VERMONT YANKEE
NUCLEAR POWER CORPORATION

RD 5, Box 169, Ferry Road, Brattleboro, VT 05301

2.C.2.1
FVY 83-50

REPLY TO:
ENGINEERING OFFICE
1671 WORCESTER ROAD
FRAMINGHAM, MASSACHUSETTS 01701
TELEPHONE 617-872-8100

June 3, 1983

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Office of Nuclear Reactor Regulation
Mr. Domenic B. Vassallo, Chief
Operating Reactors Branch No. 2
Division of Licensing

References:
a) License No. DPR-28 (Docket 50-271)
b) Letter, USNRC to VYNPC, dated 3/5/83; IE Bulletin 83-02
c) Letter, USNRC to VYNPC (NVY 83-93), dated 5/5/83
d) Letter, USNRC to VYNPC, dated 5/11/83; Meeting Report 50-271/83-10
e) Letter, VYNPC to USNRC, dated 5/26/83; Proposed Change No. 115

Dear Sir:

Subject: Response to IE Bulletin 83-02

As a result of the discovery of intergranular stress corrosion cracking (IGSCC) in large diameter stainless steel recirculation system piping at several boiling water reactor plants the NRC prescribed, with the issuance of Bulletin 83-02, that licensees augment their existing in-service inspection program, using state-of-art ultrasonic examination techniques, to reasonably assure the integrity of the recirculation system piping for continued operation.

The purpose of this letter is to formally report our selection criteria (susceptibility matrix), inspection results and to describe subsequent corrective actions taken to address the concerns expressed in the Bulletin. The majority of the information, provided as attachments to this letter, has been either: Informally transmitted; discussed in detail with members of your staff and Region I personnel at a meeting held at the Region I offices on April 19, 1983; or, discussed during the numerous telephone conversations between members of our organizations.

It should be noted that one of the "corrective actions," i.e., revision to Technical Specifications, is discussed in Enclosure F of the report and proposes that we be allowed to implement an alternate, administrative leak detection monitoring program in lieu of the current Technical Specification during the interim period until an amendment can be issued by the NRC. Inasmuch as procedural changes will be necessary to implement this administrative program, it is essential that you make us aware of the acceptability of our proposal as soon as possible.

IE11
1/11

In accordance with the provisions of Reference (c), this submittal is directed to the Division of Licensing; a copy will be sent to Mr. T.T. Martin at the regional offices in accordance with commitments made during the April 19, 1983 meeting.

We are confident that the information provided is acceptable and resolves the concerns expressed in the Bulletin; however, should you have any questions or desire additional information, please contact us.

Very truly yours,

VERMONT YANKEE NUCLEAR POWER CORPORATION

Warren P. Murphy
Vice President and
Manager of Operations

WPM/dm
cc: USNRC
Region I
631 Park Avenue
King of Prussia, PA 19406
Attn: Mr. T.T. Martin

STATE OF VERMONT)
)ss
WINDHAM COUNTY)

Then personally appeared before me, W.P. Murphy, who, being duly sworn, did state that he is Vice President and Manager of Operations of Vermont Yankee Nuclear Power Corporation, that he is duly authorized to execute and file the foregoing document in the name and on the behalf of Vermont Yankee Nuclear Power Corporation and that the statements therein are true to the best of his knowledge and belief.

Diane M. McCue Notary Public
My Commission Expires February 10, 1987

DIANE M. McCUE
NOTARY
PUBLIC
WINDHAM COUNTY, VERMONT

VERMONT YANKEE NUCLEAR POWER CORPORATION

FINAL REPORT - BULLETIN 83-02

I. INTRODUCTION

In response to I&E Bulletin 83-02, Vermont Yankee Nuclear Power Corporation was required to perform an augmented inservice inspection examination of recirculation piping during the 1983 refueling outage.

This report contains our assessment of indications found in piping as a result of that inspection, as well as the repair and/or evaluation techniques utilized to ensure recirculation system integrity for the next operating cycle.

Contained within, as part of this report, are the following enclosures:

A. Ultrasonic Examination Qualification and Techniques

B. Weld Susceptibility Matrix Development

C. Weld Examination Selection Criteria and Results

D. Evaluation of Indications and Basis for Weld Overlay Design

E. Post-Repair Inspection Criteria

F. Leakage Monitoring Systems

II. SUMMARY OF ACTIVITIES

As a result of the findings detailed in Enclosure C, the following actions have been taken.

- All 12" recirculation riser piping welds with indications of IGSCC have been repaired by the overlay method discussed in Enclosure D.

- For the large diameter 22" header and 28" suction and discharge piping welds with indications of IGSCC, linear elastic fracture mechanics analyses have been conducted which show that flaw growth during the next cycle of operation is sufficiently small so as to permit operation without repair.

- A proposed change to Vermont Yankee Technical Specifications [Reference (e) of the cover letter] has been submitted to the NRC, which enhances existing specifications for Reactor Coolant System leak rate monitoring, surveillance frequencies, and corrective actions. The limits, frequencies, and corrective actions are consistent with those contained in NUREG-0313, Revision 1 and/or license amendments previously issued by the NRC for other licensees. See Enclosure F for additional information.

- Provisions are being made to provide localized leak detection (tape) for certain large bore (22" and 28") recirculation system weld joints. The selection criteria and acceptability for these welds was discussed with members of your staff in a telecon on May 16, 1983. See Enclosure F for additional information.

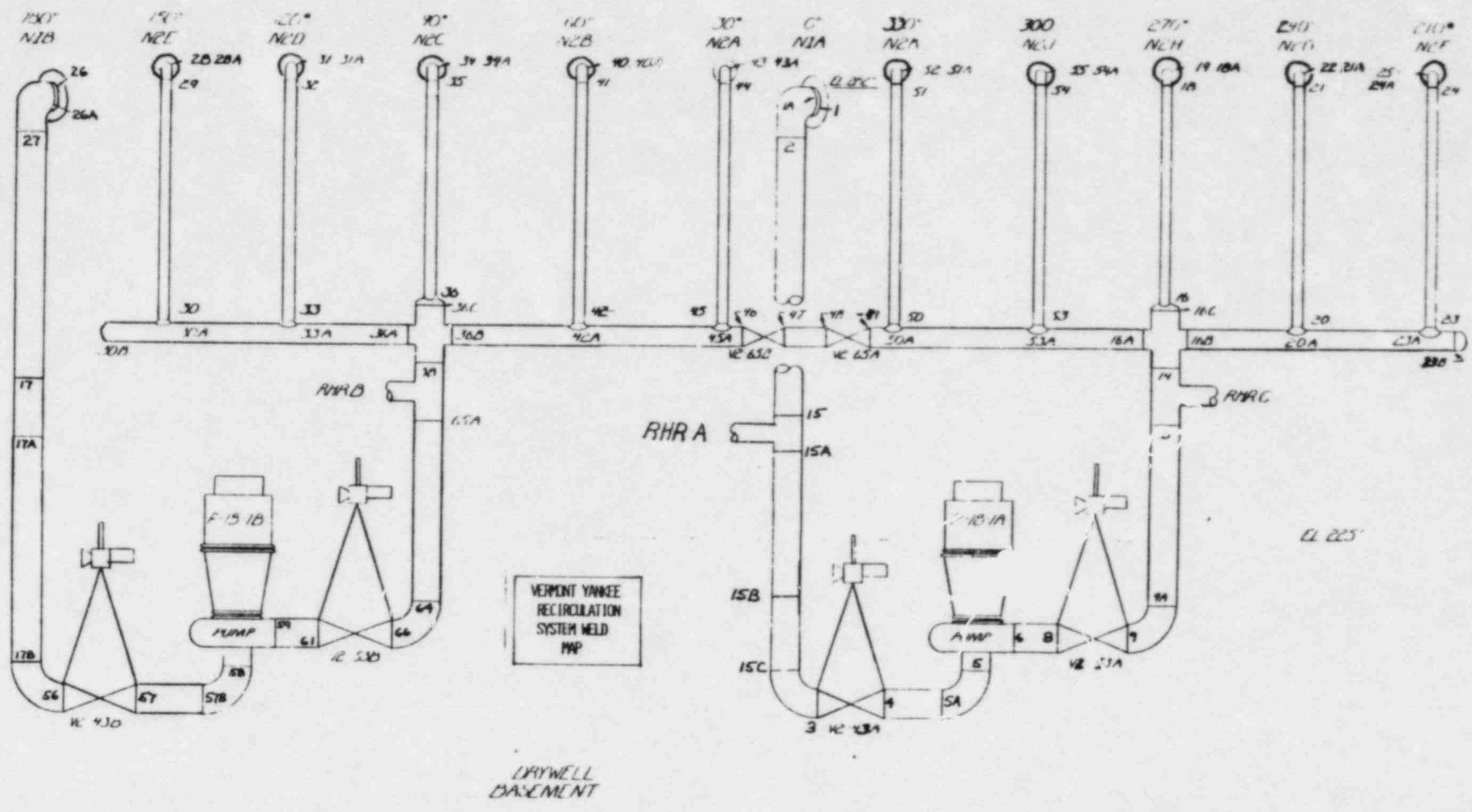
The evaluation of the overlayed weld joints and affected large bore weld joints indicate that resulting stress levels are acceptable for all design conditions. Stress levels have been evaluated from the standpoint of load capacity, fatigue, and resistance to crack growth.

Acceptance criteria for the analyses of large and small bore piping are established in Enclosure D of the report. These analyses demonstrate that:

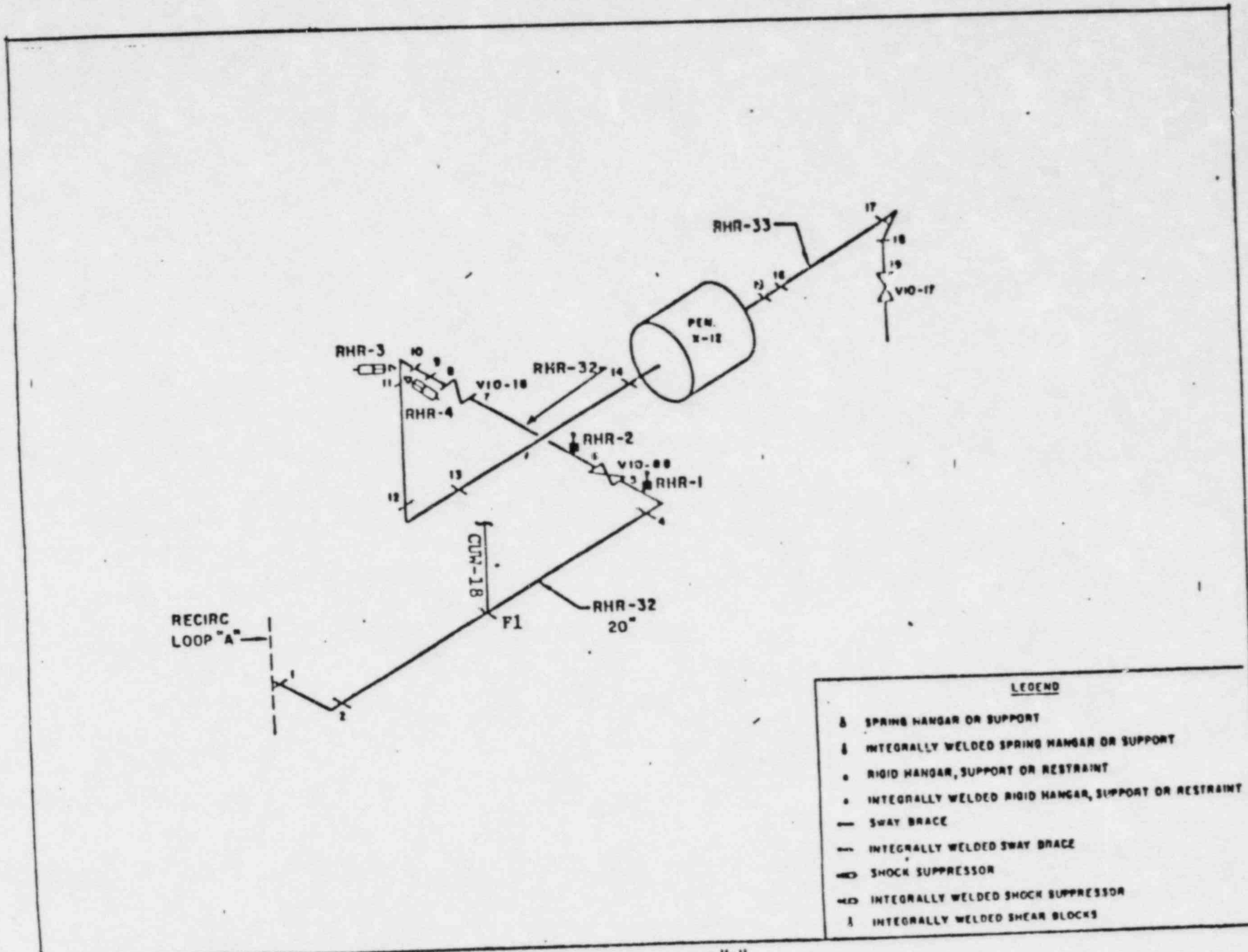
1) There is no loss of design safety margin over that provided by the rules for Class I piping in the ASME Boiler and Pressure Vessel Code, Section III; and

2) During the design lifetime of each repair (weld overlay), the observed cracks will not grow to the point where the above safety margins would be exceeded.

The results of our inspection are detailed in Enclosure C, Table I, Augmented ISI Results and Table II, Results of Flaw Evaluation - Large Diameter Piping. Attached herewith are weld maps of the Vermont Yankee Recirculation System and RHR System which depict the system weld joints.

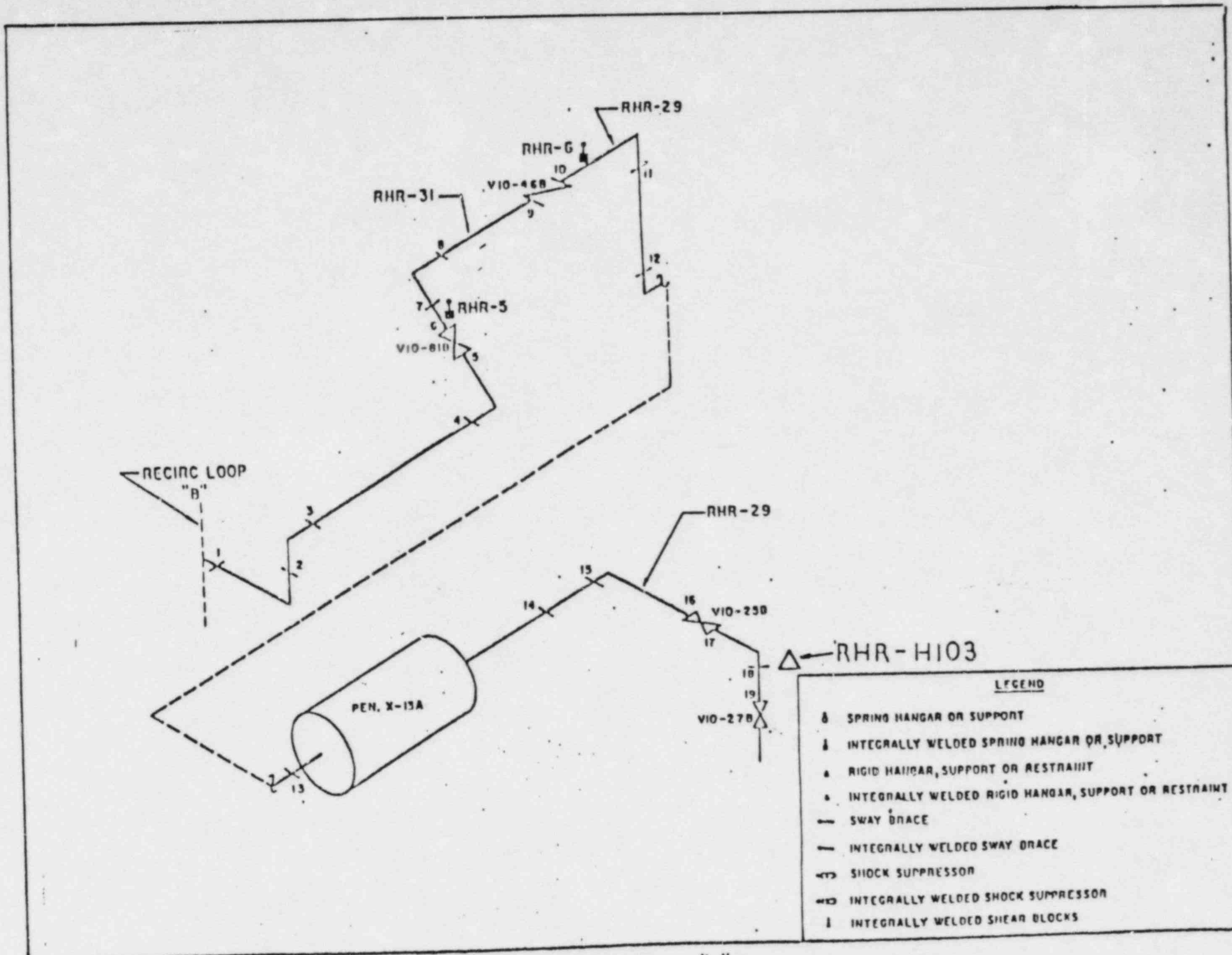


VERMONT YANKEE RECIRCULATION SYSTEM WELD MAP
DRYWELL BASEMENT
RHR A
RHR B
RHR C
PUMP
N1A
N2A
N2B
N2C
N2D
N2E
N2H
N1B
15
15A
15B
15C



RHR PIPING LINE "A"

REF. EBASCO DWG. 5920-FS-1438



RHR PIPING LINE "B"

ENCLOSURE A

VERMONT YANKEE 83-02 EXAMINATION PROGRAM

Ultrasonic Examination Technique

Bulletin 83-02 requires that we demonstrate the effectiveness of the detection capability of the Ultrasonic Examination technique to be used for examining weld joints in our recirculation system piping. The Bulletin also establishes provisions for demonstration tests to be performed at the EPRI-NDE Center in accordance with specific criteria. This includes equipment/procedure similarity, personnel participation, pipe sample size, acceptance criteria, demonstration time limit, and procedures review.

On March 11, 1983, Vermont Yankee and its contractor, Magnaflux, successfully passed the demonstration. The documentation of this demonstration is included as Figure A-1.

The examination methodology made use of dual element, 1.5 MHz, 45° and 60° shear wave search units coupled with pulse-echo ultrasonic instrumentation. The equipment was set up in a master-slave configuration, allowing maximum use of qualified examiners with minimum radiation exposure.

Detection of IGSCC was based on signal characteristics and location with respect to the weld root geometry.

The primary method utilized for sizing ultrasonic indications of IGSCC at Vermont Yankee was the "Amplitude Drop Method" using dual element 1.5 MHz transducers having a nominal shear wave beam angle of 45°. The thru wall dimension of the indication is compared to that of a 10% notch in a basic calibration block.

The sweep changes corresponding to the maximum amplitude from the 10% notch and the leading and trailing ray half maximum amplitudes (6 db drop) are recorded during the evaluation calibration. During evaluation scanning the sweep changes are recorded for the noted indications. The recorded sweep readings are then plotted on full size sketches of the weld joint section as determined by actual field measurement. A linear relationship is maintained in comparison to the 10% notch. Thru wall dimensions are calculated to the next higher full percent and reported for engineering evaluation.

Linear extent was plotted similarly. Linear extent was considered at an end point when the amplitude of the signal dropped to 50% of the average maximum signal for a given indication when scanned in a manner intended to determine linear extent.

In order to determine the reliability of the "Amplitude Drop Technique" for the sizing of IGSCC flaws two investigations were performed.

Initially Vermont Yankee assessed sizing capability by evaluating indications on a cracked specimen of large diameter Nine Mile Point-1 (NMP-1) pipe. Three teams measured the thru wall dimension of specified flaws. These measurements

were compared to the thru wall dimension of a crack which was exposed on the edge of the block. The examiners sized the flaw between 10 and 15%. Physical measurement after liquid penetrant exam indicated a crack depth at that location of 15% thru wall.

Additional confirmation of sizing accuracy was felt to be necessary; and, as a result, two areas of the same NMP-1 specimen were selected and sized by the examiner responsible for a large portion of ultrasonic examinations at Vermont Yankee.

Following ultrasonic flaw sizing, two areas of the circumferential weld joint 1D-SW-19-4 (MP-01 speciman) were sectioned, liquid penetrant examined and dimensioned for thru wall dimension. Selection of the areas to be sectioned was based upon indication location in an effort to minimize impact on the sample. These were not considered as maximum flaws and are instead average flaws. The results of this effort is tabulated as follows:

Indication No.	Destructive Testing		Ultrasonic Measurement	
	Measured	% TWD	Measured	% Error
1	.170	12%	.227	+25%
2	.150	12%	.170	+12%

NRC IE BULLETIN 83-02
Demonstration of UT Performance Capability
EPRI NDE Center
Charlotte, NC

Demonstration Results

Date: 11 March 1983 Procedure No. 22.A.35 - Summer 1978 Rev. 2

Utility: Vermont Yankee

ISI Contractor: Magnaflux

NRC Region: I

Demonstration Team Members and Levels:

1. Michael F. Sherwin Level III
2. Donald Gaskill Level II
3. Dean Mansfield Level II
4. John Mac Iver Level II
5. Michael Brault Level I tr.
6.

Results Acceptable (X) Unacceptable ( ) Pending ( )

Basis for Failure Crack detection ( ) False Calls ( )

Comments:

Improve scanning technique (skew motion)

NRC Representative

Robert G. McBrearty
(Signature)

Utility Representative

L.E. Mullins
(Signature)

cc: NDE Center
NRC IE

Figure A-1

ENCLOSURE B

WELD SUSCEPTIBILITY MATRIX DEVELOPMENT

1.0 INTRODUCTION

As a result of the stress corrosion cracking incidents in welded stainless steel primary coolant piping in Boiling Water Reactors (BWR) in recent years, the Yankee Atomic Electric Company (YAEC) requested NUTECH to evaluate the stress corrosion cracking propensity of stainless steel welds in several piping systems of the Vermont Yankee Nuclear Power Station.

The evaluation methodology involved: a review of plant fabrication records; a metallurgical review of these records to evaluate factors important to Intergranular Stress Corrosion Cracking (IGSCC) in the BWR environment, a Stress Rule Index (SRI) evaluation to assist in identifying those joints which are potentially susceptible to IGSCC, and a flaw evaluation to determine the crack growth and allowable crack sizes.

The ultimate aim of this evaluation is to provide input to the Vermont Yankee Nuclear Power Station Inservice Inspection Program so that the proper attention is focused on those joints which are most susceptible to IGSCC and to evaluate flaws discovered during the 1983 refueling outage inspections.

2.0 STRESS RULE INDEX EVALUATION

2.1 General Description

To provide a further means of determining a joint's susceptibility to IGSCC, a Stress Rule Index (SRI) evaluation was performed for each joint being studied. The Stress Rule Index is determined in the following manner. The axial stress components resulting from sustained loading conditions (i.e., pressure, dead weight, and steady state thermal expansion) are derived from the elemental forces and moments of the piping system stress analysis. These are combined with residual stress estimates and input to the General Electric Company developed Stress Rule Index equation (Reference 3) shown below.

$$SRI = \frac{P_m + P_b}{S_y} + \frac{Q + F + Resid}{S_y + .002E} \quad (2\text{-}1)$$

Where
- P_m = Primary Membrane Stress
- P_b = Primary Bending Stress
- S_y = Code Yield Strength at Temperature
- Q = Sustained Secondary Stress
- F = Sustained Peak Stress
- E = Elastic Modulus
- Resid = Weld Residual Stress

nutech ENGINEERS

For non-creviced welds, General Electric Company has determined that if the index is less than unity, susceptibility to stress corrosion cracking is mitigated; for crevices, a value somewhat lower than unity may be more suitable.

The SRI evaluation was facilitated by the use of NUTECH computer program SCORE (Reference 4) which calculates the SRI by giving the appropriate forces and moments from the piping stress report and the operating pressure. The weld residual stresses presented in Reference 3 has been built in the SCORE program for the SRI calculations.

The inservice inspection (ISI) isometric drawings presented in Appendix B of this report indicates the location of each weld joint and its ISI identification (ID). The SRI has been evaluated for each weld location as identified in the ISI drawings.

2.2 Individual System Models

2.2.1 Recirculation System

Axial forces and bending moments resulting from dead weight and steady state thermal expansion for Recirculation System Loops A and B were extracted from General Electric Company Design Report (Reference 5).

An operating pressure of 1250 psi was used throughout these systems except on the suction side of Recirculation Loops where the operating pressure is assumed at 1150 psi (Reference 5).

2.2.2 Residual Heat Removal System

A dead weight bending stress of 1500 psi for Residual Heat Removal (RHR) Systems and Core Spray Systems were provided by Yankee Atomic Electric Company (Reference 6). This stress was converted back to bending moment and input to the program SCORE. Since axial force due to dead weight is not available for RHR and Core Spray Systems, and normally has insignificant effect on SRI, it is neglected in SRI calculation.

Forces and moments due to thermal expansion for the RHR piping line A and line B were provided by YAEC (Reference 7). These forces and moments were originally given in a global coordinate system and then converted to a local coordinate system for the Computer Code SCORE input. Thermal loads for RHR line C were generated from a NUTECH piping stress analysis program, PISTAR (Reference 8).

3.0 METALLURGICAL EVALUATION

The objective of this evaluation was to identify, for each stainless steel welding joint, the material chemistry and significant fabrication practices that may have an effect on the susceptibility of a weld joint to IGSCC. Other information that could categorize the weld joint are also included, such as Inservice Inspection (ISI), weld number, pipe size, weld type, and component type. A detailed compilation of this information is documented in Appendix A of this report.

3.1 Material Chemistry

The composition of the material has an important role in the evaluation of IGSCC. The most significant element in the material chemistry is the amount of carbon. Reference 2 illustrates that carbon content has a direct relationship to the degree of sensitization of the alloy.

Austenitic stainless steels derive corrosion resistance from high chromium content. This chromium is normally in solution in the austenitic matrix. When the metal surface is exposed to air or water, it forms a tough film of chromium oxide, which protects the steel from

the environment and prevents corrosion. However, when stainless steel is held at temperatures between 600°C and 700°C for one hour or more, chromium tends to react with any carbon in solution to form chromium carbides. These carbides precipitate preferentially at the grain boundaries, thereby locally reducing the amount of chromium available to form chromium oxide. Consequently, the grain boundaries are no longer protected against corrosion. The steel is then susceptible to intergranular stress corrosion cracking; and is called sensitized.

It is important to note that sensitization depends on the carbon content. Only a small amount of chromium will be found in chromium carbides in a steel with very low carbon content, therefore, the steel will not be sensitized.

Once a steel is sensitized, it can be desensitized by applying a anneal solution treatment. During this treatment, it is heated to 1000°C for one hour or more which dissolves all the chromium carbides. It is then cooled rapidly through the carbide precipitation range so that no carbide has time to form.

In the metallurgical evaluation of the piping systems, carbon content, heat number and heat treatment were included in the metallurgical evaluation tables. This information was obtained from the available Certified Material Test Repots (CMTR).

3.2 NUREG-0313 Evaluation

An evaluation of the metallurgical data compiled for each joint was conducted according to the Nuclear Regulatory Commission (NRC) technical positions established in NUREG-0313, Rev. 1, (Reference 1). The metallurgical evaluation summary tables include the NUREG-0313 status of each joint based on the following criteria:

(a) Conforming - joints for which each of the adjoining parent materials is one of the following highly resistant materials; ferritic steels, "Nuclear Grade" or L-Grade Type 304, or 316 austenitic stainless steel (< 0.035% Carbon), or cast stainless steels. Regular grades of 304 or 316 stainless steel are not considred conforming unless the as-installed piping, including the weld, is in the annealed solution condition.

(b) Nonconforming - all joints that do not meet the above criteria. These joints are subject to augmented Inservice Inspection (ISI) requirements as identified in NUREG-0313.

(c) Service Sensitive - nonconforming joints in lines designated by the NRC as having experienced cracking of a generic nature, or that are considered to be particularly susceptible to cracking because of a combination of high local stress material condition, and high oxygen content in lines which have relatively stagnant, intermittent, or low flow coolant. Included in this category of piping runs are: core spray lines; recirculation riser lines; control rod drive hydraulic return lines; isolation condenser lines; recirculation inlet lines at safe ends where crevices are formed by recirculation bypass lines (or pipe extensions /stub tubes on plants where the bypass lines have been removed); and shutdown heat exchanger lines. A higher degrees of augmented inspection is required for these lines.

The overall metallurgical review of all the weld joints for the evaluated piping systems is presented in the Metallurgical Evaluation Summary, Appendix A of this report.

4.0 INTERGRANULAR STRESS CORROSION CRACKING SUSCEPTIBILITY MATRICES

Each weld joint was assessed for the susceptibility to IGSCC. Three main considerations that must be taken into account in determining the susceptibility of a joint are material properties, stress, and environment. In a previous section, two of these factors, stresses and material properties, have been quantitatively addressed. For both stresses and material properties, there exists sufficient analytical results, laboratory data, and field experience to provide a basis for determining relative susceptibility. The environmental factor has only been addressed in those stagnant, low flow lines (service sensitive) considered to be more susceptible to IGSCC. The degree to which one of these three ingredients must be present for IGSCC varies. It is rather difficult to define an absolute scale of susceptibility for these ingredients. There are also other variables that must be considered in the IGSCC Susceptibility evaluation, including such factors as coldwork, counterbore grinding crevices, temperature, and pH values.

To provide a rudimentary means of ranking each weld, NUTECH has developed the IGSCC Susceptibility Matrix. This matrix displays the relative susceptibility of each weld based on the material properties and stress conditions that have been compiled in this evaluation. Only welds for which sufficient information is available, are shown in the matrix.

The IGSCC Susceptibility Matrix is divided into three regions labeled I, II, and III. Region I contains welds that are either conforming from a material standpoint (less than 0.035% carbon as defined in Reference 1) or have a stress rule index less than 1.2. Welds in this region are considered to be the least susceptible to IGSCC. Region II defines an intermediate zone encompassing welds which exhibit considerable margin to failure, relative t Region III welds, but are somewhat more susceptible than Region I welds. Region III represents the most susceptible welds, those having the smallest margin to failure.

Other variables, as discussed earlier, can also play a role in affecting the degree of IGSCC susceptibility. An important factor to consider is whether welds are in service sensitive piping. Welds which are both nonconforming and in service sensitive piping are

potentially more susceptible to IGSCC than other welds of the same matrix position.

Susceptibility Matrices for all piping systems evaluated are presented in Tables 4.1 to 4.5. Weld joints in which carbon content is known for one of the two base materials only are indicated with an asterisk in the tables.

STRESS RULE INDEX

CARBON CONTENT (%)	0-1.20	1.21-1.50	1.51-2.00	≥ 2.01
≥ 0.070		12-51A 12-51 12-55* 12-54A 12-25* 12-52* 28-9B 28-9A 28-9*	12-50 12-19* 12-18 12-22* 12-21A 12-54 12-18A 12-24A 28-14 28-15A 28-15	12-53 12-16
0.060 - 0.069	28-8* 28-6*	22-53A 12-24 22-23A 22-49* 22-23B 28-C12 28-C7A 28-5* 28-5A 28-3 28-15C	22-16B 28-2 28-1A 22-50A 22-16A 12-21 22-20A	12-20 12-23 Region III (High Susceptibility)
0.050 - 0.059	28-5B 28-4* 28-15B	28-1* 22-48*	28-16C	
0.035 - 0.049		Region II (Moderate Susceptibility)		
≤ 0.035		Region I (Low Susceptibility)		

NOTE: * Carbon content known only for one base me⁻al in the joint. Depending on the carbon content of the other base material, position in matrix may shift up or down.

TABLE 4.1

IGSCC SUSCEPTIBILITY MATRIX - RECIRCULATION,

LOOP A

STRESS RULE INDEX

CARBON CONTENT (%)	0-1.20	1.21-1.50	1.51-2.00	≥ 2.01
≥ 0.070		12-43* 12-28* 12-29 28-64 28-66*	12-34* 12-34A 12-35 28-38 12-31A 12-28A 12-43A 12-40* 12-40A 12-31* 12-32 28-65A	12-36 12-33 12-30
0.060 - 0.069	28-61* 28-59*	22-45A 28-C65 28-C60A1 28-58* 22-46* 22-30B 28-57B 28-56* 28-17B	12-41 22-36B 22-42A 28-27 28-26A	12-45 12-42
0.050 - 0.059	28-57A 28-57* 28-17A 28-17	12-44 22-47* 28-26*	22-33A 28-36C 22-36A 22-30A	
0.035 - 0.049				
≤ 0.035				

Region III (High Susceptibility)

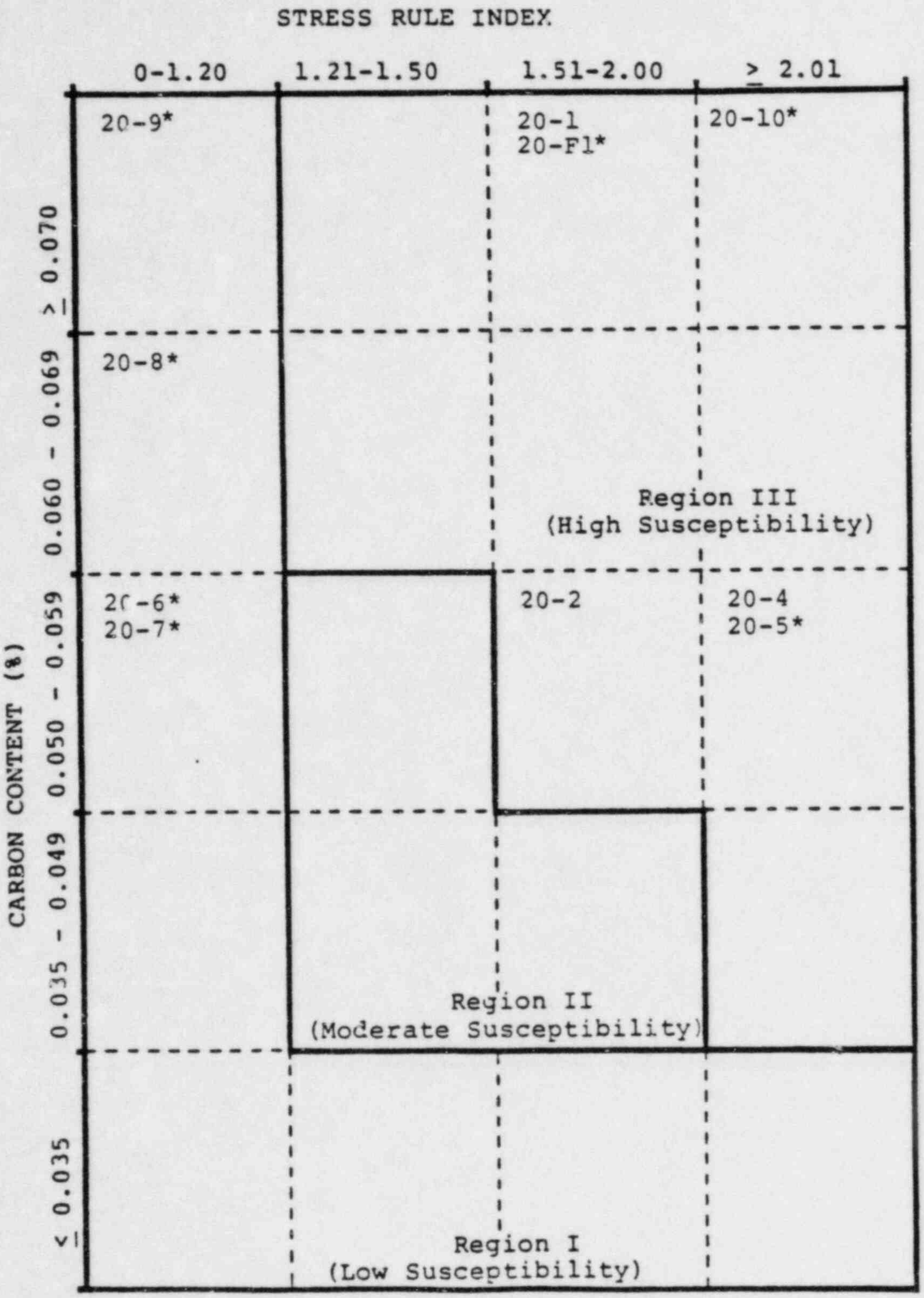
Region II (Moderate Susceptibility)

Region I (Low Susceptibility)

Note: * Carbon content known only for one base metal in the joint. Depen'ing on the carbon content of the other base material, position in matrix may shift up or down.

TABLE 4.2

IGSCC SUSCEPTIBILITY MATRIX - RECIRCULATION LOOP B



Note: * Carbon content known only for one base metal in the joint. Depending on the carbon content of the other base material, position in matrix may shift up or down.

TABLE 4.3

IGSCC SUSCEPTIBILITY MATRIX - RHR PIPING

LINE "A"

CARBON CONTENT (%)	STRESS RULE INDEX 0-1.20	1.21-1.50	1.51-2.00	≥ 2.01
≥ 0.070			24-1	
0.060 - 0.069			Region III (High Susceptibility)	
0.050 - 0.059	24-6* 24-9*		24-3 24-4 24-7 24-8	
0.035 - 0.049		24-5* Region II (Moderate Susceptibility)	24-2	
≤ 0.035		Region I (Low Susceptibility)		

Note: * Carbon content known only for one base metal in the joint. Depending on the carbon content of the other base material, position in matrix may shift up or down.

TABLE 4.4

IGSCC SUSCEPTIBILITY MATRIX - RHR PIPING

LINE "B"

STRESS RULE INDEX

CARBON CONTENT (%)	0-1.20	1.21-1.50	1.51-2.00	≥ 2.01
≥ 0.070			24-1	
0.060 - 0.069			Region III (High Susceptibility)	
0.050 - 0.059	24-6*	24-4 24-5 24-7*	24-8	24-3 24-9 24-10
0.035 - 0.049		Region II (Moderate Susceptibility)	24-2	24-11*
≤ 0.035		Region I (Low Susceptibility)		

Note: * Carbon content known only for one base metal in the joint. Depending on the carbon content of the other base material, position in matrix may shift up or down.

TABLE 4.5

IGSCC SUSCEPTIBILITY MATRIX - RHR PIPING

LINE "C"

5.0 CONCLUSION

It is generally recognized that three essential conditions are necessary to bring about stress corrosion cracking in stainless steel piping: material susceptibility; an agressive environment; and a threshold stress. In order to more accurately identify welds which are most susceptible to IGSCC, it is necessary to consider all of three factors.

In this report, an evaluation of IGSCC has been performed for three piping systems in the Vermont Yankee Nuclear Power Station. A metallurgical review was conducted and Stress Rule Indices were generated for each weld joint in these systems. Using the guidelines from NUREG-0313, a susceptibility matrix was established for all the piping systems. Each weld joint was categorized into one of the three regions. In the matrix, Region I represents combinations of SRI and material chemistry which have thus far proven to be immune to IGSCC. Region II and III represent combinations more susceptible to IGSCC. By ranking these welds, Vermont Yankee can determine the inservice inspection interval for welds which have high IGSCC susceptibility.

APPENDIX A

METALLURGICAL EVALUATION SUMMARY

YAE-02-100

Prepared for
YANKEE ATOMIC ELECTRIC COMPANY

METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

Prepared by
nutech

LINE NO.	SYSTEM	REVISION - DATE	PAGE
	RECIRCULATION RING HEADER AND INLETS		1

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NUREG 0313 REV 1 STATUS: NON CONF	NUREG 0313 REV 1 STATUS: CONF	STRESS RULE INDEX	COMMENTS
16	12	P-Red	F	Reducer	A403, TP304		68061	.058		X		2.46	
				Riser Pipe	A358, Cl. I, TP304		78123	.08	X	X			
16C	28	Red-X	S	Reducer	A403, TP304		68061	.058		X		1.53	
				Cross	A403-67, TP304		66259-1	.05		X			
16A	22	P-X	S	Header Pipe	A358, Cl. I, TP304		K43497-4B	.062		X		1.55	(1)
				Cross	A403-67, TP304		66259-1	.05		X			
16B	22	P-X	S	Header Pipe	A358, Cl. I, TP304		K43497-3B	.062		X		1.79	(1)
				Cross	A403-67, TP304		66259-1	.05		X			
20	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.060	X	X		2.41	
				Sweepolet	A403-WP304		342571S	.065		X			
20A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497	.062			X	1.60	
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
23	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.060	X	X		2.20	
				Sweepolet	A403-WP304		342571S	.065		X			
23A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497-3B	.062			X	1.47	(1)
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
23B	22	P-C	S	Header Pipe	A358 Cl. I, TP304		K43497-3B	.062		X		1.24	(1)
				End Cap	A403-67, WP304		K51416-5B	.068		X			

(1) Differences were noted between the ladle analysis and product analysis. The more conservative (higher) value was always used.

YAE-02-100

Prepared for
YANKEE ATOMIC
ELECTRIC COMPANY

METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

Prepared by
nutech

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	RECIRCULATION RING HEADER AND INLETS		2

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 - REV 1 STATUS: SERV SENS	NUREG 0313 - REV 1 STATUS: NON CONF	NUREG 0313 - REV 1 STATUS: CO F	STRESS RULE INDEX	COMMENTS
53	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		2.25	
				Sweepolet	A403-WP304		342571S	.065		X			
53A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497-4B	.062			X	1.46	(1)
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
50	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		1.97	
				Sweepolet	A403-WP304		342571S	.065		X			
50A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497-4B	.062			X	1.55	(1)
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
49	22	P-V	F	Header Pipe	A358 Cl. I, TP304		K43497-4B	.062		X		1.32	(1)
				Valve									
48	22	P-V	F	Header Pipe	A358 Cl. I, TP304		K43481-3B	.056		X		1.30	
				Valve									
47	22	P-V	F	Header Pipe	A358 Cl. I, TP304		K43481-3B	.056		X		1.32	
				Valve									
46	22	P-V	F	Header Pipe	A358 Cl. I, TP304		K43497-4C	.062		X		1.31	(1)
				Valve									
45	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.03	X		X	2.37	Large discrepancy between this result & others for %C on this heat.
				Sweepolet	A403-WP304		342571S	.065		X			

(1) Differences were noted between the ladle analysis and product analysis. The more conservative (higher) value was always used.

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	RECIRCULATION RING HEADER & INLETS		3

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NUREG 0313 REV 1 STATUS: NON CONF	NUREG 0313 REV 1 STATUS: CONF	STRESS RULE INDEX	COMMENTS
45A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497-4C	.062			X	1.50	(1)
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
42	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.03	X		X	2.78	Large discrepancy between this result and others for %C on this heat.
				Sweepolet	A403-WP304		342571S	.065		X			
42A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43497-4C	.062			X	1.53	(1)
				Sweepolet	A403-WP304	SHT	342571S	.065			X		
36	12	P-Red	F	Reducer	A403, TP304		68061	.058		X		2.86	
				Riser Pipe	A358 Cl. I, TP304		78123	.08	X	X			
36C	28	Red-X	S	Reducer	A403, TP304		68061	.058		X		1.59	
				Cross	A403-67, TP304		66259-1	.05		X			
36A	22	P-X	S	Header Pipe	A358 Cl. I, TP304		K43481-3B	.056		X		1.51	
				Cross	A403-67, TP304		66259-1	.05		X			
36B	22	P-X	S	Header Pipe	A358 Cl. I, TP304		K43497-4C	.062		X		1.95	(1)
				Cross	A403-67, TP3 4		66259-1	.05		X			
33	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		2.75	
				Sweepolet	A403-WP304		3424782S	.059		X			
33A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43481-3B	.056			X	1.69	
				Sweepolet	A403-WP304	SHT	3424782S	.059			X		

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS			STRESS RULE INDEX	COMMENTS
									SERV SENS	NON CONF	CONF		
30	12	P-S	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		2.59	
				Sweepolet	A403-WP304		3424782S	.059		X			
30A	22	P-S	S	Header Pipe	A358 Cl. I, TP304	SHT	K43481-3B	.056			X	1.61	
				Sweepolet	A403-WP304	SHT	3424782S	.059			X		
30B	22	P-C	S	Header Pipe	A58 Cl. I, TP304		K43481-3B	.056		X		1.24	
				End Cap	A403-67, WP304		51416-4A	.068		X			
28	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.43	
				Safe End	A336 F8		L1015	.071					
28A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.65	
				Elbow	A403-WP304		K43060-5B	.060	X	X			
29	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		1.45	
				Elbow	A403-WP304		K43060-5B	.060	X	X			
31	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.56	
				Safe End	A336 F8		L1015	.071					
31A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.68	
				Elbow	A403-WP304		K43060-5B	.060	X	X			
32	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X	X		1.62	
				Elbow	A403-WP403		K43060-5B	.060	X	X			

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
34	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.84	
				Safe End	A336 F8		L1015	.071					
34A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.65	
				Elbow	A403-WP304		K43060-5B	.060	X	X			
35	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78123	.08	X	X		1.82	
				Elbow	A403-WP304		K43060-5B	.060	X	X			
40	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.51	
				Safe End	A336 F8		L1015	.071					
40A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.56	
				Elbow	A403-WP304		K43184-5A	.06	X	X			
41	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.03	X		X	1.72	Large discrepancy between this result & others for %C on this heat.
				Elbow	A403-WP304		K43184-5A	.06	X	X			
43	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.41	
				Safe End	A336 F8		L1015	071					
43A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X		1.59	
				Elbow	A403-WP304		K43229-4B	.055	X	X			
44	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.03	X		X	1.43	Large discrepancy between this result and others for %C on this heat.
				Elbow	A403-WP304		K43229-4B	.055	X	X			

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
52	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.27	
				Safe End	A336 F8		L101S	.071						
51A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.46	
				Elbow	A403-WP304		K43184-5A	.05	X		X			
51	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X		X		1.35	
				Elbow	A403-WP304		K43184-5A	.06	X		X			
55	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.30	
				Safe End	A336 F8		L101S	.071						
54A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.34	
				Elbow	A403-WP304		K43060-5B	.060	X		X			
54	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.08	X		X		1.55	
				Elbow	A403-WP304		K43060-5B	.060	X		X			
19	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.68	
				Safe End	A336 F8		L101S	.071						
18A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X		X		1.58	
				Elbow	A403-WP304		K43229-4B	.055	X		X			
18	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78123	.08	X		X		1.73	
				Elbow	A403-WP304		K43229-4B	.055	X		X			

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WELD NUMBER	DIA (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
22	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X			1.61	
				Safe End	A336 F8		L101S	.071						
21A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X			1.72	
				Elbow	A403-WP304		K43060-5B	.060	X	X				
21	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.060	X	X			1.56	
				Elbow	A403-WP304		K43060-5B	.060	X	X				
25	12	P-SE	F	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X			1.31	
				Safe End	A336 F8		L101S	.071						
24A	12	P-E	S	Riser Pipe	A358 Cl. I, TP304		78267	.08	X	X			1.60	
				Elbow	A403-WP304		K43184-5A	.06	X	X				
24	12	P-E	F	Riser Pipe	A358 Cl. I, TP304		78130	.060	X	X			1.34	
				Elbow	A403-WP304		K43184-5A	.06	X	X				

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
14	28	T-X	F	Reducing Tee	A403-WP304		68144	.07		X		1.60	
				Cross	A403-67, TP304		66259-1	.05		X			
9B	28	P-T	S	Pipe	A358 Cl. I, TP304		325729	.060		X		1.50	
				Reducing Tee	A403-WP304		68144	.07		X			
9A	28	P-E	S	Pipe	A358 Cl. I, TP304		325729	.060		X		1.41	
				Elbow	A403-WP304		68129-2	.079		X			
9	28	E-V	F	Elbow	A403-WP304		68129-2	.079		X		1.43	
				Valve									
C12	28	P-W	S	Pipe	A358 Cl. I, TP304		325729	.060		X		1.44	
				28 x 4 Weldolet	A182F304		B126	.06	X	X			
C7A	28	P-W	S	Pipe	A358 Cl. I, TP304		325729	.060		X		1.42	
				28 x 4 Weldolet	A182F304		B126	.06	X	X			
8	28	P-V	F	Pipe	A358 Cl. I, TP304		325729-12	.060		X		1.09	(1)
				Valve									
6	28	P-PA	F	Pipe	A358 Cl. I, TP304		325729-12	.060		X		1.09	(1)
				Pump Assembly									

(1) Differences were noted between the ladle analysis and product analysis. The more conservative (higher) value was always used.

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WELD NUMBER	DIA (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
5	28	E-PA	F	Elbow	A403-WP304		38053	.068			X		1.[illegible]	(1)
				Pump Assembly										
5A	28	E-P	S	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.34	(1)
				Elbow	A403-WP304		38053	.068			X			(1)
5B	28	P-F	S	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		0.97	(1)
				Flange	A182-F304		HE595	.050			X			
4	28	P-V	F	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.08	(1)
				Valve										
3	28	E-V	F	Elbow	A403-WP304		K51416-5B	.062			X		1.40	(1)
				Valve										
15C	28	P-E	S	Elbow	A403-WP304		K51416-5B	.062			X		1.41	(1)
				Pipe	A358 Cl. I, TP304		K51326-1C	.059			X			(1)
15B	28	P-P	S	Pipe	A358 Cl. I, TP304		K51326-1C	.059			X		0.99	(1)
				Pipe	A358 Cl. I, TP304		K51326-1B	.059			X			(1)
15A	28	P-T	S	Pipe	A358 Cl. I, TP304		K51326-1B	.059			X		1.55	(1)
				Reducing Tee	A403-WP304		37802-2	.08			X			(1)
15	28	P-T	F	Pipe	A358 Cl. I, TP304		K51326	.059			X		1.55	
				Reducing Tee	A403-WP304		37802-2	.08			X			

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NCON	CONF	STRESS RULE INDEX	COMMENTS
2	28	P-E	F	Pipe	A358 Cl. I, TP304		K51326	.059			X		1.60	(1)
				Elbow	A403-WP304		K51416-5B	.062			X			(1)
1A	28	P-E	S	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.80	(1)
				Elbow	A403-WP304		K51416-5B	.062			X			(1)
1	28	P-SE	F	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.37	(1)
				Safe End	A182 TP304		43573	.025						

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NUREG 0313 REV 1 STATUS: NON CONF	NUREG 0313 REV 1 STATUS: CONF	STRESS RULE INDEX	COMMENTS
38	28	T-X	F	Reducing Tee	A403-WP304		68144-1	.07		X		1.73	
				Cross	A403-67, TP304		66259-1	.05		X			
65A	28	T-P	S	Reducing Tee	A403-WP304		68144-1	.07		X		1.51	
				Pipe	A358 Cl. I, TP304		32197-21	.062		X			
64	28	P-E	S	Pipe	A358 Cl. I, TP304		32197-21	.062		X		1.35	
				Elbow	A403-WP304		57761-1	.08		X			
66	28	E-V	F	Elbow	A403-WP304		57761-1	.08		X		1.39	
C65	28	P-W	S	Pipe	A358 Cl. I, TP304		32197-21	.062		X		1.39	
				28 x 4 Weldolet	A182F304		B126	.06	X	X			
C60A1	28	W-P	S	28 X 4 Weldolet	A182F304		B126	.06	X	X		1.41	
				Pipe	A358 Cl. I, TP304		32197-21	.062		X			
61	28	P-V	F	Pipe	A358 Cl. I, TP304		32197-21	.062		X		1.09	
				Valve									
59	28	P-PA	F	Pipe	A358 Cl. I, TP304		32197-21	.062		X		1.09	
				Pump Assembly									
58	28	E-PA	F	Elbow	A403-WP304		38053	.068		X		1.36	(1)

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WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
57B	28	P-E	S	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.35	(1)
				Elbow	A403-WP304		38053	.068			X			(1)
57A	28	P-F	S	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		0.97	(1)
				Flange	A182F304		HE595	.050			X			
57	28	P-V	F	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X		1.07	(1)
				Valve										
56	28	E-V	F	Elbow	A403-WP304		K51416-5B	.062			X		1.34	(1)
				Valve										
17B	28	E-P	S	Elbow	A403-WP304		K51416-5B	.062			X		1.40	(1)
				Pipe	A358 Cl. I, TP304		K51326-1B	.059			X			(1)
17A	28	P-P	S	Pipe	A358 Cl. I, TP304		K51326-1B	.059			X		0.97	(1)
				Pipe	A358 Cl. I, TP304		K51326-1A	.059			X			(1)
17	28	P-P	F	Pipe	A358 Cl. I, TP304		K51326-1A	.059			X		1.01	(1)
				Pipe	A358 Cl. I, TP304		K51326	.059			X			(1)
27	28	P-E	F	Pipe	A358 Cl. I, TP304		K51326	.059			X		1.53	(1)
				Elbow	A403-WP304		K51416-5B	.062			X			(1)
26A	28	P-E	S	Elbow	A403-WP304		K51416-5B	.062			X		1.58	(1)
				Pipe	A358 Cl. I, TP304		K51326-2C	.059			X			(1)

(1) Differences were noted between the ladle analysis and product analysis. The more conservative (higher) value was always used.

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ELECTRIC COMPANY

METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

Prepared by
nutech

LINE NO.	SYSTEM: RECIRCULATION LOOP B	REVISION - DATE	PAGE 13

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SEPS	NON	CONF	CONF	STRESS RULE INDEX	COMMENTS
26	28	P-SE	F	Pipe	A358 Cl. I, TP304		K51326-2C	.059			X			1.24	
				Safe End	A182 TP304		43573	.025							

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

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LINE NO.	SYSTEM	REVISION - DATE	PAGE
	RHR LINE "A"		1

WELD NUMBER	DIA (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
1	20	E-T	F	RHR Elbow	A403 WP304W		CCCE	.051			X		1.54	
				Recirc. "A" Tee	A403 WP304		37802-2	.08			X			
2	20	E-P	S	Elbow	A403 WP304W		CCCE	.051			X		1.68	
				Pipe	A358 Cl. I TP 304		K52169-4B	.050			X			
F1	20	P-S	S	Pipe	A358 Cl. I TP 304		K52169-4B	.050			X		1.62	
				20"x4" Sweepolet	A182 F304		HF379	*.080			X			*No material test report available. Max. %C assumed.
4	20	E-P	S	Pipe	A358 Cl. I TP 304		K52169-4B	.050			X		2.21	
				Elbow	A403 WP304W		CCCF	.051			X			
5	20	E-V	F	Elbow	A403 WP304W		CCCF	.051			X		2.17	
				Valve										
6	20	P-V	F	Pipe	A358 Cl. I TP 304		K52169-4B	.050			X		1.10	
				Valve										
7	20	P-V	F	Pipe	A358 Cl. I TP 304		K52169-4B	.050			X		1.05	
				Valve										
8	20	P-V	F	Pipe	A358 Cl. I TP 304		60078-1A	.064			X		1.05	
				Valve										
9	20	P-P	F	Pipe			60078-1A	.064			X		1.01	*This weld does not show on shop (Hartwell) spool sketch (Assume max. %C).
				Pipe			*	*.08			X			

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VERMONT YANKEE STATION

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LINE NO.	SYSTEM	REVISION - DATE	PAGE
	RHR LINE "A"		2

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS SERV	SENS	NON	CONF	STRESS RULE INDEX	COMMENTS
10	20	P-E	F	Pipe				*.08			X		2.02	*Mat'l cert. not included. Assume max. %C = 0.08.
				Elbow	carbon steel									

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

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LINE NO.	SYSTEM RHR LINE "B"	REVISION - DATE	PAGE 3

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
1	24	E-T	F	RHR Elbow	A403-WP304W		CCCG	.046			X		1.80	
				Recirc "B" Tee	A4C3-WP304		68144-1	.07			X			
2	24	E-E	S	Elbow	A403-WP304W		CCCG	.046			X		1.70	
				Elbow	A403-WP304W		CCCG	.046			X			
3	24	E-P	S	Elbow	A403-WP304W		CCCG	.046			X		1.93	
				Pipe	A358 Cl. I TP 304		600075-1A	.059			X			
4	24	P-E	S	Pipe	A358 Cl. I TP 304		600075-1A	.059			X		1.69	
				Elbow	A403-WP304W		CCCI	.046			X			
5	24	E-V	F	Elbow	A403-WP304W		CCCI	.046			X		1.50	
				Valve										
6	24	P-V	F	Pipe	A358 Cl. I TP 304		600075-1A	.059			X		1.14	
				Valve										
7	24	P-E	S	Pipe	A358 Cl. I TP 304		600075-1A	.059			X		1.74	
				Elbow	A403-WP304W		CCCH	.046			X			
8	24	P-E	S	Elbow	A403-WP304W		CCCH	.046			X		1.74	
				Pipe	A358 Cl. I TP 304		600075-1A	.059			X			
9	24	P-V	F	Pipe	A358 Cl. I TP 304		600075-1A	.059			X		1.14	
				Valve										

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

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LINE NO.	SYSTEM	REVISION - DATE	PAGE
	RHR LINE "C"		4

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON	CONF	CONF	STRESS RULE INDEX	COMMENTS
1	24	E-T	F	RHR Elbow	A403-WP304W		CCCG	.046			X			1.52	
				Recirc "A" Tee	A403-WP304		68144	.07			X				
2	24	E-E	S	Elbow	A403-WP304W		CCCG	.046			X			1.73	
				Elbow	A403-WP304W		CCCG	.046			X				
3	24	E-P	S	Elbow	A403-WP304W		CCCG	.046			X			2.04	
				Pipe	A358 Cl. I TP 304		690701-1B	.058			X				
4	24	P-P	S	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			1.38	
				Pipe (Bent)	A358 Cl. I TP 304		690701-1B	.058			X				
5	24	P-P	S	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			1.28	
				Pipe (Bent)	A358 Cl. I TP 304		690701-1B	.058			X				
6	24	P-V	F	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			1.14	
				Valve											
7	24	P-V	F	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			1.23	
				Valve											
8	24	P-E	S	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			1.95	
				Elbow	A403-WP304W		CCCI	.046			X				
9	24	P-E	S	Pipe	A358 Cl. I TP 304		690701-1B	.058			X			2.06	
				Elbow	A403-WP304W		CCCI	.046			X				

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

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LINE NO.	SYSTEM RHR LINE "C"	REVISION - DATE	PAGE 5

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREAT-MENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS SERV	SENS	NONCONF	CONF	STRESS RULE INDEX	COMMENTS
10	24	P-E	S	Pipe	A358 Cl. I TP 304		690701-1B	.058			X		2.38	
				Elbow	A403-WP304W		CCCG	.046			X			
11	24	E-V	F	Elbow	A403-WP304W		CCCG	.046			X		2.06	
				Valve										

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

LINE NO.	SYSTEM	REVISION - DATE	PAGE
	Core Spray, "A" Side (type 304)		1

WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV SENS	NUREG 0313 REV 1 STATUS: NON CONF	NUREG 0313 REV 1 STATUS: CONF	STRESS RULE INDEX	COMMENTS
F1	8	E-Pen	F	Elbow	A403WP304		*	*.08	X	X		1.65	*No heat number or %C available - assume max. %C of specification (0.08%).
				Penetration									
F1A	8	E-P	S	Elbow	A403WP304		*	*.08	X	X		1.68	
				Pipe	A312TP304		*	*.08	X	X			
F2	8	P-V	F	Pipe	A312TP304		*	*.08	X	X		1.15	
				Valve									
F3	8	E-V	F	Elbow	A403WP304		*	*.08	X	X		1.58	(No certificates in package for A403 elbows.)
				Valve									
F3A	8	E-P	S	Elbow	A403WP304		*	*.08	X	X		1.72	(No certificates in package for A403 elbows.)
				Pipe	A312TP304		2P3362	.08	X	X			
F3B	8	P-P	S	Pipe	A312TP304		2P3362	.08	X	X		1.07	
				Pipe	A312TP304		2P3362	.08	X	X			
F4	8	P-V	F	Pipe	A312TP304		2P3362	.08	X	X		1.30	
				Valve									

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METALLURGICAL EVALUATION SUMMARY

VERMONT YANKEE STATION

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LINE NO.	SYSTEM	REVISION - DATE	PAGE
	Core Spray, "B" Side (type 304)		2

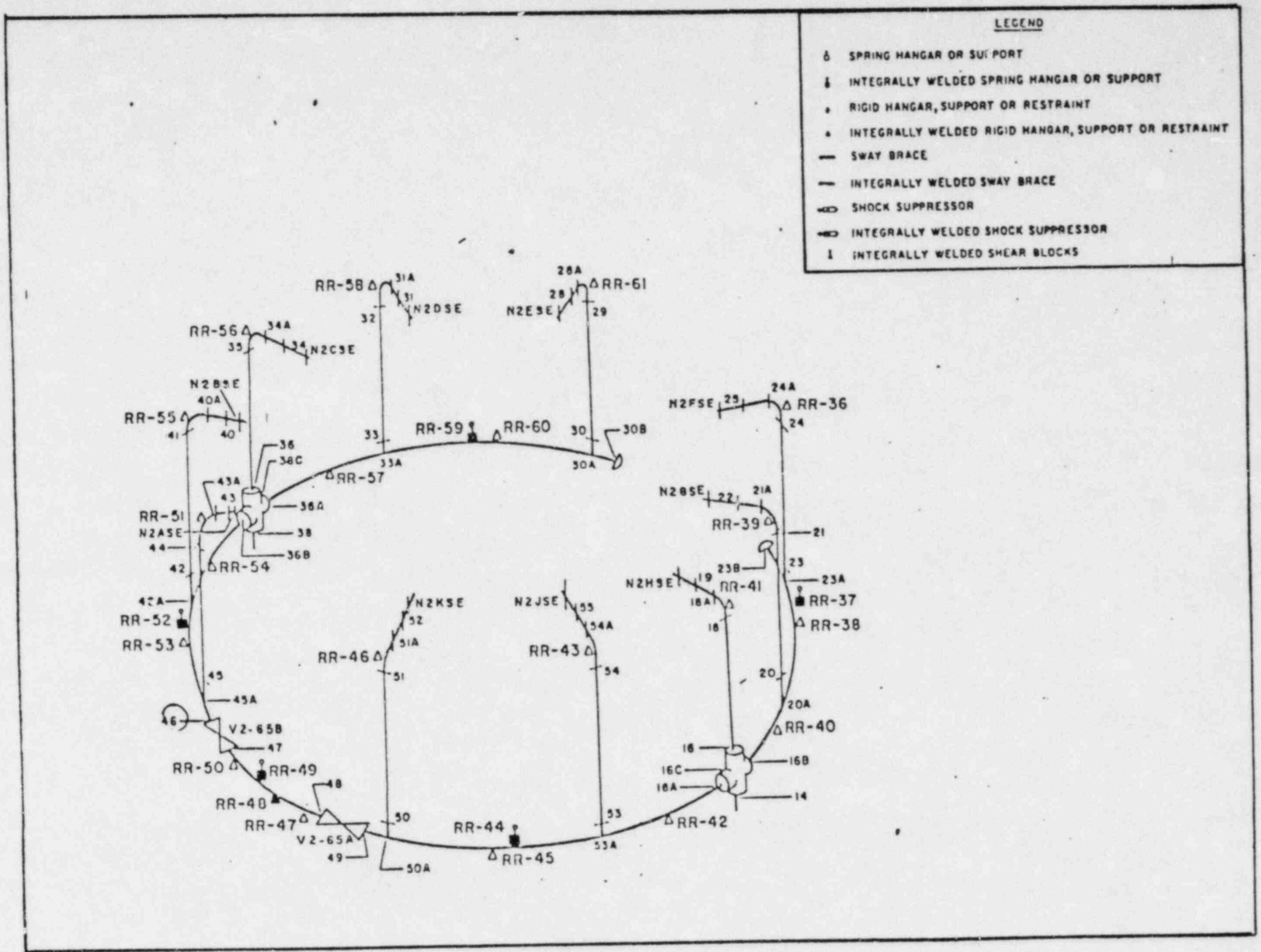
WELD NUMBER	DIA. (IN)	WELD TYPE	SHOP OR FIELD WELD	COMPONENT	MATERIAL TYPE & SPECIFICATION	HEAT TREATMENT	HEAT NUMBER	CARBON CONTENT (%)	NUREG 0313 REV 1 STATUS: SERV	SENS	NON CONF	CONF	STRESS RULE INDEX	COMMENTS
F1	8	E-Pen	F	Elbow	A403WP304		*	*.08	X	X			1.81	*No heat number or %C available - assume max. %C of specification (0.08%).
				Penetration										
F1A	8	E-P	S	Elbow	A403WP304		*	*.08	X	X			1.72	
				Pipe	A312TP304		*	*.08	X	X				
F2	8	P-V	F	Pipe	A312TP304		*	*.08	X	X			1.18	
				Valve										
F3	8	E-V	F	Elbow	A403WP304		*	*.08	X	X			1.64	(No certificates in package for A403 elbows).
				Valve										
F3A	8	E-P	S	Elbow	A403WP304		*	*.08	X	X			1.83	(No certificates in package for A403 elbows.)
				Pipe	A312TP304		2P3362	.08	X	X				
F3B	8	P-P	S	Pipe	A312TP304		2P3362	.08	X	X			1.10	
				Pipe	A312TP304		2P3362	.08	X	X				
F4	8	P-V	F	Pipe	A312TP304		2P3362	.08	X	X			1.27	
				Valve										

APPENDIX B

INSERVICE INSPECTION ISOMETRIC DRAWINGS

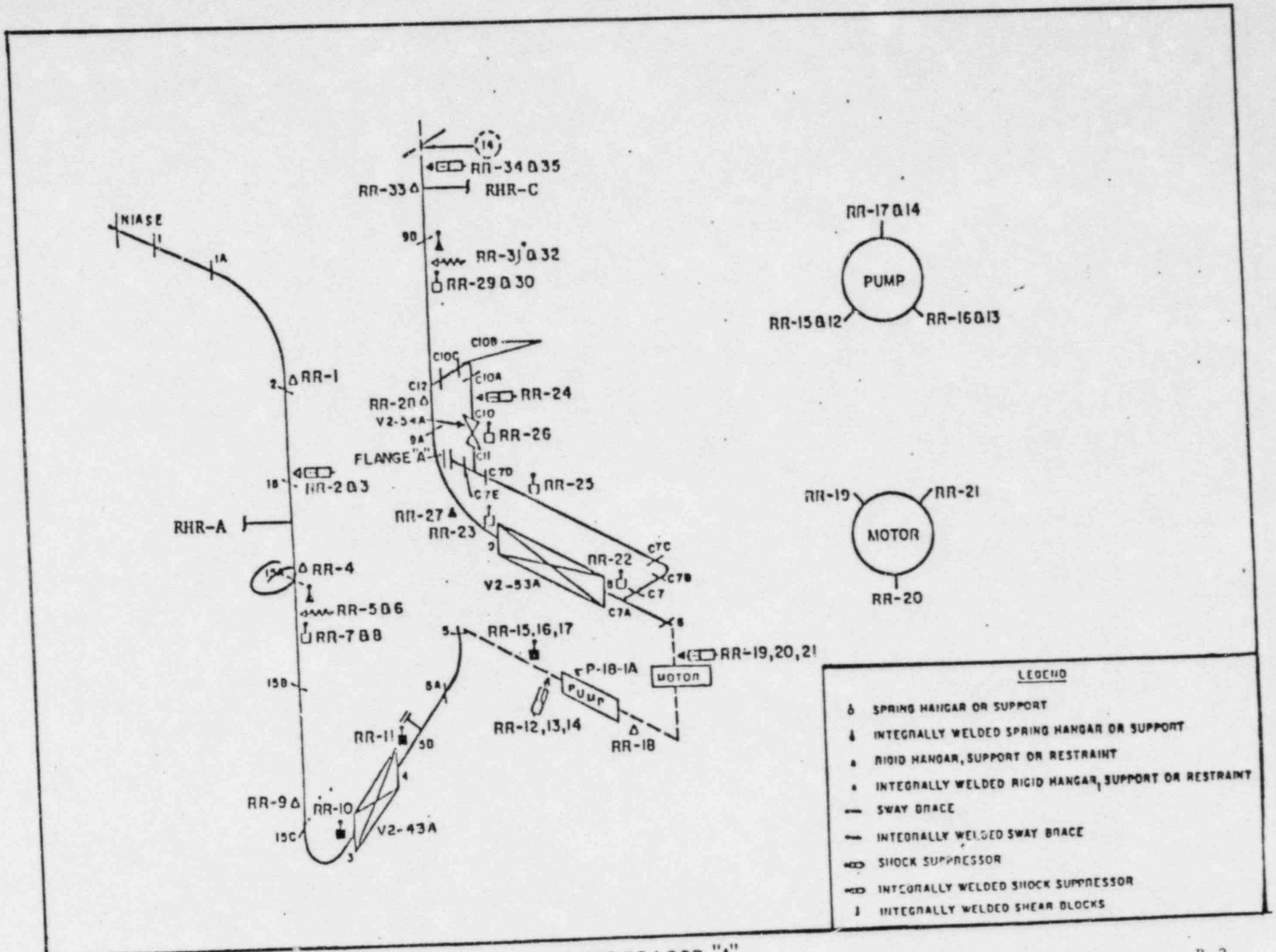
APPENDIX B

LIST OF FIGURES



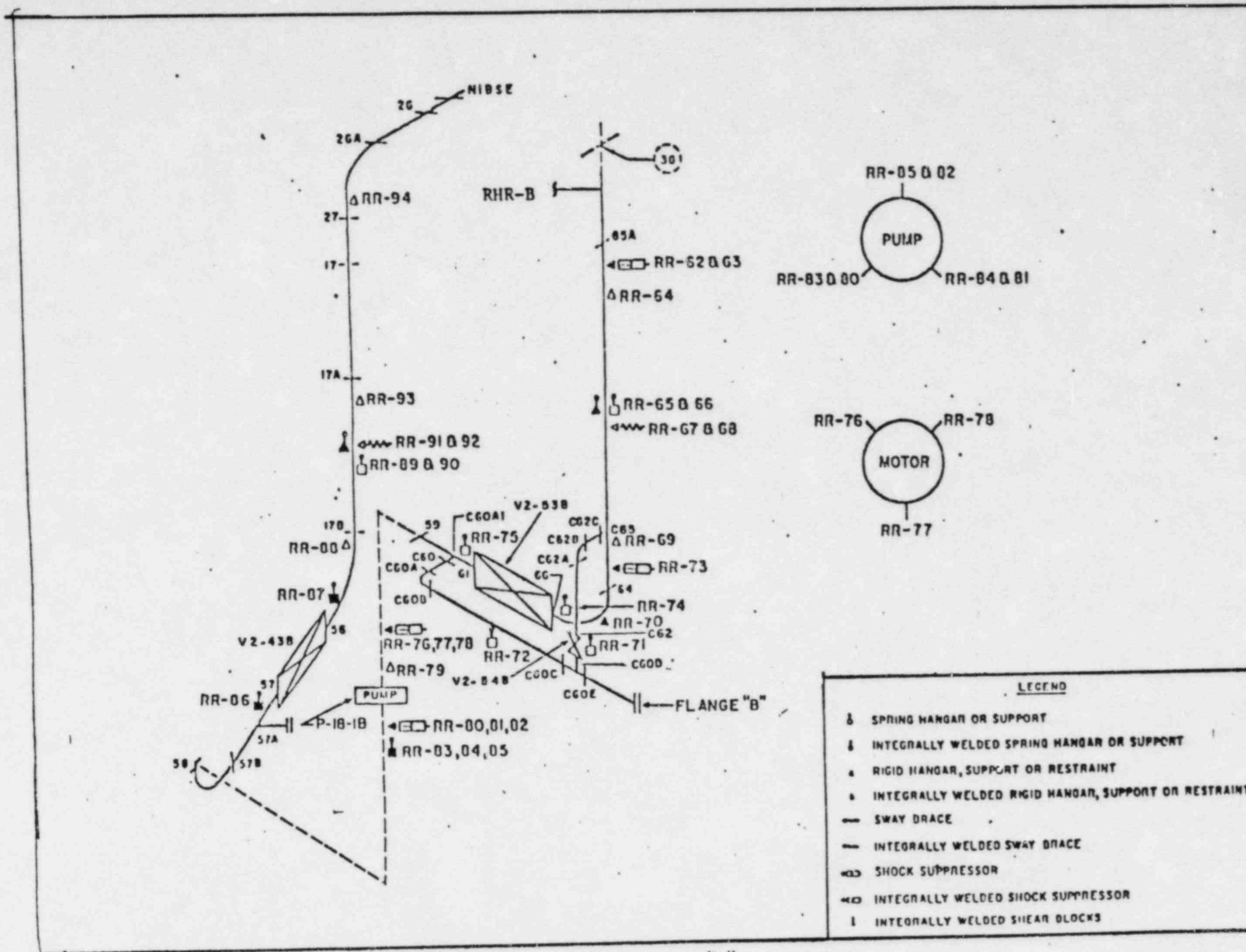
RECIRC RING HEADER & INLETS

REF EDASCO DWG. 5920-FS-I33



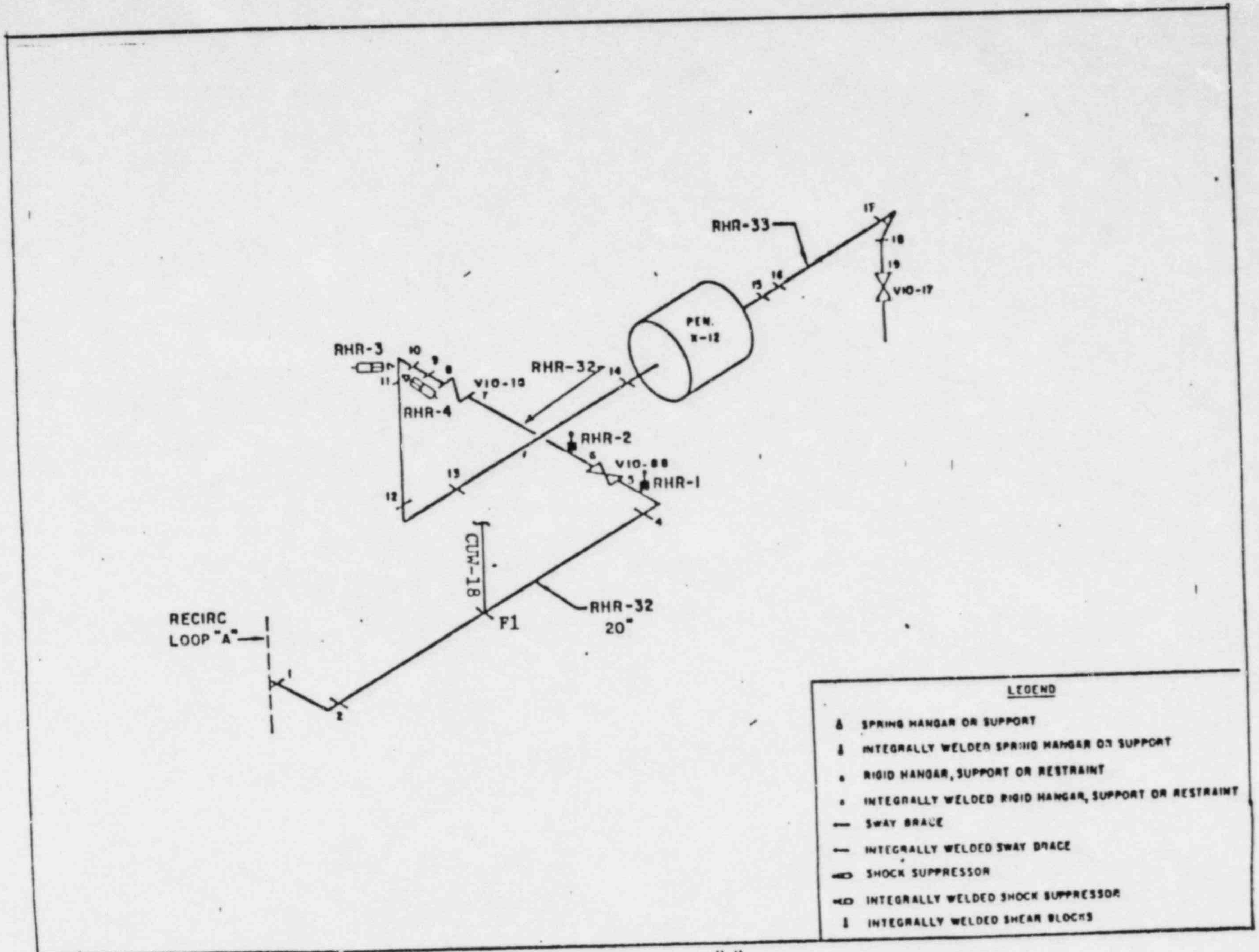
RECIRC LOOP "A"

REF EBASCO DWG. 5920-FS-733



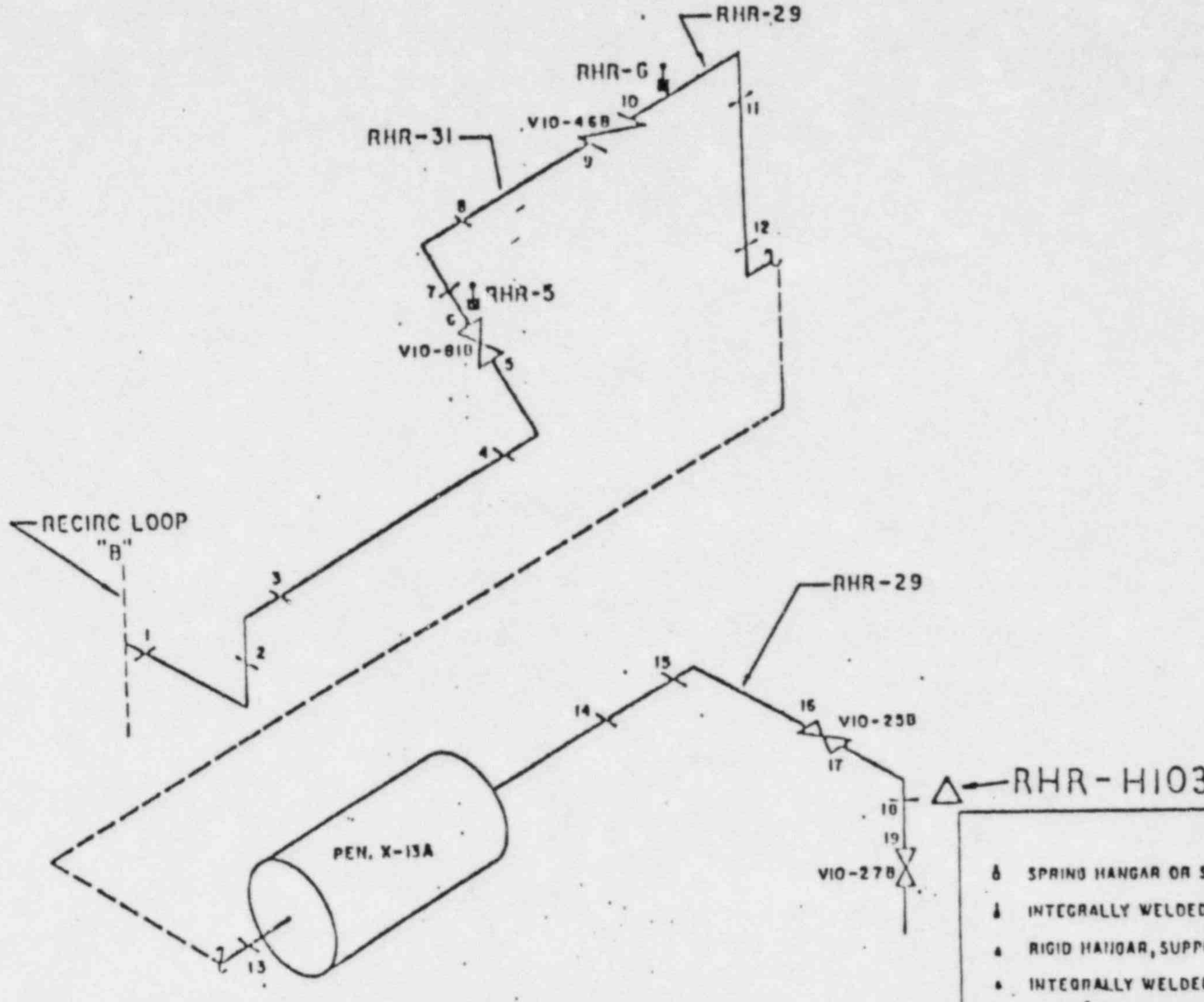
RECIRC LOOP "B"

REF. EUASCO DWG. 5920-FS-133



RHR PIPING LINE "A"

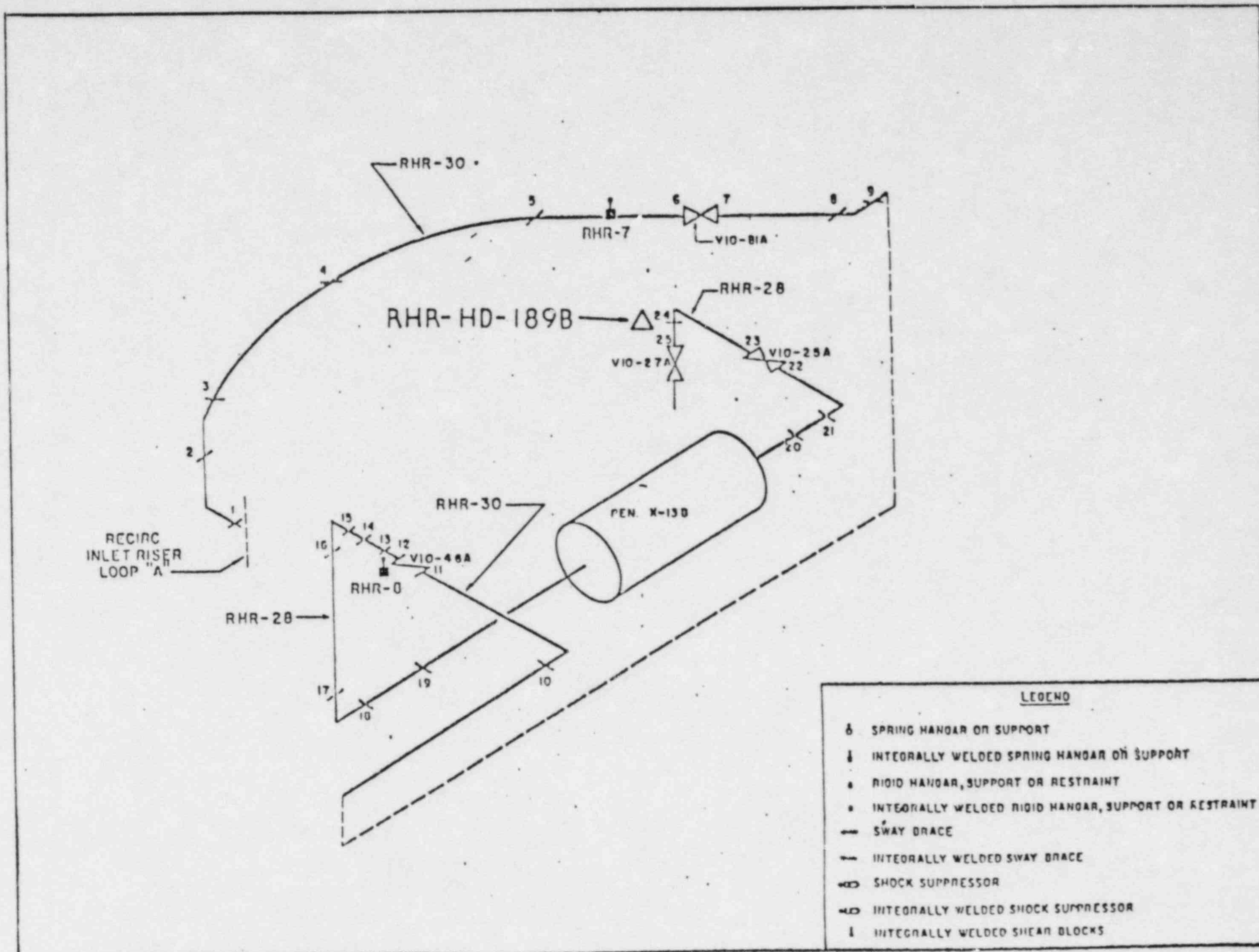
REF. EBASCO DWG. 5920-FS-143B



LEGEND

- SPRING HANGAR OR SUPPORT
- INTEGRALLY WELDED SPRING HANGAR OR SUPPORT
- RIGID HANGAR, SUPPORT OR RESTRAINT
- INTEGRALLY WELDED RIGID HANGAR, SUPPORT OR RESTRAINT
- SWAY BRACE
- INTEGRALLY WELDED SWAY BRACE
- SHOCK SUPPRESSOR
- INTEGRALLY WELDED SHOCK SUPPRESSOR
- INTEGRALLY WELDED SHEAR BLOCKS

RHR PIPING LINE "B"



RHR PIPING LINE "C"

ENCLOSURE C

VERMONT YANKEE 83-02 EXAMINATION PROGRAM

Weld Examination Selection Criteria

Vermont Yankee developed a plant specific program based on the number and location of weld joints specified in USNRC Bulletin 83-02, Action (2) and a stress rule index/carbon matrix developed for Vermont Yankee by Nutech. This matrix and its basis is included as Enclosure B.

Figure C-1 indicates the weld joints included in the first inspection, and the results of that inspection.

Further examinations were performed based on the indications found in the first inspections. It was decided that eight additional large pipe weld joints and eleven weld joints in the 12 inch diameter piping would be inspected.

The criteria for selecting the second sample of large bore weld joints was based on the stress rule index/carbon matrix, specific joint configuration, and incidence of repair during construction. This criteria was established at a meeting with the USNRC at Region 1 headquarters on April 19, 1983.

The 12 inch diameter weld joints were selected based on failures at Vermont Yankee. The joints selected were the remaining pipe to safe-end joints and the remaining riser to sweepolet joints.

A third examination was conducted on all of the remaining riser welds. This examination was conducted based on data received from the Hatch and Dresden Power Plants. This data indicated that the riser to elbow weld joints were highly susceptible to cracking. The welds examined are shown on Figure C-1.

In addition to the examinations performed in the 83-02 program, recirculation inlet safe-ends N2F, N2H, and N2K, were examined as part of the regular ISI program. No indications were found.

In summary - forty of forty weld joints were examined in the 12 inch diameter piping. Twenty-two of the forty joints were found to have unacceptable indications.

In the large bore pipe, twelve out of thirty-three welds were examined in the 28 inch diameter piping. Eight of the twelve had indications. No indications were greater than 15% through wall thickness.

The remaining inspections were performed on the 22 inch header welds and two welds in the RHR system. Four of eight welds examined had indications. No indication was greater than 15% through wall thickness.

A summary of the welds examined, welds with indications, and the location, size, and orientation of the indications is attached.

EXAMINATION SEQUENCE

	1st Exams Weld Numbers	2nd Exams Weld Numbers	3rd Exams Weld Numbers
12" DIA.	33,30,16,53, 36,24A,31A, 19,28A,34A,34, 25,28	42,45,50,20, 23,40,43,31, 22,55,52	24,32,54A,51A, 18A,21A,40A, 43A,29,44,54, 51,41,21,18,35
22" DIA.	16B,30B,23A 30A,36B	RHR-32 WELD 4(20"), 46,RHR-31 WELD 1 (24")	
28" DIA.	38,2,9A,65A 1A,9B,64	15A,17,58,59,66	

1st Exams - original bulletin exams
2nd Exams - supplemental exams
3rd Exams - supplemental exams to complete 12" dia. piping

Figure C-1

ENCLOSURE C

INSPECTION RESULTS

TABLE 1

AUGMENTED ISI RESULTS

Size	Number	Configuration	Results
12"	24	Riser Pipe to Elbow	15% TWD* - 360° Intermittent Pipe Side Only; Circumferential Only
12"	32	Riser Pipe to Elbow	20% TWD - 360° Intermittent Pipe Side Only; Circumferential Only
12"	54A	Horizontal Pipe to Elbow	No Relevant Indications
12"	51A	Horizontal Pipe to Elbow	No Relevant Indications
12"	18A	Horizontal Pipe to Elbow	No Relevant Indications
12"	21A	Horizontal Pipe to Elbow	No Relevant Indications
12"	40A	Horizontal Pipe to Elbow	No Relevant Indications
12"	43A	Horizontal Pipe to Elbow	No Relevant Indications
12"	29	Riser Pipe to Elbow	20% TWD - 360° Intermittent; Both Sides of Joint; Circumferential Only
12"	44	Riser Pipe to Elbow	No Relevant Indications
12"	54	Riser Pipe to Elbow	24% TWD - 360° Intermittent Pipe Side Only; Circumferential Only
12"	51	Riser Pipe to Elbow	40% TWD - 360° Intermittent Pipe Side Only; Circumferential Only
12"	41	Riser Pipe to Elbow	No Relevant Indications
12"	21	Riser Pipe to Elbow	No Relevant Indications
12"	18	Riser Pipe to Elbow	22% TWD - 360° Intermittent Pipe Side Only; Circumferential Only

*TWD - Through Wall Dimension

AUGMENTED ISI RESULTS

Size	Number	Configuration	Results
12"	35	Riser Pipe to Elbow	22% TWD - 360° Intermittent Pipe Side Only; Circumferential Only
12"	33	Sweepolet to Riser	16-17% TWD - 2" Linear Extent
12"	30	Sweepolet to Riser	50% TWD - 3" Linear Extent
12"	16	Sweepolet to Riser	15% TWD - 360° Intermittent
12"	53	Sweepolet to Riser	25% TWD - 360° Intermittent
12"	36	Sweepolet to Riser	25% TWD - 360° Intermittent
12"	24A	Elbow to Horizontal Pipe	No Relevant Indications
12"	31A	Elbow to Horizontal Pipe	No Relevant Indications
12"	19	Safe End to Pipe	No Relevant Indications
12"	28A	Elbow to Horizontal Pipe	No Indications
12"	34A	Elbow to Horizontal Pipe	No Indications
12"	34	Pipe to Safe End	15% TWD - 2" Linear Extent
12"	25	Pipe to Safe End	15% TWD - 2" Linear Extent
12"	28	Pipe to Safe End	No Relevant Indications
12"	42	Sweepolet to Riser	Maximum 30% TWD - 360° Intermittent

AUGMENTED ISI RESULTS

Size	Number	Configuration	Results
12"	45	Sweepolet to Riser	Maximum 30% TWD - 360° Intermittent
12"	50	Sweepolet to Riser	Maximum 30% TWD - 360° Intermittent
12"	20	Sweepolet to Riser	Maximum 35% TWD - 360° Intermittent
12"	23	Sweepolet to Riser	Maximum 32% TWD - 360° Intermittent
12"	40	Pipe to Safe End	Maximum 15% TWD - 360° Intermittent; Pipe Side
12"	43	Pipe to Safe End	No Relevant Indications
12"	31	Pipe to Safe End	20% TWD - 2 Indications - 1" Linear Extent
12"	22	Pipe to Safe End	No Relevant Indications
12"	55	Pipe to Safe End	No Relevant Indications
12"	52	Pipe to Safe End	10% TWD - 360° Intermittent; Pipe Side (Both Sides)
22"	16B	Ring Header to Cross	10% TWD - 4-1/2" Linear Extent
22"	30B	End Cap to Ring Header	15% TWD - 4-1/2" Linear Extent
22"	23A	Sweepolet to Ring Header	No Indications
22"	30A	Sweepolet to Ring Header	No Relevant Indications
22"	36B	Ring Header to Cross	10% TWD - 12" Linear Extent

AUGMENTED ISI RESULTS

Size	Number	Configuration	Results
22"	46	Header to Valve	No Relevant Indications
24"	RHR-31 Weld 1	Tee to Elbow	5 to 7% TWD - 3" to 4" Linear Extent
20"	RHR-32 Weld 4	Pipe to Elbow	No Indications
28"	38	Tee to Cross	No Relevant Indications
28"	2	Elbow to Pipe	10% TWD - 360° Intermittent
28"	9A	Elbow to Pipe	10% TWD - 360° Intermittent
28"	65A	Pipe to Tee	15% TWD - 9-1/2" Linear Extent
28"	1A	Pipe to Elbow	15% TWD - 38" Linear Extent
28"	9B	Pipe to Tee	No Relevant Indications
28"	64	Elbow to Pipe	10-15% TWD - Longest Linear Extent - 4"
28"	15A	Tee to Pipe	3 Indications - Circulation - Not Exceeding 15% TWD - Linear Extent - 5", 7-1/2", 11"
28"	17	Pipe to Pipe	No Relevant Indications
28"	58	Elbow to Pump	5-15% TWD - 5 Indications - 3, 1.5, 1.0, 7.0, 17.5" Linear Extent
28"	59	Pump to Pipe	13-15% TWD - 2 Indications - 3" Linear Extent
28"	66	Valve to Elbow	No Relevant Indication

TABLE II

RESULTS
FLAW EVALUATION
LARGE DIAMETER PIPING(1)

PIPE	WELD	(2) A	L	A/T (% TWD)	A/T ALLOW BØC	END OF CYCLE FLAW DEPTH (% TWD)	A/T ALLOW EØC	ACTION
28"	64	.19"	4"	.1-.15	.55	.21	.75	NO REPAIR REQUIRED FOR ONE OPERATION CYCLE.
28"	1A	.19"	38"	.15	.34	.21	.68	↓
28"	2	.13"	360°	.1	.41	.21	.63	
28"	9A	.13"	360°	.1	.43	.21	.63	
28"	65A	.19"	9.5"	.15	.41	.21	.75	
28"	15A	.19"	11"	.15	.41	.21	.75	
28"	58	.19"	17.5"	.15	.44	.21	.75	
28"	59	.19"	3"	.15	.44	.21	.75	
22"	16B	.1"	4.5"	.1	.35	.13	.75	
22"	36B	.1"	12.0"	.1	.29	.13	.75	
22"	30B	.15"	4.5"	.15	.48	.17	.75	
24"	RHR-31 Weld 1	.09"	4.0"	.07	.50	.1	.75	

(1) An explanation of the associated conservatisms of this table are provided in Enclosure D.
(2) For explanation of symbols see Sheet 2.

EXPLANATION OF SYMBOLS

A	-	FLAW DEPTH; MAXIMUM DETECTED
L	-	FLAW LENGTH; MAXIMUM
A/T	-	FLAW DEPTH AS A PERCENTAGE OF WALL THICKNESS
$[A/T]_{ALLOW\ BØC}$	-	ALLOWABLE BEGINNING OF FUEL CYCLE FLAW DEPTH ASSUMING THAT MAXIMUM DETECTED FLAW IS 360° AROUND THE CIRCUMFERENCE OF PIPE.
$[A/T]_{ALLOW\ EØC}$	-	ALLOWABLE END OF FUEL CYCLE FLAW DEPTH ASSUMING THAT MAXIMUM DETECTED FLAW IS 360° AROUND THE CIRCUMFERENCE OF PIPE.

ENCLOSURE D

5.0 FLAW EVALUATION

5.1 Background

The current edition of the ASME Boiler and Pressure Vessel Code Section XI (Reference 9) does not contain explicit criteria for determining allowable crack depth in stainless steel piping. A proposed addition to Section XI (Reference 10) provides such criteria. Based on Reference 10, the maxium allowable crack depth at any location in the piping can be determined. The crack growth that would occur during the next twelve month fuel cycle can then be calculated using fracture mechanics, and the allowable crack depth at the beginning of the next fuel cycle. If the ultrasonically determined crack depths are equal to or larger than the allowable beginning of fuel cycle crack depth, then a repair or replacement is required. If the ultrasonically determined crack depths are significantly smaller than the allowable beginning of fuel cycle crack depth, then a repair is not required at this time.

5.2 Load Description and Stress Profile

The applicable loads considered in the evaluation of flaws consist of internal pressure, dead weight, thermal expansion, seismic and weld residual stresses. These loads which are obtained from Enclosure B, Section 2.2 are discussed in the following paragraphs.

Axial stresses due to dead weight, thermal expansion and seismic loads tend to cause circumferential crack growth. Therefore, only axial stresses due to these loads are discussed below.

5.2.1 Internal Pressure

The axial stress due to internal pressure is considered as a primary stress and is calculated as:

$$\sigma_p = \frac{PR}{2t} \qquad (5\text{-}1)$$

where: P = Operating pressure

R = Pipe outside radius

t = Pipe wall thickness

5.2.2 Dead Weight

The stress due to dead weight is considered as a primary stress, and is calculated as:

$$_{DW} = \frac{(F_A)_{DW}}{A} + \frac{(M)_{DW}}{Z} \qquad (5\text{-}2)$$

where: F_A = Axial Force

M = Resultant bending moment = $\sqrt{M_B^2 + M_C^2}$

M_B, M_C = Two bending moments

A = Cross-Sectional Area

Z = Sectional Modulus

5.2.3 Thermal Loads

The thermal stress due to steady state thermal expansion and thermal anchor movements is considered as secondary stress, and is calculated as:

$$_{TH} = \frac{(F_A)_{TH}}{A} + \frac{(M)_{TH}}{Z} \qquad (5\text{-}3)$$

5.2.4 Seismic Loads

Stresses due to seismic are not considered for crack growth due to intergranular stress corrosion cracking (IGSCC), but are included in the (p_m+p_b) stress to calculate allowable end-of-inspection period crack size (See Section 5.3). The seismic stress is calculated as:

$$_{seismic} = \frac{(F_A)_{seismic}}{A} + \frac{(M)_{seismic}}{Z} \qquad (5-4)$$

A summary of stresses used in the flaw evaluation is shown in Table 5.1.

5.2.5 Weld Residual Stress

The magnitude and distributions of residual stresses in a non-stress relieved butt weld piping system depends on many parameters, such as welding heat inputs, heat transfer boundary conditions, pipe wall thicknesses, and pipe diameters. EPRI has summarized the residual stresses in type 304 stainless steel piping butt weldments in two separate reports, NP-1413 and NP-2662-LD, published in June 1980 and December 1982, respectively (Ref. A-1 & A-2). Based on these two references, the effects of heat inputs, boundary cooling, pipe wall thickness and pipe diameters are

summarized and plotted in Figure A.1 through A.8 of Appendix A. The through-wall residual stress distributions in 4-inch 10-inch and 26-inch pipes are plotted in Figures A.9 through A.11 from Reference A-1 and Figures A.12 through A.14 from Reference A-2.

As can be observed from these figures in Appendix A, both the magnitudes and through-wall distributions of the butt weld residual stress could vary significantly depending upon various parameters involved. To achieve a balance between conservatism and reality, NUTECH has developed a set of standard butt welds residual stress distributions. The inner wall residual stresses are specified at a magnitude between the maximum and the mean values in Figures A.5 and A.6 for axial and circumferential directions, respectively. Figures 5.2, 5.3, and 5.4 plot residual stresses in 4 to 6-inch, 8 to 12-inch, and 20 to 28-inch pipes, respectively. These residual stress profiles have been used in the crack growth evaluation.

5.3 Allowable End-of-Inspection Period Flaw Size

Reference 10 is based on the conservative net section collapse method. The results of net section collapse analyses are presented in a tabular format in Table 5.2

which gives the allowable crack size as a function of the applied primary stress (weight, seismic, etc.). The allowable crack sizes presented in the tables include the standard design safety margins implicit in ASME Section III design rules for nuclear power piping.

Table 5.2 (Reference 10) gives the allowable circumferential crack depth as a function of length for various values of applied axial primary membrane plus bending ($P_m + P_b$) Stress. In Table 5.2, stress ratio is calculated as:

$$\frac{P_m + P_b}{S_m} = \frac{1}{S_m} (\sigma_p + \sigma_{DW} + \sigma_{seismic}) \qquad (5-5)$$

where σ_p = Pressure Stress (Equation 5-1)

σ_{DW} = Axial stress due to dead weight (Equation 5-2)

$\sigma_{seismic}$ = Axial stress due to primary seismic loads (Equation 5-4)

S_m = 16,950 psi at 550°F

Note that in Table 5.2, the allowable crack depth for short cracks was not allowed to exceed 75% of the wall thickness even though net section collapse analysis would permit much deeper cracks for very short crack lengths. This truncation of the net section collapse

analysis procedure is somewhat artificial and could be eliminated for short, almost through-wall cracks if leaks are prevented by some means, such as the installation of IGSCC resistant weld material.

5.4 Crack Growth Evaluation

Existing cracks can grow due to both fatigue and stress corrosion. The fatigue crack growth within a refueling cycle is negligibly small in comparison with crack growth due to IGSCC since there will be only a few transient cycles involved. Therefore, in this analysis, only IGSCC growth is considered. IGSCC growth is a function of the total applied steady state stress including weight, pressure, thermal expansion and weld residual stress, but not including transient stresses such as seismic.

5.4.1 Crack Growth Law

Crack growth was calculated based on Reference 11 and 12. Crack growth rate as a function of applied stress intensity factor for weld sensitized 304 stainless steel is shown in Figure 5.1.

The upper bound crack growth law of Figure 5.1 was used in the analysis.

$$\frac{da}{dT} = 4.116 \times 10^{-12} K^{4.615} \qquad (5\text{-}6)$$

where: da = Differential crack size

dT = Differential time

K = Applied stress intensity factor

The stress intensity factor (K) was obtained using the procedures in Appendix A of Reference 9.

$$K = (\sigma_m M_m + \sigma_b M_b) \frac{\pi a}{Q} \qquad (5\text{-}7)$$

where: Q = Flaw shape parameter as determined from Figure A-3300-1 of Reference 9 using primary stresses $(\sigma_m + \sigma_b)/\sigma_{ys}$ and the flaw geometry.

M_m, M_b = Correction factors from Figures A-3300-3 and A-3300-5 of Reference 9, respectively.

a = Crack depth

σ_m, σ_b = Applied membrane and bending stress which tend to cause crack growth (See Sections 5.4.2 below).

5.4.2 Circumferential Cracks

For circumferential cracks, σ_m and σ_b are axial stresses due to pressure, dead weight, thermal and weld residual stresses.

$$\sigma_m = \sigma_p + \sigma_{DW} + \sigma_{TH} + (Resid)_m, \text{ and}$$

$$\sigma_b = (Resid)_b \qquad (5\text{-}8)$$

where σ_p = Pressure stress (Equation 5-1)

σ_{DW} = Axial stress due to dead weight (Equation 5-2)

σ_{TH} = Axial stress due to thermal loads (Equation 5-3)

$(Resid)_m$ = Axial weld residual membrane stress (Section 5.2.5)

$(Resid)_b$ = Axial weld residual bending stress (Section 5.2.5)

5.4.3 Allowable Beginning of Cycle Crack Sizes

Given initial crack depth (a) and crack depth to length ratio (a/ℓ), the crack growth can be calculated by integration of Equation 5-5.

During that crack growth, one can locate the time where the allowable end of cycle crack depth has been reached. The allowable beginning of cycle crack size can then be determined by going back twelve months from the end of cycle.

By repeating the procedures stated above, a number of data points which represent the allowable beginning of fuel cycle crack sizes for different a and a/ℓ ratios can be generated and plotted.

5.4.3.1 ASME Section XI Flaw Curve

In order to develop the curves for the allowable beginning of fuel cycle circumferential crack sizes, the following procedures have been used.

1. Identify the weld location where an indication is found; σ_m and σ_b are calculated by Equation 5-8.

2. Determine allowable end of fuel cycle crack sizes using Table 5.2.

3. Given an initial crack depth and crack depth to length ratio, determine the stress intensity factor (K) using Article A-3000 of ASME Section XI (Reference 9).

4. Calculate crack growth by integration of Equation 5-6.

5. From the calculated crack growth, locate the time where the crack depth reaches allowable end of fuel cycle crack size calculated in Step 2 above.

6. Find the allowable beginning of fuel cycle crack sizes by going twelve months back from the time found in Step 5 above.

7. Change initial crack depth and crack depth to length ratio, repeat steps 3 to 6 for different allowable beginning of fuel cycle crack sizes.

8. Plot the data found in steps 6 and 7.

Steps 3 and 4 are calculated using the NUTECH computer program, NUFLAW (Reference 13).

As an example, Figure 5.5 plots the allowable beginning of fuel cycle crack sizes for circumferential flaws at 28-inch pipe weld 1A.

As stated in Section 5.2.5, the axial weld residual stress distribution for pipe size over 20 inches is non-linear across the wall. The residual stress distribution has been linearized to $_{m}$ = 0 and $_{b}$ = 30,000 psi in order to use the program NUFLAW for the calculation procedure per Appendix A of the ASME Section XI.

5.4.3.2 NUTCRAK Flaw Curves

Another crack growth evaluation computer program NUTCRAK (Reference 14) has been used to adjust the allowable beginning of fuel cycle crack sizes for a long crack.

In NUTCRAK, a single edge cracked plate model was conservatively chosen and the nonlinear residual stress distribution was used. The stress intensity factor (k) is calculated on the assumption of an infinitely long crack (Reference 15). This approach differs from that of Equation 5-7 which cannot treat nonlinear residual stress distributions.

Assuming the detected circumferential flaws are infinitely long, the allowable flaw depth for a 12-month fuel cycle are tabulated in Table 5.1.

For all the circumferential cracks of pipe sizes over 20 inches, a horizontal line was drawn at the value of $a/\ell = 0$ until the NUFLAW curve was reached. A flaw found to be below these curves will be acceptable for one 12-month refueling cycle.

A sample calculation at weld 28"-1A is presented in the following section.

5.4.3.3 Sample Calculation for Long Cracks

The pipe dimensions and stress magnitudes at weld 28"-1A are summarized as follows:

O.D. = 28.106" $t = 1.088"$ $P = 1250$ psi

$S_y = 18,800$ psi $S_m = 16,950$ psi at 550°F

$\sigma_p = 7427$ psi $\sigma_{DW} = 1043$ psi

$\sigma_{TH} = 1954$ psi $\sigma_{seismic} = 585$ psi

Primary Stress:

$$\sigma_m = \sigma_p + \sigma_{DW} = 8,470 \text{ psi}$$

$$\sigma_b = 0$$

Secondary Stress:

$$\sigma_m = \sigma_{TH} + (\text{Resid})_m = 1,954 \text{ psi} + (\text{Resid})_m$$

$$\sigma_b = (\text{Resid})_b$$

where Resid = Weld residual stress (See Figure 5.4)

Stress Ratio:

$$\frac{P_m + P_b}{S_m} = \frac{1}{S_m} [\sigma_p + \sigma_{DW} + \sigma_{seismic}] = 0.534$$

Circumference:

$$2\pi r_i = \pi (O.D. - 2t) = 81.461"$$

From Table 5.2 (proposed Table IWB-3641-1)

ℓ_f	8.146	16.292	24.438	32.584	40.731	or more
$^a/t$	0.75	0.75	0.75	0.73	0.63	
a	0.816	0.816	0.816	0.794	0.685	

For a long circumferential crack the allowable end-of-inspection period flaw depth is found to be 0.685" from the above tabulation.

Given an initial crack depth of 0.1632" (= .15t), program NUTCRAK yields crack growth results as follows:

Month	a
.	.
.	.
.	.
33	.3741
.	.
.	.
.	.
45	.6064
46	.7554

As shown above the crack depth of a = 0.685" falls between Month 45 and Month 46.

To be conservative, the allowable beginning 12-month fuel cycle depth is taken to be 0.3741" which corresponds to Month 33 in the NUTCRAK computer printout.

This gives a crack depth to thickness ratio of

$$\frac{a}{t} = \frac{.3741}{1.088} = .34$$

5.5 Conservatisms

The following conservatisms have been applied in the present allowable flaw size assessment.

a. The fracture mechanics model for crack growth is based on a single edged cracked flat plate model which results in considerably higher stress intensity factors and crack growth than the actual cracked circular pipe.

b. The crack growth law used in this report was based on the upper bound limit as described in the EPRI 2423-LD Report (Reference 12). The predicted crack growth rate would have been slower if the best estimated crack growth law were used.

c. The through wall weld residual stress pattern adopted in this report is more conservative than that recommended by the EPRI (Reference 16). As shown in Figure 5.6, the EPRI recommended curve gives considerably higher compressive residual stresses in a region between 30 to 50% through wall thicknesses where critical crack growth dominates. If the EPRI weld residual stress pattern were used in the analysis, the crack growth period for a crack to reach 50% through wall thickness would be much longer.

d. All circumferential cracks for 20" to 28" pipes have been considered to be 360°.

e. The proposed ASME Section XI Table IWB-3641-1 on allowable end-of-inspection period flaw size is based on the net section collapse method of analysis. The net pipe section is assumed to behave in an elastic/perfectly plastic manner. In reality, the stainless steel will exhibit strain hardening behavior and thus gives a somewhat higher collapse load than the value used for the basis of the proposed ASME flaw acceptance criteria table.

TABLE 5.1

Stress Summary of Flaw Evaluation

PIPING SYSTEM	PIPE SIZE (inch)	COMPONENT TYPE	WELD ID	AXIAL STRESSES(1) (psi)				FLAW SIZE DETECTED a/t (%)	PREDICTED FLAW SIZE AFTER 12-MONTH a/t (%)(2)	ALLOWABLE FLAW SIZE a/t (%)
				PRESS	DW	TH	OBE			
RECIRCULATION LOOP A & B	28"	P-E	1A	7427	1043	1954	585	15	20	34
	28"	P-E	2	7427	857	716	923	10	-	41
	28"	P-E	9A	7539	340	296	854	10	-	43
	28"	P-T	15A	7427	612	892	2546	15	-	41
	28"	PP-E	58	7427	92	475	200	15	-	44
	28"	PP-P	59	7539	112	370	1357	15	-	44
	28"	P-E	64	7539	188	109	452	10-15	-	44
	28"	P-T	65A	7539	564	521	1133	15	-	41
	22"	RHD-CR	16B	7467	1420	1831	1282	10	-	35
	22"	RHD-CAP	30B	7467	0	0	822	15	-	48
	22"	RHD-CR	36B	7467	1621	3239	1481	10	13	29
RHR	24"	T-E	1	5717	1500	2108	1601	7	-	50

NOTE: (1) Residual Stress Distribution See Figure 5.4(a).
(2) The predicted a/t of 20% and 13% represent the maximum flaw size after 12 months in 28" and 22" lines respectively.

TABLE 5.2

PROPOSED TABLE IWB-3641-1

ALLOWABLE END-OF-INSPECTION PERIOD SIZE FOR CIRCUMFERENTIAL FLAWS NORMAL CONDITIONS

$\frac{P_m + P_b}{S_m}$ (1)	Ratio of Length to Circumference				
	0.1	0.2	0.3	0.4	0.5 or more
	Ratio of Flaw Depth to Thickness (2)				
1.5	(3)	(3)	(3)	(3)	(3)
1.4	0.30	0.20	(3)	(3)	(3)
1.3	0.48	0.38	0.28	0.18	0.18
1.2	0.66	0.56	0.46	0.36	0.26
1.1	0.73	0.63	0.53	0.43	0.33
1.0	0.75	0.70	0.60	0.50	0.40
0.9	0.75	0.75	0.66	0.56	0.46
0.8	0.75	0.75	0.72	0.62	0.52
0.7	0.75	0.75	0.75	0.68	0.58
0.6	0.75	0.75	0.75	0.73	0.63

(1) P_m = Primary Membrane Stress
P_b = Primary Bending Stress
S_m = ASME Code Design Stress at Temperature

(2) Crack Depth = a for a Surface Flaw
2a for a Subsurface Flaw

(3) IWB-3514-3 Standards Govern

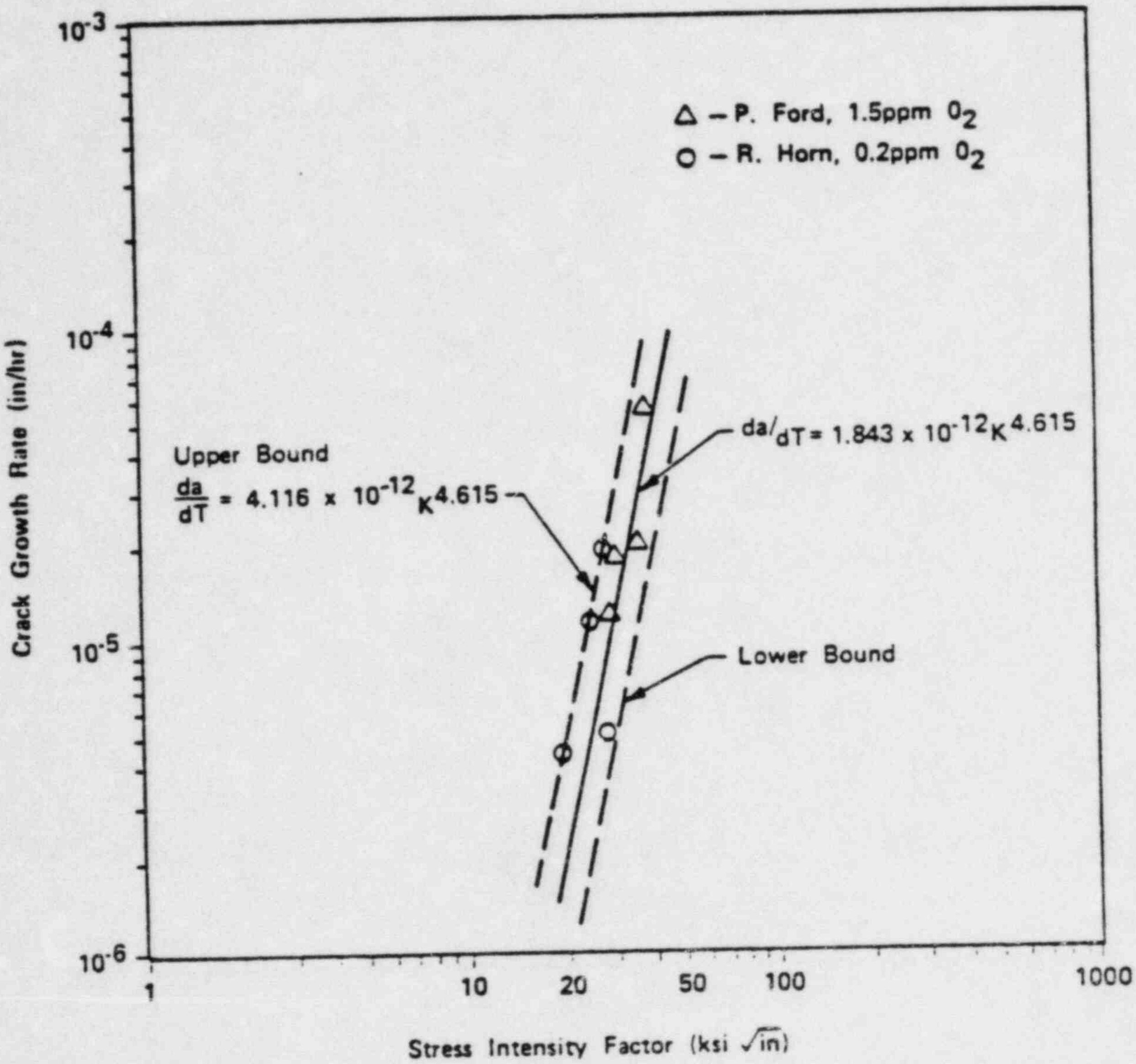
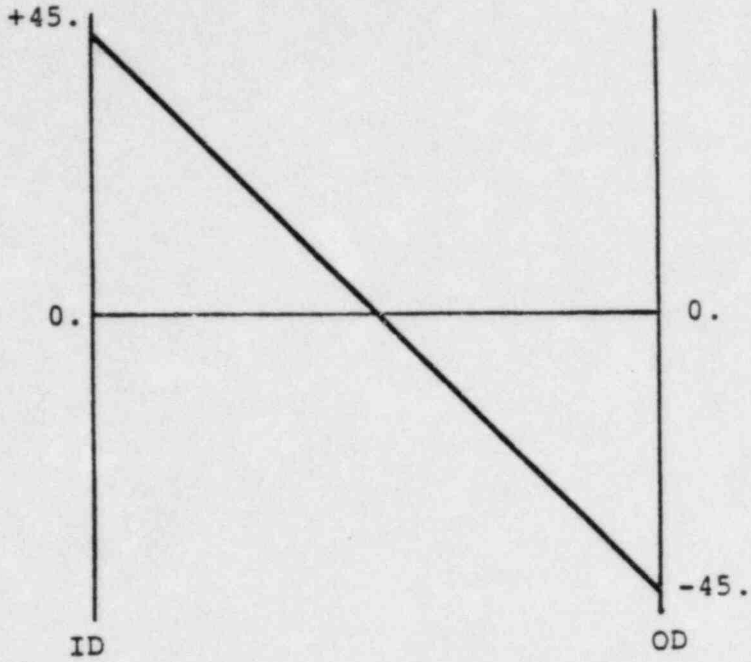
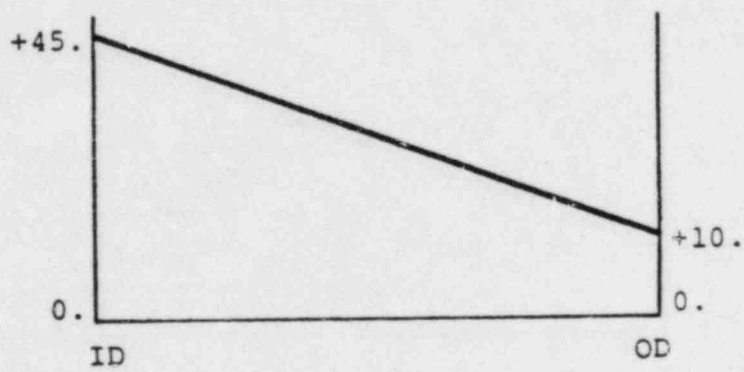


Figure 5.1

TYPICAL IGSCC CRACK GROWTH DATA (WELD SENSITIZED 304SS IN BWR ENVIRONMENT)



(a) Axial Residual Stress



(b) Hoop Residual Stress

Figure 5.2 Weld Residual Stress Distributions for Pipe Diameter of 4" to 6"

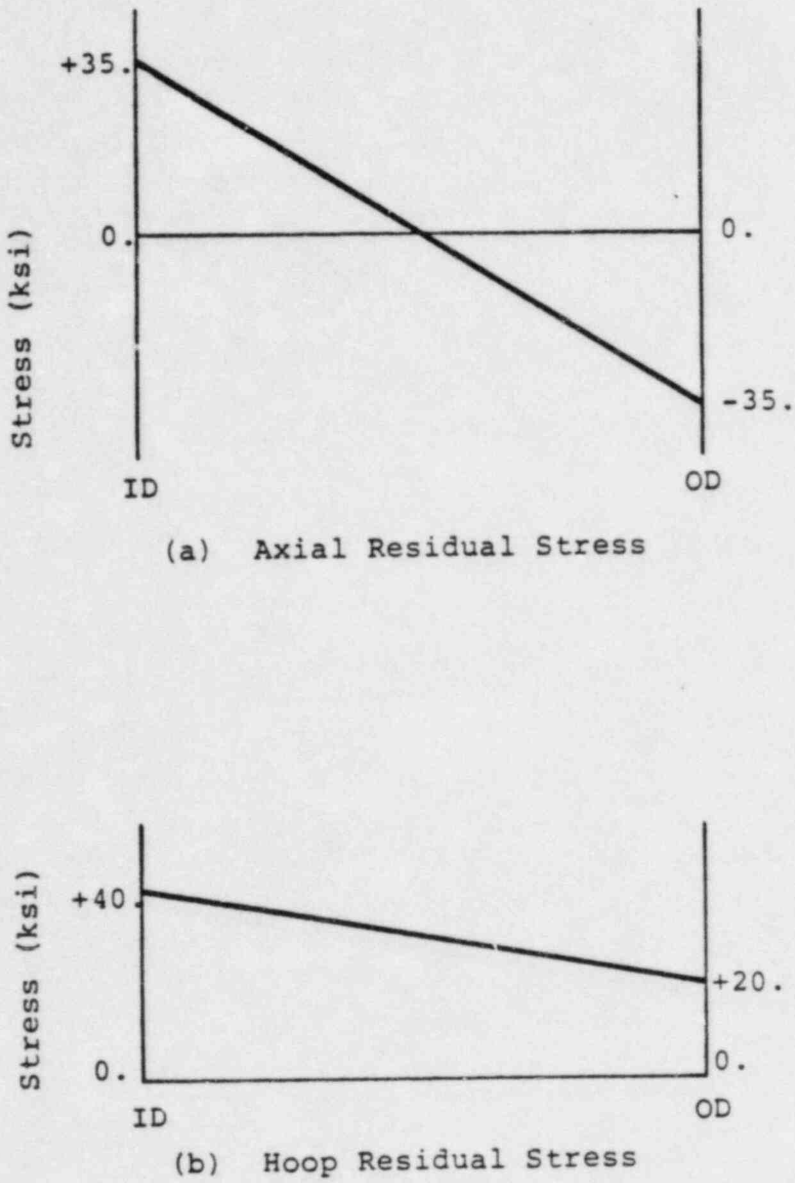


Figure 5.3 Weld Residual Stress Distributions for Pipe Diameter of 8" to 12"

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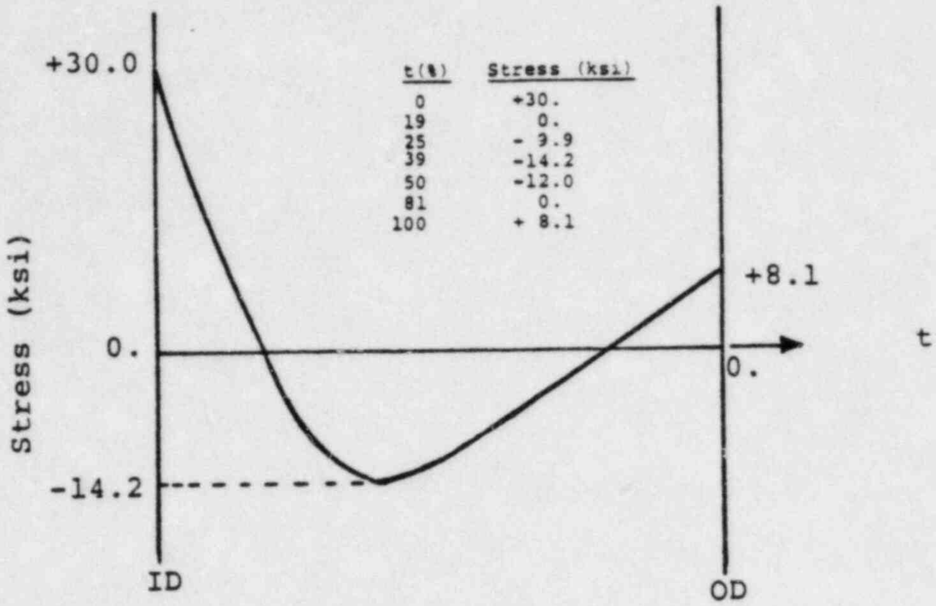
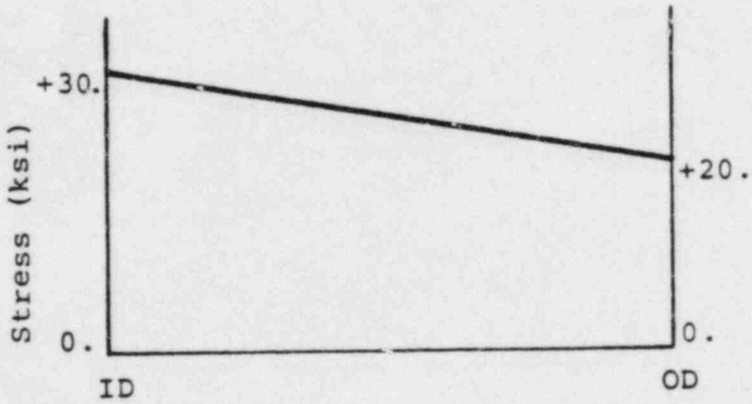


(a) Axial Residual Stress



(b) Hoop Residual Stress

Figure 5.4 Weld Residual Stress Distributions for Pipe Diameter of 20" to 28"

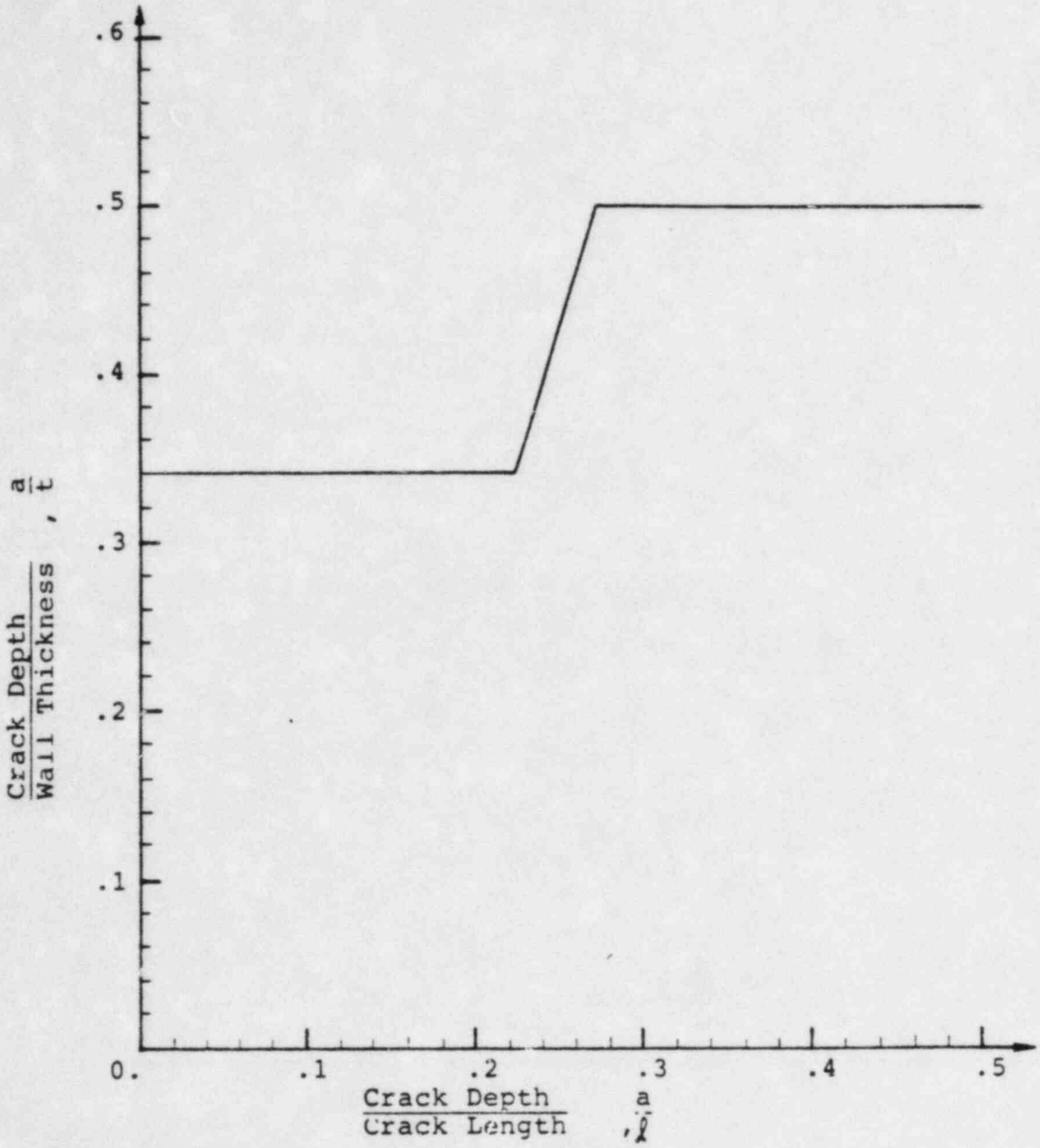


Figure 5.5

Allowable Beginning of Fuel Cycle Crack Size for Circumferential Cracks at 28" Pipe Weld 1A

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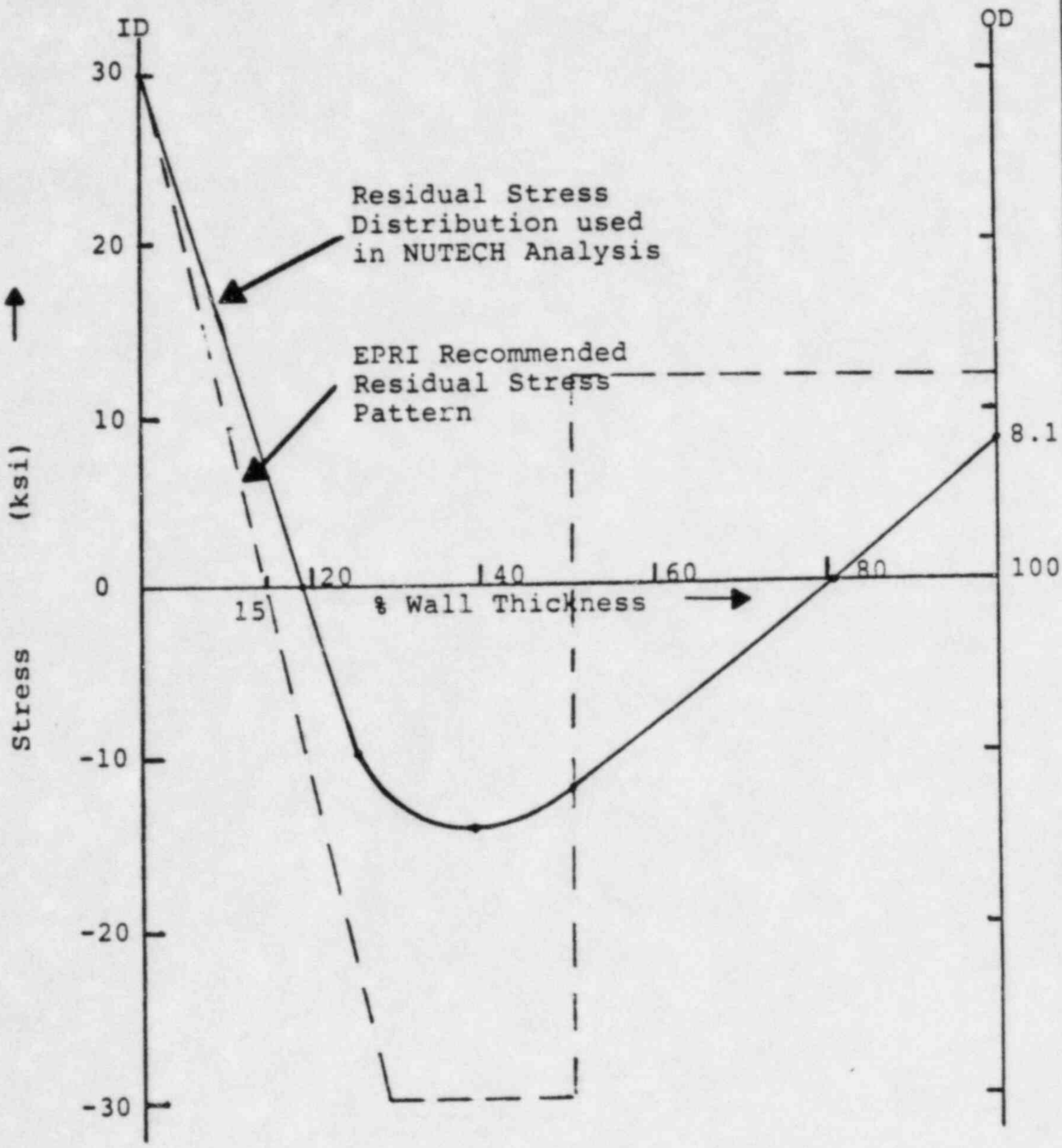

Figure 5.6
Comparison of NUTECH Recommended and EPRI Recommended Residual Stress Distribution for Large Bore Piping

6.0 CONCLUSION

On the basis of the flaw evaluations, it is concluded that the circumferential flaws detected in the 1983 refueling outage and listed in Table 5.1 of this report are significantly less than the allowable flaw sizes for a 12-month period.

7.0 REFERENCES

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11. EPRI-NP-2472, "The Growth and Stability of Stress Corrosion Cracks in Large-Diameter BWR Piping", July 1982.

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13. NUFLAW Computer Program, Revision 0, April 1983. NUTECH File No. YAE002.0094.

14. NUTCRAK Computer Program, Revision 0, April 1978, NUTECH File No. 08.039.0005.

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16. NUTECH Communication Record by L. C. Hsu, "Vermont Yankee IGSCC Problems," dated April 14, 1983, NUTECH File No. YAE002.0098.

A-1. EPRI Report NP-1413, "Measurement of Residual Stresses in Type 304 Stainless Steel Piping Butt Weldments" June 1980.

A-2. EPRI Report NP-2662-LD, "Computational Residual Stress Analysis for Induction Heating of Welded BWR Pipes", Dec. 1982.

APPENDIX A

SUMMARY OF BUTT WELD RESIDUAL STRESSES AS REPORTED BY EPRI (REPORT NO. NP-1413, NP-2662-LD)

APPENDIX A

LIST OF FIGURES

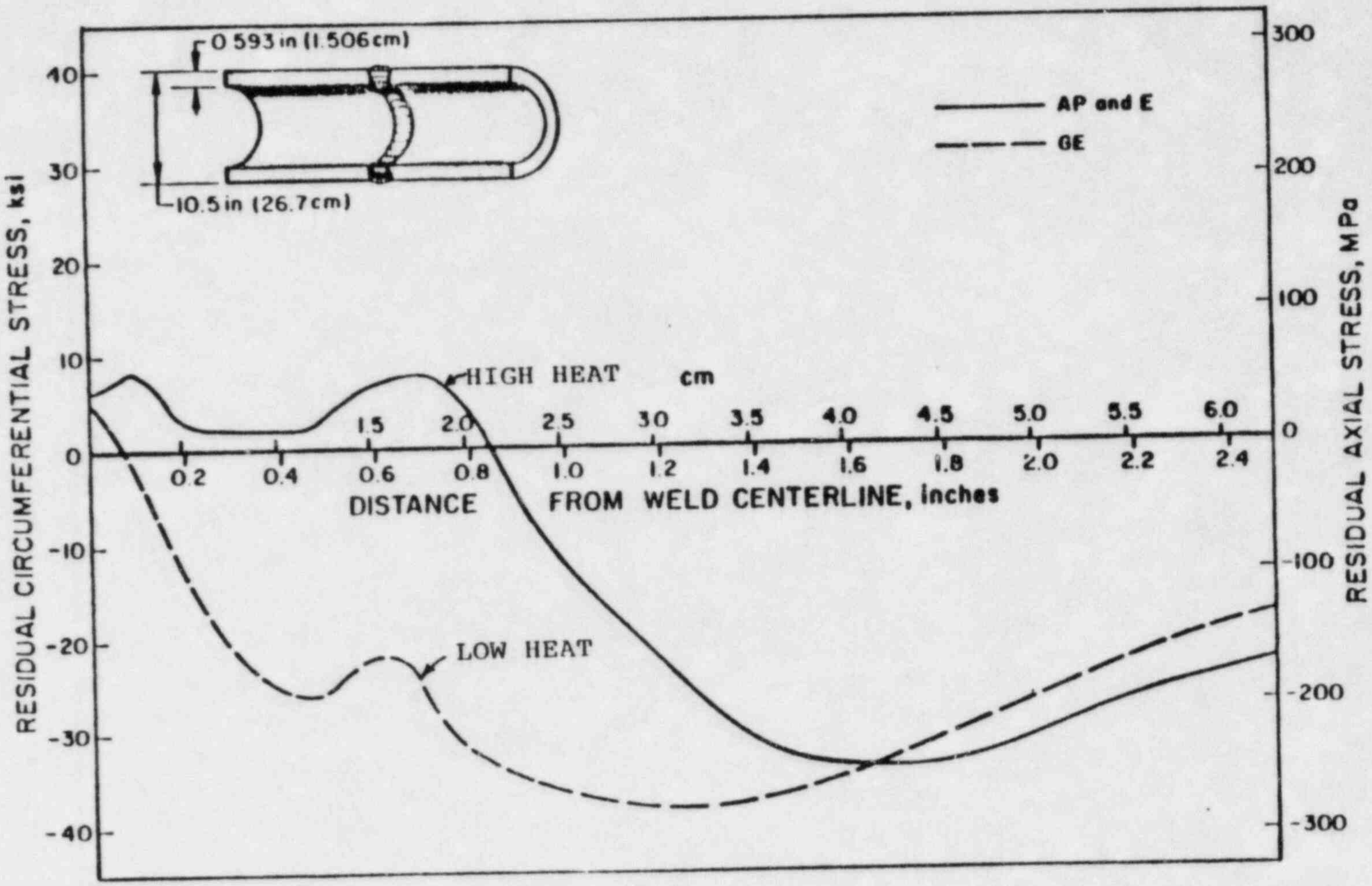

Figure A.1 Predicted Axial Stresses Along the Inner Surface of a 10-Inch Schedule 80 Pipe Welded with 2 Different Heat Inputs [Reference A-2, p.3-110]

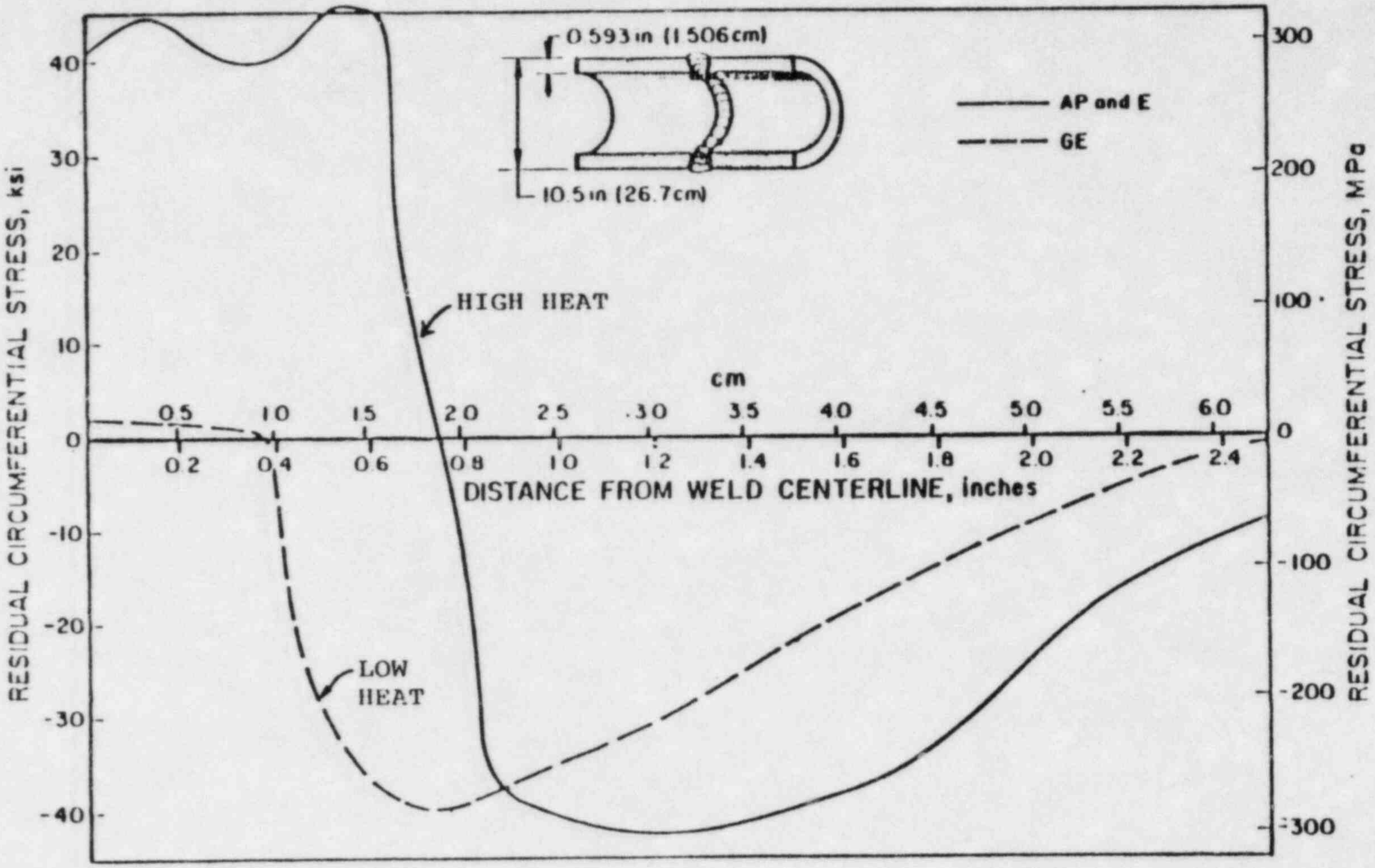

Figure A.2 Predicted Circumferential Stresses Along the Inner Surface of a 10-Inch Schedule 80 Pipe Welded with 2 Different Heat Inputs [Reference A-2, p. 3-111]

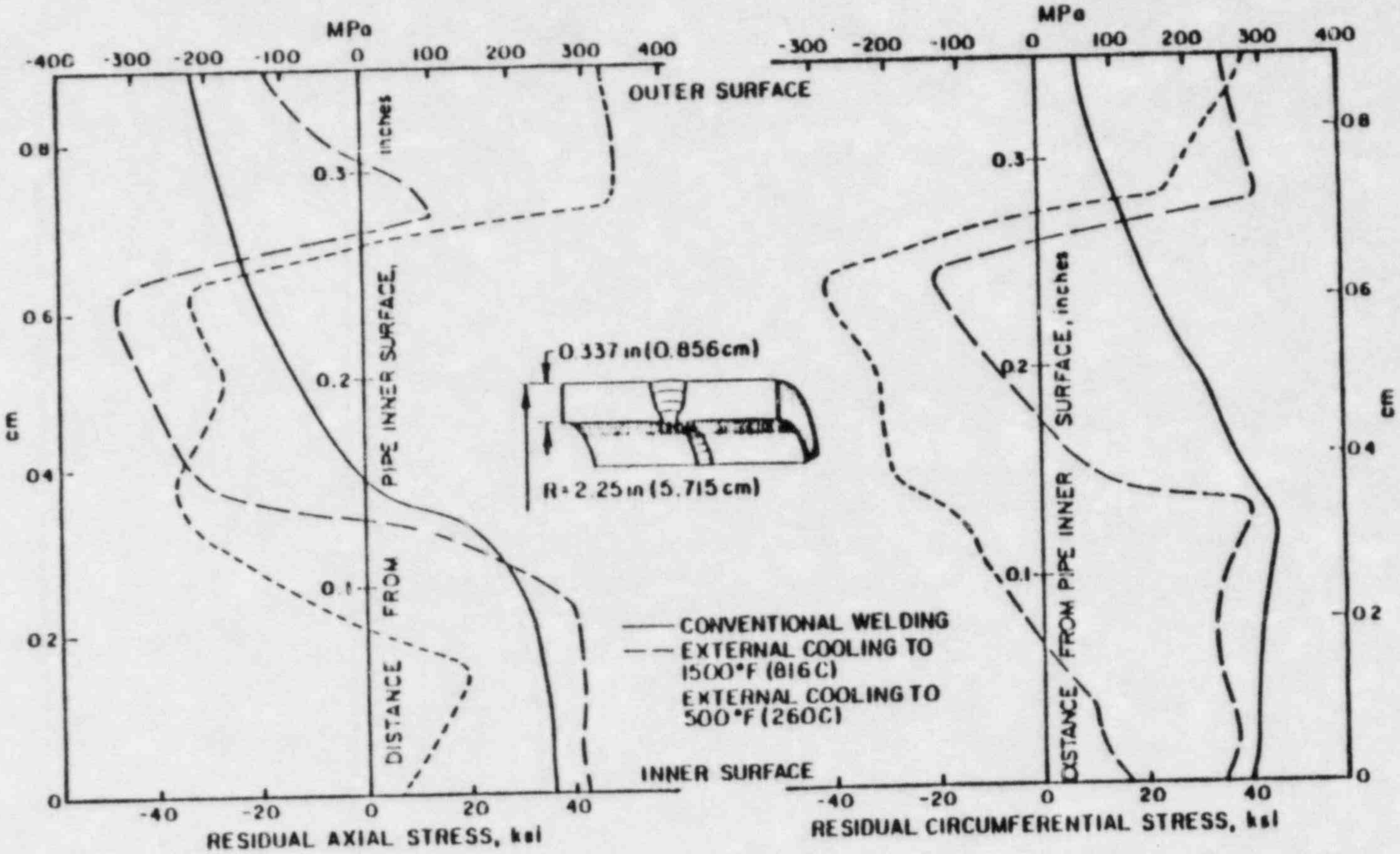

Figure A.3 Through-Wall Residual Stresses in 2 Cross Sections of a 4-Inch Schedule 80 Pipe in External Cooling Study [Reference A-2, p. 5-10]

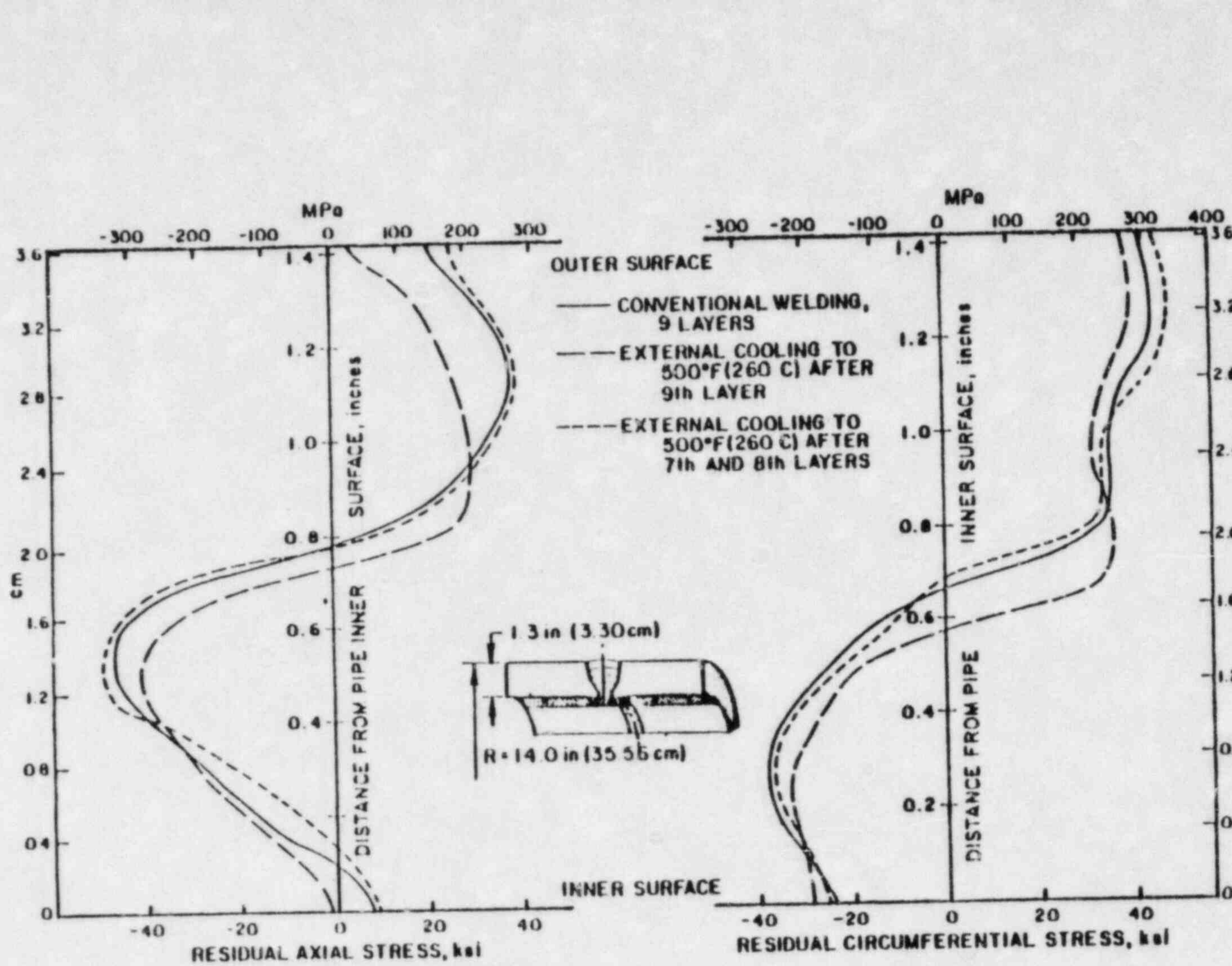

Figure A.4 Through-Wall Residual Stresses at 2 Cross Sections of a 26-Inch Schedule 80 Pipe in External Cooling Study [Reference A-2, p. 5-18]

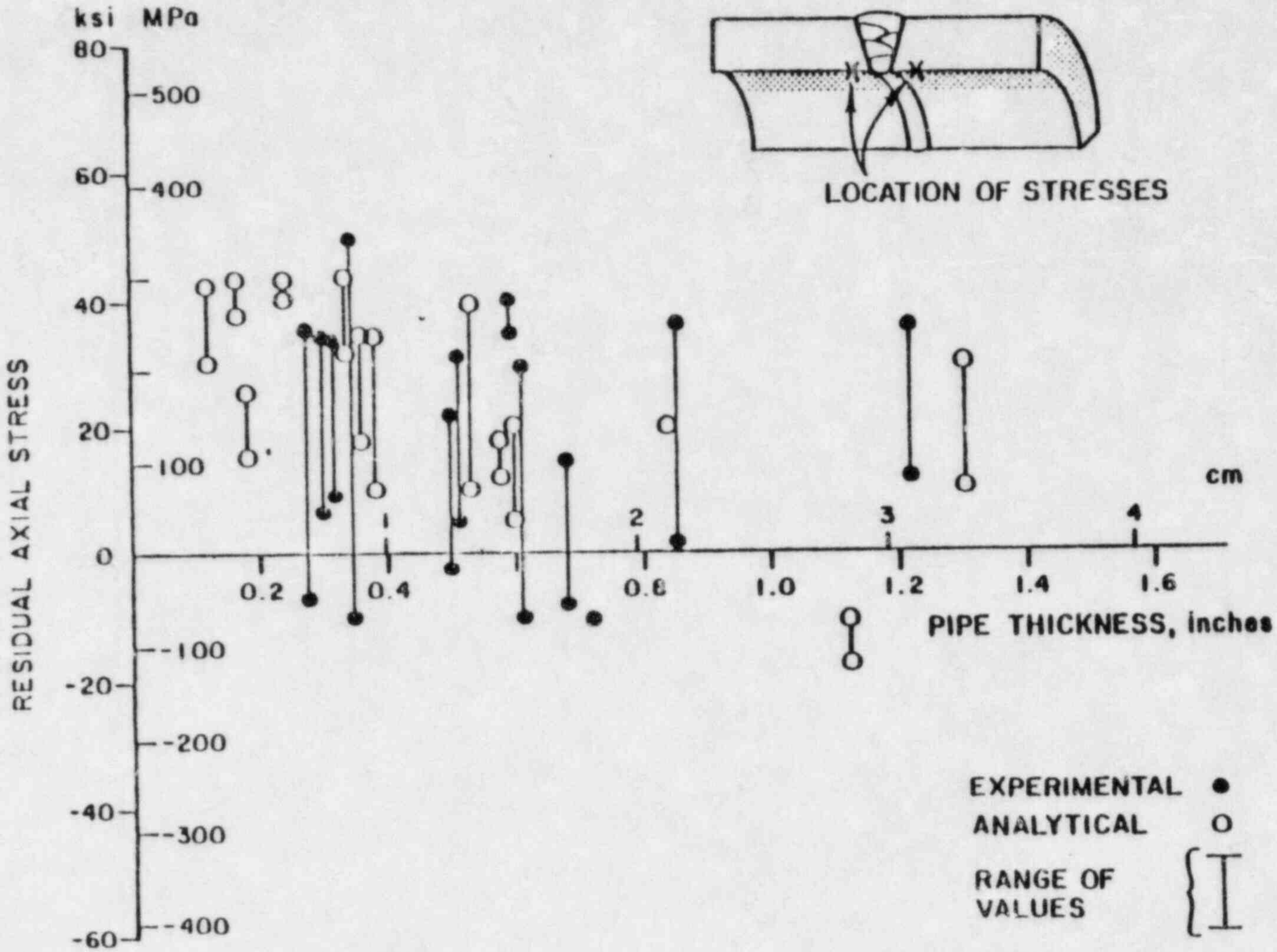

Figure A.5 Computed and Measured Weld Induced Residual Axial Stresses Near Weld Fusion Line on the Inner Surface of Pipes of Various Thicknesses [Reference A-2, p. 7-22]

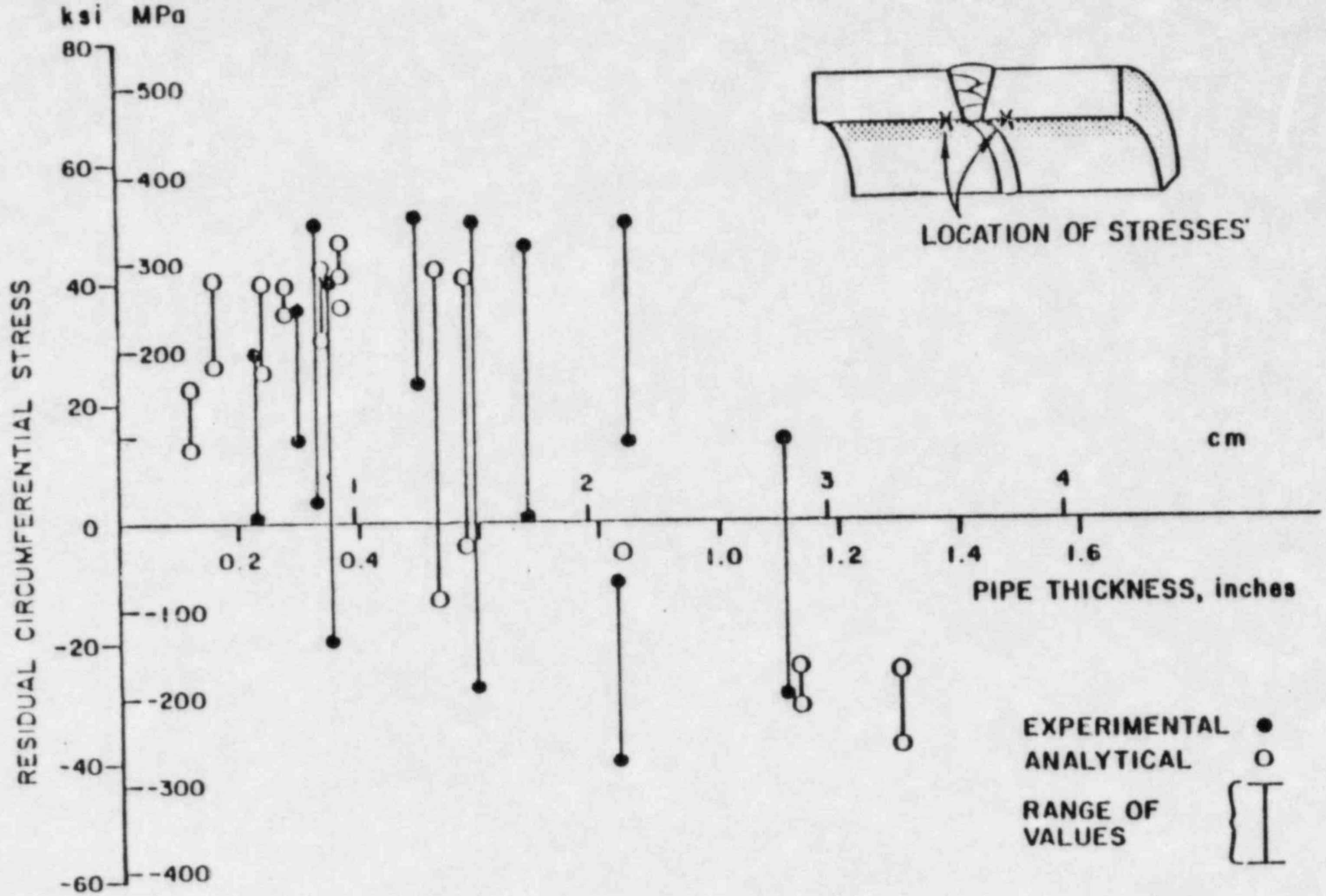

Figure A.6 Computed and Measured Weld Induced Residual Circumferential Stresses Near Weld Fusion Line on the Inner Surface of Pipes of Various Thicknesses [Reference A-2, P. 7-23]

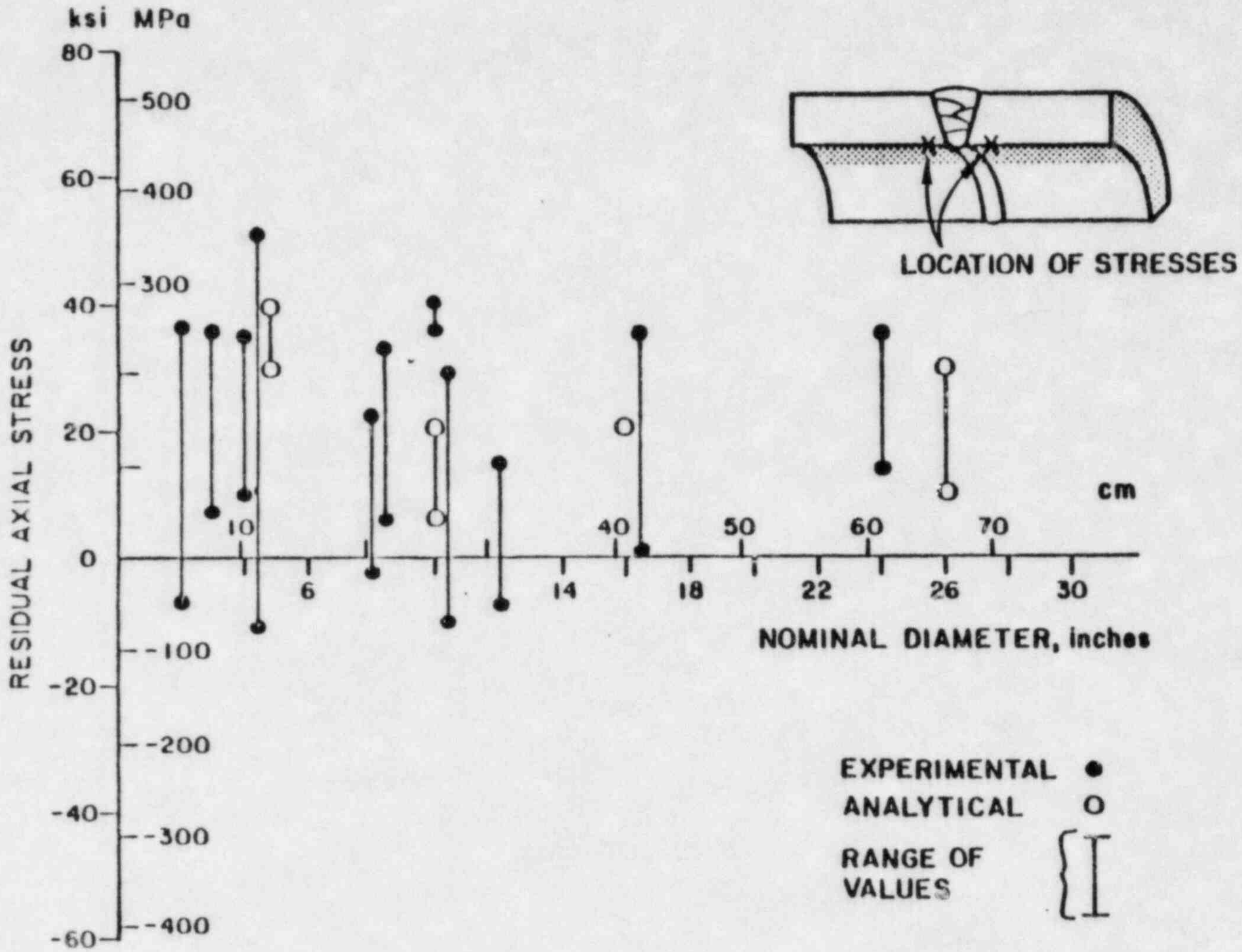

Figure A.7 Computed and Measured Weld Induced Residual Axial Stresses Near Weld Fusion Line on Inner Surface of Schedule 80 Pipes [Reference A-2, p. 7-18]

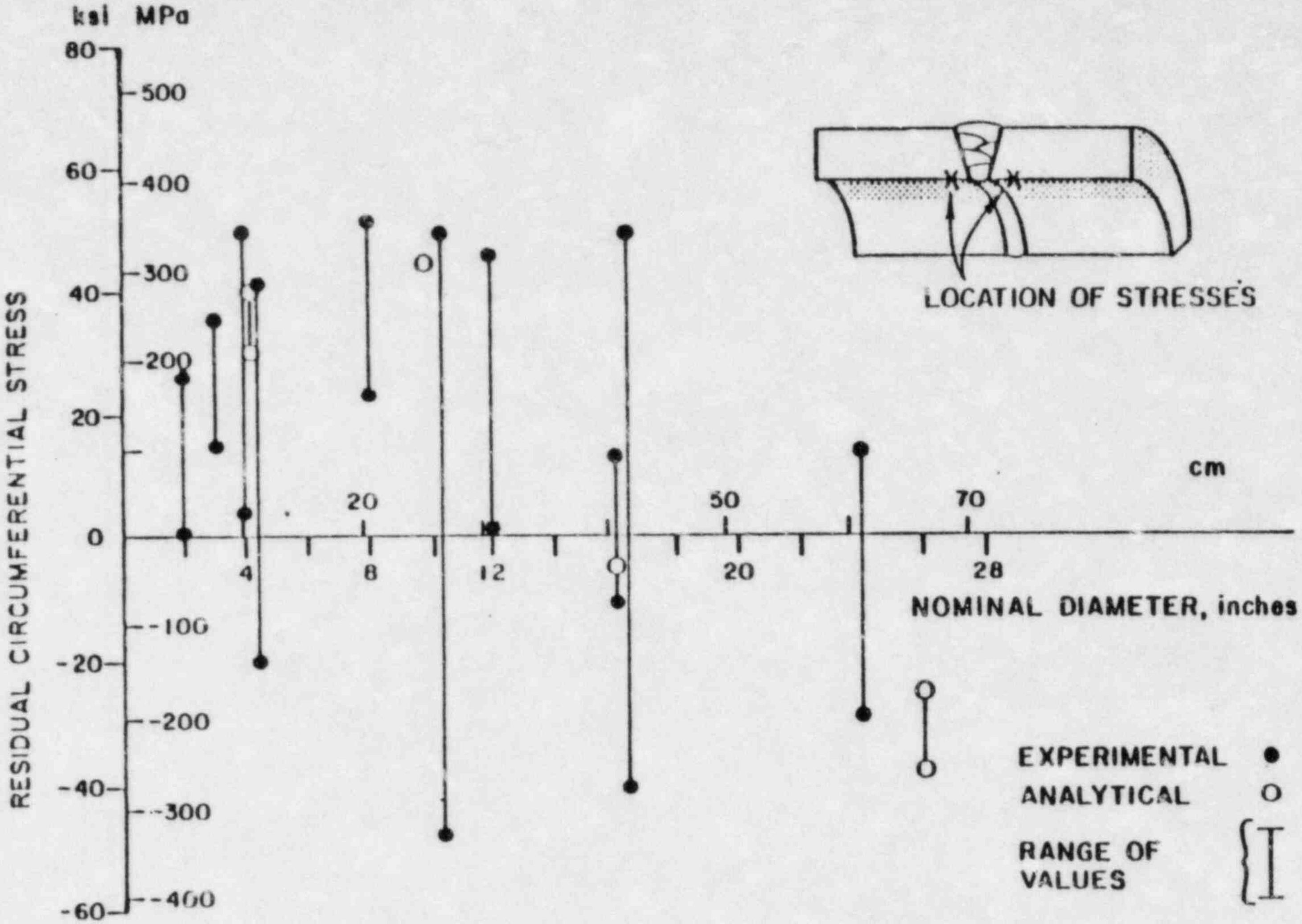

Figure A.8 Computed and Measured Weld Induced Residual Circumferential Stresses Near Weld Fusion Line on inner Surface of Schedule 80 Pipes [Reference A-2, p. 7-19]

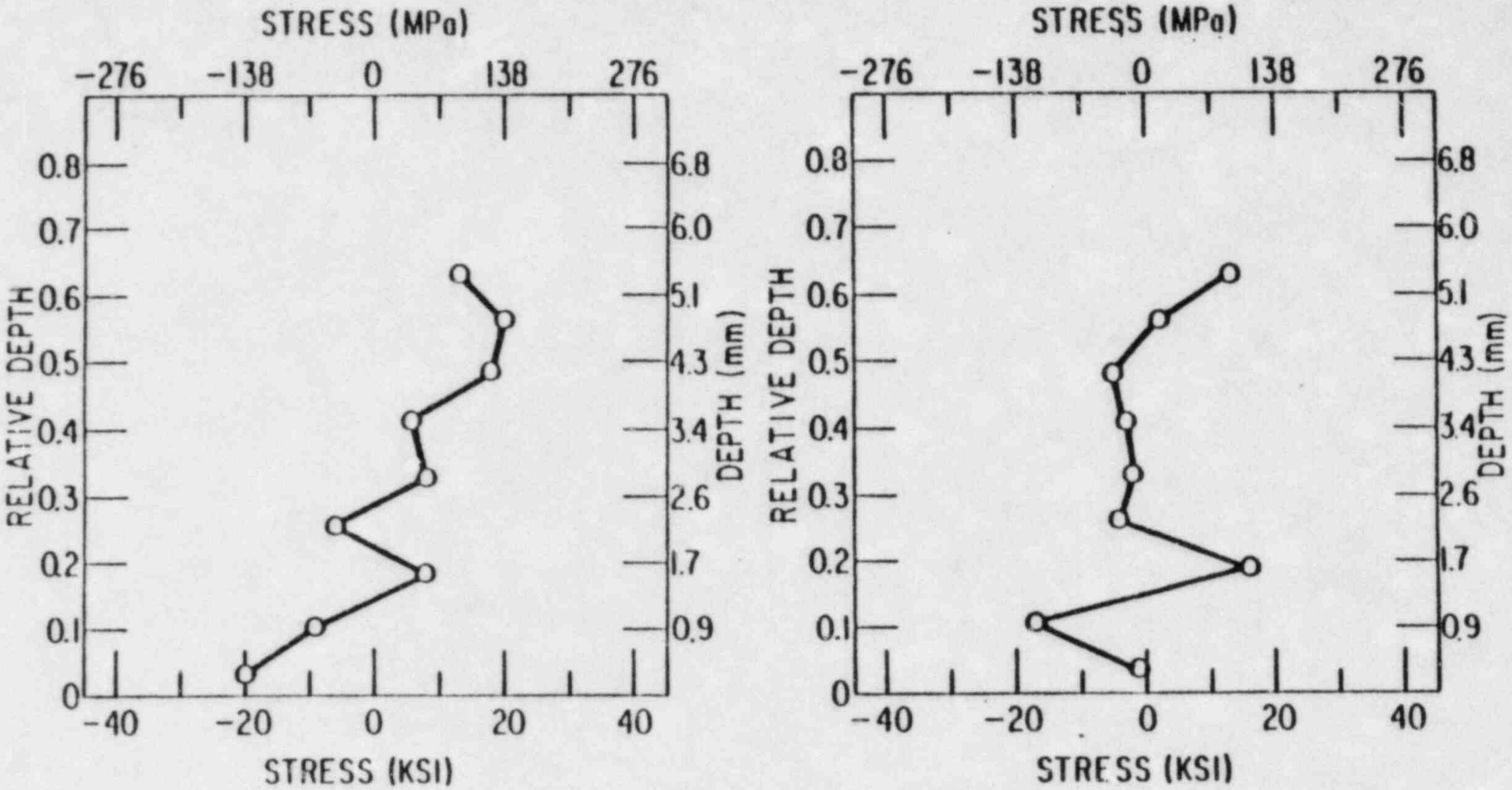

Figure A.9 Through-Wall Distribution of Self-Equilibrated Residual Stresses in 4-in. Weldment W27A ($\theta = 248^{o}$) ~5 mm on Either Side of the Weld Center Line [Reference A-1, p. 79]

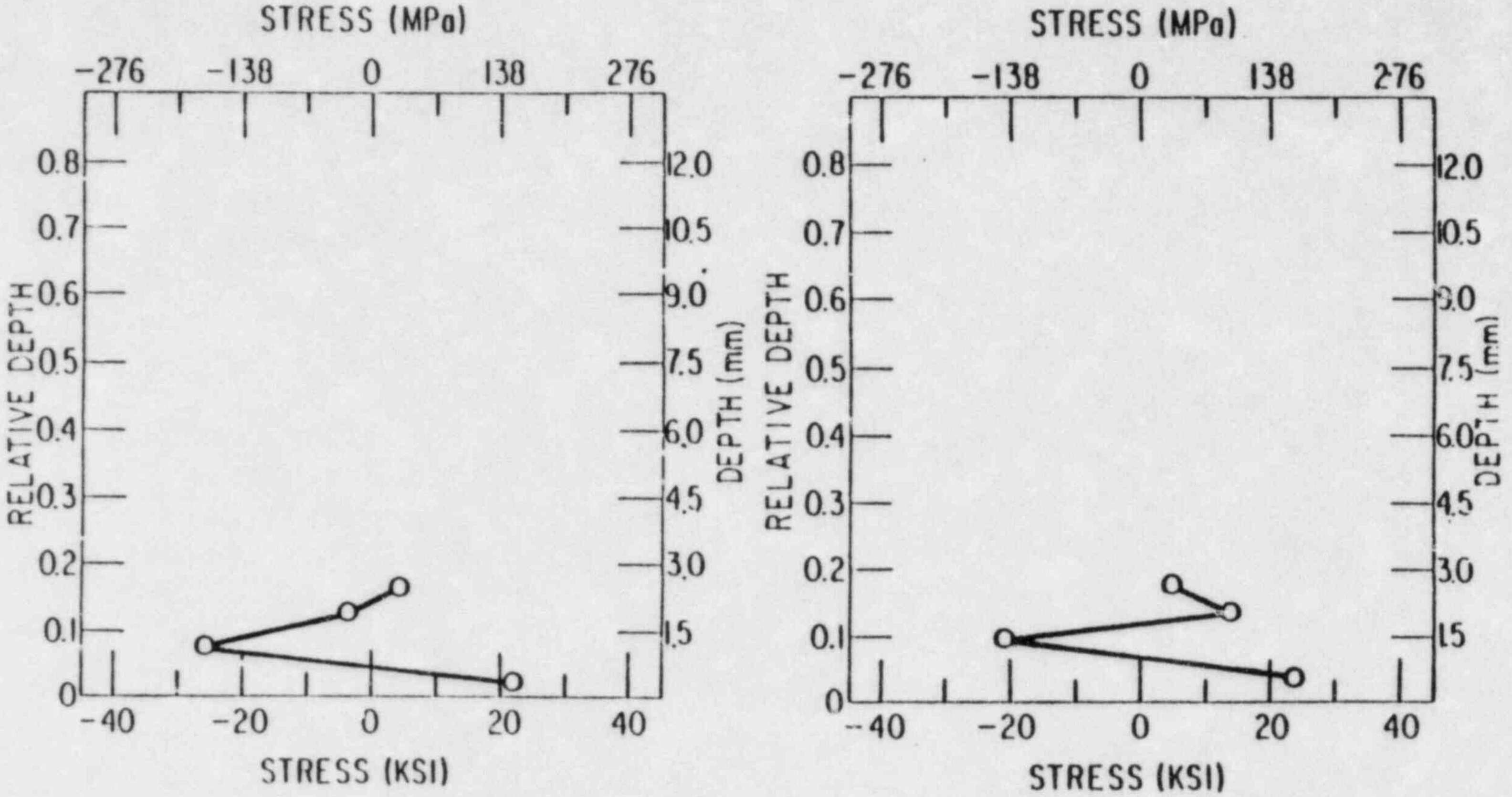

Figure A.10 Through-Wall Distribution of Self-Equilibrated Residual Stresses in the 10-in. Dresden 2 Weldment ($\theta = 90^{\circ}$) ~5 mm on Either Side of the Weld Center Line [Reference A-1, p. 84]

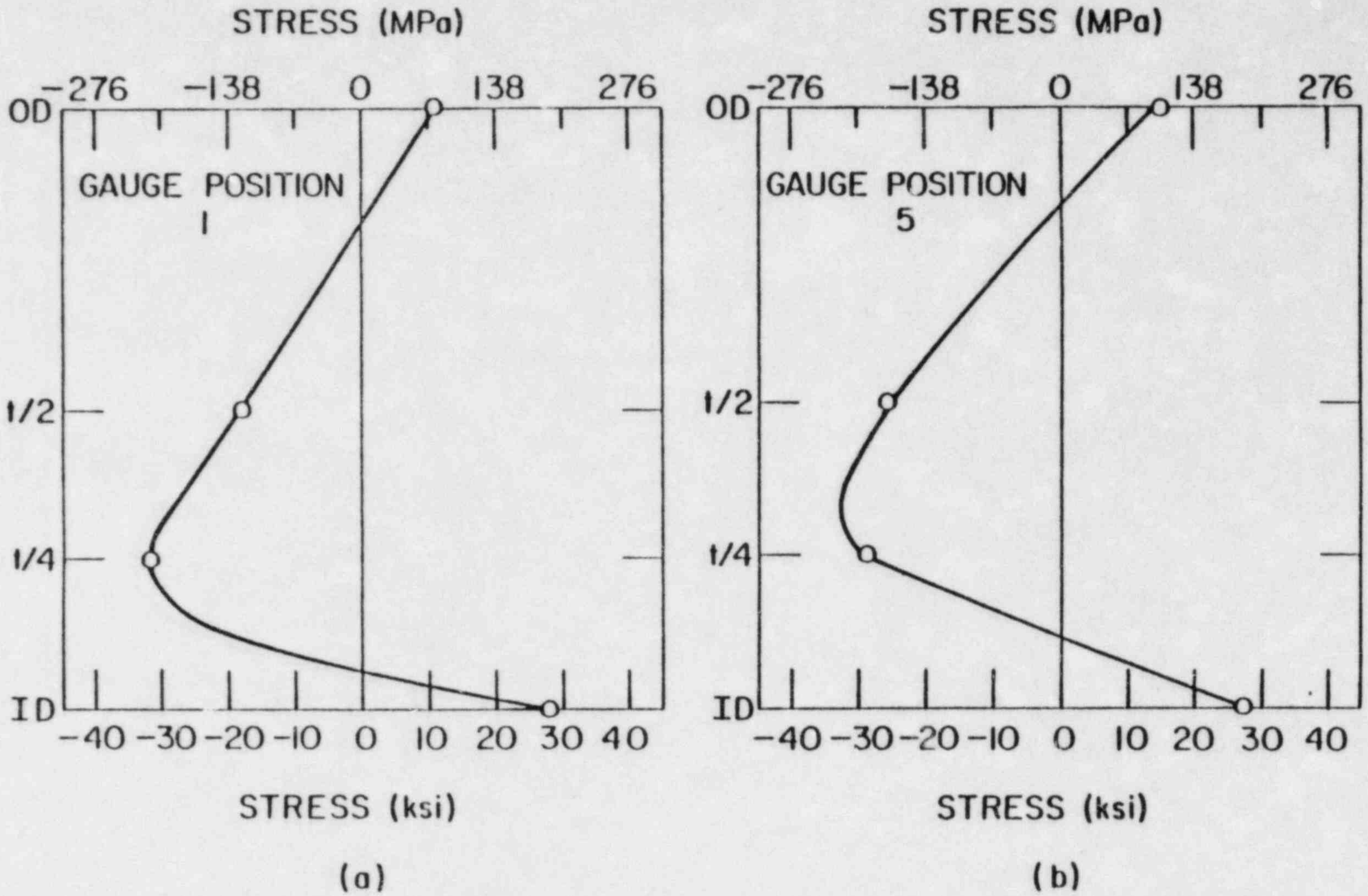

Figure A.11 Through-Wall Distribution of Total Residual Stress ~8 mm on Either Side of the Weld Center Line in the 26-inch Pipe [Reference A-1, p. 95]

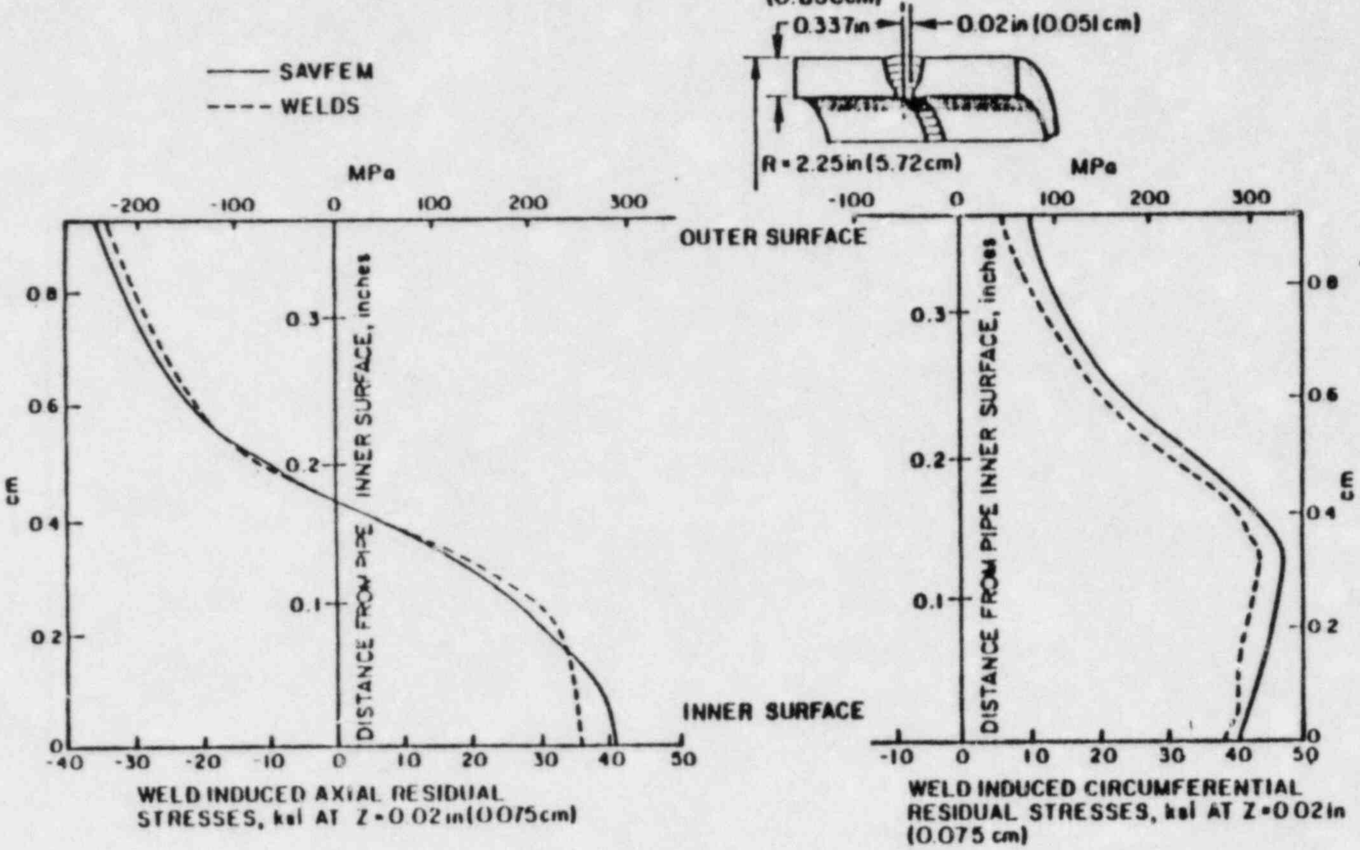

Figure A.12 Comparison of Through-Wall Residual Stresses 0.02 Inch (0.05 cm) from Weld Centerline in a 4-Inch Schedule 80 Pipe from Welding Analysis with 2 Finite Element Programs [Reference A-2, p. 3-119]

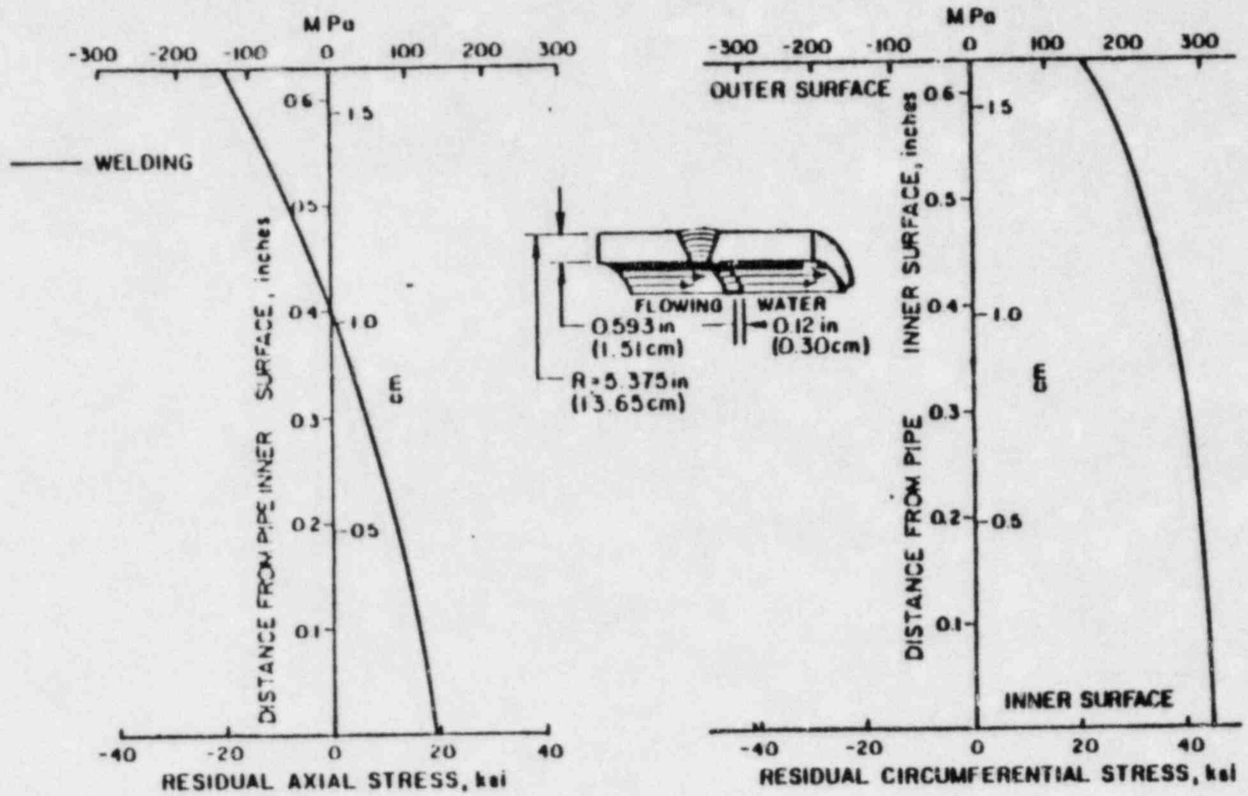

Figure A.13 Through-Wall Residual Stresses Computed at a Cross-Section in the Sensitized Zone, 0.12 Inch (0.3 cm) from Weld Centerline, of a Welded 10-Inch Schedule 80 Pipe [Reference A-2, p. 3-28]

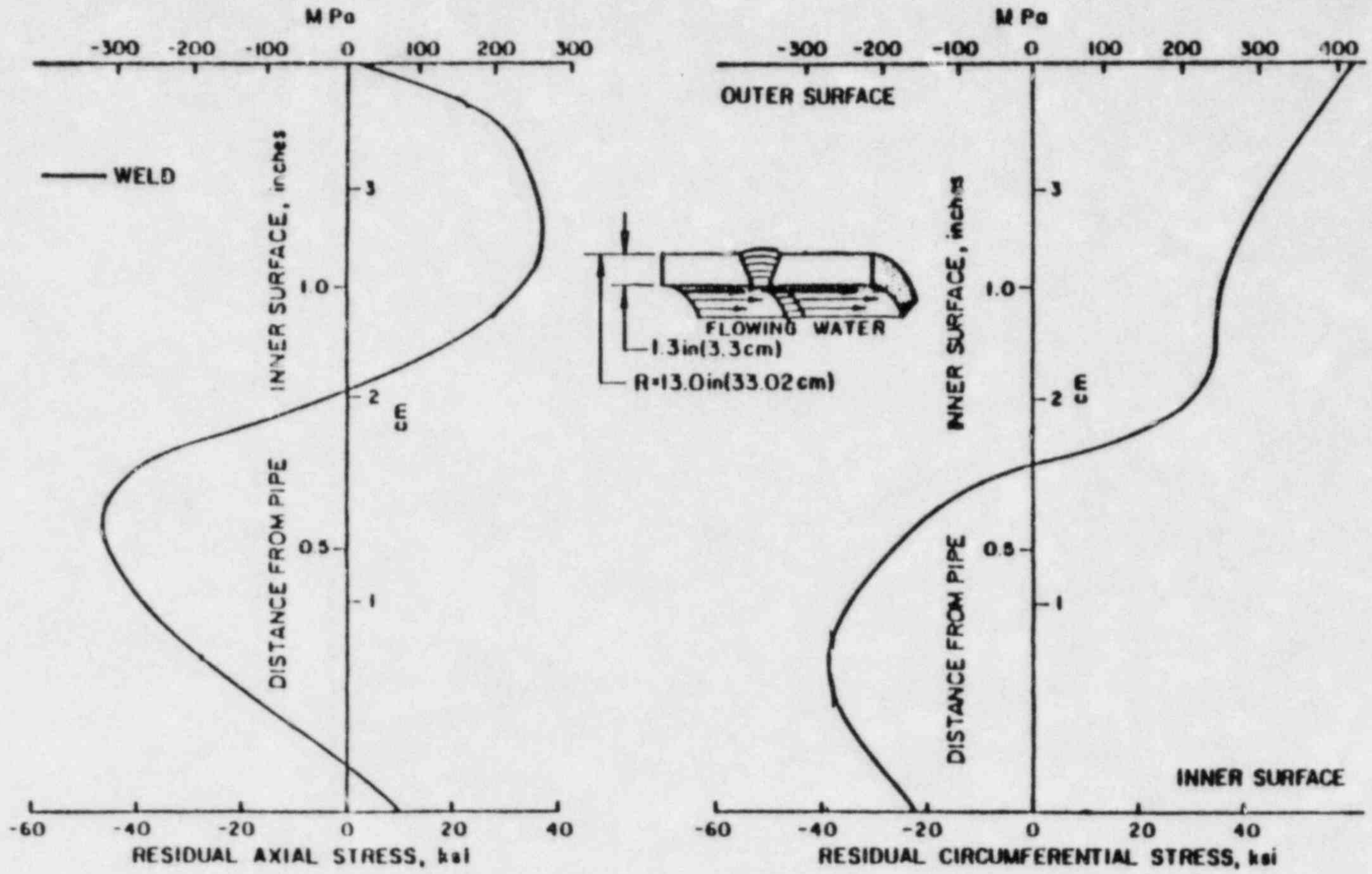

Figure A.14 Through-Wall Residual Stress Profile for a Welded 26-Inch Schedule 80 Pipe at a Cross-Section 0.12-Inch (0.3 cm) from the Weld Centerline [Reference A-2, p. 3-69]

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BASIS FOR WELD OVERLAY DESIGNS VERMONT YANKEE NUCLEAR POWER STATION

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1.0 INTRODUCTION

This report summarizes evaluations performed by NUTECH to determine the need for repair of ultrasonic indications in the Recirculation System at Vermont Yankee Nuclear Power Station. Ultrasonic examination results were used to locate and to determine the approximate size of cracks. Fracture mechanics evaluations were performed to determine upper bound crack growth versus time for one twelve month long fuel cycle. The upper bound crack depth after one fuel cycle was then used to determine which cracks require a weld overlay repair. For those cracks which require a weld overlay repair, preliminary sizing calculations for the weld overlay were also performed.

Each of four generic crack locations have been individually evaluated in Section 3.0.

1) Recirculation Manifold Sweepolet to Pipe Welds
2) Recirculation Manifold Reducer to Pipe Welds
3) Recirculation Inlet Safe End to Pipe Welds
4) Recirculation Riser Elbow to Pipe Welds

2.0 METHOD OF ANALYSIS

2.1 Background

The current edition of the ASME Boiler and Pressure Vessel Code Section XI does not contain explicit criteria for determining allowable crack depth in stainless steel piping. A proposed addition to Section XI (Reference 1) provides such criteria. Based on Reference 1, the maximum allowable crack depth at any location in the piping can be determined. The crack growth that would occur during the next twelve month fuel cycle can then be calculated using fracture mechanics, and the allowable crack depth at the beginning of the next fuel cycle can be determined. If the ultrasonically determined crack depths are equal to or larger than the allowable beginning of fuel cycle crack depth, then a weld overlay repair is required. If the ultrasonically determined crack depths are significantly smaller than the allowable beginning of fuel cycle crack depth, then a repair is not required at this time.

2.2 Allowable End of Cycle Crack Size

Reference 1 is based on the "Net Section Collapse" method of analysis. This method is illustrated schematically in Figure 2.1. The net pipe section (with the cracked material removed) is assumed to behave in an elastic/perfectly plastic manner. The moment required to cause a uniform stress equal to the material flow stress is determined for a given crack size and a given internal pressure. The allowable moment is determined by dividing the calculated collapse moment by the ASME Code required safety factor which is approximately 3.0 for normal operation and 1.5 for faulted conditions. This process is repeated many times and curves of the allowable crack size versus applied (or allowable) moment are constructed. Figure 2.2 is an example of such a curve with:

1) Axial pressure stress = 6.0 ksi,
2) Axial primary stress = 1.5 Sm (Code limit),
3) Flow stress equal to 48.0 ksi,
4) Safety factor equal to 1.0.

Figure 2.2 defines the locus of limiting crack depths and lengths for circumferential cracks which are

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predicted to cause failure by the net section collapse method. Note that a very large percentage of pipe wall can be cracked before reaching these limits (40% to 60% of circumference for throughwall cracks, and 65% to 85% of wall thickness for 360° less than through cracks).

Also shown in Figure 2.2 is a sampling of cracks which have been detected in service, either through UT examination or leakage. In each case, there has been a comfortable margin between the crack size that was observed and that which would be predicted to cause failure under service loading conditions. Also, as discussed below there is still considerable margin between these net section collapse limits and the actual cracks which would cause instability.

Elastic-plastic fracture mechanics analyses are presented in Reference 2 which give a more accurate representation of the crack tolerance capacity of stainless steel piping than the net section collapse approach described above. Figures 2.3 and 2.4 graphically depict the results of such analyses from Reference 2. Through-wall circumferential defects of arc length equal to 60° through 300° were assumed at various cross sections of a typical BWR recirculation

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system. Loads were applied to the remaining cross section of these pipes of sufficient magnitude to produce net section limit load, and the resulting values of tearing modulus were compared to that required to cause unstable fracture (Figure 2.3). Note that in all cases there is substantial margin, indicating that the net section collapse limits are not really failure limits. Figure 2.4 summarizes the results of all such analyses performed for 60° through-wall cracks in terms of margin on tearing modulus for stability. The margin in all cases is substantial.

As stated earlier, Reference 1 is based on the conservative net section collapse method. The results of net section collapse analyses are presented in a tabular format in Tables 2.1 and 2.2 which give the allowable crack size as a function of the applied primary stress (weight, seismic, etc.). The allowable crack sizes presented in the tables include the standard design safety margins implicit in ASME Section III design rules for nuclear power piping.

Table 2.1 (Reference 1) gives the allowable circumferential crack depth as a function of length for various values of applied axial primary membrane plus bending

($P_m + P_b$) stress. Similarly, Table 2.2 (Reference 1) gives the allowable axial crack depth as a function of length for various values of applied hoop primary membrane pressure stress. These tables both apply to normal operating (Service Level A and B) conditions. Similar tables are presented in Reference 1 for faulted or accident conditions (Service Level C and D). Note that in both of these tables, the allowable crack depth for short cracks was not allowed to exceed 75% of the wall thickness even though net section collapse analysis would permit much deeper cracks for very short crack lengths. This truncation of the net section collapse analysis procedure is somewhat artificial and could be eliminated for short, almost throughwall, cracks if leaks are prevented by some means, such as the installation of IGSCC resistant weld material.

2.3 Crack Growth

Existing cracks can grow due to both fatigue and stress corrosion. Based on Reference 3, fatigue crack growth in the recirculation system is small compared to intergranular stress corrosion crack (IGSCC) growth. Thus for this evaluation, only IGSCC growth is considered. IGSCC growth is a function of the total

applied steady state stress including weight, pressure, thermal expansion and weld residual stress, but not including transient stresses such as seismic.

The steady state moment due to the sum of weight and thermal expansion was obtained from Reference 4 for each crack location. The design pressure is 1233 psi at 562°F. Weld residual stress due to the existing butt welds was determined based on Reference 5.

Crack growth was calculated based on References 6 and 7. Crack growth rate as a function of applied stress intensity factor is shown in Figure 2.5. The upper bound crack growth law of Figure 2.5 was used in the analysis.

$$\frac{da}{dT} = 4.116 \times 10^{-12} K^{4.615}$$

where:

da = differential crack size

dT = differential time

K = applied stress intensity factor

2.4 Weld Overlay Sizing Calculations

A weld overlay repair can be performed in the event that the above fracture mechanics analysis shows that the observed indications are unacceptable. Such a weld overlay repair provides three major benefits:

1) It prevents leaks due to IGSCC by surrounding the existing crack with IGSCC resistant weld material.

2) It produces residual compressive stresses in the existing weld heat affected zone which will slow down or prevent a further propagation of existing cracks in the IGSCC susceptable pipe material.

3) It provides additional structural material to carry the applied loads.

The design of a weld overlay repair is based on achieving these benefits and minimizing installation time. The length of the overlay is chosen such that any unfavorable residual stresses which may develop near the ends of the overlays attenuate before they reach the crack region or the original weld heat affected zone. The welding procedures create favorable residual stress

patterns in the crack region and in the original weld heat affected zone. The weld overlay thickness ensures adequate structural margins and leak prevention.

The following conservative assumptions are made in determining the need for a weld overlay. The maximum crack depth extends over the entire crack length. The maximum or upper bound crack growth is used (see Section 3.2). The weld residual stress used in the crack growth analysis due to the original butt weld is more tensile than the expected weld residual stress.

In the design of the weld overlays, the maximum crack depth was again assumed to extend over the entire length. Also, the upper bound crack growth is used to calculate allowable crack depths.

Table 2.1

PROPOSED TABLE IWB-3641-1

ALLOWABLE END-OF-INSPECTION PERIOD
SIZE FOR CIRCUMFERENTIAL FLAWS
NORMAL CONDITIONS

$\frac{P_m + P_b}{S_m}$ (1)	Ratio of Length to Circumference 0.1	0.2	0.3	0.4	0.5 or more
	Ratio of Flaw Depth to Thickness (2)				
1.5	(3)	(3)	(3)	(3)	(3)
1.4	0.30	0.20	(3)	(3)	(3)
1.3	0.48	0.38	0.28	0.18	0.18
1.2	0.66	0.56	0.46	0.36	0.26
1.1	0.73	0.63	0.53	0.43	0.33
1.0	0.75	0.70	0.60	0.50	0.40
0.9	0.75	0.75	0.66	0.56	0.46
0.8	0.75	0.75	0.72	0.62	0.52
0.7	0.75	0.75	0.75	0.68	0.58
0.6	0.75	0.75	0.75	0.73	0.63

(1) P_m = Primary Membrane Stress
P_b = Primary Bending Stress
S_m = ASME Code Design Stress at Temperature

(2) Crack Depth = a for a Surface Flaw
2a for a Subsurface Flaw

(3) IWB-3514-3 Standards Govern

Table 2.2

PROPOSED TABLE IWB-3642-1

ALLOWABLE END-OF-INSPECTION PERIOD
SIZE FOR AXIAL FLAWS
NORMAL CONDITIONS

Stress Ratio (1)	NONDIMENSIONAL FLAW LENGTH $l_f/\sqrt{rt}$											Maximum Allowable Flaw Length $l_{max}/\sqrt{rt}$
	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	
	Ratio of Flaw Depth to Thickness (2)											
0.4	0.75	0.75	0.75	0.74	0.70	0.68	0.67	0.66	0.65	0.64	0.64	11.7
0.5	0.75	0.75	0.72	0.65	0.61	0.59	0.58	0.57	0.56	0.55		9.3
0.6	0.75	0.75	0.64	0.55	0.51	0.49	0.48	0.47				7.7
0.7	0.75	0.73	0.53	0.44	0.40	0.38	0.37					6.6
0.8	0.75	0.62	0.40	0.32	0.28	0.26						5.7
0.9	0.70	0.42	0.23	0.17	0.15	0.14						5.0
1.0	├──── (3) ────┤											4.4

(1) Stress Ratio = $\frac{PD}{2t} / S_m$

Where P = Maximum Pressure

D = Outside Diameter of the Pipe

t = Nominal Thickness

S_m = ASME Code Design Stress Intensity

(2) Crack Depth = a for Surface Flaw
2a for a Subsurface Flaw

(3) IWB-3514 Standard Govern

(4) l_f = End-of-Inspection Period Flaw Length

l_{max} = Maximum Allowable Flaw Length

r = Mean Radius

t = Nominal Thickness

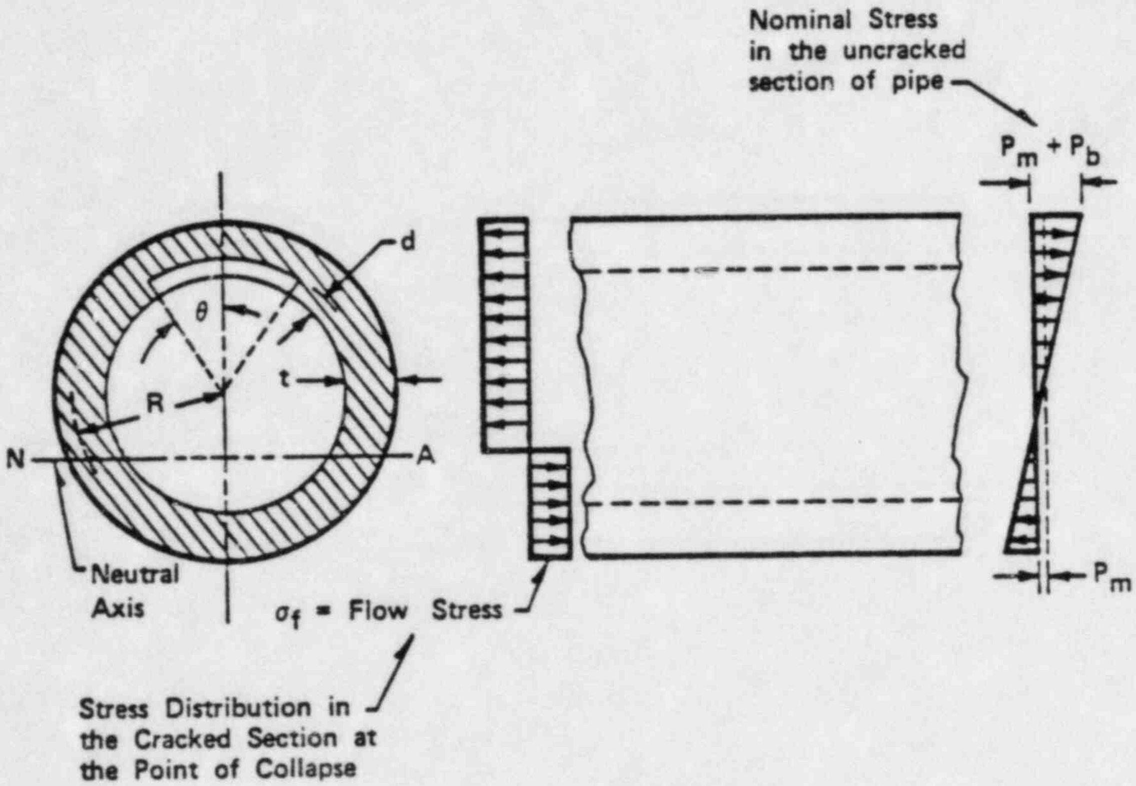

Figure 2.1

SCHEMATIC ILLUSTRATION
OF NET SECTION COLLAPSE APPROACH

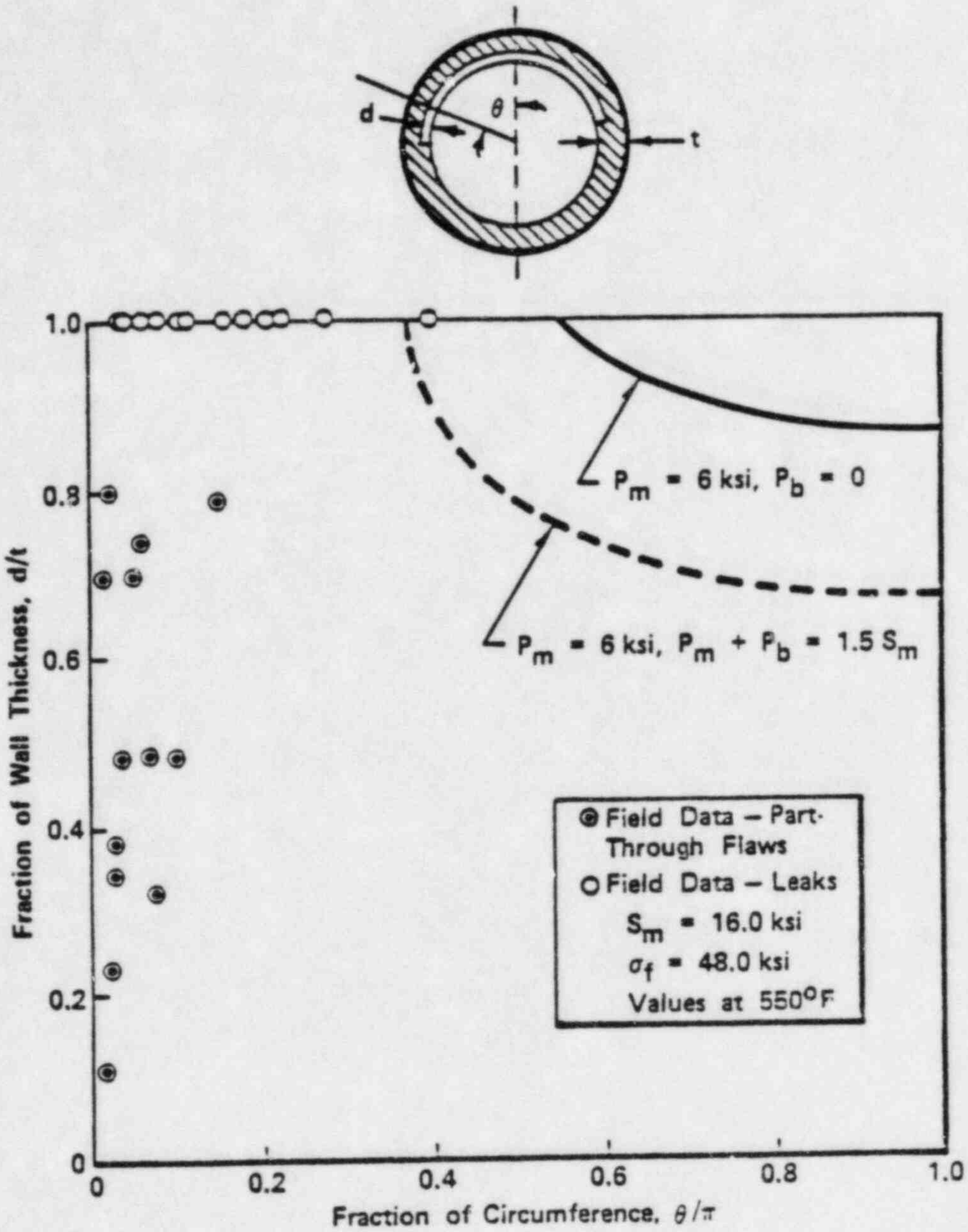

Figure 2.2

TYPICAL RESULT OF NET SECTION COLLAPSE ANALYSIS OF CRACKED STAINLESS STEEL PIPE

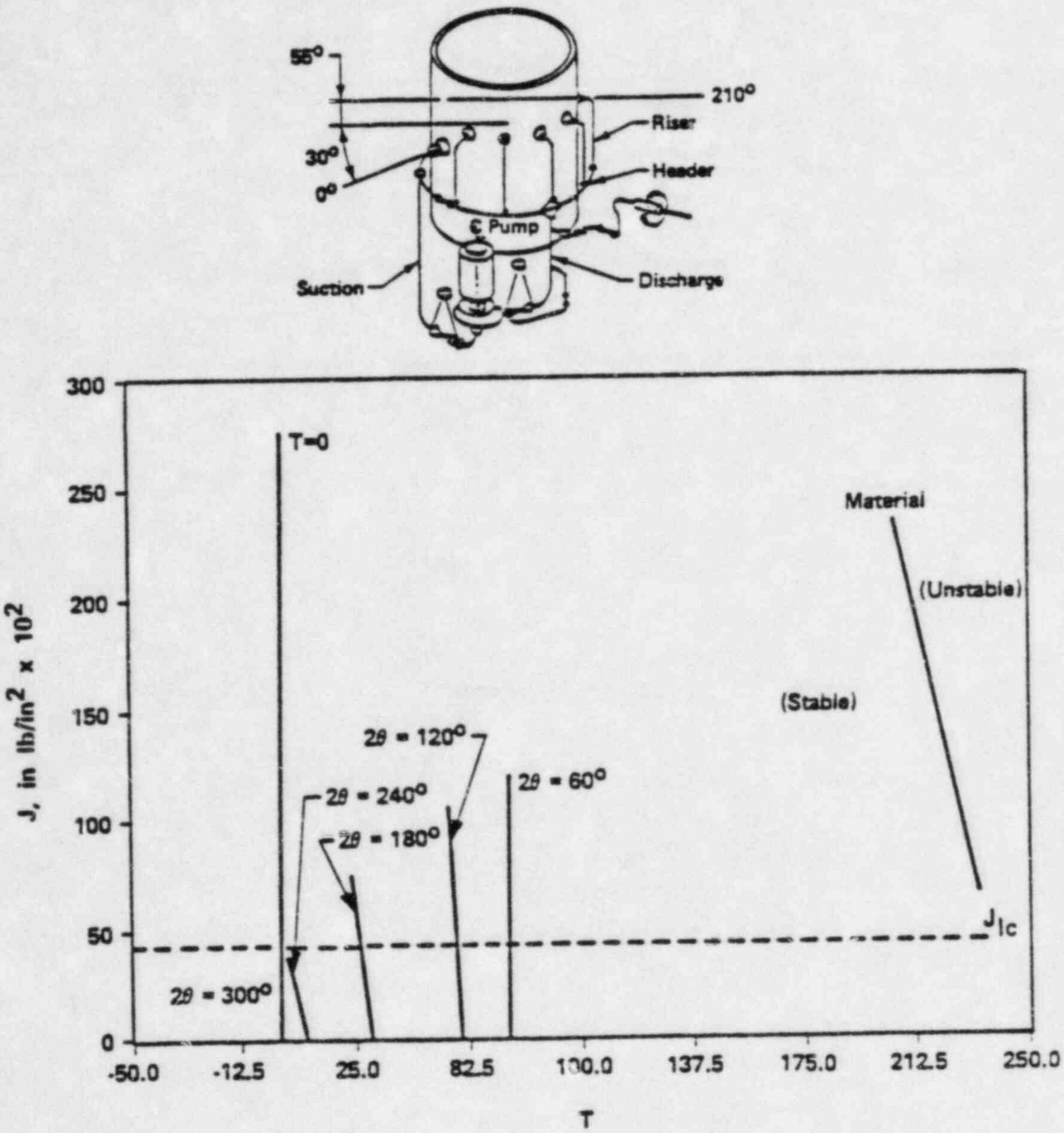

Figure 2.3

STABILITY ANALYSIS FOR BWR RECIRCULATION SYSTEM
(STAINLESS STEEL)

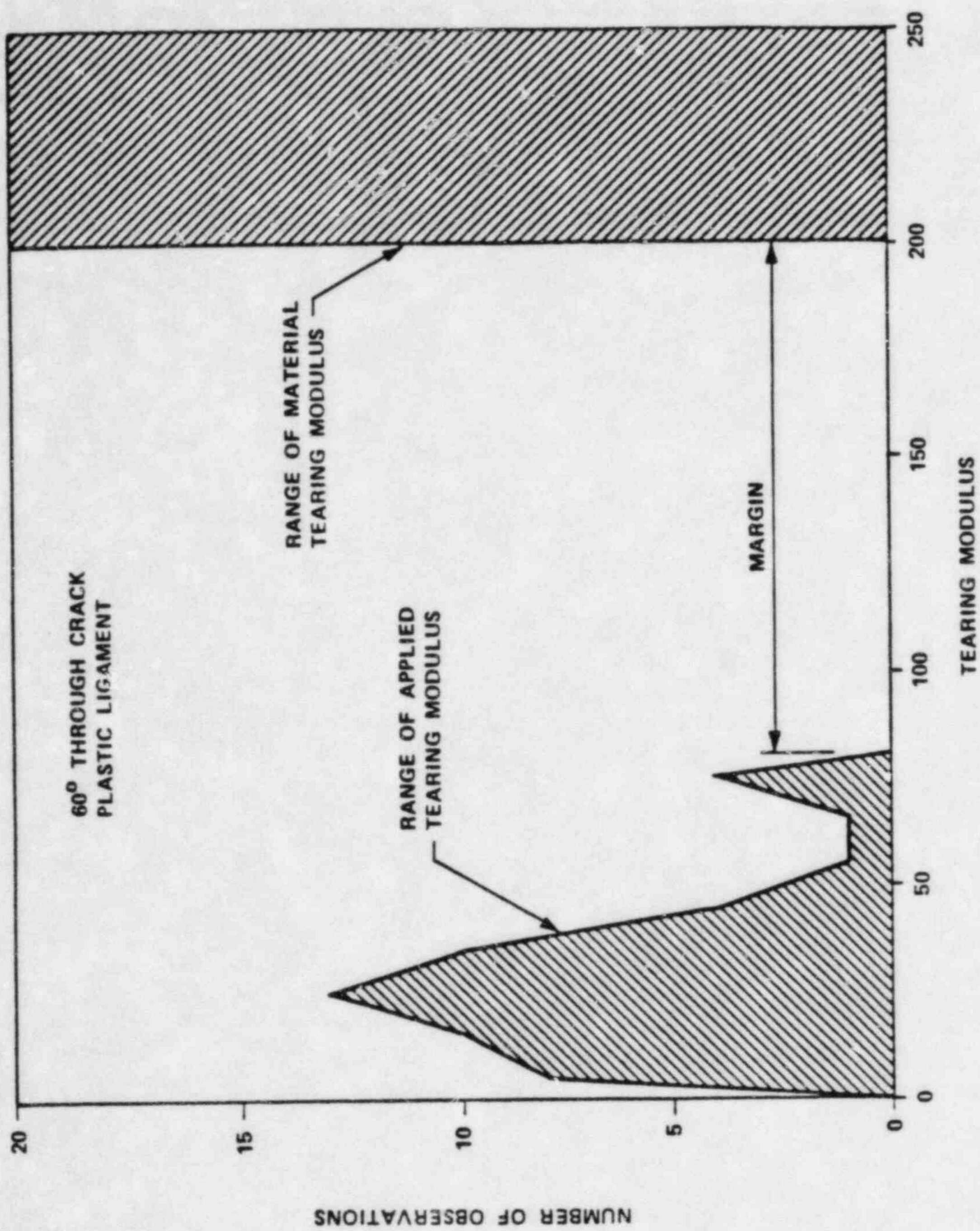

Figure 2.4

SUMMARY OF LEAK-BEFORE-BREAK ASSESSMENT
OF BWR RECIRCULATION SYSTEM

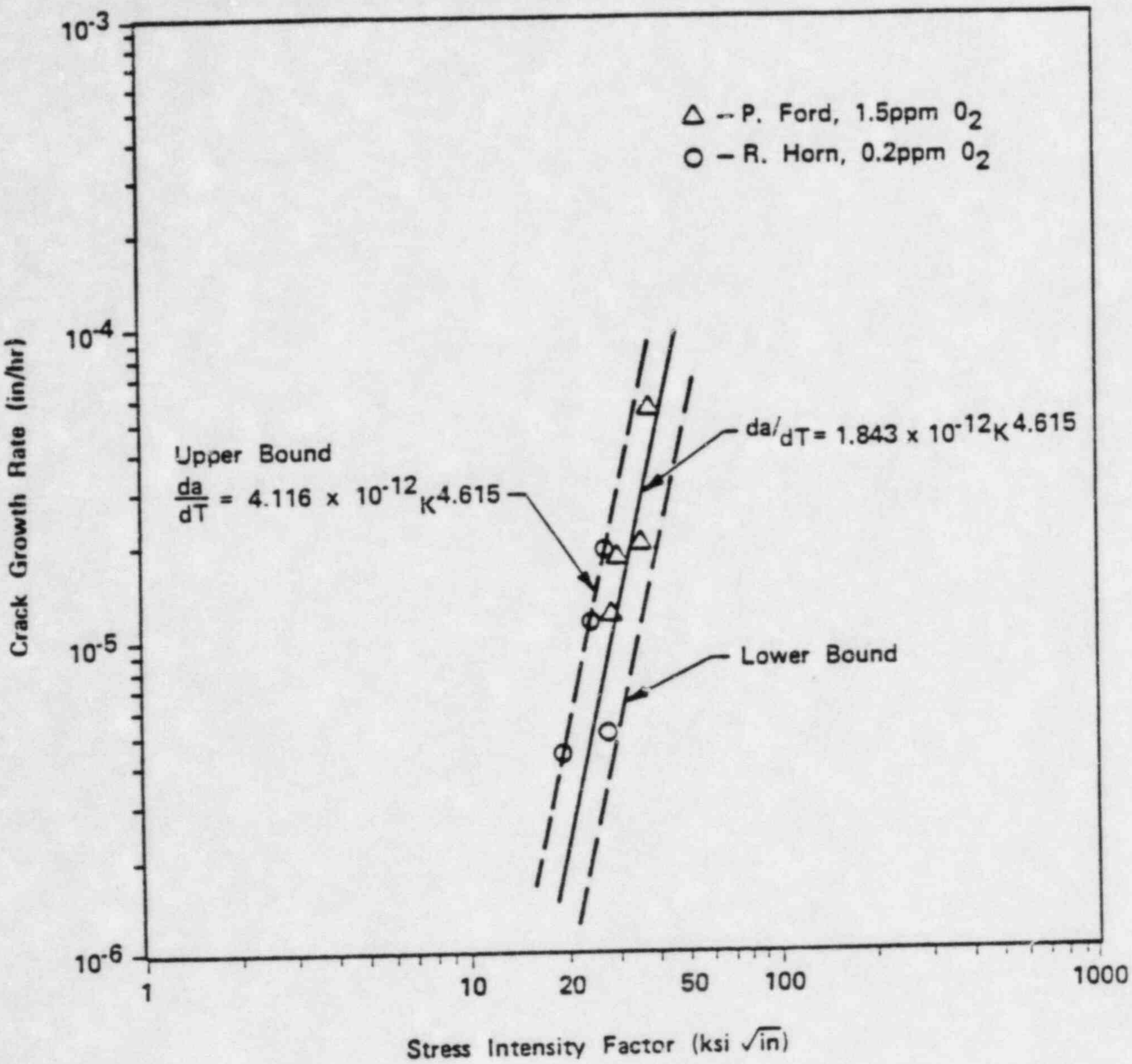

Figure 2.5

TYPICAL IGSCC CRACK GROWTH DATA
(WELD SENSITIZED 304SS IN BWR ENVIRONMENT)

3.0 FRACTURE MECHANICS EVALUATION

Each of the four generic types of crack locations are evaluated below.

3.1 Recirculation Manifold Sweepolet to Pipe Welds

The UT indications in the sweepolet to pipe welds were conservatively bounded by an assumed crack of depth equal to 50% of the pipe thickness and of length equal to 360°. All UT indications are circumferential.

The highest value of applied primary ($P_m + P_b$) stress in a sweepolet to pipe weld based on Reference 4 is:

$$P_m + P_b = 16{,}700 \text{ psi}$$

The value of axial stress due to pressure is:

$$P_m = \frac{PR_o}{2T}$$

P = Design Pressure = 1233 psi

R_o = Outside Radius of Pipe = 6.38 inches

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T = Pipe Thickness = 0.53 inch

P_m = 7,400 psi

The applied stress ratio is:

$$\text{Stress Ratio} = \frac{P_m + P_b}{S_m}$$

S_m = 16,800 psi (at 562°F)

$$\text{Stress Ratio} = \frac{16,700}{16,800} \approx 1.0$$

From Table 2.1, the allowable crack depth at the end of the next fuel cycle for a 180° or longer circumferential crack is 40%. Since the allowable end of cycle crack size is smaller than the current crack size, a weld overlay repair is required.

3.2 Recirculation Manifold Reducer to Pipe Welds

The largest UT indication in a reducer to pipe weld indicates a crack depth of 25% of the pipe thickness and a length equal to 360°. All UT indications are circumferential.

The highest value of applied primary ($P_m + P_b$) stress in a reducer to pipe weld based on Reference 4 is:

$P_m + P_b = 9{,}000$ psi

$P_m = 7{,}400$ psi

$$\text{Stress Ratio} = \frac{9{,}000}{16{,}800} = .54$$

From Table 2.1, the allowable crack depth at the end of the next fuel cycle for a 180° or longer circumferential crack is 63%.

Crack depth as a function of time was calculated using the method described in Section 2.3. The results indicate that a 360° circumferential crack of depth equal to 25% of the wall thickness will grow to 52% of the wall thickness in less than one twelve month fuel cycle. Thus a weld overlay is required.

3.3 Recirculation Inlet Safe End to Pipe Welds

The largest circumferential UT indication in a recirculation inlet safe end to pipe weld indicates a crack depth of 20% of the pipe thickness and a length of less than 2 inches. Leakage was observed during overlay welding adjacent to one safe end-pipe weld. Upon visual examination a small through wall axial crack was found on the N2B safe-end side of the weld (#40).

The highest value of applied primary ($P_m + P_b$) stress in a safe end to pipe weld based on Reference 4 is:

$P_m + P_b = 15{,}500$ psi

$P_m = 7{,}400$ psi

$$\text{Stress Ratio} = \frac{15{,}500}{16{,}800} = .92$$

From Table 2.1 allowable crack depth at the end of the next fuel cycle for a 2 inch long circumferential crack is 75%.

Crack depth and length as a function of time was calculated using the method described in Section 2.3 and

assuming a constant depth to length ratio. Calculations indicate that a 2 inch long circumferential crack of depth equal to 20% of the wall thickness will grow beyond the allowable end of cycle depth in one twelve month fuel cycle, thus a weld overly is required.

3.4 Recirculation Riser Elbow to Pipe Welds

The largest UT indications in a recirculation riser elbow to pipe weld indicate a 360° circumferential crack of 40% of the wall thickness. All UT indications are circumferential.

The highest value of applied primary ($P_m + P_b$) stress in an elbow to pipe weld based on Reference 4 is:

$$P_m + P_b = 9{,}100 \text{ psi}$$

$$P_m = 7{,}400 \text{ psi}$$

$$\text{Stress Ratio} = \frac{9{,}100}{16{,}800} = .54$$

From Table 2.1, the allowable crack depth at the end of the next fuel cycle is 63% of the wall thickness.

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Calculations indicate that a 40% deep crack for an elbow to pipe weld will grow beyond the allowable end of cycle depth, therefore a weld overlay repair is required.

Visual examinations of Weld #35 revealed a pin hole indication after the 2nd layer of the overlay had been applied. No evidence of leakage was noted. A small axial crack was found after grind-out into the base metal. Overlay design was changed from that illustrated in Figure 4.8 to that in Figure 4.9 noted on the elbow side of the joint. Lack of any evidence of water leakage would tend to affirm the existence of significant compressive stresses on the pipe I.D.

4.0 WELD OVERLAY DESIGN

4.1 Design Criteria

This section describes the criteria that are applied to evaluate the acceptability of weld overlay repairs. Because of the nature of these repairs, the geometric configuration is not directly covered by Section III of the ASME Boiler and Pressure Vessel Code, which is intended for new construction. However, materials, fabrication procedures, and Quality Assurance requirements are in accordance with applicable sections of this Construction Code, and the intent of the design criteria described below is to demonstrate equivalent margins of safety for strength and fatigue considerations as provided in the ASME Section III Design Rules. In addition, because of the IGSCC conditions that led to the need for repairs, IGSCC resistant materials have been selected for the weld overlay repairs. As a further means of ensuring structural adequacy, criteria are also provided below for fracture mechanics evaluation of the repairs.

4.1.1 Strength Evaluation

Adequacy of the strength of the weld overlay repairs with respect to applied mechanical loads will be demonstrated with the following criteria:

1. An ASME Boiler and Pressure Vessel Code Section III, Class 1 (Reference 8) analysis of the weld overlay repairs will be performed.

2. The ultimate load capacity of the repairs will be calculated with a tearing modulus analysis. The ratio between failure load and applied loads will be required to be greater than that required by Reference 8.

4.1.2 Fatigue Evaluation

The stress values obtained from the above strength evaluation will be combined with thermal and other secondary stress conditions to demonstrate adequate fatigue resistance for the design life of each repair. The criteria for fatigue evaluation include:

1. The maximum range of primary plus secondary stress will be compared to the secondary stress limits of Reference 8.

2. The peak alternating stress intensity, including all primary and secondary stress terms, and a fatigue strength reduction factor of 5.0 to account for the existing crack, will be evaluated using conventional fatigue analysis techniques. The total fatigue usage factor, defined as the sum of the ratios of applied number of cycles to allowable number of cycles at each stress level, must be less than 1.0 for the design life of each repair. Allowable number of cycles will be determined from the stainless steel fatigue curve of Reference 8.

4.1.3 Crack Growth Evaluation

Crack growth due to both fatigue (cyclic stress) and IGSCC (steady state stress) will be calculated. The allowable crack depth was established based on net section limit load for each cracked and repaired weld (Reference 1). The design life of each repair was

established as the minimum of either the predicted time for the observed crack to grow to the allowable crack depth or five years.

4.1.4 System Effects

The effect of the as-built axial weld shrinkages will be obtained with a model of the Recirculation and RHR Systems. The measured shrinkages will be imposed on the piping model and the resulting steady state secondary stress computed.

4.2 Overlay Designs

Each type of weld overlay design is discussed in this section.

4.2.1 Recirculation Manifold Sweepolet to Pipe Welds

The weld overlay design for the sweepolet to pipe welds was chosen based on a weld residual stress analysis. The analysis modeled the sub-arc pipe outside diameter weld buildup followed by the pipe to sweepolet butt weld followed by a weld overlay added in 1/8 inch increments. The finite element model is shown in

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Figure 4.1. The resulting residual stresses for a 1/4 inch overlay and a 3/8 inch overlay are shown in Figure 4.2 and 4.3 respectively. The location of the stress profiles for both Figure 4.2 and 4.3 is shown in Figure 4.1. A weld overlay thickness of 0.31 inch was chosen based on these residual stress profiles. The weld overlay design is shown in Figure 4.4. The weld overlay residual stress profile will essentially stop IGSCC crack growth, even if the entire pipe is assumed to be weld sensitized due to the sub-arc weld. Thus the end of cycle crack depth will be approximately equal to the current depth of approximately 1/4 inch. The allowable end of cycle crack depth with an overlay thickness of 0.31 inch based on Reference 1 is 58% of the overlaid wall thickness or approximately 0.4 inch. Thus a weld overlay thickness of 0.31 inch will ensure a design life of more than five years.

4.2.2 Recirculation Manifold Reducer to Pipe Welds

As shown in Sections 3.1 and 3.2, the applied stresses on the reducer to pipe welds are less than those on the sweepolet to pipe welds and the UT indications in the reducer to pipe welds are smaller than in the sweepolet to pipe welds. Thus, the results of the weld residual

stress analysis of the sweepolet to pipe weld overlay can be conservatively applied to the reducer to pipe weld overlay.

Thus, an overlay thickness of 0.31 inch was also chosen for the reducer to pipe welds. The design is shown in Figure 4.5. The design life of this weld overlay will be more than five years.

4.2.3 Recirculation Safe End to Pipe Welds

The weld overlay design for the safe end to pipe welds was chosen based on weld residual stress analyses. The analysis modeled the original butt weld followed by an incrementally added weld overlay. The results of such an analysis are shown in Figure 4.6 after an 1/8 inch (mini) overlay. Based on this analysis, the weld overlay design shown in Figure 4.7 was chosen. The weld overlay residual stress profile will essentially stop IGSCC crack growth. Thus the end of cycle crack depth will be approximately equal to the current depth of approximately 0.15 inch. The allowable end of cycle crack depth for a 2 inch long circumferential crack is 75% of the wall thickness or approximately 0.6 inch. Thus, a weld overlay thickness of 0.12 inch will ensure a design life of more than five years.

The overlay thickness was increased to 0.25" for weld number 40 to address a through wall axial crack. The length of axial cracks are limited by the width of the original butt weld heat affected zone. The weld overlay technique is designed to minimize additional sensitization by using low weld heat input during the first two layers of weld. Thus the potential for additional crack growth in the axial direction is minimized. The crack will not propagate into overlay weld material due to IGSCC and growth due to fatigue in 5 years is insignificant.

4.2.4 Recirculation Riser Elbow to Pipe Welds

The weld overlay designs for the elbow to pipe welds were chosen based on weld residual stress analyses. The analysis modeled the original butt weld followed by an incrementally added weld overlay. Based on these analyses, the weld overlay designs shown in Figures 4.8 and 4.9 were chosen. Figure 4.8 applies to all elbow to pipe welds which currently have a maximum crack depth of 30% or less. Figure 4.9 applies to all elbow to pipe welds which currently have a maximum crack depth between 30% and 60%. The weld overlay residual stress profile will essentially stop IGSCC crack growth. Thus the end of cycle crack depth will be approximately equal to the current depth of approximately 1/4 inch. The allowable

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end of cycle crack depth for a 360° circumferential crack with a 1/8 inch overlay is 63% of the wall thickness or approximately 0.4 inch. Thus, the weld overlay design shown in Figures 4.8 and 4.9 will ensure a design life of more than five years.

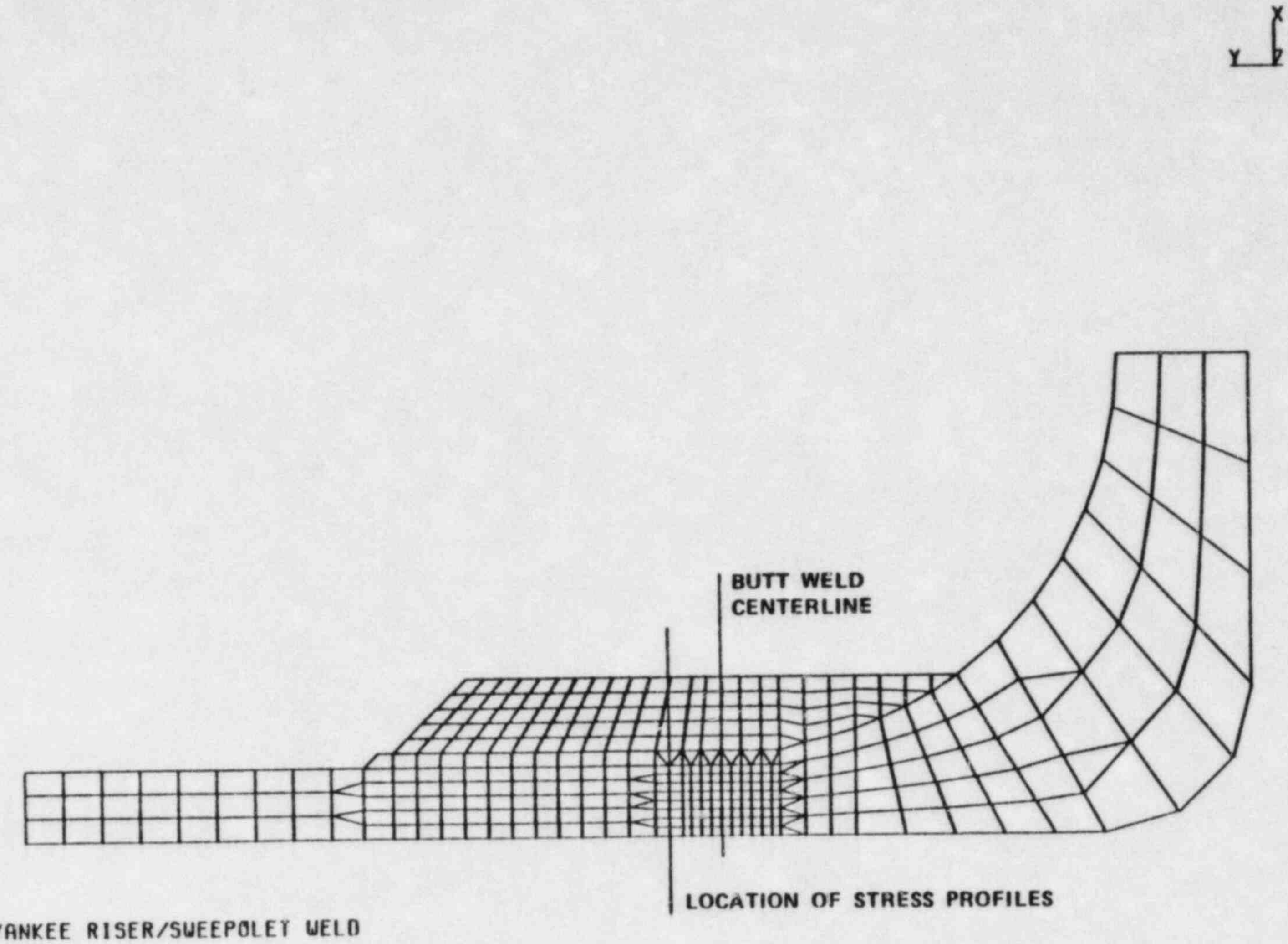

Figure 4.1

SWEEPOLET TO PIPE MODEL

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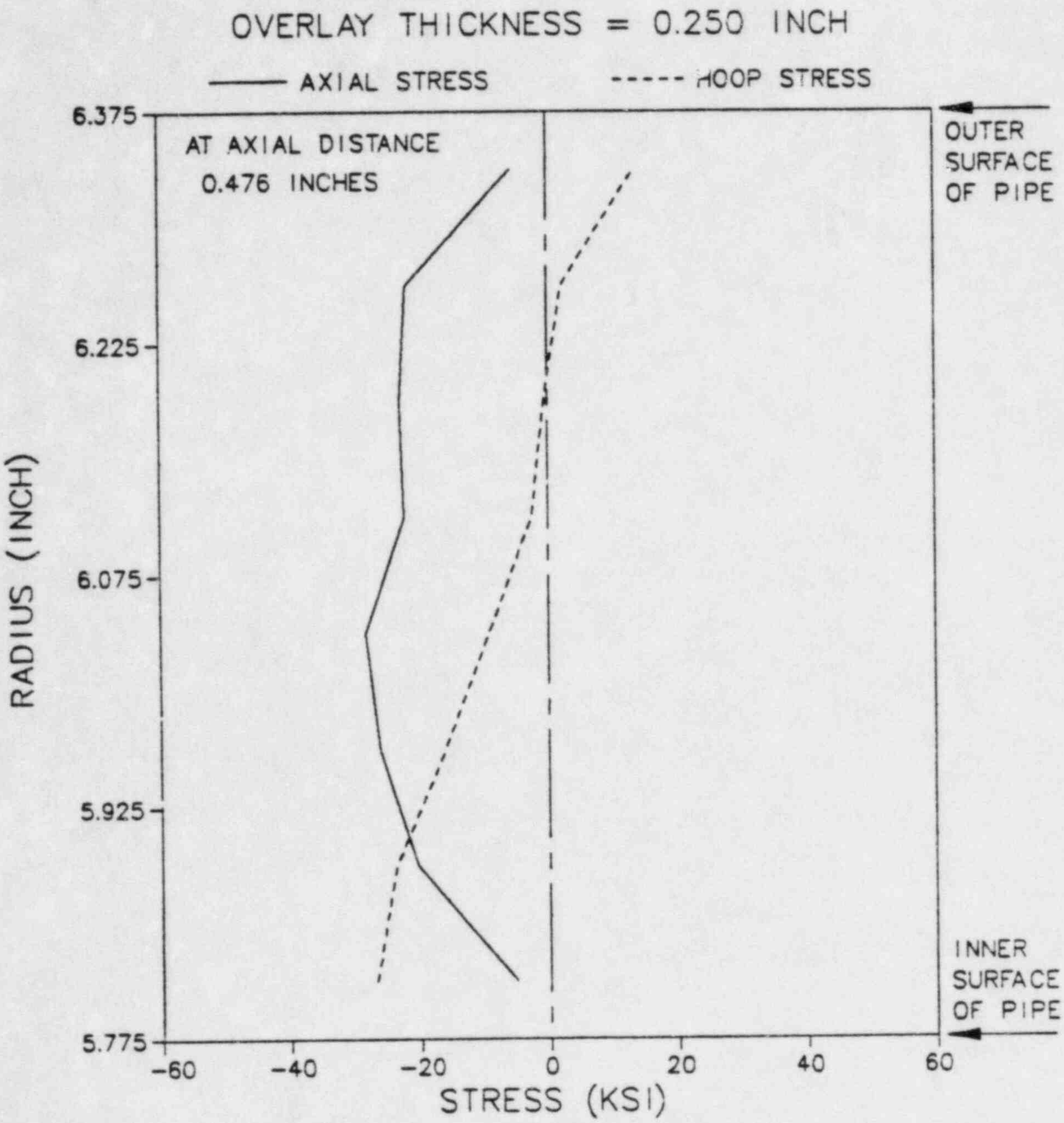

Figure 4.2

RESIDUAL STRESS FOR A 1/4" OVERLAY

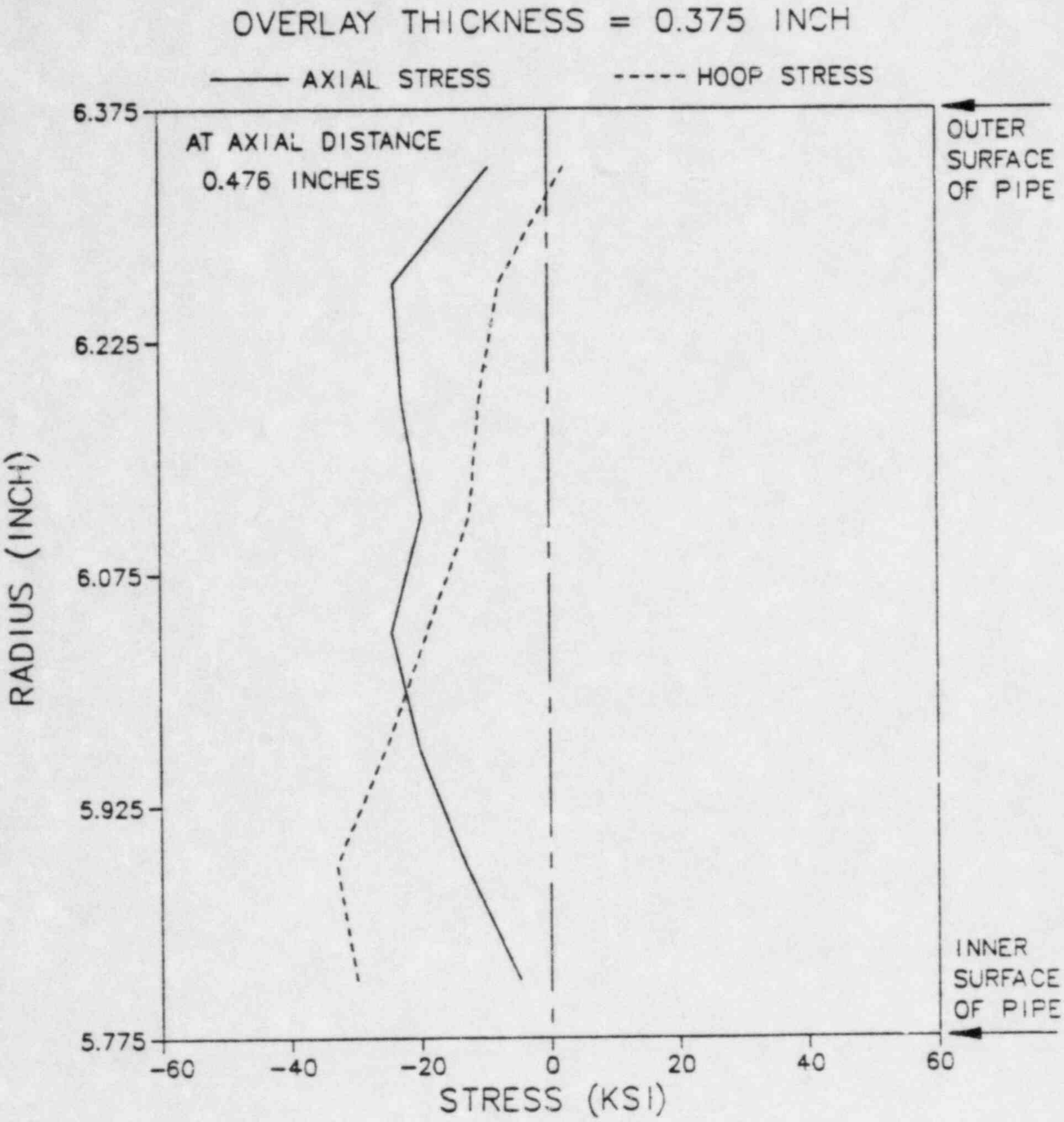

Figure 4.3

RESIDUAL STRESS FOR A 3/8" OVERLAY

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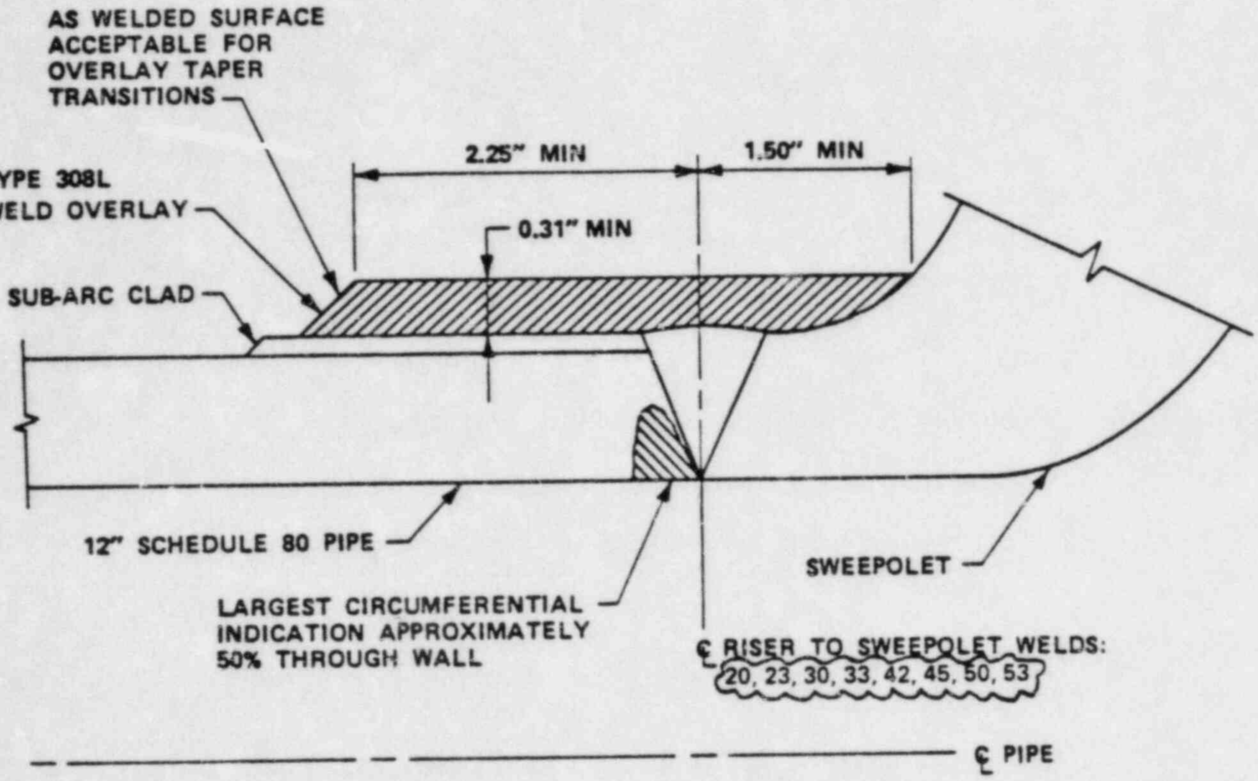

PATENT APPLIED FOR

FYAE83.06-01

Figure 4.4

SCHEMATIC OF RISER TO SWEEPOLET WELD OVERLAY

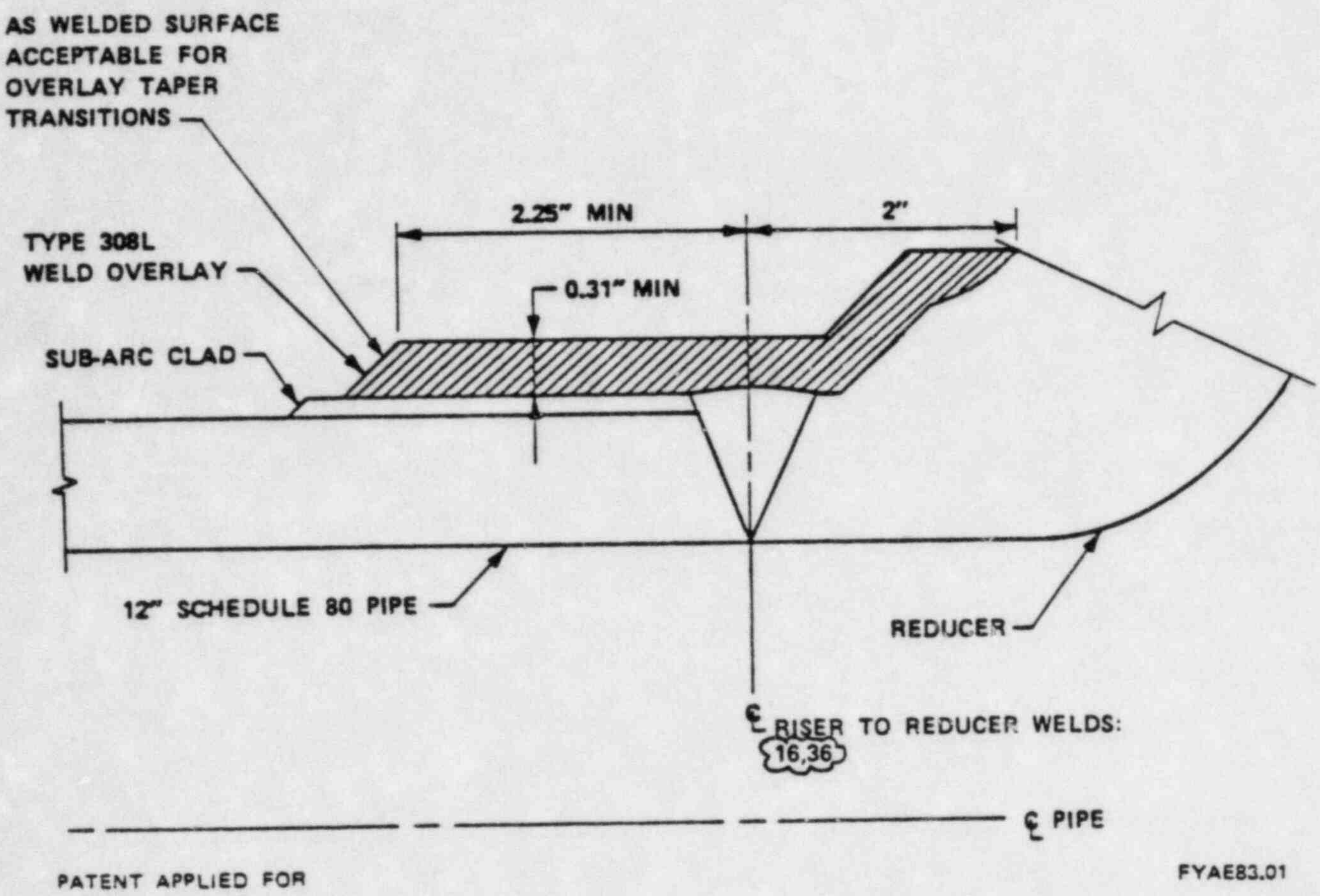

Figure 4.5

SCHEMATIC OF RISER TO REDUCER WELD OVERLAY

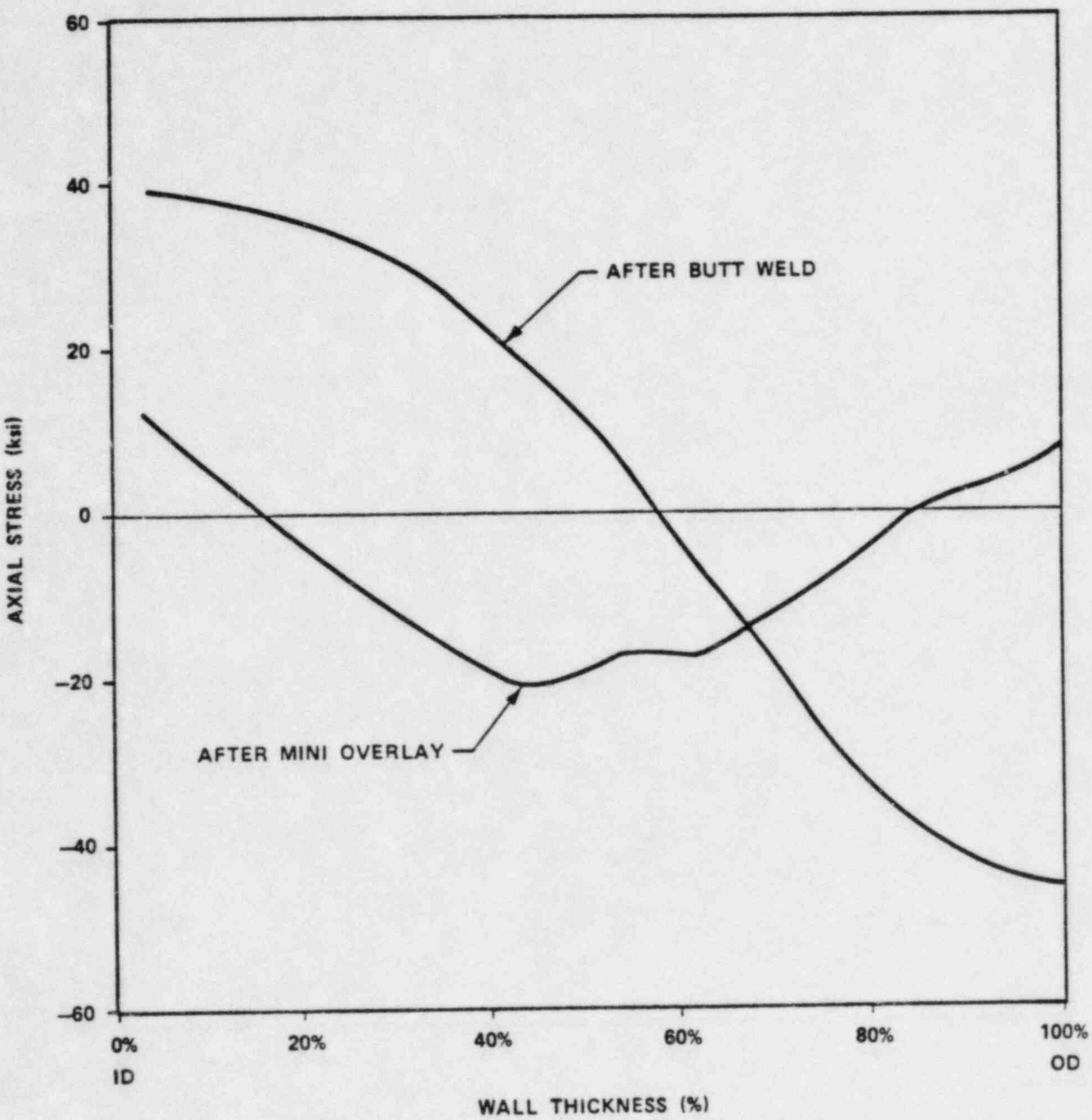

Figure 4.6

AXIAL THROUGH - WALL RESIDUAL STRESS

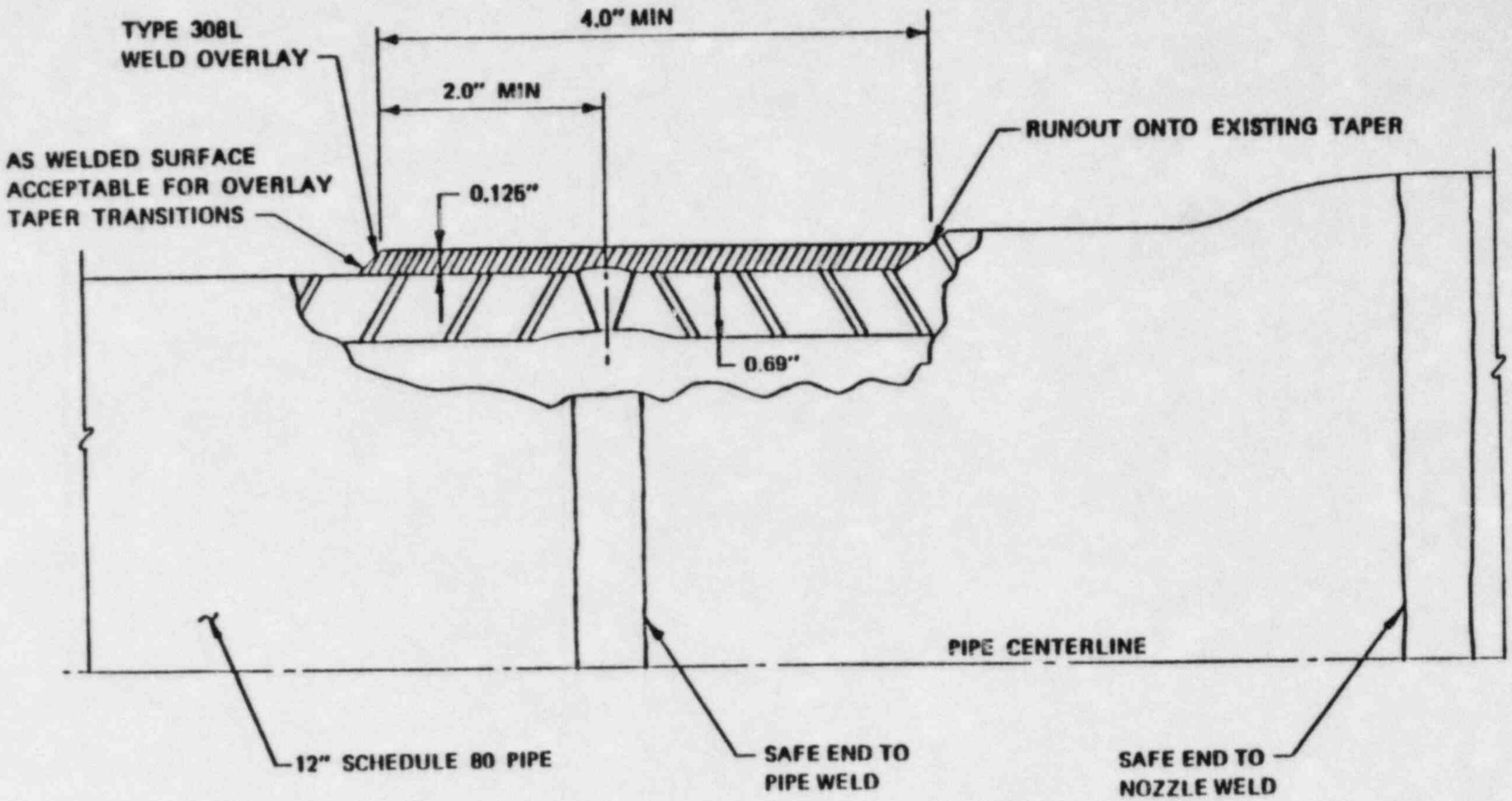

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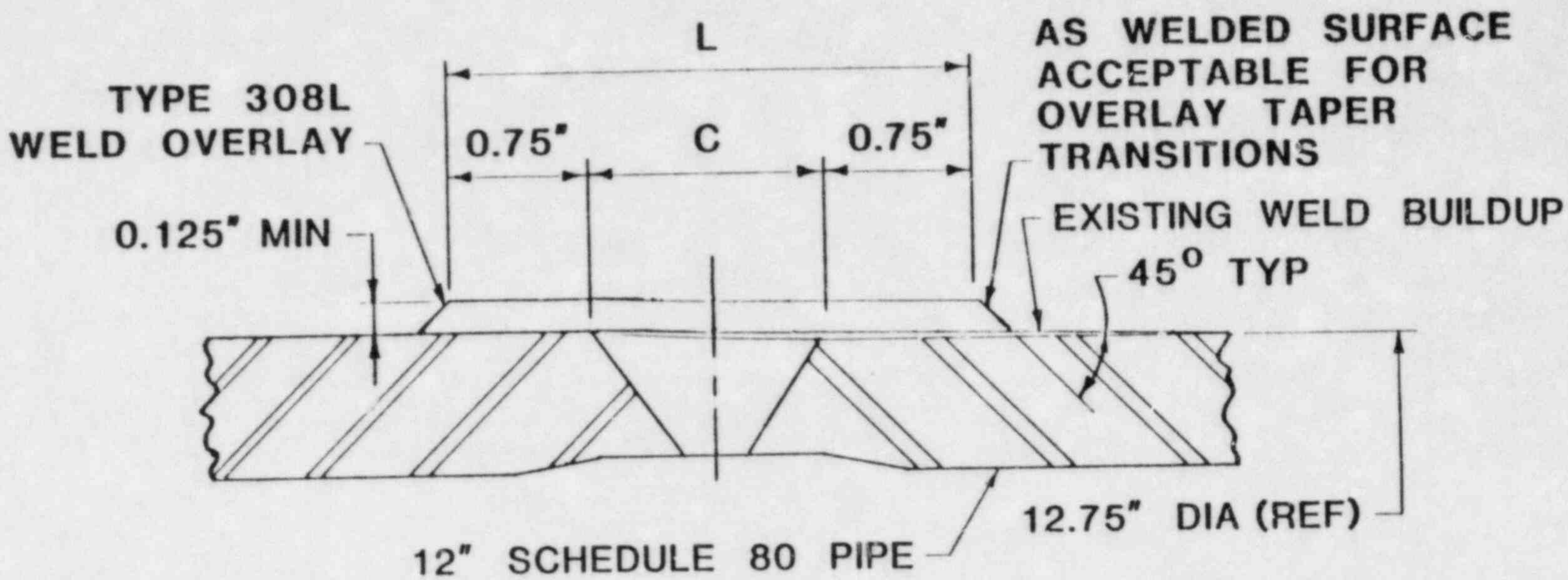
Figure 4.7

SCHEMATIC OF SAFE END TO PIPE WELD OVERLAY
(THERMAL SLEEVE OMITTED)



$L_{MINIMUM} = 1.5'' + C$

C = WELD CROWN WIDTH

Figure 4.8

MINI-OVERLAY DESIGN

RECIRCULATION RISER ELBOW INDICATIONS

YAE-03-102
Revision 1
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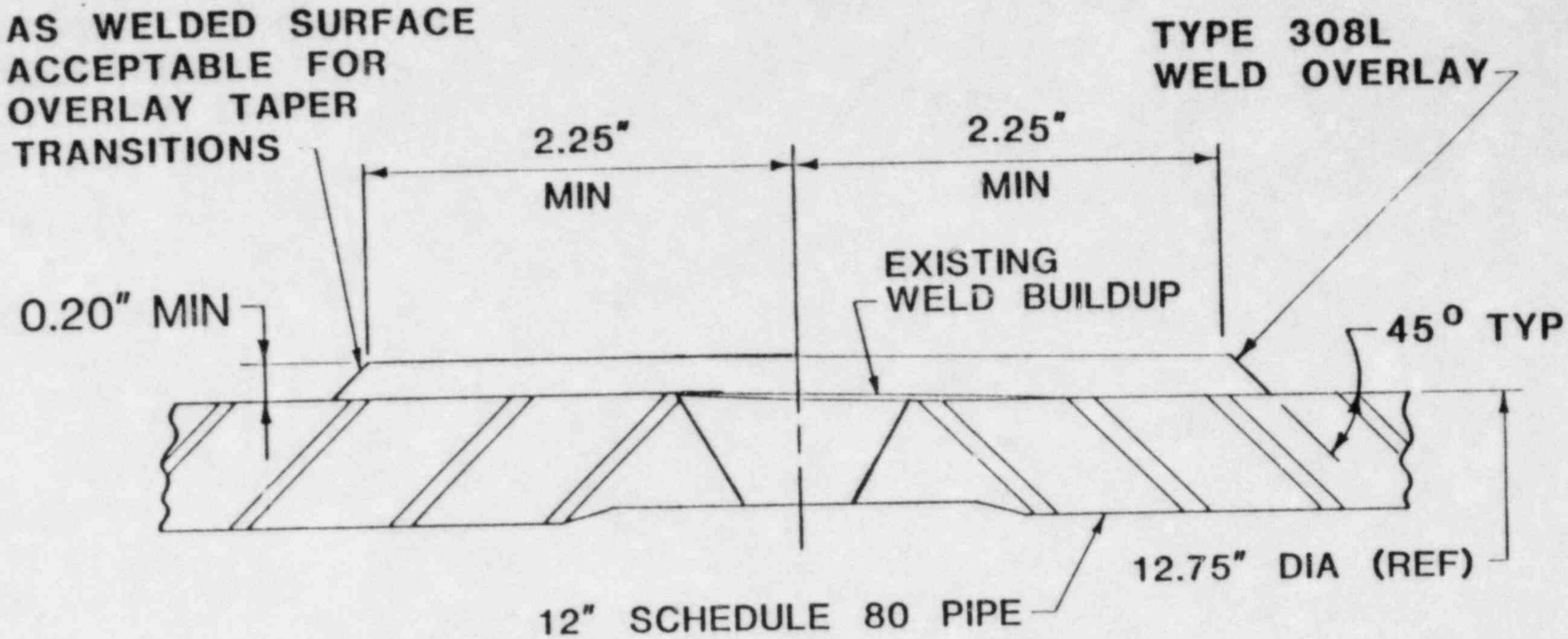

Figure 4.9

STANDARD OVERLAY DESIGN
RECIRCULATION RISER ELBOW INDICATIONS

YAE-03-102
Revision 1
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FYAE83,03-02

5.0 SUMMARY AND CONCLUSIONS

Fracture mechanics calculations have been conducted for each of the four types of welds containing reportable ISI indications in order to establish maximum allowable size and allowable beginning of fuel cycle size for circumferential crack indications. The results of these calculations are presented in summary form in Table 5.1. The method for establishing the allowable crack size is based on the net section collapse approach for evaluation of flaw indications in austenitic stainless steel piping which is currently under review by the ASME Code Committee for incorporation into ASME Section XI (Reference 1). This method sets allowable depths and lengths for axial and circumferential cracks as a function of maximum applied primary loads at the crack location (including seismic) from the piping system design stress report. The underlying philosophy inherent in this method is that there be no reduction in design basis safety margin to predicted plastic collapse of the "net section" of the pipe with the crack area removed. Such calculations have been conducted for each of the subject welds at Vermont Yankee.

The next step in the fracture mechanics analysis is to establish the size that the observed cracks would grow to during the next fuel cycle (or some other, pre-specified time period). This analysis was performed using the data base and methodology presented in References 6 and 7.

All sustained loads on the piping system (including thermal and residual, but excluding seismic) are input into this calculation, and the results are predicted crack depths versus time for each weld. These results are tabulated in Table 5.1.

The final step in the fracture mechanics analysis is to compare the observed indication sizes to the allowables of Table 5.1. Such comparisons for the three types of welds at Vermont Yankee are tabulated in Table 5.1. On the basis of these results, it is concluded that all of the three types of welds require repair.

On the basis of the above fracture mechanics analysis results, overlay repairs are being implemented. The basis for sizing these overlays is as follows. The net section collapse maximum allowable crack depth calculations are repeated assuming a total wall

thickness equal to the original pipe thickness plus the overlay thickness. The overlay thickness is then adjusted to yield an acceptable crack depth for cracks of the length and depth observed. This method uses the favorable residual stresses produced by the weld overlay to predict future growth of the observed cracks.

TABLE 5.1

SUMMARY OF RESULTS OF FRACTURE MECHANICS ANALYSIS

WELD DESCRIPTION	MAXIMUM OBSERVED INDICATION			ALLOWABLE END OF CYCLE CRACK DEPTH	END OF CYCLE CRACK DEPTH	CONCLUSION
	Orient.	Length	Depth			
Safe End to Pipe Weld	Circum.	2 inches	20%	75%	100%	Unacceptable
	Axial	Unknown (< ½ in.)	100%	75%	100%	Unacceptable
Recirculation Manifold Reducer to Pipe Weld	Circum.	360°	25%	52%	100%	Unacceptable
Recirculation Manifold Sweepolet to Pipe Weld	Circum.	360°	50%	32%	100%	Unacceptable
Recirculation Riser Elbow to Pipe Weld	Circum.	360°	40%	52%	100%	Unacceptable

6.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code Section XI, Paragraph IWB-3640 (Proposed), "Acceptance Criteria for Austenitic Stainless Steel Piping" (Presented to Section XI Subgroup on Evaluation Standards in November 1982).

2. EPRI-NP-2261, "Application of Tearing Modulus Stability Concepts to Nuclear Piping," K. H. Cotter, et. al., November 1981.

3. NUTECH Report NSP-81-105, Revision 2, "Design Report for Recirculation Line Safe End and Elbow Repairs, Monticello Nuclear Generating Plant."

4. General Electric Report 22A2615, "Design Report Recirculation System Vermont Yankee Nuclear Power Station," Revision 0, June 1970.

5. NUTECH Internal Memo PCR-83-003, "Weld Residual Stresses for IGSCC Crack Growth Calculations," March 4, 1983.

6. EPRI-NP-2472, "The Growth and Stability of Stress Corrosion Cracks in Large-Diameter BWR Piping," July 1982.

7. EPRI-2423-LD "Stress Corrosion Cracking of Type 304 Stainless Steel in High Purity Water - A Compilation of Crack Growth Rates," June 1982.

8. ASME Boiler and Pressure Vessel Code, Section III, 1980 Edition.

ENCLOSURE E

POST WELD OVERLAY EXAMINATIONS

The examinations following the weld clad repair at Vermont Yankee consist of the following:

1. Clad Bond Examination
2. Clad Integrity Examination
3. Rebaseline of weld joint

The clad bond examination is a straight beam examination from the clad surface. The principle area of concern is the clad to base metal interface. A 3/8" diameter flat bottomed hole at the clad to base metal interface is used as the reference reflector. Scanning sensitivity is at least 6 db gain. The acceptance criteria is 50% of the 3/8" diameter hole reference signal or any indication with an area less than the reference reflector at reference sensitivity.

The clad integrity examination is an angle beam inspection of the clad and clad to base metal interface. The reference reflector is a 1/16" diameter side hole at the clad to base metal interface. Acceptance criteria is any indication less than 50% of the reference reflector. No cracks, lack of penetration or lack of fusion will be allowed. No elongated indications greater than 1/4" shall be permitted.

The rebaseline examinations will be performed on the overlayed pipe to safe-end joints (34, 25, 40, 31, 52) and the riser to elbow joints (29, 54, 51, 18, 35, 24, 32). Vermont Yankee is attempting to perform an angle beam, longitudinal mode inspection of the sweepolet to riser weld joints.

The riser to sweepolet joints were previously overlayed with a submerged arc welding process to build up the wall of the pipe. The IGSCC exams were performed successfully thru this butter layer. When the GTAW process was used to overlay the joints, the grain structure changed at the subarc weld metal to base metal interface, and in the subarc weld deposit. The change is unexplored metallurgically, however, the noise associated with the grain structure increased such that the ID of the pipe could not be interrogated. The use of refracted longitudinal wave search units may provide some benefit in these inspections. If the results are not conclusive, Vermont Yankee will not perform a baseline exam on these joints.

Radiography is not planned as an alternate to ultrasonic testing. The radiographic process using IR-192 has not demonstrated sufficient sensitivity to IGSCC to provide reliable results. It is further felt that the overlay will compress the indications, effectively closing them and as such providing no sensitivity to a radiographic examination.

In addition to the volumetric examinations described, a liquid penetrant examination will be performed on the final weld overlay surface condition.

ENCLOSURE F

ENCLOSURE F

LEAK DETECTION SYSTEMS

A. Local Leak Detection

To augment our existing Leak Detection Systems and to provide further assurance that leakage from the reactor coolant boundary will not go undetected, we have installed a local Leak Detection System on selected welds of the Recirculation System, which has the capability of sensing leaks as low as 0.1 gpm.

- o Description

  The Leak Detector System utilizes a moisture sensitive tape as the active element. The tape consists of a pair of foil conductors and polyester webbing impregnated with a chloride free salt bonded with thermosetting insulating tape. In the dry (normal) condition, the tape has a resistance in the megohm range. When moisture or saturated steam reaches the tape, the resistance drops to the 10K ohm range. This change activates the display/control and provides an alarm. This control unit interrogates all sensors once per second and provides a digital display of any sensor location for alarm or trouble. The unit also provides a remote signal to the Control Room.

  The selecting of weld locations to be monitored was discussed between the Vermont Yankee and NRC staffs and it was mutually agreed that seven weld joints would be instrumented. These seven joints were not included in the augmented ISI inspections based on susceptibility, but are geometrically similar to welds which were inspected and indications found. The location of welds being monitored are illustrated on the attached figure.

B. Technical Specifications

Based on our experience with IGSCC, as well as the industry experience, we felt that modifications to our Reactor Coolant System leakage Technical Specification were warranted. That proposal has been transmitted to the NRC via Reference (e) of the cover letter. Discussions with our Project Manager reveal that an amendment cannot be processed by the NRC in a time frame consistent with our projected startup date of June 15, 1983. With this in mind, we have prepared a Manager of Operations (MOO) Directive which essentially duplicates the changes proposed in Reference (e). A copy of our draft MOO Directive is provided as an attachment. Pending your approval, we are prepared to implement the administrative controls contained in that directive upon startup, in lieu of the current Technical Specification, until such time as an amendment can be issued.

660-6.3 5-79

MEMORANDUM

VY DIRECTIVE 83-01
DRAFT

To J. P. Pelletier — Vernon (COMPANY OR LOCATION) — May 23, 1983 (DATE)

From W. P. Murphy — Brattleboro (COMPANY OR LOCATION) — File

Subject COOLANT LEAKAGE LIMITS AND MONITORING FREQUENCIES;
ADMINISTRATIVE CHANGE TO TECHNICAL SPECIFICATION 3.6.C/4.6.C

DISCUSSION

Based on meetings between representatives of Vermont Yankee and the NRC and our experience with IGSCC in large diameter piping located within the primary containment, I have decided that enhancement of the existing leakage monitoring Technical Specification is warranted. A proposed change has been drafted to reflect these changes but information from the NRC leads us to believe that an amendment cannot be prepared and issued prior to startup from the current outage. Accordingly, you are hereby directed to administratively apply the limits, surveillance frequencies, and corrective actions provided as Attachment A.

The definitions for "identified" and "unidentified" leakage shall be as described in FSAR Section 4.10 - "Pressure Boundary Leakage" shall be defined as "leakage through a nonisolable fault in a reactor coolant system component body, pipe wall, or vessel wall".

This directive shall become effective upon startup and remain in effect until an amendment is received from the NRC or this directive is cancelled.

SAFETY EVALUATION

The administrative changes mandated by this directive revise the existing Technical Specifications primarily in the area of leakage rate monitoring, surveillance frequencies, and corrective actions and are consistent with NUREG-0313 guideines and/or license amendments previously issued by the NRC to other utilities. As such, these changes do not compromise the existing margins of safety or health and safety of the public.

WPM/ds

cc: L. H. Heider
L. D. Marsolais
R. L. Smith
J. B. Sinclair
J. D. Haseltine
R. J. Wanczyk
D. A. Reid
R. D. Pagodin

-DRAFT-

ATTACHMENT A

C. COOLANT LEAKAGE

1. During power operation, reactor coolant system leakage into the primary containment shall be limited to:

   a. No known pressure boundary leakage;

   b. 5 GPM unidentified leakage when averaged over a predetermined* 24 hour period; and

   c. 20 GPM identified leakage when averaged over a predetermined* 24 hour period.

2. Any time the reactor is in the run mode, reactor coolant system leakage into the primary containment from unidentified sources shall be limited to:

   a. 2 GPM increase in unidentified leakage within any predetermined* 24 hour period (see Note 1).

3. If the requirements of Specification 3.6.C.1 cannot be met, initiate action as follows:

   a. With any known pressure boundary leakage, be in at least hot shutdown within 12 hours and in cold shutdown within the next 24 hours.

   b. With any reactor coolant system leakage greater than one of the limits specified in 3.6.C.1 b or c, reduce the leakage rate to within the limits within 4 hours or be in at least hot shutdown within the next 12 hours and in cold shutdown with the next 24 hours.

* A new 24 hour "averaging" period shall be established each time the surveillance is performed, i.e., the average shall be based on the interval between the time the last leakage rate was taken and the previous 24-hour period.

C. COOLANT LEAKAGE (Surveillance)

Reactor coolant system leakage shall be demonstrated to be within the limits of Specification 3.6.C.1 & 2 by checking and logging the leakage collected in the primary containment floor and equipment sumps at least once per 8 hours. In addition, the primary containment atmosphere activity shall be checked and logged at least once per 8 hours.

4. If the requirements of Specification 3.6.C.2 cannot be met, initiate action as follows:

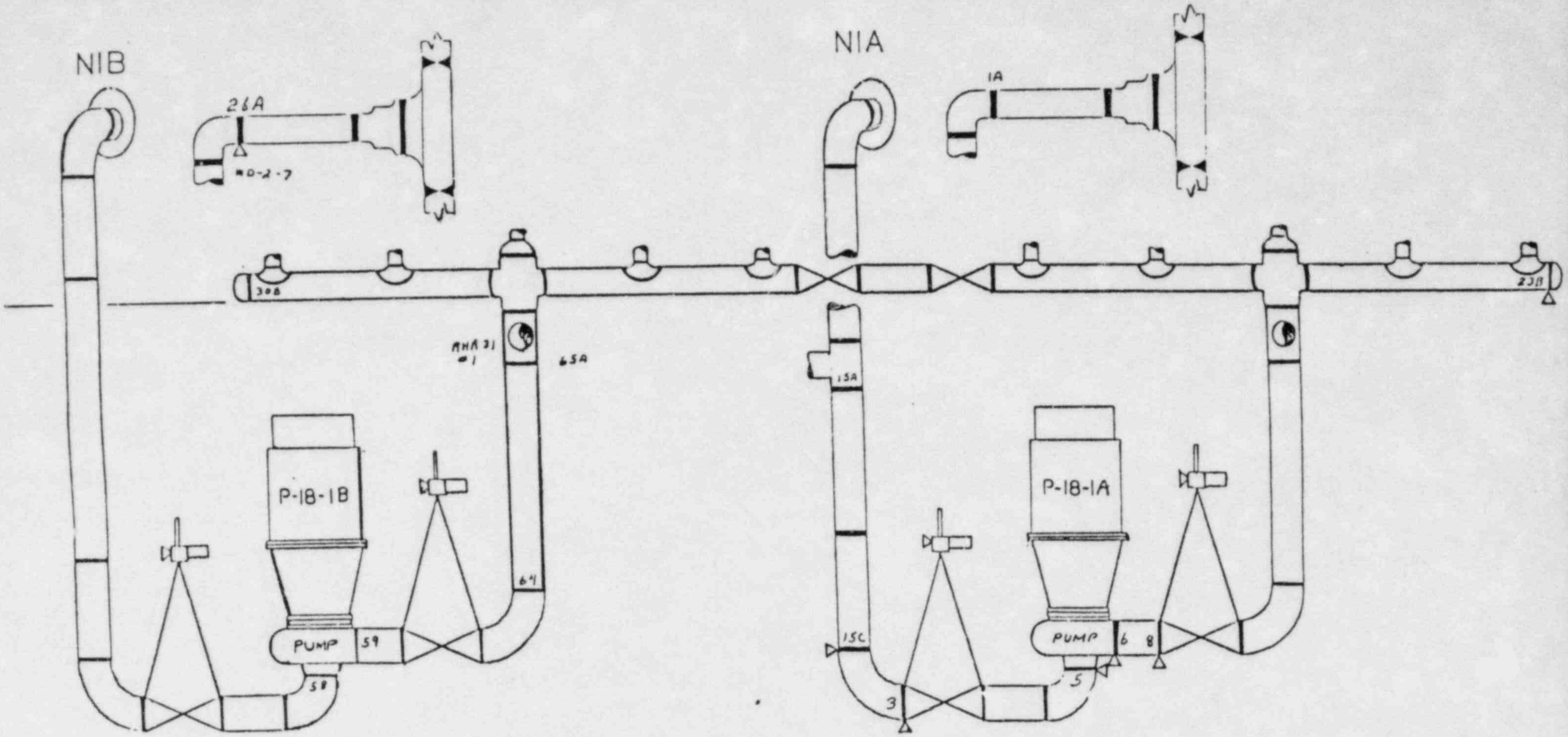
   a. With any increase in unidentified leakage of $\geq$2 GPM within a predetermined 24-hour period, identify the source of leakage within 4 hours or be in at least cold shutdown within the next 24 hours.

5. Both the sump and air sampling systems shall be operable during power operation. From and after the date that one of these systems is made or found inoperable for any reason, reactor operation is permissible only during the succeeding 7 days.

6. If the requirements of Specification 3.6.C.5 cannot be met, an orderly shutdown shall be initiated and the reactor brought to a cold shutdown condition within 24 hours.

NOTE 1: During the first 24 hours in the run mode following startup, the limits of Specification 3.6.C.2 may be waived provided the requirements of 3.6.C.1 are met.

VERMONT YANKEE



Δ - Location of Moisture Sensitive Tape