Performance of NOREM Hardfacing in Plant Valves: In Situ Application and Leak Rate Testing of Feedwater Check Valves

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Technical Report

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In-Situ Application and Leak Rate Testing of Feedwater Check Valves

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REPORT SUMMARY

The NOREM cobalt-free hardfacing alloy provides outstanding resistance to adhesive (galling) wear. This report describes the first in situ repair of nuclear plant valves using NOREM. In this case, two large 24-in check valves at the Entergy Grand Gulf BWR were refurbished during two recent refueling outages. Local leak rate tests made after the valves were refurbished and after one was in service for an 18-month fuel cycle showed outstanding performance.

Background

Iron-base NOREM hardfacing alloys have been used in more than 400 replacement valves in nuclear power plants. Entergy's Grand Gulf BWR took the lead in refurbishing installed feedwater check valves with NOREM and used local leak rate testing to monitor performance. These valves were selected because they were a significant source of released cobalt and had a history of performing poorly in mandated local leak rate tests (LLRTs). This project applied EPRI-sponsored research which developed welding consumables and procedures to facilitate the use of NOREM in field repairs of installed valves (report TR-107231).

Objectives

- To qualify welding procedures for NOREM hardfacing alloys and apply these procedures in refurbishing two 24-in feedwater check valves.
- To perform LLRTs on the valves following refurbishment and after service.
- To provide "lessons learned" that would facilitate further in situ applications of NOREM and other hardfacing alloys.

Approach

Utility personnel and a valve service organization joined forces to perform the required repair and refurbishing of two 24-in feedwater check valves, F010A and F010B. Activities included machining the existing hardfacing, procuring NOREM metal-core and solid weld wire, and qualifying welding procedures and personnel. The process involved working with a valve mock-up; performing field welding; machining and polishing the deposited hardfacing alloys to final dimensions; and conducting LLRTs in water rather than in air, as had been the case during earlier outages.

Results
During refueling outage 7 (RFO7), NOREM hardfacing was successfully applied on plugs, in-body seats, and three of the four valve guide ribs (specifically, the three ribs that contact the plug during operation) of feedwater check valve F010B. Time constraints forced completion of the refurbishment on F010A to take place during refueling outage 8 (RFO8). This report identifies the factors responsible for the delay and provides detailed recommendations to facilitate subsequent in situ repair or refurbishment using NOREM hardfacing.

The RFO7 LLRT results were 0.6 gallons per minute (gpm) for the F010B valve and 6 gpm for the F010A valve after partial refurbishing. The F010A valve seat was not lapped to the same extent as the F010B seat, which may have contributed to its higher leak rate. After 18 months of service, the RFO8 LLRT result for the F010B valve was 6 gpm. Following completion of work on F010A during RFO8, the measured LLRT was 0 gpm. The maximum acceptable LLRT value for these valves is 7 gpm. Overall, the low measured LLRT values obtained with NOREM hardfacing marked a significant improvement over those measured when the valve was hardfaced with cobalt-base alloys or subsequently modified with a resilient elastomer (“soft seat”). Conducting LLRTs in water rather than air also contributed to the improved performance.

EPRI Perspective
Although delays were encountered, both the utility and the valve service organization concluded that significant progress was made during RFO7, and the lessons learned permitted work during RFO8 to proceed more smoothly. Key lessons learned included the following: selecting welders with above average welding skills and experience in welding hardfacing alloys, using mock-ups to establish proficiency in the means and methods chosen, and developing extensive contingency plans for all phases of the refurbishment. Another important lesson concerned the heat of NOREM hardfacing alloy selected. During RFO7, an earlier heat designated B1 was used; the more “welder-friendly” NOREM 02A was used during RFO8. The majority of welders involved with the project found it easier to work with the solid NOREM 02A weld wire. These lessons learned should prove valuable to any utility planning to perform in situ repair or refurbishment of a large valve, regardless of the hardfacing alloy used.

Interest Categories
Valves
Radiation field control

Key Words
Welding
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Wear resistant materials
Valves

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ABSTRACT

The need to reduce occupational radiation exposure to plant personnel is one of the challenges facing operating nuclear power plants. Significant levels of background radiation have been attributed to the wear and corrosion of cobalt-bearing hardfacing alloys such as Stellite™. These cobalt-bearing hardfacing alloys are typically used in valves and pumps as well as other applications requiring superior resistance to wear and galling.

To support source term reduction, EPRI developed guidelines for cobalt reduction. Furthermore, EPRI developed the iron-based NOREM hardfacing alloy as a substitute for cobalt-based alloys.

Grand Gulf Nuclear Station (GGNS) took a lead role in the application of the NOREM hardfacing alloy. GGNS was the first to apply NOREM in-situ as part of its feedwater check valve repair project. This check valve project utilized NOREM hardfacing instead of Stellite™, and repairs were performed during both the GGNS Refueling Outages Number 7 & 8 (RFO7 - Spring '95, RFO8 - Fall '96).

The RFO7 scope used the NOREM B1 alloy while the RFO8 scope used the latest recommended NOREM formulation, 02A. Many valuable lessons were learned while performing the RFO7 scope. These lessons learned resulted in several improvements for both the machining and welding equipment and processes used successfully in RFO8.

This report discusses the first in-situ application of NOREM and should be helpful to utilities considering the in-situ application of NOREM.

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INTRODUCTION

GGNS used NOREM in the in-situ repair of two large feedwater check valves. These valves had a history of poor LLRT performance and required repair or replacement. NOREM was chosen to support the GGNS Source Term Reduction Program. The project marked the first in-situ repair using the NOREM alloy, and as such, included developing repair plans and procedures for machining and welding NOREM in place.

Purpose

The purpose of this report is to provide detailed information about the in-situ repair of the GGNS feedwater check valves utilizing the NOREM hardfacing alloy. This report documents the path chosen by GGNS from project inception to completion and discusses lessons learned as well as factors that should be considered in the decision making process when applying NOREM or other hardfacing alloys for repair applications.

Project Overview

The Grand Gulf Nuclear Station (GGNS) inboard feedwater check valves, B21F010A/B, had a history of poor local leak rate test (LLRT) performance. These valves are 24" William Powell "y" pattern check valves. Prior to Refueling Outage No. 1 (RFO1), these valves were modified to include a dual seat arrangement including an elastomeric or "soft" seat in addition to the original hard seats. This led to a high maintenance requirement for the valves, the minimum being "soft" seat replacement every refueling outage. No elastomer was found that could withstand the service conditions found during an 18 month fuel cycle.

"Post-service" or "as-found" LLRTs are performed after a valve has been in operation and prior to any maintenance being performed on the valve. During RFO6 "post-service" LLRTs, the test boundary could not be pressurized due to excessive leakage. Valve disassembly revealed that the elastomeric seats were degraded; the seats were replaced and the LLRT was performed satisfactorily.

Subsequently, a Project Team was formed with the mission to provide feedwater check valves capable of adequate leak tightness throughout multiple cycles of operation while minimizing required maintenance. The project scope included hardware modifications to ensure feedwater check valves performed their intended function.

The project team initiated a root cause analysis and determined that misalignment of the seating surfaces was a major contributor to the poor LLRT performance. To correct this wear or degradation of the valve plug and in-body guide surfaces, a plan was developed to rebuild the valves to obtain original manufacturers design dimensions. The project team also recommended the removal of the soft seats and return to the original 'hard seat only' configuration of the valve.

Stellite™ hardfacing was originally used in the F010s seat and guide contact areas. A major component of Stellite™ is cobalt which has been identified as a major contributor to radioactive source term at nuclear plants.

Previous cobalt reduction efforts at GGNS had identified the B21F010s as numbers 9 and 10 on the list of top plant cobalt contributors with a potential dose contribution estimated at 4 rem/year per valve.

Since the project scope required that most of the existing Stellite™ be removed from the valve prior to applying additional hardfacing, the project team decided to utilize NOREM hardfacing instead of Stellite™in the valve rebuild/repair effort.

One valve was completed in RFO7 and the remaining valve was completed in RFO8. Both valves exhibited outstanding "post-maintenance" LLRT performance. Moreover, the valve completed in RFO7 successfully completed its "post-service" LLRT in RFO8.

Cobalt Reduction

Radionuclide source term is a significant contribution to the occupational radiation exposure of plant personnel. This source term is composed of corrosion products that have been activated in the reactor and subsequently deposited on out-of-core surfaces. The major contributor to this long term source of radiation fields is Cobalt-60 (1).

Cobalt-59, the only naturally occurring cobalt isotope, is a major component of Cobalt-Chromium hardfacing such as Stellite™. Such hardfacing alloys were used in various components in nuclear stations because it was felt that the superior wear properties of these alloys outweighed the potential for increased dose rates caused by cobalt releases.

However, as cobalt alloys in a BWR plant wear, Cobalt-59 migrates to the reactor vessel where it adheres to the hot boiling surfaces of the fuel assemblies. The Cobalt-59, exposed to a significant neutron flux, is activated to Cobalt-60. On release from the fuel assemblies by either boiling or depressurization, the activated cobalt migrates to out-of-core surfaces such as recirculation lines where its decay can cause high radiation fields.

The primary source term on the recirculation lines at Grand Gulf Nuclear Station is Cobalt-60 (2). Similarly, PECO staff has estimated that 60% of the entire annual dose can be attributed to just two tablespoons of Co-60 (3). Clearly, cobalt reduction and control supports nuclear power plant's "as low as reasonably achievable" (ALARA) goals and requirements.

A majority of the research on cobalt reduction techniques has been sponsored by the Electric Power Research Institute (EPRI). To assist utilities in cobalt reduction efforts, EPRI presented EPRI NP-6737 Cobalt Reduction Guidelines Rev. 0 (March 1990) and EPRI TR-103296 Cobalt Reduction Guidelines Rev. 1 (1). These reports provide a strategy for identifying and quantifying the sources of cobalt. These reports indicate the replacement of valves or valve parts solely for reasons of cobalt reduction may not be practical or cost effective. However, they suggest cobalt-free hardfacing be considered when identified candidate valves are refurbished or replaced for reasons other than cobalt-reduction (1).

To support cobalt reduction, GGNS developed an engineering report (2) to identify the numerous contributors of cobalt to the GGNS reactor vessel. In general, the GGNS methodology followed the suggested EPRI techniques and concluded the primary source of cobalt entering the GGNS reactor is due to valve hardfacing. Furthermore, the major valve contributors were identified and ranked according to their potential for cobalt contribution. The GGNS inboard feedwater check valves were ranked in the top 10 on this list.

Meanwhile, GGNS had also developed an engineering report (4) to evaluate cobalt-free alloys for use in valves. This report concluded that, based on data accumulated, NOREM possesses physical and mechanical properties which meet or exceed those of Stellite™ for nuclear service at GGNS.

Need for Project

During the GGNS Refueling Outage 6 (RFO6), "post-service" local leak rate testing (LLRT) was performed on the reactor feedwater system containment isolation check valves, B21F010A/B. Both valves had excessive leakage and were declared inoperable. Disassembly of the valves revealed degradation of the resilient elastomeric seats. The valves were reworked and retested satisfactorily. However, the valves remained inoperable pending an engineering evaluation.

This engineering evaluation concluded the resilient seats could not be relied upon to provide a leak-tight seal throughout an entire cycle of operation. Additional analysis was performed to demonstrate functionality of the feedwater check valves during cycle 7 and a justification for continued operation was developed (5). GGNS formed a cross functional project team with the mission of providing feedwater check valves capable of providing adequate leak tightness through multiple cycles of operation while minimizing required maintenance. The project scope included: replacing the valves or providing hardware modifications to ensure the feedwater check valves performed their intended function; change the LLRT test medium from air to water (if possible) and provide acceptable testing criteria; and support cobalt reduction goals.

The remainder of this report chronicles the development and evolution of the GGNS feedwater check valve project which culminated in the first in-situ application of the NOREM alloy.

2

PROJECT DEVELOPMENT AND DESIGN

Root Cause Analysis

One of the initial efforts of the project team was to have a formal Root Cause Analysis performed. As shown in Tables 3-1 and 3-2, investigation of the F010 valves LLRT performance history revealed a history of poor leak rate performance. The F010 valves are 24″ William Powell "y" pattern or plug type check valves originally manufactured in a hard seat only configuration. At GGNS, these valves are installed horizontally and rely on gravity and pressure drop across the valve to seat the plug.

Pre-RFO1, the valves were tested during a forced outage. Neither valve's test volume could be pressurized. During this outage, the valves were modified to include a dual seat arrangement including a resilient elastomeric or "soft" seat in addition to the original hard seats. This modification was implemented to improve LLRT test performance. At that time, the LLRT was performed using air as the test media. The soft seat enabled the valves to have good "post-maintenance" LLRT performance. However, no elastomer was found that demonstrated multiple cycle performance. As a precautionary measure, the valves were disassembled and the soft seats replaced each outage, with "post-service" LLRT requirements every third outage (RFO1, RFO3, RFO6). In addition to reviewing the LLRT performance, the root cause team interviewed maintenance personnel, reviewed maintenance practices and evaluated design application considerations.

The root cause analysis (5) concluded the root causes of the poor LLRT performance were:

1. Valve design less than adequate - the original selection of a plug check valve for the F010A/B was not an optimum choice. The inherent limitations of this type of valve make it difficult to obtain a leak tight seal in a 24″ application. Also, the original design specification required a hydrostatic valve seat test, not a pneumatic test. It was not specified that the valves would be required to pass stringent leak test requirements using air as the test medium.

   The orientation of the F010 valves in the piping system causes the plug guide rings/ribs to wear unevenly. With these valves installed in a horizontal piping run, the plugs are oriented 45 degrees between horizontal and vertical. This orientation puts the weight of the plug on the lower guide ribs, causing friction and wear at the guide ring/rib interface. Wear on the guide ring/ribs results in excess clearance, allowing the plug to cock and move off the upper edge of the valve seat. The ideal valve orientation would be for the centerline of the plug to be vertical, which would reduce friction/wear on the guides, and allow the weight of the plug to aid in seating.

2. The valves had worn and required maintenance - prior to RFO6, the importance of maintaining internal clearances within the manufacturer's tolerance was not fully considered. The use of soft seats on these valves tended to mask slight misalignment problems during maintenance and testing. As a result, misalignment problems had not been fully addressed.

   Given the limitations of the F010 "y"- globe design, and the existing orientation in the piping system, maintenance of critical clearances within specified tolerances from cycle to cycle is very important. Over time, gradual degradation of guide surfaces on the plug and valve body will occur. Internal clearances must be reestablished before this wear contributes to poor valve performance caused by misalignment.

   Although not identified as a cause of failure, a primary concern raised during the root cause analysis was LLRT methods. This subject is discussed further in Section 7 of this report.

Table 2-1
1B21F010A - Maintenance/LLRT History

DATE	LLRT RESULT	RFO	LEAK RATE (SCCM)	COMMENTS
8/29/84		PO	12,318	Used to establish acceptance criteria.
10/17/85	F	FO	Unknown	Test volume could not be pressurized for test. Replaced plug with modified plug having resilient seat. Resilient seat material installed was SR 740-70.
10/27/85	P	FO	59	Forced outage "post-maintenance" retest.
9/18/86		1	1,234	As found leakage satisfactory.
12/8/87		2	9,600	Replaced the resilient seat with material type E692-75.

Table 2-1
1B21F010A - Maintenance/LLRT History

DATE	LLRT RESULT	RFO	LEAK RATE (SCCM)	COMMENTS
3/26/89	F	3	Unknown	Test volume could not be pressurized. Inspection of valve internals found lower guide to be worn and resilient seat to be broken and brittle. Replaced resilient seal (SR 740- 70 installed) and weld repaired guide.
4/9/89		3	61	Retest after replacing resilient seat.
10/9/90		4	Unknown	Inspected valve internals. Inbody guides, disc guides, and resilient sea were satisfactory. Resilient seat material installed was SR 740-70. Could not pressurize test volume.
10/10/90		4	302	Retest after replacing resilient seat.
5/3/92		5	50	Retest after soft seat replaced with SR 740-70 material. Damage to previous resilient seat, if any, was not noted. This test was for information only. A temporary cap was installed for plug adjustment.
5/4/92		5	179	Final RFO5 "post-maintenance" retest.
10/1/93		6	Unknown	"post-service" test volume could not be pressurized. Performed internal inspection. Resilient seat acceptable but replaced with SR 740-70. Wear noted on the disc guides. Weld repair performed.
10/14/93		6	40	Final RFO6 "post-maintenance" retest.

Table 2-2
1B21F010B - Maintenance/LLRT History

DATE	LLRT Result	RFO	LEAK RATE (SCCM)	COMMENTS
8/14/84		PO	13,520	Retest after lapping disc plug and seat and machining cap seal. Water test also performed with no leakage observed. Used to establish acceptance criteria.
10/19/85	F	FO	Unknown	Test volume could not be pressurized for test; Replaced plug with modified plug having resilient seat. A visual inspection was performed on the valve internals with satisfactory results. Resilient seat material installed was SR 740-70.
10/25/85	P	FO	814	Forced outage "post-maintenance" retest.
9/21/86	F	1	Unknown	As found, test volume could not pressurized due to resilient seal deterioration - replaced resilient seat.
10/3/86	P	1	8520	Retest after replacing resilient seat with SR 740-70 material.
11/27/87		2	0	Retest after replacing the resilient with E692-75 material. No damage to the previous resilient seat identified.
4/1/89	F	3	Unknown	Test volume could not be pressurized. Inspection of valve internals found lower guide to be worn and resilient seat to be broken and brittle. Replaced resilient seal and weld repaired guide (SR 740-70 installed).
4/10/89		3	80	RFO3 retest.
10/18/90		4	0	Retest after replacing resilient seat, inspected valve internals noting damage to resilient seat in one area approx. ½"long. Installed SR 740-70 material.
4/27/92		5	9115	Retest (information only) after resilient seat replaced with SR 740-70 material. Inspected valve internals noting minor guide wear. Plug was rotated 180 degrees during installation.
4/28/92		5	210	Final RFO5 retest after resilient seat replaced with SR 740-70 material.

Table 2-2
1B21F010B - Maintenance/LLRT History

DATE	LLRT Result	RFO	LEAK RATE (SCCM)	COMMENTS
10/18/93		6	97,208	As found test. Resilient seat missing in three places. Wear noted on disc guides. Weld repair performed.
10/29/93		6	0	RFO6 retest.

Project Study/Scoping

A project scoping report was prepared to examine modification options to F010A/B which could eliminate the problems identified as the root cause of the LLRT failures. As part of this effort, an industry survey was performed with the objective of maximizing feedback from industry experience. Of the fifteen BWR plants surveyed, most had problems with valves in this application. This survey is presented in Appendix A.

Although the exact nature of industry softseat failures is not readily available, the use of soft seats in feedwater application for BWRs with feedwater temperatures above 400°F has provided inconsistent LLRT results. None of the plants surveyed were currently utilizing "y" pattern check valves with soft seats. Three of four other plants utilizing a dual seat design and experiencing significant softseat degradation had returned to a hard seat only configuration. The majority of the plants utilizing soft seats were using Stillman SR740-70 or Parker E692-75 material. GGNS had originally used Stillman SR740-70 (18 month qualified life) as the soft seat material. This material was subsequently replaced with Parker E692-75 because of its longer qualified life of six years. The soft seat material was changed back to Stillman SR740-70 due to as-bad or worse degradation experienced with the Parker material.

As part of this study, a material search was conducted to identify a suitable substitute for the SR740-70 and E692-75 materials. However, no suitable alternative was found for this application. The study concluded that GGNS should remove the soft seat in feedwater valve applications and return to a hard seat only configuration. The basis of the recommendation was the lack of consistent industry LLRT results with softseats following a cycle of operation. This was reinforced by GGNS experience with the Parker E692-75 and Stillman SR740-70, materials which remain the most suitable softseat materials for use in feedwater applications. This recommendation was accepted realizing that maintaining internal valve clearances and ensuring proper seat/plug alignment is critical to the hardseat only configuration.

Alternatives Considered

The alternatives considered to address the valves' misalignment/wear issue included replacing the valve and rebuilding/modifying the valve in place. Two options were considered for the valve replacement alternative. One option was to continue to use a "y" pattern check valve but reduce the size of the valve to ensure the disc/plug is held in the full open position. Physical inspections of the valves seemed to indicate excessive movement of the plug during operations were contributing to the valve wear. Wear patterns suggested this plug movement was rotational in nature and/or slight axial movement. This option was not considered further since it does not address wear at low flow and would be as costly as changing to a different valve design which would be a better technical solution. The second option was to install a different type of valve with better operating experience at similar plants. This would include swing check valves and nozzle check valves as well as power operated or assisted valves. The most promising candidate was to replace the current valve with a swing check. Although technically desirable, the disadvantages of this option included high project cost (estimated at $1,000,000 per valve) and long lead times (30 to 36 weeks for the valve). Furthermore, the F010s are located underneath the Main Steam Isolation Valves and are not readily accessible. The project team did not consider replacing the valve a viable option due to project schedule constraints (valve modifications or replacement had to occur during the next scheduled outage), the long lead time and tremendous cost associated with the new valve purchase, engineering and installation.

In addition to returning the valve to original manufacture's design dimensions, several other modifications to the existing valve were considered including: (1) changing the guide material; (2) adding a disc/plug spring; (3) adding or modifying the plug upper stop; (4) re-orienting the valve; (5) lowering the plug weight; and (6) widening the bottom guide rib. Widening the lower guide rib to better support the disc/plug weight and improve seat approach geometry. Widening the bottom guide rib (see Figure 2-1) was the most feasible and effective modification in terms of eliminating the apparent source of wear by reducing the per-unit friction force on the plug/guide ribs and thus reducing the wear on both the guides and plug ring. Further analysis indicated that widening the bottom valve guide would not significantly effect the valve Cv and flow velocities. However, the project team realized the installation of wider guides did not address or solve the potential valve flutter problem. Additional analysis by William Powell showed the plug should be fully open (no flutter) at normal operating conditions. Based on this information, the project team did not pursue a modification for an upper stop on the plug.

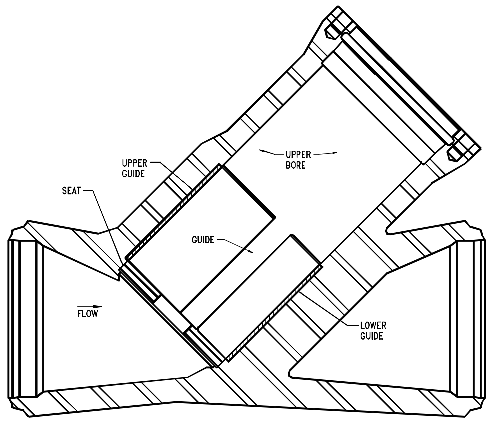

Figure 2-1 F010 Valve

Changing the guide material to a more wear resistant material would also increase the life of the disc/plug and body guides. However, the current guide material was Stellite™ #21, one of the industry's most wear resistant materials. While using a more wear resistant material, Stellite™ #6, was feasible, the increase in wear life would not be significant. If Stellite™ were used, increasing the guide width would have added to the cobalt inventory. As previously discussed, an engineering evaluation had concluded that EPRI's cobalt-free NOREM material would perform as good if not better than Stellite™. Therefore, the project team recommended utilizing NOREM hardfacing in the F010 valve modifications.

Disadvantages of in-situ modifications include extensive man-hours in a cramped high dose area. However, project cost for the modification/rebuild option was about 1/2 the cost of the replacement option.

Cost/Benefit Analysis

Initial project planning efforts had assumed that all existing Stellite™ should be removed prior to applying any new hardfacing. Based on this plan and the particular construction strategy chosen for the GGNS project, little incremental cost was associated with utilizing NOREM. The GGNS project required extensive use of automatic/remote welding machines. GGNS did not have this equipment and did not have automatic welding procedures in place for either NOREM or Stellite™. However, a cost/benefit analysis should be performed on a project-by-project basis and will vary significantly by utility. For instance, if in house personnel are to be used for welding and the utility has Stellite™ welding procedures and no NOREM welding procedures, then a major incremental cost of utilizing NOREM could be developing weld procedures and qualifying in-house personnel. However, this expense might be justified depending on individual utility plans. Also, EPRI has provided guidelines to assist in preparing NOREM welding procedures (6). On the other hand, if a field services contractor is to be utilized, then a contractor could be chosen with NOREM welding procedures in place, resulting in no incremental cost.

Another factor that should be considered is that a new layer of Stellite™ can be field welded over existing Stellite™. Although not ideal, this has been successfully accomplished after cleaning up the existing surface by machining a weld prep (removing 0.030" of existing). Therefore, if all the existing Stellite™ is not removed, the incremental cost associated with utilizing NOREM increases based on the cost of additional man-hours and dose received by personnel. These costs are offset by avoided cost from future personnel exposure reduction achieved by removing cobalt. GGNS values person-rem saved at $10,000 per person-rem. The use of NOREM in the F010 valves was estimated to save 8 person-rem annually. The present valve of total estimated savings was $656,558 calculated using a 3.5% per year escalation on the savings, a 11% discount rate and considering 20 years of plant operation.

Design Change Documents

A design change package (DCP) was developed to widen the lower valve body guide, to remove the soft seats from the plug, and to allow NOREM hardfacing. The DCP was written to allow either NOREM or Stellite™ hardfacing to be utilized. A Final Safety Analysis Report (FSAR) change/update was performed since NOREM was an additional metal that would come in contact with the reactor coolant.

3

FIELD IMPLEMENTATION STRATEGY

Project Team Organization & Division of Responsibility

The F010 project scope required specialized machining equipment, welding equipment and expertise. GGNS did not have automatic welding equipment and associated welding procedures for carbon steel, stainless steel, Stellite™ or NOREM. Furthermore, suitable portable machine tools were not on site and no site personnel had experience welding or machining NOREM.

GGNS did have skilled machinist and welders that could support the project. However, it was cost and schedule prohibitive to purchase required welding and machining equipment and to develop suitable welding procedures. Clearly, some form of contractor support would be advantageous. Three options with varying degrees of contractor involvement were considered: (1) select a contractor to perform all welding and machining; (2) GGNS forces to perform machining, select a contractor to perform welding activities; and (3) select a contractor to provide welding procedures, train GGNS personnel to these welding procedures, provide required welding and machining equipment, provide technical oversight of field welding and provide machining personnel to augment GGNS forces. For all options, GGNS would perform all valve disassembly and re-assembly with craft personnel familiar with the F010 valves.

Due to strong support from the maintenance department, option 3 was chosen. This maximized utilization of GGNS maintenance personnel without having to develop weld procedures or purchase remote welding equipment or portable machine tools. This unique project implementation strategy was utilized for the RFO7 scope.

Anchor/Darling Field Services was selected to support the project due to their field service experience and NOREM welding expertise. Anchor/Darling was recognized as a pioneer in applying NOREM hardfacing in the manufacturing of new valves. Cooperheat was chosen to provide induction heating services required for preheat. The project team logo is shown in Figure 3-1.

Responsibilities were as described for option 3 above, namely GGNS was responsible valve disassembly, re-assembly, testing and machining lead. Anchor/Darling supported machining activities by providing portable machining equipment and four machinists for staff augmentation. Anchor/Darling was responsible for welding lead and oversight. This included qualifying GGNS welders to Anchor/Darling's welding procedures, providing welding equipment and supervision, as well as providing the repair plan and technical assistance.

Since the RFO7 scope was the first in-situ application of NOREM, a full scale mockup of welding and machining activities was planned. As a RFO7 contingency, Stellite™ was procured and personnel qualified to Stellite™ welding procedures. This contingency was developed since there was no in-situ NOREM experience at that time. This contingency was not pursued for the RFO8 scope of the project. With experience gained to date, this contingency is probably not necessary for current projects.

Due to tight schedule constraints, it was imperative that work activities at the valve proceed around the clock during the scheduled window of opportunity. However, due to the nature of working in the drywell, personnel could not work continuously for one shift. Therefore, each shift was organized with two crews. These crews rotated in and out of the drywell in teams of two each to keep work activities proceeding at all times. Crew mix for each shift included one GGNS maintenance supervisor and one Anchor/Darling Welding Supervisor, four welders, four machinists, two pre-heat technicians and one QA specialist. Additional support was provided by GGNS Project and Maintenance Management and an Anchor/Darling Field Engineer.

Option 1 was chosen for the RFO8 implementation strategy due to internal manpower constraints and the limited scope of work. Changing to NOREM 02A would have also required re-qualification of the GGNS welders.

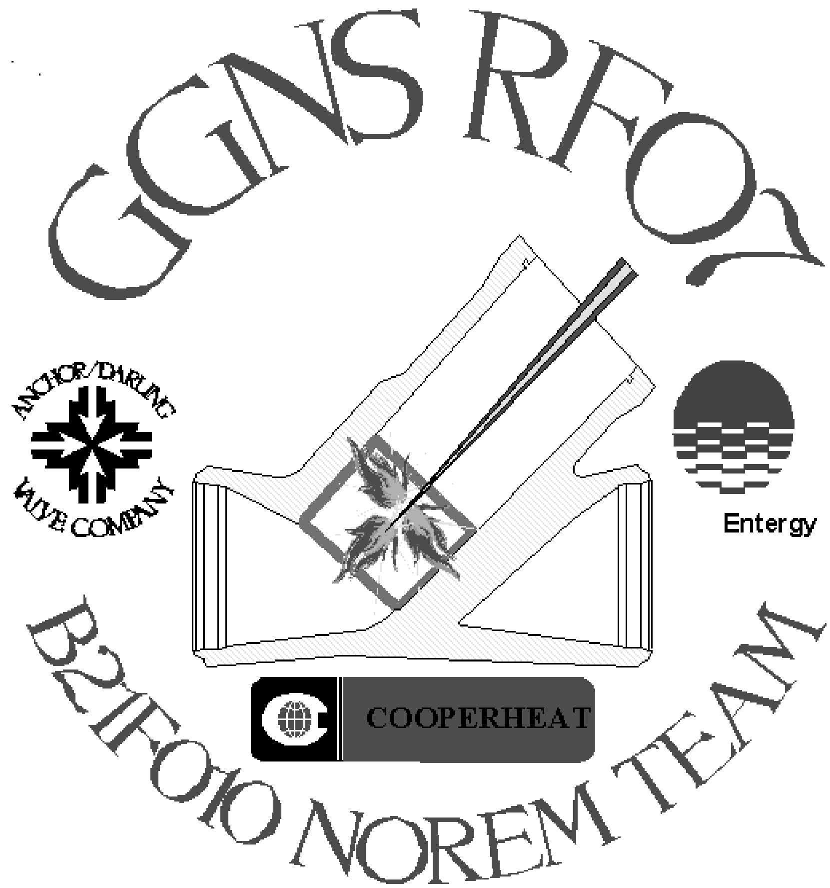

Figure 3-1 GGNS Implementation Team

ASME Code Considerations

Increasing the bottom guide width was to be accomplished by a weld build up approximately ¾ inch by 18 inches on each side of the guide. A review of the ASME Boiler and Pressure Vessel Code (the applicable code) suggested a weld build up greater than ¾" would require post weld heat treatment (PWHT) and the present code clarified this requirement. In-situ PWHT was not desired on this large valve.

Since the valve guides are integral to the valve body, all work to the valve was considered to be a ASME Section XI repair. Based on the implementation strategy chosen, Anchor/Darling was the repair organization under Section XI for all F010 welding activities.

Wear-induced hardfacing cracking had been accepted as characteristic cracking of hardfacing and allowed to remain if the crack was limited to the hardfacing layer only and did not hinder valve function. Code research was performed to see if a crack that developed while applying NOREM on a valve guide could be accepted using the same acceptance criteria as "wear-induced" cracks. This was not acceptable. All indications found during repair/rebuilding activities were evaluated using the criterion that any crack (linear indication) was unacceptable.

Quality Assurance (QA) Considerations

The Anchor/Darling contract gave them control of assignment and removal of GGNS welders from work activity. Since they were the repair organization, Anchor/Darling prepared the welding repair plan and Anchor/Darling QA controlled all welding activities. Since GGNS welders were to be used in the welding process, Anchor/Darling qualified them to the A/D procedure and maintained their qualifications under Anchor/Darling's welding performance and maintenance (continuity) procedure.

Initial work control for valve disassembly and machining was performed under a GGNS work package under GGNS QA control. Control passed to the Anchor/Darling repair plan until welding was complete at which time GGNS assumed control under a GGNS work package for final machining and assembly. This interface and overlap of people and processes is cumbersome and complicated and required extensive coordination.

Appropriate non-destructive examination (NDE) requirements were determined to be magnetic particle testing for original base metal surfaces and liquid dye penetrant testing for all welds performed during the course of the project. Acceptance criteria for any flaw indications was per the construction code.

The GGNS site Authorized Nuclear Inspection (ANI) provided ANI support for the project as needed.

Wire Procurement

As the repair organization, Anchor/Darling was responsible for all weld wire procurement including carbon steel, 309L stainless steel and NOREM. As a contingency measure, Stellite™ was also procured.

Table 3-1 presents chemical analysis of the NOREM B-1 hardfacing utilized during the RFO7 project scope. Both Cor-Met and Polymet wire was utilized in the project. The Cor-Met formulation uses atomized powder in a Type 420 stainless steel core wire, while Polymet provides a solid wire. These different formulations require different welding machine parameters and were not used interchangeably (i.e. , were not mixed). The majority of the welders favored welding with the Polymet wire. NOREM B-1 is Anchor/Darling's designation for EPRI's earlier 01 designation.

Subsequent to RFO7, additional development by EPRI led to the development of the NOREM 02 and NOREM 02A formulations. These formulations showed improved weldability, even with little or no preheat. EPRI recommends the 02 formulation for PTAW in the shop and the 02A formulation for GTAW application. The chemistry of the formulations is essentially the same except 02A has a lower nitrogen content.

EPRI reports the key factors involved in producing crack-free weldments without preheat as: high quality welding products, sound substrates, moderate heat input, consistent travel speed to control cooling rates, welders familiar with welding hardfacing alloys, and possessing above average welding skills (6).

Table 3-1
RFO7 NOREM B-1 Chemistry

Chemical Analysis (wt %)

ELEMENT	COR-MET	POLYMET	TARGET
C	1.18	1.14	0.80-1.4
Mn	4.43	4.99	4.0-6.5
Cr	25.49	25.16	24.0-26.0
Si	3.14	2.72	2.5-3.5
Ni	3.85	5.61	3.0-6.0
Mo	2.20	2.09	1.5-2.5
N	0.16	0.10	0.05-0.20
Fe	Bal.	57.9	Bal.
P	0.017	0.012	<0.018
S	0.009	0.003	<0.015
Co	0.023	0.023	0.05 max
B	<0.002	0.003	0.005 max
Cu	0.051	<.05	<0.1
Other	-	-	-
Rockwell C	41	37	35 min

Table 3-2 presents EPRI's recommended NOREM 02A product specification (6). Table 3-3 presents the chemical analysis of NOREM 02A utilized by GGNS during the RFO8 scope. As can be seen, the Si and N content is slightly off spec. However, the formulation was accepted based on its similarity to the NOREM B1 chemistry which had performed satisfactorily in the past.

Table 3-2
NOREM 02A Specification For GTAW and PTAW Products [1,2]

ELEMENT	RANGE (3)	AIM
C	1.10 - 1.35	1.25
Mn	4.0 - 5.0	4.5
Cr	23.0 - 26.0	24.0
SI	3.1 - 3.5	3.3
Ni	3.7 - 4.5	4.0
Mo	1.8 - 2.2	2.0
N	0.06 max	
Fe	Bal	
P	.020 max	
S	.010 max	
Co	.05 max	
B	.002 max	
O	<200ppm	
OTHER	0.50 max Total	

[1] All products shall be free of lubricants and "white-glove" clean.

[2] Hardness of undiluted weld metal pad shall be a minimum of 36 Rockwell "C".

[3] The "range" has been established for product fabricators and is based on a seven layer (approx. ½ -in. thick) deposit. Chemistry evaluation by users should be performed in the same manner.

Table 3-3
RFO8 NOREM 02A

Chemical Analysis (wt %)

ELEMENT	NOREM 02A
C	1.28
Mn	4.36
Cr	23.79
Si	2.85
Ni	4.02
Mo	2.18
N	0.078
Fe	Bal.
P	0.018
S	0.004
Co	0.003
B	0.001
O	0.003
Other	-
Rockwell C	36

All wire procured for the automatic GTAW process was 0.045 inch diameter wire. Both the NOREM B1 and NOREM 02A performed satisfactorily, however, the NOREM 02A did exhibit improved weldability.

Contingency Plans

Murphy's law states what could go wrong often will. Proper planning includes identifying what could go wrong and developing a contingency plan for each scenario. A useful tool is a contingency diagram. Ask the question, what could go wrong with or what would happen if?

- Equipment failures occur
- Power failures occur
- High radiation fields are encountered
- Airborne contamination occurs
- Air supply fails
- Personnel fatigues
- Personnel need a leave of absence during critical job evolutions
- Internal valve erosion is found
- Valve disassembly/re-assembly problems occur
- Other projects and activities impact your project schedule
- Valve fails LLRT

Of course this list is not all inclusive and will vary from project to project. Successfully completing a project often depends on the depth and adequacy of contingency plans. Spare parts, backup equipment, etc. are expensive but are becoming a must to support today's short outage schedules. Proactive identification of obstacles and avoiding them or quickly resolving them is mandatory. Every hour counts for projects on or near the outage critical path schedule.

One RFO8 contingency was the possibility of finding service-induced NOREM cracks in the valve body or plug seat. Such service-induced cracks are characteristic of all hardfacing and are of little concern if the crack does not propagate into substrate materials or impact valve performance. GGNS had previously performed engineering studies to develop this basis for accepting Stellite™ service-induced cracks.

As a contingency plan, GGNS investigated NOREM cracking in weld coupons to demonstrate that impact-induced cracks stop at the 309L butter layer. GGNS has also developed eddy current NDE procedures to determine the depth of cracks in NOREM weld overlays. No such cracking was observed during RFO8 inspections. However, these data will be useful in evaluating any service-induced cracking that might occur as the valves age.

Logistics

The complexity of the F010 project required input and support from every department at the GGNS site as well as several off-site departments. The project also required several contractors. Ensuring that personnel and equipment are at the right place at the right time and ready to work was part of the project's overall implementation plan. The following list is far from being all inclusive but point out a few things that should be double checked for projects similar to the F010 project:

- Power up and check all equipment to ensure no damage was sustained during shipping.
- Stage all equipment for quick deployment
- Projects in cramped spaces such as the drywell compete for space for equipment and personnel. Coordinate with other projects in your work area. Plan where all equipment will be located.
- Limit the amount of equipment that must be transported into the drywell. A temporary platform built over the suppression pool is a good place to locate argon bottles, preheat equipment, standby air compressors, etc.
- Ensure obstacles such as handrails, duct, and grating insulation are removed.
- Verify that electric power, air, and lifting services are available in the work area.
- Ensure that back-up welding, machining, and heat treating equipment is available for immediate deployment.

4

FIELD EQUIPMENT

Machining Equipment

The GGNS F010 valve bodies are basically identical to the valve bodies of globe valves utilized as Main Stream Isolation Valves (MSIV) throughout the industry. Therefore, many of the tools developed for MSIV rebuild were appropriate for the GGNS feedwater check valve project. One such tool was the Climax Model 1572 portable MSIV machining system. Manufactured by Climax Portable Machine Tools, Inc., this machine is capable of machining the in-body seat, guide ribs, and pressure seal areas of "y" pattern valves. This machine features an adjustable tool head (for cutting at any angle), and a grinder/polisher mounted on a boring bar which rotates through a 360° arc. The boring bar is driven by a rotational drive unit which utilizes a hydraulic motor. A pneumatic motor powers the axial feed system.

The Climax portable MSIV machining system, shown schematically in Figure 4-1, was the primary machining system chosen for in-situ machining. One major consideration of both machining and welding equipment was equipment footprint requirements for rigging, setup and operation due to the tight work space in the area of the F010 valves. As shown in Figure 4-2, the F010 valves are located under a MSIV and in close proximity to structural supports. The physical constraints of this location made installation and setup of field machining equipment difficult. In fact, a computer animation of the MSIV machine installation was performed by Climax staff to determine if the MSIV machine tool could be installed given the configuration shown in Figure 4-2.

This simulation demonstrated that the Climax Model 1572 MSIV machine tool could indeed be installed in the cramped project work environment. This was further verified during mockups performed in the abandoned GGNS Unit II (Figure 4-3).

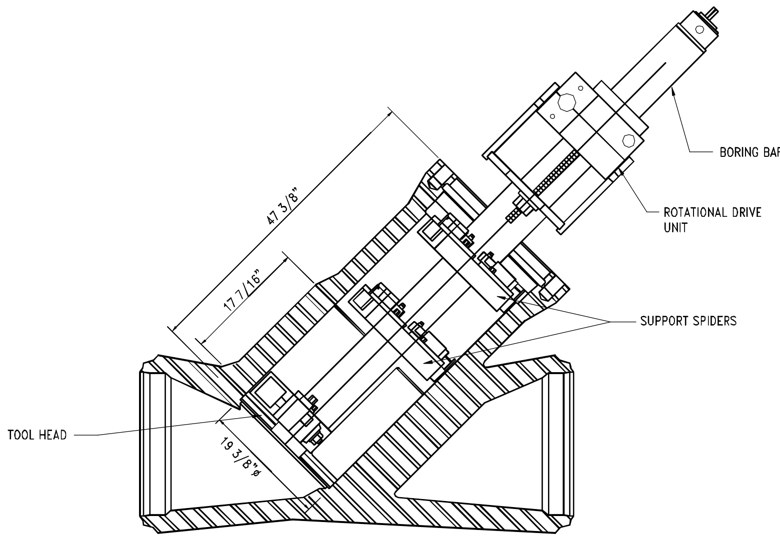

Figure 4-1 MSIV Machine Tool Schematic

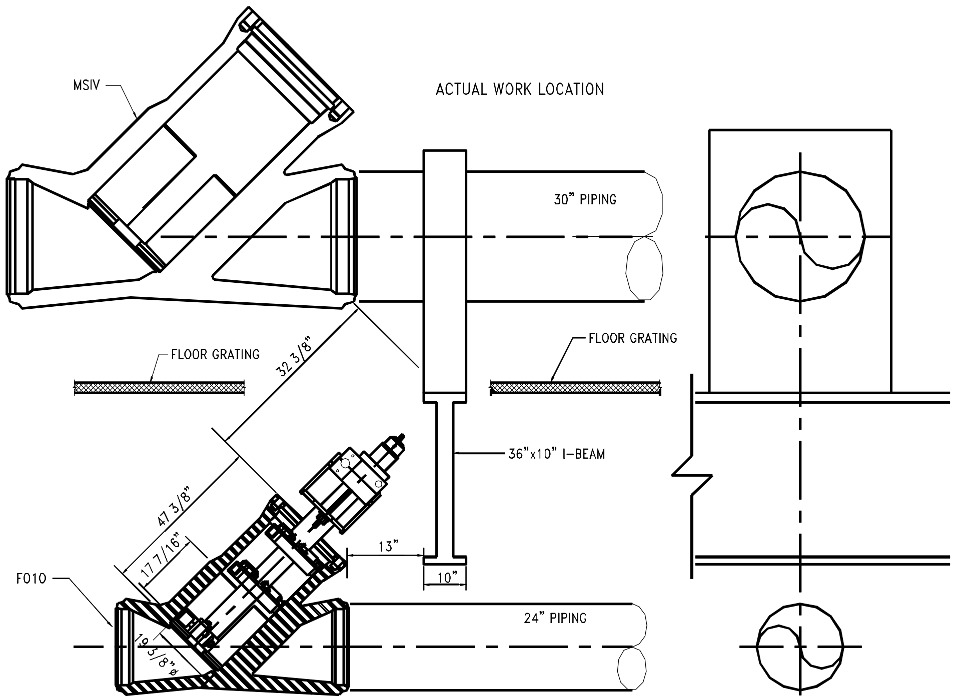

Figure 4-2 F010 Valve Location/ Work Area

Figure 4-3 RFO7 Machining Mockup

Since this was the first in-situ application of NOREM, part of the machining mockup focused on selecting tooling inserts. Based on work performed at EPRI's Repair and Replacement Applications Center (RRAC), NOREM machined similar to Stellite™ 6. Test trials performed in 1987 resulted in the recommendation of carbide insert tooling designed for machining cast iron and hardened cast steel (7). Machine tool materials falling within this classification include the industry standard "C2 through C4" types. These grades in a design with no chip breaker, a negative rake, large nose radius and thick cross section were assumed to be the best performers for interrupted machining of Stellite™. The specific recommendation for material grade was a Sandvik GC-3015 (or GC-415) or Kennametal KC990 (or KC9025). Recommended machining parameters were a 0.030" to 0.065" cut depth and a feed rate of 0.006" to 0.008" per revolution.

These recommendations for Stellite™ were the starting point for testing and trials to determine the optimum tool insert for machining NOREM.

As will be discussed later in detail, the machining required during the F010 project involved several steps. These steps required multiple machine set ups to remove existing Stellite™, machine weld preps for the NOREM and final machining of the NOREM. To support the tight schedules of today's short outages, all work activities must be scrutinized to ensure each activity's duration is as short as possible. With this in mind, the Climax MSIV machine seemed a little slow in removing the existing Stellite™ from the in-body guide ribs. The boring bar was capable of a 0.035" cut at a rate of about 12 minutes/inch. This machining step does not require the precision machining needed for the intermediate (weld prep) and final (NOREM) machining steps. To speed up the initial machining (Stellite™ removal), a Silk Model FM066 (Figure 5-4) was purchased and adapted for project needs. This portable milling machine was used to rapidly remove the Stellite™ from the in-body valve guides. The mill rail was capable of taking a 0.100" cut while feeding about 6 minutes/inch.

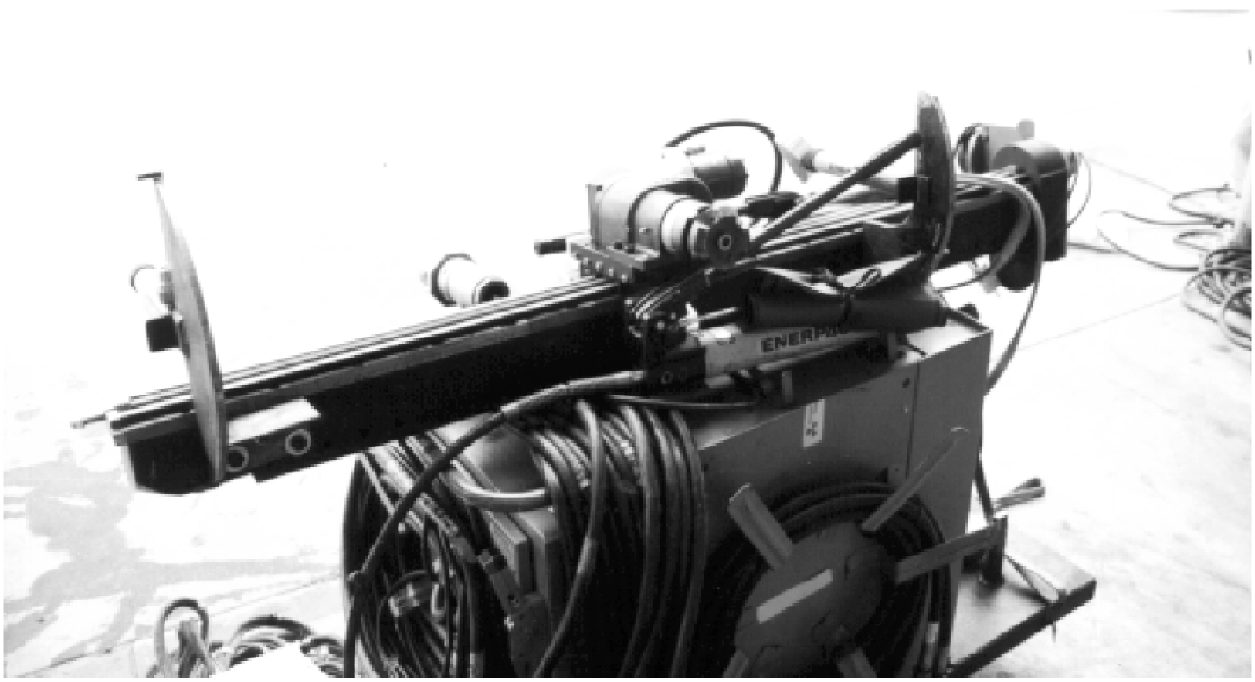

Figure 4-4 Portable Milling Machine

Although speed and the ability to work on one guide rib at a time is an advantage , several disadvantages are associated with using the portable milling machine. First of all, the machine can only be used on the guide ribs. This requires additional machine set up time since the boring bar can be set up once to work both the in-body guide and seat area. Secondly, the portable mill machines a flat surface which loses the contour of the valve bore. This means that the mill should only be used for initial machining and requires additional weld metal when building up the guides. Thirdly, using the milling machine adds additional equipment that must be taken to the drywell, additional spare parts that need to be on hand and additional equipment that must be decontaminated, stored or disposed of.

Climax staff attended the RFO7 mockup and supported and followed the project through its execution. Based on observations and lessons learned during RFO7, Climax developed an additional tooling head for their MSIV machine. This "shaper head" attachment, shown in Figure 4-5, was an outstanding performer in RFO8 mockups and RFO8 in-situ machining.

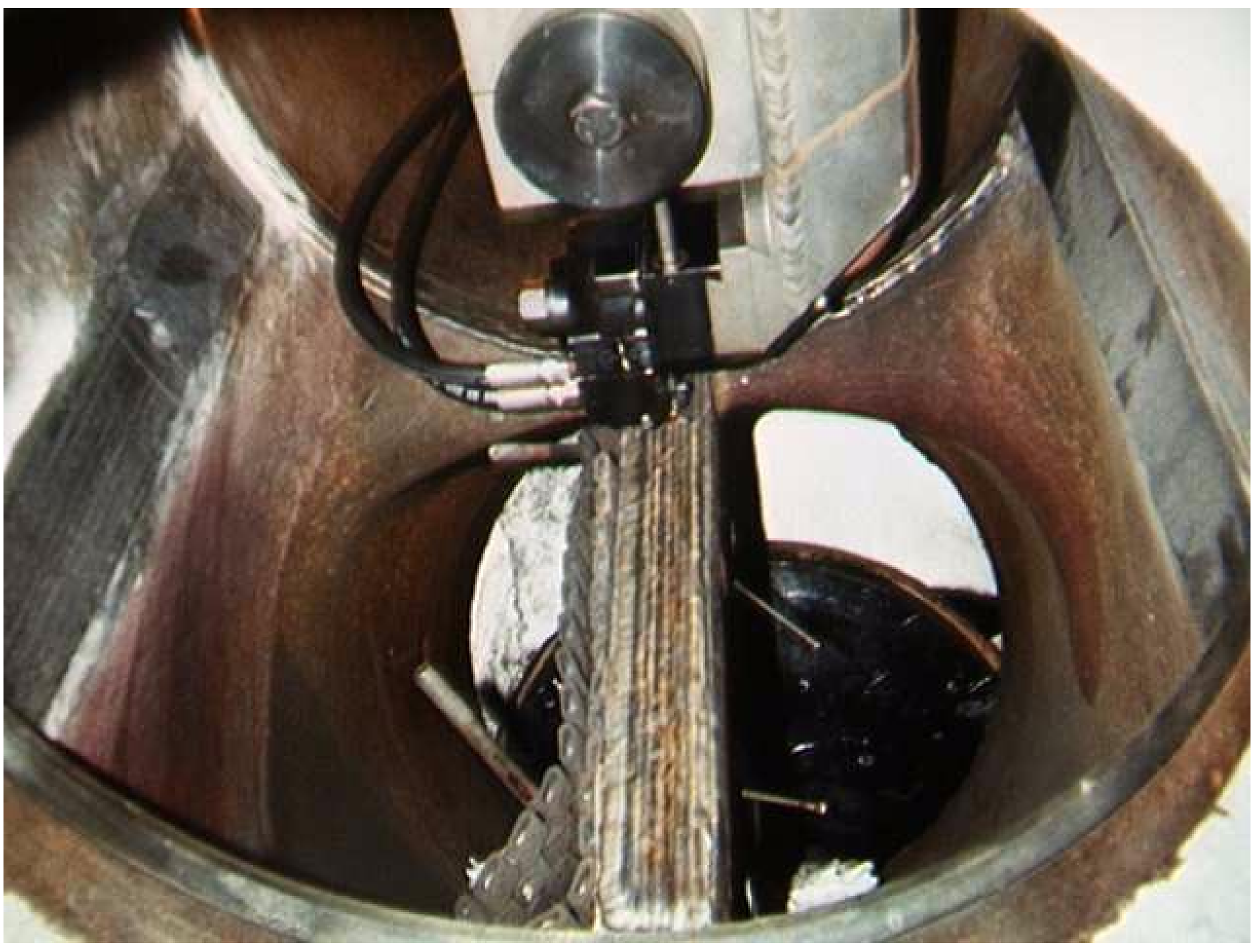

Figure 4-5 RFO8 Machining Mockup - Shaper Head

The "shaper head" attachment allows the Climax tool to operate in a user defined arc instead of rotating through 360° of travel. This allows one guide rib to be machined at a time while maintaining valve bore contour. Furthermore, significant increases in machining speeds were obtained. The "shaper head" allowed the Climax tool to take a 0.050 to 0.060 rough cut and greatly reduced tool insert wear. Travel was approximately 1½ inches per minute. The machining chips coming off the tool head had a nice "curl" indicating the tool was cutting and not scraping. During RFO8 mockup activities, the same insert was used to machine 3 guide ribs. This was accomplished with no discernible taper. The tool insert preference for NOREM machining with the "shaper head" was a Seco Carboloy TP4O with positive rake.

The Climax MSIV machine tool was used exclusively during RFO8. Since the RFO8 machining only required weld prep and final machining, the portable milling machine was not considered. However, given the outstanding performance of the "shaper head", the Climax Model 152 boring bar should be used for all machining setups.

Figure 4-6 RFO8 Machining Mockup - Polishing Wheel

Another Climax attachment utilized in RFO8 is the polishing wheel shown in Figure 4-6. This photo is taken from the downstream side of the valve and shows the bottom guide and a portion of the in-body seat. Figure 4-6 shows the polishing wheel being tested on the bottom guide. In actual practice, the polishing wheel was only used as the final seat machining step. Use of this wheel provides a 16 Ra finish and contributed to the outstanding "post-maintenance" LLRT results obtained in RFO8. All plug machining was performed utilizing lathes in the GGNS hot machine shop.

Welding Equipment

The Arc Welding Machines Model 215 welding power source with Model 15 orbital weld head modified by Anchor/Darling was used extensively for in-body and plug welding. Except for the weld build up required to widen the bottom in-body guide, all major welding operations were performed using this Arc GTAW welding system. Figure 4-7 shows the complete system including the power supply, welding head and operator interfaces. Figure 4-8 shows a close up of the Model 15 weld head. The Model 15 weld head is designed as an OD orbital pipe welder and can be fitted with two wire spools (as shown) to allow bi-directional welding.

Figure 4-7 Welding System

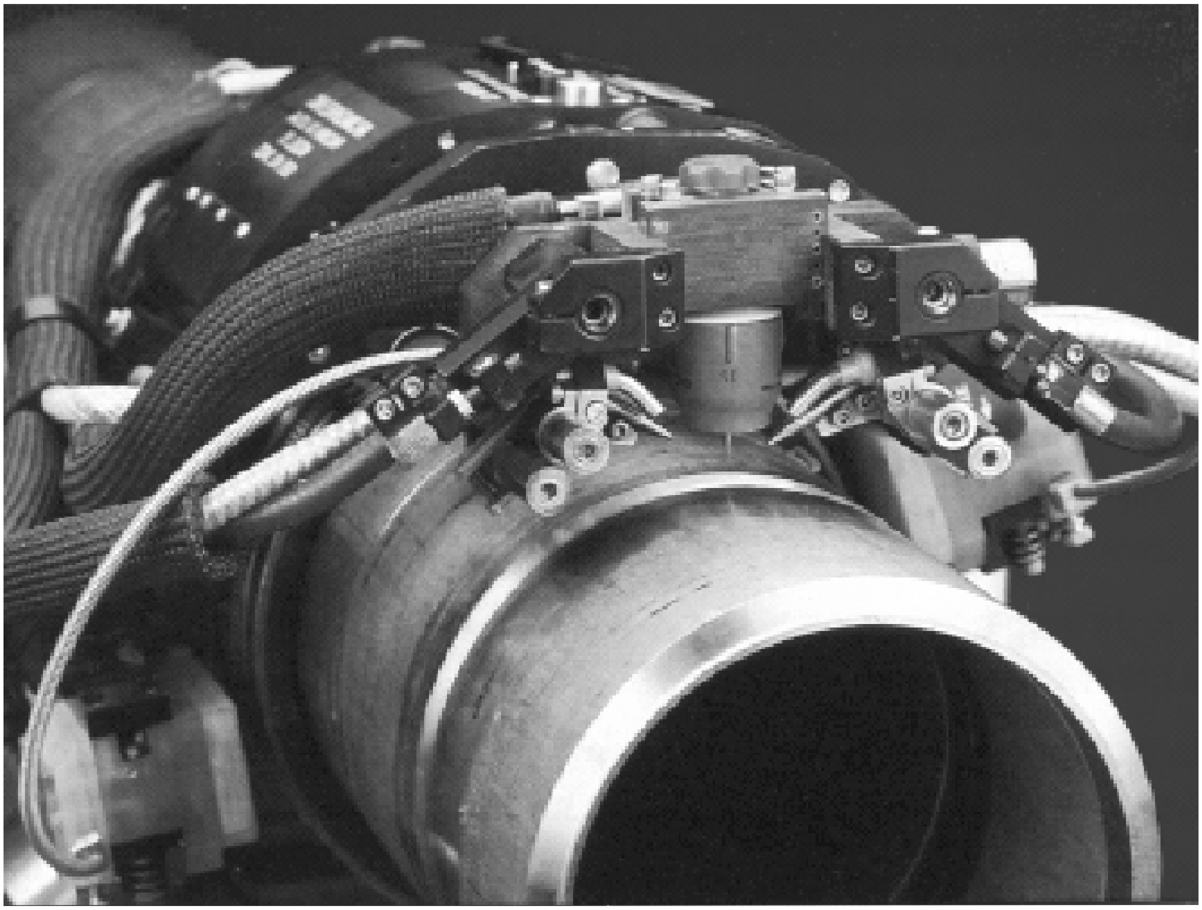

Figure 4-8 Weld Head

This welding system was not originally designed to operate in high temperature environments, so care must be taken when using this equipment to weld inside valves where high preheating is required. Several significant problems were encountered during RFO7 in-situ welding and are directly attributable to welding with the Model 15 in an environment around 300°F and having to install and remove the weld head in a very confined space. As a contingency measure, spare parts were purchased for the weld head, and an Arc technician was kept on site during critical RFO7 welding activities involving the Arc Welding Systems. Several modifications to the Model 15 weld head allowed it to perform RFO8 in-situ welding activities without experiencing heat related problems. These improvements include replacing the wire feeder tube, relocating the camera lights and providing a new ceramic base for the lights. An Arc technician was not available to support RFO8 activities. Arc manufactures a Model 43 ID weld head that should be considered for use in valve bore applications requiring high preheats. The Model 43 weld head is compact and completely jacketed and cooled.

A weld positioner was custom fabricated to position the weld head inside the valve. This positioner is shown mounted on the valve in Figure 4-9. The weld positioner consists of a mounting bracket, drive motor, bar, weld head mounting collar and stand-offs as shown in Figure 4-10. The weld head is mounted on a collar at one end of the bar to allow the weld head to rotate through 360° for valve seat welding operations. The drive motor retracts and extends the bar to position the weld head as required inside the valve. This axial movement of the bar also allows weld buildup on the in-body guide ribs to be welded axially without rotating the weld head. The weld positioner was controlled from the remote welding control station. Figure 4-11 shows the weld head performing weld buildup on the bottom guide during RFO8 mockup activities. This photo was taken looking down into the valve from the pressure seal area.

The Arc welding system was also utilized for plug welding activities. All plug welding operations were performed in the GGNS hot machine shop.

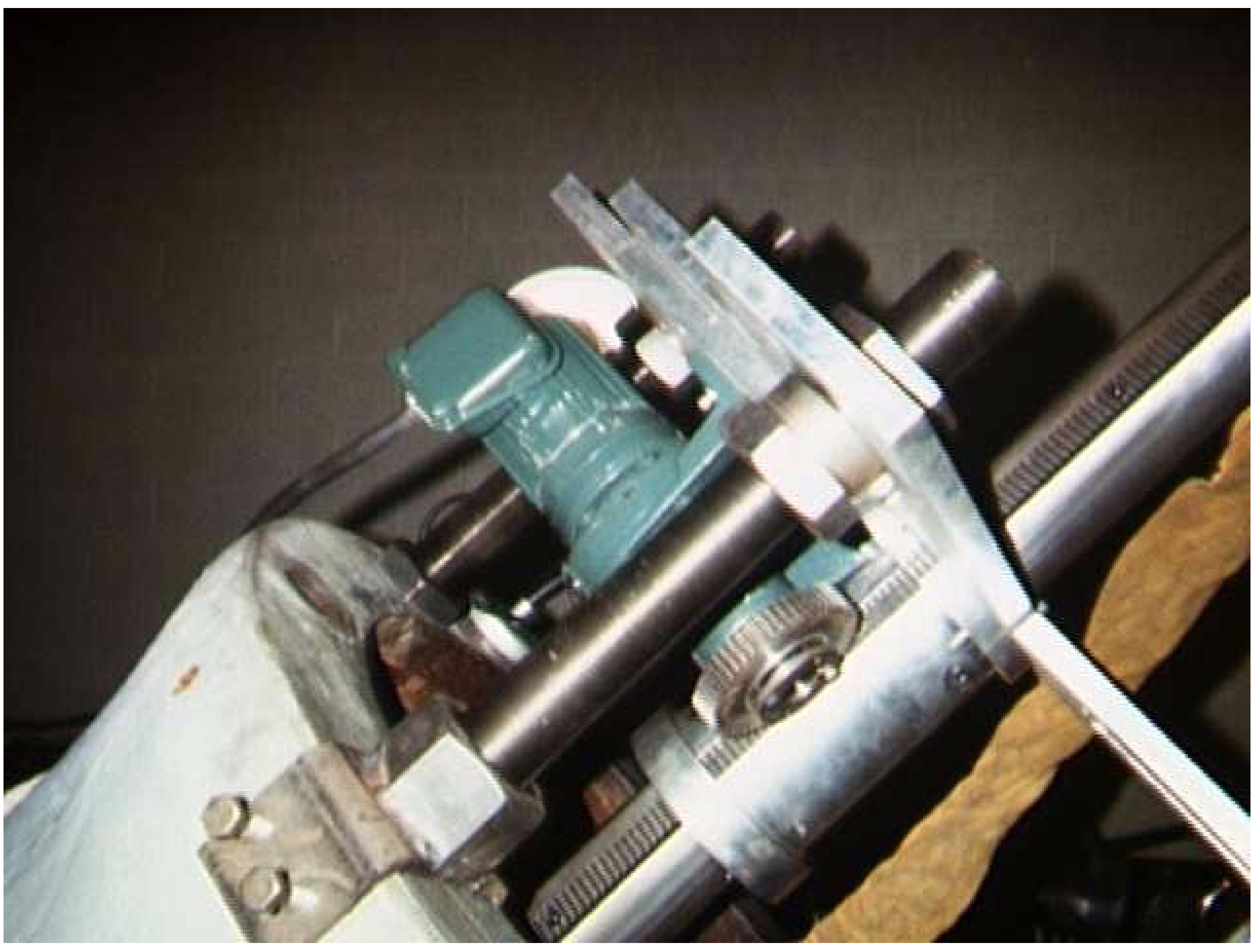

Figure 4-9 Weld Head Positioner

Figure 4-10 Weld Head Positioner Components

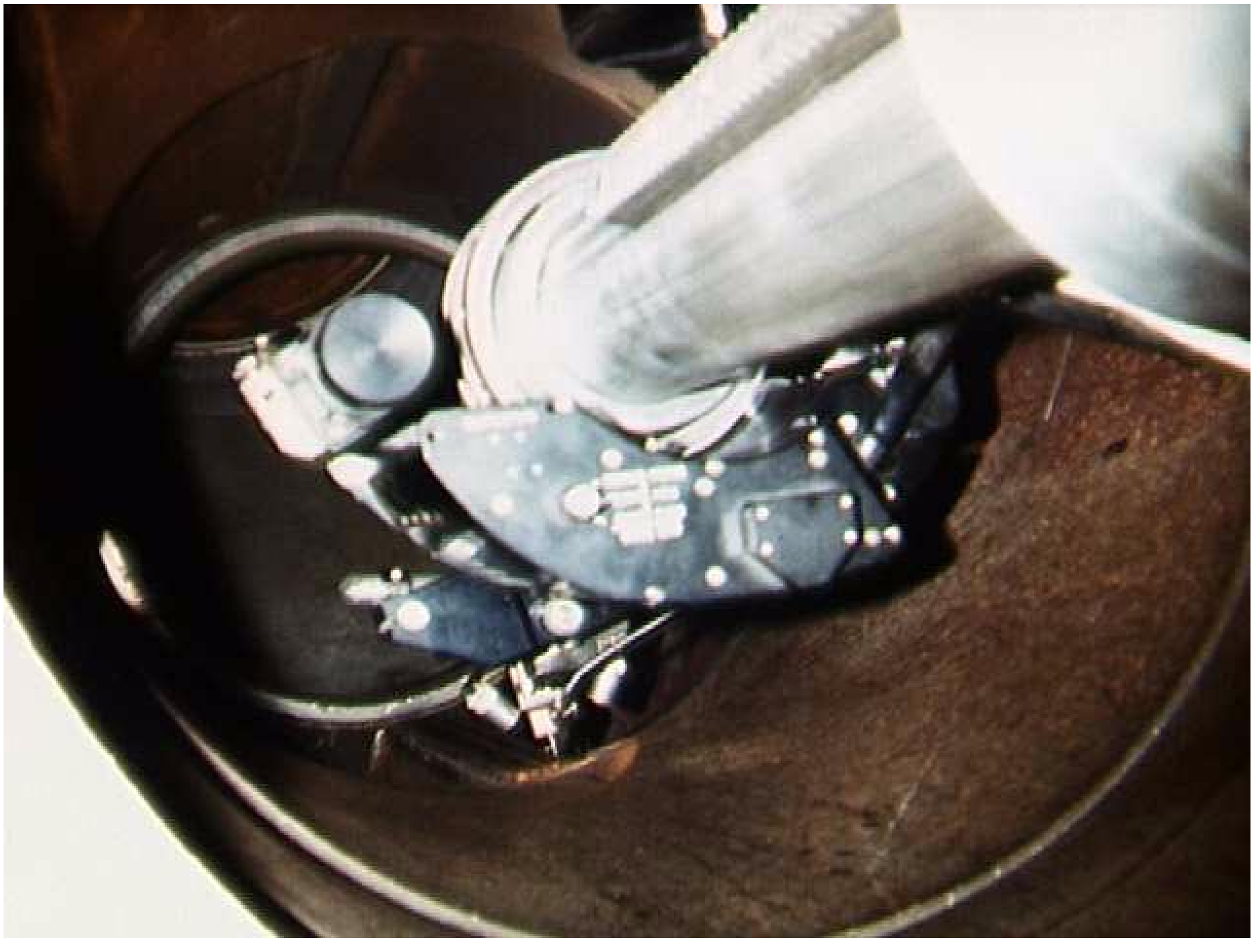

Figure 4-11 Welding of Guide Ribs on RFO8 Welding Mockup

Weld Parameters

One of the objectives of mockup activities was to determine optimum welding machine parameters for the various in-situ welding activities required to complete the F010 valve project. While these parameters are governed by welding procedures, parameter adjustments are required based on valve conditions. For instance, different parameters were used in the guide and seat welding evolutions.

EPRI has provided guidelines on appropriate weld parameters on several occasions. Table 4-1, taken from Reference 8, shows typical NOREM welding parameters recommended in 1992. Table 4-2, taken from Reference 6, shows more recent recommendations utilizing the Dimetrics Gold Track II Welding System.

Table 4-1
Typical GTA Welding Parameters (NOREM .045 Diameter Wire)

PARAMETER	VALUE
Preheat	Ambient to 800 °F
Current (amps)	
Primary	155 to 165
Background	105 to 115
Voltage (volts)	
Primary	8 to 12
Background	8 to 12
Wire Speed (in/min)	
Primary	35
Background	20
Travel Speed (in/min)	3.0
Shielding Gas	100% Argon
KJ/IN	24.30 Avg.
MJ/in^2	1.60 Avg.

Table 4-2
Example Welding Parameter Schedules (Dimetrics Gold Track II Welding System) [1]

VARIABLE	EXAMPLE A		EXAMPLE B		EXAMPLE C		EXAMPLE D
Position	6G		6G		6G		1G
Current (amps) [2]	1st	Rem	1st	Rem	1st	Rem	
Primary	170	140	185	160	180	140	200 ± 40
Background	120	120	130	130	120	120	170 ± 40
Voltage (volts)							
Primary	10.7		11.0		10.5		11 ± 1
Background	10.0		10.5		9.8		10 ± 1
Wire Feed Speed							
(in/min)	25		35		40		45 ± 20
Primary	20		30		30		35 ± 15
Background							
Dwell	.3.2.3		.3.2.3		.3.2.3		.3.2.3 ± .1
Oscillation	.01		.06		.10		.10 ± .10
Travel (in/min @ torch)	3.2		3.0		4.5		4 ± 1.0
Pulse Mode	Sync Pulse		Sync Pulse		Sync Pulse		Sync Pulse

[1] These examples do not cover all conditions. Applications may require parameter adjustments to compensate for plant conditions.

Table 4-3 shows the weld parameters reported for the RFO7 in-situ wild activities. These parameters are based on the Arc 215 welding system previously discussed. Project experience indicates "optimum" welding parameters are somewhat subjective and vary according to preferences of individual welders. However, experience also suggests that welding parameters should be consistent between welding teams and from shift to shift.

Table 4-3
RFO7 Weld Parameters

PARAMETER	SEATS	GUIDES
PREPURGE SEC	5	8
UPSLOPE SEC	8.0	8.0
DOWNSLOPE	8.0	8.0
POSTPURGE SEC	5-15	5-15
PRIMARY PULSE SEC	.60	.60
BACKGROUND CURRENT AMPS	95	100
PRIMARY CURRENT AMPS	165	175
WIRE RETRACT TIME	2	5
BACKGROUND PULSE SEC	.40	.40
WIRE START DELAY SEC	5.0	5.0
PRIMARY WIRE IPM	24	32
WIRE STOP DELAY SEC	5	5
BACKGROUND WIRE IPM	14	20

Table 4-3
RFO7 Weld Parameters

PARAMETER	SEATS	GUIDES
BACKGROUND AVC VOLTS SEC	8.8	8.8
AVC UNLOCK DELAY SEC	5.0	2.0
PRIMARY AVC VOLTS	9.8	9.8
AVC LOCK DELAY SEC	5	2
AVC RESPONSE	0	0
TRAVEL START DELAY SEC	5	3
TRAVEL IPM ACTUAL	3-6	0
TRAVEL STOP DELAY SEC	5	3
STARTER LEVEL	50	50
OSCILLATOR AMPLITUDE INCHES	0	0
OUT DWELL SEC	0	0
EXCURSION SEC	0	0
IN DWELL SEC	0	0

5

VALVE PLUG WORK SEQUENCE

Work Plan

The F010 project scope required the valve plugs be returned to a hard seat only configuration. The dual seat plugs in service at the time had experienced wear on the plug guides (see Figure 5-1) and could not be easily retrofitted to a hard seat only configuration. Furthermore, outage schedule constraints would not allow extensive plug modifications to be performed during the outage.

The dual seat modification to the valves had been performed by modifying spare plugs. Hence, the original F010 valve plugs were in inventory and available for project use. These spares were rebuilt due to the lead time and cost associated with purchasing new plugs.

These spares had experienced minimal wear but were contaminated since they had previously been in service. Thus all plug work activities were scheduled to be performed pre-outage in the GGNS hot machine shop.

Specific RFO7 valve plug work activities were as follows:

1. Decontaminate the plugs. This allowed machining activities to be performed in single PCs and welding activities to be performed in lab coats. Respirators were not needed in machining or welding activities.

2. After placing the plug in a lathe, establish machining reference points and dimensions.

3. Remove all existing Stellite™ from the plug guide and seat areas by machining down to required dimensions for re-welding (see Step 1, Figure 5-2). A nitric acid solution was used as an etchant to verify Stellite™ removal.

4. A visual and liquid penetrant (LP) examination was performed in all machined areas to ensure no flaws existed in the base metal.

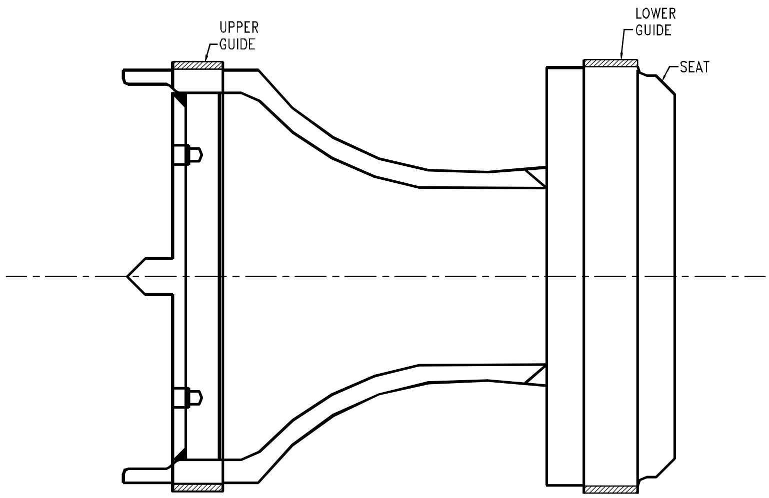

Figure 5-1 Plug Schematic

5. Warping of the plug in the guide area was expected. Additional carbon steel (E-7018) was added in the plug guide areas (Step 2, Figure 5-2) to mitigate warping effects. This build up ensured original plug geometry and dimensions could be obtained (after machining) if plug distortion was experienced. A preheat of 250°F was required prior to performing base metal build up on the plug.

6. A 309L stainless steel "butter layer" was applied as shown in Step 3, Figure 5-2. Again, this welding activity required a 250°F minimum preheat. After welding, the 309L deposit required a 2 hour, 300°F soak.

7. After allowing the plug to cool to ambient temperatures, a "cradle" was machined into the 309L as a weld prep for applying NOREM (Step 4, Figure 5-3). A visual and LP examination was performed on all machined areas.

8. After obtaining a 250°F minimum preheat, NOREM was applied as shown in Step 5, Figure 5-3. After applying the appropriate amount of weld buildup, the plug was wrapped in insulation and allowed to slow cool to ambient.

9. As shown in Step 6, Figure 5-3, machining of the plug was performed to obtain the original plug contour and design dimensions. The plugs were machined to within 0.050" of design dimensions. Final machining of the guides was performed after the final machining of the in-body valve surfaces. This ensured design clearances would be obtained.

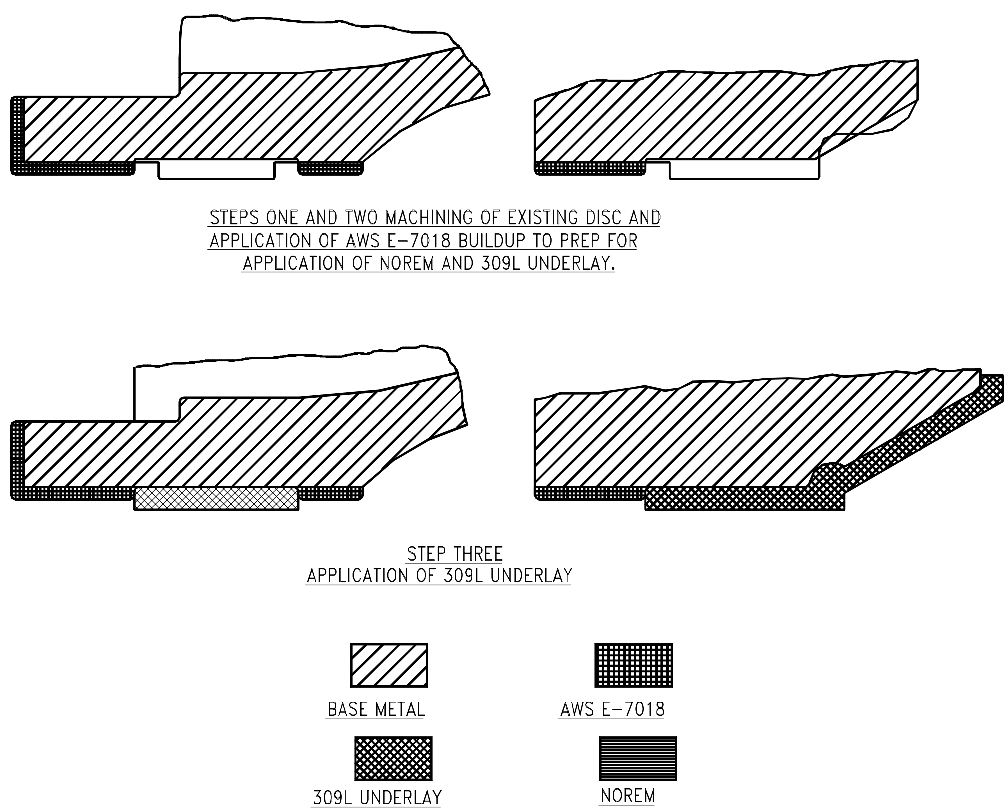

Figure 5-2 Plug Weld Prep

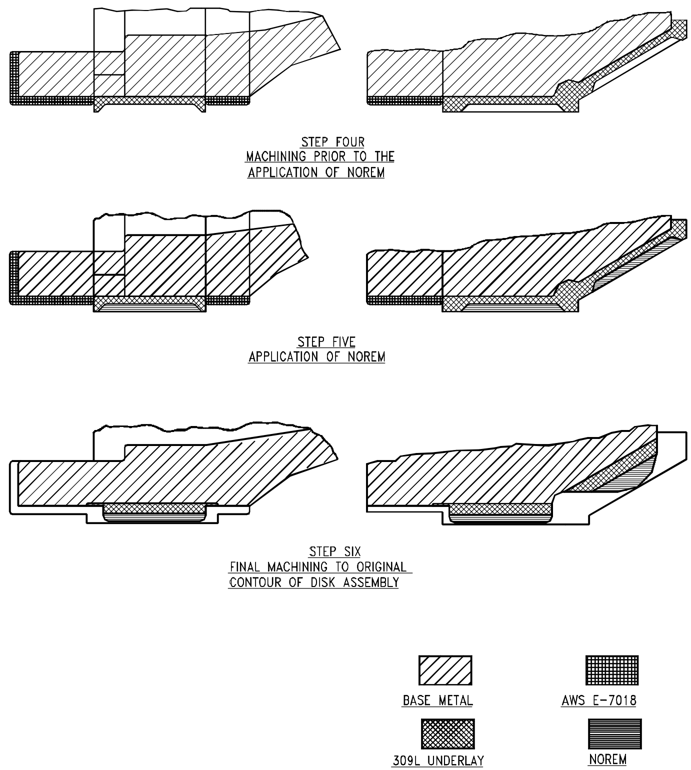

Figure 5-3 Plug Weld Prep - Continued

Plug Welding Techniques & Practices

The general welding setup used in the hot machine shop is shown in Figures 5-4 and 5-5. The plug was mounted on a turntable, which rotated the plug underneath the stationary weld head. To help maintain preheat, the plug was wrapped in insulation.

The upper guide area proved to be the most difficult area to weld. Cracking was experienced in the initial 309L welding. This cracking was attributed to welding technique. The 309L was removed and reapplied without incident. Cracking was also experienced in the initial NOREM welding. This problem was resolved by changing the method of preheat to induction heating and raising the preheat to 400°F. A torch was placed 180° from the weld head to maintain this preheat. The cracked NOREM was removed and NOREM was reapplied without incident.

It should be emphasized that this experience was with the NOREM B-1 alloy. Keys for successfully applying B-1 to the plug were utilizing high pre-heat and allowing the plug to cool slowly to ambient. RFO8 mockup work demonstrated that NOREM 02A can be applied with little pre-heat.

Rebuilding the plugs in the hot machine shop was difficult and time consuming using GTAW processes. PTAW could have been utilized but would have involved bringing additional equipment to the site and additional welding procedures to qualify welders. However, the PTAW process would have been faster. Unfortunately, all plug welding activities had to be performed on site since the spare plugs could not be decontaminated to a point that would allow them to be released to a valve shop. Problems encountered in plug activities delayed completion of plug work. In fact, plug work was not completed during the pre-outage as was planned and continued into the outage, causing scheduling conflicts and draining available manpower.

In hindsight and schedule permitting, the best option would have been to purchase new plugs with NOREM applied via the PTAW process at the factory.

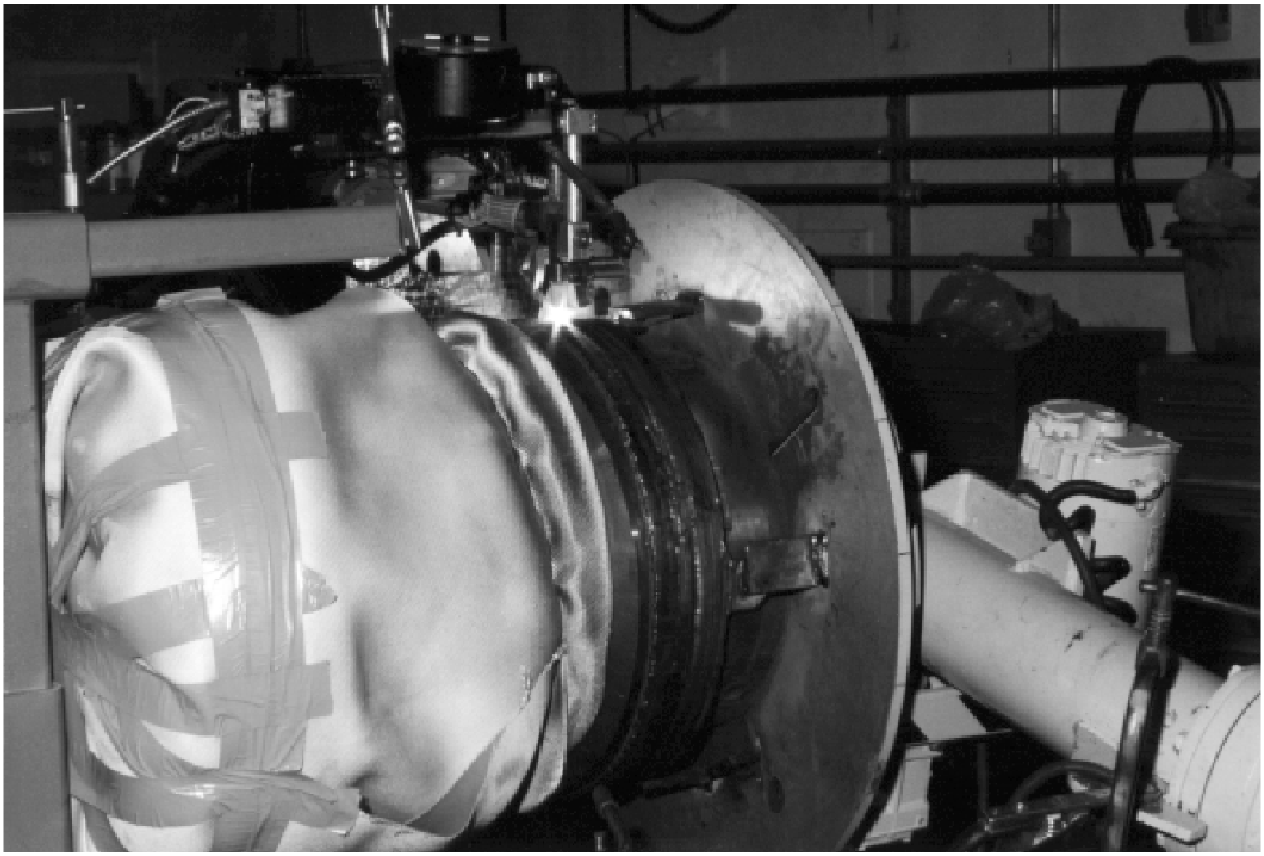

Figure 5-4 Welding Plug

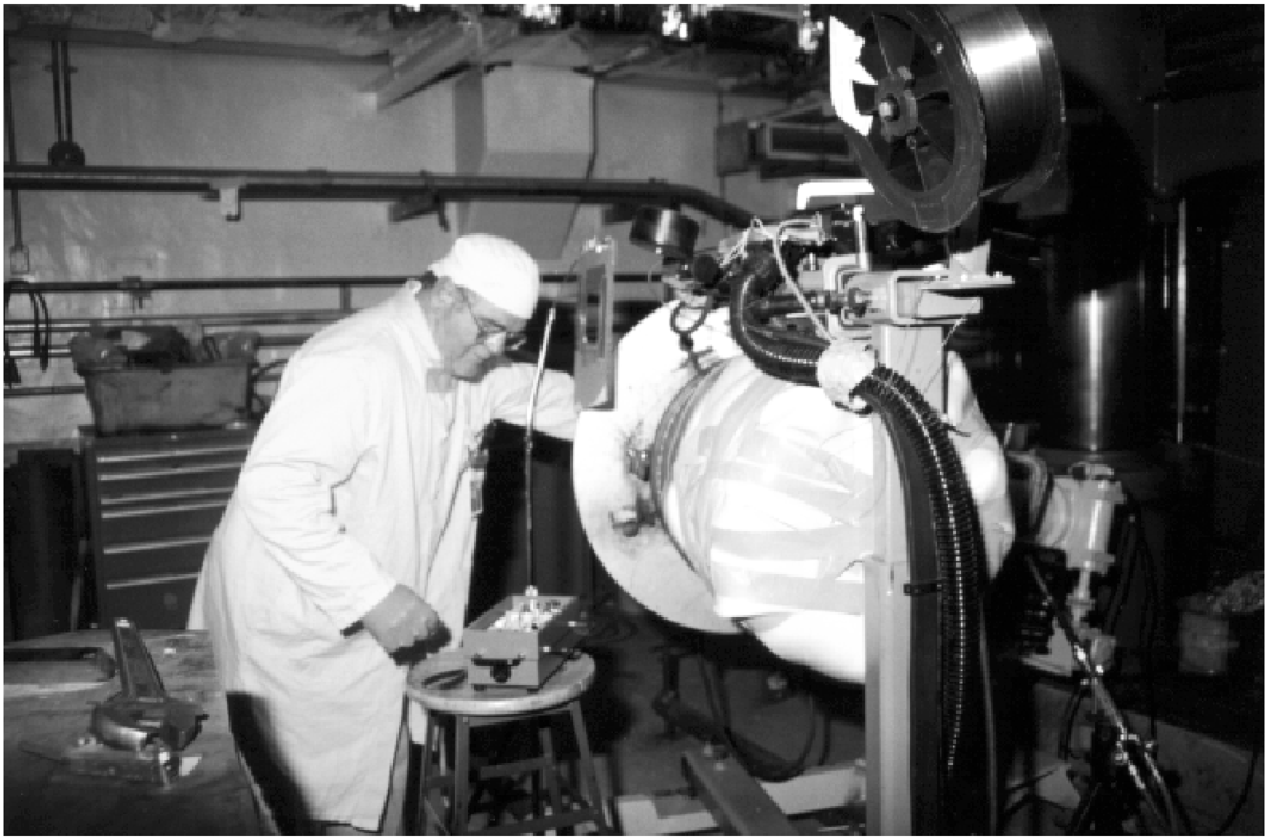

Figure 5-5 Welding Plug

Plug Machining

Figure 5-6 shows a plug mounted in the lathe while machining the plug seat. The finished plug is shown in Figure 5-7. Close ups of the plug's bottom guide and seat are shown in 5-8 and 5-9.

Machining proceeded without incident until final machining on the last plug (F010A plug). The F010A plug seat and bottom guide were finished and the upper guide was nearing completion when a crack developed with the loud "ping" characteristic of hardfacing cracks.

This crack was removed by grinding and did not propagate into the 309L layer. After removing the flaw the plug was installed. An engineering evaluation determined the small transverse grove left after removing the indication would not hinder valve performance. However, a new plug was procured and installed during RFO8.

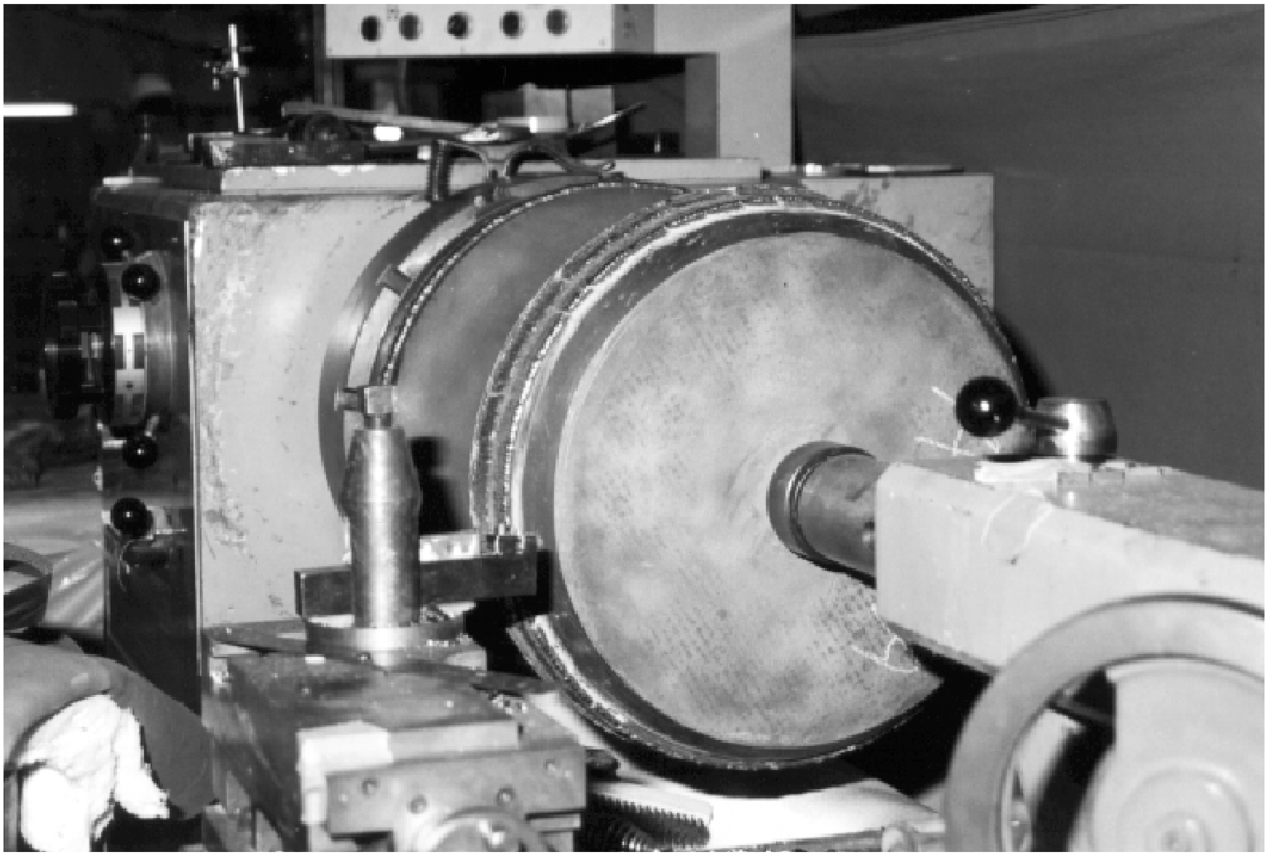

Figure 5-6 Machining Plug

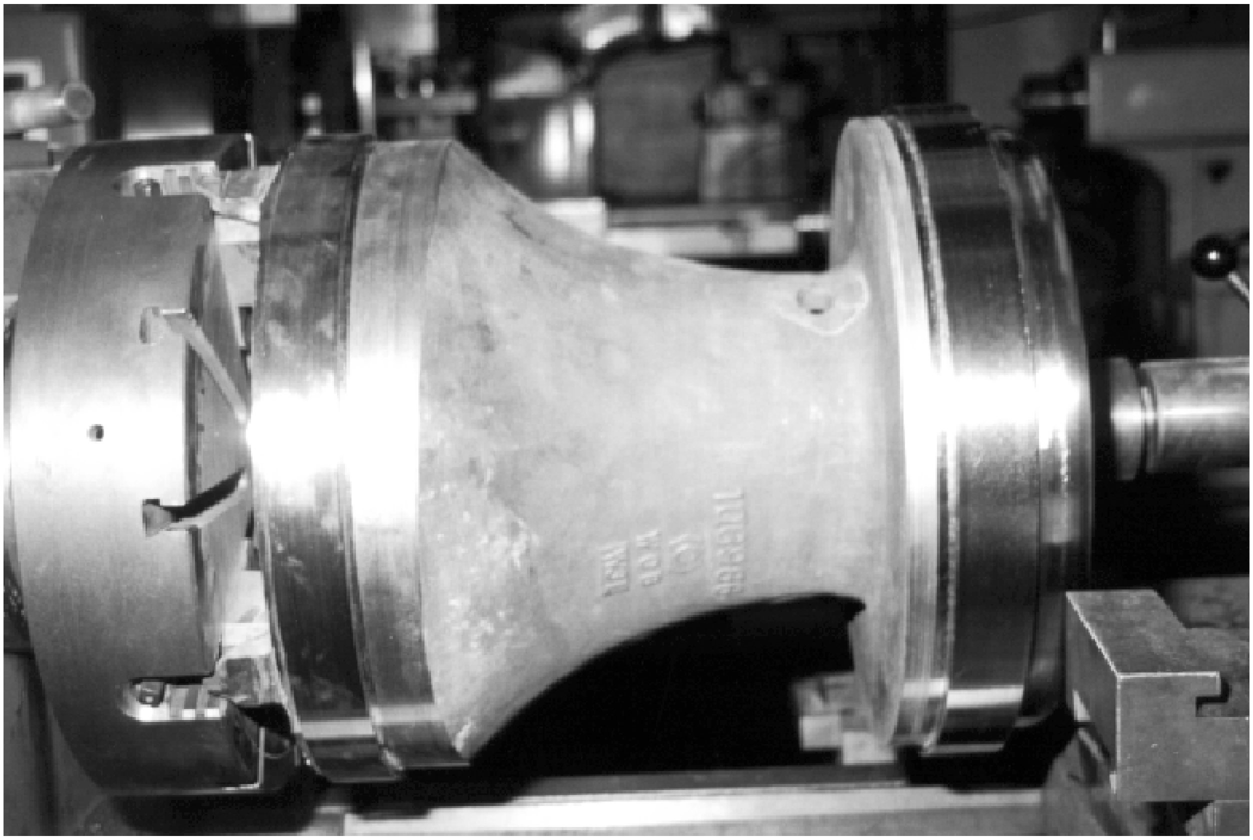

Figure 5-7 Finished Plug

Figure 5-8 Plug Bottom Guide & Seat

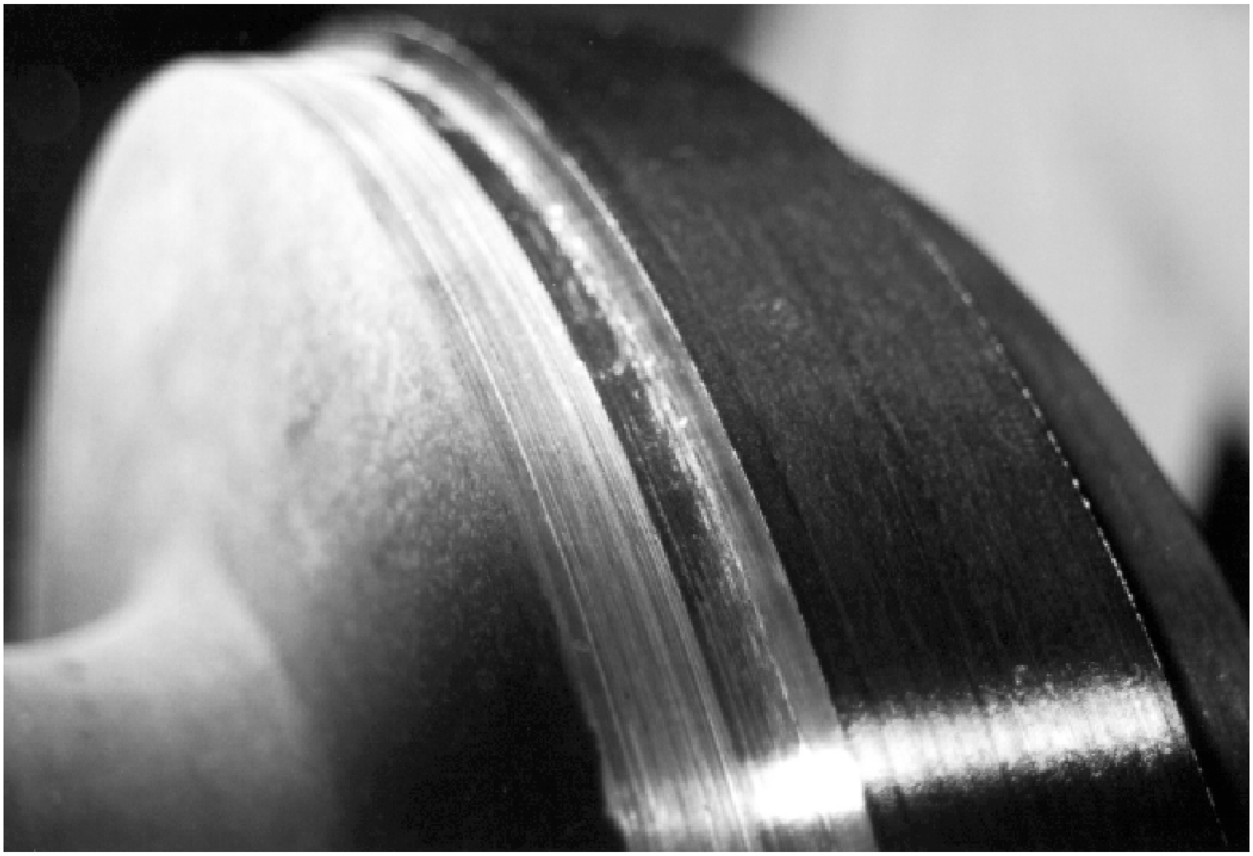

Figure 5-9 Plug Bottom Guide

6

VALVE BODY WORK SEQUENCE

Work Plan

General RFO7 valve body work activities were as follows:

1. Valve disassembly and decontamination. RFO7 valve disassembly began as soon as possible; breaking the valve cap nuts loose is easier before allowing the valve to fully cool. After disassembly, the valve body was decontaminated utilizing a hydrolase. These decontamination efforts were successful. Work inside the valve (physically entering the valve) required double PCs and a face shield. Otherwise, single PCs were utilized. Respirators were not required.

2. After recording "post-service" dimensions to document valve conditions, Stellite™ was removed from the guide and seat areas. A nitric acid solution was used as an etchant to verify complete Stellite™ removal.

3. Both sides of the lower guide ribs were cleaned by power flap. A visual and a magnetic particle examination was performed, a pre-heat of 200°F was achieved, and base metal build up of ¾" on each side of the lower guide was performed by manual welding.

4. A liquid penetrant (LP) examination of guide ribs and seat machined surfaces was performed to establish base metal integrity.

5. A 250°F pre-heat was achieved and a 309L butter layer was welded on the guide ribs and seat.

6. After allowing the valve to cool, the seat and rib weld prep was machined. A visual and LP examination was performed to ensure integrity of the 309L layer.

7. A 250°F minimum pre-heat was obtained and NOREM was welded on the seat and guide ribs.

8. After allowing the valve body to slow cool to ambient temperature, the final machining steps were performed. A final LP examination was performed on the machined NOREM surfaces.

9. The valve was reassembled and tested.

Valve Seat Details

Each F010 valve is equipped with a large seat ring welded in place by two welds. The lower weld is a substantial ½" fillet weld and neither the upper or lower welds could be located visually. Discussions with William Powell indicated these seat rings could be rebuilt in place or removed and replaced. Neither option is quick or easy and removing the seat ring requires the entire seat ring to be machined out. A decision was made to rebuild the seats in place.

Figure 6-1 shows the specific machining and welding activities required to hardface the valve seat in-situ. As shown in Step 3, the NOREM weld prep consisted of a special "cradle" to be machined into the 309L similar to that performed on the plug as discussed in chapter 5.

The welding plan called for three layers of NOREM to be applied and then be machined to a final thickness of 1/16". As shown in Figure 6-2 special precautions need to be observed in weld bead sequencing to avoid cold lap. In general, the first layer of NOREM should be the only layer of NOREM that contacts the 309L. Each subsequent layer of NOREM should over-lap the previous layer but should not contact the 309L. This weld bead sequence is suggested for the in-body and plug guide hardfacing activities.

Although not completed to 100%, two different valve seats were machined and welded during mockup activities. During RFO7, the first valve to be worked was the F010B. In actual in-situ valve body work, the seat was to be completed except for final machining after removing the Stellite™ from the guides and performing the bottom guide width build up. The work activities were scheduled this way as a contingency. Due to the geometry, seat welding and machining was assumed to be more difficult and if problems arose, the valve guide scope could be reevaluated if the project was on critical path. The F010B seat work was performed as planned without incident.

Later, the F010A seat work was performed as planned without incident until welding the final layer of NOREM on the seat. As this final layer was nearing completion, the upper seat ring to valve body seal weld cracked. This crack was visible and ran 360° around the seat ring. The only viable option at this point was to replace the seat ring.

Anchor/Darling fabricated a seat ring as shown in Figure 6-3 at their Williamsport PA facility. NOREM was applied to the new seat ring utilizing PTAW techniques. During seat ring fabrication, site activities concentrated on removing the existing seat ring. Approximately two days of continuous machining was required to perform this task.

The new ring was welded in place manually. The seat ring was supplied with excess NOREM to allow final machining to be performed in-situ. This was desired to ensure the valve seat is perpendicular to the valve plug bore. To protect the hardfacing surface from weld splatter while installing the seat ring, the seat ring was covered with "mud".

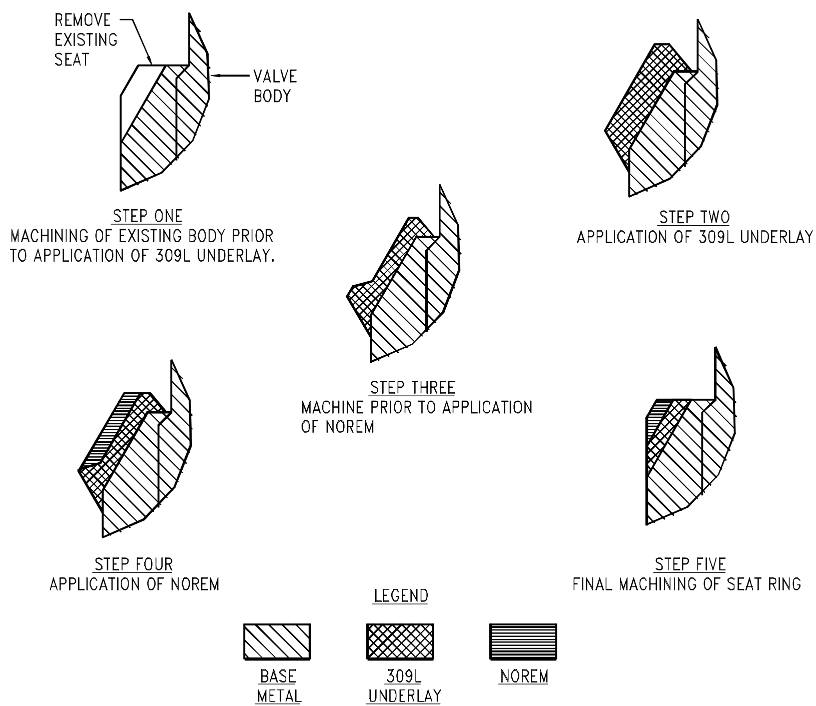

Figure 6-1 Valve Seat Weld Prep

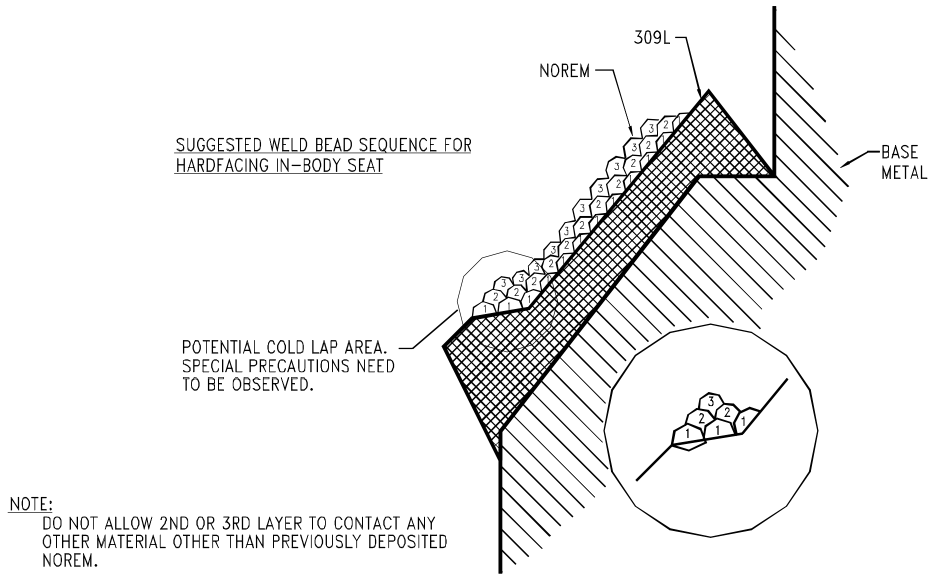

Figure 6-2 Suggested Weld Bead Sequence

This additional F010A seat work forced the project to be on the RFO7 critical path. Thus, the F010A RFO7 guide work was reduced and will be discussed in detail in the following section. Although in-situ welding and machining was performed without incident on three of four valves (including the mockup valves), valve seat rings should be replaced instead of rebuilding them in-situ. This eliminates an unknown and should allow better schedule performance over all. If seat rings are to be rebuilt in-situ, then contingency measures should include having replacement seat rings available and enough schedule float to accommodate seat ring replacement should this become a necessity.

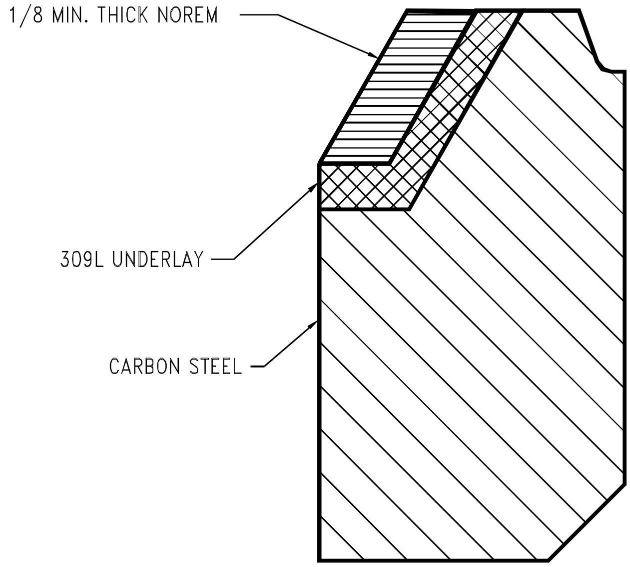

Figure 6-3 Seat Ring

Guide Rib Details

During visual inspection of the F010B valve, valve body wall erosion was discovered. This was a valve maintenance item but had a schedule impact on the project due to the time required to evaluate the erosion. Fortunately, the erosion was not significant enough to require extensive repair which would have further adversely affected the project schedule.

Inspection of the guide ribs showed evidence of wear on the bottom ribs (#1, 3, 4, Figure 6-4) and little or no wear on the top guide rib (#2, Figure 6-4). This finding was not surprising since little force is exerted on the top guide due to the horizontal configuration of the F010 valves. As a project schedule contingency, Stellite™ was left in place on rib 2.

Figure 6-4 shows the detailed machining and welding steps required to apply NOREM to the valve guides. As indicated in Step 1, Stellite™ was removed on ribs 1, 3 and 4 utilizing a portable milling machine. This results in a flat welding surface and loss of the valve bore contour as shown in Step 1. The 309L butter layer is applied as shown in Step 2 and the weld prep is machined to accommodate the hardfacing overlay deposit as shown in Step 3. This machine step should be performed with a boring bar to re-establish the bore contour. If the bore contour is not re-established in Step 3, additional NOREM hardfacing will have to be applied in Step 4 to provide enough metal to re-establish the bore contour. Step 3 shows this to be the case for the 309L layer, i.e. the 309L layer is thinner in the middle of the guide rib. This is not a problem for the 309L. However, increasing the required thickness of hardfacing will increase the possibility of cracking. During RFO7 F010B activities, machining Step 3 was performed using the portable milling machine in a effort to improve schedule performance. This effort was counterproductive. It led to inconsistent NOREM thicknesses, and varying number of deposited layers across the guide rib, which led to high residual stresses in the completed weldment. These were major contributing factors to the initial cracking of NOREM in the guide ribs. This cracking was experienced on two of three F010B guide ribs and will be discussed in detail later in this chapter. Suffice it to say at this point, the 309L and NOREM was replaced using improved design, welding, and machining techniques. This time, no NOREM cracking was discovered.

By this time, the project became critical path for RFO7 due to the additional time required for this rework as well as the unrelated seat ring cracking on F010A. In order to move the project off the outage critical path, F010A hardfacing (steps 4 & 5) was postponed to RFO8 and the F010B guide rib #2 was rebuilt with Stellite™. This was accomplished by taking a clean up cut of 0.030" and then welding additional Stellite™ on top of the existing Stellite™. Steps 1 through 3 were completed on F010A except the 309L layer was thickened to allow final machining (step 5) to the original bore diameter. An engineering evaluation justified one cycle of operation with 309L cladding (without a hardfacing overlay) on the F010A guides. Thus, F010B was completed in RFO7 and F010A was completed during RFO8.

As mentioned in Chapter 4, all RFO8 machining activities were performed with the Climax boring bar utilizing its new "shaper head" attachment. The RFO8 F010A scope was to perform Steps 3 through 5 as shown in Figure 6-4.

Of the four guide ribs, the lower guide (rib #4, Figure 6-4) was the most difficult rib to weld. As shown in Figure 2-1 this rib spans the bottom bore of the valve and is not merely a built up area of the upper (plug) bore. As such, thermal gradients were a major concern during hardfacing the lower guide. Six thermocouples were utilized to monitor the bottom rib temperature during hardfacing. Care was taken to keep the thermal gradient along the rib to less than 100°F during NOREM welding.

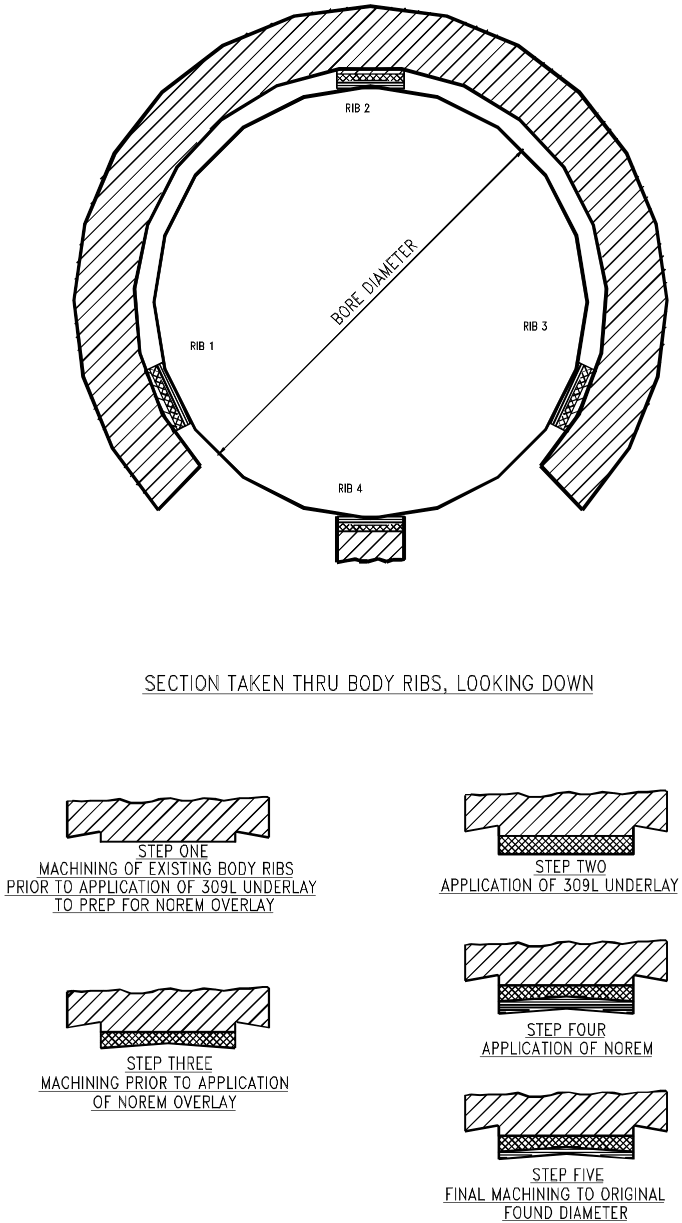

Figure 6-4 Valve Guide Weld Prep

RFO7 Activities

All automatic welding activities were performed by teams consisting of two welders each. One welder was required at the valve during welding activities. The other welder was stationed at the welding control station shown in Figure 6-5. All remote welding activities were performed from this remote control station which was located in a low dose area of the drywell. All activities at the valve could be monitored at this point via a monitor (top monitor) and remote area camera. The other two monitors shown are connected to the weld head cameras.

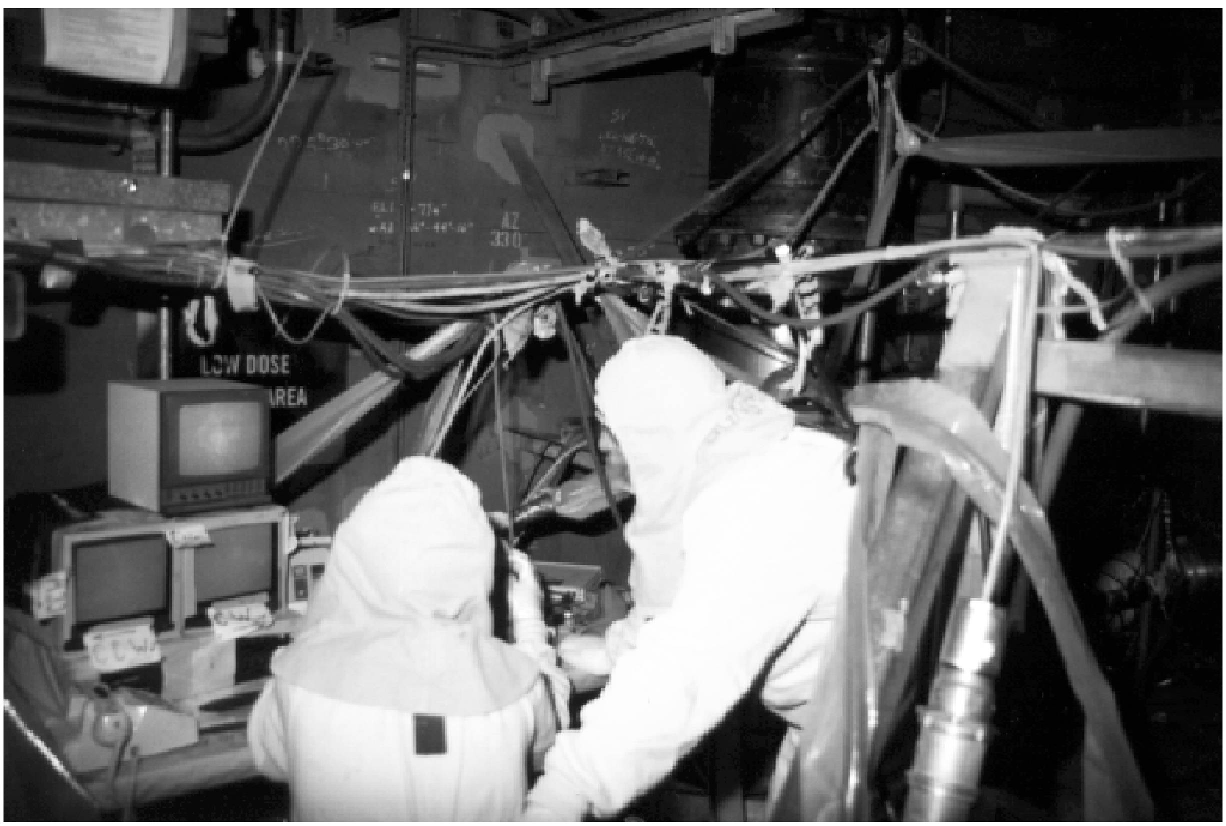

Figure 6-5 Drywell Welding Control Station

Figure 6-6 Welding At Valve

Figure 6-6 shows a welder stationed at the valve observing welding in progress during F010A welding. The welders communicated by head phone and rotated duties periodically. Each shift utilized two welding teams with two welders on each team for in-situ body welding activities. Figure 6-7 shows the weld head inside the valve body positioned to weld the bottom guide. This view is basically from the perspective of the welder shown in Figure 6-6.

Figure 6-7 Welding Inside Valve

Figure 6-8 is a photograph of the F010B valve body machining in progress with the Climax boring bar in place. This photograph clearly shows the cramped work space in the vicinity of the F010 valves. As previously stated, work in this area was performed in single PCs without respirator requirements. Figure 6-9 is a mockup photograph but is essentially the view the machinist in Figure 6-8 would have if the boring bar were removed.

Figure 6-8 Valve Body Machining

Figure 6-9 Valve Body View

Obstacles and Resolution

As previously mentioned, the initial NOREM application on the F010B guides during RFO7 resulted in cracking of the weld overlay on two guide ribs. These cracks were visible to the naked eye. As expected, they were in the hardfacing only and did not propagate into the 309L. The first crack was experienced on the bottom guide rib and was due to a coolant leak from a cracked manifold (fatigue crack) on the weld head. The hardfacing crack on the guide rib was characteristic of quenching, developing in random directions from the point of coolant impact and resulting in a "shattered" appearance.

The second guide rib to be welded (rib #3 Figure 6-4) also developed a crack in the NOREM as the final NOREM layer was nearing completion. One crack developed at the interface of two beads and ran 3" parallel with the weld beads. The other crack traversed several weld beads. Investigation of these cracks determined several contributing causes; the NOREM was too thick (over ¼") due to machining the weld prep with the milling machine, and even though welding procedures were being followed, weld parameters and techniques varied between shifts. Several steps were taken to resolve these problems including developing detailed engineered weld prep drawings, allowing the guide welding to be performed in one direction only (uphill direction), increasing preheat from 275° to 300°F, and requiring all weld parameter changes to be approved by the welding engineer. These steps limited field decisions and flexibility but provided more consistency between shifts. After taking these steps, no additional guide cracking was observed. It should be noted the cracks experienced on the guides could not be directly attributed to the use of NOREM and would probably have developed regardless of the hardfacing alloy used.

Due to the extent of NOREM cracking on the two guide ribs, the hardfacing needed to be replaced instead of attempting a local repair. However, it was not immediately clear if the 309L layer had to be removed. To aid in this decision, a metallurgical examination of two weld test coupons were performed. The lab results showed each successive layer of 309L had a higher carbon content than the previous layer, due to dilution of the NOREM with the 309L. These data suggested that all except the initial 1/16" of 309L should be removed. During machining of the 309L, the machinist had observed that the 309L seemed harder at the end of the guides. These areas of the guides would experience higher heat input during bi-directional welding. This higher heat input results from the weld head essentially remaining in the same location as the welder withdrew the wire from the weld puddle, stopped and turned off the torch, re-positioned and restarted the torch, and started the wire feed while traveling back over the area just weld. Some welders were more adapt to this than others. Table 6-1 presents Vickers Micro-Hardness from test coupons from two different welders. Sample 2 is from a welder with a tendency to "dry wash" ; note the much higher hardness in the 309L layer.

Based on the lab test data, the 309L was removed to alleviate any concerns with the potential for cracks forming in the "old" 309L while NOREM was being re-applied over it. Thus, the 309L was removed with the mill rail down to 1/16" of the carbon steel. Rockwell Hardness readings were taken as shown in Table 6-2.

Table 6-1
Vickers Micro-Hardness In Test Coupons (10kg load)

METAL	LOCATION	SAMPLE 1	SAMPLE 2
NOREM	2nd Layer	345.5	349.3
	2nd Layer	345.5	339.8
	2nd Layer	345.5	339.8
	2nd Layer	345.5	-
	1ST Layer	273.3	357.2
	1ST Layer	-	347.2
	1ST Layer	-	320.2
309L	2nd Layer	178.9	204.1
	2nd Layer	187.8	192.5
	1ST Layer	216.8	403.4
	1ST Layer	216.8	394.0
	1ST Layer	-	387.1
Carbon Steel	HAZ	169.4	179.7
	Base	170.7	180.4
	Base	170.0	180.4
	Base	174.1	181.1
	Base	178.2	184.8

Table 6-2
309L RH_B Hardness Readings

Location	Rib 4	Rib 3
Top	93.8	90.8
Mid	93.1	95.8
Bottom	92.1	98.6

A RH_B in the range of 93 was taken to be acceptable, while the 98.6 was borderline high. Additional 309L was then applied as shown in Figure 6-10. This alternate 309L weld bead sequence re-established contour on the guide and served as the NOREM weld prep. Two layers of NOREM were welded on top of the 309L without an intermediate machining step. In addition to saving the time required for machining, this saved additional time since the welding equipment didn't have to be replaced with machining equipment and the valve didn't have to cool to allow machining.

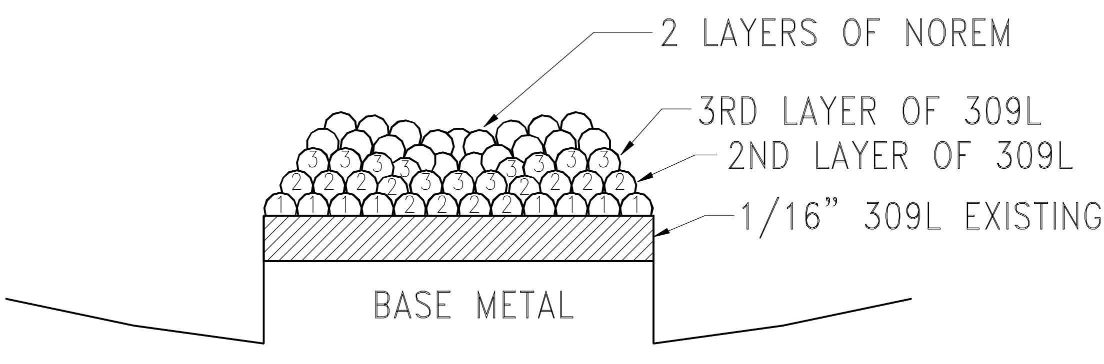

Figure 6-10 Alternate Weld Prep

After final machining, NDE revealed three small linear indications on the bottom guide. These indications were removed with a burring tool and all edges were sloped to a 4:1 slope.

RFO8 NOREM welding proceeded with no visible cracks occurring during welding activities. After final machining, NDE revealed one small lack of fusion indication on one of the four ribs. This indication was removed.

7

LOCAL LEAK RATE TESTING

Test Media: Air vs. Water

The F010 valves function as the inboard containment isolation valves. GGNS was originally licensed utilizing air as the test media for the F010 LLRT. This requirement was based on the assumption that the F010s would be required to seal against steam escaping from the reactor during a design basis accident.

Although not identified as a cause of LLRT failures, a primary concern raised during the project's root cause analysis regarded LLRT methods utilizing air as the test media. Due to the inherent limitation of a large "y" pattern check valve to provide a leak tight seal at low differential pressure, the test medium is an important consideration. Since water has a greater sealing effect on the valve seal than air, it is the preferred test medium.

The project team initiated an engineering evaluation performed by the GGNS Nuclear Plant Engineering (NPE) Department to determine if the use of water in lieu of air for the LLRT test media was justified and feasible from a regulatory standpoint. NPE performed a detailed, transient, thermohydraulic calculation of the feedwater system behavior during and following a Design Basis Accident using the RELAP 5 computer code. This calculation showed that it would be appropriate to change the LLRT test medium from air to water. Further analysis determined the maximum acceptable F010 LLRT leak rate to be 7 gpm.

Test Procedure and Requirements

A "post-service" Local Leak Rate Test (LLRT) is required every third outage for the GGNS feedwater check valves. Furthermore, if maintenance is performed on the valves, a "post-maintenance" LLRT must be performed before declaring the valves operable. The F010 LLRT is performed by pressurizing a test volume down stream of the valve. As shown in Figure 7-1, (train A shown, train B similar) this test volume is obtained by closing the F011 and F136 valves. This test volume is then pressurized through the F115 and F116 valves. The piping upstream of the F010 valves is vented through the F063 and F064 valves. The makeup rate required to maintain the test pressure is taken as the seat leakage rate.

Due to the test configuration, any additional leak path would add to the total makeup required to maintain the test pressure. Other potential leak paths include the valve bonnet and other test boundary valves. In order to ensure that the makeup rate reflects the actual F010 seat leakage, other potential leakage paths are checked when a high leakage rate is indicated. Theses paths are typically checked with a soap bubble (snoop) test or rubber glove test. However, leakage paths other than seat leakage have not been identified as significant contributors during past GGNS LLRT failures.

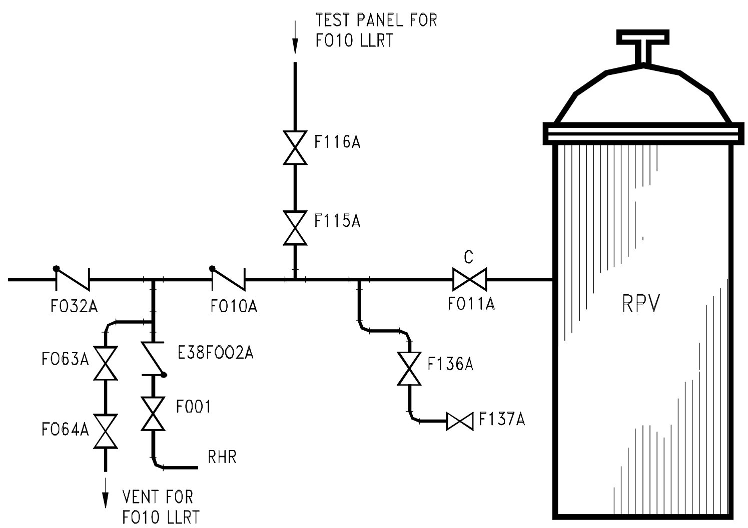

Figure 7-1 LLRT Test Schematic

Test Results

The RFO7 "post-maintenance" LLRT results were 0.6 gpm for the F010B valve and 6 gpm for the F010A valve. The F010B results were exceptional. The F010A results were marginal for a "post-maintenance" LLRT. However, the F010A valve seat was not lapped to the same extent as the F010B seat due to time constraints and the realization that the valve would be opened during RFO8. Additional fitting/lapping the seating surface was scheduled for RFO8.

The RFO8 LLRT "post-service" results for the F010B valve were 6 gpm after being in service for 18 months. This was not a required test but was performed to demonstrate valve performance. It marked the first time the valve had passed a "post-service" LLRT. No "post-service" LLRT was performed on F010A since it was scheduled for additional modifications. The F010A "post-maintenance" LLRT detected zero leakage, a very impressive performance considering the valve's previous history.

8

DISCUSSION/CONCLUSION

Recommendations

Although many of these recommendations are discussed elsewhere in this report, the following list summarizes important factors to be considered when applying NOREM in-situ:

1. High preheat (350°F or more) is important for the B1 formulation. The 02A formulation pre-heat requirements are much less stringent. Good results were obtained with 200°F preheat for the 02A.

2. When pre-heat is used it should be consistent and constant and should provide good thermal soak. Thermal gradients induce thermal stresses and should be minimized and kept to less than 100°F.

3. Controlling the rate of cooling is important to control thermal gradients. Good results were obtained by wrapping the plugs in insulation and allowing them to slow cool to ambient temperatures. Cool down rates of the valve body was controlled by ramping down the pre-heating equipment 50°F per hour.

4. NOREM hardfacing should be limited to no more than three layers (passes). Each layer should be 1/16" thick. The target was to weld three layers and then machine most of the third layer off. However, two layers provide acceptable hardfacing chemistry. Hardfacing deposits of ¼" or greater develop greater stresses during application and thus the potential to crack is much greater. Limiting the maximum thickness of the NOREM seemed to be more important than the number of layers applied.

5. Consistency of weld parameters from team to team and shift to shift is a must. Consistent travel speed and wire speed provides consistent, uniform layers of hardfacing. Good results were obtained keeping travel speed to 3 inches per minute. Travel speeds of 6 to 8 inches/minute are too fast.

6. Choose welders with above average welding skills and experience with welding hardfacing alloys.

7. Drywash should be eliminated to avoid remelting previously deposited layers of weld metal. Excessive remelting increases residual stresses and the potential for cracking.

8. Weld in the "uphill" direction only. This direction will keep the weld puddle from running away from the torch and provide layers of uniform thickness. Welding downhill can result in a thinner layer of weld metal to be applied. If this occurs,

additional layers will have to be applied to achieve the desired thickness, which is not desirable as discussed in number 4 above.

9. Mockups are invaluable for this type of project. These mockups should be complete and include all phases of the repair (machining and welding). The mockup is a test and practice of the repair plan and techniques and should establish proficiency in the means and methods chosen. The mockup should not be an equipment training exercise.

10. When pre-heat is required, detailed, specific instructions should be provided by the welding engineer. Any changes to these instructions should be approved by the welding engineer.

11. Detailed, engineered, dimensioned weld/machine prep instructions should be provided by the welding engineer. Any changes to these instructions should be provided by the welding engineer.

12. Successful completion of a project of this nature requires near flawless execution. Machining and other activities need the same level of attention as welding. Do not let the technical challenge and proactive nature of NOREM application divert too much attention from project fundamentals.

13. Weld bead sequence is important to avoid the potential for cold lap and lack of fusion. Subsequent layers should be off set ½ of a bead width from the previous layer to avoid cold lap.

14. Use of a butter layer is recommended when welding on cast materials and on non-austenitic materials.

15. Plan, plan and plan some more. Develop contingency plans for your contingency plan. The unexpected often occurs. Be prepared with spare parts, spare equipment, etc.

As with any project, realistic achievable schedules with some flexibility must be set. Furthermore, early involvement of craft personnel in the project planning and design phases are important. Their early involvement enhances the design and implementation plan and greatly enhances teamwork and ownership, necessary ingredients for successful project completion.

Conclusion

The GGNS experience suggests that the NOREM 02A formulation exhibits superior weldability over the previous 01 formulation (Anchor/Darling B1 nomenclature). Exceptional "post-maintenance" LLRT results were obtained after reworking the F010 A/B in-situ, 0 and 0.6 gpm respectively.

As expected with any pioneering or "first time" effect, obstacles were encountered but overcome. Future in-situ applications of NOREM will benefit from the GGNS experience.

In the authors opinion, NOREM hardfacing is a feasible alternative to Stellite™ in field repair. In fact, due to the current state of the technology and current body of knowledge, in-situ application of NOREM should be no more difficult than in-situ application of Stellite 21.

9

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A

FEEDWATER CHECK VALVE SURVEY

Appendix A
TABLE 1: BWR Feedwater Check Valve Survey

PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
1. LIMERICK UNITS 1 & 2	460°F	(I) Atwood & Morrill Swing (1-piece) (O) Atwood & Morrill Swing w/ AOV (2-piece) (O) Atwood & Morrill Swing stop check w/ MOV (1-piece)	(I) Hardseat (O) Hardseat (O) Hardseat	1. History of LLRT failures associated with the following: - alignment of the one-piece design - pressure seal problems 2. Implementing a design change to alleviate the alignment problems of the one-piece design by going to the two-piece design. As the valves fail their LLRT, the modification is being implemented.
2. DUANE ARNOLD	420°F-430°F	(I) 16″ Anchor-Darling Tilt-Disc (O) 16″ Anchor-Darling Tilt-Disc	(I) Hardseat (O) Hardseat	1. The inboard valves were previously configured with softseats (Parker E692-75), but, due to softseat shrinkage, the valves demonstrated unacceptable performance (no leakage rates were able to be obtained). The utility then modified the valves to hardseats and have had successful LLRT results (<500sccm) after one refueling cycle.

Appendix A
TABLE 1: BWR Feedwater Check Valve Survey

PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
3. HATCH	FW temp. not available	(I) Rockwell Tilting Disc (O) Atwood & Morrill Swing (one piece) (O) Atwood & Morrill Swing (one-piece)	(I) Hardseat (O) Hardseat (O) Hardseat	1. Intends to go with the two-piece design because of the easier maintenance and the elimination of LLRT problems caused by misalignment of the one-piece design. 2. Intends to go with the two-piece design for LLRT valves in other systems.
4. PERRY	424°F	(I) Rockwell Y-Globe (O) Rockwell Y-Globe	(I) Hardseat (O) (Hardseat)	1. LLRT tests are with water at 11.5 psig (actual range is 11.3-12.4) 2. The valves are very susceptible to water cleanliness/debris. 3. The FW valves have a 40%-50% failure rate.
5. RIVER BEND	420°	(I) 20” Velan swing (O) 20” Atwood & Morrill swing (two-piece w/AOV)	(I) Hardseat (O) Hardseat	1. The Atwood & Morrill outboard valves have the following history: RF-1 - 1 failure, RF-2 - 0 failure RF-3 - 0 failure, RF-4 - 2 failures

Appendix A
TABLE 1: BWR Feedwater Check Valve Survey

PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
6. WPN-2	420°F (up to 440°F during some shutdown ops)	(I) 24" Anchor-Darling Tilt Disc (O) 24" Anchor-Darling Tilt Disc	(I) Softseat (Stillman SR 740-70) (O) Softseat (Stillman SR 740-70)	1. Have had 2 FW LLRT failures in 5 years. Inboard valve-1989 Outboard valve-1991 (NOTE: Both failures were attributed to softseat failures) 2. Softseats are replaced as an EQ preventive maintenance task every 2-3 years.
7. FERMI	415°F-420°F	(I) Atwood & Morrill Swing (one piece) (O) Anchor-Darling Swing (two-piece)	(I) Softseat (Parker E692-75) (O) Softseat (Parker E692-75)	1. There were 0 FW LLRT failures for the past two RFO's. The leakage rates are typically on the order of 1000 sccm with some of the leakage being attributed to the leakage thru packing. 2. The Atwood & Morrill has been a better performer than the Anchor-Darling. In the past when there were LLRT problems with the Atwood & Morrill, extensive Vendor assistance was used to troubleshoot/ assist in refurbishment.
8. BRUNSWICK UNITS 1& 2	413°F	(I) Atwood & Morrill Swing (one-piece) (O) Rockwell/Edward Y-globe	(I) Hardseat (O) Hardseat	1. Inboards previously softseat problems. 2. The Atwood & Morrill inboard valves were recently installed to replace Anchor-Darling softseated Tilting Discs. Unit 1 completed one refueling cycle with no LLRT failures (results were however on the high end). Unit 2 has recently begun its RFO and has already had one failure (the leakage was

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			NOTE: Previously had softseats. CP&L responsible person could not recall material type. The mat'l was probably Parker E692-75 softseats.	such that no leakage rate was able to be determined). 3. The Rockwell Outboard valves have been outstanding performers (only 2 LLRT failures during the life of both units).
9. CLINTON	420°F	(I) Anchor-Darling Tilt disc (O) Anchor-Darling Tilt disc	(I) Softseat (Stillman SR 740-70) (O) Hardseat	1. The inboard valve was modified to tighten internal clearances and a new softseat was installed (Stillman SR 740-70). The post-modification LLRT results were <20sccm and one cycle later the leakage rate was the same. 2. The Stillman softseat was initially qualified for 18 months, but , due to the LLRT results, the qualified life was extended for another cycle. Other qualified materials are Parker E692-75 (qualified for 39 months) and E692-85 (qualified for 89 months). 3. The hardseat outboard valves have not had the LLRT success rate that the inboard valves have had. This is probably due to an actuator alignment problem which was recently corrected.

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PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
10. VERMONT YANKEE	373°F	(I) 16″ Anchor/Darling Swing Check (O) 16″ Anchor/Darling Swing Check	(I) Hardseat (O) Hardseat	1. Initially configured with Y-globes which were replaced with softseated Anchor/Darling Swing checks. These valves still presented LLRT problems. 2. Vermont Yankee is configured such that RWCU flows through only one Feedwater leg. On this side there was significant softseat degradation. On the non-RWCU side it was discovered that there were problems with softseat dimensional control. 3. The valves were subsequently modified and the softseat was removed (no other modification was made to the disc other than removing the softseat). The result has been two Refueling Outages with no Feedwater LLRT failures.
11. COOPER	365°F	(I) 18″ Anchor-Darling Tilt disc (O) 18″ Anchor/Darling Tilt disc	(I) Softseat (Parker E692-75) (O) Softseat (Parker E692-75)	1. During the last Refueling Outage there were 4 FW LLRT failures. The probable cause was softseat degradation due to abrasion. 2. Extensive Anchor-Darling assistance was used to troubleshoot and refurbish.
12. PILGRIM	364°F	(I) 18″ Anchor-Darling Tilt Disc (O) 18″ Anchor-Darling Tilt	(I) Softseat (Parker E692-75	1. Experienced extensive seat-disc alignment problems. Used extensive Anchor-Darling assistance and more detailed maintenance procedures.

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PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
		Disc	(O) Softseat (Parker E692-75)	2. Completed one Refueling cycle with 0 FW LLRT failures.
13. SUSQUEHANNA	350°F	(I) Anchor-Darling Tilt Disc (O) Atwood & Morrill swing w/ MOV (two-piece)	(I) Softseat (O) Softseat	1. Had a history of FW LLRT failures. Intended to perform the same modifications that Clinton performed during their RFO, but the valves passed their LLRT.
14. DRESDEN	340°F	(I) Crane Model 973 (O) Crane Model 973	(I) Hardseat (O) Hardseat	1. The Crane valves have elastomer material underneath the valve internal assembly. This material was Kalrez 1050, but was replaced with Parker E692-75 after the Kalrez material was found to degrade causing LLRT failures. There have been additional valve modifications performed to limit valve-assembly thru leakage.
15. OYSTER CREEK	315°F	(I) 18" Anchor-Darling Swing (O) 18" Anchor-Darling Swing	(I) Hardseat (O) Hardseat	1. FW LLRT results: 1980 - 1FW valve LLRT failures 1982 - 2FW valve LLRT failures 1984 - 1FW valve LLRT failures 1986 - 2FW valve LLRT failures

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PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
				1987 - 1FW valve LLRT failures 1988 - 2FW valve LLRT failures 1990 - 0FW valve LLRT failures 1993 - 0FW valve LLRT failures 2. Almost all failures were on horizontally-positioned outboard valves. The vertically positioned inboard valves have had good LLRT history. 3. The success since 1988 is primarily attributed to improved maintenance practices.

I= Inboard Valve O= Outboard Valve

Appendix A
Table 2: PWR Feedwater Check Valve Survey

PLANT	FW TEMP	VALVES	SEAT MATERIAL	COMMENTS
1. HB ROBINSON	400°F - 450°F	(O) Chapman/Crane Y-Globe	(O) Hardseat	1. Not part of App. J program. Reverse flow functional test performed using Steam Generator Static Head as Pressure Source.
2. BEAVER VALLEY	430°F	Unit 1 (O) Schutte-Koering Stop Check Unit 2 (O) Atwood & Morrill Swing	(O) Hardseat (O) Hardseat	2. Not part of App. J program. Reverse flow functional test performed using Steam Generator Static Head as Pressure Source. Leakage rate acceptance criteria is approx. 5 GPM.

I= Inboard Valve O= Outboard Valve

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