NSP

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November 22, 1982

Director Office of Inspection and Enforcement
Attn: Document Control Desk
U S Nuclear Regulatory Commission
Washington, DC 20555

MONTICELLO NUCLEAR GENERATING PLANT
Docket No. 50-263 License No. DPR-22

Response to IE Bulletin 82-03, Revision 1, and
Confirmatory Action Letter dated October 19, 1982
From J. Keppler Regional Administrator, Region III, USNRC

IE Bulletin 82-03, issued on October 14, 1982, required boiling water reactors scheduled to be in a refueling or other extended outage through the end of January, 1983 to perform inspections of recirculation system piping and supply information related to these inspections. This bulletin was subsequently revised and reissued on October 28, 1982. The purpose of inspections required by the Bulletin was to detect possible stress corrosion cracking in recirculation system piping similar to cracking experienced recently at the Nine Mile Point Nuclear Generating Station. Prior to the release of IE Bulletin 82-03, Northern States Power Company initiated a comprehensive inspection of recirculation system piping during the refueling outage beginning September 2, 1982.

Following the discovery of crack indications at Monticello on September 28, 1982, a meeting between Northern States Power Company, NRC Region III personnel, and NRC Office of Nuclear Reactor Regulation personnel was held on October 14, 1982 at the Region III office. Proposed corrective actions for the crack indications found in the Monticello recirculation system piping were discussed. Information required by the NRC for their review of the corrective actions proposed by Northern States Power Company was specified in a Confirmatory Action Letter dated October 19, 1982.

The purpose of this letter is to provide the information required by IE Bulletin 82-03, Revision 1, and the October 19, 1982 Confirmatory Action Letter.

The following actions and information submittals were required by IE Bulletin 82-03, Revision 1:

1. Demonstration of effectiveness of detection capability of ultrasonic methodology

2. Listing of results of recirculation system piping inspection.

3. Description of corrective actions taken if the inspections indicate the presence of cracks.

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4. Description of the inspections, including -

   a. The sampling plan used
   b. The UT procedures and calibration standards used
   c. Summary of the results of previous inspections using the validated inspection methodology
   d. Evaluation of crack detection capability

The following actions and information submittals were required by the October 19, 1982 Confirmatory Action Letter:

1. A report submitted for NRC review including -

   a. Summary of 1982 augmented examination program
   b. Description of repairs
   c. Basis for establishing accuracy of UT measurements
   d. Description of methods and analysis used, load combinations, and results of analysis using updated loads
   e. Evaluation of reactor recirculation system stresses resulting from repairs
   f. Basis for justifying continued operation with existing indications and repairs

2. Obtain NRC concurrence prior to returning to service.

Attachment (1) is a report entitled, "Summary Report of the Augmented Inservice Inspection of Stainless Steel Pipe Welds." This report addresses items 1, 2, and 4 of IE Bulletin 82-03, Revision 1, and items 1.a and 1.c of the October 19, 1982 Confirmatory Action Letter.

Attachment (2) is a report entitled, "Summary Report of Overlay Repairs." This report addresses item 3 of IE Bulletin 82-03, Revision 1, and item 1.b of the October 19, 1982 Confirmatory Action Letter.

Attachment (3) is a report prepared by Nutech Engineers, Incorporated, entitled "Design Report for Recirculation Line Safe End and Elbow Repairs Monticello Nuclear Generating Plant." Attachment (4) is a report prepared by Nutech Engineers, Incorporated, entitled "Design Report for Recirculation Line End Cap Repair Monticello Nuclear Generating Plant." Attachments (3) and (4) address items 1.d and 1.e of the October 19, 1982 Confirmatory Action Letter.

Attachment (5) is a letter dated November 18, 1982 from P C Riccardella, Nutech Engineers, Incorporated, to S J Hammer, NSP, "Leak-Before-Break Considerations for Recirculation System Stress Corrosion Cracks at the Monticello Nuclear Generating Plant." Attachment (5) addresses item 1.f of the October 19, 1982 Confirmatory Action Letter.

We believe the information provided in Attachments (1) through (5) fully satisfy the requirements of IE Bulletin 82-03, Revision 1, and the October 19, 1982 Confirmatory Action Letter.

As noted in Attachment (2), a 110% reactor coolant system hydrostatic test will be performed prior to return to service. A special addendum will be prepared to the hydrostatic test procedure to provide for detailed inspection of the recirculation riser system piping. Insulation will be removed from the piping during this inspection and a special moisture sensitive indicator material will be applied to all weld areas following a thorough cleaning. The results of this inspection will be reported to the Commission as soon as possible following the hydrostatic test.

During the next operating cycle we will implement additional operating procedures related to coolant leak detection limits and operability of leak detection equipment. The requirements of Generic Letter 81-04, "Implementation of NUREG-0313, Revision 1, Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping (Generic Task A-42)," related to leakage detection measures will be implemented. Specifically:

a. An additional operational limit on reactor coolant system leakage of an increase in unidentified leakage of two gallons/minute or more within any 24 hour period. On exceeding this limit, or the existing limits of 5 gallons/minute unidentified leakage or 25 gallons/minute total leakage (averaged over a 24-hour period), the reactor will be placed in a cold shutdown condition within 36 hours for inspection.

b. Drywell leakage will be measured and recorded every four hours.

c. At least one of the leakage measurement instruments associated with each sump will be operable.

d. The drywell atmospheric particulate radioactivity monitoring system will be operable or a sample shall be taken and analyzed every four hours.

The Monticello containment leakage detection systems are described in Attachment (6). These systems provide for rapid and accurate detection of abnormal leakage in the drywell.

Assuming acceptable results from the reactor coolant system hydrostatic test, it is our intention to place the Monticello unit in operation for fuel cycle number 10. We believe that the results of the inspections and the repair program provide an adequate basis for safe operation during cycle 10. Replacement of recirculation system riser piping is currently planned prior to commencement of cycle 11.

Please contact us if you have any questions related to the information we have provided. If necessary, a meeting can be scheduled with members of the NRC Staff to discuss this information in detail. We will make arrangements with our Project Manager in the Division of Licensing if a meeting is desired.

C E Larson
C E Larson
Director
Nuclear Generation

CEL/bd

cc: Regional Administrator, Region III, NRC
R D Walker, Region III, NRC
NRR Project Manager, NRC
NRC Resident Inspector
G Charnoff

Attachments

UNITED STATES NUCLEAR REGULATORY COMMISSION

NORTHERN STATES POWER COMPANY

MONTICELLO NUCLEAR GENERATING PLANT

Docket No. 50-263

LETTER DATED NOVEMBER 22, 1982
RESPONDING TO IE BULLETIN 82-03, REVISION 1, AND
CONFIRMATORY ACTION LETTER DATED OCTOBER 19, 1982
FROM J G KEPPLER, REGIONAL ADMINISTRATOR, REGION III, USNRC

Northern States Power Company, a Minnesota corporation, by this letter dated November 22, 1982, hereby submits information in response to NRC IE Bulletin 82-03, Revision 1, and a Confirmatory Action Letter dated October 19, 1982 from J G Keppler, Regional Administrator, Region III, USNRC.

By C E Larson
C E Larson
Director
Nuclear Generation

On this 22nd day of November, 1982, before me a notary public in and for said County, personally appeared C E Larson, Director, Nuclear Generation and being first duly sworn acknowledged that he is authorized to execute this document on behalf of Northern States Power Company, that he knows the contents thereof and that to the best of his knowledge, information and belief, the statements made in it are true and that it is not interposed for delay.

Pearl S. Duggan

PEARL S. DUGGAN
NOTARY PUBLIC - MINNESOTA
HENNEPIN COUNTY
My Commission Expires June 20, 1985

Attachment (1)
Director I&E, NRC
November 22, 1982

Monticello Nuclear Generating Plant

Summary Report of the
Augmented Inservice Inspection of Stainless Steel Pipe Welds
Prepared by: Phillip J. Krumpos

I. Introduction

This report is a summary of the augmented inservice inspection of stainless steel pipe welds at Monticello Nuclear Generating Plant. The extensive occurrence of intergranular stress corrosion cracking (IGSCC) of the pipe weld heat affected zones at Nine Mile Point, Unit I Nuclear Generating Plant, increased the concern for Monticello and resulted in the inspection of all welds classified as nonconforming welds (as defined by NUREG-0313, Rev.1) within the reactor recirculation system and the attached piping systems.

This inspection was performed during the Plants tenth refueling outage from September 4 to October 13, 1982. Lambert, MacGill, and Thomas, Inc. (LMT) was the primary inspection contractor. Hartford Steam Boiler Inspection and Insurance Company, representing ANI, provided the authorized inspection. Monticello began commercial operation on June 30, 1971 and has operated 8.69 effective full power years.

II. Discussion of Inspection Results

Evaluation of the inspection results revealed five welds of the reactor recirculation system with indications that have been interpreted as being intergranular stress corrosion cracks (IGSCCs). Table I identifies the welds and describes the respective indications. Figure IA and Figure IB identifies the location of these welds.

The 22 inch diameter manifold end cap weld RMAJ-2 was inspected and identified in the first week of the outage as having linear indications in the axial direction of the end cap. After the system was drained, these ultrasonic indications were confirmed by radiography as being three (3) axial intergranular stress corrosion cracks (IGSCCs).

Later in the inspection, four (4) other welds in the 12 inch diameter recirculation riser piping were found to contain IGSCC's. Three welds (RRCJ-3, RREJ-3, and RRFJ-3) were pipe to safe end welds and the fourth weld (RRDJ-5) was pipe to elbow weld. All four welds were in separate risers; refer to Figures 1A and 1B.

Initial evaluation of the ultrasonic results and radiographs, incorrectly identified these radial cracks as being shallow axial cracks. (The distinction between axial and radial cracks is their major dimension; axial indication is its length along the pipe ID and radial indication is its through wall depth. The length of circumferentail indication is as its name implies in the circumferential direction of the pipe.) Unlike the strong ultrasonic signal amplitude responses received from the axial indications of the end cap weld RMAJ-2 and the circumferential indications of RRCJ-3 and RREJ-3, these radial indications had very low ultrasonic amplitude responses. Thus, because of their low amplitude responses, these indications had been sized as being less than 2% of wall and interpreted from the radiographs as lying along the pipe ID in the axial direction. Therefore, a conservative course of action was thought to be the application of a weld overlay repair to RMAJ-2 and RREJ-3 and the monitoring of the other three welds with their shallow less than 2% of wall indications in subsequent refueling outages. (The uncertainty in the accuracy of ultrasonic sizing of cracks, especially IGSCC, was the primary reason for the decision in applying the weld overlay to RMAJ-2, with its 4-11% of wall axial indications and the pipe to safe end weld RREJ-3, with its 9% of wall circumferentail indications.) In the preparation for the weld overlay of weld RREJ-3, the grinding of the weld crown revealed a very small through wall leak (1/64 inch long) on the surface adjacent to the weld (1/16 inch from the edge of the weld crown) at 3 o'clock on the safe end side. This through wall leak had not been detected during the ultrasonic examination. Radiographs taken at several angles revealed that the indication appeared to spiral up the weld heat affected zone and thus making it difficult for ultrasonic detection.

It became apparent from this experience that the initial interpretation, that these low ultrasonic amplitude indications were shallow axial indications, was incorrect. These indications have now been interpreted as being deep (greater than 50% of wall) radial IGSCC within the weld heat affected zone. In addition, the ultrasonic technique that was optimized for the detection of circumferential and axial indications appears to be less than optimum for the detection of radial indications.

None of the five welds had been previously examined by the current examination methodology, which was not employed until 1980. There were 17 welds that had been examined in 1980 and 1981. These welds were compared with current inspection results; the comparison showed that there were no indications of changes in weld integrity.

III. Inspection Plan

The inspection focused on all nonconforming stainless steel circumferential butt welds of the reactor recirculation system and the attaching systems. (Refer to Table 2 for the included systems, respective pipe sizes and material and number of welds. Figures 2 through 11 are isometric drawings that show the welds that were examined.) The inspection included those few circumferential butt welds and the 10 sweepolet welds that had been solution annealed.

This refueling outage provided a unique inspection opportunity for these piping systems, in that all of the old piping insulation had been removed for replacement. Thus, an increase inspection sample, based on Stress Rule Index and carbon content, had been initially planned to augment the scheduled inservice inspections.

However, after General Electric's update meeting on Nine Mile Point's pipe cracking problem, NSP's management decided to increase the augmented inspection program to include 100% of the nonconforming welds, as well as some of the solution annealed welds, of the reactor recirculation system and associated attached systems.

It was thought that with Monticello having similar operating hours as Nine Mile Point Unit 1, an extensive inspection would provide a very valuable piece of reference information for the BWR Industry. The additional cost of dollars and man Rems would be outweighed by this benefit.

IV. Inspection Methodology

Manual ultrasonic testing was the major tool used in this inspection. The procedure used to control the pipe weld examination was a basic ultrasonic examination procedure that complied with Appendix III of the 1977 Edition through and including the Summer 1978 Addenda of ASME Section XI Code. The calibration standards used were typical Section XI standards with 10% flat bottom slots.

The main ultrasonic test system (master) consisted of a portable ultrasonic digital analog tester, which met the ASME requirements for amplifier and attenuator linearity and a two channel strip chart recorder. One channel of the recorder was calibrated to reflect the ultrasonic screen height (amplitude) and the second channel was calibrated to reflect the metal path (range) to the reflector. The tester was gated so that the recorder marked any signal that was above 20% of full screen height at scanning sensitivity (+6 db minimum). The strip chart not only provided a permanent record, but a means to evaluate the examination and the results.

The scanning sensitivity was at least two times (+6 db) the calibration reference level. Evaluation was performed at the primary reference sensitivity. It was required that all recorded chart signals be identified and the reporting and evaluation level be 20% and 50% of primary reference, respectively. In addition, any indications suspected of being a crack were recorded for further evaluation, regardless of amplitude or size.

Any indication that was suspected of being a crack was ultrasonically re-evaluated by at least one senior examiner. Radiography was used to assist in the evaluation process. Computer enhancement of radiographs were used to better define the indication with respect to its length.

To reduce the overall radiation exposure of exaimination personnel and to keep the examination under the direct control of the most highly trained and experienced examiners available, a remotely controlled tester was added to the test system. This helped to reduce the radiation exposure to the senior personnel and kept their services available for the direct evaluation of critical indications.

This addition of a remotely controlled tester (Slave unit) permitted the examination to be controlled and the results evaluated out of the high radiation area in a more conducive environment. The slave unit contained a CRT display, pulser circuitry, pre-amplifiers and impedance matching circuits. (The slave is a remotely controlled tester, not a repeater oscilloscope, and thus there is no degradation of the high frequency transducer driving pulse due to long connecting cables.) There were no controls on the slave unit subject to adjustment during the performance of an examination. Changes in sensitivity were made at the master where the senior examiner was in an environment free from distractions. Because the system was externally powered from the master, it was not subject to changes in sensitivity due to battery variations. A voice communication system was used to keep the senior examiner at the master unit in contact with the examiner using the slave unit.

Prototypes of this master/slave system had been used and proven in the past ISI examinations. The production units that were used during these examinations became available only this year.

A dual element 45 degree pitch-catch search unit, designed for the specific thickness range being examined, was used in the scanning of these welds for the detection of indications. The search units used in additional evaluation and in sizing of indications were the typical 45 degree pulse echo type.

On October 8, 1982, a team of examiners, test equipment (excluding slave unit), calibration standards and the examination procedure used to perform this inspection were sent from the plant site to Battelle Laboratories in West Jefferson, Ohio. The purpose of the trip was to demonstrate the effectiveness of the detection capability of the ultrasonic methodology used for this inspection program. The demonstration was performed on pipe samples reportedly being from Nine Mile Point Nuclear Generating Plant. Mr. Kevin Ward of the US NRC Region 3 Office, Dr. Gary Dau and Dr. Mohammed Behravesh of EPRI and several other US NRC representatives witnessed this demonstration. Although we have not received any formal notification on the effectiveness of our ultrasonic methodology in detecting service-induced cracks, informally we have received very favorable comments and verbal acceptance.

V. Ultrasonic Flaw Sizing Method

Section XI of the ASME Code, "Rules for Inservice Inspection of Nuclear Power Plant Components", 1977 edition, Summer 1978 Addenda, required that certain information be recorded for each indication in piping that equals or exceeds the reference level. This information included the search unit position, sweep reading, amplitude of the indication at its maximum amplitude point, and the search unit position and sweep reading at reference amplitude points across and along the indication.

This information was to be used in sizing the reflector for acceptance or rejection according to the requirements of paragraphs IWA-3300 and IWB-3514 of the ASME Section XI code. However, the code was not specific on the mechanics of the sizing operation. The method used by LMT was conservatively based on indication limits taken at 50% of reference level (DAC) rather than at the reference level as indicated by the code.

Flaw sizing was based on the location of the transducer, the direct metal path of the ultrasonic beam and the angle of the beam. The location of the transducer was measured in relation to the weld centerline and 12:00 o'clock position. The metal path was read from the digital readout on the tester that had been calibrated to 0.01 inch accuracy for the test and the beam angle was calculated from the response of the notch in the calibration standard.

The calibration of the ultrasonic test included the complete response of the test as the transducer was passed over the calibration notch; i.e., the transducer position and beam angle at which the beam first senses the notch, at maximum response and at which the transducer last senses the notch. The sizing operation then compared this data with the data taken from the unknown indication.

In addition, LMT utilized a computer to aid them in sizing of indications. The computer program accurately tracked the beam paths in the material for a distance of one and one half nodes. The beam path was computed on the basis that the angle of reflection was equal to the angle of incidence and the program compensated for counter bore, external taper, weld crown and mismatch. The program also took into account the curvature of the pipe when computing the shape of axial flaws.

The computer then plotted the size and position of the indication by connecting the end points (50% of reference) of the first ray to show the indication, the ray with the maximum amplitude response, and the last ray to show the indication. These end points (50% of reference) were determined by the measured transducer position, the measured metal path, and beam angles calculated from the standard response.

The computer was then used to express the flaw as a percentage of the wall thickness. This was done by taking the difference of the deepest and shallowest rays and expressing it as a percentage of the wall thickness.

This method provided a more conservative interpretation of the Code. The indication limits at 50% of reference level rather than at the reference level as expressed by the Code will provide larger flaw size values.

Unfortunately, there has not been sufficient work done in evaluating this sizing method or any other method to actual intergranular stress corrosion cracks thru destructive examination of the cracks. Thus we have not been able to obtain the precision of this sizing method for IGSCC.

VI. Conclusions

Conclusions that have been drawn from this inspection for Monticello Plant are as follows:

- The augmented inspection was complete and comprehensive.

- The crack detection capability of the ultrasonic methodology in detecting IGSCC's in the circumferential and axial direction has been adequately demonstrated.

- The ultrasonic methodology used is less than optimum for the detection of radial IGSCC's. Improvements need to be made.

- Augmented ISI on Monticello's 12 inch riser piping is required until replaced.

- Next refueling outage resume normal ISI on large bore stainless steel piping biasing the inspection to welds of high carbon material.

- The ultrasonic Master/Slave system was demonstrated as being effective in maintaining inspection quality and reducing radiation exposure to inspection personnel. (It has been estimated that a total of 52 manRems has been incurred for this inspection. It was estimated that without this system the exposure to inspection personnel would have been doubled.)

TABLE I

MONTICELLO NUCLEAR GENERATING PLANT

1982 ISI RESULTS

SYSTEM	WELD ID	INDICATION DESCRIPTION			
		ORIENTATION	DEPTH	LENGTH	LOCATION
REW 32-22" (MANIFOLD)	RMAJ-2	3-AXIAL	4-11%	1.0" 0.5" 0.5"	12:00-CAP
REW21-12" (RISER)	RRCJ-3	3-RADIAL	>50%	0.41 0.20 0.125	7:30-S.E. 8:00-S.E. 8:30 Pipe(Leak)
		2-CIRC.	3.5%	0.25	ROOT-INCOMPLETE FUSION
REW20-12" (RISER)	RRDJ-5	1-RADIAL	>50%	0.43	3:30-ELBOW
REW19-12" (RISER)	RREJ-3	4-RADIAL	>50%	0.34 0.30 0.28 -	12:00-PIPE 12:00-PIPE 12:00-S.E. 3:00 S.E.(Leak)
		1-CIRC.	9%	1.06	12:00-ROOT
REW14-12" (RISER)	RRFJ-3	2-RADIALS	>50%	0.32	8:00-SE 4:00-SE (Leak)

TABLE II

MONTICELLO NUCLEAR GENERATING PLANT

1982 AUGMENTED ISI EXAM PROGRAM

SYSTEMS				NUMBER OF WELDS EXAM.
A.	REACTOR RECIRCULATION SYSTEM *			
	28" -	LOOP A (1.088" min. wall, 304SS)		16
		LOOP B (1.088" min. wall, 304SS)		17
	22"	MANIFOLD (0.924" min. wall, 304SS)		23
	12"	RECIRCULATION RISER (Sch. 80,304SS) (INCLUDING SAFE END WELDS)		50
	4"	BYPASS (XXH, 304SS)		8
B.	REACTOR WATER CLEAN-UP SYSTEM (4" Diameter, Sch. 80, 304SS)			3
C.	RESIDUAL HEAT REMOVAL			
	TW20-18" / 16"	2/5	(Sch. 80, 316SS)	7
	TW30-18" / 16"	2/5	(Sch. 80, 316SS)	7
	REW10-18"	4	(Sch. 80, 316SS)	4
				135

Notes:

* - All nonconforming welds in the recirculation and attached systems were inspected as well as many conforming welds. Welds in the recirculation system that were not inspected consisted of ten welds in the 4" Loop A Bypass Line and ten welds in the 4" Loop B Bypass Line.

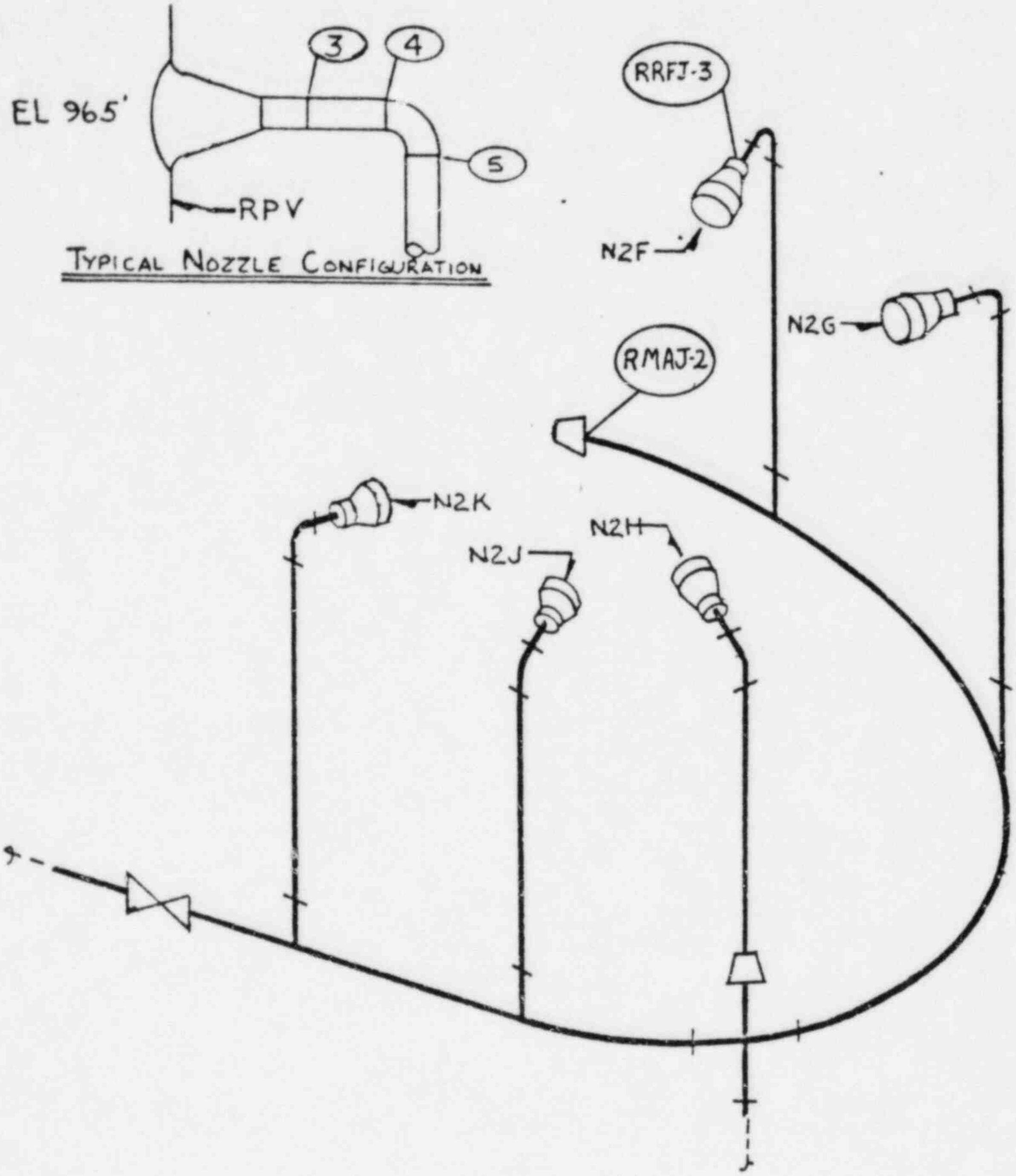


FIGURE 1A

RECIRCULATION MANIFOLD "A"

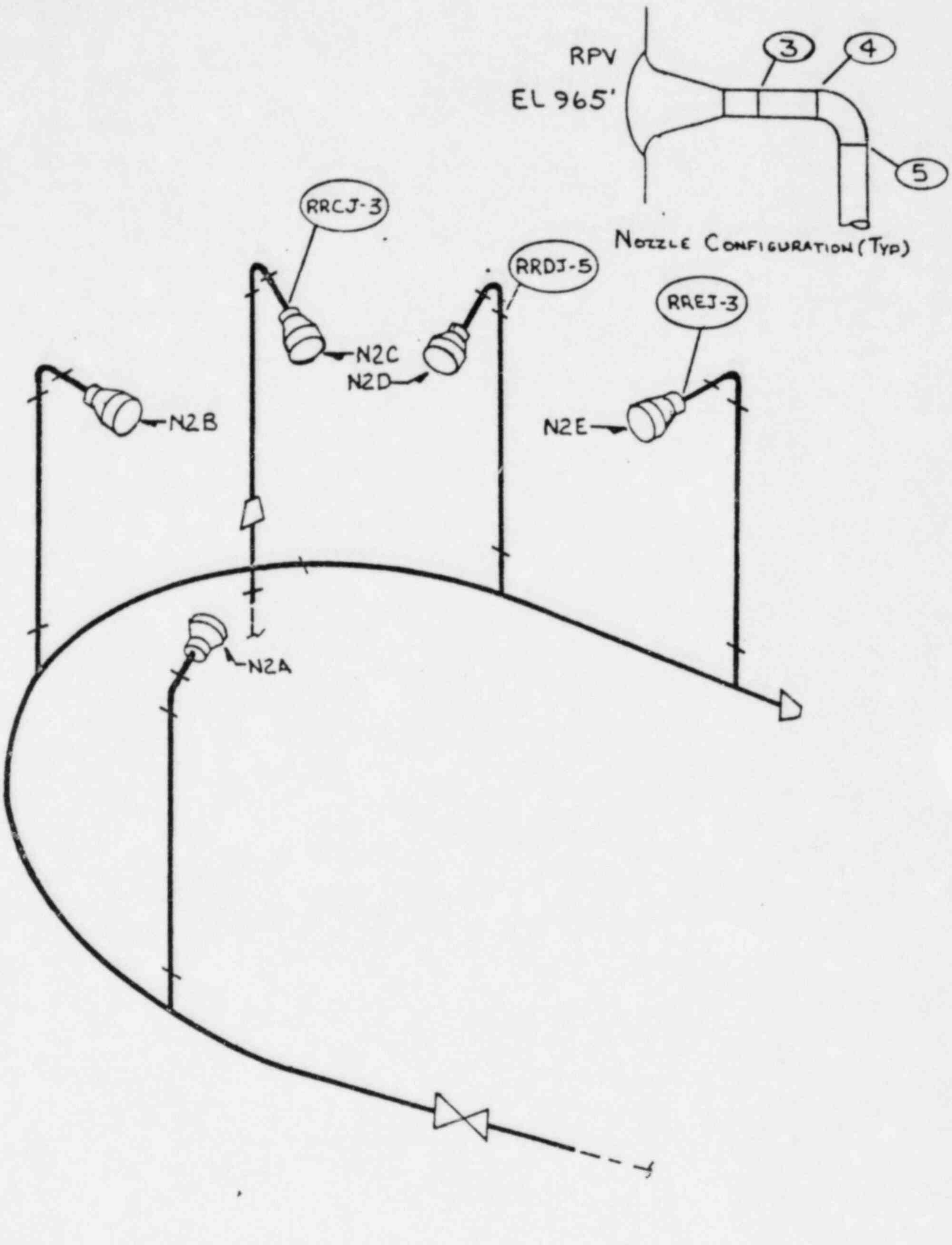


FIGURE 1B

RECIRCULATION MANIFOLD "B"

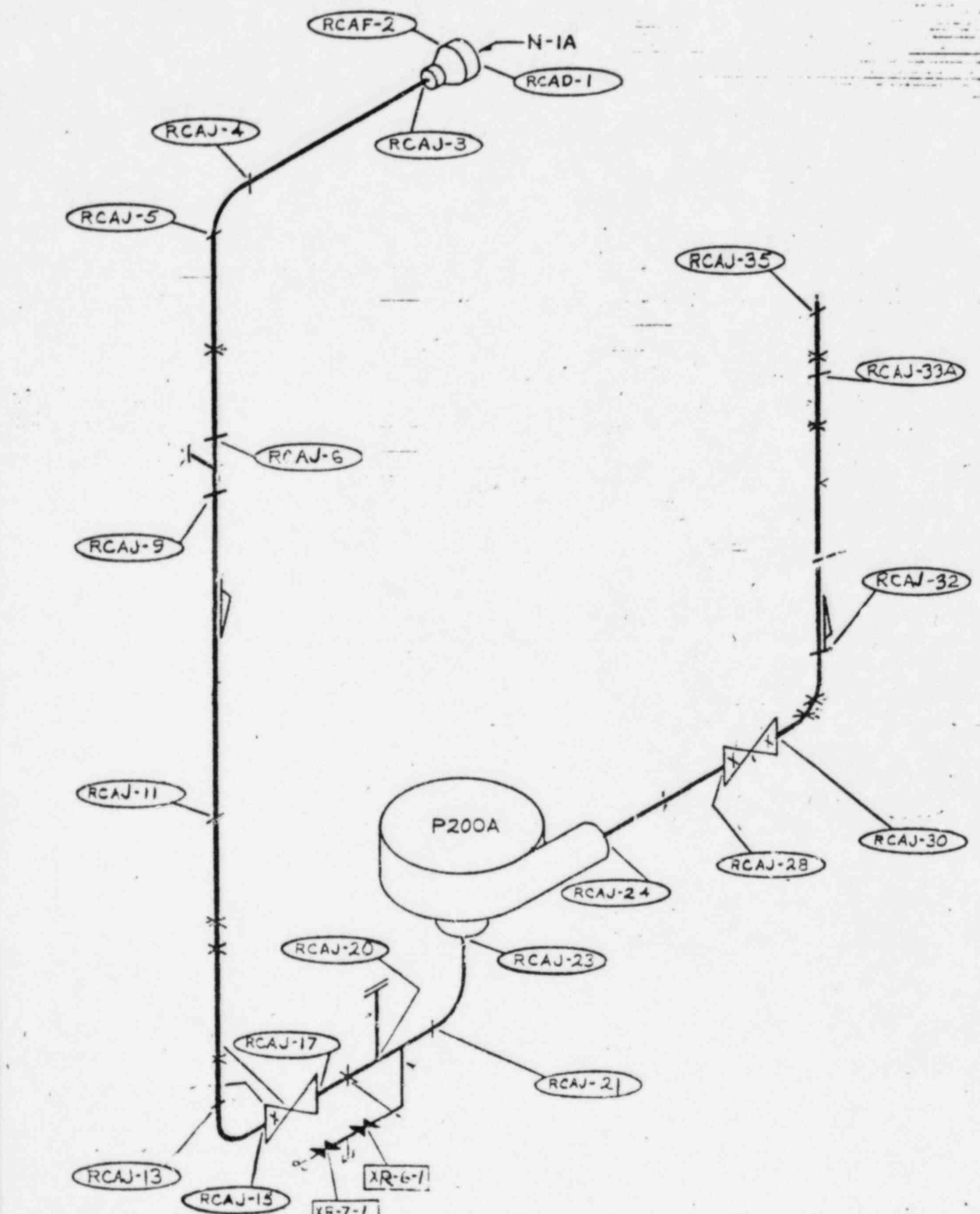
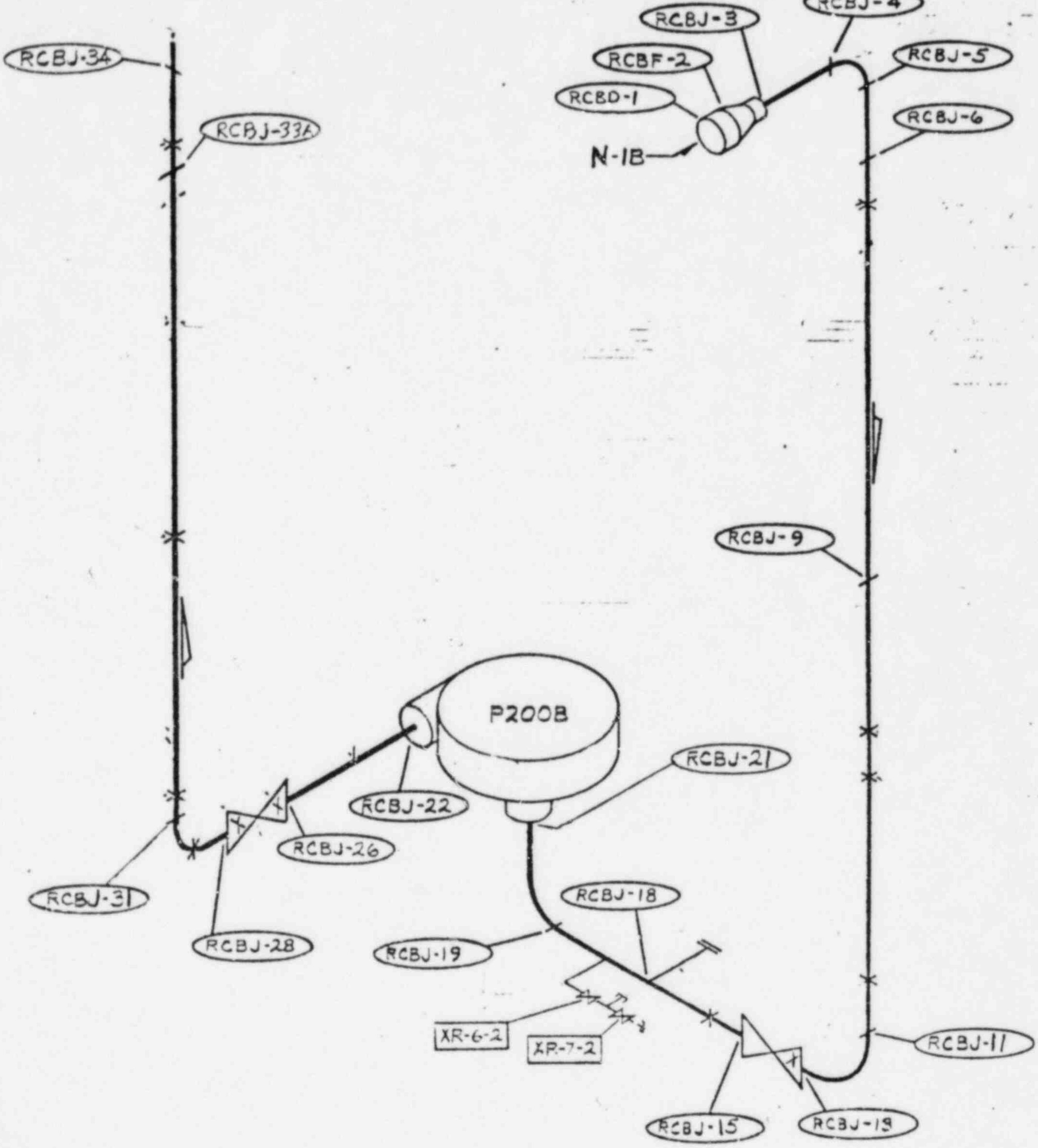


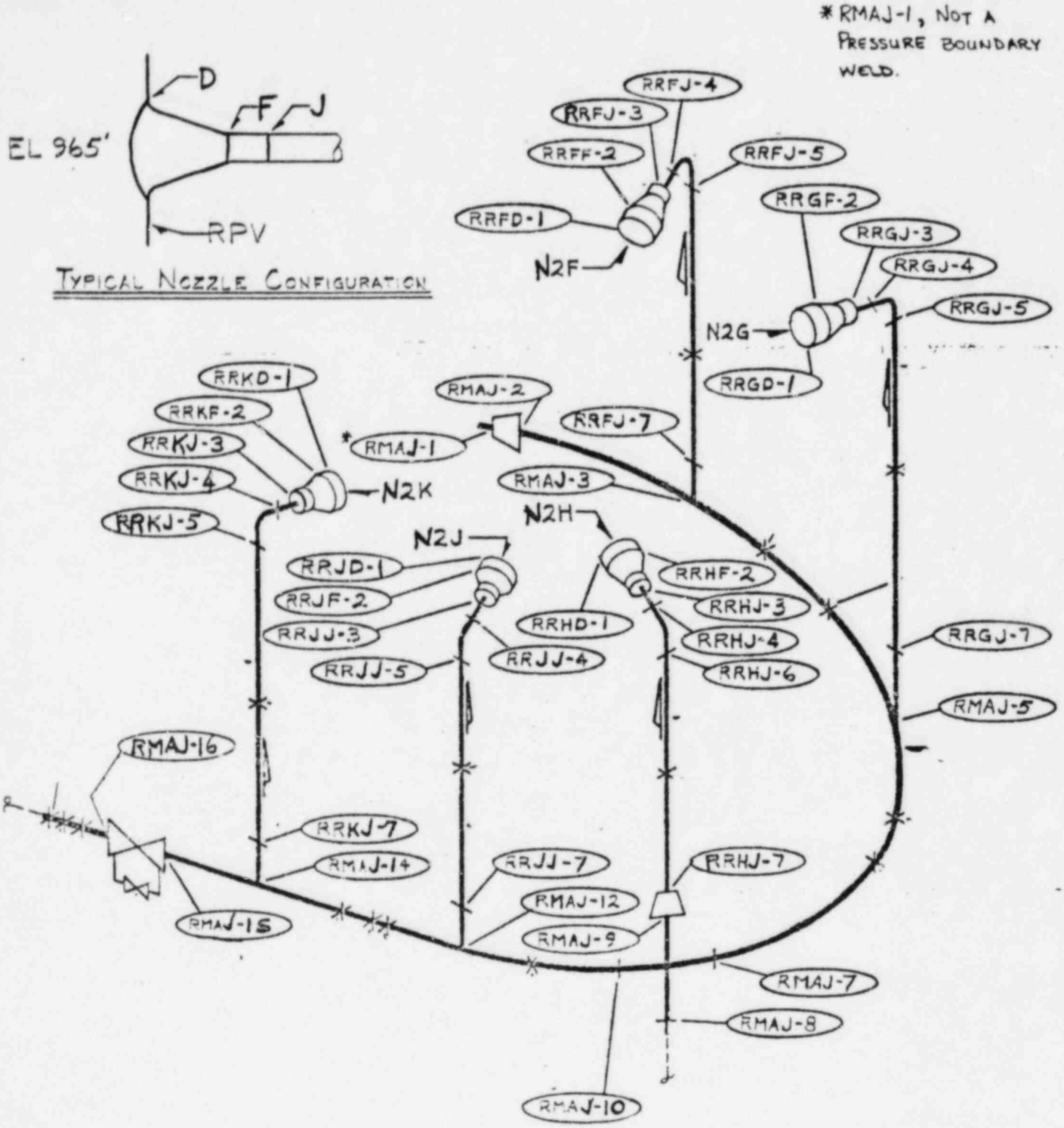
FIGURE 2

RECIRCULATION "A" (REW13A-28")



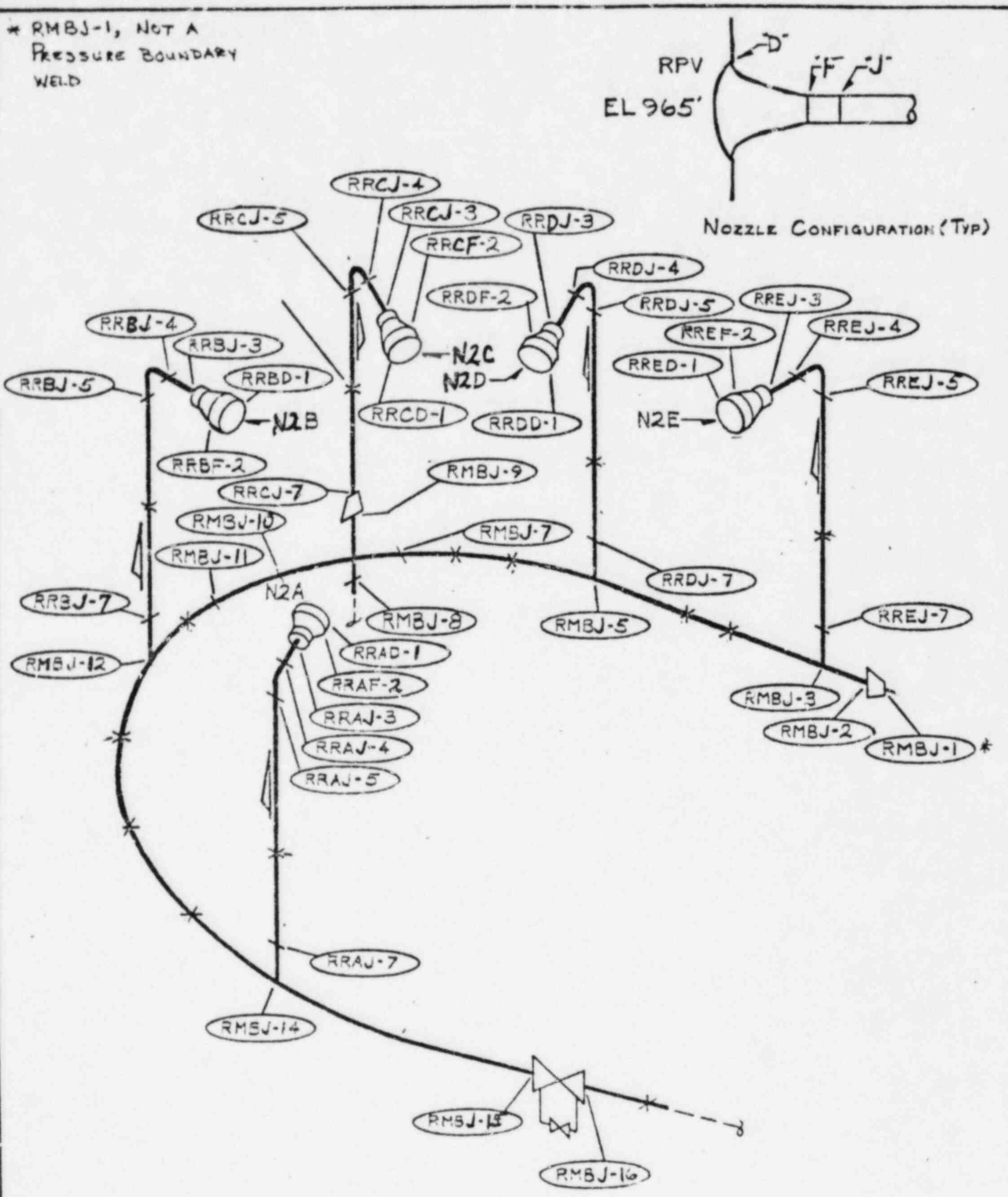
RECIRCULATION "B" (REW13B-28")

FIGURE 3



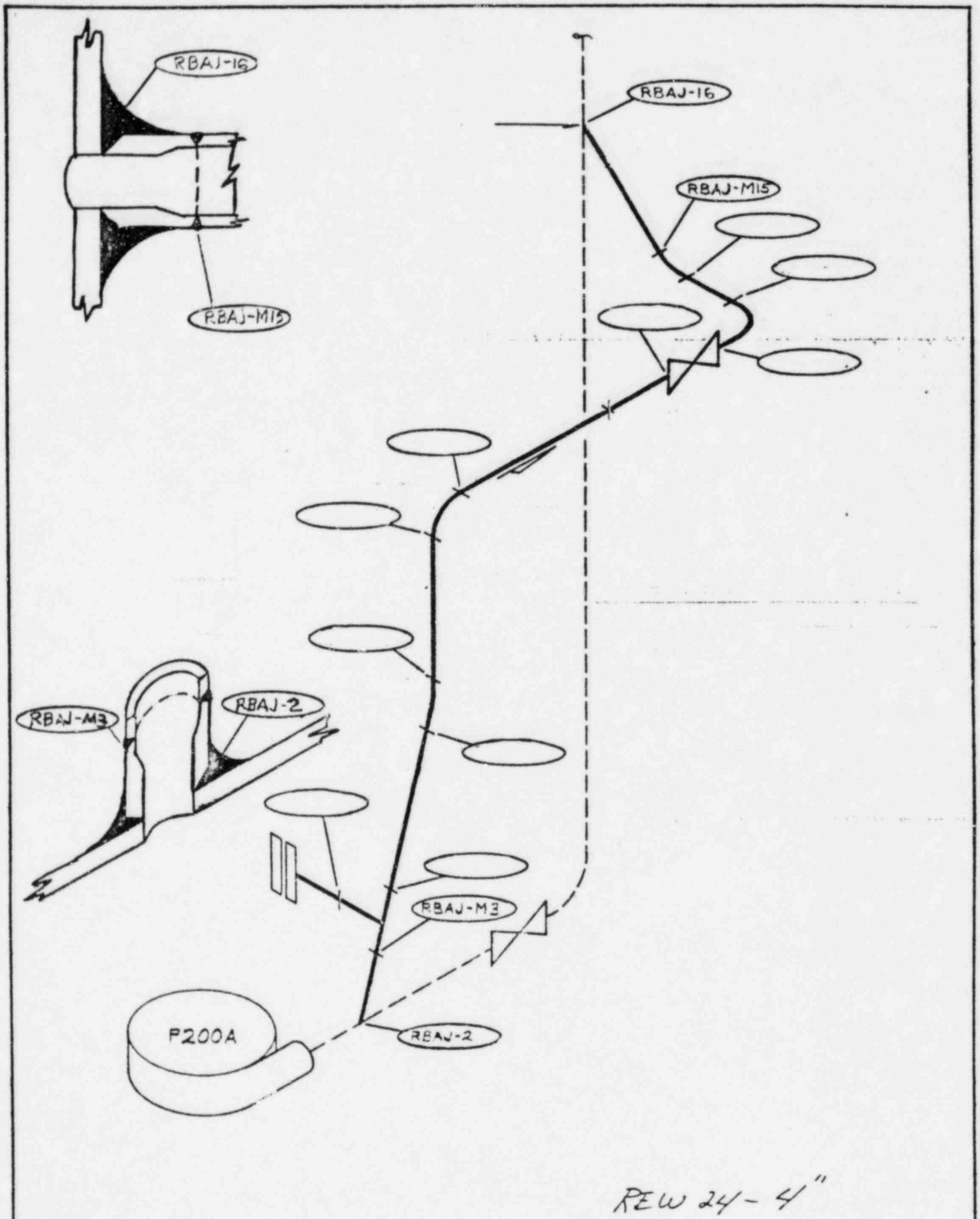
RECIRCULATION MANIFOLD A

FIGURE 4



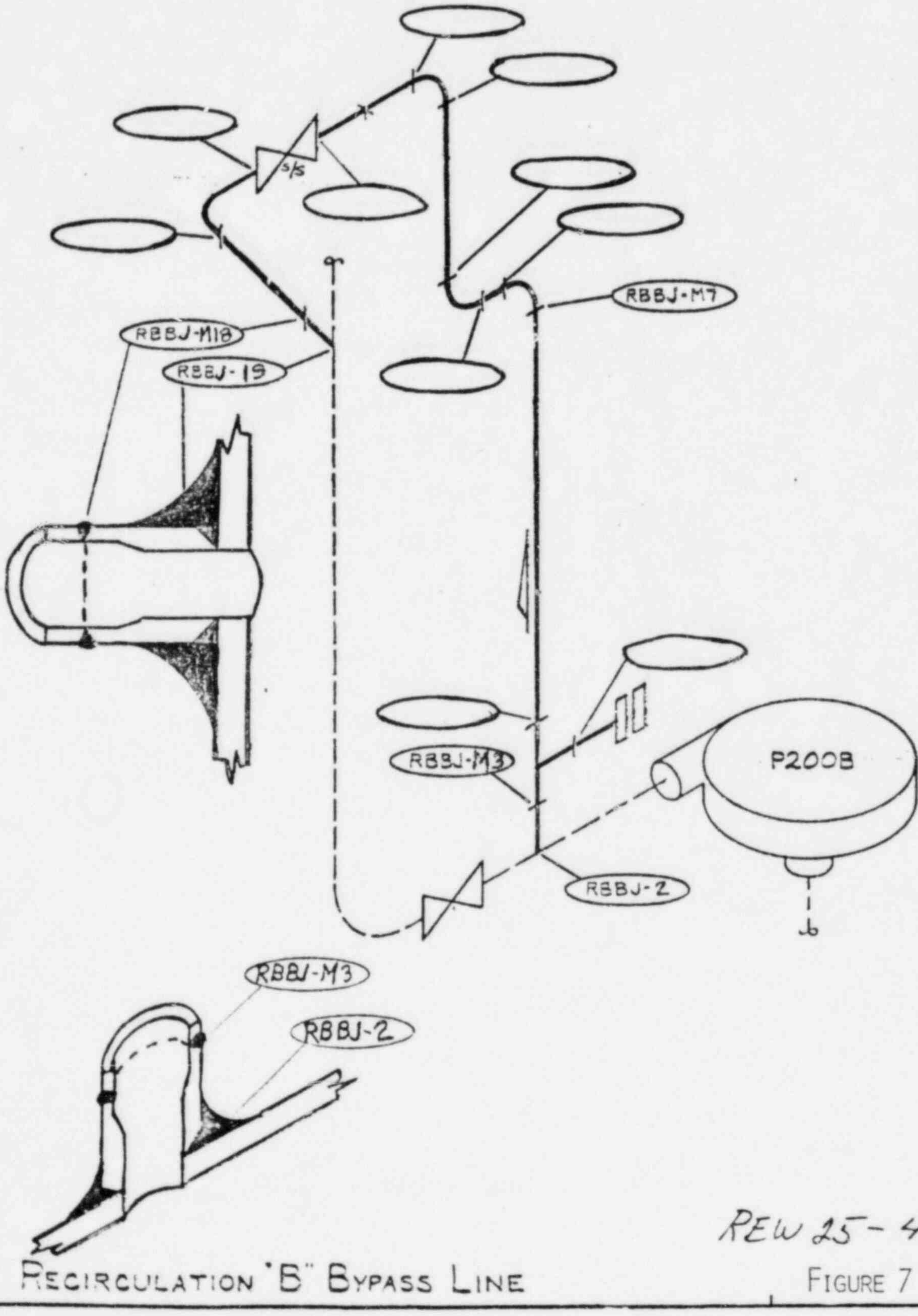
RECIRCULATION MANIFOLD "B"

FIGURE 5

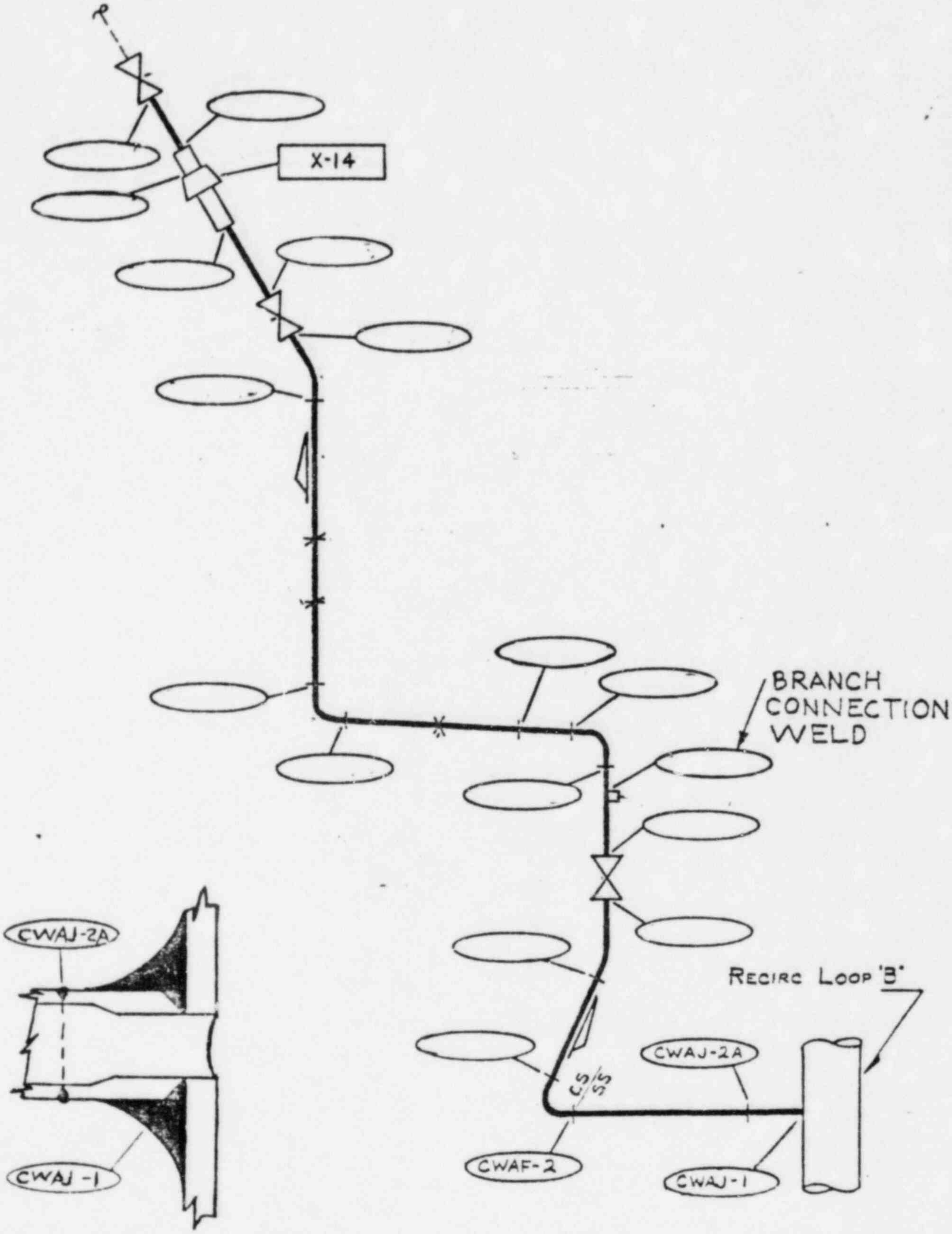


RECIRCULATION "A" BYPASS LINE

FIGURE 6

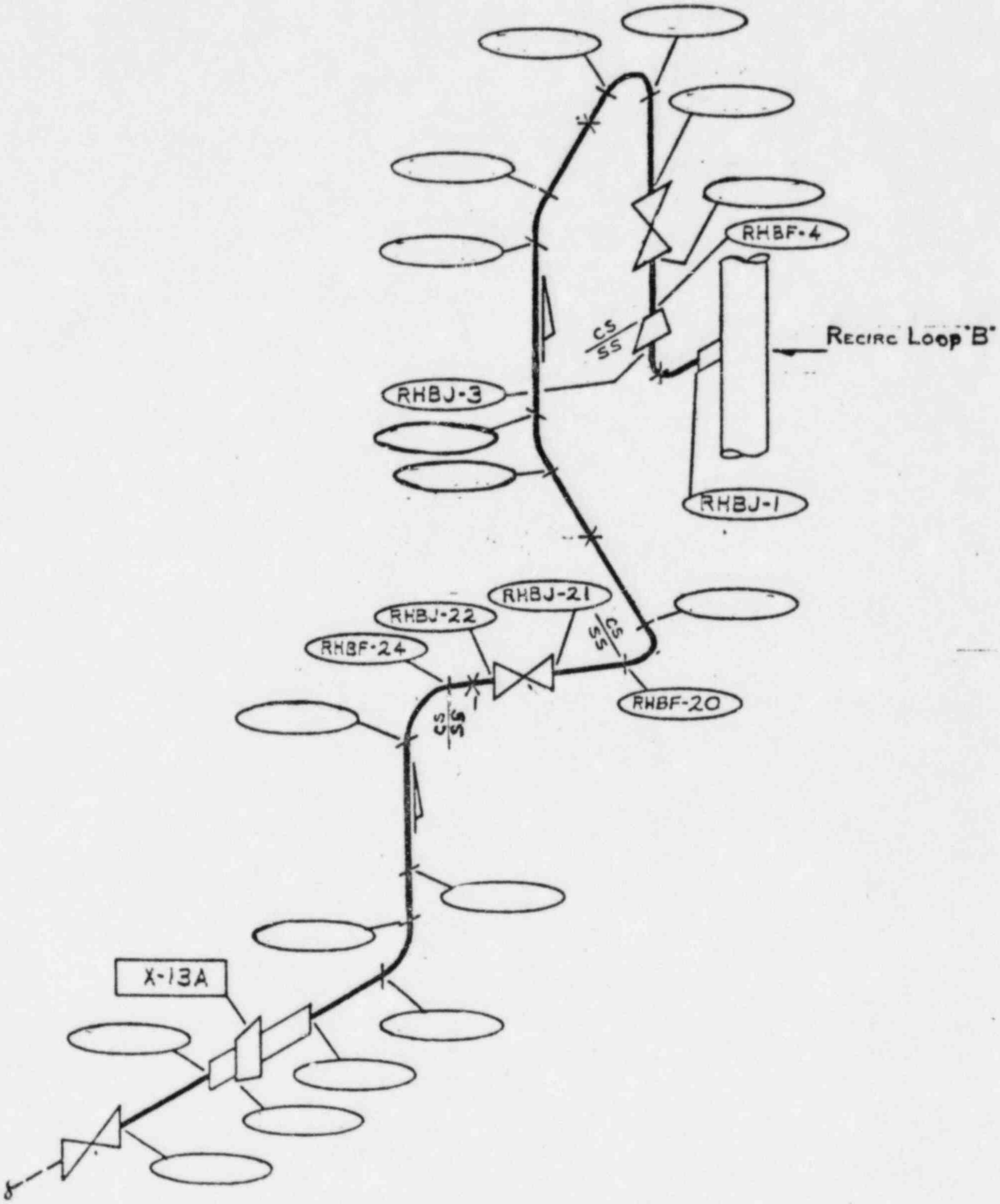


RECIRCULATION "B" BYPASS LINE FIGURE 7



INSULATED
REACTOR WATER CLEANUP

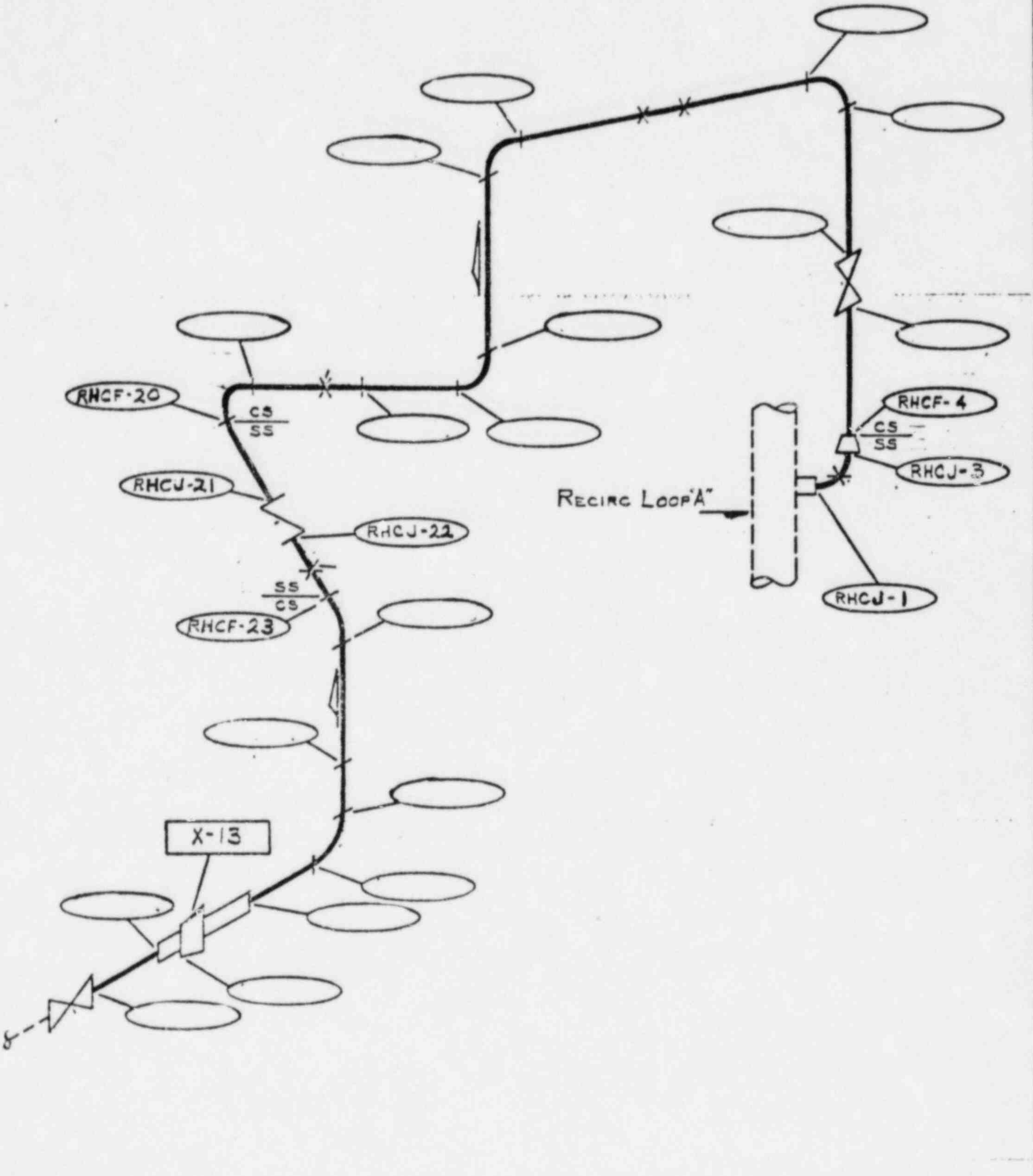
REW3 - 4"
FIGURE 8



TW 20 – 16"/18"

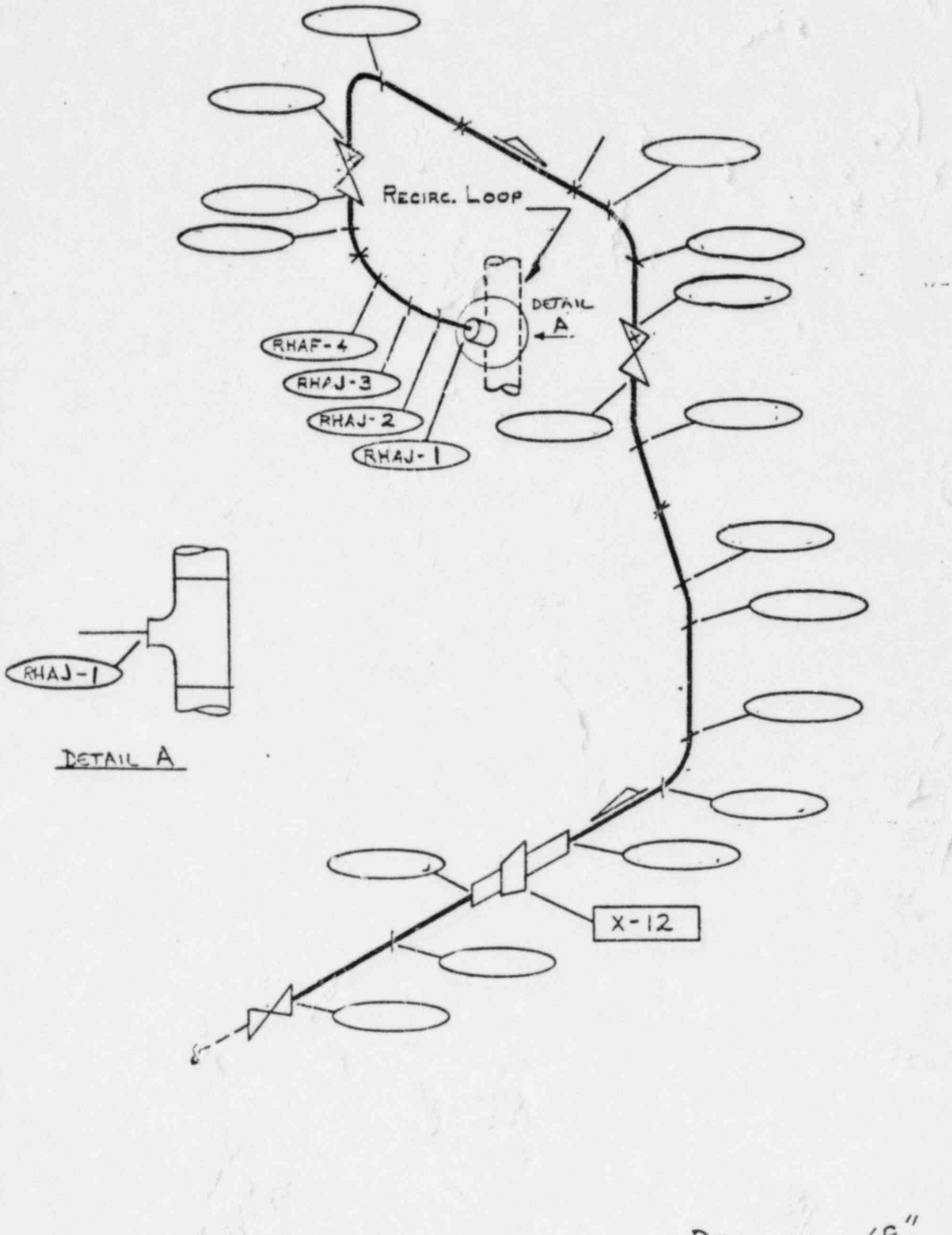
RESIDUAL HEAT REMOVAL

FIGURE 9



RESIDUAL HEAT REMOVAL

FIGURE 10



RESIDUAL HEAT REMOVAL

FIGURE 11

Attachment (2)
Director I&E, NRC
November 22, 1982

MONTICELLO NUCLEAR GENERATING PLANT

Summary Report

of

Weld Overlay Repairs

of

Recirculation System Piping

Prepared by Greg Krause
Materials and Special Processes Engineer

November 19, 1982

I. CONTENTS

II. INTRODUCTION

Weld overlay repairs of recirculation system piping were performed at Monticello during the Fall 1982 refueling outage. The overlays were designed to repair piping with intergranular stress corrosion cracks adjacent to the following welds:

Weld Number	Location
RMAJ-2	End Cap to Ring Header Weld in "A" Loop
RRCJ-3	Safe-end to Pipe Weld in "B" Loop
RRDJ-5	Elbow to Riser Weld in "B" Loop
RREJ-3	Safe-end to Pipe Weld in "B" Loop
RRFJ-3	Safe-end to Pipe Weld in "A" Loop

Each overlay consists of multiple circumferential passes of weld metal fused together to form a "cast-in-place" pressure boundary. The actual overlay dimensions are shown in the attached Overlay Summary sheets.

The overlays are sized to produce a pressure boundary that meets the piping design requirements. In addition, the welded overlays produce compressive stresses in the pipe which should compress cracks and inhibit crack growth.

III. ADMINISTRATIVE AND PROCESS CONTROLS

The following controls were used to produce sound weld overlay repairs:

- ASME Section XI repair programs.
- NSP approved Quality Assurance programs.
- Authorized Nuclear In-service Inspector review and inspection.

III. (Continued)

- Work control travellers with appropriate sign-offs
- Welding procedures qualified and written per ASME Sections III and IX
- Welders and welding operators qualified per ASME Section IX
- Welders and welding operators trained on mock-ups of the weld area and surrounding interferences
- Measurement of delta ferrite content of the original weld crown, the overlay first layer, and the overlay last layer.
- Ultrasonic verification of water backing
- Measurement of preheat and interpass temperatures
- Monitoring of adherance to welding procedure variables
- Measurement of shrinkage and distortion
- Ultrasonic verification of overlay thickness
- Liquid penetrant inspection per ASME Section XI of all crack seal areas, the final weld overlays, and base metal within one inch of the overlay
- Ultrasonic inspection per ASME Section XI of:
  - overlay/pipe interface bonding
  - overlay soundness
  - pipe and original weld soundness
- Radiographic inspection of the overlay and one inch of adjacent base metal. Methods and acceptance criteria were in accordance with NB-5000 of ASME Section III, except obscuring of the radiograph by the existing thermal sleeve or threads was not cause for rejection.
- For ultrasonic and radiographic inspection, acceptance standards for the original defects were in accordance with the Overlay Design Reports.
- A hydrostatic leak test at 1.1 times the system operating pressure will be performed.

IV. REPAIR SEQUENCE

The repair sequence and welding procedures were designed to produce a sound crack-resistant overlay, compressive stresses in the pipe, and a low degree of sensitization of the pipe.

The general repair sequence was as follows:

1. Qualify welding operators.
2. Train welders and welding operators on mock-ups.
3. Install shielding.
4. Measure ferrite content of original weld crown.
5. Grind and flap to prepare surface of pipe with water inside.

IV. (Continued)

6. If leakage is detected, seal the crack (refer to section VI for crack sealing).

7. Layout pipe for overlay location and shrinkage measurements.

8. Penetrant inspect the overlay area.

9. Ultrasonic thickness measurement of pipe wall .

10. For manual welding, install arc strike shields and welding guide.

11. Verify system prerequisites:

    a) water backing

    b) water flowing

    c) water temperature below 85°F (below 95°F for RMAJ-2)

    d) one core spray system operable

12. Verify qualified welders, welding operators, and filler metal.

13. Weld first layer (refer to section V for welding procedure).

14. Measure ferrite content of first layer.

15. Weld remaining layers.

16. Measure ferrite content of last layer.

17. Grind as necessary for inspection (little or no grinding necessary on automatic welds).

18. Ultrasonic thickness measurement of overlay.

19. Verify overlay dimensions.

20. Obtain shrinkage and distortion measurements.

21. Liquid penetrant inspect.

22. Ultrasonic inspect.

23. Drain pipe.

24. Radiographic inspect.

25. Hydrostatic leak test.

26. Remove shielding, clean up area.

V. WELDING PROCEDURE

The welding procedure was designed to produce sound weld metal, a crack resistant overlay, and compressive stresses in the piping.

Type 308L filler metal was used for crack resistance. The delta ferrite content of this filler metal was 8 ferrite number or greater. Small weld beads were deposited on the first two layers of the overlay. This minimized base metal dilution and therefore minimized reduction of ferrite content of the weld metal. Actual ferrite measurements of the overlays exceeded 7 ferrite number. With this ferrite content, weld metal is resistant to intergranular stress corrosion cracking.

The solidification pattern of small beads on the first two layers is resistant to crack growth.

The small beads were welded at low heat inputs with low preheat/interpass temperatures. Welding heat was controlled by limits on bead size, SMAW electrode size, and welding amperage. These controls, combined with flowing water, minimize sensitization of the pipe. This minimized the potential for further intergranular crack growth in the pipe just under the overlay.

The higher heat input passes of the fill layers result in high circumferential compressive residual stresses in the pipe. Water backing increases the tendency to produce compressive residual stresses at the pipe inside surface. These stresses should compress cracks and inhibit crack growth.

VI. CRACK SEALING

Through wall cracks were found on the safe-end side of welds RRCJ-3, RREJ-3 and RRFJ-3. The overlay design does not take credit for strength of the pipe in the crack zone under the overlay. Therefore, the objective of the repair was to seal the crack so that it would not propagate into the overlay during welding; nor cause porosity in the overlay.

The sealing of through wall cracks included the following steps:

1. Install jet pump plugs and drain the line.
2. Preheat area to 250°F - 300°F for one hour, then allow to cool.
3. Grind into crack to a minimum depth of 3/16 inch below pipe surface.
4. Use SMAW to weld at least two layers and fill the groove above the original pipe surface.
5. Grind the weld flush with the original pipe surface or 1/16 inch maximum above the original pipe surface.
6. Liquid penetrant inspect.
7. If defects are detected, grind and repeat from step 3.
8. When the crack seal areas are accepted, fill pipe with water and return to the repair sequence with GTAW.

VI. (Continued)

During welding of the first layer of the overlays at RRDJ-5, RREJ-3 and RRFJ-3, small blowholes were formed in the overlays in the crack seal areas. (Note: RRDJ-5 did not have a through wall crack, but a blowhole formed over the crack location indicated on the radiograph.)

The small blowholes were removed by grinding back into the pipe. Linear crack indications were visible at the bottom of these ground areas on RREJ-3 and RRDJ-5. However, no weeping was observed at RREJ-3 and RRFJ-3. These areas were welded with water backing starting from Step 3 above. Attempts to weld RRDJ-5 with water backing resulted in grinding to a depth of 3/8 inch, at which point weeping occurred. This area was then welded from Step 1 above.

All crack seals were acceptable by liquid penetrant inspection after grinding to within 1/16 inch or less of the pipe surface.

The overlays were then continued with gas tungsten arc welding. This process penetrates at least 1/16 inch below the pipe surface. Blowholes will form when welds penetrate into cracks or porosity. The fact that sound gas tungsten arc welds were made over the inspected crack seal surfaces provides added assurance that the overlays are sound.

When the welding included overlay weld metal, the repaired overlay surface was also acceptable by liquid penetrant inspection.

VII. CONCLUSION

Weld overlays and crack seals have been welded to meet the overlay repair program and design requirements. This conclusion is further assured by acceptable results of visual, liquid penetrant, ultrasonic, and radiographic inspection. The hydrostatic leak test will provide additional assurance.

OVERLAY SUMMARY

WELD NUMBER: RMAJ-2 OVERLAY PROCESS: Manual SMAW

NUMBER OF LAYERS: 6 FILLER METAL: E308L-16

AVERAGE FERRITE NUMBER

ORIGINAL WELD: 10.7 FIRST LAYER: 11.0 LAST LAYER: 11.5

AVERAGE HEAT INPUT (KJ/IN)

FIRST LAYER: 23 SECOND LAYER: 43 FILL: 75 COVER: 83

MAXIMUM PREHEAT AND INTERPASS TEMPERATURE (°F)

FIRST TWO LAYERS: 125 REMAINING LAYERS: 170

OVERLAY DIMENSIONS

WIDTH AT BASE: 6 1/ 4" TO 6 3/4" TAPER ANGLE (PIPE SIDE) AT TOE: <45°

WIDTH AT TOP: 5" TO 5 5/8" TAPER ANGLE (OTHER SIDE) AT TOE: <45°

THICKNESS: 0.50" TO 0.69"

MAXIMUM SHRINKAGE (INCH) AXIAL: 3/32" RADIAL: 1/8"

CRACK SEAL: None

INSPECTION

LIQUID PENETRANT: Acceptable

ULTRASONIC: Acceptable

RADIOGRAPHIC: Acceptable

HYDROSTATIC LEAK TEST: Later

OVERLAY SUMMARY

WELD NUMBER: RRCJ-3 OVERLAY PROCESS: Automatic GTAW

NUMBER OF LAYERS: 10 FILLER METAL: ER308L

AVERAGE FERRITE NUMBER

ORIGINAL WELD: 4.4 FIRST LAYER: 7.2 LAST LAYER: 11.4

AVERAGE HEAT INPUT (KJ/IN)

FIRST LAYER: 20 SECOND LAYER: 24 FILL: 33 COVER: 20

MAXIMUM PREHEAT AND INTERPASS TEMPERATURE (°F)

FIRST TWO LAYERS: 119 REMAINING LAYERS: 160

OVERLAY DIMENSIONS

WIDTH AT BASE: 10 3/4" TO N/A TAPER ANGLE (PIPE SIDE): 28° AT TOE

WIDTH AT TOP: 6 3/4" TO N/A TAPER ANGLE (OTHER SIDE): 27 to 40° AT TOE

THICKNESS: 0.74" TO 0.78" Taper angles approved by Engineering Design Change

MAXIMUM SHRINKAGE (INCH) AXIAL: 7/16" RADIAL: 3/16"

CRACK SEAL: Drained, preheated, ground, and welded at 8:30 azimuth on safe end.

INSPECTION

LIQUID PENETRANT: Crack seal and overlay acceptable

ULTRASONIC: Acceptable

RADIOGRAPHIC: Acceptable

HYDROSTATIC LEAK TEST: Later

OVERLAY SUMMARY

WELD NUMBER: RRDJ-5 OVERLAY PROCESS: Automatic GTAW

NUMBER OF LAYERS: 7 FILLER METAL: ER308L

AVERAGE FERRITE NUMBER

ORIGINAL WELD: 7.8 FIRST LAYER: 9.6 LAST LAYER: 12.5

AVERAGE HEAT INPUT (KJ/IN)

FIRST LAYER: 19.0 SECOND LAYER: 19.0 FILL: 31.2 COVER: 21.6

MAXIMUM PREHEAT AND INTERPASS TEMPERATURE (°F)

FIRST TWO LAYERS: 90 REMAINING LAYERS: 106

OVERLAY DIMENSIONS

WIDTH AT BASE: 6" TO N/A TAPER ANGLE (PIPE SIDE): 17° AT TOE

WIDTH AT TOP: 9" TO N/A TAPER ANGLE (OTHER SIDE): 18° AT TOE

THICKNESS: 0.58" TO 0.70"

MAXIMUM SHRINKAGE (INCH) AXIAL: 3/8" RADIAL: 5/16"

CRACK SEAL: After third layer of overlay, ground and welded twice to repair blowhole at 3:30 azimuth on elbow. Weeper when ground 3/8 inch into elbow on third attempt. Drained, preheated, ground, and welded.

INSPECTION

LIQUID PENETRANT: Crack seal and overlay acceptable

ULTRASONIC: Acceptable

RADIOGRAPHIC: Acceptable

HYDROSTATIC LEAK TEST: Later

OVERLAY SUMMARY

WELD NUMBER: RREJ-3 OVERLAY PROCESS: Automatic GTAW

NUMBER OF LAYERS: 10 FILLER METAL: ER308L

AVERAGE FERRITE NUMBER

ORIGINAL WELD: 8.4 FIRST LAYER: 7.1 LAST LAYER: 10.6

AVERAGE HEAT INPUT (KJ/IN)

FIRST LAYER: 20 SECOND LAYER: 24 FILL: 33 COVER: 20

MAXIMUM PREHEAT AND INTERPASS TEMPERATURE (°F)

FIRST TWO LAYERS: 120 REMAINING LAYERS: 130

OVERLAY DIMENSIONS

WIDTH AT BASE: 11 1/8" TO 11 5/16" TAPER ANGLE (PIPE SIDE): 21° AT TOE

WIDTH AT TOP: 6" TO 6 ¼" TAPER ANGLE (OTHER SIDE): 27° AT TOE

THICKNESS: 0.59" TO 0.69" Taper angle approved by Engineering Design Change

MAXIMUM SHRINKAGE (INCH) AXIAL: 17/32" RADIAL: 3/16"

CRACK SEAL: Drained, preheated, ground, and welded at 2:00 on safe end. After second layer of overlay, ground and welded twice at 3:00 to repair a blowhole. After second layer of overlay repaired, ground 1/16" into overlay and reinspected with liquid penetrant.

INSPECTION

LIQUID PENETRANT: Crack seal and overlay acceptable

ULTRASONIC: Acceptable

RADIOGRAPHIC: Acceptable

HYDROSTATIC LEAK TEST: Later

OVERLAY SUMMARY

WELD NUMBER: RRFJ-3   OVERLAY PROCESS: Automatic GTAW

NUMBER OF LAYERS: 10   FILLER METAL: ER308L

AVERAGE FERRITE NUMBER

ORIGINAL WELD: 3.7   FIRST LAYER: 7.1   LAST LAYER: 11.3

AVERAGE HEAT INPUT (KJ/IN)

FIRST LAYER: 20   SECOND LAYER: 24   FILL: 33   COVER: 20

MAXIMUM PREHEAT AND INTERPASS TEMPERATURE (°F)

FIRST TWO LAYERS: 122   REMAINING LAYERS: 132

OVERLAY DIMENSIONS

WIDTH AT BASE: 10½" TO N/A   TAPER ANGLE (PIPE SIDE): 21° AT TOE

WIDTH AT TOP: 7½" TO N/A   TAPER ANGLE (OTHER SIDE): 23° AT TOE

THICKNESS: 0.73" TO 0.89"   Taper angle approved by Engineering Design Change

MAXIMUM SHRINKAGE (INCH) AXIAL: 13/32"   RADIAL: 1/4"

CRACK SEAL: Drained, preheated, ground, and welded at 4:00 azimuth on safe-end. After second layer of overlay, ground and welded three times at 4:00 to repair a blowhole.

INSPECTION

LIQUID PENETRANT: Crack seal and overlay acceptable

ULTRASONIC: Acceptable

RADIOGRAPHIC: Acceptable

HYDROSTATIC LEAK TEST: Later

ALARA Considerations and Occupational Radiation Exposure - 1983 Outage Recirculation System Inspection and Repair

ALARA measures taken during the 1983 outage to reduce occupation radiation exposures during inspection and repair of recirculation system piping consisted of:

1. Temporary shielding. Extensive use was made of both blanket type and sheet lead shielding.
2. Vessel nozzles were cleaned with a hydro laser from the reactor side to remove hot spots. A factor of five to ten reduction in local radiation levels near the vessel safe ends was achieved.
3. A mockup of the weld repair area was used.
4. Inspection and repair personnel were experienced personnel thoroughly trained in their tasks.
5. Weld repairs on riser piping were made with an automatic welding machine.
6. Closed circuit television was used to observe welding.
7. Access areas to piping was modified to make these areas easier to get to and easier to work in.
8. Use of ultrasonic master/slave inspection system.

Prior to discovery of recirculation system cracking, approximately 10 man-rem was received performing the inservice inspection program scheduled for the 1983 outage. Following discovery of the cracks and going to a 100% inspection plan, 52 man-rem total exposure was received.

The following occupational exposure was received in crack repairs through November 17, 1982. Some additional exposure will be received in additional RT work, insulation work, weld cleaning, and hydrostatic testing. This additional exposure is estimated to total about 10 man-rem.

End Cap Repair	-	25 man-rem	(manual welding)
C Riser	-	16 man-rem	
D Riser	-	15 man-rem	
E Riser	-	28 man-rem	
F Riser	-	23 man-rem	
		107 man-rem	