260.00	0.488	-0.843	25.929	7.318	26.942	275.76
270.00	0.488	-0.843	27.467	10.336	29.347	290.62
280.00	0.488	-0.843	29.506	13.042	32.260	303.85
290.00	0.488	-0.668	31.901	12.631	34.311	311.60
300.00	0.488	-0.155	33.610	6.900	34.311	311.60
310.00	0.488	0.362	34.298	0.959	34.311	311.60
320.00	0.488	0.868	33.943	-5.011	34.311	311.60
330.00	0.488	1.348	32.558	-10.829	34.311	311.60
340.00	0.488	1.787	30.183	-16.318	34.311	311.60
350.00	0.488	1.967	27.048	-17.991	32.485	316.37

MINIMUM STRESS (Pb,x') = 14.905 AT 60.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 14.921 AT 62.72 DEGREES

Arbitrary Net Section Collapse ANSC 2.0 (4/26/94)
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DESCRIPTION:
   Case 4 MNS-05Q Valve Body - 1NV-240
    Pipe with 116 degree thru-wall crack, Pm=5ksi
    Crack not assumed to take compression


WARNING:
  RADIUS TO THICKNESS RATIO < 10
  THIN SHELL THEORY NOT A GOOD REPRESENTATION

RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

 TENSION STRESS         =    5.000 KSI
 MATERIAL FLOW STRESS   =   60.000 KSI


ANGLE FOR MOMENT ITERATION =  10

FLAWS DEFINED  =  2    (AS FOLLOWS)
   1 ANGLES:    0.0000 TO  116.0000  (DTHETA =  116.000) DEPTH (IN) =
0.813
   2 ANGLES:  116.0000 TO  360.0000  (DTHETA =  244.000) DEPTH (IN) =
0.366

TOTAL AREA (IN2)                         =  15.15701
REMAINING DEGRADED SECTION AREA (IN2) =  5.650512
  (APPROX. DEGRADED METAL AREA  =  5.65063 )

AREA IN TENSION     =  3.456857
AREA IN COMPRESSION =  2.193655

Program Output:
   Angle = Angle that tension-to-compression axis x' is rotated
       t = Thickness in wall at position corresponding to angle
   delta = Distance from center to tension-to-compression axis
   Pb,x' = Bending stress due to moment about tension-to-compression
axis
   Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
  Pb,max = Maximum bending stress due to total limit moment
Anglemax = Angle for total limit moment relative to original Y axis
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Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.223	2.011	21.470	-15.103	26.250	324.87
10.00	0.000	2.011	18.990	-13.234	23.146	335.13
20.00	0.000	2.011	16.871	-10.963	20.120	346.98
30.00	0.000	2.011	15.180	-8.358	17.329	1.16
40.00	0.000	2.011	13.966	-5.499	15.010	18.51
50.00	0.000	2.011	13.268	-2.473	13.496	39.44
60.00	0.000	2.011	13.105	0.629	13.120	62.75
70.00	0.000	2.011	13.484	3.711	13.985	85.39
80.00	0.000	2.011	14.392	6.681	15.867	104.90
90.00	0.000	2.011	15.802	9.448	18.411	120.88
100.00	0.000	2.011	17.671	11.929	21.320	134.02
110.00	0.000	2.011	19.942	14.047	24.393	145.16
120.00	0.447	2.011	22.547	15.738	27.497	154.92
130.00	0.447	2.011	25.406	16.952	30.542	163.71
140.00	0.447	1.715	28.177	13.668	31.317	165.88
150.00	0.447	1.268	30.125	8.565	31.319	165.87
160.00	0.447	0.782	31.158	3.203	31.322	165.87
170.00	0.447	0.273	31.243	-2.257	31.325	165.87
180.00	0.447	-0.245	30.380	-7.649	31.328	165.87
190.00	0.447	-0.755	28.593	-12.808	31.331	165.87
200.00	0.447	-0.787	26.478	-10.960	28.657	177.51
210.00	0.447	-0.787	24.786	-8.356	26.157	191.37
220.00	0.447	-0.787	23.573	-5.497	24.205	206.87
230.00	0.447	-0.787	22.874	-2.471	23.007	223.83
240.00	0.447	-0.787	22.712	0.631	22.720	241.59
250.00	0.447	-0.787	23.090	3.713	23.387	259.14
260.00	0.447	-0.787	23.998	6.683	24.911	275.56
270.00	0.447	-0.787	25.408	9.451	27.109	290.40
280.00	0.447	-0.787	27.277	11.931	29.772	303.62
290.00	0.447	-0.553	29.416	10.764	31.324	310.10
300.00	0.447	-0.038	30.838	5.493	31.324	310.10
310.00	0.447	0.479	31.323	0.054	31.324	310.10
320.00	0.447	0.980	30.857	-5.386	31.324	310.10
330.00	0.447	1.452	29.453	-10.662	31.324	310.10
340.00	0.447	1.879	27.154	-15.615	31.324	310.10
350.00	0.447	2.011	24.237	-16.513	29.328	315.73

MINIMUM STRESS (Pb,x') = 13.105 AT 60.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 13.120 AT 62.75
DEGREESArbitrary Net Section Collapse ANSC 2.0 (4/26/94)
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DESCRIPTION:
   Case 5 MNS-05Q Valve Body - 1NV-240
    Pipe with 116 degree thru-wall crack, Pm=5ksi
    Crack not assumed to take compression


WARNING:
  RADIUS TO THICKNESS RATIO < 10
  THIN SHELL THEORY NOT A GOOD REPRESENTATION

RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

 TENSION STRESS           =    5.000 KSI
 MATERIAL FLOW STRESS     =   60.000 KSI


ANGLE FOR MOMENT ITERATION =  10

FLAWS DEFINED  =  2    (AS FOLLOWS)
   1 ANGLES:    0.0000 TO  116.0000  (DTHETA =  116.000) DEPTH (IN) =
0.813
   2 ANGLES:  116.0000 TO  360.0000  (DTHETA =  244.000) DEPTH (IN) =
0.406

TOTAL AREA (IN2)                        =  15.15701
REMAINING DEGRADED SECTION AREA (IN2) =  5.135909
  (APPROX. DEGRADED METAL AREA  =  5.135953 )

AREA IN TENSION     =  3.199518
AREA IN COMPRESSION =  1.936391

Program Output:
   Angle = Angle that tension-to-compression axis x' is rotated
       t = Thickness in wall at position corresponding to angle
   delta = Distance from center to tension-to-compression axis
   Pb,x' = Bending stress due to moment about tension-to-compression
axis
   Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
  Pb,max = Maximum bending stress due to total limit moment
Anglemax = Angle for total limit moment relative to original Y axis
```

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Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.203	2.063	18.891	-13.711	23.342	324.03
10.00	0.000	2.063	16.636	-12.012	20.519	334.17
20.00	0.000	2.063	14.711	-9.948	17.758	345.93
30.00	0.000	2.063	13.173	-7.580	15.198	0.08
40.00	0.000	2.063	12.070	-4.982	13.058	17.57
50.00	0.000	2.063	11.435	-2.231	11.651	38.96
60.00	0.000	2.063	11.288	0.588	11.303	62.98
70.00	0.000	2.063	11.632	3.390	12.115	86.25
80.00	0.000	2.063	12.457	6.089	13.866	106.05
90.00	0.000	2.063	13.738	8.605	16.211	122.06
100.00	0.000	2.063	15.437	10.859	18.874	135.12
110.00	0.000	2.063	17.502	12.784	21.674	146.15
120.00	0.406	2.063	19.870	14.322	24.493	155.78
130.00	0.406	2.062	22.469	15.425	27.254	164.47
140.00	0.406	1.828	25.069	13.191	28.327	167.75
150.00	0.406	1.394	26.974	8.641	28.324	167.76
160.00	0.406	0.918	28.060	3.828	28.320	167.77
170.00	0.406	0.413	28.293	-1.101	28.314	167.77
180.00	0.406	-0.103	27.666	-5.997	28.309	167.77
190.00	0.406	-0.617	26.199	-10.710	28.304	167.76
200.00	0.406	-0.718	24.297	-9.940	26.251	177.75
210.00	0.406	-0.718	22.759	-7.572	23.986	191.60
220.00	0.406	-0.718	21.656	-4.974	22.220	207.06
230.00	0.406	-0.718	21.021	-2.223	21.139	223.96
240.00	0.406	-0.718	20.874	0.596	20.882	241.64
250.00	0.406	-0.718	21.218	3.398	21.488	259.10
260.00	0.406	-0.718	22.043	6.097	22.871	275.46
270.00	0.406	-0.718	23.325	8.613	24.864	290.27
280.00	0.406	-0.718	25.024	10.867	27.281	303.47
290.00	0.406	-0.413	26.885	8.886	28.315	308.29
300.00	0.406	0.104	28.020	4.083	28.315	308.29
310.00	0.406	0.617	28.303	-0.844	28.316	308.29
320.00	0.406	1.112	27.727	-5.746	28.316	308.29
330.00	0.406	1.573	26.308	-10.473	28.316	308.29
340.00	0.406	1.987	24.089	-14.882	28.316	308.29
350.00	0.406	2.062	21.406	-14.992	26.134	314.99

MINIMUM STRESS (Pb,x') = 11.288 AT 60.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 11.303 AT 62.98 DEGREES

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 DESCRIPTION:
    Case 6 MNS-05Q Valve Body - 1NV-240
     Pipe with 116 degree thru-wall crack, Pm=5ksi
     Crack not assumed to take compression


 WARNING:
   RADIUS TO THICKNESS RATIO < 10
   THIN SHELL THEORY NOT A GOOD REPRESENTATION

 RADIUS (IN) =  2.969      WALL THICKNESS (IN) =  .8125

  TENSION STRESS          =    5.000 KSI
  MATERIAL FLOW STRESS    =   60.000 KSI


 ANGLE FOR MOMENT ITERATION =  10

 FLAWS DEFINED  =  2    (AS FOLLOWS)
    1 ANGLES:    0.0000 TO  174.0000  (DTHETA =  174.000) DEPTH (IN) =
0.813
    2 ANGLES:  174.0000 TO  360.0000  (DTHETA =  186.000) DEPTH (IN) =
0.406

 TOTAL AREA (IN2)                       =  15.15701
 REMAINING DEGRADED SECTION AREA (IN2) =  3.915078
   (APPROX. DEGRADED METAL AREA  =  3.915182 )

 AREA IN TENSION     =  2.589133
 AREA IN COMPRESSION =  1.325944

 Program Output:
    Angle = Angle that tension-to-compression axis x' is rotated
        t = Thickness in wall at position corresponding to angle
    delta = Distance from center to tension-to-compression axis
    Pb,x' = Bending stress due to moment about tension-to-compression
axis
    Pb,y' = Bending stress due to moment perpendicular to tens./comp.
axis
   Pb,max = Maximum bending stress due to total limit moment
 Anglemax = Angle for total limit moment relative to original Y axis
```

Arbitrary Net Section Collapse ANSC 2.0 (4/26/94)
06-24-2007 19:44:28
Page 2

Angle	Wall t	Delta	Pb,x'	Pb,y'	Pb,max	AngleMax
0.00	0.203	1.617	17.013	-10.454	19.968	328.43
10.00	0.000	2.025	14.939	-13.250	19.968	328.43
20.00	0.000	2.371	12.411	-15.642	19.968	328.43
30.00	0.000	2.532	9.568	-15.977	18.623	330.91
40.00	0.000	2.532	6.948	-13.931	15.567	336.51
50.00	0.000	2.532	4.724	-11.460	12.396	342.40
60.00	0.000	2.532	2.962	-8.641	9.135	348.92
70.00	0.000	2.532	1.717	-5.559	5.818	357.16
80.00	0.000	2.532	1.026	-2.308	2.525	13.96
90.00	0.000	2.532	0.910	1.014	1.363	138.11
100.00	0.000	2.532	1.372	4.306	4.520	172.32
110.00	0.000	2.532	2.400	7.468	7.844	182.19
120.00	0.000	2.532	3.960	10.403	11.131	189.16
130.00	0.000	2.532	6.007	13.022	14.341	195.24
140.00	0.000	2.532	8.477	15.246	17.445	200.93
150.00	0.000	2.490	11.290	16.486	19.982	205.60
160.00	0.000	2.172	13.978	14.280	19.983	205.61
170.00	0.000	1.787	16.242	11.640	19.982	205.63
180.00	0.406	1.348	18.012	8.645	19.980	205.64
190.00	0.406	0.868	19.235	5.389	19.976	205.65
200.00	0.406	0.362	19.874	1.968	19.971	205.66
210.00	0.406	-0.155	19.908	-1.512	19.966	205.66
220.00	0.406	-0.668	19.338	-4.946	19.961	205.65
230.00	0.406	-1.160	18.180	-8.231	19.957	205.64
240.00	0.406	-1.417	16.574	-8.630	18.686	212.49
250.00	0.406	-1.417	15.328	-5.548	16.302	230.10
260.00	0.406	-1.417	14.637	-2.297	14.816	251.08
270.00	0.406	-1.417	14.521	1.026	14.557	274.04
280.00	0.406	-1.417	14.984	4.317	15.593	296.07
290.00	0.406	-1.417	16.011	7.479	17.672	315.04
300.00	0.406	-1.348	17.560	9.506	19.968	328.43
310.00	0.406	-0.868	18.944	6.313	19.968	328.43
320.00	0.406	-0.362	19.752	2.927	19.968	328.43
330.00	0.406	0.156	19.960	-0.547	19.968	328.43
340.00	0.406	0.668	19.562	-4.005	19.968	328.43
350.00	0.406	1.160	18.570	-7.341	19.968	328.43

MINIMUM STRESS (Pb,x') = 0.910 AT 90.00 DEGREES
MINIMUM TOTAL STRESS (Pb,max) = 1.363 AT 138.11 DEGREES

APPENDIX B

pc-CRACK OUTPUT

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557
Voice: 408-978-8200
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Linear Elastic Fracture Mechanics

Date: Sun Jun 24 15:22:40 2007
Input Data and Results File: AXIALP1.LFM **[CASE 1]**

Title: McGuire Nuclear Station - Valve 1NV-240 Crack Growth - Axial Flaw

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
pressure	10	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case pressure
0.0000	10
0.6000	10
1.2000	10
1.8000	10
2.4000	10
3.0000	10
3.6000	10
4.2000	10
4.8000	10
5.4000	10
6.0000	10

Crack Model: Through-Wall Axial Crack in Pressurized Cylinder

Crack Parameters:
Wall thickness: 0.8125
Outside diameter(Rm/t>=10): 5.9380
Half crack length(max a<=10(Rmt)^0.5): 6.0000
Co = Hoop stress due to pressure
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case pressure
0.1200	6.29794
0.2400	9.19696
0.3600	11.6927
0.4800	14.071
0.6000	16.4405
0.7200	18.8534
0.8400	21.3373
0.9600	23.9072
1.0800	26.5705
1.2000	29.3307
1.3200	32.1885
1.4400	35.1431
1.5600	38.1926
1.6800	41.3345
1.8000	44.5662
1.9200	47.8848
2.0400	51.2871
2.1600	54.7703
2.2800	58.3313
2.4000	61.9672
2.5200	65.6754
2.6400	69.453
2.7600	73.2974
2.8800	77.2062
3.0000	81.1768
3.1200	85.2069
3.2400	89.2943
3.3600	93.4368
3.4800	97.6323
3.6000	101.879
3.7200	106.174
3.8400	110.517
3.9600	114.905
4.0800	119.336
4.2000	123.809
4.3200	128.322
4.4400	132.874
4.5600	137.462
4.6800	142.086
4.8000	146.743
4.9200	151.433
5.0400	156.154
5.1600	160.904
5.2800	165.682
5.4000	170.487
5.5200	175.318
5.6400	180.172
5.7600	185.049
5.8800	189.948
6.0000	194.867

Crack Growth Laws:

Law ID: Cast SS
Type: Fatigue
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 2.5800e-010
n = 3.3000
Kthres = 0.0000

Material Fracture Toughness KIc:

Material ID: Cast SS

Depth	KIc
0.0000	500.0000
0.6000	500.0000

Initial crack size= 2.0000
Max. crack size= 6.0000

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
No. 1	100	1	1	Cast SS	Cast SS

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
No. 1	pressure	1.0000	pressure	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1	1	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2	0.00
2	2	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2	0.00
3	3	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2	0.00

4	4	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2	0.00
5	5	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2.001	0.00
6	6	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2.001	0.00
7	7	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2.001	0.00
8	8	5.02e+001	0.00e+000	5.02e+001	0.00	1.05e-004	1.05e-004	2.001	0.00
9	9	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
10	10	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
11	11	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
12	12	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
13	13	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
14	14	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.001	0.00
15	15	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
16	16	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
17	17	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
18	18	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
19	19	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
20	20	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
21	21	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
22	22	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
23	23	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.002	0.00
24	24	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
25	25	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
26	26	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
27	27	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
28	28	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
29	29	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
30	30	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
31	31	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
32	32	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
33	33	5.02e+001	0.00e+000	5.02e+001	0.00	1.06e-004	1.06e-004	2.003	0.00
34	34	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
35	35	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
36	36	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
37	37	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
38	38	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
39	39	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
40	40	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
41	41	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
42	42	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.004	0.00
43	43	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
44	44	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
45	45	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
46	46	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
47	47	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
48	48	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
49	49	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
50	50	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
51	51	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.005	0.00
52	52	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.006	0.00
53	53	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.006	0.00
54	54	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.006	0.00
55	55	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.006	0.00
56	56	5.03e+001	0.00e+000	5.03e+001	0.00	1.06e-004	1.06e-004	2.006	0.00
57	57	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.006	0.00
58	58	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.006	0.00
59	59	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.006	0.00
60	60	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.006	0.00

61	61	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.006	0.00
62	62	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
63	63	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
64	64	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
65	65	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
66	66	5.03e+001	0.00e+000	5.03e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
67	67	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
68	68	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
69	69	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
70	70	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.007	0.00
71	71	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
72	72	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
73	73	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
74	74	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
75	75	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
76	76	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
77	77	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
78	78	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
79	79	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
80	80	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.008	0.00
81	81	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
82	82	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
83	83	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
84	84	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
85	85	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
86	86	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
87	87	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
88	88	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
89	89	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.009	0.00
90	90	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
91	91	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
92	92	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
93	93	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
94	94	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
95	95	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
96	96	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
97	97	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
98	98	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.01	0.00
99	99	5.04e+001	0.00e+000	5.04e+001	0.00	1.07e-004	1.07e-004	2.011	0.00
100	100	5.05e+001	0.00e+000	5.05e+001	0.00	1.07e-004	1.07e-004	2.011	0.00

End of pc-CRACK Output

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
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Voice: 408-978-8200
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E-mail: pccrack@structint.com

Linear Elastic Fracture Mechanics

Date: Sat Jun 23 13:32:37 2007
Input Data and Results File: AXIALP2.LFM **[CASE 2]**

Title: McGuire Nuclear Station - Valve 1NV-240 Crack Growth - Axial Flaw

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
pressure	14.99	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case pressure
0.0000	14.99
0.6000	14.99
1.2000	14.99
1.8000	14.99
2.4000	14.99
3.0000	14.99
3.6000	14.99
4.2000	14.99
4.8000	14.99
5.4000	14.99
6.0000	14.99

Crack Model: Through-Wall Axial Crack in Pressurized Cylinder

Crack Parameters:
Wall thickness: 0.5417
Outside diameter(Rm/t>=10): 5.9380
Half crack length(max a<=10(Rmt)^0.5): 6.0000
Co = Hoop stress due to pressure
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case pressure
0.1200	9.49488
0.2400	13.9794
0.3600	17.9458
0.4800	21.8204
0.6000	25.7605
0.7200	29.8373
0.8400	34.0848
0.9600	38.5178
1.0800	43.1414
1.2000	47.9546
1.3200	52.9536
1.4400	58.1327
1.5600	63.4853
1.6800	69.0047
1.8000	74.6837
1.9200	80.5155
2.0400	86.4932
2.1600	92.6105
2.2800	98.8611
2.4000	105.239
2.5200	111.738
2.6400	118.354
2.7600	125.08
2.8800	131.912
3.0000	138.845
3.1200	145.875
3.2400	152.996
3.3600	160.205
3.4800	167.498
3.6000	174.87
3.7200	182.318
3.8400	189.838
3.9600	197.427
4.0800	205.08
4.2000	212.795
4.3200	220.568
4.4400	228.396
4.5600	236.276
4.6800	244.205
4.8000	252.179
4.9200	260.196
5.0400	268.253
5.1600	276.347
5.2800	284.475
5.4000	292.635
5.5200	300.823
5.6400	309.037
5.7600	317.275
5.8800	325.534
6.0000	333.811

Crack Growth Laws:

Law ID: Cast SS
Type: Fatigue
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 2.5800e-010
n = 3.3000
Kthres = 0.0000

Material Fracture Toughness KIc:

Material ID: Cast SS

Depth	KIc
0.0000	500.0000
0.6000	500.0000

Initial crack size= 0.8200
Max. crack size= 6.0000

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
No. 1	100	1	1	Cast SS	Cast SS

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
No. 1	pressure	1.0000	pressure	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1	1	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.82	0.00
2	2	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8201	0.00
3	3	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8201	0.00

4	4	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8201	0.00
5	5	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8201	0.00
6	6	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8202	0.00
7	7	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8202	0.00
8	8	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8202	0.00
9	9	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8202	0.00
10	10	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8203	0.00
11	11	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8203	0.00
12	12	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8203	0.00
13	13	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8204	0.00
14	14	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8204	0.00
15	15	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8204	0.00
16	16	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8204	0.00
17	17	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8205	0.00
18	18	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8205	0.00
19	19	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8205	0.00
20	20	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8206	0.00
21	21	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8206	0.00
22	22	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8206	0.00
23	23	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8206	0.00
24	24	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8207	0.00
25	25	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8207	0.00
26	26	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8207	0.00
27	27	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8207	0.00
28	28	3.34e+001	0.00e+000	3.34e+001	0.00	2.75e-005	2.75e-005	0.8208	0.00
29	29	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8208	0.00
30	30	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8208	0.00
31	31	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8209	0.00
32	32	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8209	0.00
33	33	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8209	0.00
34	34	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8209	0.00
35	35	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.821	0.00
36	36	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.821	0.00
37	37	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.821	0.00
38	38	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.821	0.00
39	39	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8211	0.00
40	40	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8211	0.00
41	41	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8211	0.00
42	42	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8212	0.00
43	43	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8212	0.00
44	44	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8212	0.00
45	45	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8212	0.00
46	46	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8213	0.00
47	47	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8213	0.00
48	48	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8213	0.00
49	49	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8213	0.00
50	50	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8214	0.00
51	51	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8214	0.00
52	52	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8214	0.00
53	53	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8215	0.00
54	54	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8215	0.00
55	55	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8215	0.00
56	56	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8215	0.00
57	57	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8216	0.00
58	58	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8216	0.00
59	59	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8216	0.00
60	60	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8217	0.00

61	61	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8217	0.00
62	62	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8217	0.00
63	63	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8217	0.00
64	64	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8218	0.00
65	65	3.34e+001	0.00e+000	3.34e+001	0.00	2.76e-005	2.76e-005	0.8218	0.00
66	66	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8218	0.00
67	67	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8218	0.00
68	68	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8219	0.00
69	69	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8219	0.00
70	70	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8219	0.00
71	71	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.822	0.00
72	72	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.822	0.00
73	73	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.822	0.00
74	74	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.822	0.00
75	75	3.34e+001	0.00e+000	3.34e+001	0.00	2.77e-005	2.77e-005	0.8221	0.00
76	76	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8221	0.00
77	77	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8221	0.00
78	78	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8222	0.00
79	79	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8222	0.00
80	80	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8222	0.00
81	81	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8222	0.00
82	82	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8223	0.00
83	83	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8223	0.00
84	84	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8223	0.00
85	85	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8223	0.00
86	86	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8224	0.00
87	87	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8224	0.00
88	88	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8224	0.00
89	89	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8225	0.00
90	90	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8225	0.00
91	91	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8225	0.00
92	92	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8225	0.00
93	93	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8226	0.00
94	94	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8226	0.00
95	95	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8226	0.00
96	96	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8226	0.00
97	97	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8227	0.00
98	98	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8227	0.00
99	99	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8227	0.00
100	100	3.35e+001	0.00e+000	3.35e+001	0.00	2.77e-005	2.77e-005	0.8228	0.00

End of pc-CRACK Output

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557
Voice: 408-978-8200
Fax: 408-978-8964
E-mail: pccrack@structint.com

Linear Elastic Fracture Mechanics

Date: Sat Jun 23 13:34:14 2007
Input Data and Results File: AXIALP3.LFM [CASE 3]

Title: McGuire Nuclear Station - Valve 1NV-240 Crack Growth - Axial Flaw

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
pressure	16.66	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case pressure
0.0000	16.66
0.6000	16.66
1.2000	16.66
1.8000	16.66
2.4000	16.66
3.0000	16.66
3.6000	16.66
4.2000	16.66
4.8000	16.66
5.4000	16.66
6.0000	16.66

Crack Model: Through-Wall Axial Crack in Pressurized Cylinder

Crack Parameters:

Wall thickness:	0.4875
Outside diameter(Rm/t>=10):	5.9380
Half crack length(max a<=10(Rmt)^0.5):	6.0000

Co = Hoop stress due to pressure
All other stress coefficients are neglected.

-------------------Stress Intensity Factor--------------------

Crack Size	Case pressure
0.1200	10.5714
0.2400	15.6043
0.3600	20.0919
0.4800	24.5066
0.6000	29.0209
0.7200	33.711
0.8400	38.6117
0.9600	43.7368
1.0800	49.0895
1.2000	54.667
1.3200	60.4631
1.4400	66.4701
1.5600	72.6796
1.6800	79.0827
1.8000	85.6707
1.9200	92.4352
2.0400	99.368
2.1600	106.461
2.2800	113.707
2.4000	121.098
2.5200	128.629
2.6400	136.291
2.7600	144.079
2.8800	151.987
3.0000	160.01
3.1200	168.14
3.2400	176.375
3.3600	184.707
3.4800	193.133
3.6000	201.647
3.7200	210.246
3.8400	218.924
3.9600	227.677
4.0800	236.501
4.2000	245.392
4.3200	254.346
4.4400	263.359
4.5600	272.427
4.6800	281.547
4.8000	290.714
4.9200	299.926
5.0400	309.179
5.1600	318.469
5.2800	327.793
5.4000	337.148
5.5200	346.53
5.6400	355.937
5.7600	365.364
5.8800	374.809
6.0000	384.269

Crack Growth Laws:

```
Law ID:   Cast SS
  Type:   Fatigue
 Model:   Paris

   da/dN = c * (dK)^n
 where
   dK = Kmax - Kmin
   dK > Kthres
   Kmax < K1c
```

Material parameters:

```
      c =  2.5800e-010
      n =     3.3000
 Kthres =     0.0000
```

Material Fracture Toughness KIc:

Material ID: Cast SS

Depth	KIc
0.0000	500.0000
0.6000	500.0000

```
Initial crack size=     0.5850
Max. crack size=         6.0000

Number of blocks=             1
Print increment of block=     1
```

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
No. 1	100	1	1	Cast SS	Cast SS

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
No. 1	pressure	1.0000	pressure	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1	1	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.585	0.00
2	2	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.585	0.00
3	3	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.585	0.00

4	4	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
5	5	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
6	6	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
7	7	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
8	8	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
9	9	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5851	0.00
10	10	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5852	0.00
11	11	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5852	0.00
12	12	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5852	0.00
13	13	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5852	0.00
14	14	2.85e+001	0.00e+000	2.85e+001	0.00	1.62e-005	1.62e-005	0.5852	0.00
15	15	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5852	0.00
16	16	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
17	17	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
18	18	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
19	19	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
20	20	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
21	21	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5853	0.00
22	22	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
23	23	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
24	24	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
25	25	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
26	26	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
27	27	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5854	0.00
28	28	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
29	29	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
30	30	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
31	31	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
32	32	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
33	33	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5855	0.00
34	34	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
35	35	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
36	36	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
37	37	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
38	38	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
39	39	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5856	0.00
40	40	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
41	41	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
42	42	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
43	43	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
44	44	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
45	45	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
46	46	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5857	0.00
47	47	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
48	48	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
49	49	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
50	50	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
51	51	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
52	52	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5858	0.00
53	53	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
54	54	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
55	55	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
56	56	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
57	57	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
58	58	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5859	0.00
59	59	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00
60	60	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00

61	61	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00
62	62	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00
63	63	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00
64	64	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.586	0.00
65	65	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
66	66	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
67	67	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
68	68	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
69	69	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
70	70	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5861	0.00
71	71	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
72	72	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
73	73	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
74	74	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
75	75	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
76	76	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5862	0.00
77	77	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
78	78	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
79	79	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
80	80	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
81	81	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
82	82	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5863	0.00
83	83	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
84	84	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
85	85	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
86	86	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
87	87	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
88	88	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
89	89	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5864	0.00
90	90	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
91	91	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
92	92	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
93	93	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
94	94	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
95	95	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5865	0.00
96	96	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5866	0.00
97	97	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5866	0.00
98	98	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5866	0.00
99	99	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5866	0.00
100	100	2.85e+001	0.00e+000	2.85e+001	0.00	1.63e-005	1.63e-005	0.5866	0.00

End of pc-CRACK Output

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557
Voice: 408-978-8200
Fax: 408-978-8964
E-mail: pccrack@structint.com

Linear Elastic Fracture Mechanics

Date: Sat Jun 23 13:35:45 2007
Input Data and Results File: AXIALP4.LFM **[CASE 4]**

Title: McGuire Nuclear Station - Valve 1NV-240 Crack Growth - Axial Flaw

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
pressure	18.17	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case pressure
0.0000	18.17
0.6000	18.17
1.2000	18.17
1.8000	18.17
2.4000	18.17
3.0000	18.17
3.6000	18.17
4.2000	18.17
4.8000	18.17
5.4000	18.17
6.0000	18.17

Crack Model: Through-Wall Axial Crack in Pressurized Cylinder

Crack Parameters:

Wall thickness:	0.4469
Outside diameter(Rm/t>=10):	5.9380
Half crack length(max a<=10(Rmt)^0.5):	6.0000

Co = Hoop stress due to pressure
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case pressure
0.1200	11.5476
0.2400	17.0839
0.3600	22.0549
0.4800	26.9747
0.6000	32.0285
0.7200	37.2965
0.8400	42.8136
0.9600	48.5926
1.0800	54.6345
1.2000	60.9343
1.3200	67.4837
1.4400	74.273
1.5600	81.2917
1.6800	88.5293
1.8000	95.9753
1.9200	103.62
2.0400	111.453
2.1600	119.466
2.2800	127.649
2.4000	135.995
2.5200	144.496
2.6400	153.143
2.7600	161.93
2.8800	170.849
3.0000	179.894
3.1200	189.059
3.2400	198.337
3.3600	207.723
3.4800	217.21
3.6000	226.794
3.7200	236.469
3.8400	246.229
3.9600	256.071
4.0800	265.988
4.2000	275.976
4.3200	286.031
4.4400	296.148
4.5600	306.322
4.6800	316.55
4.8000	326.826
4.9200	337.147
5.0400	347.509
5.1600	357.908
5.2800	368.339
5.4000	378.799
5.5200	389.284
5.6400	399.79
5.7600	410.313
5.8800	420.85
6.0000	431.397

Crack Growth Laws:

Law ID: Cast SS
Type: Fatigue
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 2.5800e-010
n = 3.3000
Kthres = 0.0000

Material Fracture Toughness KIc:

Material ID: Cast SS

Depth	KIc
0.0000	500.0000
0.6000	500.0000

Initial crack size= 0.3900
Max. crack size= 6.0000

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
No. 1	100	1	1	Cast SS	Cast SS

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
No. 1	pressure	1.0000	pressure	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1	1	2.33e+001	0.00e+000	2.33e+001	0.00	8.37e-006	8.37e-006	0.39	0.00
2	2	2.33e+001	0.00e+000	2.33e+001	0.00	8.37e-006	8.37e-006	0.39	0.00
3	3	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.39	0.00

4	4	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.39	0.00
5	5	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.39	0.00
6	6	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
7	7	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
8	8	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
9	9	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
10	10	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
11	11	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
12	12	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
13	13	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
14	14	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
15	15	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
16	16	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
17	17	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3901	0.00
18	18	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
19	19	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
20	20	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
21	21	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
22	22	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
23	23	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
24	24	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
25	25	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
26	26	2.33e+001	0.00e+000	2.33e+001	0.00	8.38e-006	8.38e-006	0.3902	0.00
27	27	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3902	0.00
28	28	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3902	0.00
29	29	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3902	0.00
30	30	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
31	31	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
32	32	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
33	33	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
34	34	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
35	35	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
36	36	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
37	37	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
38	38	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
39	39	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
40	40	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
41	41	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3903	0.00
42	42	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
43	43	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
44	44	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
45	45	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
46	46	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
47	47	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
48	48	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
49	49	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
50	50	2.33e+001	0.00e+000	2.33e+001	0.00	8.39e-006	8.39e-006	0.3904	0.00
51	51	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3904	0.00
52	52	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3904	0.00
53	53	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3904	0.00
54	54	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
55	55	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
56	56	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
57	57	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
58	58	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
59	59	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
60	60	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00

61	61	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
62	62	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
63	63	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
64	64	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
65	65	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3905	0.00
66	66	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
67	67	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
68	68	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
69	69	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
70	70	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
71	71	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
72	72	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
73	73	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
74	74	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
75	75	2.33e+001	0.00e+000	2.33e+001	0.00	8.40e-006	8.40e-006	0.3906	0.00
76	76	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3906	0.00
77	77	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3906	0.00
78	78	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
79	79	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
80	80	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
81	81	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
82	82	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
83	83	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
84	84	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
85	85	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
86	86	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
87	87	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
88	88	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
89	89	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3907	0.00
90	90	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
91	91	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
92	92	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
93	93	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
94	94	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
95	95	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
96	96	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
97	97	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
98	98	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
99	99	2.33e+001	0.00e+000	2.33e+001	0.00	8.41e-006	8.41e-006	0.3908	0.00
100	100	2.33e+001	0.00e+000	2.33e+001	0.00	8.42e-006	8.42e-006	0.3908	0.00

End of pc-CRACK Output

Linear Elastic Fracture Mechanics

Date: Sat Jun 23 13:36:54 2007
Input Data and Results File: AXIALP5.LFM **[CASE 5]**

Title: McGuire Nuclear Station - Valve 1NV-240 Crack Growth - Axial Flaw

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
pressure	19.99	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case pressure
0.0000	19.99
0.6000	19.99
1.2000	19.99
1.8000	19.99
2.4000	19.99
3.0000	19.99
3.6000	19.99
4.2000	19.99
4.8000	19.99
5.4000	19.99
6.0000	19.99

Crack Model: Through-Wall Axial Crack in Pressurized Cylinder

Crack Parameters:
Wall thickness: 0.4063
Outside diameter(Rm/t>=10): 5.9380
Half crack length(max a<=10(Rmt)^0.5): 6.0000
Co = Hoop stress due to pressure
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case pressure
0.1200	12.7274
0.2400	18.8792
0.3600	24.4473
0.4800	29.9949
0.6000	35.7223
0.7200	41.7137
0.8400	48.0036
0.9600	54.6025
1.0800	61.5089
1.2000	68.7147
1.3200	76.2088
1.4400	83.9787
1.5600	92.0116
1.6800	100.294
1.8000	108.815
1.9200	117.561
2.0400	126.521
2.1600	135.684
2.2800	145.039
2.4000	154.578
2.5200	164.289
2.6400	174.166
2.7600	184.198
2.8800	194.378
3.0000	204.698
3.1200	215.15
3.2400	225.727
3.3600	236.423
3.4800	247.23
3.6000	258.142
3.7200	269.153
3.8400	280.257
3.9600	291.447
4.0800	302.718
4.2000	314.065
4.3200	325.482
4.4400	336.962
4.5600	348.502
4.6800	360.096
4.8000	371.74
4.9200	383.427
5.0400	395.153
5.1600	406.914
5.2800	418.704
5.4000	430.519
5.5200	442.354
5.6400	454.205
5.7600	466.067
5.8800	477.936
6.0000	489.807

```
Crack Growth Laws:

Law ID:   Cast SS
  Type:   Fatigue
 Model:   Paris

   da/dN = c * (dK)^n
 where
   dK = Kmax - Kmin
   dK > Kthres
   Kmax < K1c

Material parameters:
       c =  2.5800e-010
       n =     3.3000
  Kthres =     0.0000


Material Fracture Toughness KIc:

Material ID: Cast SS

     Depth          KIc
_______________________
    0.0000    500.0000
    0.6000    500.0000


Initial crack size=     0.0300
Max. crack size=         6.0000

Number of blocks=              1
Print increment of block=      1
```

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
No. 1	100	1	1	Cast SS	Cast SS

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
No. 1	pressure	1.0000	pressure	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1	1	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
2	2	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
3	3	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00

4	4	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
5	5	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
6	6	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
7	7	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
8	8	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
9	9	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
10	10	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
11	11	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
12	12	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
13	13	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
14	14	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
15	15	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
16	16	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
17	17	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
18	18	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
19	19	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
20	20	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
21	21	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
22	22	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
23	23	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
24	24	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
25	25	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
26	26	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
27	27	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
28	28	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
29	29	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
30	30	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
31	31	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
32	32	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
33	33	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
34	34	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
35	35	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
36	36	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
37	37	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
38	38	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
39	39	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
40	40	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
41	41	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
42	42	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
43	43	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03	0.00
44	44	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
45	45	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
46	46	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
47	47	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
48	48	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
49	49	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
50	50	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
51	51	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
52	52	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
53	53	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
54	54	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
55	55	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
56	56	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
57	57	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
58	58	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
59	59	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
60	60	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00

61	61	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
62	62	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
63	63	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
64	64	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
65	65	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
66	66	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
67	67	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
68	68	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
69	69	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
70	70	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
71	71	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
72	72	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
73	73	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
74	74	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
75	75	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
76	76	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
77	77	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
78	78	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
79	79	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
80	80	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
81	81	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
82	82	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
83	83	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
84	84	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
85	85	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
86	86	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
87	87	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
88	88	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
89	89	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
90	90	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
91	91	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
92	92	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
93	93	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
94	94	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
95	95	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
96	96	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
97	97	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
98	98	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
99	99	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00
100	100	6.36e+000	0.00e+000	6.36e+000	0.00	1.16e-007	1.16e-007	0.03001	0.00

End of pc-CRACK Output

APPENDIX C

CITED EMAIL REFERENCE

REFERENCE 4

McGill, Bob

From: Setzer, Fred R [frsetzer@duke-energy.com]
Sent: Thursday, June 21, 2007 12:08 PM
To: McGill, Bob; Davis, J M
Cc: Kirk, Robert W Jr
Subject: RE: P.O Issuance for Structural Integrity-Fracture Mechanics evaluation for 1NV-240

I agree with the information Bob provided.

From: Kirk, Robert W Jr
Sent: Thursday, June 21, 2007 3:04 PM
To: Setzer, Fred R
Subject: FW: P.O Issuance for Structural Integrity-Fracture Mechanics evaluation for 1NV-240

Fred please review the below & send on to Bob McGill & copy JM Davis & Chad, thanks Bob

From: Kirk, Robert W Jr
Sent: Thursday, June 21, 2007 1:42 PM
To: 'McGill, Bob'
Cc: Kidd, Ronald J; Davis, J M
Subject: RE: P.O Issuance for Structural Integrity-Fracture Mechanics evaluation for 1NV-240

Body Material SA351 GR CF8M reference is: MCM 1205.00-1186 001 (Crane-Aloyco, Inc. Gate Valve PS-HW)
Our typical operating pressure is 2500 psig, temperature of 110 deg F is a little on the conservative side, but these #s were base on typical operating parameters, but the design parameters are as follows:
Design Pressure 2735 psig (reference MCFD-1554-03.00, Rev. 9 Flow Diagram of Chemical and Volume Control System)
Design Temperature 189 deg F (reference MCFD-1554-03.00, Rev. 9 Flow Diagram of Chemical and Volume Control System)

McGuire Nuclear Station – Unit 1
Relief Request Number 07-MN-001
Operability Evaluation

ATTACHMENT 8
Metallurgical Report
Nuclear Generation Materials Engineering & Lab Services
"Speculated Failure Mode for MNS 1NV-240"

Duke Energy - Nuclear Generation Materials Engineering & Lab Services

Date: June 24, 2007

Memorandum to: M. K. Pyne, Nuclear Generation, NGO

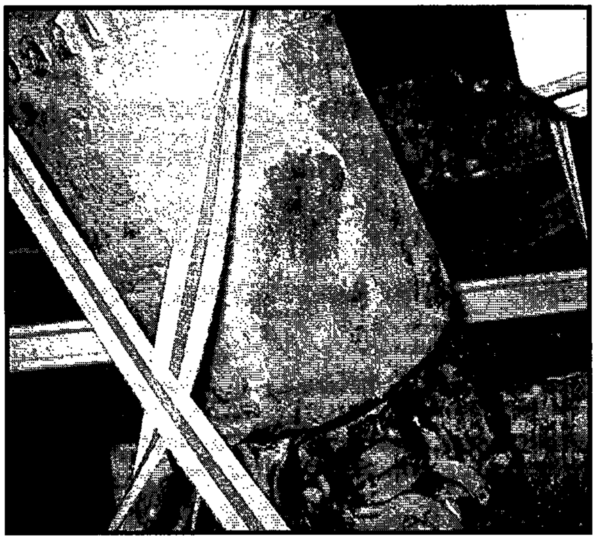
cc: C.T. Alley Jr., Nuclear Generation, NGO

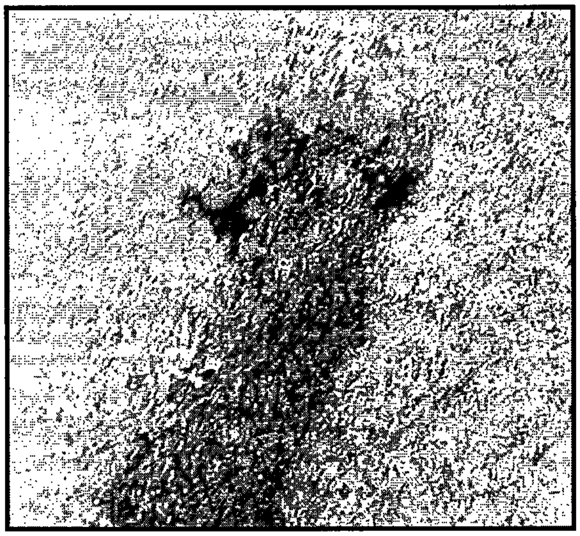
Subject: **Speculated Failure Mode for MNS 1NV-240**

Introduction: MNS 1NV-240 was recently discovered to have a through-body leak in the neck of the valve. The leakage was reported as "minor", with no accumulation of water on the floor beneath the valve. This valve is in the charging flow path and is used for system isolation; the leak itself is difficult or impractical to isolate. This is a 3-inch gate valve manufactured by Walworth in 1976. The valve body material is a cast austenitic stainless steel (SA-358, CF8M).

The valve normally operates with a nominal internal pressure of 2500 psi (borated water). Operating temperature is normally below 120°F as it is downstream of the regenerative heat exchanger. The valve has likely been in service for 30 years or longer (i.e., since plant startup).

Site Inspection Results: Initial inspections performed under W/R 00927504 indicated the leak was possibly emanating from two small pinhole defects (see photo below). The pinholes are in close proximity and appear to be located at small depressions in the rough, casting surface. More careful inspection of the photos suggests that the flaw may actually be associated with a small thumbnail-shaped defect interconnecting the two primary leak sites (see photo below).





Subsequent UT examinations determined that the leak is located in the center of a 2.5 inch diameter circular-shaped weld repair. Per the MCTR, the weld filler material used for the repair was E316-16. This is one of 9 documented weld repair areas performed on the valve body by the original manufacturer.

Comments on Probable Damage Mechanism: The flaw appears to be curved and discontinuous where it is breaking the OD surface of the valve body. This is not consistent with a mechanically driven crack. Therefore the possibility of fatigue cracking seems unlikely.

Despite the presence of a weld repair, which would increase the localized residual stress in this area and possibly cause some sensitization in the weld HAZ, stress corrosion cracking (SCC) also seems improbable due to the low susceptibility of this material in a deoxygenated borated water environment at relatively low temperatures. Additionally, the materials are welded and cast austenitic stainless steel, both of which contain a small percentage of delta-ferrite in their microstructure; this structure is inherently more resistant to SCC than wrought materials.

Based on the shape and surface morphology of the defect, as well as being located in the center of a weld-repaired area, the most likely cause of the leak is a weld flaw, which may possibly have been influenced by the presence of a pre-existing casting flaw. Possible weld and/or casting flaws include shrinkage cracks, hot tearing, porosity, and/or entrapped slag/inclusions – alone or in combination. The weld procedure and filler material used for the valve repair were appropriate. Due to the geometry of the valve body, complexity of the cast microstructure, roughness of the casting surface and other factors, detection of such flaws can be difficult, if not impossible.

Although the repair may have been leak tight following the weld repair, through repeated pressure and temperature cycles over time, and slow removal of any entrapped slag or oxidation products within the defect, a tortuous leak path was eventually created. This type of flaw is consistent with the very low observed leak rate, and would also be unlikely to develop a rapid increase in leak rate.

The rust staining observed on the exterior of the valve body is most likely a result of dissolved iron (e.g., soluble iron hydroxides) contained in the leaking borated water which re-precipitated out upon cooling and drying on the OD valve surface.

Operating Experience Review: An initial review of available operating experience indicates one similar occurrence in a cast austenitic stainless steel weldment. During SG replacement at MNS in 1997, a hot leg elbow casting developed a crack during welding which was attributed to the presence of small micro-fissures in an old repair weld, and to some extent, pre-existing fine porosity in the cast elbow (see PIP M-97-4224).

Also, there have been some cases of system leaks attributed to various types of casting flaws. Point Beach experienced a leak on a cast stainless steel valve body which was attributed to a cold shut in the CF8 casting (see OEDB 99-023175). In 1997, a small leak on the CNS 2A Boric Acid Transfer Pump casing was caused by a casting flaw (see PIP C-97-2991). At ONS, a pin hole or crack on the side of the valve bonnet for SF-14 was attributed to a pre-existing casting defect (see PIP O-00-4299).

Based on personal experience, there have been other cases of leaks in castings and/or welds on the Duke system resulting from the gradual deterioration of preexisting as-manufactured or as-welded flaws.

If the Metallurgy Lab can be of further assistance, please call us at (704) 875-5275.

Prepared by:

Kevin Redmond, P.E., Senior Engineer
Duke Energy
13339 Hagers Ferry Road MG03A6
Huntersville, NC 28078

Reviewed by:

C. T. Alley, Technical System Manager II
Duke Energy