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DENTON,H.R.	Office of Nuclear Reactor Regulation, Director

SUBJECT: Forwards addl info re repairs to welds in recirculation sys piping,including methodology used for detection,evaluation & sizing of IGSCC & weld overlay ultrasonic testing,per 850531 request.

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Iowa Electric Light and Power Company

June 7, 1985
NG-85-2743

Mr. Harold Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
Results of Inspection of Stainless Steel Piping at the Duane Arnold Energy Center

Reference: Letter, R.W. McGaughy (Iowa Electric) to H.R. Denton, dated May 3, 1985 (NG-85-1901); Letter, R.W. McGaughy (Iowa Electric) to H.R. Denton, dated May 24, 1985 (NG-85-2480)

File: B-31c, SpF-118, A-107a

Dear Mr. Denton:

In a May 31, 1985, telephone conference between representatives of Iowa Electric and the NRC regarding repairs to welds in recirculation system piping at Duane Arnold Energy Center, a request was made for additional information on the methodology used for detection, evaluation, and sizing of Intergranular Stress Corrosion Cracking, weld overlay ultrasonic testing methodology, and the identification of limitations to ultrasonic examination of welds in the recirculation system.

In addition to the above requested information, it has been determined that the weld overlay design report for the J4-J4A welds (submitted May 24, 1985) must be resubmitted to reflect revised mininum overlay thicknesses.

Included in Attachment 1 of this letter are responses to the Staff's questions. Attachment 2 includes the revised J4-J4A weld overlay design report that supersedes the report previously submitted on May 24, 1985.

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Should you have any additional questions, please contact this office.

Very truly yours,

Philip [illegible] FOR

Richard W. McGaughy
Manager, Nuclear Division

RWM/SAR/ta*

Attachments

cc: S. Reith
L. Liu
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M. Thadani
NRC Resident Office

DUANE ARNOLD ENERGY CENTER

DOCKET NO. 50-331

ADDITIONAL INFORMATION
REGARDING UT EXAMINATIONS

JUNE 7, 1985

NRC REQUEST FOR ADDITIONAL INFORMATION CONCERNING UT RESULTS OF RECIRCULATION SYSTEM WELDS

Introduction

During the current refueling outage at the Duane Arnold Energy Center, a comprehensive program for the detection of Intergranular Stress Corrosion Cracking was undertaken. As a result of UT inspections performed by Lambert, MacGill, Thomas, Inc. (LMT), indications were detected in 11 welds in the recirculation system. Subsequent to these findings, General Electric (GE) was contracted to perform a third party review on 12 welds chosen by Iowa Electric. The welds inspected by GE included seven welds that were found to have no indications and four welds in which indications were found. Prior to GE performing their inspections, they were not made aware of those welds in which LMT had reported indications.

In a May 31, 1985, telephone conference between representatives of Iowa Electric and the NRC regarding repairs to welds in recirculation system piping at Duane Arnold Energy Center, a request was made for additional information on the methodology used for detection, evaluation, and sizing of Intergranular Stress Corrosion Cracking, weld overlay ultrasonic testing methodology, and the identification of limitations to ultrasonic examination of welds in the recirculation system. The following responds to the Staff's requests for additional information.

NRC Question #1: A discussion of the UT procedures and equipment used by both LMT and GE is requested. The basic information that should be included is as follows:

NRC Question #1A: Method used to establish the weld centerline and the weld profile. Was this information determined for all welds or only welds with flaw indications?

Response:

LMT: The weld centerline was first established at the center of the weld crown. In some cases the root was located by an "L" wave scan and was established as the centerline. The centerline of the weld crown was established for all welds that required charting. The OD profile of the weld was made with a contour gage at the location corresponding to the indication.

GE: The weld centerline was established at the center of the weld crown. Cross-sectional profile was established by two thickness readings on each side of the weld and one on the crown of the weld with an "L" wave scan. This technique was used on all welds inspected by GE.

NRC Question #1B: Type and angle of transducers generally used when flaws were not observed and when IGSCC indications were evaluated and sized.

Response:

LMT: The basic scanning on all welds was performed with a pulse echo, 2.25 or 1.5 MHz, 45° transducer. The evaluation and sizing of the indications were performed with both a 45° transducer and a 60° refracted "L" wave. In some cases a 70° ID creeper wave was used to confirm indications.

GE: The Ultra Image scan was performed with a pulse echo, 2.25 MHz, 45° transducer, on a spherically focused probe. All data was recorded on disks and later reviewed and evaluated by the color image on the computer display. All reflectors above a threshold of 20% of DAC were recorded. GE used manual scan to confirm evaluation results from the Ultra Image examinations.

NRC Question #1C: Recording and reporting criteria for the length and depth of IGSCC indications.

Response:

LMT: All signals were recorded in the basic scan as the transducer was moved from positions no less than 1/2 to 1-1/2 V paths in the axial scans on both sides of the weld. Also, all signals from the circumferential scans were recorded. These scans were made in clockwise and counterclockwise directions while skewing the transducer no less than 45°.

As required, the indications were charted and data was recorded for evaluation. The maximum percent DAC, metal paths and distances of transducer index to datum point were recorded at maximum DAC and at positions toward and away from the point of max DAC. The near and far positions are at a point where the amplitude is 50% DAC. Scans continued in lateral directions until the reflector disappeared. Only the maximum depth was determined and recorded; however, the full length of the indication was determined and recorded.

GE: All reflectors with amplitude above 20% DAC were recorded. All indicators were evaluated from the color image on the computer display.

NRC Question #2: Furnish a comparison of welds examined by both LMT and GE.

Response: See attached summary report for LMT and GE comparison of results.
See response to Question #1C.

SUMMARY REVIEW OF FINDINGS OF ULTRASONIC EXAMINATION
OF RECIRCULATION SYSTEM WELDS BY GE AND LMT

During the Spring 1985 outage, General Electric examined twelve circumferential welds in the recirculation system piping. The ultrasonic method was used with a computer control mechanized scanner and computer data acquisition equipment. The data was recorded on discs and later reviewed and evaluated on a computer display.

These welds were examined by LMT using the manual ultrasonic scan. The following is a summary of the findings of examinations of each weld of both General Electric and LMT:

1. Weld No. RCB-J4 - Loop B; 22" Pipe to Elbow Weld

   G.E. Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scans.

   LMT Findings: No reportable indications were detected. Near continuous ID geometry was detected in the axial scans.

2. Weld No. RMB-J12 - Loop B - 16" Cap to Header Pipe Weld

   G.E. Findings: No reportable indications were detected. Near continuous ID geometry was detected in the axial scan on the pipe side of the weld. No axial scan was done on the cap side of the weld.

   LMT Findings: No reportable indications were detected. Near continuous ID geometry was detected in the axial scans.

3. Weld No. RMB-J6 - Loop B - 16" Cross to Header Pipe Weld

   G.E. Findings: No reportable indications were detected. Intermittent ID and OD geometry was detected in axial and circumferential scans. No axial scan was done on the cross side of the weld.

   LMT Findings: No reportable indications were detected. Intermittent ID and OD geometry was detected in the axial scan. No axial scan was done on the cross side of the weld.

4. Weld No. RRD-J7 - Loop B - 10" Riser Pipe to Transition Piece from Header Weld

   G.E. Findings: A laminar indication with planar configurations which extended to the inside surface of the pipe was detected in the first scan. A 0° longitudinal scan was then performed to map the laminar area. The area was located axially 1" downstream of the weld centerline to 6" downstream of the weld centerline. The circumferential location extended from a line 10-1/8" to a line 14-1/4" measured clockwise around the pipe from the zero reference line. The depth of the indication varied from 0" to .162" from the ID surface of the pipe. A 45° shear wave scan confirmed that the planar flaw extended from the inside surface of the pipe to the laminar flaw.

LMT Findings: A 25% through wall 1" linear indication was detected. The indication was oriented axially and was located approximately 1" from the centerline of the weld on the pipe side of the weld and 13-3/4" CW from 0° (0° is point on pipe in line with the outer radius of the riser elbow).

The detection and evaluation of the laminar flaws were essentially the same as GE's.

5. Weld No. RMB-J2 - Loop B - 10" Nozzle to Transition Piece to Pipe Weld

   G.E. Findings: No reportable indications were detected. Continuous ID geometry was detected in the axial scan. No axial scan was done on the nozzle side of the weld.

   LMT Findings: No reportable indications were detected.

6. Weld No. RRC-J4 - Loop B - 10" Elbow to Pipe Weld

   G.E. Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scans.

   LMT Findings: The linear indication originally detected during the May 1981 inspection has not changed. The indication is approximately 3-1/2" long and is oriented circumferentially on the pipe side of the weld. No other reportable indications were detected.

7. Weld No. RRD-J4A - 10" Pipe to Pipe Weld

   G.E. Findings: One circumferential linear indication was detected. The total length of the indication is 14-1/4". It is located in the HAZ on the upstream side of the weld and is approximately 37% maximum throughwall. Intermittent ID geometry was detected in other areas in the axial scans.

   LMT Findings: A circumferential linear indication was detected in the same area as that detected by GE but was charted to be only 6-1/2" long. The indication measures a maximum 42% throughwall. ID and OD geometry was detected in other areas of the weld in the axial scans.

8. Weld No. RRF-J4 - Loop B - 10" Pipe to Elbow Weld

   G.E. Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scans.

   LMT Findings: No reportable indications were detected ID and OD geometry was detected in one area.

9. Weld No. RRE-F2A - Loop B - 10" Pipe to Safe End Weld

   GE Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scan.

LMT Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scan.

10. Weld No. RRE-J3 - Loop B - 10" Pipe to Pipe Weld

G.E. Findings: No reportable indications were detected. Continuous ID geometry was detected in the axial scans.

LMT Findings: No reportable indications were detected. Intermittent ID geometry was detected in the axial scans.

11. Weld No. RRF-J4A - Loop B - 10" Pipe to Pipe Weld

G.E. Findings: Preliminary results showed two circumferential and three axial indications. The final resolution on the condition of this weld was not completed due to the fact weld overlay operations were enacted on the weld prior to final manual evaluation.

LMT Findings: One 82.5% through wall circumferential linear indication was detected. The indication was approximately 2" long and was located on the upstream side of the weld.

12. Weld No. RRD-J4 - Loop B - 10" Elbow to Pipe Weld

G.E. Findings: No reportable indications were detected.

LMT Findings: A cluster of linear indications were detected. Two of these indications are axial and were evaluated to be 60% maximum throughwall. One circumferential indication appeared between the two axial indications and was evaluated to be 13% maximum throughwall.

NRC Question #3: Provide a description of the UT methodology for inspection of the "Weld Overlay Repair." This includes the following: Will angle beam examination be performed in addition to straight beam examination for weld bond; the type and size of transducers to be used; the dimensions of calibration reflectors; the UT acceptance criteria.

Response:

The entire weld overlay will be examined for bond to the base metal with the straight beam. A 3/8" diameter, 5.0 MHz, pitch catch transducer will be used for the bonding examination. Calibration will be at 80% full screen height (FSH) over a 3/8" diameter flat bottom hole.

The entire weld overlay surface will be scanned using a straight beam technique to detect reflectors in the overlay and overlay to base metal interface. A 3/8" diameter, 5.0 MHz, pitch catch transducer will be used. Calibration will be at 80% FSH over a 1/8" flat bottom hole.

The weld overlay and base metal will be scanned with angle beams directed both circumferentially and axially. Each directed scan will be in two directions. A 60° refracted L wave with a 2.25 MHz, 1/4" x 1/2" pitch catch transducer will be used. Calibration will be with the reflectors from side drill hole (SDH) at the interface between the overlay and base metal on the calibration standard and from notches in the ID of the calibration standard. The sweep and delay controls will be adjusted to set the SDH reflectors at 3 divisions and the ID notch reflectors at 8 divisions. The sensitivity controls will be adjusted to set the SDH signal to 80% of FSH. The side drilled holes are .060" diameter and the depth of the notches are 10% of the total thickness of the calibration standard. Each standard has SDH and notches in both axial and circumferential directions. Calibration for the circumferential scan will be from the axial SDH and notch, and the axial scan will be from the circumferential SDH and notch. The overlay thicknesses on the calibration standards are .300" for the 10" and .375" for the 18". The same welding procedure was used for welding both the calibration standards and the production welds. The surface of the 18" calibration standard overlay was machined, whereas the surface of the 10" standard overlay was buffed.

Any reflector over 50% of DAC will be recorded and evaluated; however, any indication determined to be a crack will be recorded and evaluated regardless of amplitude or size.

NRC Question #4: Revise Table 2 of the May 3, 1985, letter to add a column describing significant limitations to examinations for detection of circumferential reflectors.

Response: (See revised table.)

LIMITATIONS TO UT EXAMINATIONS

LOOP "A"

Weld #	Weld Type	Limitations
RMA-J1	16" Pipe - End Cap	Limited scan, cap side, 2.5" from weld center-line; not scanned due to curvature of end cap
RCA-J8	22" Pipe - Pipe	None
RCA-J12	22" Pipe - Elbow	None
RCA-J13	22" Elbow - Valve	• No axial scan, valve side, due to valve configuration • No circumferential scans on valve due to valve configuration
RCA-J15	22" Pipe - Valve	• No axial scan, valve side, due to valve configuration • No circumferential scans on valve due to valve configuration
RMA-J4	10" Manifold-Transition	No axial scan, extrusion side, due to extrusion welded to transition pipe
RMA-J2	10" Manifold-Transition	No axial scan, extrusion side, due to extrusion welded to transition pipe
RRG-J7	10" Transition-Pipe	None
RRH-J7	10" Transition-Pipe	None
RCA-J28	22" Pipe - Valve	• No axial scan, valve side, due to valve configuration • No circumferential scans on valve, limited to weld and pipe
RCA-J22	22" Elbow - Pump	• No axial scan, pump side, due to pump interference • Circumferential scan, limited to weld and elbow side of weld due to pump interference
RCA-J21	22" Pipe - Elbow	None
RCA-J24	22" Pipe - Pump	• No axial scan, valve side, due to valve configuration • No circumferential scans on valve
RRE-J7	10" Transition-Pipe	None
RMA-J10	10" Manifold-Transition	Axial scan, transition side, due to valve configuration
RRF-J7	10" Transition-Pipe	None
RMA-J6	22" Pipe - End Cap	• No axial scan, fitting side, due to 4-way configuration • No circumferential scans on 4-way due to configuration

Weld #	Weld Type	Limitations
RCA-J30	22" Elbow - Valve	No axial scan, valve side, due to valve configuration
RMA-J8	10" Manifold-Transition	No circumferential scan, pipe side, due to extrusion
RMA-J11	16" Pipe - End Cap	Limited axial scan, end cap side, limited to 2" from weld edge
RCA-J41	22" Pipe - Tee	None
RCA-J38	22" Pipe - Pipe	None
RHC-F2	20" Pipe - Pipe	None
RHC-J1	20" Pipe - Tee	No axial scan from tee side, 9-12 o'clock, two plates welded on pipe (1) 2-5/8" from centerline (2) 2-3/8" from centerline
RRE-J4A	10" Pipe - Pipe	None
RRE-J4	10" Pipe - Elbow	None
RRE-J5	10" Pipe - Elbow	None
RRF-J4A	10" Pipe - Pipe	None
*RRF-J4A	10" Pipe - Pipe	None
RRF-J4	10" Pipe - Elbow	None
*RRF-J4	10" Pipe - Elbow	No axial examination from elbow side of weld 12"-22" due to configuration of elbow inside radius
RRF-J5	10" Pipe - Elbow	None
RRG-J4A	10" Pipe - Pipe	None
RRG-J4	10" Pipe - Elbow	None
RRG-J5	10" Pipe - Elbow	None
RRH-J4A	10" Pipe - Pipe	None
RRH-J4	10" Pipe - Elbow	None
RRH-J5	10" Pipe - Elbow	None
RCA-J4	22" Pipe - Elbow	None
RCA-J32	22" Pipe - Elbow	None

*General Electric UT Inspection

LOOP "A", continued

Weld #	Weld Type	Limitations
RCA-J6	22" Pipe - Pipe	None
RCA-J3	22" Pipe - Safe End	None
RRH-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration
RRH-J3	10" Pipe - Pipe	None
RRG-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration
RRG-J3	10" Pipe - Pipe	None
RRF-J3	10" Pipe - Pipe	None
RRF-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration
RRE-J3	10" Pipe - Pipe	None
*RRE-J3	10" Pipe - Pipe	None
RRE-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration
*RRE-F2A	10" Pipe - Safe End	No examination, safe end side, due to safe end configuration
RMA-J7	16" Pipe - Cross	No axial scan, cross side, due to cross configuration
RMA-J5	16" Pipe - Cross	No axial scan, cross side, due to cross configuration
RCA-J43	22" Tee - Cross	None
RCA-J5	22" Pipe - Elbow	None

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LOOP "B"

Weld #	Weld Type	Limitations
RCB-J44	22" Pipe - Tee	• No axial scan, tee side, due to configuration • No circumferential scans on tee due to tee configuration
RCB-J41	22" Pipe - Pipe	None
RRB-J4A	10" Pipe - Pipe	None
RRB-J4	10" Pipe - Elbow	Axial scan, elbow side, inner radius inhibits coupling of transducer
RRB-J5	10" Pipe - Elbow	Axial scan, elbow side, inner radius inhibits coupling of transducer
RHD-J1	20" Pipe - Tee	No axial scan, tee side, 11 o'clock and 5-7 o'clock, due to tee
RHD-F2	20" Pipe - Pipe	None
RCB-J31	22" Pipe - Valve	No axial scan, valve side, due to valve configuration
RCB-J33	22" Elbow - Valve	• Circumferential scans limited to weld and elbow side due to valve configuration • No axial scan, valve side, due to valve configuration
RRC-J5	10" Pipe - Elbow	None
RRD-J5	10" Pipe - Elbow	None
RRC-J4	10" Pipe - Elbow	None
*RRC-J4	10" Pipe - Elbow	No axial exam upstream side of weld from "L" 10" to "L" 21" due to configuration of inside radius of elbow - Scan 1
RCB-J9	22" Pipe - Pipe	None
RCB-J27	22" Pipe - Pump	• No axial scan, pump side, due to pump interference • No circumferential scans on pump due to configuration
RCB-J25	22" Elbow - Pump	No axial scan, pump side, due to pump orientation
RCB-J15	22" Pipe - Elbow	None
RCB-J16	22" Elbow - Valve	No axial scan, valve side, due to valve orientation

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LOOP "B", continued

Weld #	Weld Type	Limitations
RCB-J18	22" Pipe - Valve	No axial scan, valve side, due to valve orientation
RCB-J24	22" Pipe - Elbow	None
RCB-J4	22" Pipe - Elbow	None
*RCB-J4	22" Pipe - Elbow	None
RRA-J4	10" Pipe - Elbow	None
RRA-J4A	10" Pipe - Pipe	None
RRA-J5	10" Pipe - Elbow	None
RRD-J4	10" Pipe - Elbow	None
*RRD-J4	10" Pipe - Elbow	None
RRD-J4A	10" Pipe - Pipe	None
*RRD-J4A	10" Pipe - Pipe	None
RCB-J35	22" Pipe - Elbow	None
RCB-J3	Pipe - Safe End	None
RRC-J4A	10" Pipe - Pipe	None
RRB-J7	10" Transition-Pipe	None
RMB-J9	10" Manifold-Transition	No axial scan, manifold side, due to extruded manifold
RRA-J7	10" Transition-Pipe	None
RCB-J5	22" Pipe - Elbow	None
RCB-J6	22" Pipe - Tee	None
RCB-J7	22" Pipe - Tee	None
RHB-J1	18"Pipe - Tee	No axial scan, tee side, due to configuration of tee
RHB-F3	18" Pipe - Pipe	None
RRA-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration

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LOOP "B", continued

Weld #	Weld Type	Limitations
RRA-J3	10" Pipe - Pipe	None
RRB-J3	10" Pipe - Pipe	None
RRB-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration
RMB-J1	16" Pipe - End Cap	None
RMB-J12	16" Pipe - End Cap	None
*RMB-J12	16" Pipe - End Cap	No axial examination was performed on cap side due to cap configuration
RMB-J8	16" Pipe - Cross	No axial scan, cross side, due to cross configuration
RMB-J6	16" Pipe - Cross	No axial scan, cross side, due to cross configuration
*RMB-J6	16" Pipe - Cross	No examination, cross side, due to cross configuration
RCB-J46	22" Tee - Cross	None
RMB-J7	22" Cross - End Cap	None
RRD-J3	10" Pipe - Pipe	None
RRD-F2A	10" Pipe - Safe End	No axial scan, safe end side, due to safe end configuration (taper)
RRC-J3	10" Pipe - Pipe	None
RRD-J7	10" Transition-Pipe	None
*RRD-J7	10" Transition-Pipe	Examination from pipe side only due to component configuration
RRC-J7	10" Transition-Pipe	None
RMB-J5	10" Manifold-Transition	No axial scan, manifold side, due to header extrusion configuration
RMB-J2	10" Manifold-Transition	No axial scan, manifold side, due to header extrusion configuration
*RMB-J2	10" Manifold-Transition	No scans, manifold side, due to header extrusion configuration
RMB-J11	10" Manifold-Transition	No axial scan, manifold side, due to header extrusion configuration

*General Electric UT Inspection

DUANE ARNOLD ENERGY CENTER

DOCKET NO. 50-331

WELD OVERLAY DESIGN

JUNE 7, 1985

MDE-129-0585
SASR #85-44

WELD OVERLAY DESIGN AND ANALYSIS
FOR THE INDICATIONS IN THE DUANE ARNOLD
RECIRCULATION AND RESIDUAL HEAT REMOVAL SYSTEMS

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GENERAL ELECTRIC

TABLE OF CONTENTS

I. INTRODUCTION

This report provides a summary of the analysis and design of the weld overlays for the indications in the Duane Arnold recirculation and residual heat removal systems. Weld overlay design was provided for seven horizontal riser welds, one vertical riser weld and one RHR tee weld. The overlayed welds and corresponding minimum overlay thicknesses are shown below.

WELD ID	DESCRIPTION	MINIMUM OVERLAY* THICKNESS (in.)
RRA - J4/J4A	Riser Horizontal Pipe	0.190
RRB - J4/J4A	" " "	0.170
RRD - J4/J4A	" " "	0.185
RRE - J4/J4A	" " "	0.185
RRF - J4/J4A	" " "	0.165
RRG - J4/J4A	" " "	0.165
RRH - J4/J4A	" " "	0.190
RHB - J1	RHR Tee	0.280
RRD - J7	Riser Vertical Pipe	0.190 total, two layers after first layer

* excludes first layer except as stated for RRD-J7

II. WELD OVERLAY DESIGN

The indications found during inspection of the Duane Arnold recirculation and residual heat removal system were predominantly circumferential in orientation. However, weld RRD-J7 was found to contain an axial indication connected to a large lamination indication. Although a through-wall axial flaw is acceptable from the viewpoint of structural margin (Reference 1), and a minimum overlay thickness could be applied, the overlay was conservatively sized assuming a 360° fully circumferential flaw. It was also decided to overlay the entire lamination area. Because this overlay influences system shrinkage stress more than the other overlays of this report (Section III), the first layer was included in the total overlay thickness required for a circumferential flaw. This was justified by continually monitoring and video recording the first layer welding operation to document the integrity of the first layer.

Weld overlay design for all cracked locations was determined using General Electric recommended minimum thicknesses along with considerations for future in-service inspectability. Nuclear Regulatory Commission (NRC) Generic Letter 84-11 (Reference 2) requirements were also incorporated into the overlay design and application controls. The overlay design also meets the requirements for being a full structural (Type 1) overlay and maintains the ASME Code intended safety margins (Reference 3) for a 360° through-wall circumferential flaw. Also, no credit was taken for the beneficial compressive residual stress induced by the weld overlay process that would oppose crack extension through the thickness. The assumption of a through-wall crack also provides assurance that the overlay design is independent of the crack size as determined by the ultrasonic testing. Finally, the selection of IGSCC-resistant material assures that IGSCC crack growth into the weld overlay material does not occur.

II. WELD OVERLAY DESIGN (Continued)

The results of the calculations using typical wall thickness data gives the following minimum weld overlay thicknesses.

TABLE 1 Initial Weld Overlay Dimensions

WELD ID	MINIMUM WELD OVERLAY THICKNESS (in.)	WELD OVERLAY LENGTH (in.)
RRA-J4/J4A	0.215 after first layer	6.75
RRB-J4/J4A	0.215 " "	6.75
RRD-J4/J4A	0.215 " "	6.75
RRE-J4/J4A	0.215 " "	6.75
RRF-J4/J4A	0.215 " "	6.75
RRG-J4/J4A	0.215 " "	6.75
RRH-J4/J4A	0.215 " "	6.75
RHB-J1	0.280 " "	4.0
RRD-J7	0.190 total, two layers after first layer	6.5

In most cases only one of the riser welds (J4 or J4A) had an indication reported. Due to the proximity of J4 and J4A, weld overlay of only one location could produce a tensile stress field at the other weld location. Overlay of only one weld would also impede future in-service inspection of the adjacent weld. Therefore, weld overlay of both J4 and J4A was performed.

Figure 1 through 3 show the weld overlay design for all cracked locations. The weld overlay thickness of 0.215" for the J4/J4A welds was selected to provide an overlay suitable for any riser location since examinations were still in progress. Subsequently, detailed wall thickness data was obtained prior to weld overlay. The updated thickness data and the design stresses at each riser were used to calculate specific weld overlay thicknesses for each riser J4/J4A weld location.

II. WELD OVERLAY DESIGN (Continued)

This allowed reduced overlay thickness while maintaining all requirements for a full structural (Type 1) weld overlay. Additional thickness margin is applied by the first layer material, which is sound (as determined by welding monitoring and liquid penetrant examination), and stress corrosion resistant (as determined by in situ ferrite measurement and the use of low weld carbon material).

These specific weld overlay thicknesses are given in Table 2.

TABLE 2 Final Weld Overlay Thickness Dimensions

WELD ID	MINIMUM WELD OVERLAY THICKNESS (in.)
RRA-J4/J4A	0.190 after first layer
RRB-J4/J4A	0.170 " "
RRD-J4/J4A	0.185 " "
RRE-J4/J4A	0.185 " "
RRF-J4/J4A	0.165 " "
RRG-J4/J4A	0.165 " "
RRH-J4/J4A	0.190 " "
RHB-J1	0.280 " "
RRD-J7	0.190 total, two layers after first layer

The overlay lengths were applied as specified in Table 1 and Figures 1 through 3. References 4 and 5 are the detailed reports describing the weld overlay design and calculations.

In addition to the weld overlay design analysis, a subsequent residual stress analysis was performed to evaluate the effect of weld overlay at RRD-J7 on the IHSI treated joint, RMB-J2. The results of this analysis showed that IHSI retreatment of RMB-J2 was not required. In addition, the weld overlay of RRD-J7 was shown to produce compressive stress under the overlay and in the transition piece heat affected zone. The residual stress analysis is contained in Reference 6.

III. WELD OVERLAY SHRINKAGE

Application of weld overlay results in local axial shrinkage. The induced axial shrinkage produces stress throughout the piping system. An analysis was performed to determine the effect of the local axial shrinkage on the overall piping system away from the weld overlays. The analysis was performed using the piping analysis code, PISYS (Reference 7).

The analysis was performed to simulate the actual weld overlay conditions. Two different weld overlay conditions were examined. In both cases, all cracked risers and the RHR cracked pipe were assumed overlayed. The difference between the two cases was the assumed weld overlay shrinkage at RRD-J7. At this location, the option existed of using a shorter overlay for the axial crack indication since the lamination was not considered IGSCC. The weld overlay shrinkage values used in the shrinkage stress analysis are based on General Electric mockup and field experience, and are considered conservative. Actual measured values will be checked and reconciled against the assumed values.

The analyses were performed for the following assumed shrinkage values:

	Weld Overlay Induced Axial Shrinkage (in.)	
	Case 1	Case 2
All riser J4/J4A cracked locations	0.5	0.5
Riser RRD-J7	0.3	0.6
RHR, RHB-J1	0.5	0.5

III. WELD OVERLAY SHRINKAGE (Continued)

Table 3 summarizes the stresses at various key locations in the piping system for the weld shrinkages assumed in the analysis.

TABLE 3 WELD OVERLAY SHRINKAGE INDUCED STRESS

LOCATION	DESCRIPTION (SHRINKAGE)	STRESS (ksi)
Pipe to Safe End on D Riser	Case 1- All risers overlayed except C (0.5") RHR, RHB-J1 overlayed (0.5") RRD-J7 overlayed (0.3")	6.3 ksi
	Case 2- All risers overlayed except C (0.5") RHR, RHB-J1 overlayed (0.5") RRD-J7 overlayed (0.6")	9.94 ksi
Riser C, Loop B welds, J4/J4A	Case 1- All risers overlayed except C (0.5") RHR, RHB-J1 overlayed (0.5") RRD-J7 overlayed (0.3")	4.2 ksi
	Case 2- All risers overlayed except C (0.5") RHR, RHB-J1 overlayed (0.5") RRD-J7 overlayed (0.6")	7.06 ksi

* Stresses at pipe to safe end on D riser were maximums.

The highest stress at any location without an overlay is 9.94 ksi (Case 2 with .6" axial shrinkage) at the pipe to safe end on riser D. This stress is mainly due to the weld overlay at RRD-J7. Presently, there is no Code requirement regarding these types of stresses. However, the weld shrinkage stress are similar in nature to cold spring stress and are acceptable since they are well below the material yield strength. In addition, the weld shrinkage stress, which is a sustained stress, would require special evaluation only if a crack existed that had not been overlayed. Since all cracked locations have been overlayed, the sustained stress is not a concern.

IV. WELD OVERLAY APPLICATION

In this section, the welding requirements and other special controls applied to weld overlay application are described including the welding process, material, water cooling and examination requirements. It is shown that the General Electric process application controls assure that all overlay design requirements are met and provide a high quality weld overlay that is considered technically acceptable for longer term operation.

All welding is performed using the Gas-Tungsten-Arc welding process with automatic orbital weld systems. These systems feature color video monitoring ahead and behind the weld puddle so that a continual surveillance of the welding operation can be performed remotely. The Gas-Tungsten-Arc process also produces a weld deposit that has high fracture toughness which avoids any of the recent concerns in the industry regarding the toughness of weld deposits for other welding processes.

The weld material applied for all overlays is in accordance with ASME Code Section II Part C, SFA 5.9 Type ER308L with added restrictions on carbon content and delta ferrite. Carbon content is limited to 0.02 weight percent, and delta ferrite is controlled to over 8.0 Ferrite Number (FN). In practice, even higher ferrite wire is actually used to assure first layer ferrite measurement requirements described later are maintained.

Prior to any overlay, repair of small axially-oriented leaks is performed. Such repairs were required on one riser weld (RRA-BJ4) and on the one RHR weld (RHB-J1). These were performed by draining down the system and locally excavating to a depth of 0.12-0.19 inches. The cavity and indication is then repaired using small diameter, high ferrite type 308L covered electrodes. Following repair and surface dressing, the area is liquid penetrant examined.

IV. WELD OVERLAY APPLICATION (Continued)

During weld overlay, no additional leaking indications were encountered during the surface preparation and pre-weld overlay liquid penetrant examinations, or the first layer welding, or the first layer liquid penetrant examinations.

Two additional items are performed prior to weld overlay. First, the area to be overlayed plus 0.5 inch on either side is liquid penetrant examined using ASME Section III procedures/acceptance criteria. Secondly, layout marks are established on either side of the weld overlay to, 1) measure and record weld overlay shrinkage in the axial direction, and 2) provide reference marks that can later be used to locate the weld centerline(s) during subsequent final and in-service inspections of the weld overlay.

During all weld overlay, water cooling on the inside surface of the pipe is required. The flow velocities are conservatively selected based on prior tests with the Induction Heating Stress Improvement (IHSI) process. This requires 3.9 feet/sec flow for horizontal pipe that is not pitched (to allow air/steam bubbles to escape), and 1.6 feet/second flow for vertical pipes or pitched horizontal pipes. These high flow rates are conservative for weld overlay since the amount of heat generated on the I.D. surface is considerably lower than IHSI.

The weld overlay first layer is applied with parameters to minimize dilution of the base metal (which increases ferrite and reduces carbon pickup to the first layer deposit). The first layer is liquid penetrant examined using ASME Section III procedures/acceptance criteria. Also the delta ferrite content of the first layer is measured using a Ferritescope calibrated in accordance with AWS A4.2 requirements. The ferrite acceptance criteria is 8.0 FN minimum average with no reading less than 5.0 FN. If a first layer fails to pass the liquid penetrant or ferrite acceptance criteria, additional layers are applied until all the requirements are satisfied.

IV. WELD OVERLAY APPLICATION (Continued)

The remainder of the overlay is applied until the required thickness (after the first layer) is obtained. The final overlay surface and adjacent 0.5 inch of base material is liquid penetrant examined and the entire weld overlay is volumetrically examined by ultrasonic examination, 1) for soundness according to ASME Code Section III volumteric examination requirements, and 2) for Section XI baseline examination requirements.

The total axial shrinkage due to overlay is recorded and reconciled against assumed values in the shrinkage stress calculation.

V. ACCEPTABILITY FOR MULTIPLE CYCLE OPERATION

The weld overlay design recommended here is based on the conservative assumption of a through-wall crack. Furthermore, the weld overlay design accounts for a potential circumferential indication by providing adequate thickness for an assumed 360° circumferential crack. Thus, the weld overlay sizing considers all potential crack sizes and orientations and still provides the required Code margins. This, coupled with the fact that the overlay is made of a high ferrite, low carbon weld material resistant to IGSCC, provides assurance for satisfactory long term performance.

General Electric under sponsorship from EPRI, is currently involved in the Degraded Pipe Remedy Program (EPRI Project T302-1). The objective of the program is to, 1) demonstrate a factor of improvement of at least 36 months (two fuel cycles) of operation with weld overlay, and 2) define the effective life of remedies applied to IGSCC cracked piping still in service.

V. ACCEPTABILITY FOR MULTIPLE CYCLE OPERATION (Continued)

To achieve the objectives, a test method has been developed and implemented. The test method involves;

1) Precrack welded pipe in representative environment in pipe test laboratory.

2) Apply weld overlay to precracked pipe using processes representative of field.

3) Use 4-inch pipe specimen to span and identify controlling parameters and establish a factor of improvement.

4) Perform 12-inch pipe tests to confirm factor of improvement for large pipe.

5) Calculate minimum plant life for remedies based on pipe test laboratory exposure.

6) Establish factor of improvement for each remedy by monitoring crack growth rate using UT and final destructive evaluation.

The results to date show a predicted minimum plant life of 5.8 cycles. The tests are still in progress and plant life is expected to be even higher. The GE/EPRI degraded pipe program has confirmed that weld overlays provide structural and IGSCC margins for several cycles. Recognizing this, the Pipe Crack Task Group of the NRC Piping Review Committee has stated in NUREG-1061 (Reference 8) that weld overlays for circumferential cracks are considered acceptable for two fuel cycles. Overlays for axial cracks are considered acceptable for longer periods of time. Based on this it can be concluded that the overlay is acceptable for more than two operating cycles.

VI. SUMMARY

Weld overlay design and analysis has been performed for the indications in the Duane Arnold recirculation and residual heat removal systems. The final weld overlay dimensions are shown below.

WELD ID	MINIMUM WELD OVERLAY THICKNESS (in.)		WELD OVERLAY LENGTH (in.)
RRA-J4/J4A	0.190	after first layer	6.75
RRB-J4/J4A	0.170	" "	6.75
RRD-J4/J4A	0.185	" "	6.75
RRE-J4/J4A	0.185	" "	6.75
RRF-J4/J4A	0.165	" "	6.75
RRG-J4/J4A	0.165	" "	6.75
RRH-J4/J4A	0.190	" "	6.75
RHB-J1	0.280	" "	4.0
RRD-J7	0.190	total, two layers after first layer	6.5

REFERENCES

1. Ranganath, S., "Technical Basis for the Acceptance Criteria for Axial Cracks in Stainless Steel Piping," General Electric Company, San Jose, CA, August 1982.

2. United States Nuclear Regulatory Commission, Inspections of BWR Stainless Steel Piping (Generic Letter 84-11), April 19, 1984.

3. ASME Boiler and Pressure Vessel Code, Section XI, 1983 Edition, Paragraph IWB-3640.

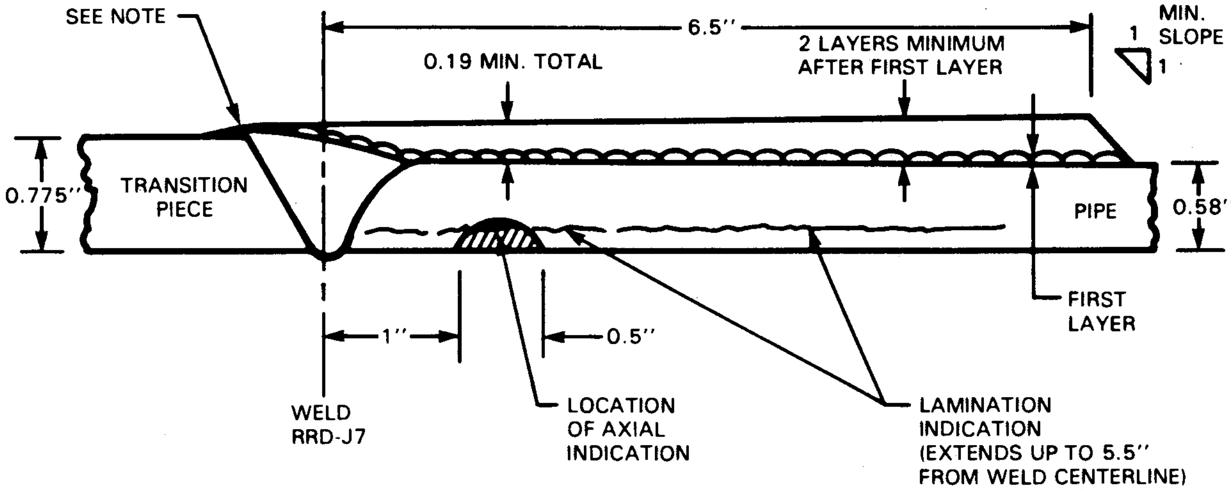
4. Stevens, G. L., "Weld Overlay Design for the Indication in the Duane Arnold Recirculation Riser Pipe," General Electric Document MDE-57-0485, Rev. 2, SASR 85-25, DRF #137-0010, May 1985.

5. Herrera, M. L., "Weld Overlay Design for the Indications in the Duane Arnold Recirculation and Residual Heat Removal Piping Systems," General Electric document MDE-105-0485, SASR 85-34, DRF #137-0010, April 1985.

6. Herrera, M. L., "Residual Stress Analysis of the Weld Overlay Application at Joint RRD-J7 in the Duane Arnold Recirculation Line," General Electric document MDE-118-0585, SASR 85-43, DRF #137-0010, May 1985.

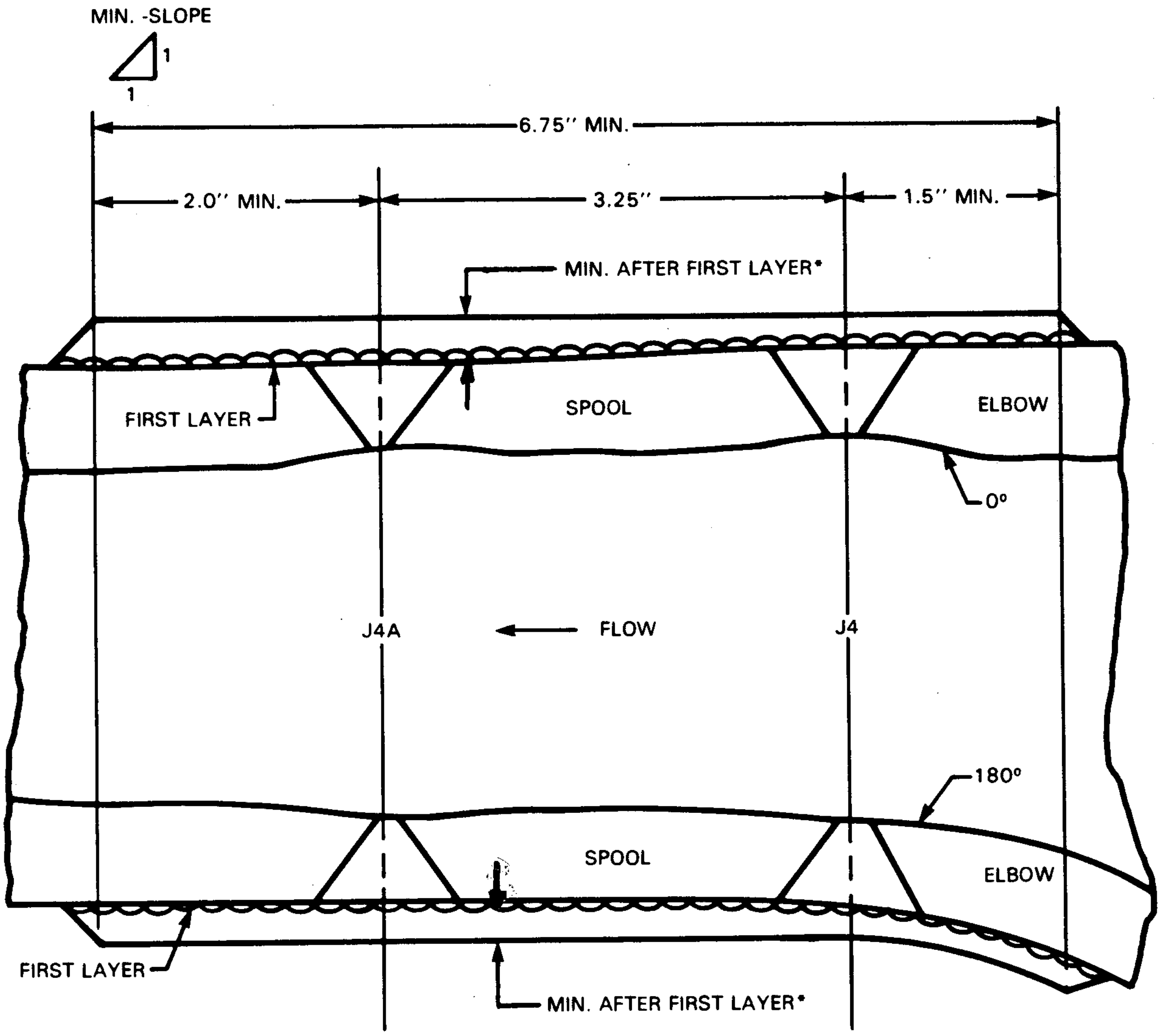
7. PISYS05, GE Piping System Analysis Computer Program, NEDE-24077, April 1979.

8. Pipe Crack Task Group of the NRC Piping Review Committee, Investigation and Evaluation of Stress-Corrosion in Piping of Boiling Water Reactor Plants, Second Draft, April 1984.



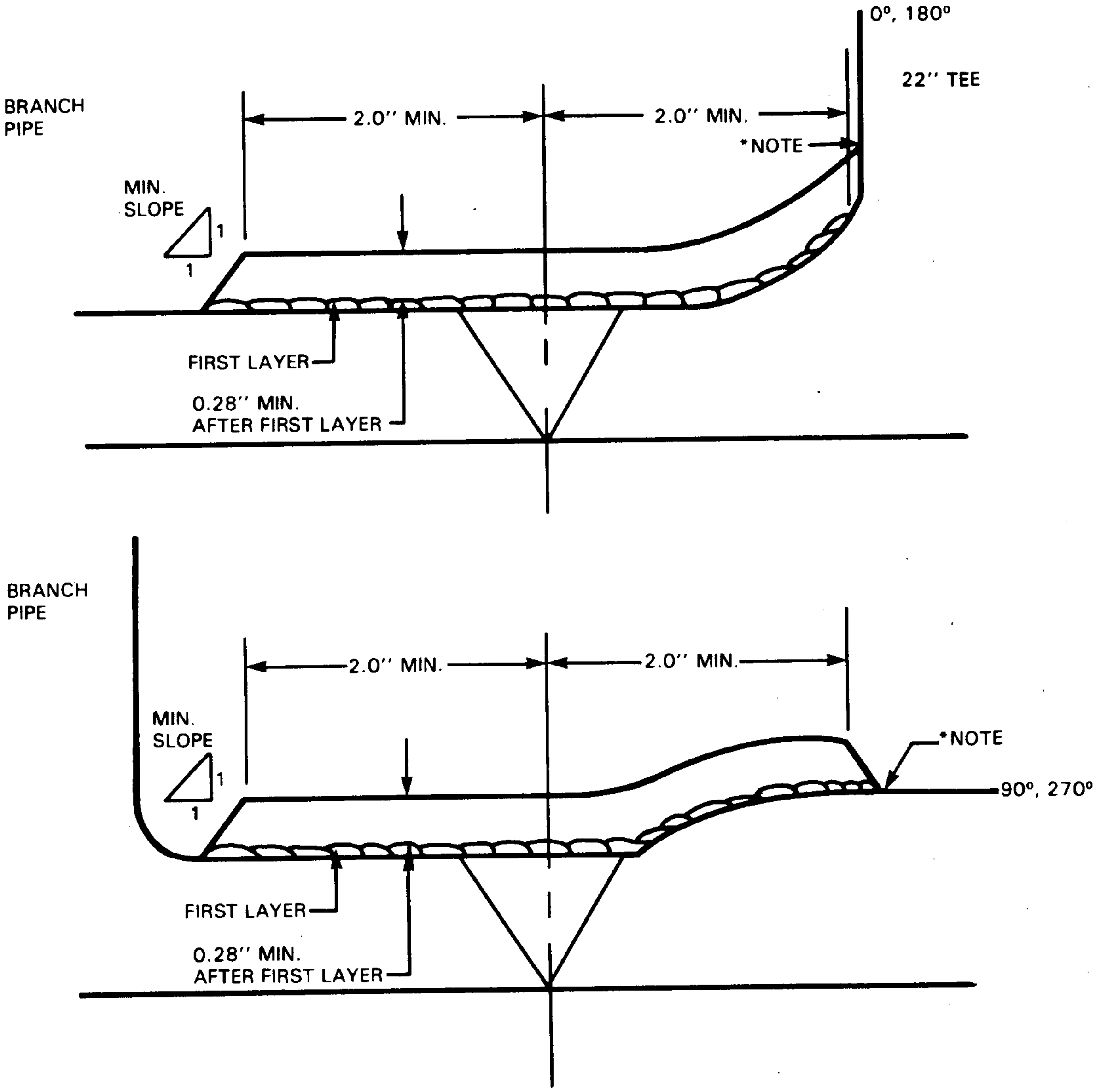
NOTE:
DO NOT OVERLAY BEYOND WELD CROWN EDGE. IF OVERLAY THICKNESS RISES ABOVE TRANSITION PIECE O.D., GRIND EDGE WITH A 4 TO 1 MINIMUM SLOPE.

Figure 1. Weld Overlay Design for RRD-J7



* THICKNESS AFTER FINAL SURFACE FINISHING (SEE TABLE 2)

Figure 2. Weld Overlay Design For Recirculation Risers



*NOTE: ANGLE BETWEEN WELD AND BASE METAL – 135° MIN. OR .25" RADIUS MIN.

Figure 3. Weld Overlay Design For Weld RHB-J1