ABSTRACT

This report contains the results of a special inspection concerning a circumferential thru-wall rupture near the weld prep section of valve MUV-43 in the makeup line of A-1 loop. Preliminary reports attribute the failure to thermally induced cyclic fatigue. The affected valve and related piping has been replaced. Similar areas in the three (3) high pressure injection (HPI) lines have been inspected and no distress/degradation was observed. The thermal characteristics of all the HPI nozzles are being reanalyzed by B&W.

The licensee reported no effect upon the health or safety of the general public.

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1.0 INTRODUCTION

1.1 Purpose and Scope of Inspection

This was a special inspection, conducted during the period of February 2-18, 1982, by RII, Engineering and Technical Inspection Division Staff performed for the following purposes:

a. To establish a factual recounting of significant events surrounding the Crystal River-3 make-up line valve body rupture.

b. To evaluate the licensee's performance with respect to component failure analysis, engineering evaluation and corrective actions taken to preclude recurrence of this event.

This work effort involved 67 inspector-hours onsite. The inspection focused in the areas of work observation, technical interviews/discussions with licensee and vendor personnel and, review of failure analysis results, nondestructive examinations, procedures and QA/QC records. Of the four areas inspected one violation of NRC requirements was identified (Failure to Retrieve Construction Radiographs - paragraph 3.3).

1.2 NRC Inspection Personnel

	INSPECTION DATES
A. R. Herdt, Section Chief, Engineering Inspection Branch	02/17-18
N. Economos Metallurgical Engineer	02/2-5, 9-10, 17-18

1.3 Licensee Personnel Contacted

Florida Power Corporation
*T. C. Lutkehaus, Nuclear Plant Manager
*Q. B. Dubois, Assistant. Plant Manager
*S. W. Johnson, Nuclear Technical Support Engineer
*J. E. Colby, Assistant Manager, Nuclear Engineer
*J. C. Hicks, Supervisor Material Technology
*L. Tittle, Project Engineer
*G. Boldt, Technical Service Superintendent
*J. Lander, Maintenance Superintendent
*M. Clary, Project Engineer, Stress Analysis
*C. Brown, Nuclear Compliance Supervisor
*I. Bienkowski, ISI Engineer
*F. V. Fusick, Nuclear Engineer
S. Primo, ISI Pumps and Valves Specialist
I. Orlosky, Level II RT Examiner

1.4 Other Organizations

A. M.P.R. Associates, Inc. (Consultants)
N.M. Cole, Consulting Engineer

B. Babcock and Wilcox Company
W. Johnson Sr. Welding Engineer, B&W Construction
R. Dankovic, Project Engineer, B&W Construction
J. Buskill, Welding Engineer, B&W Construction
R. Nelson Sr. QA Engineer, B&W Construction
K. E. Moore, Metallurgical Engineer NPGD
G. Navratil, NDE Examiner NPGD

NRC Resident Inspectors
*T. Stetka
*B. Smith

*Attended Exit Interview

2.0 SUMMARY OF NRC FOLLOWUP ISSUES

2.1 Violations of Regulatory Requirements

Construction radiographs of make-up system welds MV-429,-437 and -456 could not be retrieved. Section 1.7.6.7.1q of the FSAR requires records to be identifiable and retrievable (82-03-01). See Section 3.3.

2.2 Unresolved Items (UI)

a. Control of Welding Consumables

Record review, discussions with craft and cognizant licensee personnel disclosed that existing measures do not provide sufficient guidance to assure accountability of welding material issued and returned (82-03-02). See Section 3.4.

b. Rejectable Weld Defects in Weld MV-456

The licensee is reviewing archives in order to explain why rejectable, lack of penetration (LOP), indications documented on radiograph reader sheet of weld MV-456 as acceptable. Objective evidence to show the weld was repaired could not be located, (82-03-03). See Section 3.3.

2.3 Inspector Followup Items

a. Safety Related Systems Design Interface

Code design interface between USAS B31.1 and USAS B3.7 pipe systems must be evaluated to determine if they meet plant design conditions (82-03-04). See Section 3.5.

b. Cracked Vent Pipe Weld in RCP-A Seal Package

A pressure boundary leak that was attributed to a crack in a vent pipe weld-joint on the third stage RCP-A seal package cavity is being investigated to determine cause of failure mechanism (82-03-05). See Section 4.0.

3.0 MAKEUP/HPI LINE FAILURE

3.1 Description of Failure

On February 2, 1982 the inspector arrived on-site to investigate a nonisolatable pressure boundary leak related to the check valve next to the HPI nozzle on the cold leg of RC Loop A. The valve is used for normal makeup and was identified as MUV-43. Discussions with the licensee representative disclosed the crack was located on the downstream side of the valve at or near the fusion line of the safe-end to valve weld (see figure 1). The crack extended over 180° of the circumference.

3.2 Investigation and Findings

The failed section was removed and sent to Battelle, Columbus Laboratories for failure analysis. Preliminary results of the investigation as reported by the licensee disclosed that the affected material showed evidence of two crack initiation sites associated with the failure. One

point of initiation was a machine tool mark inside the valve body near the weld prep area and the other on the OD at/or near the fusion line in the toe of the weld, see Figure 2. The OD crack propagated towards the center of the valve wall and away from the center of the weld at an angular direction of about 45° but at a slightly different plane direction from the ID crack. Both linked-up somewhere at midpoint which produced the thru wall crack, see Figure 3. The mode of failure was identified as thermal cycle fatigue. There were numerous longitudinal cracks on the inside surfaces of the valve and in the weld which were not associated with any specific stress risers. Most of these cracks had the appearance of "heat checks" and propagated to approximately 20-25% of wall thickness, see Figure 6. Propagation of both ID and OD cracks in the valve body probably occurred by combined mechanical and thermal loading of the system. Scanning Electron Microscope (SEM) fractography showed the presence of river markings and crack arrest markings (striations), characteristic of fatigue, at the root of both the OD and ID circumferential cracks, see Figure 4. Thumbnail markings were reported seen on the OD crack. Metallography showed that the cracks were transgranular with very little branching which further supports the fatigue mechanism. There was no evidence of chemical attack on the valve body or safe-end.

3.3 Chemical Analyses

Table 1 presents the results of various chemical analyses. The valve base material and valve-to-safe end weld material were confirmed to be within specification tolerance levels for all elements except molybdenum which is slightly below the specification limit of 2.0 percent.

TABLE 1. RESULTS OF CHEMICAL ANALYSES

Location	Element								
	C	Mn	P	S	Si	Cr	Ni	Mo	Fe
Valve Body	0.073	1.8	*	*	0.6	17.4	13.4	1.95	Bal
Reqt. [ASTM A182][1]	0.08	2.0	0.04	0.03	1.0	16-18	10-14	2-3	Bal
Heat Cert. (49292)	0.07	1.50	0.019	0.024	0.74	16.70	12.85	2.40	Bal
Weld Metal	0.039	1.8	*	*	0.3	18.4	13.2	1.85	Bal
Reqt. [ER 316][1] [2]	0.08	1-2.5	0.03	0.03	0.3-.65	18-20	11-14	2-3	Bal
Heat Cert.	-	-	Not Available			-	-	-	-

[1]Value quoted for the specification requirement is a maximum unless a range is specified.
[2]ER 316 requires a maximum of 0.5 Cu X-ray fluorescence analysis for Cu was not performed.
*Insufficient material available for analysis by X-ray fluorescence.

3.4 Nondestructive Examinations

Because of this event, the licensee performed extensive nondestructive examinations (NDE) surface and volumetric on welds of the affected HPI line, used for normal makeup and the remaining three HPI lines. Ultrasonic inspection was performed using an ISI, ASME Section XI procedure. Instrument calibration was performed on a regular ISI block and the cracked safe-end. The safe-end was used to qualify the procedure and/or verify its ability to detect cracks in the material such as those shown in figure 5. Scanning sensitivity was adjusted to ≥ calibration setting or ~14 db.unless noise problems were encountered. All indications above a 2.1 noise ratio were evaluated. Examination was performed with a 1/4 inch 2.25 MHz transducer. Radiography performed by the licensee on the affected components in the line and, by B&W Lynchburg Research Center on the safe-end failed to detect most known cracks which had been previously identified by surface examination (PT). Results of these examinations appear as Appendix *B* to this report. In addition the inspector requested and the licensee produced archive construction radiographs. A review of these films disclosed the following: (1) for the most part film quality has degraded to the point where it is difficult if not impossible to obtain reliable information relative to weld integrity; (2) the radiograph reader sheet of valve to safe-end weld MUV-456 in the HPI to pump B-1 discharge line, had been signed acceptable with lack of penetration noted for film position 0-1 and 3-0. There was no objective evidence (records) to verify that the weld had been repaired nor were there reshot radiographs to show the weld defects had been repaired. The licensee agreed to look further into this matter and the inspector identified this as unresolved item (302/82-03-03) pending the outcome of the licensee's resolution, "Rejectable Weld Defects in Weld MV-456."

In a similar manner the licensee could not retrieve radiographs for valve to pipe welds MUV-437 and -429 in HPI line A-2. In discussing this problem with the licensee the inspector expressed concern over the apparent loss/misplacement of these radiographs and asked how many other safety related welds exist without the required fabrication records. Moreover the inspector stated that as part of the corrective action appropriate measures would have to be implemented to provide the necessary assurance this matter was not of a generic nature. The inspector stated that failure to retrieve required radiographs and/or supporting NDE documents is contrary to 10 CFR 50, Appendix B Criterion XVII as implemented by FSAR Section 1.7.6.7.1q. which requires that records shall be identifiable and retrievable. This failure to identify and retrieve required radiographs was identified as a violation (302/82-03-01), "Failure to Retrieve Construction Radiographs."

3.5 Repair and Replacement of Affected Components

The as built configuration of the makeup pipe line segment that failed had the check valve (MUV-43) attached on one side to the HPI nozzle safe-end and to the 2½" diameter pipe on the other side. The line segment was essentially in a horizontal position. See Figure 5. A review of design drawings as conducted by the licensee and B&W disclosed that original design assumptions included a pipe extension piece between the valve and the HPI nozzle safe-end which was missing from this and the other three HPI lines. This matter will be discussed later in this report.

The new configuration included the pipe extension in accordance with design calculations. The new configuration appears as shown in Figure 7. Also the licensee disclosed that the upstream end of the new thermal sleeve will be hard rolled to fit the contour inside the safe-end and contact rolled on the downstream end inside the nozzle above the restraining button welds as shown in Figure 7. At the time of this inspection, repair activity had progressed to the extent where a short piece of pipe had been welded on each end of the replacement valve. The welds were radiographed and subsequently ultrasonically examined to satisfy applicable code (B31.7/ASME XI) requirements.

Within these areas the inspector reviewed radiographs of the new welds, witnessed ultrasonic examination, reviewed weld procedure qualification, fabrication records, personnel qualification and, quality documents of replacement components and weld consumables.

Within these areas the inspector noted that the fabrication records including rod issue slips showed the amount of material issued but not the amount of material consumed and/or returned. Discussions with the cognizant licensee representative and review of the approved compliance procedure CP-103 "Control of Welding Material" disclosed that the procedure is rather vague in the area of accountability of material returned to the issue station i.e., ... unused consumables shall be returned to the controlled issue station for accountability and identification. The method used to maintain accountability is not defined. A case in point was that the records showed 116 pieces of consumable material was issued for the fabrication of the two 2½" diameter pipe to valve welds on the replacement makeup valve. However, a review of the returned issue slips showed no account of amount material returned. Discussions with cognizant personnel disclosed that some material had been returned but was unaware what had happed to it or whether it was stored somewhere inside the issue station in anticipation of using it to fabricate the remaining welds on this work request.

The inspector stated and the licensee agreed that procedure (CP-103) should be reviewed and revised to include specific guidance on material accountability and thereby provide written instruction to assure that when implemented, material accountability will be maintained at all times. This item was identified as unresolved item (302/82-03-02), "Welding Consumables Accountability".

3.6 Safety Related System Design Interface

The licensee's review and evaluation of the HPI/makeup line failure, included a review of design assumptions, stress calculation and a comparison between design and as built pipe configurations in the affected system. B&W performed the stress analysis on the primary system up to the affected check valve which is the design code (USASB31.7/USASB31.1) interface boundary. Gilbert Associates, Inc. (Gilbert), is the Architect Engineer (A-E) and provided balance of plant design calculations. The aforementioned review disclosed that one of the assumptions in B&W's design calculations included a four inch (4") pipe extension piece attached to the safe-end on each of the four HPI nozzles. However the licensee's review of as built conditions disclosed that the Gilbert drawings did not show the pipe extension piece on the upstream of the safe-end as required, this was documented as nonconforming operating report: NCOR-82-47. Region II requested and the licensee agreed to review and evaluate similar code design interface involving safety related systems and determine whether design conditions and operating assumptions have been violated. Since this finding, the licensee performed and completed the review/evaluation effort. Results showed that nine out of 20 systems reviewed, the as-built or operating characteristics of the as-built configuration differed in some manner from the original design assumptions. The licensee stated, however, that these differences have been evaluated and found to be not safety significant with the exception of the differences noted in the cracked HPI/makeup line. The inspector stated that this matter would be identified as a followup item (302/82-03-04) until Region II staff has had an opportunity to review the licensee's evaluations and related drawings, "Safety Related System Design Interface."

4.0 Reactor Coolant Pump-A Seal Package Weld Leak

On January 29, 1982 the licensee reported identifying a leak of less than 1 gpm emanating from a small crack in the weld between the third stage cavity and a 3/4" vent pipe in the reactor coolant pump (RCP) - A seal package; this event was identified as NCOR-82-25. At the time of this inspection, the licensee had removed the seal package and performed a surface examination (liquid penetrant test (PT) to better define the extent of the crack. The PT test results showed the crack was located in the fusion line of the weld. Discussions with the licensee disclosed that the weld failure would be investigated to determine the cause of failure. This item was identified as inspector followup item (302/82-03-05), "Cause of Seal Package Weld Failure."

5.0 EXIT INTERVIEW

Exit interviews were conducted to inform the licensee of preliminary findings at the conclusion of each segment of this inspection. These meetings were conducted at the Crystal River-3 site on February 5, 10 and 18, 1982 with individuals shown in Section 1.3. The licensee acknowledged the findings and stated that reviews/corrective actions were underway for most of the items.

6.0 SUMMARY OF CONCLUSION

Results of the metallurgical investigation indicate the crack initiated inside the casing of valve MUV-43, by thermal fatigue and probably propagated by combined mechanical and thermal loading. Crack initiation on the valve's outer surface was at/or near the fusion line of the valve to safe-end weld. The presence of a notch at this interface probably acted as a stress riser and the site of crack initiation. Propagation probably occurred by mechanical loading of the system. The crack path was transgranular in all cases. SEM fractography showed the presence of river markings characteristic of fatigue at the root of both the OD and ID circumferential cracks. There was no evidence of chemical attack.

The root cause of this problem has not been identified at this time. However, investigation of this problem is being persued by B&W licensees.

CRYSTAL RIVER UNIT 3

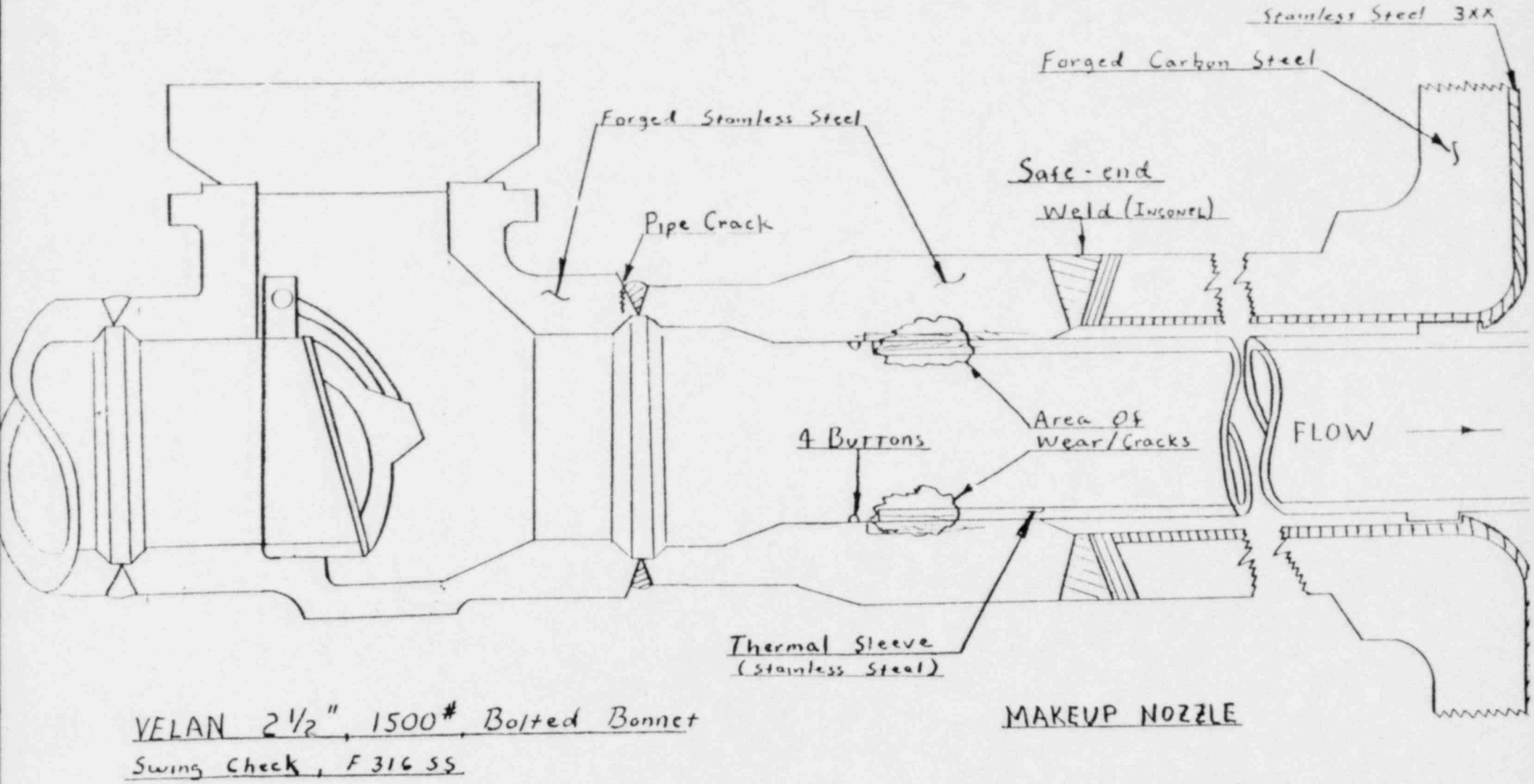

Figure 1.
Schematic showing position of safe-end and thermal sleeve relative to cracked weld. Crack ran 180° from top center to 6 o'clock.

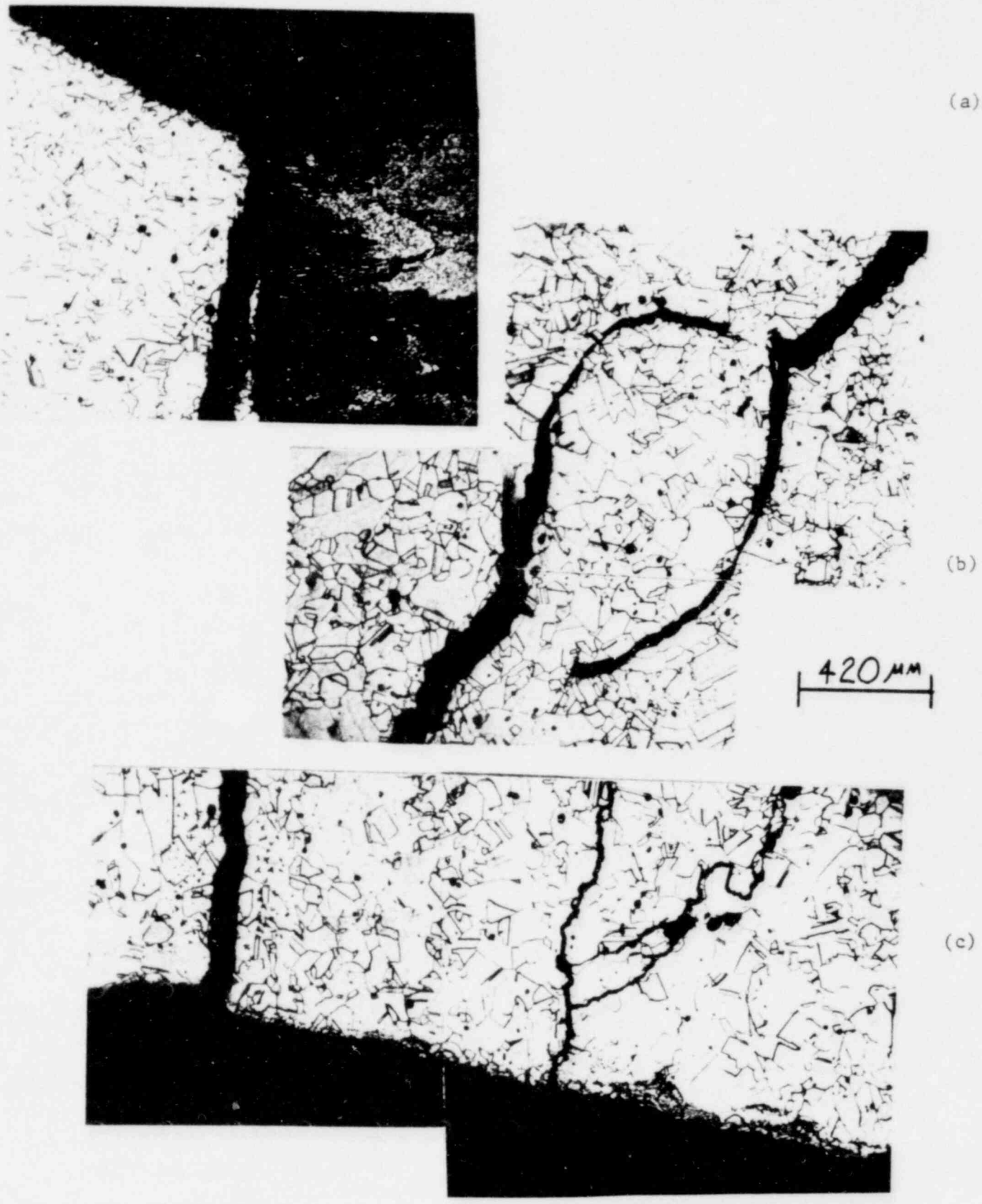

FIGURE 2 PHOTOMICROGRAPHS OF IMPORTANT FEATURES OF THE OD TO ID CIRCUMFERENTIAL CRACK

Note: This figure shows (a) that the OD crack initiated at the discontinuity between the check valve and the safe end-to-check valve weld, (b) that the cracks appear to move away from each other, and (c) that the ID crack initiated at a discontinuity formed by a machine tool. The crack is transgranular

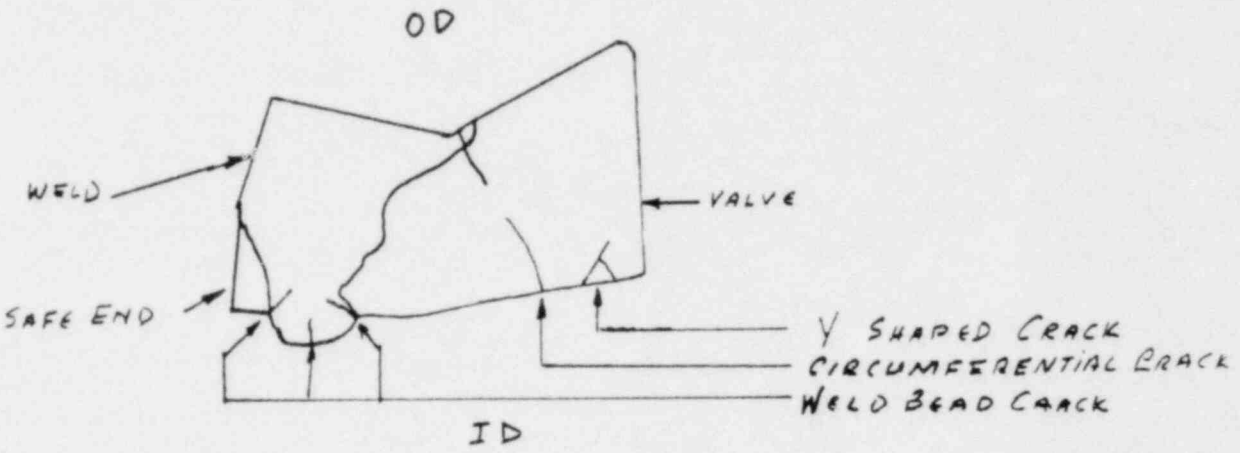

Figure 3.
Schematic depicting approximate location on direction of trough wall crack.

FIGURE 4. SEM PHOTOGRAPH OF THE ID CIRCUMFERENTIAL CRACK FRONT

Note: This photograph shows the river markings and crack arrest markings which are evidence of fatigue.

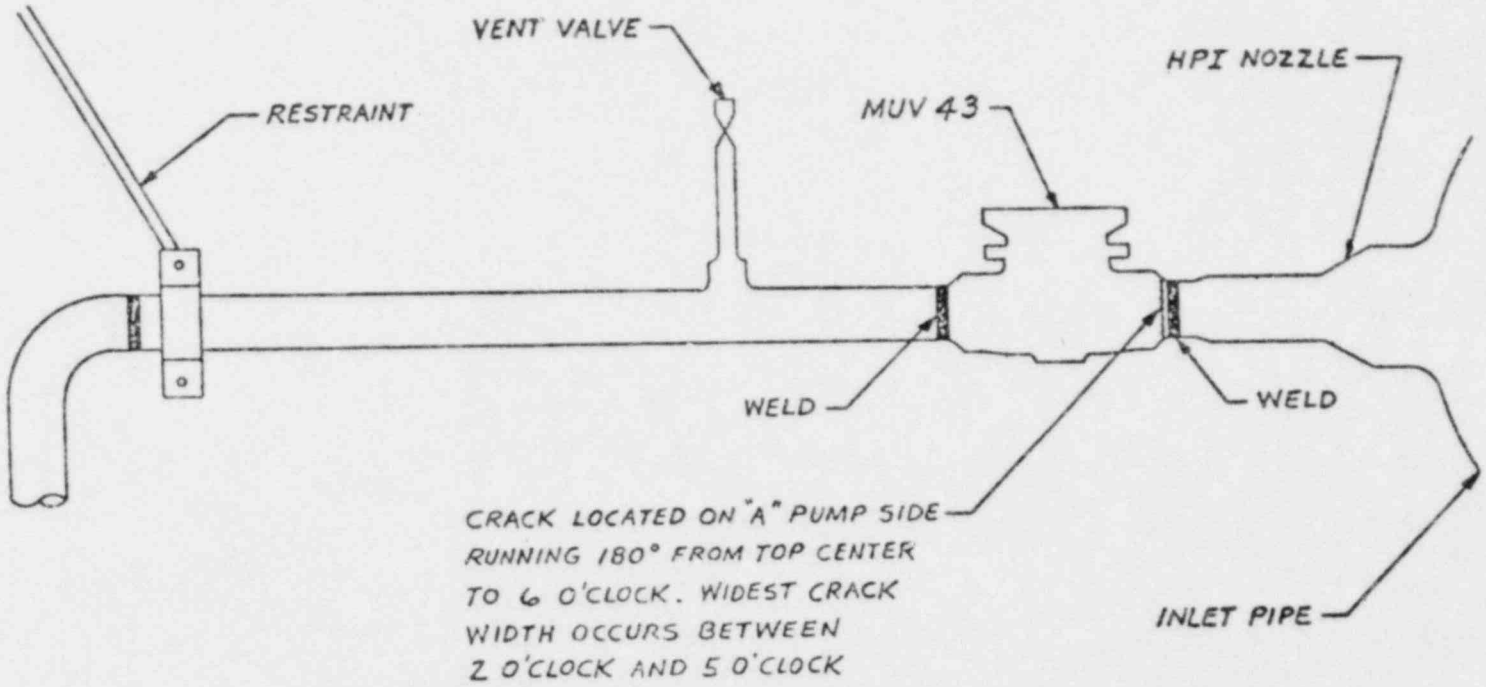

Figure 5. Schematic of HPI Hardware Relative to Crack Location

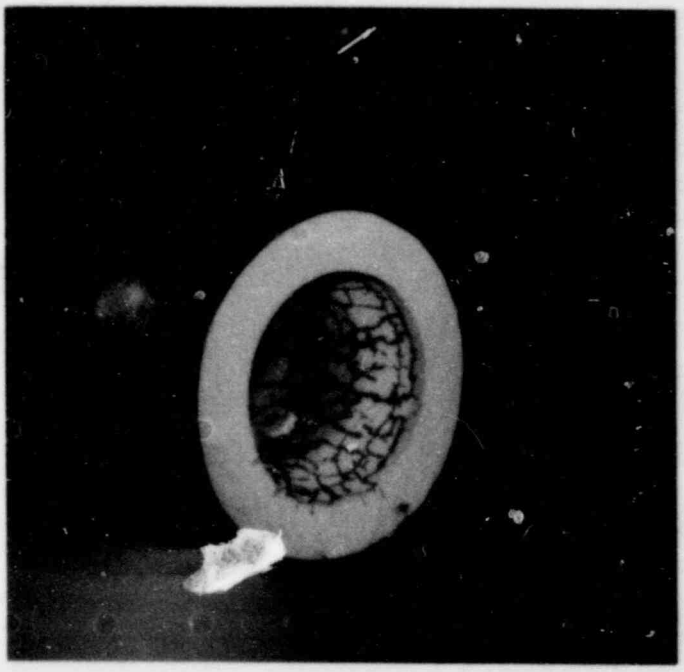

Figure 6.
Photograph of HPI/makeup nozzle safe-end depicting network of thermal fatigue crack indications as they appeared after liquid penetrant examination.

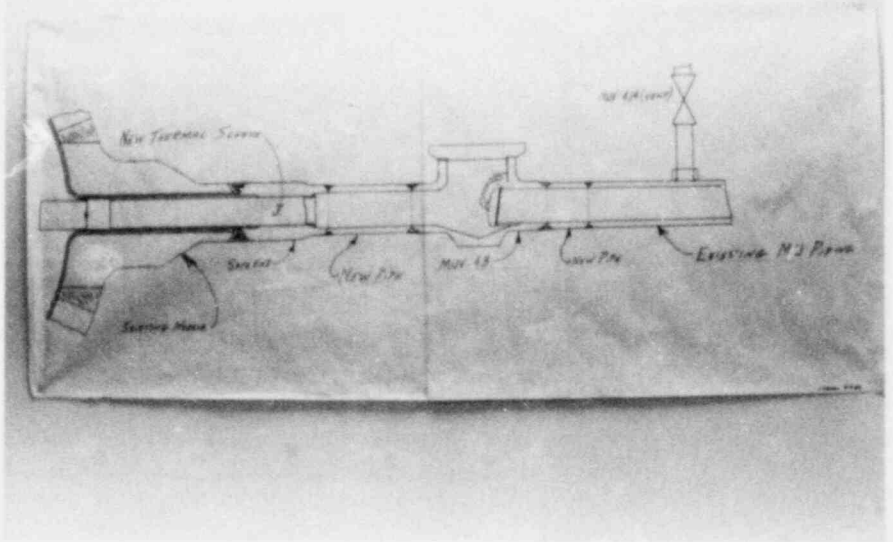

Figure 7
Photograph depicting new pipe configuration which conforms with design stress calculations.

APPENDIX B

PRELIMINARY NONDESTRUCTIVE EXAMINATION
RESULTS ON HPI/MAKEUP PIPE SECTION AND
VALVE MUV-43

	ITEM	DATE
1.	Preliminary Report on Old MUV-43 to QCIR 82-06	2-15-82
2.	Radiography Results at Lynchburg Research Center, Babcock and Wilcox	2-15-82
3.	MUV-43 Failure	2-10-82

Florida Power
CORPORATION

INTEROFFICE CORRESPONDENCE

Crystal River Nuclear Plant (Office) | CR-3 (Mail Code)

SUBJECT: Preliminary Report on Old MUV-43
to QCIR 82-026

TO: Whom It May Concern **DATE:** February 15, 1982

BACKGROUND:

MUV-43 was cut from the high pressure injection line after a crack was discovered in the downstream valve to pipe weld. Valve now located in Hot Machine Shop Weld Tent.

QA/QC investigation so far has revealed the following:

A. Seating area on valve and disc visually examined and penetrant tested. No signs of cracking.

B. External valve body and upstream weld visually examined and penetrant tested. No signs of cracking.

C. From downstream discharge cut to disc seating area numerous cracks evident visually and clearly visable with a penetrant examination. See attached drawing. Area in pink denotes location of cracks.

D. Overall visual examination of valve body, cover and internals did not show any evidence of excessive wear.

E. Penetrant test of valve cover seating area and valve seating area for cover revealed no linear indications.

F. Ultrasonic test of upstream weld revealed one reflector at root area. Believed to be due to geometry.

G. M. Williams
NQA/QC Supervisor

GMW/mlg

Babcock & Wilcox

a McDermott company

Nuclear Power Generation Division

3315 Old Forest Road
P.O. Box 1260
Lynchburg, Virginia 24505-1260
(804) 385-2000

582-7087/T1.2
ESC-073
February 15, 1982

Mr. J. E. Colby
Florida Power Corporation
P. O. Box 219
Crystal River, FL 32629

Attention: Mr. S. Johnson

Subject: Radiography Results at LRC

Gentlemen:

The purpose of this letter is to describe the difficulty encountered at the Lynchburg Research Center during radiography of the make up nozzle safe end regarding identification of cracks by radiography which had previously been detected by dye penetrant testing (PT).

Both sections of the safe end were x-ray examined over the full length. The settings used were: 150 Kv, 20 ma, with a 20-inch film to source distance. Exposures of one to five minutes were used. Most known cracks from the PT exam performed at the site were not detected with this set up. Full details of the radiography will be included in the report to be issued this week.

If you have any questions, please contact me at 804/385-2751.

Very truly yours,

RW Ganthner

R. W. Ganthner, Product Manager
Owners Group Engineering Services

RWG/bc

cc: J. C. Hicks
W. P. Ellsberry

Florida Power
CORPORATION

INTEROFFICE CORRESPONDENCE

Crystal River Nuclear Plant (Office) CR-3 (Mail Code)

SUBJECT: MUV-43 Failure

TO: T. C. Lutkehaus
P. F. McKee
J. Colby L. B. Tittle
S. Johnson D. Morrison
F. Fusick R. Ganthner (B&W)

DATE: February 10, 1982
CS-82-040
3-0-19

The following is an account of NDE inspections performed to date associated with MUV-43 failure at Crystal River Unit 3:

New MUV-43 (S/N 5800)
PT of inlet pipe end prep, one end
PT of valve end prep, both ends
PT of root pass both ends
RT of root pass " "
PT of final pass " "
RT of final pass " "
UT of final pass " "
PT of discharge pipe end prep, both ends.

Existing MUV-43 piping in place
PT of inlet pipe end prep
PT of inlet pipe I.D. (appr. 4 inches)

Original MUV-43 Safe End and Nozzle
UT thickness inspection of HPI nozzle safe end prior to removal from nozzle.
PT of HPI safe end ID prior to removal from nozzle.
PT of HPI safe end OD (including weld to nozzle) prior to removal from nozzle.
PT of HPI safe end ID after removal from nozzle.
UT of HPI nozzle OD from safe end weld (after cutting off safe end) up to nozzle transition.
UT of HPI nozzle OD from nozzle transition to 36" RC piping.
VT to determine dimension from end of HPI nozzle (after removing safe end) to fusion line between inconel buttering and carbon steel on O.D. of HPI nozzle, prior to end prep of nozzle.
PT of HPI nozzle ID 5 inches into nozzle bore, after safe end removal and prior to end prep.
PT and dimensional check of HPI nozzle end prep.
Remote PT/video inspection of HPI nozzle ID at transition from ID of bore to ID of RC piping.
Remove PT/video inspection of HPI nozzle ID from weld buttons out to the ID previously PT'd 5 inches into nozzle bore.

In addition, the following NDE inspections were performed on each of the sister valves MUV-36, 37, and 42.

PT/UT of inlet and discharge piping-to-valve weld.
PT/UT of safe end-to-nozzle weld.
UT thickness inspection of safe end.
UT volumetric inspection of safe end.

G. M. Williams
NQA/QC Supervisor (FPC)

Gene Nauratil
NDT Examiner (B&W)

GMW/rc

cc: J. Cooper, Jr.