Gimpel Trip and Throttle Valve Spindle Testing Project

1009703

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Technical Update, December 2004

EPRI Project Manager

Mike Pugh

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CITATIONS

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ABSTRACT

For decades, nuclear power plants across the world have been using Gimpel Trip/Throttle Valves to admit steam and to protect Terry Turbines from destruction due to overspeed. Because of a few failures, Gimpel (the manufacturer of most of the Trip/Throttle valves in operation in the US) redesigned the valve spindle to endure cyclic stresses better and, thus, be less prone to failure. However the supplier of this spindle only qualified the spindle life for 200 cycles – after which time it would have to be replaced. The 200-cycle limit has caused consternation in the nuclear power industry. The 200-cycle limit would require annual replacement of the valve spindle in some plants. There was no indication from Gimpel or Dresser-Rand that any type of cyclic failure mechanism initiated at 200 cycles. A limit higher than the 200 cycles would allow for a longer time between spindle replacements.

To address this problem, NMAC funded a project to demonstrate the capability of the new spindle design. This project tested three spindles of the new design that were procured from Gimpel. These tests were be performed under a controlled program for a predetermined number of cycles. This test report is being issued to describe the results for NMAC Members in 2004.

ACKNOWLEDGMENTS

EPRI NMAC would like to acknowledge the following individuals for their contributions during the testing and in the development of this report.

Sam Harrell	EPRI
Brady Hightower	EPRI
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Stan Walker	EPRI
Bob Knipshield	EPRI
Justin Thibault	EPRI
Andy McGehee	EPRI
Mary K. Havens	EPRI
Phil Hitchcock	TVA

TTUG Officers	
Mark Miller (Chairman)	Duke Energy
Michael Chambers	FP&L
Harold Thompson	Dominion
Bill Stuart	Entergy

NMAC and the Terry Turbine Users Group would also express it appreciation to TVA for the use of their Trip and Throttle Valve during the conduct of this test.

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1 INTRODUCTION

1.1 Background

For decades, nuclear power plants across the world have been using Gimpel Trip/Throttle Valves to protect Terry Turbines from destruction due to overspeed. Within the past five years, a few plants experienced failure of the valve spindle that caused the valve to fail in the closed position. While most of these failures were attributed to issues with the valve spindle materials, Gimpel (the manufacturer of most of the Trip/Throttle valves in operation in the US) redesigned the valve spindle to endure cyclic stresses better and, thus, be less prone to failure.

Dresser-Rand (the supplier of Terry Turbines)is now recommending that the spindle be replaced after 200 cycles. The 200-cycle limit has caused consternation in the nuclear power industry. The original spindle design has, by experience, lasted decades at a time. This 200-cycle limit on the improved design would require annual replacement of the valve spindle in some plants. There was no indication from Gimpel or Dresser-Rand that any type of cyclic failure mechanism initiated at 200 cycles. A limit higher than the 200 cycles would allow for a longer time between spindle replacements.

To address this problem, NMAC funded a project to demonstrate the capability of the new spindle design. This project was accomplished by testing three spindles of the new design that were procured from Gimpel. These tests were performed under a controlled program for a predetermined number of cycles. This test report is being issued to describe the results for NMAC Members in 2004.

1.2 Test Equipment

A 4 inch Gimpel Trip and Throttle Valve was provided by TVA for use during the tests described in this report. This valve was provided to TVA by Terry Turbine in the early 1980s as part of a Terry Turbine skid package for a subsequently cancelled nuclear plant. The valve is equipped with a standard Gimpel trip mechanism and a Limitorque 000 Valve Actuator. The actuator was originally supplied with a DC electric motor. However to facilitate more rapid cycling of the valve an air motor was adapted to the actuator. This along with a servo to actuate the trip lever and automatic controls were used to facilitate the test by automating the test cycle.

Terry turbines typically include a Gimpel trip and throttle (T & T) valve, which is a semi-balanced globe-type valve with steam inlet flow above the valve disc and seat. In addition to its primary protective function of rapid closure, the T & T valve has the capability of throttling steam flow into the turbine, thereby controlling turbine speed independent of the normal turbine control/governor system. All T & T valves have a hand-wheel for local operation. Most valves also have a motor operator for remote operation.

For applications, there is a normally closed motor-operated steam admission valve upstream of the turbine T & T valve, which is fully open during system standby conditions and normal turbine operation (that is, it is usually used as a protective valve only). A few applications do not have the motor-operated valve, so they use a normally closed T & T valve as their steam admission valve.

Following is a brief description of valve operation:

> Starting with the valve in the tripped position, turn the hand-wheel (or motor operator) in the valve closed direction (clockwise) (CW). The rotation of the screw spindle will raise the sliding nut and the latch-up lever, compressing the trip spring until the latch-up lever engages the trip hook. Turning the hand-wheel in the counterclockwise (CCW) direction will now lift the valve disc and open the valve.
>
> Initial movement of the valve stem in the opening direction unseats the pilot valve, permitting steam to flow from the balance chamber to the outlet of the valve. Because the flow area into the balance chamber is restricted, the pressure in the balance chamber drops as the pilot valve is opened. The force required to unseat the main disc is thereby reduced. When the pilot valve is fully open, it contacts the main disc. Further movement of the valve stem unseats the main disc.
>
> The valve is tripped by rotating the trip hook, disengaging it from the latch-up lever, and allowing the sliding nut (with the screw spindle, valve stem, and disc assembly) to move downward under spring force to the closed position. The valve operator remains in the open position.

1.3 Test Description

For this test, it was deemed that the most conservative test method would be to trip the valve with no steam forces present. This configuration results in the greatest load on valve/spindle during the trip process. The valve manufacturer was consulted to determine if the valve internal components were capable of withstanding the constant forces exerted on them during the testing. The manufacturer's representative indicated that valve internals would be capable of withstanding these loads.

The NMAC Terry Turbine Maintenance Guide, AFW Application, Report Number 1007461, was used as a reference and guide on valve and actuator assembly and set up.
Prior to testing, a field representative of Gimpel inspected the valve and actuator set-up to confirm that the valve was properly setup. He also advised test personnel on how best to facilitate the spindle replacements and what valve actuator components to pay particular attention to during the test.

1.4 Test Procedure

A test procedure was developed to guide the technicians involved on the conduct of the test. This procedure is included in this report as Appendix 1.

1.5 Test Spindle Data

The valve that was used in the test was a 4” Gimpel Trip and Throttle Valve that was loaned from TVA. Pertinent Valve Data: Customer Order 81336-38185 JO Number 74-12216.

Three Spindle Screw Kits, Gimpel Part Number L5637-4 (replacement for L3604-1) were procured from Gimpel. Table l-1 provides the specific details on each spindle. The spindles were received by EPRI NMAC and subjected to NDE and material examination by EPRI NDE and Metallurgical staff. The results of this inspection confirmed the material to be 1018 Carbon Steel. Appendix 2 & 3 contains results of these examinations.

Table 1-1
Example of a Table with Caption

Spindle #	Serial #	Assy #	Heat #
1	266571-2	L5636-1	622500
2	266571-3	L5636-1	622500
3	266571-1	L5636-1	622500

2
TEST RESULTS

2.1 Test Results

Each of the three spindles were initially subjected to number of trips shown in the table below.

Test Spindle #	Number of Trips	Indications
1	3,204	Indication 165^{o} @ radius
2	3,300	Indication 90^{o} @ radius
3	3,000/5,000*	Indication 180^{o} @ radius

No failures were experienced on any of the stems during the initial testing. At approximate intervals of 500 trips, each of the spindles were examined using liquid penetrant(in accordance with approved EPRI NDE Procedures). Each of the spindles developed linear indications in or near the transition radius area of the spindle head. (See Appendix 4 for complete test and inspection results).

After completion of initial testing on spindle #3, it was decided to continue to cycle the spindle for an additional 2000 trips(*). No additional growth of the indication in the spindle was noted upon completion of these additional tests. It was decided to destructively examine spindle #3 to determine the nature and extent of the indication. The examination report is included as Appendix 5 of this report. As can be seen in the report, the indication that developed was of relatively minor depth, with the greatest depth of 4 sections being 0.021inches.

Conclusions

This project demonstrated the ability of the new spindle to withstand a large number of repeated trips without failure. Indications that did develop are relative shallow depth and do not indicate incipient failure, at least for the scope of this testing effort.

Spindle life is dependent upon proper valve setup and operation as defined in NMAC Maintenance Guides 1007460 and 1007461 Section 6.0. Specific cautions include proper assembly alignment, proper limit switch settings and torque switch settings no greater than described.

3
APPENDICES

Appendix 1 Test Plan

Trip/Throttle Valve Spindle Test Plan

Prepared by:	Justin Thibault	Date:	06/08/2004
Reviewed By:	Mike Pugh	Date:	10/6/2004
Approved By:	Mike Pugh	Date:	10/6/2004

Record of Revision

Date:	Revision:	Section:	Description:
10/6/2004	0	All	Original Release

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1.0 Introduction

1.1 Purpose

This document describes the purpose, methods, and parameters of the Terry Turbine Trip Throttle Valve Spindle test. This document will direct all aspects of the test and will prioritize the analysis and presentation of the results.

1.2 Applicability

This document is applicable to all EPRI, EPRIsolutions, service providers, and vendors working on the test; contributing time and/or equipment; and analyzing and reporting results.

1.3 Document Overview

This document covers the reason for the test, dedication and verification parameters, test procedures, and description of pre and post-test NDE analysis.

1.4 Definitions and Abbreviations

Deleted

1.5 Attachments

Deleted

1.6 References

1.6.1	EPRI Report	Terry Turbine Maintenance Guide, AFW Application. 1007461

1.7 Roles

1.1 Project Manager – responsible for the entire project and makes decisions as to major procedure changes, testing protocols, and equipment changes.

1.7.1.1 The Project Manager for this project is Mike Pugh.

1.2 Engineer – responsible for proper maintenance of the Trip-Throttle Valve and the testing mechanism, performs assembly and disassembly of the valve, makes minor procedure adjustments, trains and certifies operators, diagnoses system faults, and prepares reports to the Project Manager on progress of testing.

1.7.2.1 The Project Manager can add or remove names from the list of Engineers.
1.7.2.2 The Engineers for this project are Justin Thibault and Robert Knipshield.

1.3 Operators – responsible for recording testing events, setting up test cycles, and monitoring test operation.

1.7.3.1 The Project Manager or one of the Engineers can add or remove names from the list of operators.
1.7.3.2 The Operators for this project are Brady Hightower, Sam Harrell, Robert Knipshield.

2.0 Background

2.1 Reason for Testing

2.1 For decades, nuclear power plants across the world have been using Trip/Throttle Valves to protect Terry Turbines from destruction due to overspeed. The reliable operation of this valve is the solitary defense in the design of a standard Terry Turbine from overspeeding.

2.2 Within the past five years, a number of plants experienced experienced failure of the valve spindle that caused the valve to fail in the closed position. While most of these failures were attributed to issues with the valve spindle materials, Gimple (the manufacturer of most of the Trip/Throttle valves in operation in the US) redesigned the valve spindle to endure cyclic stresses better and, thus, be less prone to failure.

2.3 Following this design, Dresser-Rand (the supplier of Terry Turbines), based on data received from testing by Gimple, qualified the spindle life for 200 cycles – after which time it would have to be replaced.

2.4 The 200-cycle limit has caused consternation in the nuclear power industry. The original spindle design has, by experience, lasted decades at a time. This 200-cycle limit on the improved design would require annual replacement of the valve spindle in some plants.

2.5 There was no indication from Gimple or Dresser-Rand that any type of cyclic failure mechanism initiated at 200 cycles. A limit higher than the 200 cycles would allow for a longer time between spindle replacements.

2.2 General Parameters

2.1 The major goal is to demonstrate that the valve can operate through a minimum of 3000 cycles and still open the valve.

2.2 Every 300 - 500 cycles, the spindle coupling will be removed from the valve and the stem examined for any signs of damage. The “button area” will be NDE for signs of cracks.

2.3 The operation of the valve will be controlled through an automated routine including an automatic mechanical trip device.

2.4 The population of the number of valve spindles will be no less than three valve spindles and that population will consist only of spindles of the new Gimple design.

3.0 Notes on Valve Disassembly and Reassembly

3.1 Procedure Basis

3.1 The valve disassembly will follow the procedure in section 6.3.1 in Reference 1.6.1 up to the point of preparing the yoke for removal. The point of disassembly will be to replace the spindle.

3.2 **While carrying out disassembly, it is important that the trip hook be secured by a soft block as described in the reference document to prevent in-advertent release of the latch-up lever.**

3.3 The valve assembly will follow the procedure in section 6.5.1 in Reference 1.6.1.

3.2 Guidelines for Valve Assembly and Disassembly

3.1 Only personnel who have demonstrated successful valve assembly and disassembly can be the primary individual responsible for removing or replacing the spindle.

3.2 Only individuals who have been properly briefed on the safety procedures and correct operation of the trip-throttle valve and the motor logic can take part in replacing the spindle.

3.3 The spindle must be handled with the utmost care. While it may operate in a violent mechanical process, introductions of scrapes, dents, scratches, etc. could create "false positives" which may endanger the validity of the test conclusions.

3.4 Copies of Figures 6.1 and 6.2 from Reference 1.6.1 should be made available to those involved in replacing the spindles. This will allow all involved to follow accurately each direction in spindle replacement in the proper order.

3.5 After a spindle is replaced, the trip counter value at the tripping mechanism should be recorded in the test log and the counter should be reset.

3.6 Following replacement, the valve should be operated through one cycle using the manual handwheel to insure that the valve was assembled correctly.

4.0 Instructions for Using the Trip-Throttle Valve Test Stand (TTVTS)

4.1 Safety Guidelines

4.1 Only people who have been properly briefed on the safe operation of the Trip-Throttle Valve Test Stand (TTVTS) can operate the Trip-Throttle Valve Test Stand.

4.2 Because the TTVTS is in an area (RRAC highbay) which requires eye protection, approved eye protection is to be worn at all times when in the RRAC highbay.

4.3 Ear protection is to be worn by all personnel when the TTVTS is in operation. Also, spare earplugs should be available for people who may be working near the TTVTS.

4.4 Proper signage is to be displayed when the TTVTS is in operation or if the trip mechanism is armed.

4.5 The signage should be positioned in front of the valve itself.

4.6 The trip mechanism should be armed only when the TTVTS is in operation.

4.7 The system should only be pressurized when the TTVTS is in operation.

4.8 The TTVTS should only be operated with this procedure and it should be readily available to everyone operating the TTVTS.

4.2 Standard Shutdown Procedure

4.1 This shutdown procedure should be carried out for planned shutdown of the TTVTS and not when the *Fault* light is on.

4.2 This shutdown procedure is to be executed at the completion of a test sequence, pausing the test for an extended period of time, or relubricating the system.

4.3 Standard Shutdown Procedure:

4.2.3.1 Disarm the trip mechanism on the control panel by moving the *Trip Off (CW)* switch to the clockwise position.
4.2.3.2 Press in the red “E. Stop” button. The green *Power* light should shut off.
4.2.3.3 At the pressure regulator, move the shut-off valve to the *Off* position. The pressure at the regulator should drop to zero (0).
4.2.3.4 Record the counter value at the tripping mechanism and the reason for the shutdown in the test log.

4.3 Fault Shutdown Procedure

4.1 A fault shutdown is executed by the logic of the system under two circumstances: a torque switch in the motor actuator was activated or the system detected that the valve is not opening. In either case, the red *Fault* light will turn on.

4.2 Testing shall not resume until the fault has been diagnosed and appropriate action taken to rectify the cause of the fault has been fully executed.

4.3 Fault Shutdown Procedure:

4.3.3.1 Disarm the trip mechanism on the control panel by moving the *Trip Off (CW)* switch to the clockwise position.
4.3.3.2 Note the pressure at the regulator and then move the shut-off valve to the *Off* position.
4.3.3.3 Check the TTVTS for the following:

All of the hoses are properly connected.
The spindle and coupling are intact.
The position of the valve (Is it closed all of the way or opened all of the way)

4.3.3.4 Find the Project Manager or one of the Engineers to check out the situation and clear the system for testing.

4.3.3.5 Record notes on the fault on a Fault Report, perform a Standard Shutdown.

4.3.3.6 Restart the system and continue the testing.

4.4 Test Startup and Operation

4.1 Check that all hoses and fittings are secure.

4.2 Check that the panel is plugged in.

4.4 Startup Procedure:

4.4.4.1 Disarm the trip mechanism by moving the *Trip Off (CW)* position to the clockwise position.
4.4.4.2 Check that the *Jog Close* and *Jog Open* switches are both in the counter-clockwise positions.
4.4.4.3 Record the counter value on the tripping mechanism in the test log.
4.4.4.4 Place signage in front of the valve.
4.4.4.5 Pressurize system by doing the following:

Check that the misting oil is at the *Max Fluid* level.
Turn the shut-off valve at the regulator to the *Open Position*.
Adjust the regulator valve so that the pressure is set at the test pressure. Currently that is 60 PSI. If that is changed, a notice will be placed in a conspicuous place on the test stand.

4.4.4.6 Enter the number of tests that are to be performed for this cycle in the *Control Counter* on the panel.
4.4.4.7 Reset the *Control Counter* on the panel, so the current count is zero.
4.4.4.8 Pull the red *E. Stop* button out, the green *Power* light should turn on. If not, check the power cabling.
4.4.4.9 Move the valve to the Reset and Closed position with the *Jog Close* switch.
4.4.4.10 The TTVTS should start once the valve is in the appropriate position.
4.4.4.11 Once the valve starts moving, arm the tripping mechanism by moving the *Trip Off (CW)* switch to the counter – clockwise position.
4.4.4.12 The test should run to the number of cycles that were programmed in the *Control Counter* on the panel, and it will stop automatically after the last trip is completed.
4.4.4.13 If the test needs to be stopped at any point, push in the red *E. Stop* button. Record the counter value on the tripping mechanism in the test log.

4.5 Abnormal Shutdown

4.5 If the system stops mid-cycle and the fault light is not on, it is either because the system is depressurized or it suffered a power outage. In order to handle the situation, use the following procedure.

4.5.5.1 Disarm the tripping mechanism by moving the *Trip Off (CW)* switch to the clockwise position.
4.5.5.2 Record the counter value on the tripping mechanism in the test log.
4.5.5.3 Find the Project Manager or one of the Engineers to check out the situation and clear the system for testing.

4.6 Lubrication

4.1 The lubrication interval is 50 cycles. If this changes, it will be noted conspicuously on the panel. Lubrication for spindle and valve components will be MOV Long Life Grade 1.

4.2 When the lubrication interval is reached, perform a standard shutdown and record the counter value on the tripping mechanism in the test log comments section.

4.3 Re-grease the spindle/sliding nut interface with the grease provided in the grease gun.

4.4 Check the oil in the inline oiler. If it is below the minimum level, refill it to the maximum level.

4.5 Restart the testing.

A.0 Appendix A – Test Log

Trip Throttle Valve Spindle Test Log

Spindle Number:_____________ **Page:______________**

Date	Operator	Counter Value Start (a)	Counter Value End (b)	Inspection (yes/no)	Test Cycles (b-a)	Total Cycles	Comments:

Appendix 2 Receipt Inspection and Material Verification

Met. Lab Report Form

Date: 10-8-04

Report: 02135

Project: Chemical Analysis and Photography of Carbon Steel Valve Rods

Project Manager: Andy McGehee

Material: 1018 Carbon Steel Valve Rods

Investigator: M.K. Havens

Examination: OES Chemical Analysis

Objective: Perform chemical analysis to verify 1018 Carbon Steel Valve Rod material.

TABLE 1: Results of Chemical Analysis

ELEMENT	VALVE #1	VALVE #2	VALVE #3	1018 ASTM A29
Carbon	0.200	0.192	0.196	0.15 – 0.20
Manganese	0.83	0.82	0.81	0.60 – 0.90
Phosphorus	0.025	0.024	0.023	0.040 max
Sulfur	.026	0.022	0.021	0.050 max

Summary: The chemical analyses of the three submitted valve rods are given in the table above along with the ASTM A29 Chemistry Standard for 1018 carbon steel. The results show that all three valve rods meet the chemical specification.

PT of #2 and #3 valves revealed areas with minor bleed out in the machined radius to the seat head of the valve rod. Photographs of areas revealing slight PT indications are given in Figure 1 and 2 below.

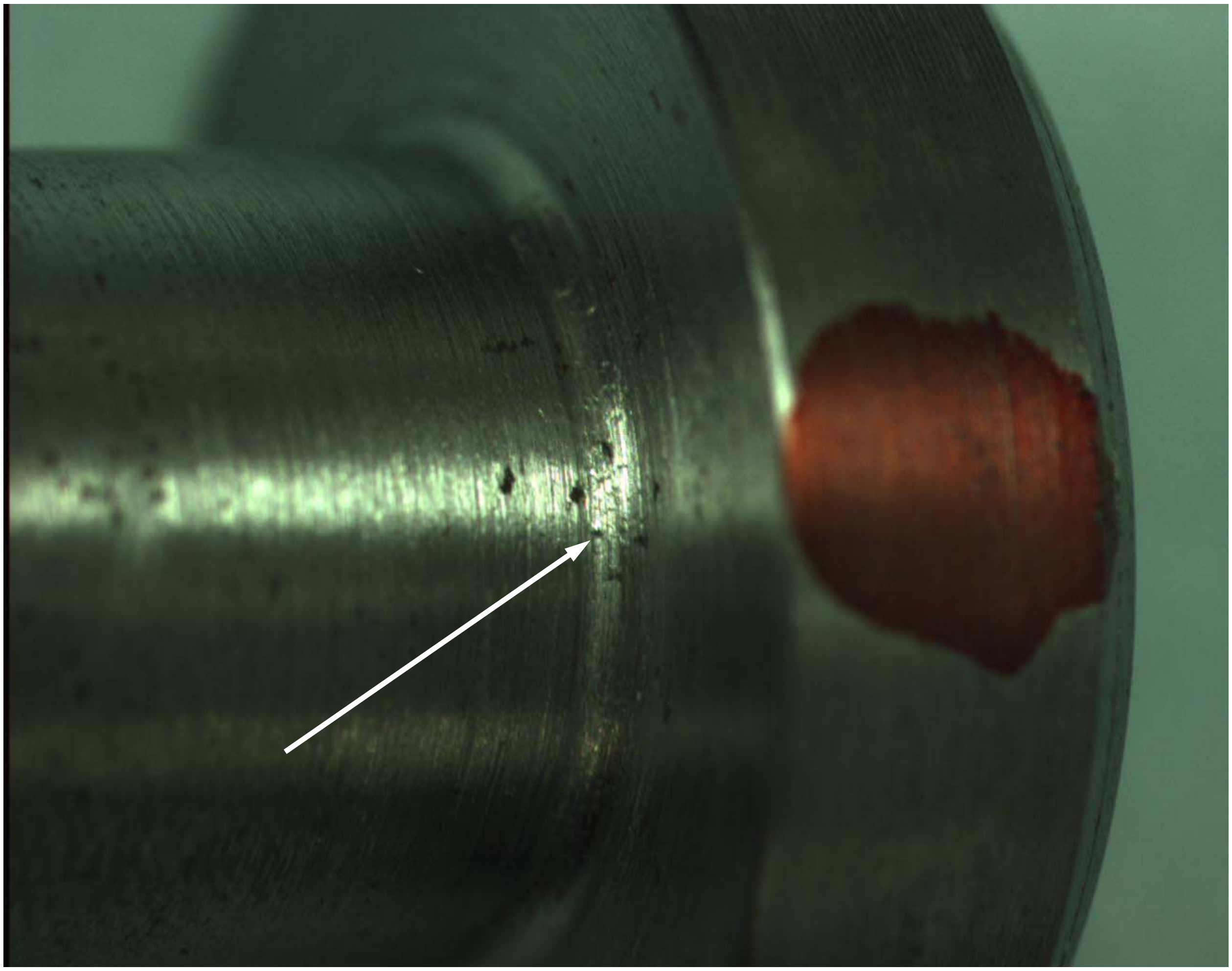

Figure 1: #2 Valve Rod showing ink mark at the approximate location where a PT indication occurred in the machined radius.

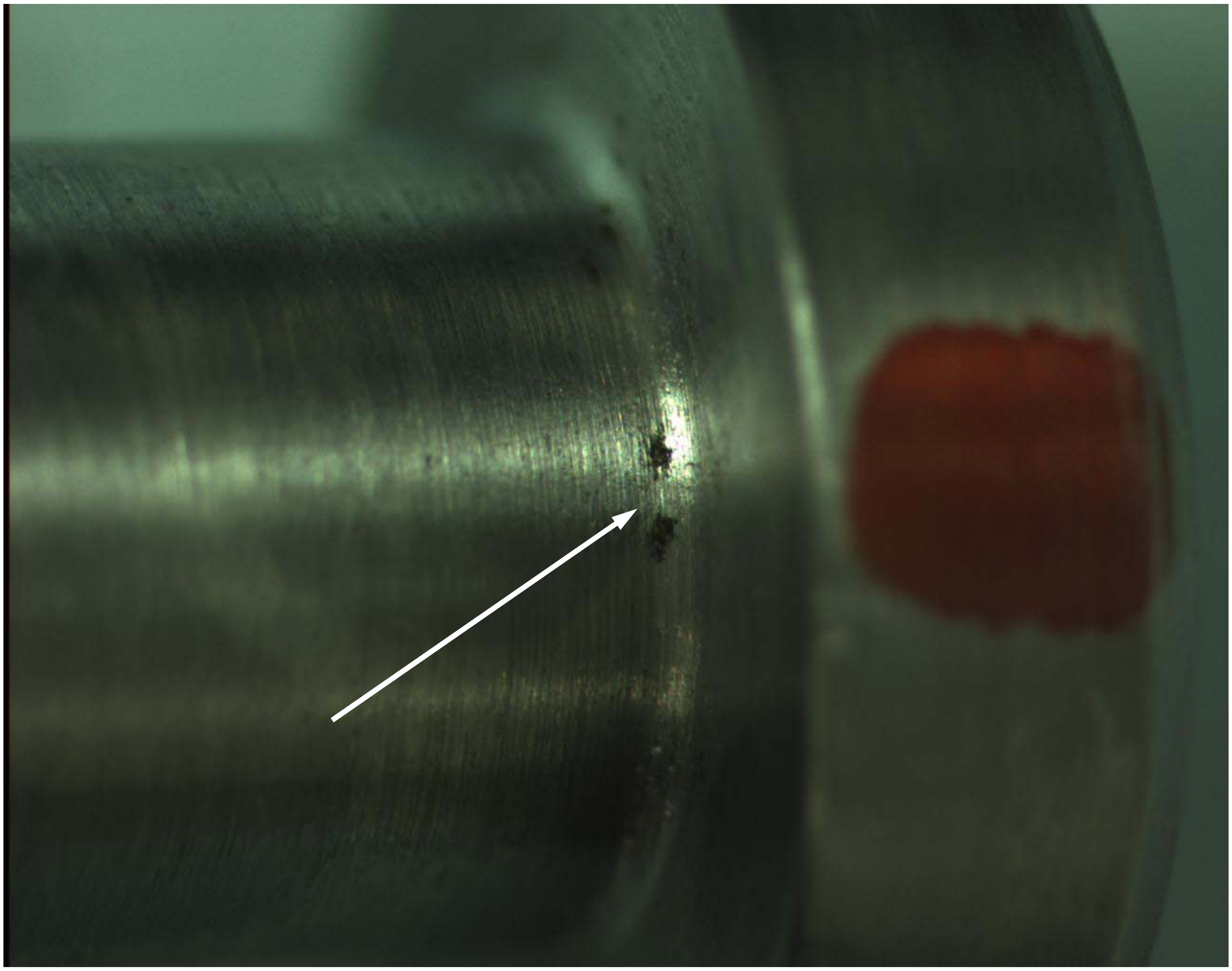

Figure 2: #3 Valve Rod showing ink mark at the approximate location where a PT indication occurred in the machined radius.

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Appendix 3 NDE of New Stems

Baseline PT

ARC-NDE-001
Exhibit "A"

J.A. JONES APPLIED RESEARCH COMPANY

LIQUID PENETRANT EXAMINATION

JOB NO. 059143	PROCEDURE NO. ~~REV. NO.~~ ASTM-E165	DATE 1995
DRAWING NO. —	MATERIAL C/S	ACCEPTANCE STANDARD Info Only
PENETRANT BRAND Spotcheck	PENETRANT BATCH NO. 97F06K	PENETRANT DWELL TIME 20 min

NOTES
* critical area is radius on lower end (away from keyway)
* indications appear to be very small machining tears.

~~WELD~~/PIECE NO.	DIA.	AREA	ACC.	REJ.	INDICATIONS
Spindle #1	/	*			No indications
Spindle #2	/	*			**Two non-relevant indications 1/64" aligned radially on shaft (70° CCW from keyway) at radius.
Spindle #3	/	*			**Two non-relevant indications 1/32", aligned circumferentially on shaft (180° CCW from keyway) at radius.
					Note: Digital photos of above made by Met. Lab.

TECHNICIAN CWB LEVEL III DATE 10-6-04

Appendix 4 Test Data

Contents:

Trip Throttle Valve Spindle Test Logs

NDE Inspection Reports

Spindle Photos

Trip Throttle Valve Spindle Test Log

Spindle Number:_______1_____ **Page:_______1______**

Date	Operator	Counter Value Start (a)	Counter Value End (b)	Inspection (yes/no)	Test Cycles (b-a)	Total Cycles	Comments:
10/13	JBH	0	403	yes	403	403	
10/14	JBH	0	401	Yes	401	804	
10/15	JBH	0	500	Yes	500	1304	
10/15	JBH	0	500	Yes	500	1804	"tool mark" appears, see NDE report
10/18	JBH	0	500	Yes	500	2304	
10/18	JBH	0	500	Yes	500	2804	"tool mark" growing, see NDE report
10/19	JBH	0	400	Yes	400	3204	

Trip Throttle Valve Spindle Test Log

Spindle Number:______2______   **Page:______1_______**

Date	**Operator**	**Counter Value Start (a)**	**Counter Value End (b)**	**Inspection (yes/no)**	**Test Cycles (b-a)**	**Total Cycles**	**Comments:**
10/20	JBH	0	500	Yes	500	500	
10/21	JBH	0	500	Yes	500	1000	
10/21	JBH	0	500	Yes	500	1500	
10/22	JBH	0	300	Yes	300	1800	
10/25	JBH	0	500	Yes	500	2300	
10/25	JBH	0	500	Yes	500	2800	
10/26	JBH	0	500	Yes	500	3300	

Trip Throttle Valve Spindle Test Log

Spindle Number:______3______ **Page:_______1______**

Date	**Operator**	**Counter Value Start (a)**	**Counter Value End (b)**	**Inspection (yes/no)**	**Test Cycles (b-a)**	**Total Cycles**	**Comments:**
10/27	JBH	0	500	Yes	500	500	
10/28	JBH	0	500	Yes	500	1000	
10/29	JBH	0	500	Yes	500	1500	
10/29	JBH	0	500	Yes	500	2000	
11/1	JBH	0	500	Yes	500	2500	Indication appears, see NDE report
11/1	JBH	0	500	Yes	500	3000	End of initial testing, decision made to continue test to 5000 cycles
11/4	JBH	0	500	Yes	500	3500	
11/5	JBH	0	500	Yes	500	4000	
11/5	JBH	0	500	Yes	500	4500	
11/8	JBH	0	500	Yes	500	5000	

ARC-NDE-001
Exhibit "A"

J.A. JONES APPLIED RESEARCH COMPANY

LIQUID PENETRANT EXAMINATION

JOB NO. 059143	PROCEDURE NO. REV. NO. ASTM E165	DATE 1995
DRAWING NO. —	MATERIAL 4/5-1018	ACCEPTANCE STANDARD Info Only
PENETRANT BRAND Spotcheck / PENETRANT BATCH NO. 97F06K	PENETRANT DWELL TIME 10-30 minutes	

NOTES
* radius on lower end of Spindle plus 1/2" each side

WELD/PIECE NO.	DIA.	AREA	ACC.	REJ.	INDICATIONS
Spindle #1 403 cy	—	*			No indications found (10-14-04) 8:30 AM
804 cy.	—	*			" " " 1:45 PM
1304 cy	—	*			" " " (10-15-04) 9:30 AM
1804 cy	—	*			" " " 3:30 PM
2304 cy.	—	*			Apparent linear indication, top of radius, 120° of circumference, very thin, no depth 10-[illegible] 11:2[illegible]
2804 cy	—	*			Linear indication as above, larger, more bleedout into developer 3:55
3204 cy.	—	*			Linear indication as above, larger & longer (165° of circ.), more bleedout. 10-[illegible] 11:[illegible]

TECHNICIAN CWAB LEVEL III DATE 10-14-04

ARC-NDE-001
Exhibit "A"

J.A. JONES APPLIED RESEARCH COMPANY

LIQUID PENETRANT EXAMINATION

JOB NO.	PROCEDURE NO. / REV. NO.	DATE
059143	ASTM E165	1995

DRAWING NO.	MATERIAL	ACCEPTANCE STANDARD
—	C/S - 1018	Info Only

PENETRANT BRAND	PENETRANT BATCH NO.	PENETRANT DWELL TIME
Spotcheck	97F08K	10-30 min.

NOTES
* radius on lower end of spindle plus ½" each side.

WELD/PIECE NO.	DIA.	AREA	ACC.	REJ.	INDICATIONS
Spindle #2 500 cy.	—	*			No indications found (SW) (10-20-04) 3:00
1000 cy	—	*			No indications found. (10-21-04) 11:00 AM
1500 cy	—	*			" " " (4:30 PM)
1800 cy	—	*			" " " (SW) (10-22-04) 1:00 PM
2300 cy	—	*			" " " (10-25-04) 9:45
2800 cy	—	*			Linear indication on radius, about ¼" long 3:30
3300 cy	—	*			Linear indication on radius with 2 rounded indications 1" long 90° around 10-26-04 11:30 AM

TECHNICIAN CWZ LEVEL II DATE 10-20-04

ARC-NDE-001
Exhibit "A"

J.A. JONES APPLIED RESEARCH COMPANY

LIQUID PENETRANT EXAMINATION

JOB NO. 059143		PROCEDURE NO. REV. NO. ASTME165	DATE 1995
DRAWING NO. —	MATERIAL 4S-1018		ACCEPTANCE STANDARD Info Only
PENETRANT BRAND Spotcheck	PENETRANT BATCH NO. 97F06K	PENETRANT DWELL TIME 20 min.	

NOTES
* critical area is radius on lower end plus 1/2" each side.

WELD/PIECE NO.	DIA.	AREA	ACC.	REJ.	INDICATIONS
Spindle #3 500 cy	—	*			No indications found. 10-27-04 3:00PM
1000 cy	—	*			No indications found. 10-28-04 1:10PM
1500 cy	—	*			No Indications found 10-29-04 9:00 AM
2000 cy	—	*			No Indications found 10-29-04 3:15 PM
2500 cy	—	*			Linear Indication @ mark, approx 180° radially 11-1-04 11:00am
3000 cy	—	*			Linear indication @ mark, approx 180° radially 3:45 PM
3500 cy	—	*			Linear indication @ mark, approx. 180° 11-4-04 4:00PM
4000 cy	—	*			Linear Indication @ mark, approx 180° 11-5-04 8:30AM
4500 cy	—	*			Linear Indication @ mark, approx. 180° 11-8-04 3:45PM
5000 cy	—	*			Linear Indication @ mark, approx. 180° (PZ) 11-9-04 10:30AM
—					(Final PT photo by Met Lab.)

TECHNICIAN [signature] LEVEL III DATE 10-27-04

Photo of Indication in Spindle 1 at Completion of Test:

Photo of Spindle #3 after 3500 cycles Showing Indication

Appendix 5 Spindle #3 Metallurgy Test Report

Met. Lab Report Form

Date: 11-12-04

Report: 02135-2

Project: Metallography of PT Crack indication of Valve Rod

Project Manager: Andy McGehee

Material: 1018 Carbon Steel Valve Rods

Investigator: M.K. Havens

Examination: Metallographic Analysis

Objective: Size Crack in the Radius of the Valve Rod to Button Head Seat

Summary: A 1018 carbon steel valve rod was subjected to 5000 total opening and closing cycles. A crack was detected via PT after 3500 Cycles. Upon witnessing the operation of the valve assembly it is hypothesized that the crack initiation is from the repeated impact loading that occurs when the compression spring is activated to close the valve. This appears to be the only mechanism which can produce the tensile loading forces necessary to propagate a crack in the radius location of the valve rod. Any misalignment or non parallel contact that is present in the coupling assembly during the impact could serve to exacerbate the time to crack initiation as well as the crack propagation rate.

The metallography contained in this report is intended to document the extent of the crack depth relative to the valve assembly and sample utilized for this testing.

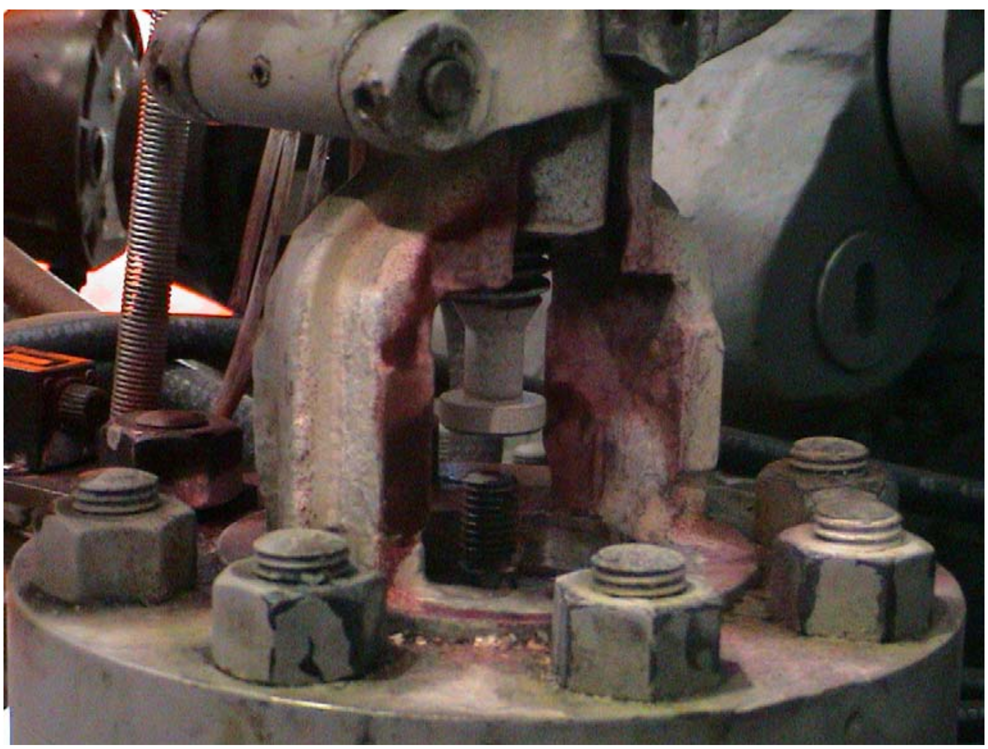


Figure 1: Photograph of the valve rod in the valve assembly with the coupling removed.

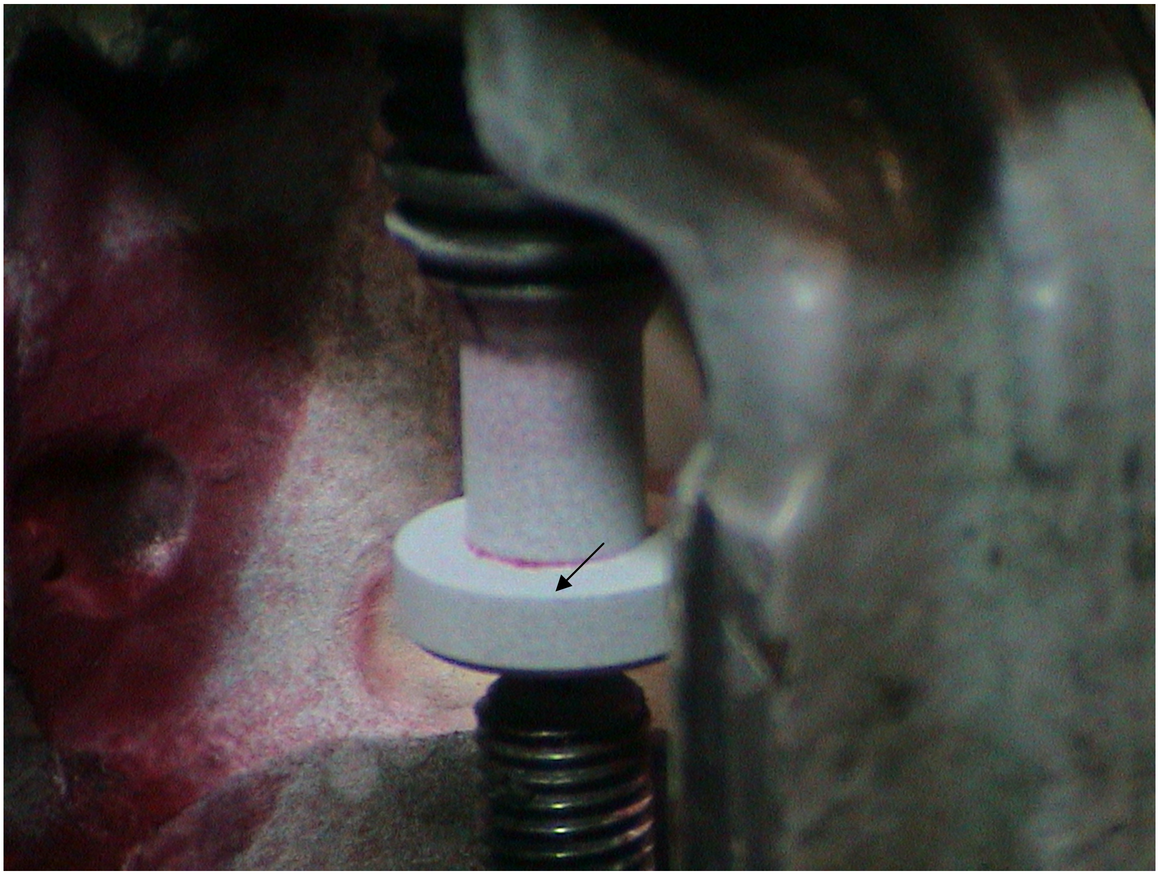


Figure 2: Close up of the crack in the radius revealed by PT.

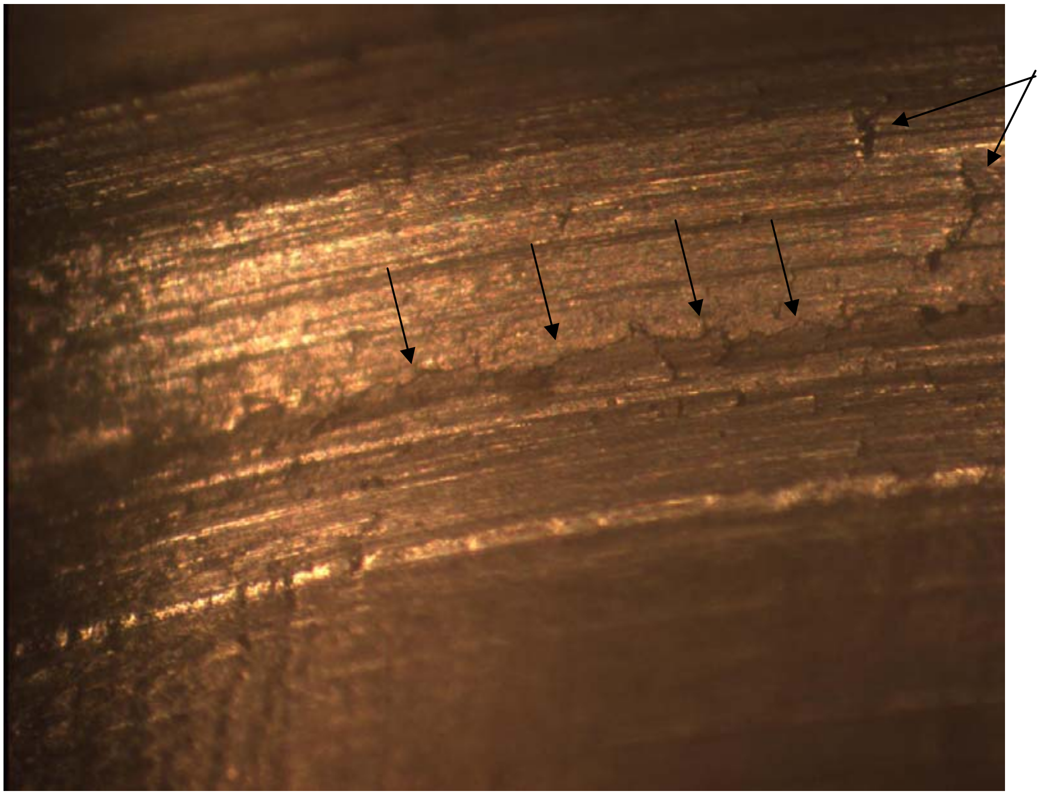


Figure 3: Close up of the radius area showing the crack and tooling marks resultant from machining in the radius.

The valve rod was sectioned into four quadrants so that crass sections of the crack propagation could be seen. Figures 5 thru 8 show the crack propagation through the base metal in the etched and unetched condition. Measurements of the crack depths are included on the unetched micrographs.

The cross sections show the irregular curvature associated with the machined radius. The banded appearance in the microstructure is a result of the manufacturing process employed for the fabrication of the raw bar stock from which the rod was made. The bands consist of pearlite and most likely manganese sulfide inclusions. Further analysis would be needed to positively identify the micro constituents of the non-metallic inclusions. They can be seen more clearly in the unetched photomicrographs.

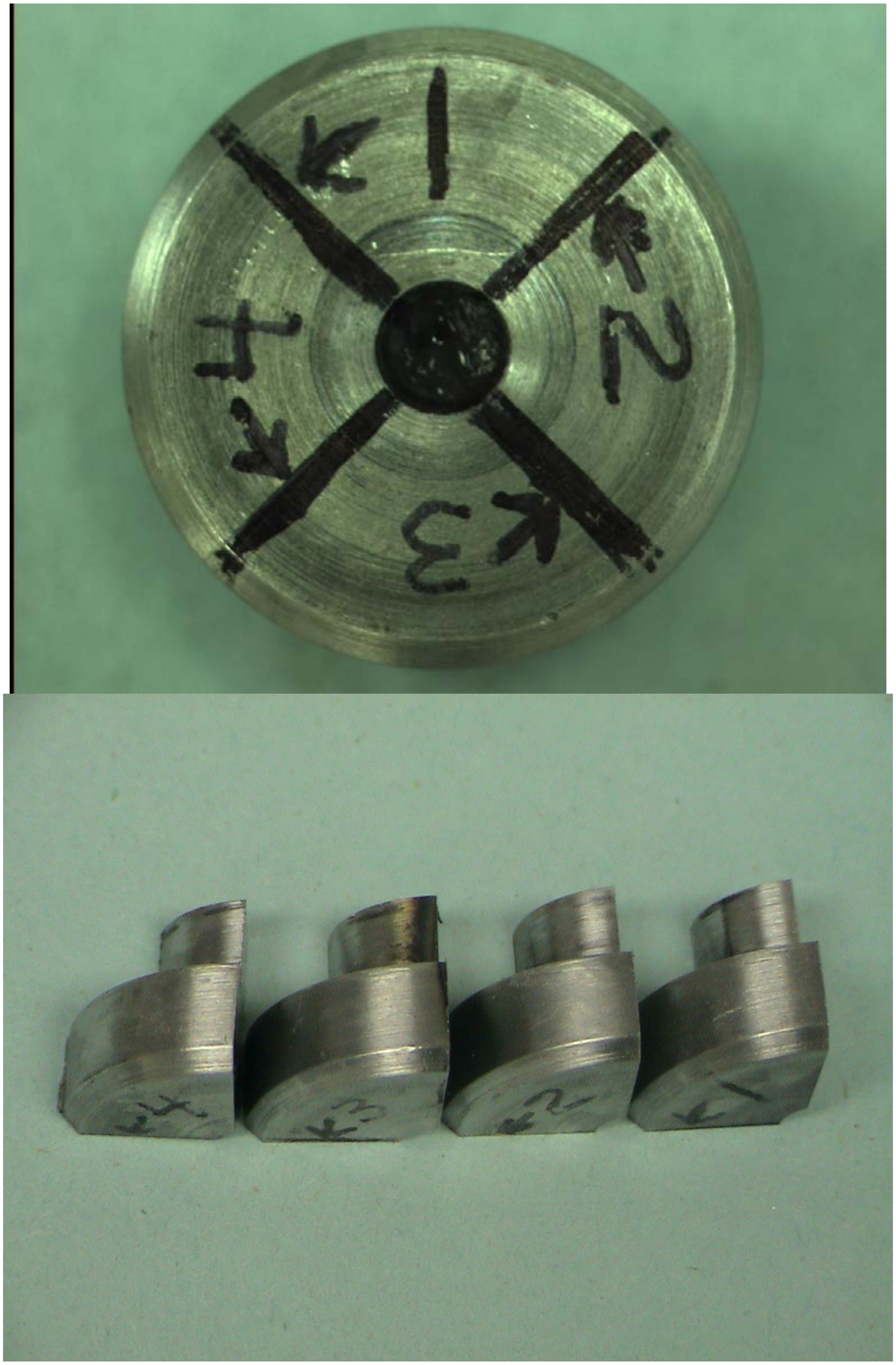


Figure 4: Photograph showing sectioning plan

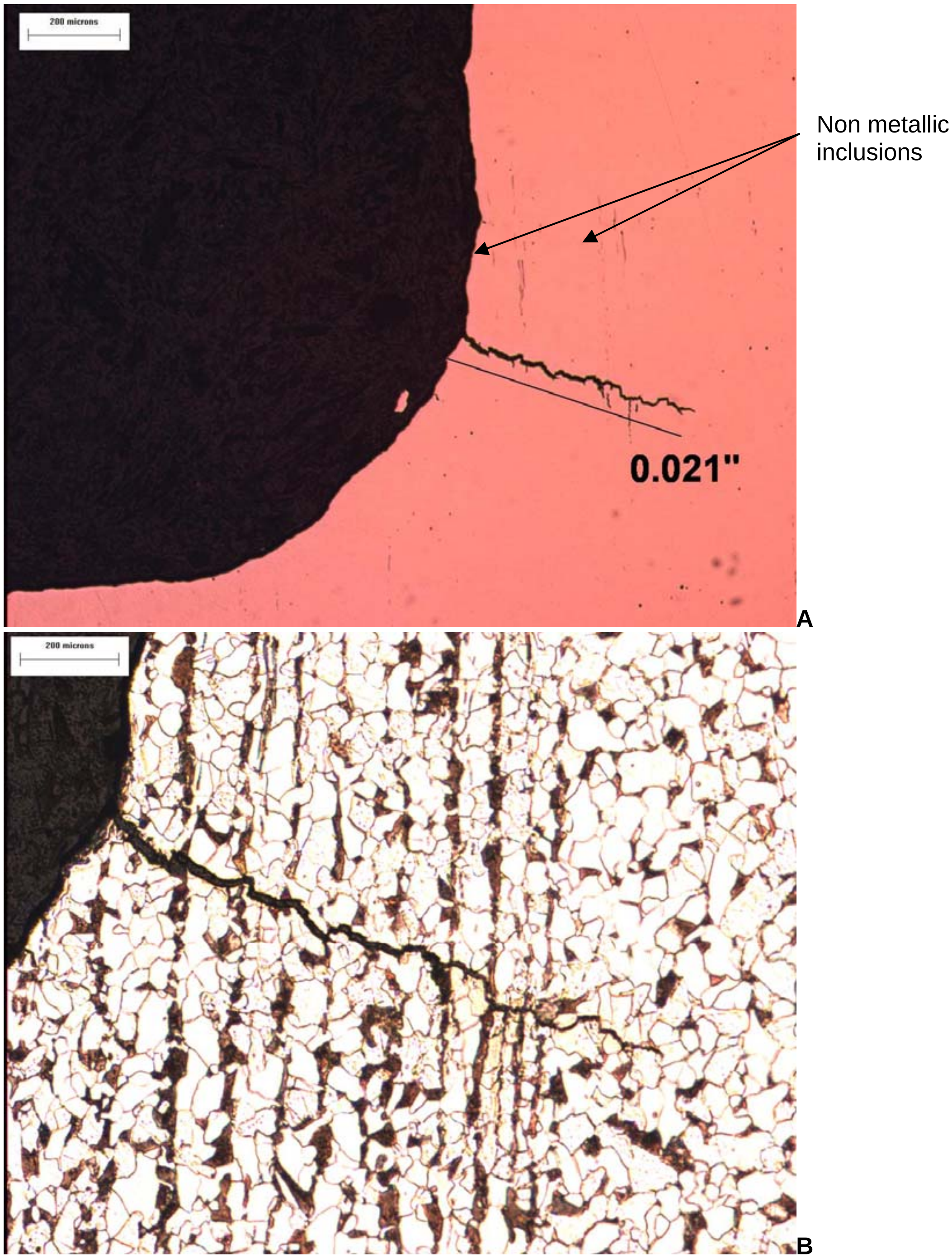


Figure 5: Photograph of the crack in the unetched condition @ 50X magnification (A) and etched condition @ 125 X magnification (B) from the 1st quadrant.

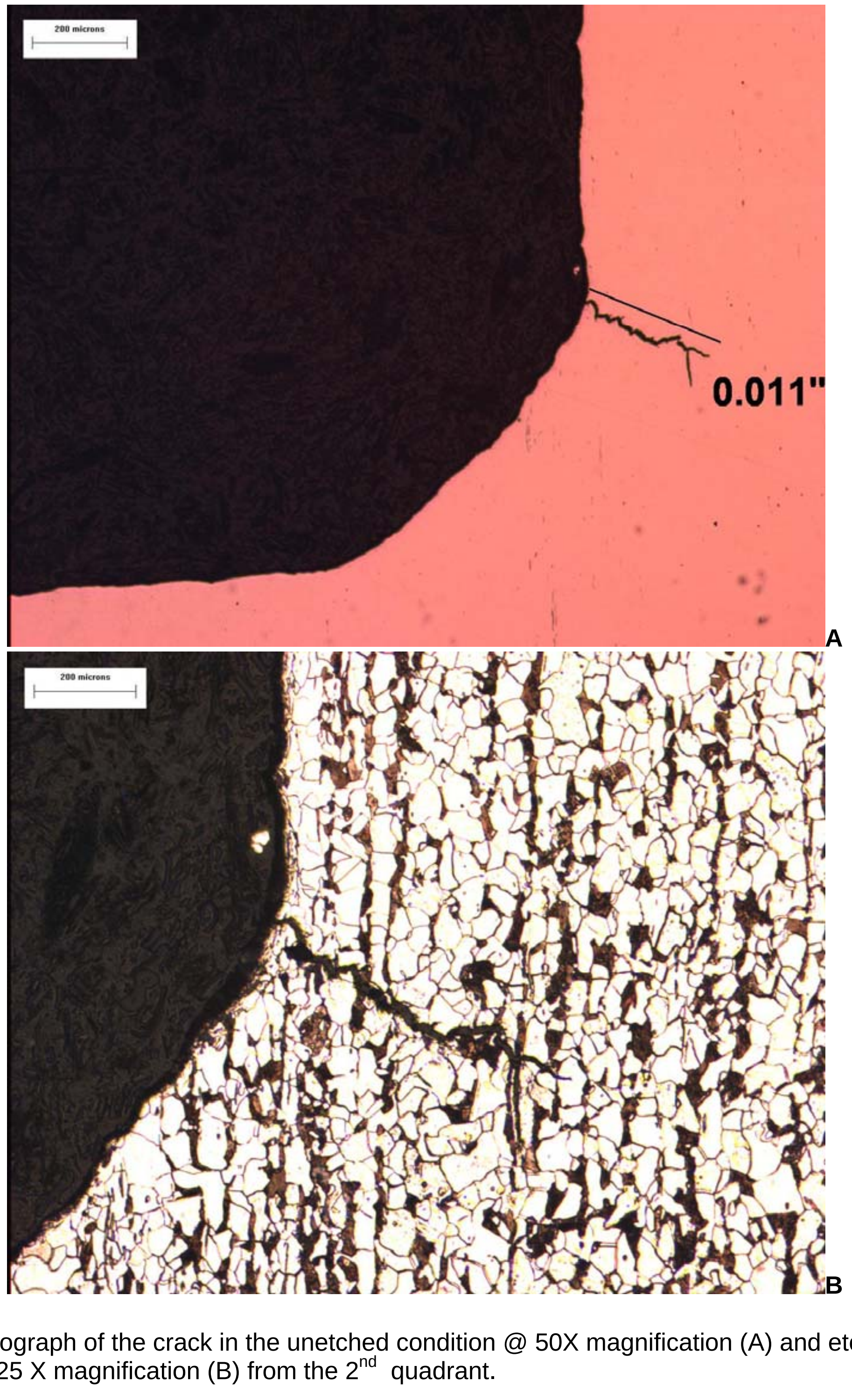
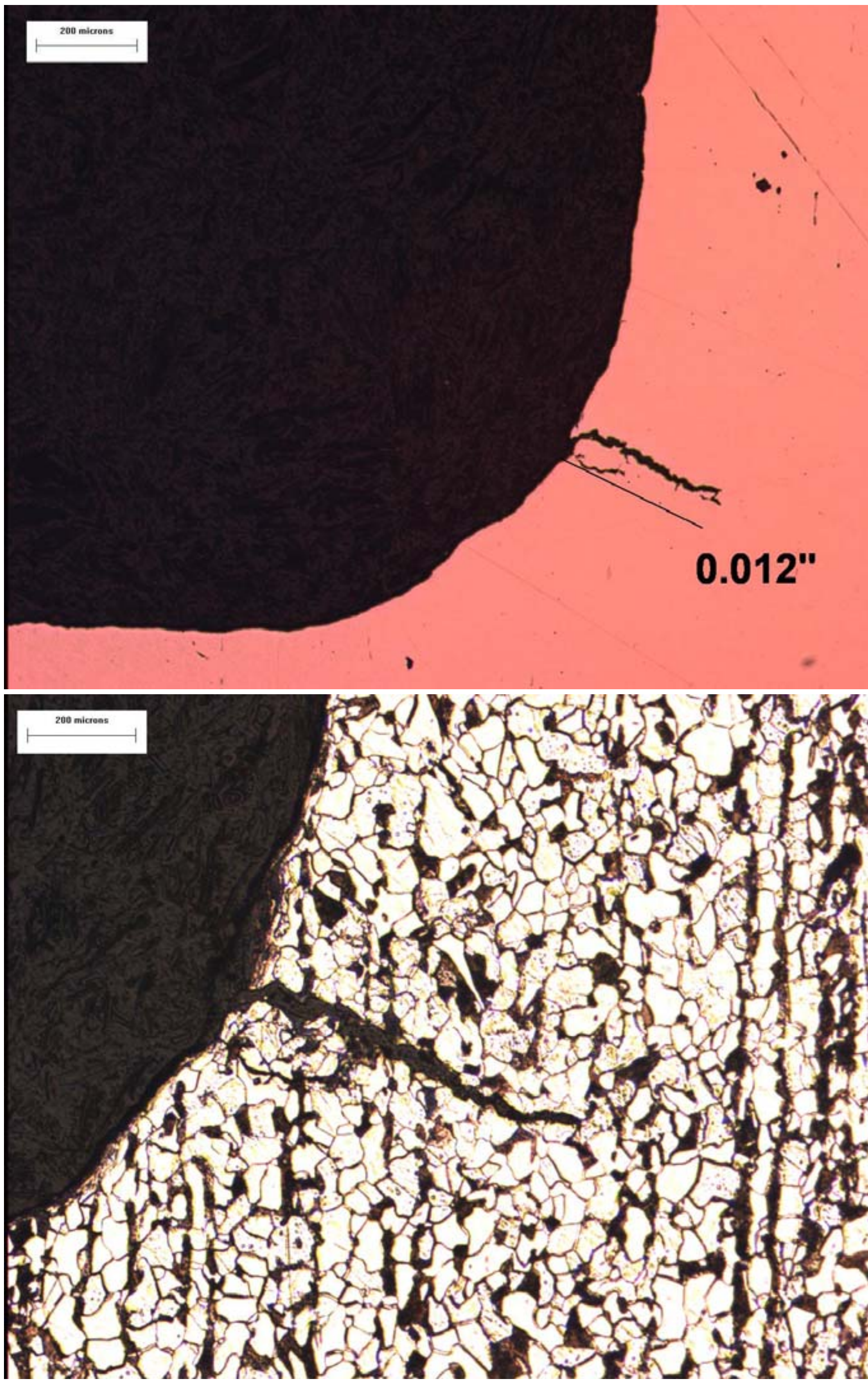


Figure 6: Photograph of the crack in the unetched condition @ 50X magnification (A) and etched condition @ 125 X magnification (B) from the 2nd quadrant.



A

B

Figure 7: Photograph of the crack in the unetched condition @ 50X magnification (A) and etched condition @ 125 X magnification (B) from the 3rd quadrant.

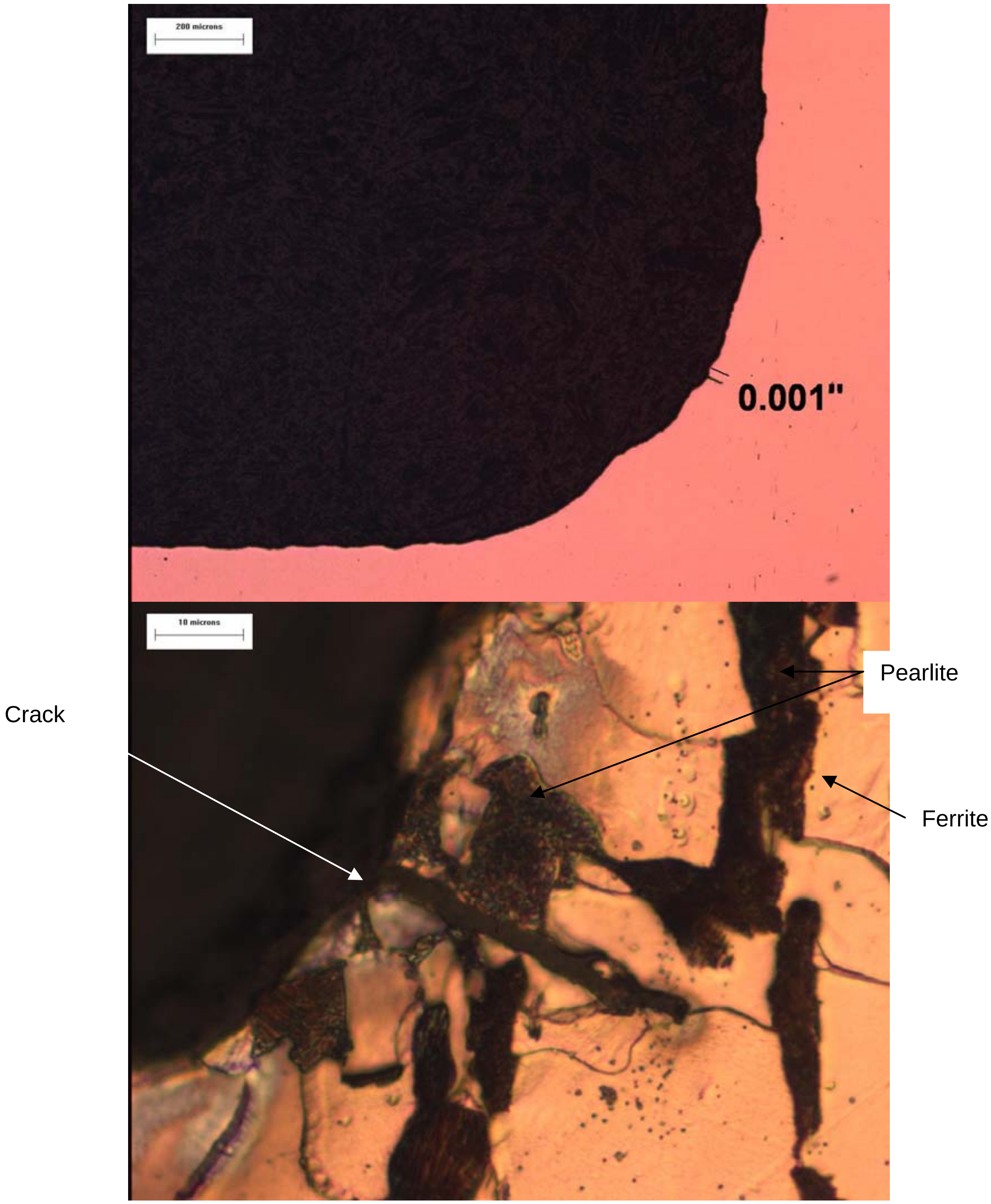


Figure 8: Photograph of the crack in the unetched condition @ 50X magnification (A) and etched condition @ 1000 X magnification (B) from the 4th quadrant.

Please let me know should you have any questions or if I can be of further assistance in this matter.

Report submitted by:

Andrew O. McGehee

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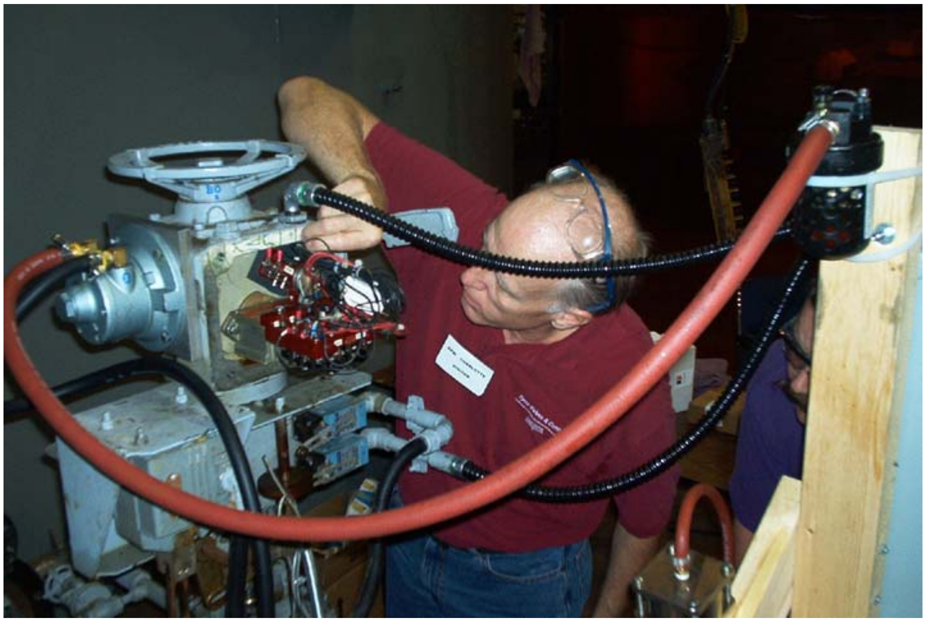
Appendix 6 Test Apparatus Photos



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