Iowa Electric Light and Power Company

September 18, 1993
NG-93-4013

JOHN F. FRANZ, JR.
VICE PRESIDENT, NUCLEAR

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Mail Station P1-137
Washington, DC 20555

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
"D" Outboard MSIV Relief Request, RR-002, Revision 1

Reference: Letter from J. Franz (Iowa Electric) to T. Murley (NRC) dated September 11, 1993 (NG-93-3831)

File: A-100, A-286

Dear Dr. Murley:

A conference call was held between members of your Staff and Iowa Electric personnel on September 16, 1993 to discuss the repair of unacceptable indications found in the "D" outboard Main Steam Isolation Valve (MSIV) body. As previously presented to your Staff, weld overlays had been applied to two unacceptable surface indications after grinding to a depth of approximately 10% of wall thickness had failed to reduce them to an acceptable size.

After discussions with your Staff and our further evaluation, these weld overlay repairs were removed and an attempt was made to reduce the indications to acceptable sizes by additional grinding. The depth of this grinding was limited to 20% of wall thickness due to GE and ASTM specifications requiring post weld heat treatment for welds exceeding 20% of wall thickness. This additional grinding process removed one indication and the excavated area was then repaired in accordance with the Code. During the attempt to remove the second indication, three more smaller indications were brought to the surface. One of these indications was an acceptable length. A total of three unacceptable surface indications remained (Attachment 1).

Code repair of these three remaining defects would have required the unacceptable indications be ground to an acceptable size before depositing weld metal. Following the repair welding, post weld heat treatment would be required. Our previous experience

A001
1/1

with such repair on an MSIV indicates that the heat treatment results in excessive valve body distortion which causes the valve's leakage performance to degrade. For this reason, a Code repair was found to be undesirable and, as discussed with your Staff, an alternate repair method was evaluated and used (Attachment 2).

Magnetic particle (MT) and radiographic (RT) examinations performed on the repaired areas show acceptable results (Attachment 3). Though the results of the repair are acceptable, the repair method itself was not in strict compliance with the Code. Therefore, relief is required and Iowa Electric herewith submits a revised relief request which supersedes our request of September 11, 1993 (Reference). In support of startup from our current refueling outage, we request that you review and respond to this submittal by September 24, 1993.

Should you have any additional questions or concerns regarding this submittal, please contact this office.

Very truly yours,

David Wilson for

John F. Franz
Vice President, Nuclear

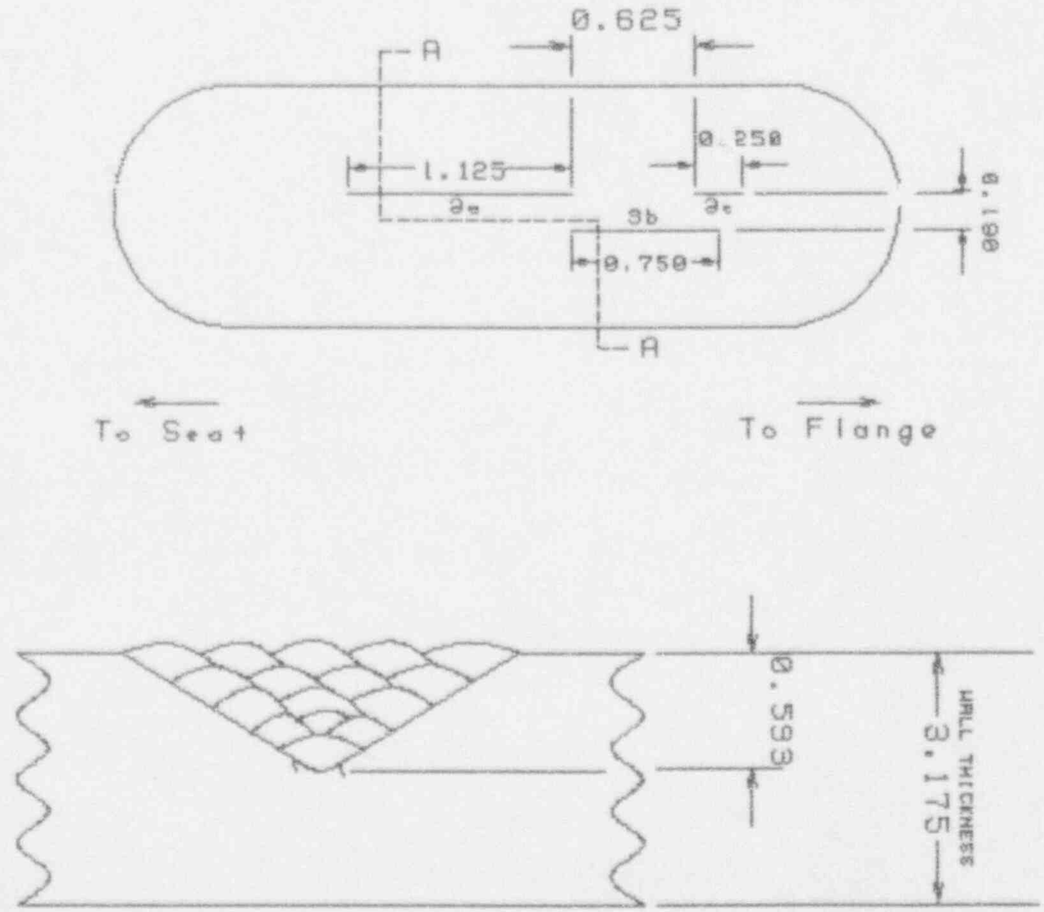
JFF/CJR/pjv

Attachments:
1) Map of Surface Indications of Area #3 and Weld Bead Placement
2) Supporting Information for Relief Request RR-002, Revision 1
3) Internal Memo, M. Huting to M. McDermott, "RT Results of Area 3 Repair to D MSIV"
4) Relief Request RR-002, Revision 1

cc: C. Rushworth
L. Liu
L. Root
R. Pulsifer (NRC-NRR)
J. Martin (Region III)
NRC Resident Office
DCRC

CV4421

MAP OF SURFACE INDICATIONS OF AREA #3 AND WELD BEAD PLACEMENT (AFTER ≈20% EXCAVATION)



SECTION AA

NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE
   DRAWING NOT TO SCALE

SUPPORTING INFORMATION FOR RELIEF REQUEST RR-002, REVISION 1

Background:

As-found local leakage rate testing (LLRT) of the Main Steam Isolation Valves (MSIVs) in Refueling Outage (RFO) 12 indicated that the "D" Outboard MSIV (CV4421) had failed its test, 122.3 standard cubic feet per hour (scfh) versus 11.5 scfh allowable. Based on these test results the valve was disassembled and inspected. The inspections indicated that the valve body bore had a 0.005" taper toward the seat in the cylinder of travel of the valve disk. Based on these inspection results, it was determined that the taper toward the seat was a contributing factor to the LLRT failure of this valve. Consequently, a decision was made to restore the bore to within design specifications and to remove the taper. This required machining the entire valve bore to remove the necessary material. Restoring the valve bore required removal of approximately 0.015" from the diameter of the valve.

The valve machining exposed (brought to the surface) material which had previously been subsurface material. A magnetic particle (MT) examination performed on the machined surfaces identified three indications which were not acceptable per the design specification (Appendix 1). One of the three indications was removed by grinding. The remaining two indications were still an unacceptable length after grinding approximately 10% of the wall thickness, and were repaired with weld overlays.

After further evaluations, and discussions with the NRC, the weld overlays were removed and additional grinding performed. Grinding was performed in area 1 with the result being the removal and subsequent Code repair of the smaller indication. Grinding was completed to a maximum depth of approximately 0.593 inches (approximately 19% of wall thickness) in area 3. Grinding beyond 20% of wall thickness would have required post weld heat treatment (PWHT) per GE and ASTM specifications. This is undesirable due to potential distortion of the valve.

Grinding in area 1 resulted in the removal of the indication. Grinding in area 3 to 0.593 inches resulted in the presence of three more indications. One of the additional indications was of acceptable length; this left three unacceptable indications in area 3. These were repaired with a weld overlay. Since the indications were not reduced to an acceptable length before welding, the repair did not meet Code requirements.

Construction Code Repair Requirements

The specified construction code for the valve body is ANSI B31.1 - 1967 with code cases N-2, N-7, N-9, and N-10. A review of these code cases indicates that N-2 is the only one applicable for this situation.

The GE specification identifies that nondestructive examination will be performed in accordance with ASME Section III, 1968, Winter 1968 addenda.

The valve body material is ASTM A216 Grade WCB. A review of this specification indicates the following information is pertinent to this repair:

a. The cavity shall be visually checked for defect removal. If the defect is a crack, the cavity shall be MT inspected. (paragraph 16(a))
b. Weld repairs shall be inspected to the same quality standards as are used to inspect the casting. (paragraph 16(c))
c. If supplementary S2 is specified, weld repairs shall be inspected by MT examination. (paragraph 16(c))
d. If supplementary S3 is specified, radiography (RT) shall be performed on weld repairs which have leaked on hydrotest or any cavity prepared for repair welding which exceeds 20% of the wall or 1", whichever is smaller. (paragraph 16(c))
e. Cavities prepared for welding greater than 10 sq. inches shall be examined via radiograph (RT). (paragraph 16(c))
f. Any repair weld that exceeds 20% or 1", whichever is smaller or which exceeds 10 sq. in. or which was made to correct hydro defects, shall be stress relieved or heat treated. (paragraph 16(c))

The purchase specification for the MSIV body is GE Specification 21A9230 rev. 2. A review of this specification indicates the following information is pertinent to this repair:

a. Carbon and low alloy steel piping components and equipment pressure parts shall be heat treated in accordance with the requirements of the applicable ASTM materials specifications. (paragraph 4.3.2.1)
b. Surface defects (laps. seams, tears, etc) shall be removed by machining or grinding and blended into the adjacent metal. (paragraph 4.3.3.1)
c. Defects encroaching on minimum wall thickness, shall be repaired by welding. (paragraph 4.2.3.2)

d. Major repairs are defined as (paragraph 4.3.3.4):
   (1) repair which requires excavation of material to a depth of > 20% of wall thickness or 1" whichever is lesser and when the extent of the cavity is greater than 10 sq. in.
   (2) repair of defects which are indicative of fundamental material problems.

e. Inspection of repair welds - repair welds of a depth greater than 10% of the wall thickness shall meet the requirements for the base material. (paragraph 4.3.4)

f. Surface finish shall be suitable for inspection and testing. Surface discontinuities which are markedly different from the overall finish shall be removed or blended into adjacent surfaces. (paragraph 4.3.5)

g. Castings for pressure-containing parts shall be 100 % examined by radiography and all accessible surfaces, including machined surfaces, shall be examined by either liquid penetrant (PT) or magnetic particle methods following heat treatment. Re-examination of repaired areas shall be by the above techniques following heat treatment. (paragraph 6.2.4)

Detailed Description of the Repair

The area 1 repair was in compliance with the Code, since the indication was totally removed by grinding prior to the weld deposit.

The three unacceptable indications in area 3 in the valve body casting were repaired in the following manner:

a. The area around the indications was ground to provide a groove configuration without sharp edges and leaving a blended contour.

b. Weld material was deposited as follows:
   - The weld procedure specification used for the repair was P1-AT-Lh (CVN 1-2), rev. 1, which is qualified for P1 material up to 8 inches thick using the shielded metal arc welding (SMAW) process with 200°F minimum preheat and 500°F maximum interpass temperatures. The procedure is also qualified to meet Charpy V Notch requirements. There are no Charpy V Notch requirements for the base metal.
   - The base metal thickness in the region of the repair is 3.175 inches and weld metal deposited was a maximum 0.593 inches. Post weld heat treatment (PWHT) was exempted per ASME Section III Table NB 4622.3-1, ASTM A216 and GE Specification 21A9230

rev. 2.

- Weld material was deposited using E7018 3/32 inch diameter electrode. The first weld pass over the indication used a slight weave motion. The fluxing action of the E7018 electrode allowed the impurities from the casting to be deposited as slag, which was removed after each pass.
- Each weld pass was inspected visually and by MT.
- The overlay technique was used to fill the excavation in a sequence so that the next weld bead covered the previous weld bead by approximately 50% of its width, thereby providing some stress relieving to the previous bead.
- The weld repair was done with the preheat and interpass temperature monitored and controlled to avoid any repeated heat/cooling cycles. The welder performing the repair was trained for the specifics of this repair. The welder assigned to this job is a qualified weld inspector and visually inspected each weld bead/weld pass.

c. The welded area was ground/machined to achieve a surface equal to or below the existing surface (adjacent to the repair area).

d. An MT examination was performed on the finished surface.

e. The repair areas have been mapped for records.

f. The repair areas were radiographed to verify that no defects exist in the repair weld and that the casting around the repaired area meets the requirements of the original construction code.

Justification for Not Meeting the Construction Code

The area where the indications are located is in the upper bore of the valve. This area provides the guiding surface for the piston during valve stroking and the riding surface for the disk and piston in the open position. The stresses in this area are primarily from system pressure, structural and seismic loading, and any thermal stresses during heatup and cooldown. The wall thickness in the repair area is 3.175". The minimum wall thickness is 1.29" for the repair areas. The actual thickness is significantly more than required to accommodate the stresses on the valve. The casting, due to its PWHT during construction and being in service for over 15 years, does not have any significant residual stresses. The indications that were repaired with welding are passive and fracture mechanics analysis shows that they will not propagate (applied stress intensity less than $K_{IA} / \sqrt{10}$ for normal loads). The maximum thickness of the weld metal deposited in area 3 was 0.593" and did not require PWHT per

the Code. No significant stresses were introduced in the weld metal or base metal.

Major weld repairs requiring stress-relieving may downgrade the metallurgical properties of the casting; thereby decreasing its service life. Excavating the indications further would have required major weld repairs requiring stress-relieving. This could introduce distortion on the machined parts of the valve body. Past experience at DAEC in 1985 with PWHT on an MSIV resulted in significant distortion of the valve body. Subsequent local leakage rate failures of this valve were attributed in part to this distortion. Machining of the valve body was required to correct this condition. Excavating the indications further would require PWHT, which would require remachining, and the process could be repeated. Although the valve body wall thickness is considerably over the design minimum, the guide ribs of the valve could be machined below minimum thickness potentially affecting valve performance (unless repaired).

The identified MT indications have been reviewed against the fabrication radiographs. Areas of casting shrinkage are present on the original radiographs in the location of the MT indications. We have concluded that these indications are areas of subsurface casting shrinkage that were brought to the surface by recent machining operations, rather than service related indications. After the weld repair of the ground cavities around each of these indications, visual and magnetic particle inspections were performed and revealed no reportable indications. In addition, radiography was performed of the repaired area. Radiographs were acceptable per the original construction code and G.E. specification which refers to ASTM E-186, severity level 2. It should be noted that shrinkage indications previously found on construction radiographs and radiographs performed after the 20 % repair, have been greatly reduced in size. The repair welding along with the removal of the additional material appears to have significantly reduced the indications. Radiography shows only very minor indications.

Engineering Evaluation

An Engineering Evaluation has been performed which demonstrates that the subsurface indications are acceptable per ASME Section XI 1980, with 1981 Addenda, Table IWB-3518-1. (Appendix 2)

We have also performed a fracture mechanics calculation which demonstrates that the acceptable flaw depth is large and that the propagation rates of subsurface flaws are very small. (Appendix 3)

Conclusions

The risk of any adverse effects occurring as a result of depositing weld metal on a surface indication of the size reported in this valve body casting is much less than the risk involved in excavating, post weld heat treating, and remachining the casting.

The wall thickness in the repair areas has sufficient thickness and there are no pressure boundary concerns with this repair.

The final condition of the casting is better than the as-found condition based on the removal of the majority of the shrinkage which existed in both repaired areas, as evidenced by post weld MT and RT results.

Appendix 1 Record of Nondestructive Examination

Appendix 2 CAL-M93-024, Determination of Bounding Flaw Depth of Subsurface Defects on CV4421 per ASME Section XI

Appendix 3 CAL-M93-023, Fracture Mechanics Evaluation of Subsurface Defects on CV4421 per ASME Section XI, Appendix A

RECORD OF NONDESTRUCTIVE EXAMINATION
MAGNETIC PARTICLE - (DRY OR WET METHOD) MT-1

MAR NO A17413 MIF STEP Att 12 DCP/PMP NO N/A TRAVELER NO N/A INDEX ITEM N/A

GIR NO. N/A ISI NO N/A QDR NO N/A

COMPONENT OR SYSTEM "D" outboard MSIV DWG. OR ISO NO N/A

THICKNESS N/A PROCEDURE NO. 2162.4 REV 0 PCN A ACCEPT STD 6.10.1

EQUIPMENT NO. ID QDO-15A CAL DUE DATE 9-30-93 (AC) DC

DC CURRENT GUN N/A CAL DUE DATE N/A

YOKE/PROD SPACING 6" - 8" AMP N/A DRY POWDER: RED 88F027 BLACK N/A

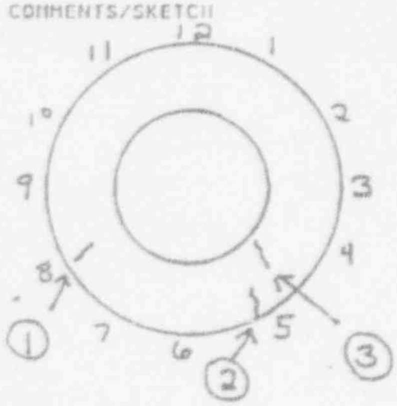
MX-WCP BATCH NO N/A 9 CM RED BATCH NO N/A 7 C-F BLACK BATCH NO N/A

ITEM	INITIAL INSPECTION		DEFECT CODE*	INITIAL INSPECTION REMARKS	REINSPECTION		DEFECT CODE*	REINSPECTION REMARKS
	ACC	REJ		(SIZE/LOCATION)	ACC	REJ		(SIZE/LOCATION
(1)		✓	LI	1/4" @ 8 o'clock 3 1/4" From top Bore				
(2)		✓	LI	2" Intermitten @ 3 1/2" From top Bore				
(3)		✓	LI	1 1/4" @ 3 1/2 From Bottom of				
				Bore				

*DEFECT CODE

P - POROSITY, R - RO[UN]DED, LI - LINEAR INDICATION, LA - LAMINATION, O - OTHER

COMMENTS/SKETCH



Note: Witness Point ANII waived. ANII will Review MT Report. [initials]

EXAMINER: [signature] II 8/29/93
SIGNATURE/LEVEL/DATE

REVIEWED BY: N/A
LEVEL III SIGNATURE/DATE

REVIEWED BY: ______
ANII SIGNATURE/DATE

ENGINEERING CALCULATION COVER SHEET

IOWA ELECTRIC LIGHT & POWER COMPANY

DUANE ARNOLD ENERGY CENTER

Calculation Number: CAL-M93-024

Calculation Title: Determination of Bounding Flaw Depth of Subsurface Defects on CV4421 per ASME Section XI

Project Description: Startup System 83.01
(Include Structure,
System or Component) Component CV4421, APED-B21-F028

Reference Documents: EWR____________ DDC____1988_____ DCP/PMP______________

Other: QDR 93-126, NG-93-4013

Method of Verification: ______ Design Review ______ Alternate Calculation
_xxx__ Engr. Review ______ Qualification Testing

Rev	Prepared/Date	Verified/Date	Reviewed/Date	Approved/Date
3				
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1				
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Engineering Evaluation of Indication #3 per ASME Section XI.

Purpose:

1. Determine the flaw length per IWA-3000.
2. Determine the acceptance standard for the flaw indication for both the preservice and inservice conditions per IWB-3518.

Objective:

The objective of the calculation is to determine the bound flaw depth for a subsurface defect in accordance with ASME Section XI.

Background:

This evaluation is being performed to determine the bounding flaw depth for subsurface indications on the valve body in the upper bore region for the 'D' Outboard MSIV (CV4421). The indications were identified by magnetic particle (MT) examination after excavation. Subsequently, the excavation cavity was weld overlayed. The indications were unacceptable per ASME Section XI and a relief request has been submitted. The map of the preweld cavity is included as Attachment 1.

The applicable code for this calculation is ASME Section XI, 1980, Winter 1981 Addenda.

References:

ASME Section XI, 1980, Winter 1981 Addenda.

Corrective Maintenance Action Request (CMAR) A1/...3, CV4421

Method:

The method will be in accordance with Section XI, Articles IWA-3000 and IWB-3000.

Assumptions

The length of the flaw is assumed to be the length of the flaw as measured during the MT of the indications.

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Rev	Prepared/Date	Verified/Date	Sheet# 1 Continued On 2

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1. Determination of the flaw length per ASME Section XI, Article IWA-3000.

a. Surface versus Subsurface

Per IWA-3330(b) and IWA-3320 the flaw is subsurface if $S \geq 0.4$ a. Where 'S' is the depth below the surface and 'a' is 1/2 the flaw depth.

Since S = 0.593" then a $\leq$ 0.593 / 0.4 = 1.4825" for the indication to be subsurface. This would be a flaw depth of 2.965". The measured valve body wall thickness in the area of the indications is 3.175".[2] Hence the indication would have to be through wall for the flaw to be a surface flaw. 2.965 + 0.593 $\geq$ 3.175"

b. Determination of flaw length.

The indications are characterized as two planar indications and a third indication that is on a plane parallel to those two.

The two planar indications are identified as 3a and 3c of Attachment 1. The parallel planar indication is identified as 3b.

The two planar indications are compared against IWA-3330(a) and Figure IWA-3330-1 for multiple planar flaws. Using subsurface flaw #2 of the Figure, the indications may be treated separately if the greater of the two flaw depths is less than the spacing. The spacing is 5/8 " per attachment 1. As the depth is unknown, indications 3a and 3c will be considered as a single 2" flaw.

The parallel planar indication (3b) is compared against flaw 3a-3c per IWA-3350(a) and Figure IWA-3350-1 for parallel planar flaws. Using subsurface flaws #1 and #2 of the Figure, the indications may be treated separately if the perpendicular distance between the planes is greater than 1/2 ". The measured value is 3/16", hence the indications will be treated as a single flaw (3a-3b-3c). As indication 3b overlaps both 3a and 3c, the concern with the depth of flaws 3a and 3c is unnecessary as the flaws must be considered as a single flaw.

The flaw length is 2".

2. Determine the acceptance standard for the flaw indication for both the preservice and inservice conditions per IWB-3518.

Paragraph IWB-3518 is used for this evaluation as this provides standards for pressure retaining welds in valve bodies. Paragraph IWB-3518(b) is applied as the indications extend beyond the boundary of the examination volume (weld deposit). The standards or IWB-3518(a) are then used, specifically Table IWB-3518-1. The portion of the table applicable is the is the volumetric examination by ultrasonics (UT) as it provides for quantification based on flaw depth, flaw length and wall thickness.

The input values for this table are:

wall thickness	t = 3.175 "
flaw length	l = 2 "
depth below the surface	S = 0.593
depth of indication (2a)	2a = unknown
minor half-diameter of flaw (a)	a = unknown

Calculate the bounding 'a' for the maximum aspect ratio.

a/l = 0.5 , then a = 1", and a/t = 31.5 %, which is well above the allowable ratio for either preservice or inservice conditions.

Determine the aspect ratio when Y = 1.

Y = S / a , per note (4) of the table.
When a = 0.593, a/l = 0.2965, and a/t = 18.7 %, again this is above the allowable ratio for either preservice or inservice conditions.
Hence a < S, and Y = 1 for the allowable indication standard.

The following methodology is used to determine the bounding aspect ratio for both the preservice and inservice conditions.

1. Assume an aspect ratio.
2. Determine the a/t ratio from the table.
3. Knowing 't', calculate the minor half diameter 'a'.
4. Using the aspect ratio and knowing 'l', calculate the half depth 'a'.
5. Iterate until the 'a' from steps 3 and 4 are equal.
6. Determine the bounding flaw depth, 2a.

For the preservice conditions:

1. Let a/l = 0.056
2. a/t = 3.52 %
3. a = 0.0352 x t = 0.112 "
4. a = 0.056 x l = 0.112 "
5. 2a = 0.224"

For the inservice conditions:

1. Let a/l = 0.086
2. a/t = 5.42 %
3. a = 0.0542 x t = 0.172"
4. a = 0.086 x l = 0.172"
5. 2a = 0.344"

Conclusions

1. Flaw is subsurface for analysis.
2. Flaw length is 2 ".
3. Bounding aspect ratios and flaw depths:
   a. Preservice: a/l = 0.056, a = 0.112 ", flaw depth (2a) = 0.224 "
   b. Inservice: a/l = 0.086, a = 0.172 ", flaw depth (2a) = 0.344 "

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Attachment 1

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Attachment # 1 Total Sheets 1

Description MAP OF INDICATIONS

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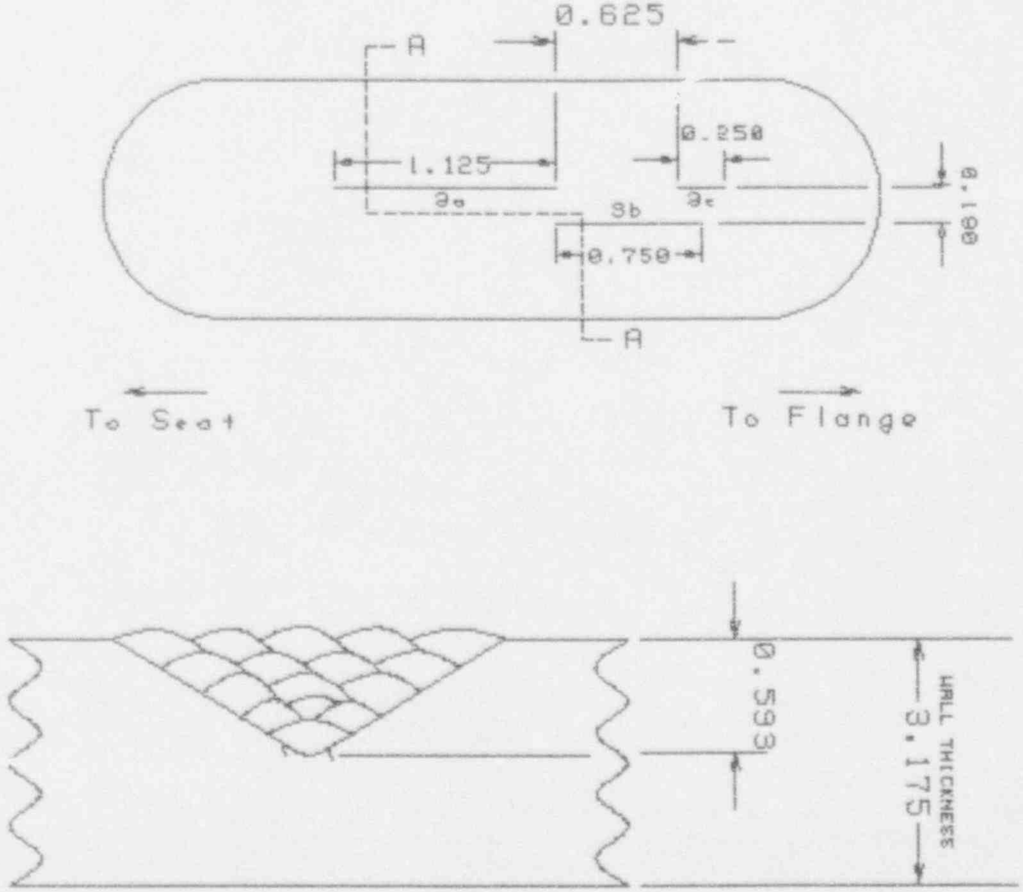
CV4421

MAP OF SURFACE INDICATIONS OF AREA #3 AND WELD BEAD PLACEMENT (AFTER ≈20% EXCAVATION)



SECTION AA

NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE
   DRAWING NOT TO SCALE

Attachment 2

Doc # CAL-M93-Ø24 Rev # Ø
Attachment # 2 Total Sheets 3
Description ASME SECTION XI EXTRACT

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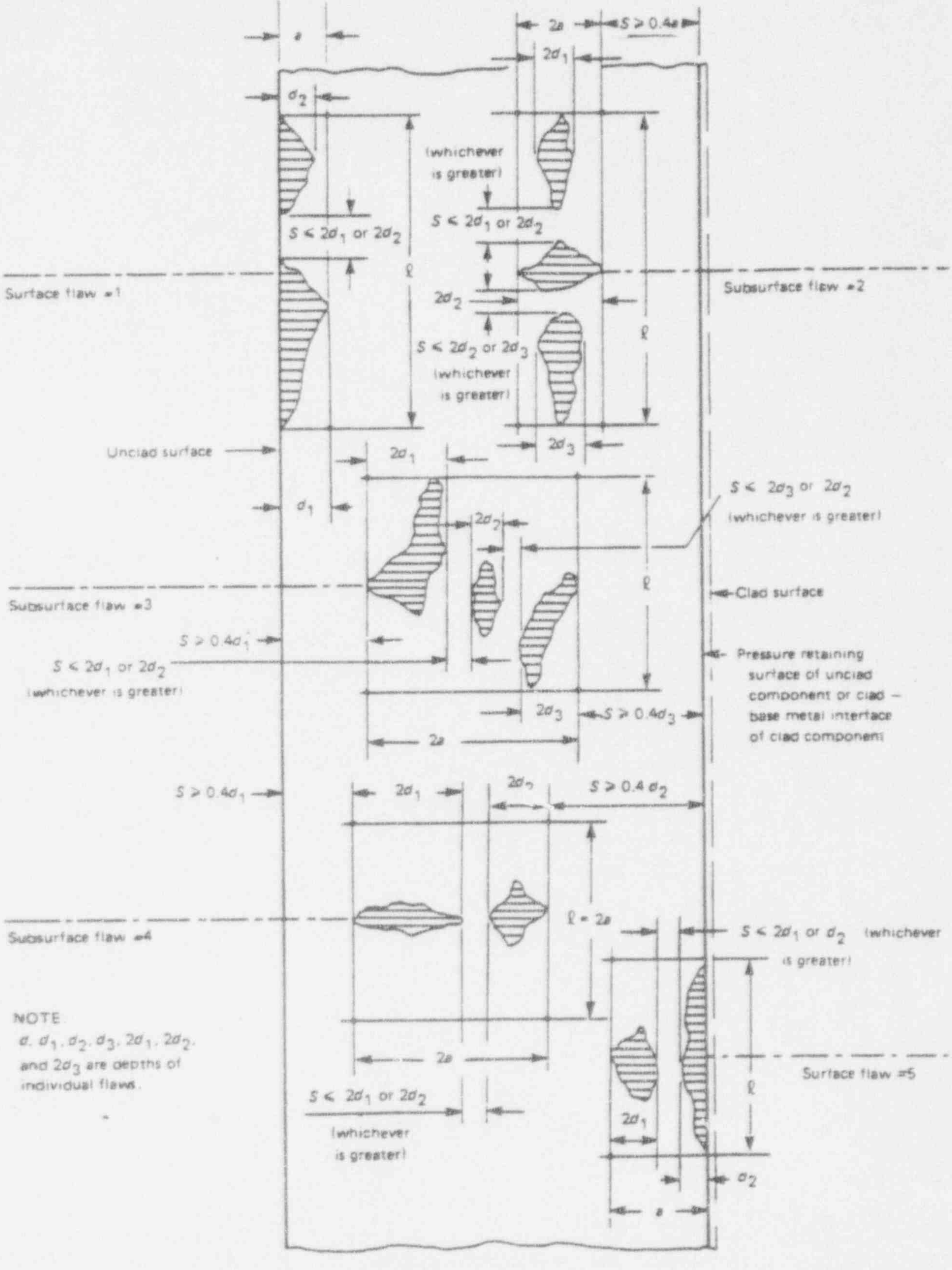
Ø	[signature] 9/18/93	[signature] 9/18/93



W81

FIG. IWA-3330-1 MULTIPLE PLANAR FLAWS ORIENTED IN PLANE NORMAL TO PRESSURE RETAINING SURFACE
Illustrative Flaw Configurations and Determination of Dimensions a, $2a$, and ℓ

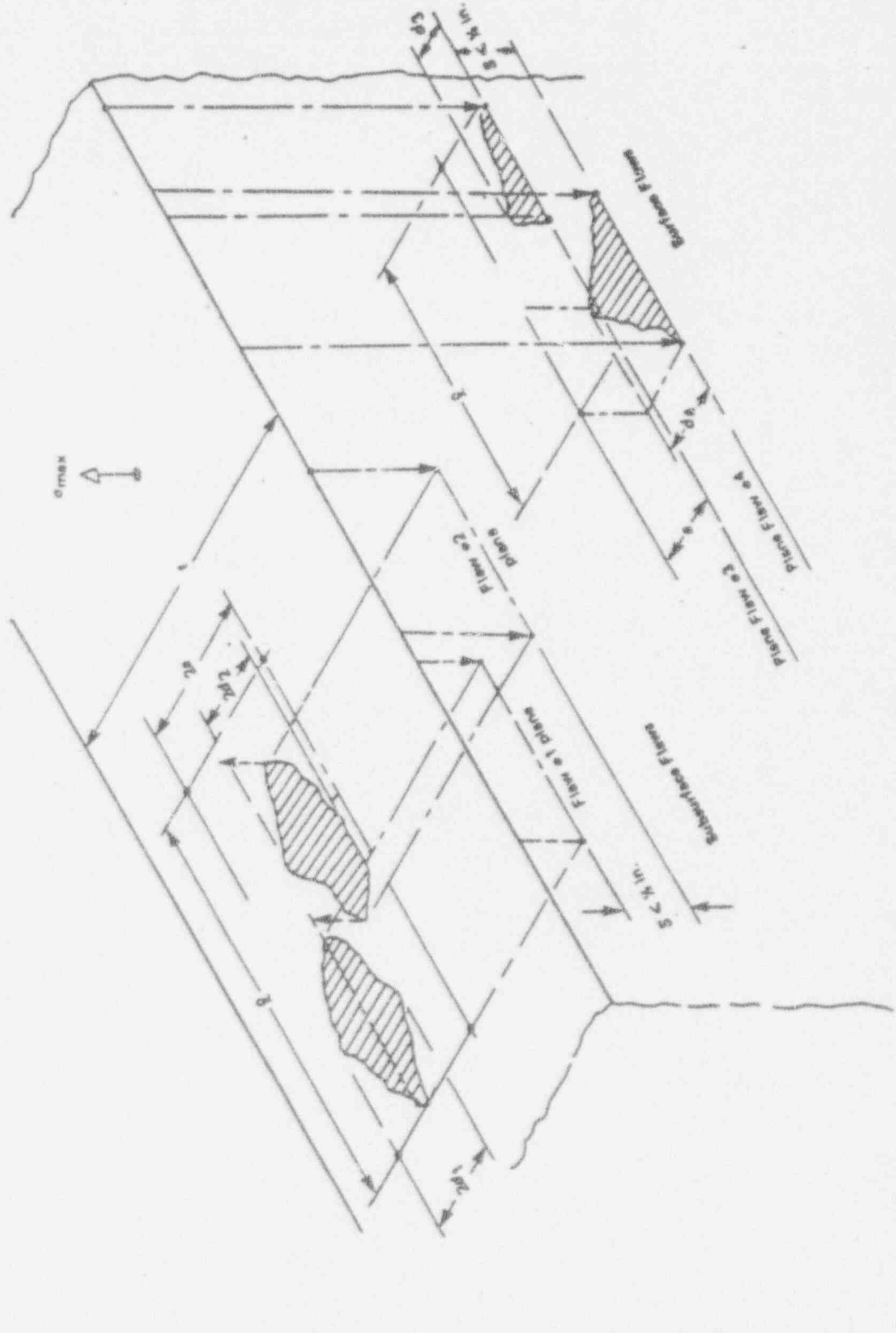


FIG. IWA-3350-1 PARALLEL PLANAR FLAWS
Illustrative Flaw Configurations and Determination of Dimensions a, $2a$, and ℓ

TABLE IWB-3518-1
ALLOWABLE PLANAR INDICATIONS
Material: Ferritic steels that meet the requirements of NB-2300 and the specified minimum yield strength of 50 ksi or less at 100°F
Thickness Range: 2 in. or greater

	Volumetric (UT)			Volumetric (RT) and Surface Method	Volumetric (RT)
Aspect Ratio,[1] a/ℓ	Surface Indication,[2] a/t, %	Subsurface Indication,[2–4] a/t, %	Nominal Wall Thickness,[1] t, in.	Surface Indication, Length, ℓ, in.	Subsurface Indication, Length, ℓ, in.
Preservice Examination			Preservice Examination		
0.00	2.6	3.3Y	2.0	1/4	3/4
0.05	2.8	3.5Y			
0.10	3.1	3.7Y	3.0	1/4	3/4
0.15	3.5	4.1Y			
0.20	3.9	4.7Y	4.0	1/4	3/4
0.25	4.4	5.3Y			
0.30	5.0	5.9Y	5.0	1/4	3/4
0.35	5.0	6.7Y			
0.40	5.0	7.5Y	6.0 and over	1/4	3/4
0.45	5.0	8.4Y			
0.50	5.0	9.3Y			
Inservice Examination			Inservice Examination		
0.00	3.9	4.9Y	2.0	0.3	0.8
0.05	4.2	5.2Y			
0.10	4.6	5.5Y	3.0	0.45	0.9
0.15	5.2	6.3Y			
0.20	5.8	7.0Y	4.0	0.6	1.2
0.25	6.6	7.9Y			
0.30	7.5	8.8Y	5.0	0.75	1.5
0.35	7.5	10.0Y			
0.40	7.5	11.2Y	6.0 and over	0.9	1.8
0.45	7.5	12.6Y			
0.50	7.5	14.1Y			

W80

NOTES:
(1) For intermediate flaw aspect ratios a/ℓ and thickness t, linear interpolation is permissible. Refer to IWA-3200(b) and (c).
(2) Component thickness t is measured normal to the pressure retaining surface of the component. Where section thickness varies, the average thickness over the length of the indication is the component thickness.
(3) The total depth of a subsurface indication is $2a$.
(4) $Y = (S/t)/(a/t) = S/a$. If $Y < 0.4$, the flaw indication is classified as a surface indication. If $Y > 1.0$, use $Y = 1.0$.

are allowable provided the requirements of IWA-3390 are met.

IWB-3523.2 Allowable Indication Standards for Surface Examination

(a) The size of allowable indications shall not exceed 3/16 in. (4.8 mm) for the preservice examination, and 1/4 in. (6.4 mm) for the inservice examination.

(b) Where an indication on the outer surface of the housing exceeds the allowable standards, the indication may be examined using the volumetric method, and the acceptance standards of IWB-3523.3 shall apply.

IWB-3523.3 Allowable Indication Standards for Volumetric Examination

(a) The depth of an allowable preservice indication shall not exceed 10% of weld thickness; the length shall not exceed 60% of weld thickness.

(b) The depth of an allowable inservice indication shall not exceed 12.5% of weld thickness; the length shall not exceed 75% of weld thickness.

IWB-3523.4 Ultrasonic Reflectors of Geometric and Metallurgical Origin

(a) Ultrasonic indications that can be identified as reflectors due to surface configuration (such as weld

ENGINEERING CALCULATION COVER SHEET

IOWA ELECTRIC LIGHT & POWER COMPANY

DUANE ARNOLD ENERGY CENTER

Calculation Number: CAL-M93-023

Calculation Title: Fracture Mechanics Evaluation of Subsurface Defects on CV4421 per ASME Section XI, Appendix A

Project Description: Startup System 83.01
(Include Structure,
System or Component) Component CV4421, APED-B21-F028

Reference Documents: EWR______ DDC 1988 DCP/PMP______

Other: QDR 93-126, NG-93-4013

Method of Verification: ______ Design Review ______ Alternate Calculation
_xxx__ Engr. Review ______ Qualification Testing

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1. SCOPE OF ANALYSIS

Indications have been found by magnetic particle (MT) inspection in the body of the 'D' Outboard main steam isolation valves (MSIV) at the Duane Arnold Energy Center. An analysis has been performed, using the methods described in Section XI, ASME Code, to verify that the indications will not propagate into the valve bodies to a depth that could result in brittle fracture of the valves. A bounding analysis was done for the valve body upper bore.

This report describes the results of the analysis. Details of the analysis and calculations are shown in Attachment 1.

2. BACKGROUND

As the depth of the specific flaws are not known, assumptions have to be made concerning the current flaw size to be used in the evaluation. Furthermore, the valve material is Cast Carbon Steel (ASTM A216 Grade WCB) for which there is no established toughness curve prescribed in the ASME Code. Finally, there is no plant specific stress analysis for the valve body and stress information can only be implied from stress reports from other plants with similar valves. The process used in determining the initial flaw size, fracture toughness and stresses is described below.

2.1 Initial Flaw Size.

The specific depths of the indications in the 'D' Outboard MSIV are not known and the evaluation has to be based on reasonable assumptions. The flaw length has been determined based on the magnetic particle (MT) inspection results and the proximity rules from Article IWA-3000. The indications have been weld overlayed to a depth of 0.593 inches. Magnetic particle inspections performed during the weld process and radiography (RT) performed post-weld have verified that flaws do not exist in the weld overlay. The initial flaws are subsurface with a depth below the surface of 0.593 inches. The MT map of the indications in the preweld condition is provided as Attachment 2.

In the analysis performed here, a conservative approach that is based on the length of the flaw is assumed. A crack aspect ratio of 1/6 is assumed (commonly used in most crack growth analyses) and the crack depth determined. The resultant flaw size is compared against the acceptance standards of ASME Section XI paragraph IWB-3612 and the assumed aspect ratio is adjusted until a bounding initial flaw size is determined.

2.2 Fracture Toughness

The material of the valve body is ASTM A216 (SA216) Cast Carbon Steel. Toughness properties of this material are comparable to that for SA106 GrB carbon steel piping. Although no plant specific information for the DAEC MSIV material is available, there is Charpy data for similar valve material in more recent plants. Table 1 shows a collection of Charpy energy data for several plants and several valve vendors. It is seen that an average value of 30 ft-lb at 60°F is reasonable. Since the temperature corresponding to 30 ft-lb is often used for RT_{NDT} shift calculations, it is reasonable to assume 60°F as an upper bound RT_{NDT} value. This compares with the requirement of 30 ft-lb at 40°F for the DAEC vessel plate material. By using the higher RT_{NDT} of 60°F (corresponding to the 30 ft-lb temperature for A216) the use of the low alloy steel fracture toughness curve is validated. This approximation can be verified by comparing the Section XI, ASME Code K_{Ia} value with that predicted using the commonly available K_{IC}-CVN correlations in the transition range. Figure 1 shows the Rolfe-Corten relationship in the transition temperature regime. The fracture toughness is given by $K_{IC}^2/E = 5$ (CVN) where K_{IC} is in psi-$\sqrt{in}$, CVN is the Charpy energy in ft-lb and E is the Youngs Modulus in psi. Substituting CVN = 30 ft-lb and E = 30×10^6 psi, the calculated K_{IC} value is 67 ksi-$\sqrt{in}$. Figure 2 shows the fracture toughness curves in Section XI, ASME Code for low alloy steel. Assuming an RT_{NDT} value of 60°F is approximately 54 ksi-$\sqrt{in}$. Clearly, using the code K_{Ia} value for low alloy steel and assuming an RT_{NDT} of 60°F provides a conservative fracture prediction.

Finally, the analytical procedures of Section XI, ASME Code are applicable for sections exceeding 4 in. thickness. This assumes plane strain conditions in most cases. The MSIV components are below this thickness. This means that the fracture conditions may be closer to plane stress than plane strain. Since the material fracture toughness is higher for plane stress conditions, the present analysis based on K_{IC} is conservative.

3. CONSERVATIVE NATURE OF ANALYSIS

Conservative methods and assumptions were used in the analysis. This was especially true in the case of initial flaw size. Methods and assumptions are presented below for subsurface flaws in the valve body.

1. The initial subsurface flaw was assumed to be as long as the preweld surface flaw using the proximity rules of IWA-3000. The initial flaw depth was assumed to be 2/3 of an inch which corresponds to an aspect ratio of 1/6.

2. Fatigue loadings representative of the worst location in the valve, the crotch region, were applied.

3. All stresses were treated as membrane stresses in predicting crack growth.

4. The crack growth rate for subsurface flaws from Figure A-4300-1 of Reference 2 was used.

5. The flat plate flaw model, which is more conservative than either a circumferential or axial flaw, from Reference 2 Appendix A was used.

4. TECHNICAL APPROACH

4.1 Methods

The approach used was to evaluate crack growth under typical mechanical and thermal loadings anticipated for a 40 year life. The DAEC MSIV design report [1] does not include fatigue evaluation, so DAEC-specific cyclic loadings were not available. For the body valve analysis, thermal cyclic stresses from more recent MSIV analyses were scaled to magnitudes representative of the DAEC valves.

These normal duty and transient stresses were used with an assumed final flaw depth to calculate ΔK values, and the appropriate transient cycle numbers, were used with Figure A-4300-1 of [2] to predict da/dN crack growth per cycle, and crack growth Δa. The final flaw size, including fatigue crack growth, was compared to the allowable flaw size using the criteria in IWB-3612 of Reference 2. Limiting conditions for normal operation, faulted events and test conditions were evaluated. The reduction in cross section due to the final flaw size was evaluated to assure that local primary stresses would be acceptable. Final flaw depth was evaluated to verify the flaw remained subsurface.

4.2 Allowables

The limiting MSIV condition for normal operation occurs during the system leak test, where temperature as low as 180°F may occur with normal operating pressure. Assuming a conservative RT_{NDT} of 60°F for the MSIV body and internals materials, Figure A-4200-1 shows allowable toughness K_{IA} of 100 ksi-$\sqrt{in}$. Temperatures at which the MSIVs experience the faulted condition loadings are high enough that the valve carbon steel materials are in the ductile condition, or $K_{IA}=K_{IC}=200$ ksi-$\sqrt{in}$. For the room temperature test condition, the K_{IA} on Figure A-4200-1 of Reference 2 is 38 ksi-$\sqrt{in}$. IWB-3612 requires that the K_I associated with the final flaw depth must be less than $K_{IA}/\sqrt{10}$

for normal and test conditions and less than $K_{1C}/\sqrt{2}$ for faulted conditions. Calculations of local primary stresses were also made to assure that they are within Section III allowables. This assures ductile fracture margins.

5. RESULTS

The results of the analyses of the MSIV valve body are shown in Table 2. The final flaw depths, including fatigue crack growth, for each aspect ratio are shown in the table. These final flaw sizes were used to calculate the ΔK values, also in the table, for comparison to the allowable stress intensity factors described above. The results of the comparison are acceptable, as are calculations of local primary stress against the allowables of 1.1 S_m.

6. CONCLUSION

The indications identified in the MSIV body are bounded by the assumed initial flaw sizes in this analysis, and those assumed flaw sizes were evaluated using a series of conservative assumptions and were determined to be acceptable for 40 years of operation per the requirements of IWB-3600. Removal of the indications is not necessary. A bounding aspect ratio of 1/2 has been determined with a bounding flaw depth of 2".

7. REFERENCES

1. "Calculation for Rockwell-Edward 20x16x20 Valve," Rockwell Report 2791-02-01, Revision 3, January 1971.

2. 1980 ASME Code, Winter 1981 Addenda, Section SI, IWB-3600 and Non-Mandatory Appendix A.

3. "Fracture Mechanics Evaluation of the Duane Arnold MSIV Indications", GE Report DRF #137-0010, December 1988.

4. "Design Report for a size 20x16x20 Fig. 1612 JMMNY Flite Flow Main Steam Isolation Valve Iowa Electric Light and Power Co. Duane Arnold Energy Center", Edward Valves, Inc., Report RAL-2147 rev 3, February 1990.

5. "Mechanical Engineering Design", 2nd Edition, Joseph E. Shigley, 1972, pages 73-76.

6. "The Stress Analysis of Cracks Handbook", Hiroshi Tada, Del Research Corporation, February 1978, page 11-2.

Table 1

CHARPY IMPACT TOUGHNESS PROPERTIES OF
MSIV CASTING MATERIAL IN SEVERAL BWR/6 PLANTS - [3]

	Plant A	Plant B	Plant C	Plant D	Plant E
Material Specification	SA216 GrWCB	SA216 GrWCB	SA216 GrWCB	SA216 GrWCC	SA216 GrWCB
Test Temperature °F	60	60	60	40	60
Charpy Impact* Toughness ft/lb	31,31,34	66,56,54	30,24,34	29,33,35	32,38,40
Mils Lateral* Expansion Mils	33,32,31	53,50,53	37,27,33	25,25,33	33,41,40
Percent Shear*	40,40,40	40,40,40	40,40,40	15,15,15	10,10,10

*Results of three test samples.

Table 2

RESULTS OF FATIGUE CRACK GROWTH ANALYSES OF
'D' OUTBOARD MSIV BODY

Aspect ratio/Case	Final Flaw, a_f (inch)	Maximum K_I (ksi$\sqrt{in}$)	Allowable K_I (ksi$\sqrt{in}$)	Local σ_m (ksi)	Allowable Local σ_m (ksi)
Aspect Ratio = 1/2					
Normal	1.005	4.82	31.6	11.74	20.2
Faulted	1.005	63.26	141.4		
Test	1.005	0.35	12.02		

Where,
Normal $K_I = C \times (3.031) \times \sqrt{a_f}$
Test $K_I = C \times (0.221) \times \sqrt{a_f}$
Local $\sigma_m = 1250 \times (10.94) / (t - (2 \times a_f))$

The basic equation used is,

$$K_I = \Delta\sigma M_m \sqrt{\frac{\pi a}{Q}} \quad \text{and} \quad C = M_m \sqrt{\frac{\pi}{Q}}$$

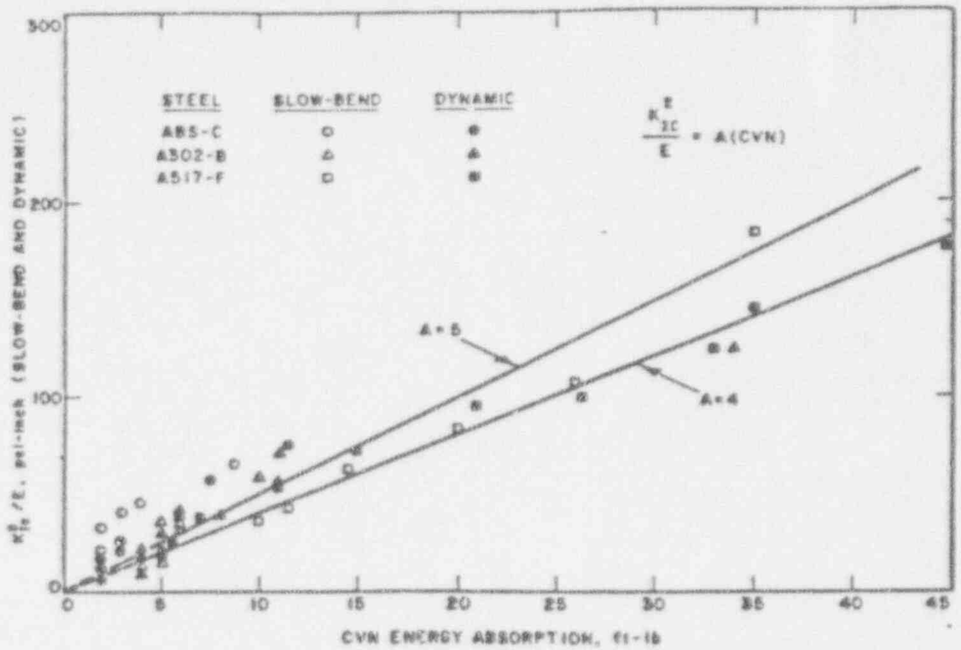

Figure 1 K_{IC}-CVN CORRELATION IN THE TRANSITION TEMPERATURE REGION

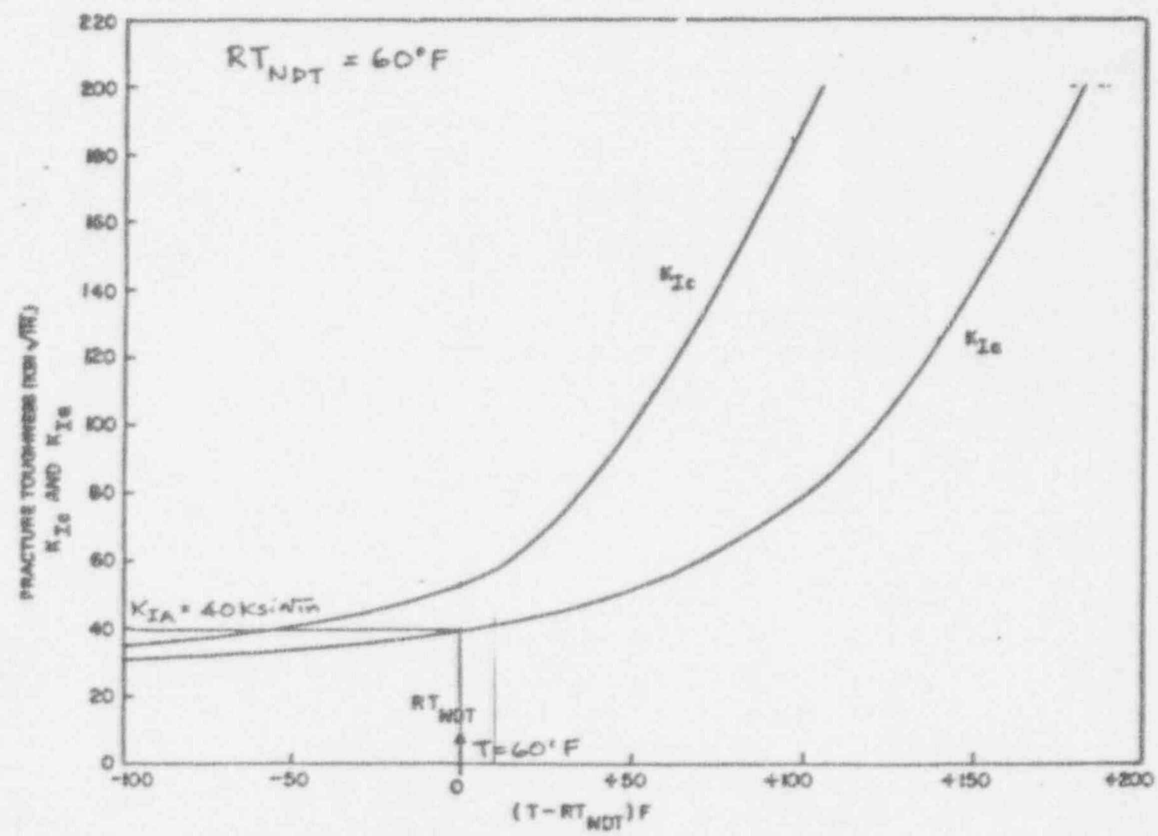

Figure 2 FRACTURE TOUGHNESS OF LOW ALLOY STEEL AS A FUNCTION OF $T-RT_{NDT}$ (FROM REFERENCE 2)

ATTACHMENT 1

Doc # CAL-M93-Ø23 Rev # Ø

Attachment # 1 Total Sheets 11

Description ANALYSIS & CALCULATION

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Duane Arnold MSIV Indications
MSIV Body Bore

MT inspection of the MSIV body bore h shown indications up to 2" long oriented axial, as shown in Attachment 2.

In order to bound the indications, a flaw size is assumed using an aspect ratio of 1/6.

Appendix A of Section XI provides methods to analyze the assumed flaw for growth during service. The calculated final flaw size is compared to allowables in IWB-3600.

STEP 1: Loading

For comparison to IWB-3600 allowables, the hydrotest case will be used to bound normal conditions (P = 1000 psi, T = 180°F). Faulted conditions will be taken as the worst transient stress.

The design report [1] for the DAEC MSIV did not include analysis of valve body fatigue. Therefore, fatigue stresses from more recent BWR/6 analyses are scaled for use with the DAEC sized valve.

The scaling is based on valve wall thickness:

Nominal Valve Size	Nom Wall Thickness	Stress for ΔT = 265°F
28" [3]	1.9375"	106,878 psi
24" [3]	1.875"	114,665 psi
20" (DAEC)	1.781" [2]	?

The stress ratio for $\frac{24"}{28"}$ valve is

$$\frac{114,665}{106,878} = 1.073$$

$$The\ ratio\ \frac{t_{28}}{t_{24}} = \frac{1.9375}{1.875} = 1.033$$

$$\left(\frac{t_{28}}{t_{24}}\right)^2 = 1.068 \quad , \quad \left(\frac{t_{28}}{t_{24}}\right)^3 = 1.103$$

The $(1/t)^2$ relationship is assumed. This still provides conservative results because the BWR/6 stresses are from the worst location in the valve. The scaling factor for

$$\frac{DAEC}{28''BWR/6} = \left(\frac{1.9375}{1.781}\right)^2 = 1.183$$

ΔT	n	$\Delta\sigma_{28}$ (psi) [3]	$\Delta\sigma_{DAEC}$ (psi)
265°F	8	106,878	126,486
176°F	2	87,031	102,998
138°F	18	78,557	92,969
100°F	91	70,083	82,940
96°F	10	69,191	81,885

The actual wall thickness in the area of the flaw has been measured at 3.175". The scaling factor for this wall thickness has been similarly determined.

$$\frac{DAEC_{ACTUAL}}{28''BWR/6} = \left(\frac{1.9375}{3.175}\right)^2 = 0.372$$

ΔT	n	$\Delta\sigma_{28}$ (psi) [3]	$\Delta\sigma_{DAEC}$ (psi)
265°F	8	106,878	39,759
176°F	2	87,031	32,376
138°F	18	78,557	29,223
100°F	91	70,083	26,071
96°F	10	69,191	25,739

In addition to thermal loads, valve closure loading for 2000 cycles is considered. The valve disk is seated with 100 psi on a 314 in^2 cylinder, plus 9752 lb spring force [4] pg 12.

$$F_C = 314(100) + 9752 = 41152 \text{ lb}$$

The bore has an inside diameter of 15.530 in, which is used. The closure load results in an axial load in the valve body. The closure stress in the valve body is

$$\sigma_c = \frac{F_c}{[\pi[\left(\frac{15.530}{2}+3.175\right)^2 - \left(\frac{15.530}{2}\right)^2]]}$$

$$\sigma_c = 221 \text{ psi}$$

This is combined with the pressure stress due to 1000 psig.

$$\text{Since} \quad \frac{t}{2R} = \frac{3.175}{15.530} = .204,$$

the upper bore will be treated as a thick-walled cylinder.

$$\text{Then} \quad \sigma_P = \frac{a^2 P}{b^2 - a^2}\left(1 + \frac{b^2}{r^2}\right)$$

where, a is the inner radius
b is the outer radius
and r is the radius at which the stress is determined

The highest stress is when r = a, and this will be used (conservative),

$$\text{and} \quad \sigma_P = \frac{a^2 P}{b^2 - a^2}\left(1 + \frac{b^2}{a^2}\right)$$

$$\text{since} \quad a = \frac{15.530}{2} = 7.765 \quad \text{and} \quad b = \frac{15.530}{2} + 3.175 = 10.94$$

then $\sigma_P = 3031$ psi

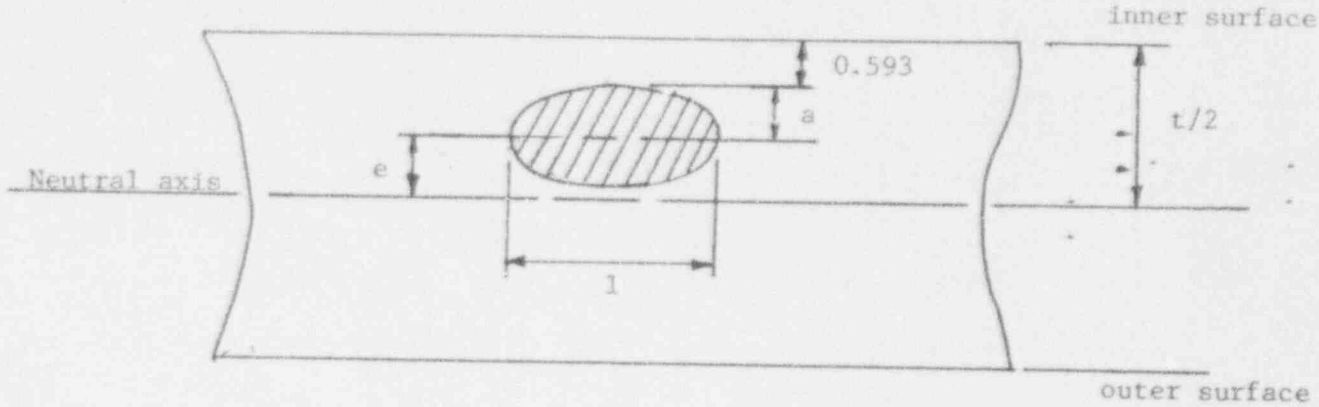
$\sigma_{CLOSURE} = \sigma_C + \sigma_P = 3252$ psi

Appendix A of Section XI [2] provides methods for predicting final flaw depth, a_f, from cyclic fatigue crack growth from the initial value a_i.

Given $t = 3.175$in. and $\ell = 2$in.

Assume $a/\ell = 1/6 = 0.167$

Then $a_i = 0.333$ inches



STEP 2: Stress Intensity Factor ΔK

The thermal and closure loads are conservatively treated as membrane stresses. The centerline of the subsurface flaw is on the inside of the neutral axis, consequently, bending stresses would be negative.

$$\Delta K = \Delta \sigma \; M_m \sqrt{\frac{\pi a}{Q}}$$

$$For \quad \frac{a}{l} = .167 \quad , \quad \frac{\sigma_m}{\sigma_y} = 1 \quad (worst\ case)$$

then Q = 1.05 per Fig A-3300-1 of [2]

$$For \quad \frac{2a}{t} = \frac{.667}{3.175} = .21 \quad and \quad e = \frac{t}{2} - (.593 + a) = .6615$$

$$and \quad \frac{2e}{t} = .417$$

Then M_m = 1.06 for Point 1 per Fig A-3300-2

and M_m = 1.05 for Point 2 per Fig A-3300-2

Therefore, by using the greater M_m;

$$\Delta K = \Delta \sigma (1.06) \sqrt{\frac{\pi a}{1.05}}$$

$$\Delta K = 1.834\ \Delta\sigma \sqrt{a}$$

The constant term (1.834) has been compared to the constant term determined by alternate calculations [6] with good correlation.

STEP 3: Crack Growth Δa:

Fig A-4300-1 of [2] shows crack growth rates da/dN vs. ΔK for various conditions. The curve subsurface flaws in an air environment is used. As the flaw is subsurface it does not communicate with a steam or water environment and this relationship is appropriate.

$$then\ \frac{da}{dN} = (2.67\ x\ 10^{-11})\,\Delta K^{3.726}$$

Since ΔK depends on a, which depends on da/dN, an iterative process was used. The results are in Table 2.1. This process differs from the method described in Paragraph A-5200 in Appendix A [2] as the final flaw size is applied to all design transients in lieu of the chronological application of transients described, however, the process used results in a conservative final flaw size and is therefore acceptable.

STEP 4: Allowable Stress Intensity Factor K_{Ia}

Fig. A-4200-1 in [2] shows crack arrest stress intensity factor K_{Ia} versus temperature relative to RT_{NDT} ($T-RT_{NDT}$). These conditions are needed:

Normal T = 180°F (pressure test)

Faulted T = 552 - 265 = 287°F (worst case ΔT stress)

Test T = room temp. ≈ 70°F (closure load only)

Testing of MSIV body material SA-216 GrWCB has shown that RT_{NDT} = 60°F is conservative. Therefore, the following K_{Ia} values are obtained from Fig. A-4200-1

Normal $(T - RT_{NDT}) = 120$ $K_{1a} = 100$ ksi $\sqrt{in}$

Faulted $(T - RT_{NDT}) = 227$ $K_{1c} = K_{1a} = 200$ ksi $\sqrt{in}$

Test $(T - RT_{NDT}) = 10$ $K_{1a} = 40$ ksi $\sqrt{in}$

STEP 5: IWB-3612 Evaluation

IWB-3612 requires:

$$K_1 < \frac{K_{1a}}{\sqrt{10}} \text{ for normal stress}$$

$$K_1 < \frac{K_{1c}}{\sqrt{2}} \text{ for faulted stress}$$

Normal Stress: Pressure Test

$a_f = 0.334$ in. $K_1 = 1.834\ \Delta\ \sigma_p \sqrt{a_f} = 3.21$ ksi$\sqrt{in}$
$\Delta\ \sigma = 3.031$ ksi

allowable = $100/\sqrt{10} = 31.6$ ksi$\sqrt{in}$ ∴ OK

$3.21 < 31.6$ ksi$\sqrt{in}$

Faulted Stress: $\Delta T = 265°F$

$a_f = 0.334$ in. $K_1 = 1.834\ \Delta\ \sigma \sqrt{a_f} = 42.14$ ksi$\sqrt{in}$
$\Delta\ \sigma = 39.759$ ksi

allowable = $200/\sqrt{2} = 141.4$ ksi$\sqrt{in}$ ∴ OK

$42.14 < 141.4$ ksi$\sqrt{in}$

Closure Test:

$a_f = 0.334$ in $K_1 = 1.834\ \Delta\ \sigma_C \sqrt{a_f} = 0.234$ ksi$\sqrt{in}$
$\Delta\ \sigma_C = 0.221$ ksi

allowable = $38/\sqrt{10} = 12.02$ ksi$\sqrt{in}$

$0.234 < 12.02$ ksi$\sqrt{in}$ ∴ OK

Local Primary Stress:

Primary stress, taking no credit for the flaw depth, must be less than 1.1 Sm. The pressure stress $PR/(t-2a_f)$, where

$P = 1250$ psig

$R = 7.765 + 3.175 = 10.94$

$t = 3.175$

$a_f = 0.334$

$$\sigma_m = \frac{(1250)(10.94)}{(3.175-2(0.334))} = 5454\ psi$$

For SA 216, GrWCB, Sm = 18.4 ksi at 575°F

allowable = 1.1(18.4) = 20.2 ksi

5.45 ksi < 20.2 ksi ∴ OK

STEP 6: Bounding Aspect Ratio:

STEPS 2, 3, and 5 are repeated for several aspect ratios. The results of these calculations are summarized in tables 1, 2, and 3.

REFERENCES: Same as for the base document

TABLE 1

a/l	1/6	1/4	1/3	1/2	
a_i	0.333	0.500	0.667	1.000	
e	0.662	0.495	0.328	-0.006	Note 1
2e/t	0.417	0.311	0.206	0.004	
2a/t	0.210	0.315	0.420	0.629	
Q	1.05	1.24	1.54	2.24	Note 2
M_m	1.06	1.11	1.16	1.34	Note 3
C	1.834	1.767	1.657	1.587	Note 4
a_f	0.334	0.502	0.670	1.005	

Note 1: $e = (t/2) - (0.593 + a)$
Note 2: Q is from Fig. A-3300-1 to Appendix A to ASME Section XI
Note 3: M_m is from Fig. A-3300-2 to Appendix A to ASME Section XI
Note 4: $C = M_m \times (\sqrt{\pi / Q})$

TABLE 2.1

CRACK GROWTH FOR D OUTBOARD MSIV BODY INDICATION

ASPECT RATIO $(a/\ell) = 1/6$

$\Delta\sigma$ (ksi)	ΔK	da/dN	Cycles N	Δa (in)	Notes
39.759	42.14	3.02E-5	8	0.0002	a_f = 0.334 a_i = 0.333 Δa = 0.001 Σa = 0.334 ΔK = 1.060 x $\Delta\sigma$
32.376	34.32	1.41E-5	2	0.0000	
29.223	30.98	0.96E-5	18	0.0002	
26.071	27.64	0.63E-5	91	0.0006	
25.739	27.28	0.60E-5	10	0.0001	
3.252	3.45	2.69E-9	2000	0.0000	

Method:
1. Estimate a_f
2. Calculate Δa for each $\Delta\sigma$ using a_f (conservative since the final flaw size is used for each cycle)
3. sum the Δ 'a's and add to the initial flaw size total a = $a_i + \Delta a$
4. Compare total 'a' with a_f, repeat until total 'a' = a_f.

TABLE 2.2

CRACK GROWTH FOR D OUTBOARD MSIV BODY INDICATION

ASPECT RATIO $(a/\ell) = 1/4$

$\Delta\sigma$ (ksi)	ΔK	da/dN	Cycles N	Δa (in)	Notes
39.759	49.78	5.62E-5	8	0.0004	a_f = 0.502 a_i = 0.500 Δa = 0.002 Σa = 0.502 ΔK = 1.252 x $\Delta\sigma$
32.376	40.53	2.61E-5	2	0.0001	
29.223	36.59	1.78E-5	18	0.0003	
26.071	32.64	1.17E-5	91	0.0011	
25.739	32.23	1.11E-5	10	0.0001	
3.252	4.07	4.99E-9	2000	0.0000	

TABLE 2.3

CRACK GROWTH FOR D OUTBOARD MSIV BODY INDICATION

ASPECT RATIO $(a/\ell) = 1/3$

$\Delta\ \sigma$ (ksi)	ΔK	da/dN	Cycles N	Δa (in)	Notes
39.759	53.91	7.59E-5	8	0.0006	$a_f = 0.670$ $a_i = 0.667$ $\Delta a = 0.003$ $\Sigma a = 0.670$ $\Delta K = 1.356 \times \Delta\sigma$
32.376	43.90	3.52E-5	2	0.0001	
29.223	39.63	2.40E-5	18	0.0004	
26.071	35.35	1.57E-5	91	0.0014	
25.739	34.90	1.50E-5	10	0.0001	
3.252	4.41	6.72E-9	2000	0.0000	

Method:
1. Estimate a_f
2. Calculate Δa for each $\Delta\sigma$ using a_f (conservative since the final flaw size is used for each cycle)
3. sum the Δ 'a's and add to the initial flaw size total a = $a_i + \Delta a$
4. Compare total 'a' with a_f, repeat until total 'a' = a_f.

TABLE 2.4

CRACK GROWTH FOR D OUTBOARD MSIV BODY INDICATION

ASPECT RATIO $(a/\ell) = 1/2$

$\Delta\ \sigma$ (ksi)	ΔK	da/dN	Cycles N	Δa (in)	Notes
39.759	63.26	13.72E-5	8	0.0011	$a_f = 0.005$ $a_i = 0.000$ $\Delta a = 0.005$ $\Sigma a = 0.005$ $\Delta K = 1.591 \times \Delta\sigma$
32.376	51.51	6.38E-5	2	0.0001	
29.223	46.49	4.36E-5	18	0.0008	
26.071	41.48	2.85E-5	91	0.0026	
25.739	40.95	2.72E-5	10	0.0003	
3.252	5.17	12.20E-9	2000	0.0000	

Table 3

RESULTS OF FATIGUE CRACK GROWTH ANALYSES OF
'D' OUTBOARD MSIV BODY

Aspect ratio/Case	Final Flaw, a_f (inch)	Maximum K_I (ksi√in)	Allowable K_I (ksi√in)	Local σ_m (ksi)	Allowable Local σ_m (ksi)
Aspect Ratio = 1/6					
Normal	0.334	3.21	31.6	5.45	20.2
Faulted	0.334	42.14	141.4		
Test	0.334	0.23	12.02		
Aspect Ratio = 1/4					
Normal	0.502	3.79	31.6	6.30	20.2
Faulted	0.502	49.78	141.4		
Test	0.502	0.28	12.02		
Aspect Ratio = 1/3					
Normal	0.670	4.11	31.6	7.45	20.2
Faulted	0.670	53.91	141.4		
Test	0.670	0.30	12.02		
Aspect Ratio = 1/2					
Normal	1.005	4.82	31.6	11.74	20.2
Faulted	1.005	63.26	141.4		
Test	1.005	0.35	12.02		

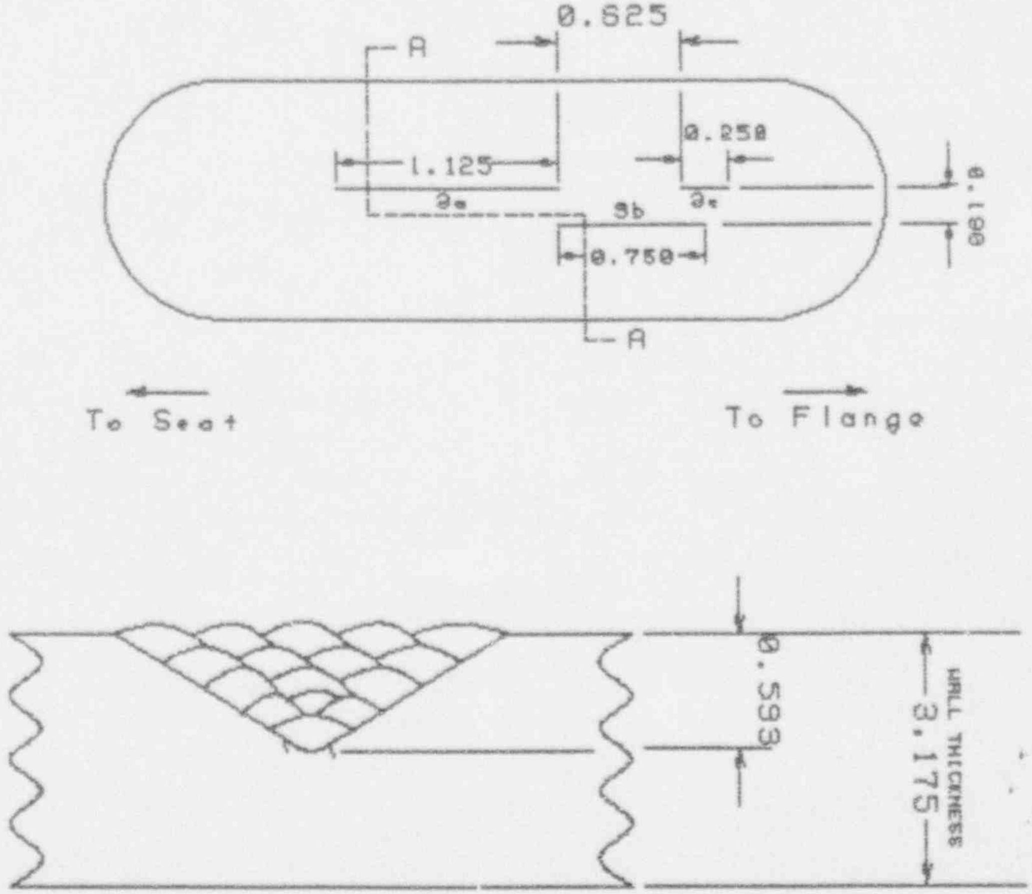
Where,
Normal $K_I = C \times (3.031) \times \sqrt{a_f}$
Test $K_I = C \times (0.221) \times \sqrt{a_f}$
Local $\sigma_m = 1250 \times (10.94) / (t - (2 \times a_f))$

ATTACHMENT 2

Doc # CAL-M93-Ø23		Rev # Ø
Attachment # 2		Total Sheets 1
Description MAP OF SURFACE INDICATIONS		
Rev	Prepared/Date	Verified/Date
Ø	[signature] 9/20/93	[signature] 9/20/93

CV4421

MAP OF SURFACE INDICATIONS OF AREA #3 AND WELD BEAD PLACEMENT (AFTER ≈20% EXCAVATION)



SECTION AA

NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE
   DRAWING NOT TO SCALE

Attachment 3
to NG-93-4013

IOWA ELECTRIC LIGHT AND POWER COMPANY
QUALITY ASSURANCE
MEMORANDUM
NG-93-4028

To: Mike McDermott, Manager, Design Engineering

Date: September 18, 1993

Subject: RT Results of Area #3 Repair to "D" MSIV

File: Q-11

On September 17, 1993 final radiography was performed on the weld repair of area #3 inside the bore of "D" Outboard MSIV. The results of the radiography were satisfactory per ASTM E-186, Severity Level 2, as required by the original purchase specification (GE 21A9230 Rev. 2).

Close examination of the radiographs revealed only very minor shrinkage indications. This would allow me to conclude that whatever shrinkage remained in the cavity after grinding to a depth of 0.593" was either too small to image or was actually fused together during the welding process. This represents a significant improvement in this area in that original, and recently taken, radiographs showed an area of moderate shrinkage which imaged clearly on the film. Since the sensitivity of the final radiograph was quite good (1T), I am confident that no significant indications exist in this area of the casting.

If you have any questions please contact me.

Mark A. Huting
Quality Control Supervisor

cc: K. Peveler
K. Young
B. Mueller
F. Dohmen
S. Shangari
E. Sorenson
J. Kinsey
DCRC

QA Form 1106.4-2a (Jan. '92)

IOWA ELECTRIC LIGHT AND POWER COMPANY

DUANE ARNOLD ENERGY CENTER TEN YEAR EXAMINATION SUMMARY ASME SECTION XI SYSTEMS - REQUEST FOR RELIEF	CEDAR RAPIDS, IA	MAJOR ITEM:REQUEST FOR RELIEF NUMBER RR-002 Rev.1 TABLE:SECTION 7.0 & 8.0 PAGE 1 OF 1

COMPONENT OR SYSTEM	ASME XI CODE CLASS	PROGRAM TABLE	CODE CATEGORY	CODE ITEM
MAINSTEAM ISOLATION VALVE "D" OUTBOARD, CV-4421	1	N/A	N/A	N/A

CODE REQUIREMENTS IWA-4120 "REPAIRS SHALL BE PERFORMED IN ACCORDANCE WITH THE OWNER'S DESIGN SPECIFICATION AND CONSTRUCTION CODE OF THE COMPONENT OR SYSTEM". THE MATERIAL SPEC. (ASTM A216 GR.WCB) REQUIRES THE REMOVAL OF UNACCEPTABLE DEFECTS PRIOR TO PERFORMING ANY WELD REPAIRS. ALSO CASTINGS CONTAINING ANY REPAIR WELD THAT EXCEEDS 20% OF WALL THICKNESS OR 1" WHICHEVER IS SMALLER OR WHICH EXCEEDS 10 IN^2 AREA SHALL BE STRESS RELIEVED AFTER WELDING. THE GE PURCHASE SPEC. 21A9230 REQUIRES WELD REPAIRS ON CASTINGS TO BE EXAMINED BY MAGNETIC PARTICLE (MT) OR LIQUID PENETRANT (PT) METHODS AND REPAIR WELDS OF DEPTH GREATER THAN 10% OF THE WALL THICKNESS TO BE EXAMINED BY RADIOGRAPHY (RT).

BASIS FOR RELIEF THE SPECIFICATIONS FOR THE MSIVs REQUIRE AN MT OR PT EXAMINATION ON ALL MACHINED SURFACES. DURING REPAIR MACHINING OF THE D OUTBOARD MSIV, UNACCEPTABLE LINEAR INDICATIONS WERE DISCOVERED ON THE MT EXAM. THESE INDICATIONS WERE COMPARED TO THE ORIGINAL RADIOGRAPHS AND DETERMINED TO BE SHRINKAGE DEFECTS FROM THE CASTING PROCESS. FURTHER GRINDING WAS PERFORMED TO A DEPTH OF 0.593 IN (CLOSE TO THE LIMIT FOR STRESS RELIEVING) AND THREE UNACCEPTABLE INDICATIONS IN GROUND AREA WERE FOUND ON MT EXAM. THE INDICATIONS HAVE NOT BEEN REMOVED BUT HAVE BEEN WELD OVERLAYED, WITH A MT AFTER EACH WELD LAYER AND AN MT AND RT EXAMINATION PERFORMED AFTER FINAL MACHINING. ACCEPTANCE OF THE MACHINED SURFACE WAS BASED ON THE ORIGINAL CODE ACCEPTANCE CRITERIA. THE DETAILS OF THE REPAIR PROCESS ARE DESCRIBED IN ATTACHMENT 2 OF NG-93-4013.

ALTERNATIVE EXAMINATION THE SHRINKAGE INDICATIONS WERE REPAIRED BY GRINDING THE AREAS IN PREPARATION FOR WELDING. THE SHRINKAGE DEFECTS WERE WELD OVERLAYED AND AN MT AND RT EXAMINATION PERFORMED AFTER FINAL MACHINING, ACCEPTANCE WAS BASED ON ORIGINAL CODE ACCEPTANCE CRITERIA. ENGINEERING EVALUATION HAS BEEN PERFORMED FOR ACCEPTING THE SUBSURFACE INDICATIONS USING ASME SECTION XI 1980 WITH W81 ADDENDA, TABLE IWB-3518-1.

SCHEDULE FOR IMPLEMENTATION
RFO12