Interim Report

Limerick Generating Station - Unit 2
Core Shroud Ultrasonic Examination

Prepared for
PECO Energy

Prepared by:
GE Nuclear Energy

Report No.: 1H61R, Rev. 0

May 1999

Prepared By: Original Signed By: _____ Date: _____
John Hayden, GE Inspection Services, Sr. NDE Specialist Level III - Ultrasonic Method

Reviewed By: Original Signed By: _____ Date: _____
Richard Keck, GE Inspection Services, Project Manager

Reviewed By: Original Signed By: _____ Date: _____
Thomas Anderson, PECO Energy, ISI Engineer

Project Summary

From 29 April 1999 through 8 May 1999, General Electric (GE) Inspection Services conducted ultrasonic examinations of Core Shroud Assembly welds at Limerick Generating Station - Unit 2. The scope of the examinations included selected portions of four circumferential welds, H3, H4, H5 and H7. The detection of flaw indications forced an expansion of the work scope to include the examination of accessible portions of welds H1, H2 and H6.

All welds were examined using the GE OD Tracker scanning device, while employing the conventional technique, which uses 45° shear wave, 60° longitudinal wave and OD/ID Creeping wave search units in an integral housing.

This report contains specific details regarding the performance and results of the examinations.

References

- ASME Boiler and Pressure Vessel Code, Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, 1989 edition.

  Note: The ultrasonic examinations described in this report are not addressed by the ASME Code. The examinations were performed in accordance with the intent of ASME Sections V and XI with regard to the basic ultrasonic requirements, whenever possible.

- BWRVIP-03 *Reactor Pressure Vessel and Internals Guidelines*.

- General Electric document GE-UT-503, Version 8, *Procedure For Automated Ultrasonic Examination Of Shroud Assembly Welds.*

Equipment

The capabilities of the MicroTomo™ data acquisition system, TomoView™ Workstation and GE Trimodal search unit were successfully demonstrated in accordance with BWRVIP-03 "Reactor Pressure Vessel and Internals Guidelines".

MicroTomo™ Acquisition System

The MicroTomo™ data acquisition system was utilized for this examination. The MicroTomo™ is a multiplexed, digital system. The system digitizes the entire A-scan or RF waveform at the rate of up to 120 MHz. The entire A-scan is digitized and archived to a one gigabyte optical disk or 2 gigabyte removable hard disk for off-line analysis and subsequent examination comparisons.

OD Tracker Scanner

This device rests upon and drives around the steam dam structure of the core shroud assembly. Interchangeable vertical arms of appropriate length descend from the carriage of the GE OD Tracker to the elevation of each of the four welds examined. The search units are applied to the outside surface of the shroud, and are manipulated about the accessible portions of the circumference of the shroud. Search units are also moved toward and away from each weld, in a raster scan pattern. This scanning motion generally provides full coverage of the BWRVIP-specified surface regions on both sides of the weld.

GE TriModal Search Unit

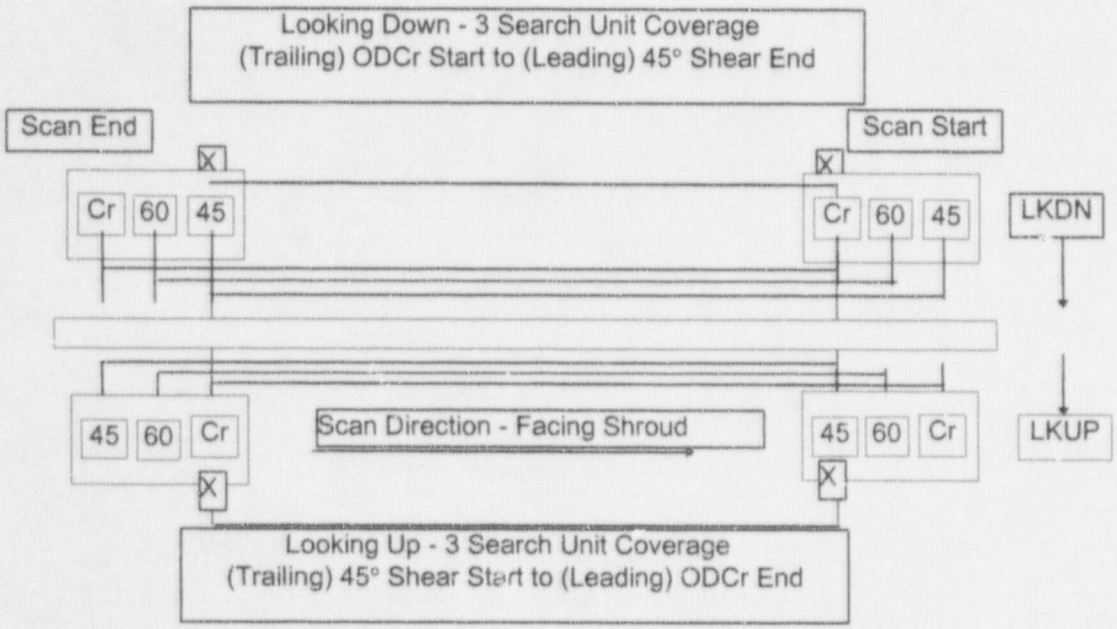
The GE Trimodal search unit was employed during the examinations of Weld H7. This device consists of a stainless steel housing for 45° shear wave, a dual-element 60° longitudinal wave and dual-element OD/ID Creeping wave transducers.

TomoView™ Data Analysis Workstation

The TomoView™ Workstation was used for the evaluation of ultrasonic data. The data is displayed with any combination of time or amplitude in A-scan, B-scan, C-scan and D-scan views, with 1024 X 768 pixel resolution. The TomoView™ software permits any desired manipulation of the A, B, C or D-scan images. An adjustable color palette is provided for image enhancement. Each image, or specific region therein, can be selectively enlarged. GE data analysts have used the TomoView™ software to successfully demonstrate complete flaw detection and sizing capabilities in the PDI Piping Program at the EPRI NDE Center.

TriModal Technique Examination Methodology

The examinations employed 45° shear wave, 60° longitudinal wave and OD/ID creeping wave transducers units which direct ultrasound to interrogate the regions of interest. The following sketch depicts the relationship between each search unit during scanning.

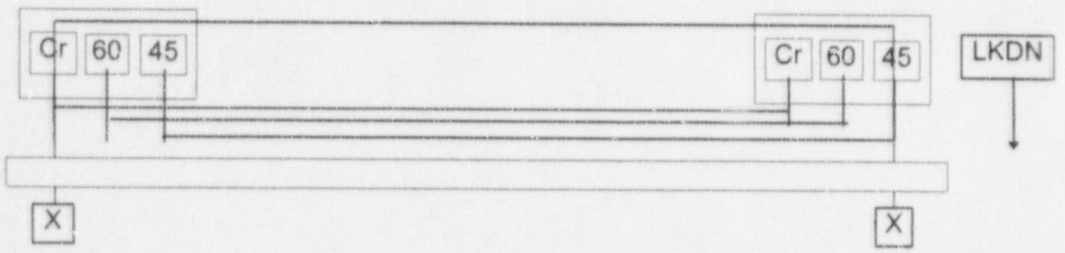


Examination Results

Numerous indications of intergranular stress corrosion were observed during the course of the examinations of welds H1, H2, H3, H4 H5 and H6. The examination of weld H7 did not reveal flaw indications. This document also contains a section of Examination Summary Sheets for each weld examined.

Circumferential Examination Coverage

This approach defines examination coverage as that length of weld scanned by the *combined* coverage of the 45° and OD/ID Creeping wave elements. This technique is considered to be satisfactory since both the 45° and OD/ID Creeping wave transducers have been demonstrated (in accordance with BWRVIP-03) to be effective for the detection of surface-breaking flaws at both the outside and inside surfaces of the shroud.



Examination Personnel

The examinations were conducted by the following GE Inspection Specialists:

MicroTomo™/Carousel/OD Tracker System Operators:

Martin Crane	Level II
Nicholas Labella	Level II
Terry Rockwood	Level III
Michael Webster	Level II

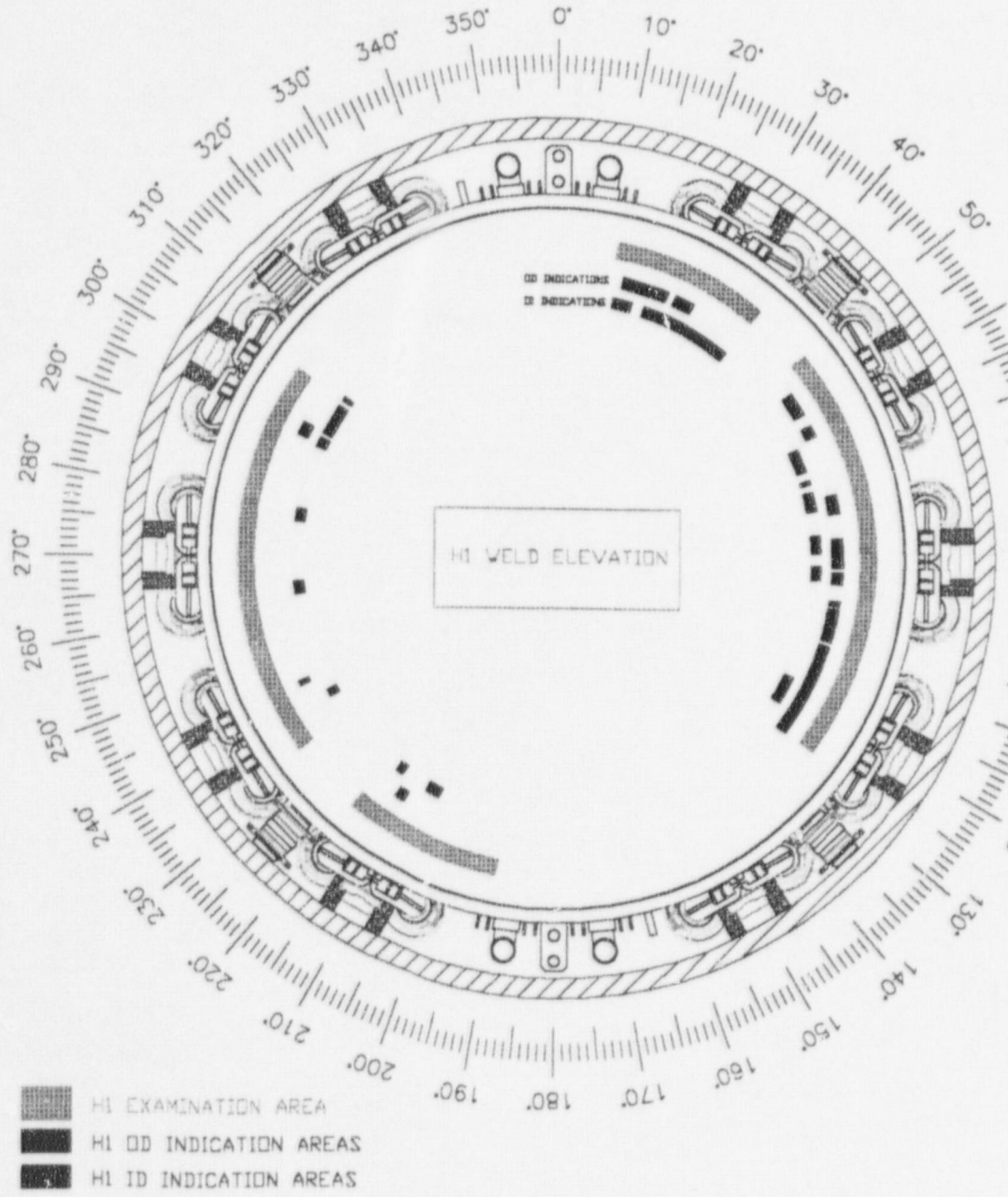
Ultrasonic Data Analyst:

John Hayden	Level III
James Halley	

Project Manager:

Richard Keck

LIMERICK-2 SHROUD UT INSPECTION

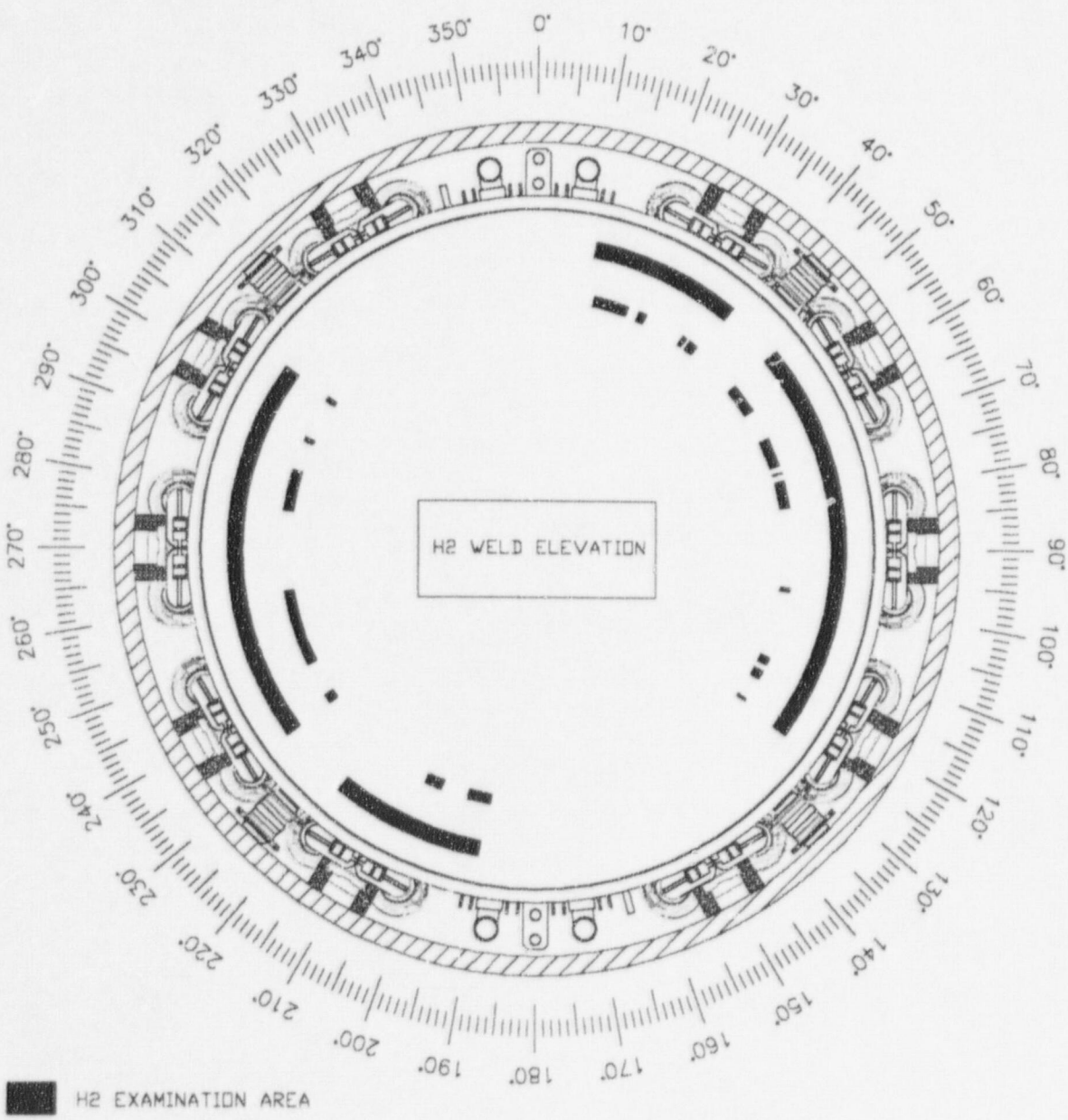


DRAWING NO. LK2-001
TITLE: SHROUD TOP VIEW
PROJECT: LIMERICK UNIT 2
GE DWG NO. XXXXXXXXXX
NOTE: THIS SKETCH IS FOR ISI PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	03-01-99	R.F. GRIZZI					SHROUD INSPECTABILITY STUDY
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

LIMERICK-2 SHROUD UT INSPECTION



SHROUD TOP VIEW

LIMERICK UNIT 2

LK2-001

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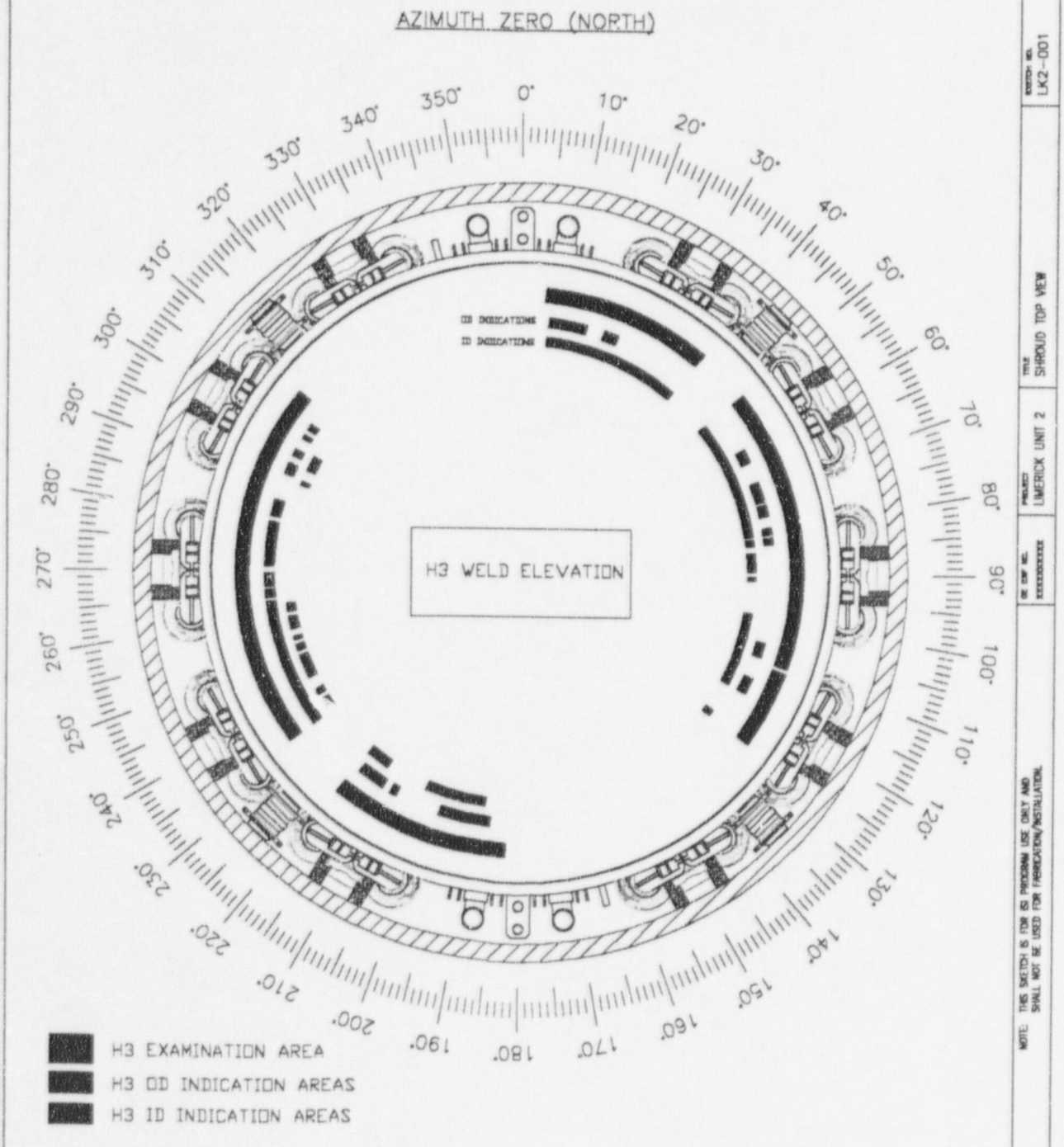
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

LIMERICK-2 SHROUD UT INSPECTION



SKETCH RELEASE RECORD

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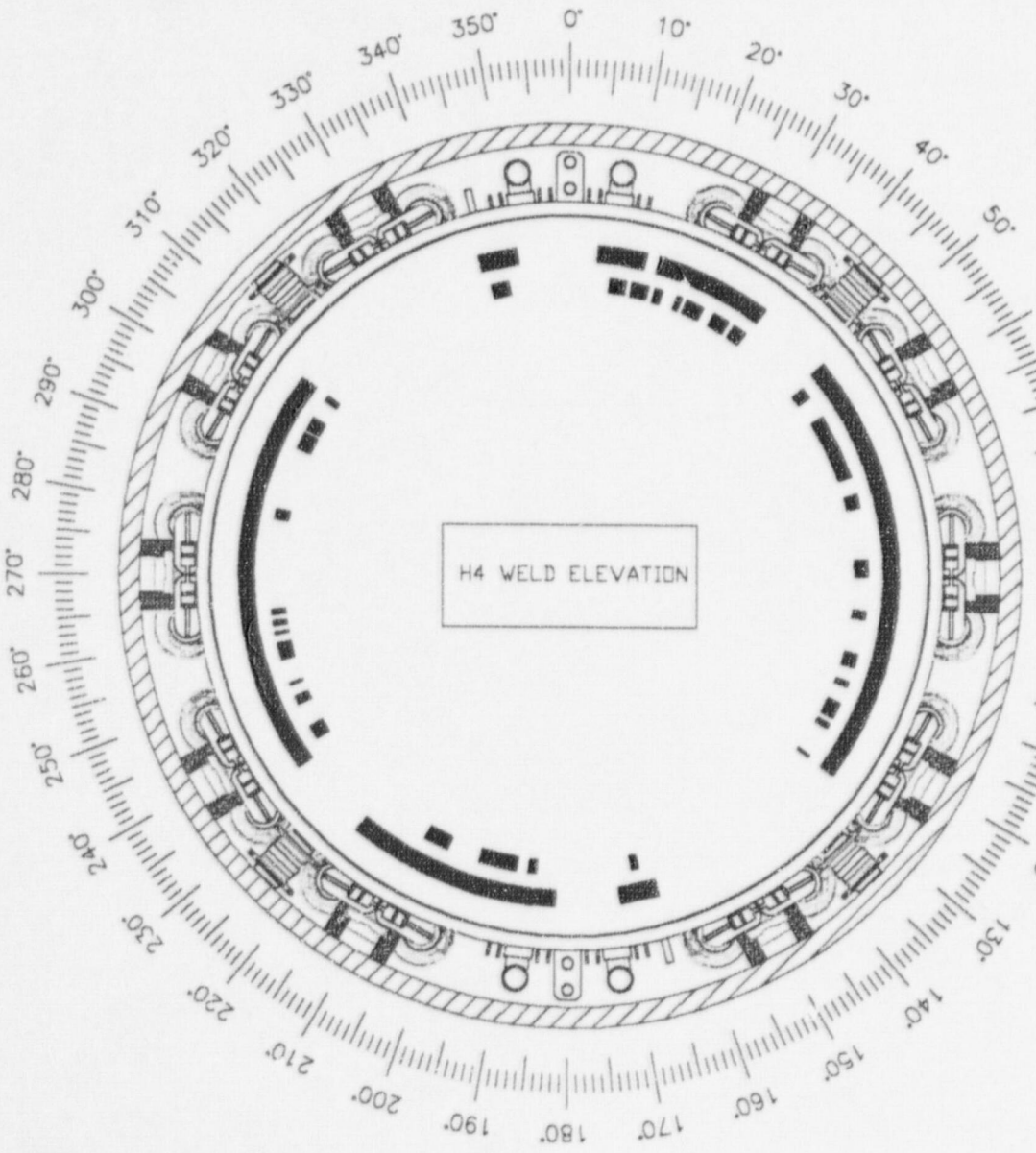
1	05-11-98	R.F. GRIZZI					SHROUD COVERAGE

LIMERICK-2 SHROUD UT INSPECTION



SKETCH NO. LK2-001

TITLE: SHROUD TOP VIEW

PROJECT: LIMERICK UNIT 2

GE DRF NO. XXXXXXXXX

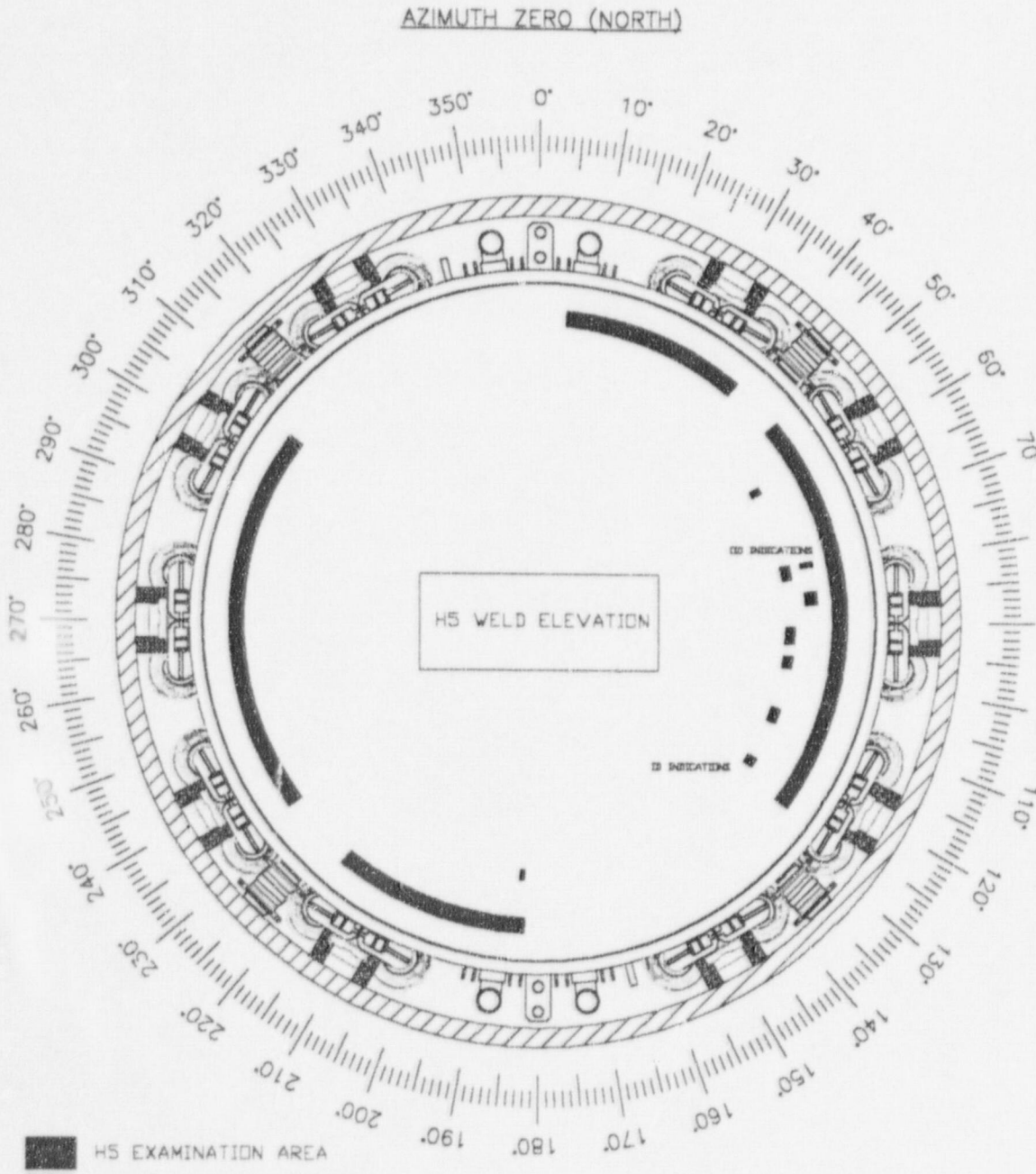
NOTE: THIS SKETCH IS FOR ISI PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	03-01-99	R.F. GRIZZI					SHROUD INSPECTABILITY STUDY
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

1H61R

LIMERICK-2 SHROUD UT INSPECTION

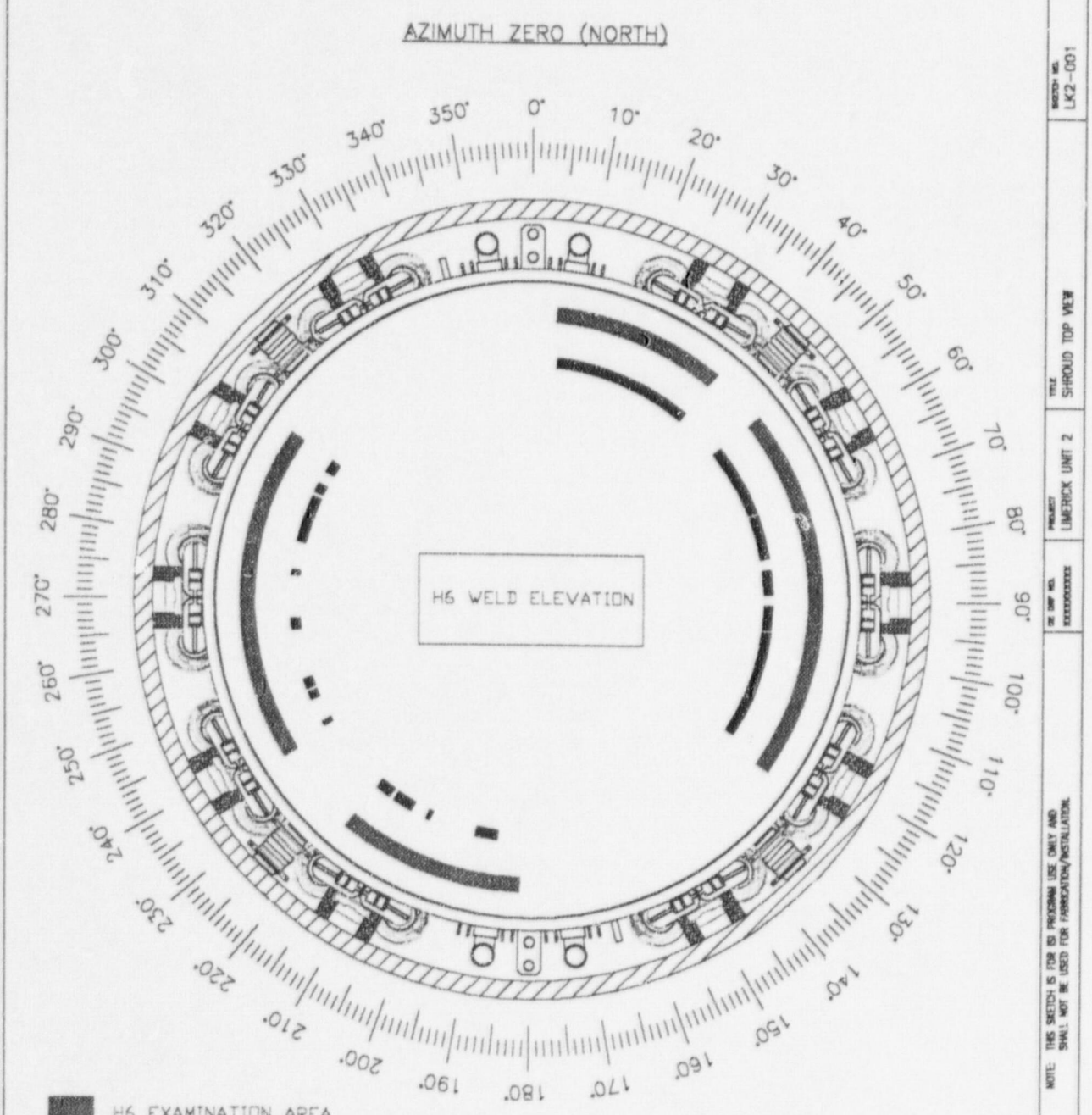


DRAWING NO. LK2-001
TITLE SHROUD TOP VIEW
PROJECT LIMERICK UNIT 2
GE DWG NO. xxxxxxxxxx
NOTE: THIS SKETCH IS FOR IS PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	03-01-99	R.F. GRIZZI					SHROUD INSPECTABILITY STUDY
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

LIMERICK-2 SHROUD UT INSPECTION



SKETCH NO. LK2-001

TITLE SHROUD TOP VIEW

PROJECT LIMERICK UNIT 2

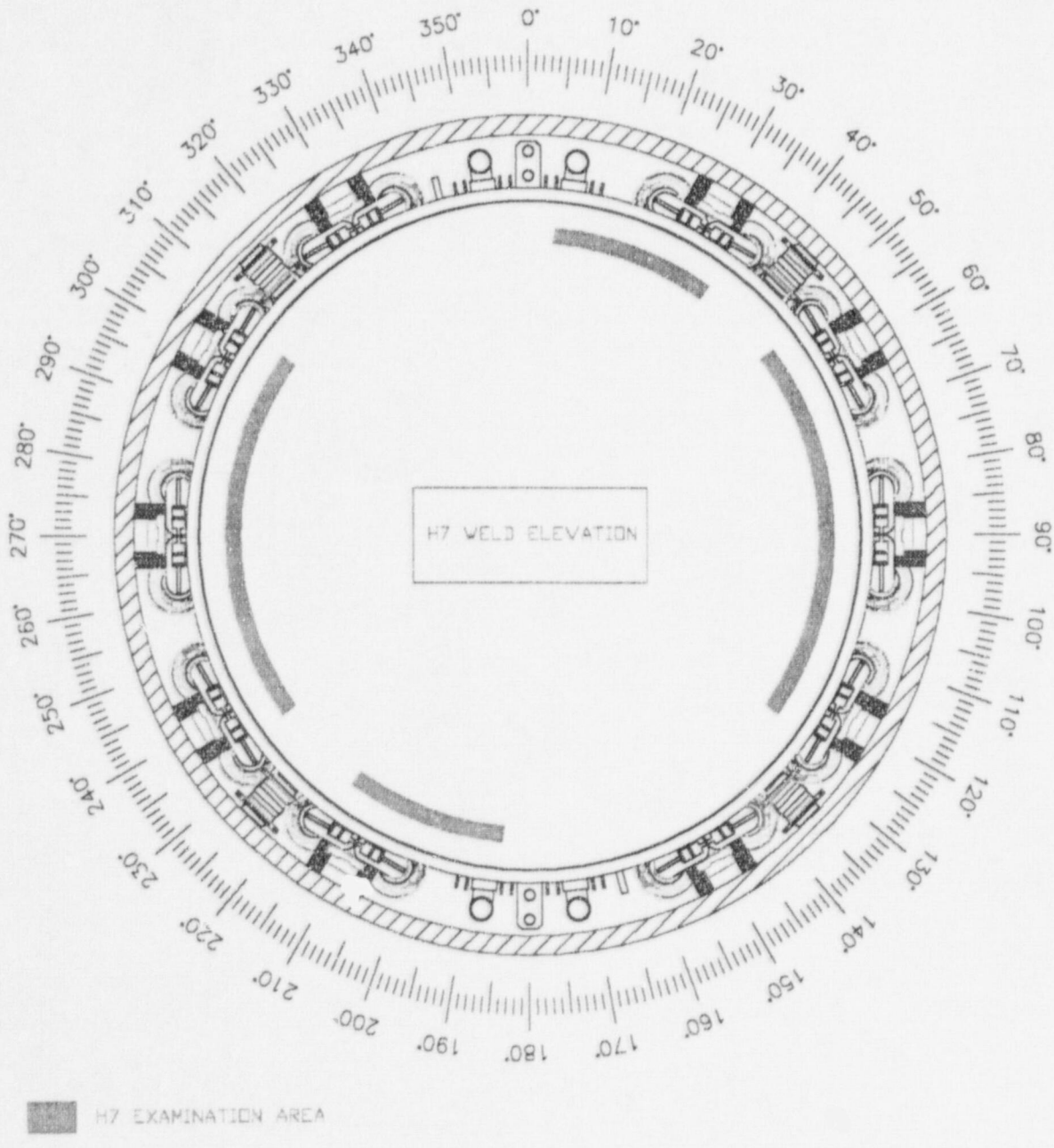
DC DWG NO. XXXXXXXXX

NOTE: THIS SKETCH IS FOR ISI PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	03-01-99	R.F. GRIZZI					SHROUD INSPECTABILITY STUDY
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

LIMERICK-2 SHROUD UT INSPECTION



DRAWING NO. LK2-051

TITLE SHROUD TOP VIEW

PROJECT LIMERICK UNIT 2

GE DRF NO. XXXXXXXXX

NOTE: THIS SKETCH IS FOR ISI PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	03-01-99	R.F. GRIZZI					SHROUD INSPECTABILITY STUDY
1	05-11-99	R.F. GRIZZI					SHROUD COVERAGE

Weld H-1

Examination Summary

Examination from Bottom Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	206.66°	*Shroud Thickness (In.)*	2.00
Total Scan Length Examined (In.)	396.78	*Circumference (In.)*	691.15
Percent of Weld Length Examined	57.41%	*Inches per Degree*	1.92
Percent of Examined OD Weld Length Flawed	34.30%	ID	66.02°
Percent of Total OD Weld Length Flawed	19.69%		126.76
Percent of Examined ID Weld Length Flawed	31.95%	OD	70.89°
Percent of Total ID Weld Length Flawed	18.34%		136.11

		Weld H-1 45° - OCDr									
	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H1H2011-1	12.06°	16.46°	11.01°	15.41°	4.40°	5.45°	3.95°	11.01°	39.46°	28.45°
TriModal	H1H2018-1	13.56°	24.01°	12.51°	22.96°	10.45°	11.50°	4.00°			
TriModal	H1H2026-1	21.06°	31.51°	20.01°	30.46°	10.45°	11.50°	7.95°			
TriModal	H1H2033-1	24.61°	39.46°	23.56°	38.41°	14.85°	15.90°				
TriModal	H1H2056-1	51.56°	66.41°	50.51°	65.36°	14.85°	15.90°	12.99°	50.51°	126.46°	75.95°
TriModal	H1H2063-1	54.47°	64.37°	53.42°	63.32°	9.90°	10.95°	3.45°			
TriModal	H1H2071-1	61.97°	72.42°	60.92°	71.37°	10.45°	11.50°	4.00°			
TriModal	H1H1078-1	69.47°	79.92°	68.42°	78.87°	10.45°	11.50°	4.00°			
TriModal	H1H2086-1	76.97°	87.42°	75.92°	86.37°	10.45°	11.50°	4.00°			
TriModal	H1H2093-1	84.47°	94.92°	83.42°	93.87°	10.45°	11.50°	4.00°			
TriModal	H1H2101-1	91.97°	102.42°	90.92°	101.37°	10.45°	11.50°	4.00°			
TriModal	H1H2108-1	99.47°	112.67°	98.42°	111.62°	13.20°	14.25°	2.66°			
TriModal	H1H2116-1	111.06°	126.46°	110.01°	125.41°	15.40°	16.45°				
TriModal	H1H2191-1	191.56°	196.51°	190.51°	195.46°	4.95°	6.00°	2.97°	190.51°	219.88°	29.37°
TriModal	H1H2198-1	194.59°	205.04°	193.54°	203.99°	10.45°	11.50°	5.03°			
TriModal	H1H2206-1	201.06°	211.51°	200.01°	210.46°	10.45°	11.50°	7.95°			

		Weld H-1 45° - OCDr									
	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*		*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H1H2213-1	204.61°	219.88°	203.56°	218.83°	15.27°	16.32°					
TriModal	H1H2243-1	234.61°	244.92°	233.56°	243.87°	10.31°	11.36°	4.00°		233.56°	306.46°	72.90°
TriModal	H1H2251-1	241.97°	252.42°	240.92°	251.37°	10.45°	11.50°	4.00°				
TriModal	H1H2258-1	249.47°	259.92°	248.42°	258.87°	10.45°	11.50°	4.00°				
TriModal	H1H2226-1	256.97°	267.42°	255.92°	266.37°	10.45°	11.50°	4.00°				
TriModal	H1H2273-1	264.47°	274.92°	263.42°	273.87°	10.45°	11.50°	4.00°				
TriModal	H1H2281-1	271.97°	281.87°	270.92°	280.82°	9.90°	10.95°	3.45°				
TriModal	H1H2288-1	279.47°	292.67°	278.42°	291.62°	13.20°	14.25°	2.66°				
TriModal	H1H2296-1	291.06°	306.46°	290.01°	305.41°	15.40°	16.45°					
							303.66°	97.00°				
		Total Scanned:			303.66°							
		Overlap:			97.00°				Total Ligament Length:			206.66°
		Net Coverage:			206.66°							
		Percentage of Weld Scanned:			57.41%				Percentage of Total Weld Length:			57.41%

Weld H-1

UT Indication Length Summary

Inside Surface Flaws							
Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*
1*	NS	ID	12.06°	16.46°	4.40°	8.45	ODCr
2*	NS	ID	19.06°	39.46°	20.40°	39.17	ODCr
3*	NS	ID	65.27°	70.57°	5.30°	10.18	ODCr
4	NS	ID	72.22°	73.32°	1.10°	2.11	ODCr
5*	NS	ID	74.97°	79.17°	4.20°	8.06	ODCr
6*	NS	ID	84.47°	88.32°	3.85°	7.39	ODCr
7*	NS	ID	91.07°	94.31°	3.24°	6.22	ODCr
9*	NS	ID	116.01°	120.41°	4.40°	8.45	ODCr
10	NS	ID	120.96°	122.06°	1.10°	2.11	ODCr
11*	NS	ID	206.01°	209.31°	3.30°	6.34	ODCr
12	NS	ID	215.48°	217.13°	1.65°	3.17	ODCr
13	NS	ID	238.46°	240.11°	1.65°	3.17	ODCr
14*	NS	ID	261.92°	264.67°	2.75°	5.28	ODCr
15*	NS	ID	277.47°	280.57°	3.10°	5.95	ODCr
16	NS	ID	294.36°	296.56°	2.20°	4.22	ODCr
17*	NS	ID	297.11°	304.26°	7.15°	13.73	ODCr
18	NS	ID	305.36°	306.46°	1.10°	2.11	ODCr
					70.89°	136.11	

Outside Surface Flaws							
law No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*
1*	NS	OD	13.16°	21.26°	8.10°	15.55	45.00°
2*	NS	OD	21.28°	22.91°	1.63°	3.13	45.00°
3*	NS	OD	24.36°	28.21°	3.85°	7.39	45.00°
4*	NS	OD	54.86°	59.81°	4.95°	9.50	45.00°
5*	NS	OD	61.97°	64.17°	2.20°	4.22	45.00°
6*	NS	OD	76.62°	80.27°	3.65°	7.01	45.00°
7*	NS	OD	85.22°	91.62°	6.40°	12.29	45.00°
8*	NS	OD	92.17°	94.92°	2.75°	5.28	45.00°
9*	NS	OD	98.02°	99.12°	1.10°	2.11	45.00°
10*	NS	OD	99.67°	101.32°	1.65°	3.17	45.00°
11*	NS	OD	101.67°	103.32°	1.65°	3.17	45.00°
12*	NS	OD	103.87°	106.62°	2.75°	5.28	45.00°
13*	NS	OD	107.17°	126.46°	19.29°	37.04	45.00°
14*	NS	OD	212.18°	214.38°	2.20°	4.22	45.00°
15*	NS	OD	243.07°	244.17°	1.10°	2.11	45.00°
16*	NS	OD	294.91°	297.66°	2.75°	5.28	45.00°
					66.02°	126.76	

Weld H-1

UT Indication Depth Summary

Inside Surface Flaws						Outside Surface Flaws								
No.	*Location*	*Through-Wall Height*	*No.*	*Location*	*Through-Wall Height*	*No.*	*Location*	*Through-Wall Height*	*No.*	*Location*	*Through-Wall Height*	*No.*	*Location*	*Through-Wall Height*
1	13.79°	0.15	24	117.19°	0.18	1	13.56°	0.13	23	78.27°	0.14	45	116.14°	0.13
2	15.44°	0.19	25	118.84°	0.28	2	13.71°	0.10	24	79.37°	0.14	46	117.79°	0.16
3	20.24°	0.19	26	119.94°	0.20	3	15.21°	0.14	25	86.67°	0.15	47	117.79°	0.16
4	21.34°	0.23	27	207.19°	0.24	4	15.76°	0.18	26	86.87°	0.12	48	121.51°	<0.05
5	23.54°	0.14	28	207.74°	0.17	5	17.41°	0.15	27	88.87°	0.12	49	121.09°	0.08
6	24.99°	0.24	29	208.41°	0.24	6	17.96°	0.15	28	89.42°	0.15	50	122.19°	0.19
7	26.64°	0.39	30	208.84°	0.19	7	19.06°	0.13	29	89.97°	0.14	51	123.29°	0.18
8	28.29°	0.43	31	216.11°	0.15	8	20.36°	0.14	30	93.07°	0.18	52	124.39°	0.14
9	31.04°	0.41	32	239.51°	0.31	9	20.71°	0.16	31	93.62°	0.15	53	212.73°	0.14
10	33.36°	0.27	33	262.56°	0.07	10	22.16°	0.14	32	93.82°	0.19	54	213.28°	0.16
11	35.56°	0.19	34	263.66°	0.19	11	22.36°	0.18	33	99.12°	0.08	55	243.62°	0.14
12	38.31°	0.23	35	279.56°	0.29	12	24.91°	0.14	34	100.22°	0.09	56	295.46°	0.13
13	65.91°	0.07	36	294.99°	0.36	13	25.06°	0.12	35	102.22°	0.12	57	296.56°	0.19
14	67.01°	0.08	37	295.54°	0.25	14	25.46°	0.14	36	102.42°	0.10	58	297.11°	0.09
15	68.11°	0.17	38	297.74°	0.22	15	27.11°	0.16	37	105.52°	0.14			
16	69.76°	0.17	39	298.84°	0.19	16	27.23°	0.13	38	108.27°	0.15			
17	72.77°	<0.05	40	300.49°	0.30	17	55.57°	0.15	39	109.37°	0.13			
18	77.61°	0.17	41	301.59°	0.25	18	55.96°	0.14	40	109.92°	0.18			
19	78.16°	0.25	42	303.24°	<0.05	19	56.51°	0.14	41	110.47°	0.18			
20	84.56°	0.29	43	305.99°	0.16	20	57.61°	0.15	42	111.61°	0.18			
21	87.31°	<0.05				21	63.62°	0.19	43	112.16°	0.15			
22	92.81°	0.13				22	77.17°	0.14	44	113.88°	0.20			
23	93.16°	0.12												

Weld H-2

Examination Summary

Examination of Top Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	206.80°	*Shroud Thickness (In.)*	2.00
Total Scan Length Examined (In.)	397.05	*Circumference (In.)*	691.15
Percent of Weld Length Examined	57.44%	*Inches per Degree*	1.92
Percent of Examined ID Weld Length Flawed	39.54%		
Percent of Total ID Weld Length Flawed	22.71%		
			81.77

Weld H-2
45-ODCr

	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H1H2011-1	12.03°	16.43°	10.98°	15.38°	4.40°	5.45°	3.95°	10.98°	39.30°	28.32°
TriModal	H1H2018-1	13.53°	23.98°	12.48°	22.93°	10.45°	11.50°	.00°			0.00°
TriModal	H1H2026-1	21.03°	31.48°	19.98°	30.43°	10.45°	11.50°	8.28°			0.00°
TriModal	H1H2033-1	24.25°	39.30°	23.20°	38.25°	15.05°	16.10°				0.00°
TriModal	H1H2056-1	51.53°	66.38°	50.48°	65.33°	14.85°	15.90°	12.98°	50.48°	126.43°	75.95°
TriModal	H1H2063-1	54.45°	64.35°	53.40°	63.30°	9.90°	10.95°	3.32°			0.00°
TriModal	H1H2071-1	62.08°	72.53°	61.03°	71.48°	10.45°	11.50°	4.13°			0.00°
TriModal	H1H2078-1	69.45°	79.90°	68.40°	78.85°	10.45°	11.50°	4.00°			0.00°
TriModal	H1H2086-1	76.95°	87.40°	75.90°	86.35°	10.45°	11.50°	3.98°			0.00°
TriModal	H1H2093-1	84.47°	94.90°	83.42°	93.85°	10.43°	11.48°	4.00°			0.00°
TriModal	H1H2101-1	91.95°	102.40°	90.90°	101.35°	10.45°	11.50°	4.00°			0.00°
TriModal	H1H2108-1	99.45°	112.65°	98.40°	111.60°	13.20°	14.25°	2.67°			0.00°
TriModal	H1H2116-1	111.03°	126.43°	109.98°	125.38°	15.40°	16.45°				0.00°
TriModal	H1H2191-1	191.53°	196.48°	190.48°	195.43°	4.95°	6.00°	3.00°	190.48°	219.85°	29.37°
TriModal	H1H2198-1	194.53°	204.95°	193.48°	203.90°	10.42°	11.47°	4.97°			0.00°
TriModal	H1H2206-1	201.03°	211.48°	199.98°	210.43°	10.45°	11.50°	8.55°			0.00°
TriModal	H1H2213-1	203.98°	219.85°	202.93°	218.80°	15.87°	16.92°				0.00°

Weld H-2
45-ODCr

	Looking Up Data Files	45° Scan Start	45° Scan End	ODCr Scan Start	ODCr Scan End	Scan Length	45-ODCr Coverage	45-ODCr Overlap		Ligament Start	Ligament End	Ligament Length
TriModal	H1H2243-1	234.45°	244.90°	233.40°	243.85°	10.45°	11.50°	4.00°		233.40°	306.57°	73.17°
TriModal	H1H2251-1	241.95°	252.40°	240.90°	251.35°	10.45°	11.50°	4.00°				0.00°
TriModal	H1H2258-1	249.45°	259.90°	248.40°	258.85°	10.45°	11.50°	4.00°				
TriModal	H1H2266-1	256.95°	267.40°	255.90°	266.35°	10.45°	11.50°	4.00°				
TriModal	H1H2273-1	264.45°	275.03°	263.40°	273.98°	10.58°	11.63°	4.13°				
TriModal	H1H2281-1	271.95°	281.98°	270.90°	280.93°	10.03°	11.08°	3.58°				
TriModal	H1H2288-1	279.45°	292.65°	278.40°	291.60°	13.20°	14.25°	2.55°				
	H1H2296-1	291.15°	306.57°	290.10°	305.52°	15.42°	16.47°					
							304.83°	98.03°				
									Total Ligament Length:			206.80°
								206.80°				
									Percentage of Total Weld Length:			57.44%

Weld H-2

UT Indication Length Summary

Inside Surface Flaws

Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*
1*	NS	ID	12.72°	20.82°	8.10°	15.55	45°
2*	NS	ID	23.49°	25.14°	1.65°	3.17	45°
3	NS	ID	34.49°	35.59°	1.10°	2.11	45°
4	NS	ID	36.14°	38.34°	2.20°	4.22	45°
5*	NS	ID	50.57°	57.33°	6.76°	12.98	45°
6*	NS	ID	64.28°	70.88°	6.60°	12.67	45°
7	NS	ID	72.33°	73.98°	1.65°	3.17	45°
8*	NS	ID	74.53°	81.48°	6.95°	13.34	45°
9*	NS	ID	98.48°	99.58°	1.10°	2.11	45°
10	NS	ID	114.47°	116.12°	1.65°	3.17	45°
11	NS	ID	117.77°	119.97°	2.20°	4.22	45°
12	NS	ID	124.92°	125.47°	1.65°	3.17	45°
13	NS	ID	191.12°	195.52°	4.40°	8.45	45°
14	NS	ID	201.72°	203.37°	1.65°	3.17	45°
15*	NS	ID	203.92°	205.63°	1.71°	3.28	45°
16	NS	ID	233.48°	235.68°	2.20°	4.22	45°
17*	NS	ID	243.18°	261.48°	18.30°	35.14	45°
18*	NS	ID	278.13°	287.83°	9.70°	18.62	45°
19	NS	ID	294.47°	295.57°	1.10°	2.11	45°
20	NS	ID	304.37°	305.47°	1.10°	2.11	45°
					81.77°	157.00	

* Flaw detected in adjacent overlapping scan region.

Weld H-2

UT Indication Depth Summary

Inside Surface Flaws					
No.	*Location*	*Through-Wall Height*	*No.*	*Location*	*Through-Wall Height*
1	13.18°	0.12	32	195.13°	0.17
2	13.03°	0.12	33	196.23°	0.18
3	14.68°	0.11	34	203.93°	0.25
4	17.43°	0.09	35	204.93°	0.24
5	20.18°	0.11	36	204.50°	<0.05
6	20.53°	0.11	37	234.50°	0.18
7	23.28°	0.17	38	235.05°	0.16
8	24.50°	0.10	39	235.60°	0.09
9	34.95°	<0.05	40	244.40°	0.18
10	37.15°	<0.05	41	245.38°	0.07
11	51.03°	0.10	42	247.03°	0.14
12	53.23°	0.12	43	248.68°	0.18
13	54.33°	0.17	44	251.43°	0.11
14	54.50°	0.09	45	256.10°	0.15
15	64.75°	0.28	46	257.75°	0.17
16	69.15°	0.18	47	256.45°	0.18
17	69.50°	0.18	48	257.55°	0.16
18	72.80°	0.31	49	259.75°	0.18
19	77.00°	0.14	50	278.60°	<0.05
20	78.10°	0.08	51	280.25°	<0.05
21	80.85°	<0.05	52	282.80°	<0.05
22	99.15°	0.23	53	283.43°	0.11
23	98.95°	0.17	54	258.63°	<0.05
24	102.88°	0.24	55	286.73°	<0.05
25	115.02°	0.11	56	292.94°	<0.05
26	118.79°	<0.05	57	305.39°	<0.05
27	125.39°	0.17			
28	191.67°	0.08			
29	192.37°	<0.05			
30	192.68°	0.09			
31	194.42°	0.24			

Weld H-3

Examination Summary

Examination from Bottom Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	221.51°	*Shroud Thickness (In.)*	2.00
Total Scan Length Examined (In.)	400.36	*Circumference (In.)*	650.69
Percent of Weld Length Examined	61.53%	*Inches per Degree*	1.81
Percent of Examined OD Weld Length Flawed	56.4%		
Percent of Total OD Weld Length Flawed	30.7%	ID	136.04
Percent of Examined ID Weld Length Flawed	61.4%	OD	110.50
Percent of Total ID Weld Length Flawed	37.8%		

	Weld H-3 45° - ODCr										
	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H3011LU1	6.09°	15.99°	5.04°	14.94°	9.90°	10.95°	3.45°	5.04°	39.91°	34.87°
TriModal	H3018LU1	13.59°	24.04°	12.54°	22.99°	10.45°	11.50°	4.00°			
TriModal	H3026LU1	21.09°	31.54°	20.04°	30.49°	10.45°	11.50°	8.08°			
TriModal	H3033LD1	24.51°	39.91°	23.46°	38.86°	15.40°	16.45°				
TriModal	H3056LU1	51.09°	61.54°	50.04°	60.49°	10.45°	11.50°	8.08°	50.04°	109.96°	59.92°
TriModal	H3063LU1	54.51°	64.96°	53.46°	63.91°	10.45°	11.50°	4.00°			
TriModal	H3071LU1	62.01°	72.46°	60.96°	71.41°	10.45°	11.50°	4.00°			
TriModal	H3078LU1	69.51°	79.96°	68.46°	78.91°	10.45°	11.50°	4.00°			
TriModal	H3086LU1	77.01°	87.46°	75.96°	86.41°	10.45°	11.50°	4.00°			
TriModal	H3093LU1	84.51°	94.96°	83.46°	93.91°	10.45°	11.50°	4.00°			
TriModal	H3101LU1	92.01°	102.46°	90.96°	101.41°	10.45°	11.50°	4.00°			
TriModal	H3108LU1	99.51°	109.96°	98.46°	108.91°	10.45°	11.50°				
TriModal	H3116LU1	111.09°	126.49°	110.04°	125.44°	15.40°	16.45°		110.04°	126.49°	16.45°
TriModal	H3191-0	183.71°	193.61°	182.66°	192.56°	9.90°	10.95°	8.57°	182.66°	219.91°	37.25°
TriModal	H3191-1	186.09°	196.54°	185.04°	195.49°	10.45°	11.50°	4.00°			
TriModal	H3198-1	193.59°	204.04°	192.54°	202.99°	10.45°	11.50°	4.00°			

Weld H-3
45° - ODCr

	Looking Up Data Files	45° Scan Start	45° Scan End	ODCr Scan Start	ODCr Scan End	Scan Length	45-ODCr Coverage	45-ODCr Overlap	Ligament Start	Ligament End	Ligament Length
TriModal	H3206-1	201.09°	211.54°	200.04°	210.49°	10.45°	11.50°	8.08°			
TriModal	H3213-1	204.51°	219.91°	203.46°	218.86°	15.40°	16.45°				
TriModal	H3243LU1	234.51°	244.41°	233.46°	243.36°	9.90°	10.95°	3.45°	233.46°	306.49°	73.03°
TriModal	H3251LU1	242.01°	252.46°	240.96°	251.41°	10.45°	11.50°	4.00°			
TriModal	H3258LU1	249.51°	259.96°	248.46°	258.91°	10.45°	11.50°	4.00°			
TriModal	H3266LU1	257.01°	267.46°	255.96°	266.41°	10.45°	11.50°	4.00°			
TriModal	H3273LU1	264.51°	274.96°	263.46°	273.91°	10.45°	11.50°	4.00°			
TriModal	H3281LU1	272.01°	282.46°	270.96°	281.41°	10.45°	11.50°	4.00°			
TriModal	H3288LU1	279.51°	292.71°	278.46°	291.66°	13.20°	14.25°	2.75°			
TriModal	H3296LU1	291.01°	306.49°	289.96°	305.44°	15.48°	16.53°				
							319.90°	98.40°			

Total Scanned:	319.90°		
Overlap:	98.40°	Total Ligament Length:	221.51°
Net Coverage:	221.51°		
Percentage of Weld Scanned:	61.53%	Percentage of Total Weld Length:	61.53%

Weld H-3

UT Indication Length Summary

Outside Surface Flaws					Inside Surface Flaws				
Flaw No.	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Length (Degrees)*	*Length (Inches)*	*Flaw No.*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Length (Degrees)*	*Length (Inches)*
1*	6.17°	14.97°	8.80°	15.93	1*	6.09°	39.91°	33.82°	61.21
2	18.62°	22.27°	3.65°	6.61	2*	51.09°	80.86°	29.77°	53.88
3	60.69°	63.94°	3.25°	5.88	3	81.41°	83.06°	1.65°	2.99
4	68.69°	73.44°	4.75°	8.60	4	84.71°	89.46°	4.75°	8.60
5	73.99°	76.74°	2.75°	4.98	5	90.56°	91.66°	1.10°	1.99
6	79.29°	80.94°	1.65°	2.99	6*	99.51°	117.69°	18.18°	32.91
7	81.49°	83.14°	1.65°	2.99	7	124.84°	126.49°	1.65°	2.99
8	105.64°	108.94°	3.30°	5.97	8*	188.12°	203.29°	15.17°	27.46
9	113.92°	117.77°	3.85°	6.97	9	213.86°	219.91°	6.05°	10.95
10*	186.46°	198.54°	12.08°	21.86	10	234.51°	237.26°	2.75°	4.98
11	208.79°	210.56°	1.77°	3.20	11	238.31°	240.01°	1.70°	3.08
12	212.21°	218.81°	6.60°	11.95	12	243.11°	249.16°	6.05°	10.95
13*	233.49°	263.14°	29.65°	53.67	13	250.06°	251.91°	1.85°	3.35
14	263.69°	265.89°	2.20°	3.98	14	252.81°	253.91°	1.10°	1.99
15	266.24°	269.54°	3.30°	5.97	15	255.56°	258.86°	3.30°	5.97
16	270.99°	281.24°	10.25°	18.55	16	259.96°	262.16°	2.20°	3.98
17*	282.34°	286.19°	3.85°	6.97	17	291.09°	292.19°	1.10°	1.99
18*	292.27°	295.02°	2.75°	4.98	18	294.94°	298.79°	3.85°	6.97
19	296.67°	298.32°	1.65°	2.99					
20	301.07°	302.17°	1.10°	1.99					
21*	303.27°	304.92°	1.65°	2.99					
		Totals:	110.50°	200.01			Totals:	136.04°	246.23

Weld H-3

UT Indication Depth Summary

Inside Surface Flaws				Outside Surface Flaws			
Location	*Through-Wall Height*	*Location*	*Through-Wall Height*	*Location*	*Through-Wall Height*	*Location*	*Through-Wall Height*
6.69°	0.22	91.16°	0.22				
9.99°	0.19	100.66°	0.10	6.64°	0.15	254.46°	0.16
11.09°	0.16	101.76°	0.10	8.29°	0.11	255.56°	0.15
13.29°	0.25	103.41°	0.26	9.39°	0.11	258.11°	0.15
14.94°	0.10	104.51°	0.21	10.49°	0.16	261.06°	<0.05
16.89°	0.28	105.61°	0.24	12.14°	0.11	262.51°	0.10
21.84°	0.36	107.26°	0.10	13.24°	0.17	265.26°	0.11
22.24°	0.25	110.54°	0.20	19.64°	0.21	265.71°	0.15
23.49°	0.24	111.64°	0.10	62.76°	0.2	268.91°	0.10
26.64°	0.34	113.84°	0.21	72.26°	0.19	274.41°	0.10
27.74°	0.25	115.49°	0.18	74.46°	0.07	276.41°	0.06
30.49°	0.31	117.14°	0.20	75.56°	0.18	280.26°	0.11
31.71°	0.27	125.99°	0.27	76.11°	0.21	282.94°	0.24
33.36°	0.26	194.39°	<0.05	80.31°	0.19	292.74°	0.12
34.46°	0.17	197.49°	0.19	106.66°	0.17	297.14°	0.12
36.11°	0.25	210.01°	<0.05	107.76°	0.16		
51.69°	0.21	214.46°	<0.05	108.86°	0.22		
53.34°	0.18	217.21°	0.19	114.39°	0.17		
56.64°	0.35	218.31°	<0.05	116.04°	0.14		
57.74°	0.28	235.11°	0.10	187.57°	<0.05		
61.71°	0.15	236.21°	0.19	188.67°	<0.05		
63.36°	0.30	243.71°	0.16	189.77°	0.09		
64.46°	0.25	244.26°	0.19	191.97°	<0.05		
65.91°	0.31	245.36°	0.19	192.69°	<0.05		
67.01°	0.39	246.46°	0.10	194.34°	<0.05		
68.86°	0.27	248.11°	0.14	195.99°	<0.05		
69.76°	0.23	250.86°	0.17	216.06°	<0.05		
72.31°	0.25	253.41°	0.11	217.71°	<0.05		
73.96°	0.36	256.71°	0.10	235.06°	0.29		
75.06°	0.37	257.06°	0.17	236.71°	0.14		
76.16°	0.24	258.16°	0.30	240.67°	0.33		
77.81°	0.27	258.71°	0.13	242.76°	0.15		
78.71°	0.24	291.14°	0.10	243.86°	0.15		
80.36°	0.32	296.09°	0.11	245.86°	0.15		
82.59°	<0.05	296.94°	0.10	249.71°	0.14		
85.31°	0.24	301.62°	<0.05	251.36°	0.14		
85.66°	0.22	304.37°	<0.05	253.36°	0.17		
88.41°	0.24						

Weld H-4

Examination Summary

Examination of Top Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	229.65°	Shroud Thickness (In.)	2.00
Total Scan Length Examined (In.)	415.08	Circumference (In.)	650.69
Percent of Weld Length Examined	63.79%	Inches per Degree	1.81
Percent of Examined OD Weld Length Flawed	40.85%	Total Flawed Length (In.)	169.80
Percent of Total OD Weld Length Flawed	26.06%	Total Flawed Length (Deg.)	93.81°
		OD	93.81

								Weld H-4 45-ODCr			
	Looking Down Data Files	*ODCr Scan Start*	*ODCr Scan End*	*45° Scan Start*	*45° Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H4011-1	6.06°	13.76°	5.01°	12.71°	7.70°	8.75°		5.01°	13.76°	8.75°
TriModal	H4026-1	16.98°	25.78°	15.93°	24.73°	8.80°	9.85°	5.77°	15.93°	36.46°	20.53°
TriModal	H4026-2	21.06°	36.46°	20.01°	35.41°	15.40°	16.45°				
TriModal	H4056-1	51.06°	66.46°	50.01°	65.41°	15.40°	16.45°	13.03°	50.01°	126.92°	76.91°
TriModal	H4063-1	54.48°	69.88°	53.43°	68.83°	15.40°	16.45°	1.43°			
TriModal	H4078-1	69.50°	84.90°	68.45°	83.85°	15.40°	16.45°	1.47°			
TriModal	H4098-1	84.48°	99.88°	83.43°	98.83°	15.40°	16.45°	1.45°			
TriModal	H4108-1	99.48°	114.88°	98.43°	113.83°	15.40°	16.45°	4.41°			
TriModal	H4116-1	111.52°	126.92°	110.47°	125.87°	15.40°	16.45°				
Trimodal(SC)	H4168-1	164.72°	170.77°	163.67°	169.72°	6.05°	7.10°		163.67°	170.77°	7.10°
TriModal	H4191-0	183.63°	194.08°	182.58°	193.03°	10.45°	11.50°	9.07°	182.58°	219.88°	37.30°
TriModal	H4191-1	186.06°	196.51°	185.01°	195.46°	10.45°	11.50°	4.00°			
TriModal	H4198-1	193.56°	204.01°	192.51°	202.96°	10.45°	11.50°	4.00°			
TriModal	H4206-1	201.06°	211.51°	200.01°	210.46°	10.45°	11.50°	8.08°			
TriModal	H4213-1	204.48°	219.88°	203.43°	218.83°	15.40°	16.45°				

							Weld H-4 45-ODCr				
	Looking Down Data Files	*ODCr Scan Start*	*ODCr Scan End*	*45° Scan Start*	*45° Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H4243-1	235.55°	249.85°	234.50°	248.80°	14.30°	15.35°	1.40°	234.50°	306.48°	71.98°
TriModal	H4258-1	249.50°	264.90°	248.45°	263.85°	15.40°	16.45°	1.45°			
TriModal	H4273-1	264.50°	279.90°	263.45°	278.85°	15.40°	16.45°	1.45°			
TriModal	H4288-1	279.50°	294.95°	278.45°	293.90°	15.45°	16.50°	4.92°			
TriModal	H4296-1	291.08°	306.48°	290.03°	305.43°	15.40°	16.45°				
Trimodal(SC)	H4341-3	344.72°	350.77°	343.67°	349.72°	6.05°	7.10°		343.67°	350.77°	7.10°
									Total Ligament Length:		229.65°
									Percentage of Total Weld Length:		63.79%

(SC) = Suction Cup Scanner

Weld H-4

UT Indication Length and Depth Summary

Outside Surface Flaws											
Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*	*Maximum Flaw Height*	*Flaw Thru-Wall Percent*	*Remaining Ligament (Inches)*	*Through-Wall Search Unit*
1	NS	OD	7.79°	11.09°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
2*	NS	OD	12.11°	15.49°	3.38°	6.12	ODCr	0.10	5.00%	1.90	45°
3	NS	OD	16.59°	18.24°	1.65°	2.99	ODCr	0.10	5.00%	1.90	45°
4	NS	OD	21.06°	22.16°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
5*	NS	OD	23.03°	26.56°	3.53°	6.39	ODCr	0.10	5.00%	1.90	45°
6	NS	OD	28.76°	32.06°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
7	NS	OD	33.16°	35.91°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
8	NS	OD	51.13°	52.78°	1.65°	2.99	ODCr	0.10	5.00%	1.90	45°
9	NS	OD	53.33°	55.53°	2.20°	3.98	ODCr	0.10	5.00%	1.90	45°
10*	NS	OD	57.68°	70.58°	12.90°	23.35	ODCr	0.11	5.50%	1.89	45°
11	NS	OD	73.88°	76.63°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
12	NS	OD	86.68°	89.98°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
13	NS	OD	96.58°	98.23°	1.65°	2.99	ODCr	0.10	5.00%	1.90	45°
14	NS	OD	104.98°	107.73°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
15	NS	OD	110.48°	111.58°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
16*	NS	OD	114.82°	118.12°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
17	NS	OD	119.22°	120.32°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
18	NS	OD	126.37°	127.47°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
19	NS	OD	166.20°	167.70°	1.50°	2.72	ODCr	0.10	5.00%	1.90	45°
20	NS	OD	186.06°	187.71°	1.65°	2.99	ODCr	0.10	5.00%	1.90	45°
21	NS	OD	189.91°	194.31°	4.40°	7.96	ODCr	0.10	5.00%	1.90	45°
22	NS	OD	194.66°	197.41°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
23	NS	OD	203.81°	208.76°	4.95°	8.96	ODCr	0.10	5.00%	1.90	45°
24	NS	OD	236.94°	239.69°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
25	NS	OD	244.35°	246.00°	1.65°	2.99	ODCr	0.10	5.00%	1.90	45°

Weld H-4

UT Indication Length and Depth Summary

Outside Surface Flaws

Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*	*Maximum Flaw Height*	*Flaw Thru-Wall Percent*	*Remaining Ligament (Inches)*	*Through-Wall Search Unit*
26	NS	OD	248.20°	249.30°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
27	NS	OD	253.40°	256.70°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
28	NS	OD	258.35°	259.45°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
29	NS	OD	260.00°	261.10°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
30	NS	OD	262.20°	263.30°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
31	NS	OD	280.70°	282.70°	2.00°	3.62	ODCr	0.10	5.00%	1.90	45°
32	NS	OD	294.93°	298.23°	3.30°	5.97	ODCr	0.10	5.00%	1.90	45°
33	NS	OD	298.78°	301.53°	2.75°	4.98	ODCr	0.10	5.00%	1.90	45°
34	NS	OD	305.38°	306.48°	1.10°	1.99	ODCr	0.10	5.00%	1.90	45°
35	NS	OD	343.70°	344.70°	1.00°	1.81	ODCr	0.10	5.00%	1.90	45°
36	NS	OD	344.70°	348.20°	3.50°	6.34	ODCr	0.10	5.00%	1.90	45°
					93.81°	169.80					

Weld H-5

Examination Summary

Examination from Top Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	221.09°	Shroud Thickness (In.)	2.00
Total Scan Length Examined (In.)	399.61	Circumference (In.)	650.69
Percent of Weld Length Examined	61.41%	Inches per Degree	1.81
Percent of Examined OD Weld Length Flawed	1.73%	Total Flawed Length (In.)	131.06
Percent of Total OD Weld Length Flawed	1.06%	Total Flawed Length (Deg.)	72.41°
Percent of Examined ID Weld Length Flawed	8.17%	ID	18.06
Percent of Total ID Weld Length Flawed	5.02%	OD	3.83

		Weld H-5 45-ODCr								
	Looking Down Data Files	*ODCr Scan Start*	*ODCr Scan End*	*45° Scan Start*	*45° Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H5011LD1	6.12°	16.57°	5.07°	15.52°	10.45°	11.50°	4.00°	5.07°	39.94°	34.87°
TriModal	H5018LD1	13.62°	24.07°	12.57°	23.02°	10.45°	11.50°	4.00°			
TriModal	H5026LD1	21.12°	31.57°	20.07°	30.52°	10.45°	11.50°	8.08°			
TriModal	H5033LD1	24.54°	39.94°	23.49°	38.89°	15.40°	16.45°				
TriModal	H5056LD1	51.12°	61.57°	50.07°	60.52°	10.45°	11.50°	8.08°	50.07°	126.52°	76.45°
TriModal	H5063LD1	54.54°	64.99°	53.49°	63.94°	10.45°	11.50°	4.00°			
TriModal	H5071LD1	62.04°	72.49°	60.99°	71.44°	10.45°	11.50°	4.00°			
TriModal	H5078LD1	69.54°	79.99°	68.49°	78.94°	10.45°	11.50°	4.00°			
TriModal	H5086LD1	77.04°	87.49°	75.99°	86.44°	10.45°	11.50°	4.00°			
TriModal	H5093LD1	84.54°	94.99°	83.49°	93.94°	10.45°	11.50°	4.00°			
TriModal	H5101LD1	92.04°	102.49°	90.99°	101.44°	10.45°	11.50°	4.00°			
TriModal	H5108LD1	99.54°	112.74°	98.49°	111.69°	13.20°	14.25°	2.67°			
TriModal	H5116LD1	111.12°	126.52°	110.07°	125.47°	15.40°	16.45°				
TriModal	H5190-1	183.63°	194.08°	182.58°	193.03°	10.45°	11.50°	9.07°	182.58°	219.33°	36.75°
TriModal	H5191-1	186.06°	195.96°	185.01°	194.91°	9.90°	10.95°	4.44°			

Weld H-5
45-ODCr

	Looking Down Data Files	*ODCr Scan Start*	*ODCr Scan End*	*45° Scan Start*	*45° Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H5198-1	192.57°	203.02°	191.52°	201.97°	10.45°	11.50°	3.01°			
TriModal	H5206-1	201.06°	211.51°	200.01°	210.46°	10.45°	11.50°	8.08°			
TriModal	H5213-1	204.48°	219.33°	203.43°	218.28°	14.85°	15.90°				
TriModal	H5243LD1	234.54°	244.99°	233.49°	243.94°	10.45°	11.50°	4.00°	233.49°	306.52°	73.03°
TriModal	H5251LD1	242.04°	252.49°	240.99°	251.44°	10.45°	11.50°	4.00°			
TriModal	H5258LD1	249.54°	259.99°	248.49°	258.94°	10.45°	11.50°	4.00°			
TriModal	H5266LD1	257.04°	267.49°	255.99°	266.44°	10.45°	11.50°	4.00°			
TriModal	H5273LD1	264.54°	274.99°	263.49°	273.94°	10.45°	11.50°	4.00°			
TriModal	H5281LD1	272.04°	282.49°	270.99°	281.44°	10.45°	11.50°	4.00°			
TriModal	H5288LD1	279.54°	292.74°	278.49°	291.69°	13.20°	14.25°	2.67°			
	H5296LD1	291.12°	306.52°	290.07°	305.47°	15.40°	16.45°				
							323.12°	102.03°			
										Total Ligament Length:	221.09°
							221.09°				
										Percentage of Total Weld Length:	61.41%

Weld H-5

UT Indication Length Summary

inside and Outside Surface Flaws							
Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Search Unit*
1	NS	ID	58.44°	59.97°	1.53°	2.77	45°
2*	NS	ID	77.01°	80.31°	3.30°	5.97	45°
3	NS	OD	77.29°	78.36°	1.07°	5.00	ODCr
4	NS	OD	83.49°	86.25°	2.76°	6.97	ODCr
5	NS	ID	90.91°	94.76°	3.85°	4.98	45°
6*	NS	ID	97.51°	100.26°	2.75°	6.03	45°
7*	NS	ID	109.49°	112.82°	3.33°	6.03	45°
8	NS	ID	121.62°	123.82°	2.20°	3.98	45°
9	NS	ID	183.11°	184.21°	1.10°	1.99	45°
Total Flaw Length at Inside Surface:			18.06°				
Total Flaw Length at Outside Surface:			3.83°				
*Flaw detected in adjacent overlapping scans							

Weld H-5

UT Indication Depth Summary

Inside Surface Flaws				Outside Surface Flaws			
No.	*Sizing Location*	*Through-Wall Height*	*Search Unit*	*No.*	*Sizing Location*	*Through-Wall Height*	*Search Unit*
1	59.42°	<0.05	60°	1	77.84°	<0.05	45°
2	58.96°	<0.05	60°	2	84.04°	<0.05	45°
3	78.39°	<0.05	60°				
4	92.09°	<0.05	60°				
5	93.74°	<0.05	60°				
6	98.14°	<0.05	60°				
7	99.79°	<0.05	60°				
8	111.72°	<0.05	60°				
9	122.17°	<0.05	60°				
10	123.82°	<0.05	60°				
11	183.11	<0.05	60°				

Weld H-6

Examination Summary

Examination from Bottom Side of Weld - 45 & ODCr Coverage

Total Scan Length Examined (Deg.)	214.21	Shroud Thickness (In.)	2.00
Total Scan Length Examined (In.)	346.69	Circumference (In.)	630.67
Percent of Weld Length Examined	59.50%	Inches per Degree	1.75
Percent of Examined ID Weld Length Flawed	64.8%	Total Flawed Length (In.)	242.90
Percent of Total ID Weld Length Flawed	38.6%	Total Flawed Length (Deg.)	138.80°

		Weld H-6 45° - OCDr								
	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H6011LU1	6.09°	16.54°	5.04°	15.49°	10.45°	11.50°	4.00°	5.04°	39.36°	34.32°
TriModal	H6018LU1	13.59°	24.04°	12.54°	22.99°	10.45°	11.50°	4.00°			
TriModal	H6026LU1	21.09°	31.54°	20.04°	30.49°	10.45°	11.50°	8.08°			
TriModal	H6033LD1	24.51°	39.36°	23.46°	38.31°	14.85°	15.90°				
TriModal	H6056LU1	51.09°	61.54°	50.04°	60.49°	10.45°	11.50°	11.50°	50.04°	126.49°	76.45°
TriModal	H6063LU1	51.09°	61.54°	50.04°	60.49°	10.45°	11.50°	0.58°			
TriModal	H6071LU1	62.01°	72.46°	60.96°	71.41°	10.45°	11.50°	4.00°			
TriModal	H6078LU1	69.51°	79.96°	68.46°	78.91°	10.45°	11.50°	4.00°			
TriModal	H6086LU1	77.01°	87.46°	75.96°	86.41°	10.45°	11.50°	4.00°			
TriModal	H6093LU1	84.51°	94.96°	83.46°	93.91°	10.45°	11.50°	4.00°			
TriModal	H6101LU1	92.01°	102.46°	90.96°	101.41°	10.45°	11.50°	4.00°			
TriModal	H6108LU2	99.51°	112.16°	98.46°	111.11°	12.65°	13.70°	2.12°			
TriModal	H6116LU2	111.09°	126.49°	110.04°	125.44°	15.40°	16.45°				
TriModal	H6191-0	183.71°	193.61°	182.66°	192.56°	9.90°	10.95°	8.57°	182.66°	219.36°	36.70°
TriModal	H6191-1	186.09°	196.54°	185.04°	195.49°	10.45°	11.50°	3.00°			
TriModal	H6198LU1	194.59°	205.04°	193.54°	203.99°	10.45°	11.50°	5.00°			
TriModal	H6206LU1	201.09°	211.54°	200.04°	210.49°	10.45°	11.50°	8.08°			
TriModal	H6213LU1	204.51°	219.36°	203.46°	218.31°	14.85°	15.90°				

						Weld H-6 45° - ODCr					
	Looking Up Data Files	*45° Scan Start*	*45° Scan End*	*ODCr Scan Start*	*ODCr Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*		*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H6243LU1	238.59°	247.47°	237.54°	246.42°	8.88°	9.93°	6.51°		237.54°	304.29°	66.75°
TriModal	H6251LU1	242.01°	252.46°	240.96°	251.41°	10.45°	11.50°	4.00°				
TriModal	H6258LU1	249.51°	259.96°	248.46°	258.91°	10.45°	11.50°	4.00°				
TriModal	H6266LU1	257.01°	267.46°	255.96°	266.41°	10.45°	11.50°	4.00°				
TriModal	H6273LU1	264.51°	275.04°	263.46°	273.99°	10.53°	11.58°	4.08°				
TriModal	H6281LU1	272.01°	282.46°	270.96°	281.41°	10.45°	11.50°	4.00°				
TriModal	H6288LU1	279.51°	292.71°	278.46°	291.66°	13.20°	14.25°	2.67°				
TriModal	H6296LU1	291.09°	304.29°	290.04°	303.24°	13.20°	14.25°					
							318.33°	104.12°				
		Total Scanned:			318.33°							
		Overlap:			104.12°				Total Ligament Length:			214.21°
		Net Coverage:			214.21°							
		Percentage of Weld Scanned:			59.50%				Percentage of Total Weld Length:			59.50%

Weld H-6

UT Indication Length Summary

Inside Surface Flaws

Flaw No.	*Weld Side*	*Initiating Surface*	*Flaw Start (Degrees)*	*Flaw End (Degrees)*	*Flaw Length (Degrees)*	*Flaw Length (Inches)*	*Length Search Unit*
1*	NS	ID	6.09°	21.84°	15.75°	27.56	45.00°
2*	NS	ID	22.19°	39.36°	17.17°	30.05	45.00°
3*	NS	ID	51.09°	63.11°	12.02°	21.04	45.00°
4*	NS	ID	65.86°	68.61°	2.75°	4.81	45.00°
5*	NS	ID	69.16°	79.76°	10.60°	18.55	45.00°
6	NS	ID	82.51°	88.36°	5.85°	10.24	45.00°
7*	NS	ID	91.11°	93.86°	2.75°	4.81	45.00°
8*	NS	ID	92.01°	96.96°	4.95°	8.66	45.00°
9*	NS	ID	97.51°	123.19°	25.68°	44.94	45.00°
10*	NS	ID	187.74°	193.24°	5.50°	9.63	45.00°
11*	NS	ID	204.39°	205.49°	1.10°	1.93	45.00°
12*	NS	ID	209.34°	214.41°	5.07°	8.87	45.00°
13*	NS	ID	215.51°	219.36°	3.85°	6.74	45.00°
14*	NS	ID	238.59°	239.69°	1.10°	1.92	45.00°
15*	NS	ID	245.31°	247.39°	2.08°	3.64	45.00°
16	NS	ID	248.06°	250.26°	2.20°	3.85	45.00°
17*	NS	ID	262.51°	265.26°	2.75°	4.81	45.00°
18*	NS	ID	275.31°	276.96°	1.65°	2.89	45.00°
19*	NS	ID	283.91°	294.94°	11.03°	19.30	45.00°
20	NS	ID	296.04°	298.24°	2.20°	3.85	45.00°
21*	NS	ID	301.54°	304.29°	2.75°	4.81	45.00°
				Total Degrees:	138.80°		
				Total Inches:	242.90		

Weld H-6

UT Indication Depth Summary

Inside Surface Flaws

Location	*Through-Wall Height*		*Location*	*Through-Wall Height*	
1	7.79°	0.08	32	103.96°	0.23
2	9.99°	0.07	33	105.06°	0.16
3	12.74°	0.06	34	107.26°	0.17
4	14.39°	0.06	35	111.69°	0.18
5	16.39°	0.06	36	113.34°	0.17
6	19.14°	0.06	37	117.74°	0.24
7	20.24°	<0.05	38	119.94°	0.19
8	23.89°	0.10	39	188.89°	0.21
9	25.54°	0.06	40	191.64°	0.27
10	29.39°	0.15	41	192.74°	0.35
11	30.06°	0.15	42	204.94°	<0.05
12	31.63°	0.21	43	210.49°	0.26
13	37.21°	0.17	44	211.25°	0.28
14	51.14°	0.16	45	212.90°	0.20
15	52.24°	0.27	46	217.03°	0.15
116	53.85°	0.29	47	239.19°	0.07
17	52.24°	0.23	48	245.36°	<0.05
18	54.99°	0.14	49	250.11°	<0.05
19	58.84°	0.23	50	263.66°	0.27
20	61.51°	0.22	51	264.56°	0.19
21	67.01°	0.19	52	275.91°	0.30
22	70.86°	0.18	53	285.61°	0.20
23	73.96°	0.24	54	286.71°	0.27
24	76.16°	0.20	55	288.36°	0.28
25	83.11°	<0.05	56	289.46°	0.28
226	84.76°	0.12	57	292.21°	0.28
217	86.76°	0.10	58	293.89°	0.16
28	93.86°	0.27	59	297.19°	0.16
29	95.91°	0.24	60	302.69°	<0.05
30	98.66°	0.18			
31	100.66°	0.28			

Weld H-7

Examination Summary

Total Scan Length Examined (Deg.)	212.74°	*Shroud Thickness (In.)*	2.00
Total Scan Length Examined (In.)	372.69	*Circumference (In.)*	630.67
Percent of Weld Length Examined	59.09%	*Inches per Degree*	1.75
Percent of Examined Weld Length Flawed	0.0%		
Percent of Total Weld Length Flawed	0.0%		

	Weld H-7 45-ODCr									
	Looking Down Data Files	*ODCr Scan Start*	*ODCr Scan End*	*45° Scan Start*	*45° Scan End*	*Scan Length*	*45-ODCr Coverage*	*45-ODCr Overlap*	*Ligament Start*	*Ligament End*	*Ligament Length*
TriModal	H7011LD1	6.08°	21.48°	5.03°	20.43°	15.40°	16.45°	5.53°	5.03°	36.42°	31.39°
TriModal	H7026LD1	17.00°	22.50°	15.95°	21.45°	5.50°	6.55°	2.47°			
TriModal	H7026LD2	21.08°	36.42°	20.03°	35.37°	15.34°	16.39°				
	H7041LD1	Not Scanned									
	H7048LD1	Not Scanned									
TriModal	H7063LD1	54.50°	69.90°	53.45°	68.85°	15.40°	16.45°	1.45°	53.45°	126.48°	73.03°
TriModal	H7078LD1	69.50°	84.90°	68.45°	83.85°	15.40°	16.45°	1.45°			
TriModal	H7093LD1	84.50°	99.90°	83.45°	98.85°	15.40°	16.45°	1.45°			
TriModal	H7108LD1	99.50°	114.90°	98.45°	113.85°	15.40°	16.45°	1.87°			
TriModal	H7116LD1	111.08°	126.48°	110.03°	125.43°	15.40°	16.45°				
	H7123LD1	Not Scanned									
	H7183LD1	Not Scanned									
TriModal	H7191LD1	186.08°	201.48°	185.03°	200.43°	15.40°	16.45°	1.45°	185.03°	216.48°	31.45°
TriModal	H7206LD1	201.08°	216.48°	200.03°	215.43°	15.40°	16.45°				
	H7221LD1	Not Scanned									
	H7236LD1	Not Scanned									
TriModal	H7243LD	235.55°	249.87°	234.50°	248.82°	14.32°	15.37°	1.42°	234.50°	311.38°	76.88°
TriModal	H7258LD1	249.50°	264.95°	248.45°	263.90°	15.45°	16.50°	1.50°			

Weld H-7
45-ODCr

	Looking Down Data Files	ODCr Scan Start	ODCr Scan End	45° Scan Start	45° Scan End	Scan Length	45-ODCr Coverage	45-ODCr Overlap	Ligament Start	Ligament End	Ligament Length
TriModal	H7273LD1	264.50°	279.95°	263.45°	278.90°	15.45°	16.50°	1.50°			
TriModal	H7288LD1	279.50°	294.95°	278.45°	293.90°	15.45°	16.50°	4.92°			
TriModal	H7296LD1	291.08°	306.53°	290.03°	305.48°	15.45°	16.50°	6.40°			
TriModal	H7303LD1	301.18°	311.38°	300.13°	310.33°	10.20°	11.25°				
	H7356LD1	Not Scanned									
							247.11°	34.37°			

Total Scanned:	247.11°		
Overlap:	34.37°	Total Ligament Length:	212.74°
Net Coverage:	212.74°		
Percentage of Weld Scanned:	59.09%	Percentage of Total Weld Length:	59.09%

PECO ENERGY COMPANY
LIMERICK GENERATING STATION
UNIT 2
REACTOR PRESSURE VESSEL CORE SHROUD INSPECTIONS
2R05 INSPECTION FINAL REPORT
May 1999

ATTACHMENT 3

Structural Integrity Associates Report
Evaluation of the Limerick, Unit 2 Shroud Examination Results
Report No. SIR-99-061, Revision 0
May 14, 1999

(21 Pages)

May 14, 1999
SIR-99-061
RAM-99-053

rmattson@structint.com

Mr. Richard E. Ciemiewicz
PECO Energy Systems
965 Chesterbrook Blvd., 63B-3
Wayne, PA 19087-5691

Subject: Evaluation of Limerick, Unit 2 Shroud Examination Results

Dear Rich:

Structural Integrity Associates (SI) has performed an evaluation of the ultrasonic examination results recorded during the 1999 inspections of shroud circumferential welds H1 through H7 at Limerick, Unit 2, in order to determine acceptance for continual operation. The evaluations performed and documented herein were designed to justify operation without reinspection of these welds for at least one two year operating cycle. The evaluations were performed following the approach used in the BWR Vessel and Internals Project (BWRVIP) shroud evaluation guidelines [1], based on limit load and linear elastic fracture mechanics (LEFM) techniques. The following sections of this report describe the methodology used to evaluate each weld, the resulting safety margins, and the recommended inspection intervals.

INSPECTION AND EVALUATION METHODOLOGY

The inspection and evaluation approach employed at Limerick, Unit 2 provides the necessary information for determination of the required amount of unflawed material to meet specified safety margins, including the appropriate amount for postulated crack growth and nondestructive examination detection and sizing uncertainties. Ultrasonic examination (UT) techniques were utilized which provided complete through-thickness interrogation of all welds. Due to accessibility limitations, the circumferential extent of examination of these welds varied. However, sufficient weld length was adequately interrogated to quantifiably demonstrate the condition, and hence, the structural integrity of all welds evaluated. Because both limit load and LEFM assessments have been performed, evaluation methodologies will be addressed separately with respect to structural integrity evaluation.

ACCEPTANCE CRITERIA

The core shroud is a core support structure which provides lateral support for the fuel. The applicable codes, standards and classification for the core shroud are as follows:

- The core shroud is classified as a safety-related component.
- The core shroud is not an ASME Code, Section III component. However, the original design is in accordance with the intent of Section III of the ASME Code.
- The evaluation of the core shroud was performed in accordance with the requirements of the BWRVIP's shroud evaluation guidelines [1].

FLAW EVALUATION RESULTS

Based upon the inspection data reported in 1999, flaw evaluations were performed to justify continued operation, with the results documented herein. The analyses were performed using limit load as the failure criterion for each of the welds. The analyses performed take into account the distribution of good material at each weld around the circumference of the shroud. In addition, the H4 weld, which is the most highly irradiated, was evaluated using the LEFM methodology.

Substantial conservatisms were built into the evaluation to account for the weld area examined, the weld area which was not examined, evaluation guidelines' detection and sizing uncertainties, crack growth, and the evaluation guidelines' flaw proximity criteria as applied to adjacent flaws. The specific conservatisms utilized in this evaluation are as follows:

1. All areas not examined were considered cracked through-wall for all evaluations.
2. A bounding crack growth rate (5×10^{-5} inches/hour) [1] in the length and depth directions was applied to all identified flaws, as well as to all the uninspected regions.
3. UT inspection uncertainty factors were applied to all identified indications, as well as to uninspected regions.
4. Two years of crack growth were included in the evaluation of all welds.
5. ASME Code, Section XI proximity criteria for adjacent flaws were applied, after accounting for crack growth and inspection uncertainties.
6. ASME Code, Section XI pressure boundary safety margins were applied to these evaluations even though the core shroud is not a primary pressure boundary.
7. Dead weight of the shroud and supported components was conservatively ignored.

The conservative assumptions described above were applied to each of the horizontal welds examined in this report. Table 1 documents the input data. Tables 2 through 8 present the results of the ultrasonic examination for each of the horizontal welds evaluated in this report.

The results of the limit load analyses for each of the horizontal welds examined are presented in Table 9, based upon the stresses reported in Table 1, and the examination results reported in Tables 2 through 8. Based upon the stresses reported in Table 1, the upset condition governs for welds H2 through H7, while the faulted condition governs for weld H1. One observes from Table 9 that the factors-of-safety for the upset condition vary from 4.50 to 15.15, and for the faulted condition the factor-of-safety is 1.89. This compares to ASME Code minimum factors-of-safety of 2.77 and 1.39, respectively, specified for pressure boundary components [1]. One should note that the conservatisms utilized in this study are as described previously in this section.

Finally, an evaluation of the H4 weld was performed using the LEFM methodology to determine the applied stress intensity factor resulting from the bounding loading conditions. The results of this analysis demonstrate that the 150 ksi $\sqrt{\text{inch}}$ material toughness which is presented in the evaluation guidelines [1] as the acceptable fracture toughness for this material under irradiation embrittled conditions is met. Table 10 illustrates that the evaluation guidelines [1] minimum required factors-of-safety have been met for weld H4.

SUMMARY

Based upon a review of the examination data for circumferential welds H1 through H7, there is substantial margin for each of these welds under conservative, bounding conditions to allow for continued operation for at least one twenty-four month cycle. The analyses performed included limit load analyses under bounding design basis conditions, and LEFM evaluations for the postulated highest fluence weld. The evaluations were performed with the assumption that all regions uninspected, or reported with flaws, were cracked through-wall for all calculations. Additionally, all uninspected areas and areas with reported cracking were grown in the length and depth directions at the bounding crack growth rate of 5×10^{-5} inches/hour, and increased in length and depth by UT uncertainty factors. Required safety margins were used, and were exceeded in all cases.

Very truly yours,

Prepared by:

Original Signed By:

R. A. Mattson, P. E.

Reviewed by:

Original Signed By:

M. L. Herrera, P. E.

pq
Attachments

REFERENCES

1. BWR Vessel and Internals Project, "BWR Core Shroud Inspection and Flaw Evaluation Guideline, Revision 2 (BWRVIP-01)," EPRI Report No. TR-107079, October 1996, SI File No. BWRVIP-01-201P.

2. Fax from Rich Ciemiewicz (PECO) to Dick Mattson (SI) with Attached Figure, May 9, 1999, SI File No. PECO-30Q-211.

3. GE Nuclear Energy, "Evaluation of the Limerick Unit-1 Core Shroud Inspections (Refuel Outage 6)," Report No. GE-NE-B13-01805-16, February 1996, SI File No. PECO-30Q-202.

4. GE Nuclear Energy, "Determination of Inspection Lengths for the Limerick Unit-1 Shroud," Report No. GENE-523-A037-0495, July 1995, SI File No. PECO-30Q-205.

5. Structural Integrity Associates, "Impact of RIPD's on the Shroud Evaluation for Limerick Generating Station, Unit 1," Report No. SIR-99-046, April 9, 1999, SI File No. PECO-30Q-401.

6. BWR Vessel and Internals Project, "Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03), Revision 1," EPRI Report No. TR-105696-R1, March 1999, SI File No. BWRVIP-01-203P.

7. E-mail from Richard Ciemiewicz (PECO) to Dick Mattson (SI) dated May 13, 1999, 9:52 a.m., SI File No. PECO-30Q-213.

8. Structural Integrity Associates, Software User Manual, "ANSC for Determining Net Section Collapse of Arbitrarily Thinned Cylinder," Report No. SIR-94-035, Revision 0, April 29, 1994, SI File No. QA-1900.

9. Tada, H., "The Stress Analysis of Cracks Handbook," Paris Productions Inc., Second Edition, 1985.

10. Electric Power Research Institute, "Ductile Fracture Handbook," Report No. NP-6301-D, June 1989.

11. Rooke, D. P. and Cartwright, D. J., "Compendium of Stress Intensity Factors," The Hillingdon Press, 1976.

12. BWR Vessel and Internals Project, "Evaluation of Crack Growth in BWR Stainless Steel RPV Internals (BWRVIP-14)," EPRI Report No. TR-105873, March 1996, SI File No. BWRVIP-01-214P.

13. Letter from Carl Terry (BWRVIP Chairman) to C. E. Carpenter (U.S. NRC), "Project No. 704 – BWRVIP Response to NRC Safety Evaluation of BWRVIP-14," November 24, 1998, SI File No. EPRI-89-403.

1. Letter from Carl Terry (Vice President, Niagara Mohawk Power Corporation) to U.S. NRC Docket Control Desk, Letter Number NMP2L 1803, July 9, 1998, SI File No. PECO-30Q-214.

Table 1

Design Input[1]

Weld Designation	Shroud Mean Radius [2]	Shroud Thickness [2]	Bending Moment Stresses (ksi)		Pressure Differential Stresses (ksi)	
			Upset	Faulted	Upset	Faulted
H1	109.0"	2.0"	0.594[4]	1.045[4]	0.322[3]	0.777[3]
H2	109.0"	2.0"	0.810[4]	1.377[4]	0.322[3]	0.777[3]
H3	102.5625"	2.0"	0.935[3]	1.583[3]	0.300[3]	0.724[3]
H4	102.5625"	2.0"	1.471[3]	2.411[3]	0.300[3]	0.724[3]
H5	102.5625"	2.0"	2.740[3]	4.468[3]	0.300[3]	0.724[3]
H6	99.375"	2.0"	2.982[2]	4.851[2]	0.570[5]	1.000[5]
H7	99.375"	2.0"	3.746[3]	6.140[3]	0.570[5]	1.000[5]

Notes: 1. Other design input includes the following:
- The shroud material is Type 304L stainless steel, with S_m equal to 14.4 ksi at 550°F [4].
- The crack growth rate to be used is 5×10^{-5} inches/hour [1]. For purposes of this evaluation, it is assumed that Limerick, Unit 2 is on twenty-four month fuel cycles, with 16,000 hours per cycle.
- The factors-of-safety to be considered are 2.77 for the upset condition, and 1.39 for the faulted condition [1].

2. The stress is calculated based upon the bending moment in Reference 4.
3. The stress is calculated based upon the pressure in Reference 4.

Table 2

Weld Designation H1
Flaw Detection Results[2,3]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)
1	0.00[1,4]	11.01[1,4]
2	12.06[1]	39.46[1]
3	39.46[1,4]	50.51[1,4]
4	54.86[1]	59.81[1]
5	61.97[1]	64.17[1]
6	65.27	70.57
7	72.22	73.32
8	74.97[1]	80.27[1]
9	84.47[1]	94.92[1]
10	98.02	99.12
11	99.67[1]	101.32[1]
12	101.67	103.32
13	103.87	106.62
14	107.17[1]	126.46[1]
15	126.46[1,4]	190.51[1,4]
16	206.01[1]	209.31[1]
17	212.18[1]	214.38[1]
18	215.48	217.13
19	219.88[1,4]	233.56[1,4]
20	238.46	240.11
21	243.07[1]	244.17[1]
22	261.92	264.67
23	277.47	280.57
24	294.36[1]	304.26[1]
25	305.36	306.46
26	306.46[1,4]	360.00[1,4]

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for both the creeping wave and 45° shear [6, 7]. The uncertainty factor is added to each end of the flaws.
3. All reported indications are assumed to be through-wall, as are all uninspected regions.
4. Uninspected regions.

Table 3

Weld Designation H2
Flaw Detection Results[2]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
1	0.00[1,4]	10.98[1,4]	2.0
2	12.72[1]	20.82[1]	0.31
3	23.49	25.14	0.31
4	34.49	35.59	0.31
5	36.14	38.34	0.31
6	39.30[1,4]	50.48[1,4]	2.0
7	50.57[1]	57.33[1]	0.31
8	64.28	70.88	0.31
9	72.33	73.98	0.31
10	74.53[1]	81.48[1]	0.31
11	98.48	99.58	0.31
12	114.47	116.12	0.31
13	117.77	119.97	0.31
14	124.92	125.47	0.31
15	126.43[1,4]	190.48[1,4]	2.0
16	191.12[1]	195.52[1]	0.31
17	201.72	203.37	0.31
18	203.92	205.63	0.31
19	219.85[1,4]	233.40[1,4]	2.0
20	233.48	235.68	0.31
21	243.18[1]	261.48[1]	0.31
22	278.13[1]	287.83[1]	0.31
23	294.47	295.57	0.31
24	304.37	305.47	0.31
25	306.57[1,4]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for 45° shear [6, 7]. The uncertainty factor is added to each end of the flaws.
3. UT uncertainty factors for depth are based upon the transducer which determines the depth. For near side detection, the factor is 0.106" for 60° longitudinal [6, 7]. The maximum reported flaw depth is assumed for all flaws. For analysis purposes, the entire shroud will be assumed to be flawed to the maximum reported flaw depth, in conjunction with through-wall flaws at the uninspected regions.
4. Uninspected regions.

Table 4

Weld Designation H3
Flaw Detection Results[2,3]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
1	0.00[1,4]	5.04[1,4]	2.0
2	6.09[1]	39.91[1]	2.0
3	39.91[1,4]	50.04[1,4]	2.0
4	51.09[1]	80.94[1]	2.0
5	81.41	83.14	2.0
6	84.71[1]	89.46[1]	0.39
7	90.56	91.66	0.39
8	99.51[1]	109.96[1]	0.39
9	109.96[1,4]	110.04[1,4]	2.0
10	110.04[1]	117.77[1]	2.0
11	124.84	126.49	0.39
12	126.49[1,4]	182.66[1,4]	2.0
13	186.46[1]	203.29[1]	2.0
14	208.79	210.56	0.33
15	212.21[1]	219.91[1]	2.0
16	219.91[1,4]	233.46[1,4]	2.0
17	233.49[1]	263.14[1]	2.0
18	263.69	265.89	0.33
19	266.24[1]	269.54[1]	0.33
20	270.99[1]	281.24[1]	0.33
21	282.34	286.19	0.33
22	291.09	292.19	0.39
23	292.27[1]	298.79[1]	2.0
24	301.07	302.17	0.33
25	303.27[1]	304.92[1]	0.33
26	306.49[1,4]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for both the creeping wave and 45° shear [6, 7]. The uncertainty factor is added to each end of the flaws
3. UT uncertainty factors for depth are based upon the transducer which determines the depth. For near side detection, the factor is 0.131" for 45° shear [6, 7]. The maximum reported flaw depth on the applicable surface is assumed for all flaws. For cracking from both surfaces, a through-wall flaw is conservatively assumed.
4. Uninspected regions.

Table 5

Weld Designation H4
Flaw Detection Results[2]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
1	0.00[1,4]	5.01[1,4]	2.0
2	7.79	11.09	0.10
3	12.11	13.76	0.10
4	13.76[1,4]	15.93[1,4]	2.0
5	16.59	18.24	0.10
6	21.06	22.16	0.10
7	23.03[1]	26.56[1]	0.10
8	28.76	32.06	0.10
9	33.16[1]	35.91[1]	0.10
10	36.46[1,4]	50.01[1,4]	2.0
11	51.13	52.78	0.10
12	53.33	55.53	0.10
13	57.68[1]	70.58[1]	0.11
14	73.88	76.63	0.10
15	86.68	89.98	0.10
16	96.58	98.23	0.10
17	104.98	107.73	0.10
18	110.48	111.58	0.10
19	114.82[1]	118.12[1]	0.10
20	119.22	120.32	0.10
21	126.37	126.92	0.10
22	126.92[1,4]	163.67[1,4*]	2.0
23	166.20	167.70	0.10
24	170.77[1,4*]	182.58[1,4]	2.0
25	186.06	187.71	0.10
26	189.91[1]	194.31[1]	0.10
27	194.66	197.41	0.10
28	203.81[1]	208.76[1]	0.10
29	219.88[1,4]	234.50[1,4]	2.0
30	236.94	239.69	0.10
31	244.35	246.00	0.10
32	248.20	249.30	0.10
33	253.40	256.70	0.10
34	258.35[1]	259.45[1]	0.10
35	260.00	261.10	0.10
36	262.20	263.30	0.10

Table 5 (concluded)

Weld Designation H4
Flaw Detection Results[2]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
37	280.70[1]	282.70[1]	0.10
38	294.93[1]	298.23[1]	0.10
39	298.78	301.53	0.10
40	305.38	306.48	0.10
41	306.48[1,4]	343.67[1,4*]	2.0
42	343.70	344.70	0.10
43	350.77[1,4*]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end, except those marked with a *, which are increased in length by 0.02° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for the creeping wave [6, 7]. The uncertainty factor is added to each end of the flaws.
3. UT uncertainty factors for depth are based upon the transducer which determines the depth. For near side detection, the factor is 0.131" for 45° shear [6, 7]. For analysis purposes, the entire shroud will be assumed to be flawed to the maximum reported flaw depth, in conjunction with through-wall flaws at the uninspected regions.
4. Uninspected regions.

Table 6

Weld Designation H5
Flaw Detection Results[2]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
1	0.00[1,4]	5.07[1,4]	2.0
2	39.94[1,4]	50.07[1,4]	2.0
3	58.44	59.97	0.05
4	77.01[1]	80.31[1]	2.0[5]
5	83.49	86.25	0.05
6	90.91[1]	94.76[1]	0.05
7	97.51	100.26	0.05
8	109.49	112.82	0.05
9	121.62[1]	123.82[1]	0.05
10	126.52[1,4]	182.58[1,4]	2.0
11	183.11[1]	184.21[1]	0.05
12	219.33[1,4]	233.49[1,4]	2.0
13	306.52[1,4]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for the creeping wave and 45° shear [6, 7]. The uncertainty factor is added to each end of the flaws.
3. UT uncertainty factors for depth are based upon the transducer which determines the depth. For near side detection, the factor is 0.131" for 45° shear [6, 7]. For analysis purposes, the entire shroud will be assumed to be flawed to the maximum reported flaw depth, in conjunction with through-wall flaws at the uninspected region.
4. Uninspected regions.
5. For cracking from both surfaces, a through-wall flaw is conservatively assumed.

Table 7

Weld Designation H6
Flaw Detection Results[2]

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth[3] (inches)
1	0.00[1,4]	5.04[1,4]	2.0
2	6.09[1]	21.84[1]	0.35
3	22.19[1]	39.36[1]	0.35
4	39.36[1,4]	50.04[1,4]	2.0
5	51.09[1]	63.11[1]	0.35
6	65.86	68.61	0.35
7	69.16[1]	79.76[1]	0.35
8	82.51[1]	88.36[1]	0.35
9	91.11[1]	96.96[1]	0.35
10	97.51[1]	123.19[1]	0.35
11	126.49[1,4]	182.66[1,4]	2.0
12	187.74[1]	193.24[1]	0.35
13	204.39	205.49	0.35
14	209.34[1]	214.41[1]	0.35
15	215.51	219.36	0.35
16	219.36[1,4]	237.54[1,4]	2.0
17	238.59	239.69	0.35
18	245.31	247.39	0.35
19	248.06	250.26	0.35
20	262.51	265.26	0.35
21	275.31	276.96	0.35
22	283.91[1]	294.94[1]	0.35
23	296.04[1]	298.24[1]	0.35
24	301.54[1]	304.29[1]	0.35
25	304.29[1,4]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. UT uncertainty factors for length are based upon the transducer which determines the length. For near side detection, the factor is 0.000" for 45° shear [6, 7]. The uncertainty factor is added to each end of the flaws.
3. UT uncertainty factors for depth are based upon the transducer which determines the depth. For near side detection, the factor is 0.131" for 45° shear [6, 7]. For analysis purposes, the entire shroud will be assumed to be flawed to the maximum reported flaw depth, in conjunction with through-wall flaws at the uninspected regions.
4. Uninspected regions.

Table 8

Weld Designation H7
Flaw Detection Results

Flaw Number	Starting Azimuth (°)	Ending Azimuth (°)	Depth (inches)
1	0.00[1,4]	5.03[1,4]	2.0
2	36.42[1,4]	53.45[1,4]	2.0
3	126.48[1,4]	185.03[1,4]	2.0
4	216.48[1,4]	234.50[1,4]	2.0
5	311.38[1,4]	360.00[1,4]	2.0

Notes:
1. Flaws which cross over lug sets are increased in length by 0.5° at each end [6, 7]. All uninspected regions are also increased in length by 0.5° at each end.
2. Uninspected regions.

Table 9

Limit Load Factors-of-Safety[1,2]

Weld Designation	Factor-of-Safety[3,4,5]	
	Calculated	Allowable
H1	1.89	1.39
H2	15.15	2.77
H3	6.03	2.77
H4	12.19	2.77
H5	7.35	2.77
H6	4.50	2.77
H7	8.26	2.77

Notes:
1. Based upon one cycle (two years) of crack growth for all welds.
2. See Appendix B for the detailed ANSC [8] output.
3. The allowable factors-of-safety are 2.77 for the upset condition, and 1.39 for the faulted condition.
4. The factors-of-safety are calculated as follows, with all stresses in ksi:

$$S.F. = \frac{P_b' + P_m}{P_b + P_m}$$

where: P_b = bending moment stress from Table 1

P_m = pressure differential stress from Table 1

P_b' = minimum failure bending stress from Appendix B output

5. For weld H1, the faulted condition governs. For welds H2 through H7, the upset condition governs.

Table 10

Linear Elastic
Fracture Mechanics Factors-of-Safety[1,2]

Weld Designation	K_I[3]	Factor-of-Safety[4]
H4	44	3.4

Notes:
1. Based upon one cycle (two years) of crack growth.
2. See Appendix C for the detailed calculations.
3. Units are ksi √in.
4. The factor-of-safety equals the material toughness (K_{Ic}) divided by the applied stress intensity factor (K_I), where the material toughness is 150 ksi √in [1]. The allowable factor-of-safety for upset conditions is 2.77.

APPENDIX A

Inspection Results

(See ATTACHMENT 2 to the PECO Energy Report)

APPENDIX B

Flaw Evaluation Results Using the ANSC Software [8]

Basis for Analyses:

1. All reported indications are increased in length at each end by one cycle of crack growth (0.8 inches), and by the UT length sizing uncertainty shown in Tables 2 through 8, as appropriate.

2. All areas not examined are assumed to be flawed through-wall, and increased in length as stated above.

3. Flaws increased in length per Note 1 will be combined if closer than 4 inches (twice the shroud thickness) apart [1].

APPENDIX C

Linear Elastic Fracture Mechanics Evaluation

Weld H4 will be evaluated using linear elastic fracture mechanics techniques, and one cycle of operation for crack growth. The methodology to be utilized is as follows:

- Those areas which have partial through-wall flaws will be evaluated using the methodology of Tada [9].
- Those areas which are postulated to have through-wall flaws adjacent to partial through-wall flaws will be evaluated using the methods outlined by EPRI [10], and will consider flaw interaction per Rooke [11].

Partial Through-Wall Flaw Evaluation

For evaluation of a partial through-wall flaw of depth equal to 1.041 inches (two years of crack growth at 5 x 10^{-5} inches/hour plus a depth uncertainty factor of 0.131 inches plus an initial crack depth of 0.11 inches), the stress intensity factor can be calculated using the methods of Tada [9]:

$$K = \sigma\sqrt{\pi a}\ F(a/b)$$

where the term F(a/b) accounts for the crack depth (a) as a function of plate depth (b).

From Tada, page 2.11:

$$F(a/b) = \sqrt{\frac{2b}{\pi a}\tan\frac{\pi a}{2b}} \cdot \frac{0.752 + 2.02(a/b) + 0.37\left(1 - \sin\frac{\pi a}{2b}\right)^3}{\cos\frac{\pi a}{2b}} = 3.0$$

$$K = (1.771)(3.0)\sqrt{(\pi)(1.041)} = 10\ \text{ksi}\sqrt{\text{in.}}\ \text{(upset conditions)}$$

However, this value of stress intensity only accounts for applied stresses. The effect of residual stresses must also be taken into account. From the austenitic stainless steel crack growth report [12], the stress intensity factor due to weld residual stresses is negative for flaws deeper than about 45% through-wall. Even considering the industry's latest position on this subject [13], the applied stress intensity factor for a flaw 52% through-wall is under 19 ksi$\sqrt{\text{in}}$. If this is added to the above value, the applied stress intensity factor is still well within any allowable value.

Through-Wall Flaw Evaluation

For evaluation of postulated through-wall flaws adjacent to partial through-wall flaws in weld H4, methods outlined in the EPRI Ductile Fracture Handbook [10] will be used.

From Chapter 5, Section 1, the stress intensity factor (K) for a compound crack when subjected to a bending moment can be calculated as follows:

$$K = (\sigma_b)(F_b)\sqrt{\pi R\theta}$$

The terminology is provided in the referenced handbook. For stress, the total stress will be utilized for this evaluation.

For a total upset stress of 1.771 ksi (controlling condition), a through-wall flaw of length equal to 38.61° (37.19° flaw length plus 0.9° for crack growth plus 0.52° for UT length sizing uncertainty), the stress intensity factor equals 39.1 ksi.

However, because of proximity to an adjacent through-wall flaw, this stress intensity must be increased by a factor. From Rooke [11], for a ligament of 6.16° (7.1° ligament minus 0.9° for crack growth minus 0.04° for UT length sizing uncertainty) and an adjacent flaw length equal to 15.66° (14.24° flaw length plus 0.9° for crack growth plus 0.52° for UT length sizing uncertainty), the flaw interaction effect can be calculated per the methodology of Figure 76 [11]. For $a_1/b = 0.56$ and $a_2/b = 1.38$, K_I/K_o equals 1.12.

Therefore, the total stress intensity factor in the shroud equals 44 ksi$\sqrt{\text{in}}$.

One should note that the use of the methodology described above is only applicable for bending moments applied to a cylinder with a radius to thickness ratio between 5 and 10. The validity of the use of this method will be substantiated through the use of detailed finite element analyses. It should also be noted that the methodology utilized herein is consistent with that utilized by GE Nuclear Energy in the evaluation of the cracking at Nine Mile Point, Unit 2 [14].

PECO ENERGY COMPANY
LIMERICK GENERATING STATION
UNIT 2
REACTOR PRESSURE VESSEL CORE SHROUD
2R05 INSPECTION FINAL REPORT
May 1999

ATTACHMENT 4

Structural Integrity Associates Report
Evaluation of Shroud Vertical Welds at Limerick, Unit 2
Report No. SIR-99-063
May 14, 1999.

(2 Pages)

May 14, 1999
SIR-99-063
RAM-99-055

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Mr. Richard E. Ciemiewicz
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Subject: Evaluation of Shroud Vertical Welds at Limerick, Unit 2

References:
1. GE Nuclear Energy, "Shroud Vertical Weld Inspection and Evaluation Guidelines," Report No. GENE-B13-01980-14 (Draft), March 1999.
2. Structural Integrity Associates, "Evaluation of Limerick, Unit 2 Shroud Examination Results," Report No. SIR-99-061, May 14, 1999.
3. Letter from Carl Terry (BWRVIP Chairman) to C. E. Carpenter (U.S. NRC), "Project No. 704 – BWRVIP Response to NRC Safety Evaluation of BWRVIP-14," November 24, 1998, SI File No. EPRI-89-403.

Dear Rich:

Per your request, we have evaluated the allowable flaw depth for continuous flaws in the Limerick, Unit 2 shroud vertical welds, assuming that the shroud horizontal welds are flawed through-wall for their entire length. The methodology utilized in this evaluation is contained in the shroud vertical weld evaluation guidelines [1], with the design input obtained from the Reference 2 report.

The methodology utilized is that described in Section 4.2.1 of the guidelines. For the high fluence welds, the applied stress intensity factor can be calculated utilizing Equations (4) and (5). For an assumed 1.6" deep flaw, for the controlling faulted condition (σ_h = 1.448 ksi), the applied stress intensity factor (K) is:

$$K = \sigma_h \sqrt{\pi a}\, F(a/b)$$

where:

σ_h	=	1.448 ksi
a	=	1.6"
F(a/b)	=	12.0

or, the applied intensity factor equals 39 ksi $\sqrt{in}$. However, the stress intensity factor due to residual stresses must also be taken into account. Utilizing the latest BWRVIP methodology for shroud horizontal welds [3], the stress intensity factor for a flaw 80% through-wall is approximately 7 ksi$\sqrt{in}$. Therefore, the total stress intensity factor is 46 ksi, with an allowable value of 100 ksi$\sqrt{in}$ [1].

For the welds which only need to be evaluated utilizing limit load techniques, Equation (6) can be solved. The allowable flaw depth (a), for the governing upset condition below the core plate, is as follows:

$$a = t - \left[(SF)(2t\sigma_h)/(2\sigma_f)\right]$$

where:

t	=	2"
SF	=	3.0
σ_h	=	1.14 ksi
σ_f	=	43.2 ksi

Therefore, a continuous 1.84" deep flaw is allowed for all shroud vertical welds evaluated to limit load criteria.

In conclusion, all vertical welds in the Limerick, Unit 2 shroud can be flawed at the end of the next cycle to a depth of at least 1.6". Taking into account one cycle of crack growth (0.8") and a maximum UT depth sizing uncertainty factor (0.131"), the allowable flaw size at the beginning of the cycle is 0.67", which is deeper than any flaw measured in the horizontal welds in the current outage.

Very truly yours,

Prepared by:

Original Signed By:

Richard A. Mattson, P. E.
Associate

Reviewed by:

Original Signed By:

Marcos L. Herrera
Associate

gsv

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UNIT 2
REACTOR PRESSURE VESSEL CORE SHROUD
2R05 INSPECTION FINAL REPORT
May 1999

ATTACHMENT 5

General Electric Technical Services Report
The Evaluation of Limerick Unit 2 Shroud Cracking For At Least One Cycle of Operation
GE-NE-B13-02010-33
May 1999

(16 Pages)

Proprietary Document