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Application and Repair of Overlay Welds

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ABSTRACT

Waterwall tubing in electric utility boilers is experiencing high rates of wastage. This wastage is increasing exponentially since environmental commitments dictated installing low NO_x burners. In many cases, the staged combustion required to lower NO_x emissions results in operating boilers in highly oxidizing/reducing environment. These combustion conditions have accelerated pressure boundary wall wear and have resulted in emergency, unscheduled outages from tube failures. Such failures affect unit availability and capacity factors.

Maintenance and repair organizations have been forced to look for new ways to deal with the accelerated waterwall wear. Weld overlays have become one of the leading choices installed in the filed and in shop applications for replacement panels. Many overlay materials have been evaluated to help curb this extreme wastage. Materials include stainless steels such as 309 and 312, traditional nickel-based alloys 625 and 622, and some of the less traditional nickel-based alloys such as alloys 51 and 72. These alloys are being chosen because of their corrosion resistance due to chemical composition, including chrome content over 20%. The elevated chrome content deters wear and corrosion in these operating conditions as identified in previous EPRI investigations.

In many instances, overlaid boiler tube have experienced repeat failures in shorter-than-desired service durations. This suggests that returning a unit to service has classically been more of an important factor than understanding the mechanism or root cause of each boiler tube failure. This document does not discuss root causes, but it does address what to do when a boiler must undergo weld metal overlay or when the situation requires a temporary fix such as pad welding.

This guideline includes specific information for the repair of waterwall tubing; for weld metal overlay for buildup of eroded/wasted areas; and for temporary pad welds including material selection, repair approaches, and inspection. Flow charts are used to show steps and directions for inspectors/inspections of in-service pad welds and overlays. These charts are provided to aid the decision-making process.

Additionally, separate technical/bid specifications have been developed for field-welded and shop-welded overlays. These specifications will aid the user to define the work scope and ensure inclusion of important technical details.

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INTRODUCTION

Waterwall tubing is experiencing high wastage rates in electric utility boilers that have been converted to low NO_x burners for pollution control. To combat these high wastage rates, waterwall tubes have been protected with corrosion-resistant weld overlays. Overlays of waterwall surfaces were first used in isolated boilers for corrosion protection in the mid-1980s. As a result of the increasingly stringent EPA clean air emission standards, more utilities are installing low NO_x burners and are experiencing the resultant wastage. Approximately 850 boilers in the United States have had low NO_x burners installed or are candidates for their installation. Waterwall overlays have been installed on only about 10% of these boilers to date [3].

Competition between utilities is also adding to the problem. To drive production costs down, utilities are purchasing coal on the spot market. These coals often have quite different chemical compositions from the coal the boilers were originally designed to burn. Combinations of different coals in the combustion process contribute to the problem. EPRI research has shown that the chlorine and sulfur content of the coal, as well as reducing atmospheres created by the low NOx burners, contribute to the wastage rate of the waterwall tubing [2,3].

One of the more effective means for controlling waterwall wastage rates is through the use of high chromium, corrosion-resistant weld overlays. Utility experience has determined that a minimum chromium content of at least 20% is required to slow the corrosion rate to acceptable levels [1]. As higher corrosive environments are encountered, fillers with higher chromium contents will be required to combat the wastage.

Weld buildup is commonly used in other areas of boilers where erosion on the tube OD is occurring. This erosion is frequently caused by sootblower or flyash erosion. Weld buildup repair for these damage mechanisms is generally considered a “band-aid” repair for both of these damage mechanisms although harder alloys with high chromium content do offer extended life over carbon steel tubing. Sootblower and flyash erosion can be eliminated through maintenance practices. Proper maintenance of sootblowers to eliminate water or wet steam from being blown onto the tubing and use of flow distribution devices to eliminate high gas flow locations have proven to solve these problems.

Many different alloys have been used for corrosion protection, including Type 309 stainless steel and 312 stainless steel. Nickel-based alloy ERNiCrMo-10 (alloy 622) and alloy ERNiCrMo-3 (alloy 625) have been the most used; other non-traditional nickel-based alloys 52 and 72 are starting to be used for overlays. Problems have been encountered with each of these fillers. The 309 stainless steel has a substantially different thermal expansion rate than the low-alloy waterwall base materials. Boilers that operate in a cycling mode that experience numerous temperature swings have developed dissimilar metal weld- (DMW-) type failures at the overlay-to-tube-base-material interface. ERNiCrMo-3 is expensive to install and has experienced circumferential cracking problems in extreme service. ERNiCrMo-10 is starting to be use more, but it too is not immune from cracking or wastage in some environments. One major problem with the nickel alloys is that they are very expensive.

An inexpensive filler metal with high chromium content was explored for waterwall applications to provide utilities with another option for highly corrosive environments. EPRI Materials and Repair (M&R) Program worked to develop overlay designs with Type 312 stainless steel for waterwall applications. This alloy contains over 30% chromium and can provide excellent corrosion protection in many environments. Its major drawback is that it becomes embrittled in service at waterwall operating temperatures. Details of this research can be found in EPRI report Weld Overlay of Waterwall Tubing, Alternative Filler (TE-1001268).

The high corrosion protection afforded by high levels of chromium has associated problems. As chromium levels increase, materials become susceptible to an embrittlement phenomenon called 885 embrittlement. This embrittlement causes materials that have been exposed to elevated temperatures to lose ductility and impact strength at room temperature. The embrittlement occurs quickest at 885°F (450°C)—hence the name. Typical super-critical waterwalls operate around 800°F (425°C), which can cause embrittlement of high chromium overlay materials. The embrittlement may not be a concern at the operating temperature of the boiler because the material is above the brittle-to-ductile transition temperature, but it may have an undesirable effect on repair operations during periods of unit shutdown.

The current report discusses options for performing repairs to boiler tubing and waterwall panels that exhibit cracking, wastage, or both. Additional information is provided to help utilities write contracts to welding vendors for overlay work. Specifications are included for restoring tube minimum wall thickness, corrosion-resistant overlay for wastage, repairing corrosion-resistant overlays, and pad welds.

2 REPAIR OF WATERWALL TUBING AND WELD METAL OVERLAY DEPOSITS

2.1 General

Before repair operations can be implemented, it is necessary to identify the materials involved, the extent of the flaws or defects, and the existing condition of the material. The required repair of a tube may be only to correct cracking or wastage problems or to repair the tube substrate as a result of weld overlay cracking that extends into the tube or the repair may be restricted only to the weld overlay. Where erosion and wastage have been the problem on unprotected or previously overlaid tubes, repair may involve restoring the substrate to the original wall thickness and then adding a corrosion-resistant weld overlay.

2.2 Fitness for Repair

Before overlays are applied, the original tubing needs to be inspected to determine if repairs are appropriate. Each individual repair subsection discusses inspections that are specific to that type of repair, but there are some issues that need to be addressed before any weld overlay repair can be done. The primary concerns are remaining wall thickness and condition of the tubing.

2.2.1 Remaining Wall Thickness

The thickness of the tubing is a concern for several reasons. If the tubing is too thin, burnthrough or distortion of the inside surface may occur during the welding process. Distortion of the ID surface can lead to deposits, flow disruptions, and other operational problems. Burnthrough can also introduce contaminates from the tubing ID into the solidifying weld metal, such as copper, which can cause embrittlement of the tube and weld metal. Repairs have been completed on very thin tubing, but repairs of this type require specialized welding procedures and processes and require significant time to complete. Remaining life of tubing repaired in this manner may not be sufficient to justify the cost.

A minimum wall thickness of 0.100" (2.54 mm) has been adopted to minimize the potential for burnthrough. This minimum thickness also results in a good production rate during the overlay process and minimizes the need to continuously change welding parameters during the repair process, resulting in a better quality weld. Thickness of the tubing should be determined using ultrasonic thickness measuring equipment` or by physical measurements of removed tubing.

2.2.2 Condition of Tubing

Several failures have been reported in overlaid tubing soon after completion of the overlay [4]. These failures are often traced back to existing damage in the tubing before the application of the overlay. Any of the failure mechanisms listed in EPRI’s boiler tube failure guideline may be active in the boiler tubing to be repaired [3]. Table 2-1 lists some of the water-touched damage mechanisms that can cause unsuccessful waterwall overlays. Table 2-2 lists some steam-touched damage mechanisms that are applicable to overlays of superheat/reheat tubing and higher temperature waterwall tubes in supercritical boilers.

Table 2-1
Water-Touched Damage Mechanisms of Concern When Applying Overlays

Water-Touched Damage Mechanism
Acid phosphate corrosion
Caustic gouging
Chemical cleaning damage
Corrosion fatigue
Fatigue
Hydrogen damage
Low-temperature creep
Pitting

Table 2-2
Steam-Touched Damage Mechanisms of Concern When Applying Overlays

Steam-Touched Damage Mechanism
Chemical cleaning damage
Fatigue
Graphitization
Long-term overheating/creep
Low-temperature creep
Pitting
Stress corrosion cracking

The failure mechanism of most concern at the current time is hydrogen damage. Hydrogen damage is hard to detect using typical nondestructive examination (NDE) techniques and is undetectable using ultrasonic thickness equipment. This damage mechanism is classified as an under deposit failure mechanism and is covered in Section 15 of the boiler tube failure guideline. It results in microfissuring of the base metal from the accumulation of methane gas at grain boundaries [3]. The microfissuring combined with the potential differential expansion between the base metal and overlay material may result in crack propagation and rapid failure.

Utilities planning to perform weld overlays should remove tubing from the highest heat flux areas to be overlaid and perform inspections for hydrogen damage and other damage mechanisms. This evaluation can be performed by the utility or contracted to the overlay contractor; however, the responsibility to perform this analysis should be addressed in the overlay contract. It is EPRI's recommendation that the utility perform this analysis because evaluation of this and other damage mechanisms is generally outside the field of expertise of the overlay vendor.

Hydrogen damage generally results from poor water chemistry (low pH) and heavy internal deposit loading. Utilities with a history of water chemistry problems and/or heavy internal deposits on their boiler tubing should consider chemically cleaning the boiler before the application of waterwall overlays.

2.3 Code and Standards

In most jurisdictions, the work scope must meet and be conducted in accordance with the original code of construction as stated in the rules in the National Board Inspection Code, ANSI/NB-23 [5]. For domestic repairs, ASME Code rules must also be used, particularly ASME Section I, Rules for Construction of Power Boilers [6]. NB-23 considers both application of corrosion-resistant weld overlay and repair of wasted tube areas as "Repair" as defined in NB-23; Appendix 6; Para. 6-2000 (c) and (d).

Repairs to boiler tubing generally can be exempted from post-weld heat treatment (PWHT) because of wall thickness. To obtain this often requires an elevated preheat. Exemption criteria for avoiding PWHT when applying corrosion-resistant weld overlay can be found for P-No. 1 - 4 tube materials in ASME Section I, Table PW-39. Recently, these requirements were changed for corrosion-resistant overlays to eliminate both the elevated PWHT and preheat, which are impractical for field-applied overlays. When situations occur where these exemptions are not adequate, rules are included in NB-23, RD-1000, Alternatives to Post Weld Heat Treatment, which gives guidance for other methods to qualify such welding procedures. For shop-applied overlays, PWHT is recommended.

Welding procedures, welders, and welding operators must be qualified in accordance with ASME Section IX, Welding and Brazing Qualifications [7]. Rules for groove welding qualifications, welders, and welding operator performance qualifications apply to tubing repair, restoration of tubing wall thickness, and tubing replacement.

Special process variables for the qualification of corrosion-resistant weld overlay for the shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW) processes are listed in ASME IX; QW-253.1, QW-255.1, and QW-256.1, respectively. Welders and welding operators must be qualified in accordance with QW-381 when they are required to deposit corrosion-resistant weld overlay.

In the event that the standard governing the original construction is not the ASME Code, repairs must conform, insofar as possible, to the edition of the construction standard or specification most applicable to the work, as outlined in NB-23, RC-1020. Where this is not possible or practicable, it is permissible to use other codes, standards, or specifications, including the ASME Code, provided an "R" Certificate Holder has the concurrence of the Authorized Inspector (AI) and the jurisdiction where the pressure-retaining item is installed.

All welding discussed herein must be conducted by an "R" Certificate Holder, as defined by NB-23, RC-1030.

2.4 Tubing Specifications

Before making any weld repairs or replacement of tubing, the existing tube composition must be identified. Table 2-3 identifies the most common tubing materials and corresponding ASME IX P-Numbers for welding qualification purposes [7].

Table 2-3
Typical Tubing Materials and Corresponding ASME IX P-Numbers per QW-422.

Tube Material	Nominal Chemical Composition	P-Number
SA 178	Low Carbon	P1
SA 210	C-Si	
SA 209-A1	C-0.5Mo	P3
SA 213-T2	0.5Cr-0.5Mo	
SA 213-T11	1.25Cr-0.5Mo-Si	P4
SA 199-T11*	1.25Cr-0.5Mo	
SA213-T22	2.25Cr-1Mo	P5A
SA 199-T22*		

*SA-199 was deleted from ASME II and IX in the 2003 Addenda. Where this material is encountered, rules in the original Code of Construction and or NB-23 should apply and be followed.

It is very important to know the composition of the tubing or weld deposit that you are about to repair. Where possible, original drawings should be secured and reviewed by corresponding elevations and weld lines to determine what material was originally installed or changed in later modifications.

If drawings are not available, then the boiler name/identification plate may be consulted. It is normally located on the outside of the installation; usually on the ground floor. It will identify the boiler manufacturer, serial number, and year of manufacture. With this information, the boiler manufacturer can be contacted for help in determining the materials involved. The plant/owner can also search maintenance records to identify field-overlaid material and tubing replacements/upgrades. When the materials are identified, a weld procedure can be chosen or developed to make the proper weld repair.

It may be beneficial to use a portable alloy analyzer (for example, Texas Nuclear or Niton) to determine the chemical composition of the tubing or weld deposit and to confirm installed material chemistry. Most analyzers can determine the material and identify individual component chemistry or at least generically classify the alloy. These analyzers are available through various nondestructive testing organizations, or they can be purchased by the utility. Purchasing an alloy analyzer may be justified when frequent analysis is necessary.

Where time permits or a detailed analysis is required, a sample can be removed and forwarded to a competent metallurgical laboratory for analysis. This method can also be used to confirm or validate the portable analyzer's data.

PWHT is not normally required for boiler tubing if the rules of ASME Section I, PW-39 are followed [6]. It should be recognized that many of the original boiler tube walls have been upgraded over time and may now include the P No-5A alloys that typically require alternative welding parameters and heat treatment.

The most recent addenda of the Code should be consulted because changes may have occurred that will assist in making repairs. One of the most recent changes is an exemption to preheat and PWHT for P-No 1 through P-No 4 materials during overlay operations if specific conditions are met.

2.5 Restoring Tube Minimum Wall Thickness

Base metal repairs required to restore the pressure boundary to minimum thickness are performed with weld filler metal that matches the chemistry of the base metal unless an alternative is determined satisfactory. This section is primarily for the build-up of wasted areas when the cause of wastage has been corrected (that is, the repair of sootblowers or gas stream balancing) or prior to installing corrosion-resistant overlays (CROs). Currently, CRO thickness cannot be used to enhance the pressure boundary or wall thickness. Wasted base metal must first be restored to the original minimum wall using filler metal that matches the base metal chemistry and strength, and then a CRO may be applied. Under a separate project, the EPRI Materials & Repair Program is working to change the ASME Code to allow CRO thickness to be counted in the stress calculations. This will eliminate this step and provide significant cost savings during build-up operations on waterwalls and superheater/reheaters.

2.5.1 Inspection Prior to Restoration

Boiler walls that exhibit thinning or eroded (wasted) areas may fail unless corrective measures are initiated. The primary goal of inspection is to find areas that may fail before the next outage and allow for repairs before the remaining metal thickness is too thin for a successful repair. Areas to be inspected can be determined from previous failures and from visual inspection. During visual inspection, the inspector should pay particular attention to flatness of the tubing, grooving at the membrane-to-tube interface, roughness of the surface, fresh oxidation or rust (which can indicate active wear), and any other obvious discontinuities on the surface of the tubing. Figure 2-1 provides a guide for inspection logic.

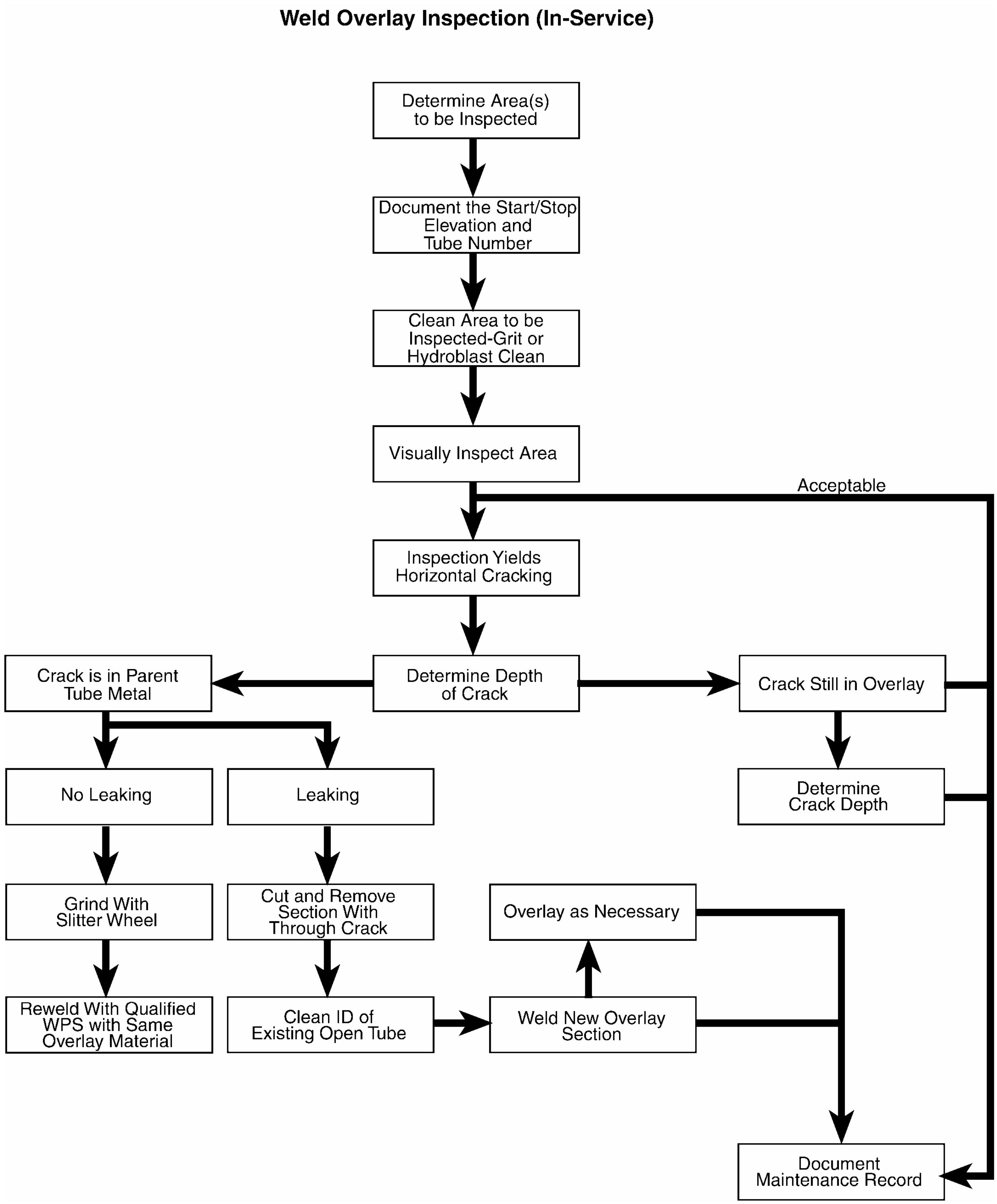

Figure 2-1
Flow Chart for Restoration of Wasted Tubing

Inspection of ID surfaces is also recommended before overlay application. Several instances have been noted where overlays were applied to damaged tubing which resulted in failure by other failure mechanisms than the oxidation of the OD surface. Hydrogen damage, internal deposits, and other abnormalities should be considered before the application of an overlay. Removal of tube samples to inspect for these problems is recommended before large overlay application (see Section 2.2).

Many types of NDE can be used to evaluate the integrity of individual tubes or entire panels. The methods discussed here are suggested in the order in which they should be used. Prior to any NDE, a good surface cleaning should be performed. This can be accomplished using high-pressure water blasting or a local grit blast. If the deposit is not too thick, adequate cleaning can be accomplished by light grinding or power wire brushing. The following inspections can then be performed:

- Visual inspection is a prerequisite for any subsequent NDE. Items of interest include surface quality or any visual discontinuities, especially cracks, thinning, and surface imperfections. Work aids may include the use of a ruler, flashlight, any available templates, and/or a magnifying glass to enhance the effort.
- Magnetic particle testing can also be used to identify any tight cracks in carbon and chrome-moly tubing. The alternating current (AC) method will show surface discontinuities. The direct current (DC) method can identify surface indications as well as shallow subsurface (approximately 0.0625" (1.6 mm) deep) flaws. Proper procedures and calibration are required for all test methods. Portable yokes or more cumbersome prod equipment can be used, depending on access and the extent of inspection required.
- An ultrasonic thickness measuring device should be used to determine the number of thin tubes so an area for replacement can be developed. Using a grid or pattern to take measurements aids in determining the repair area. Grids are generally laid out so that one elevation of inspections is performed for each scaffold elevation. Initial surveys can be performed by taking a thickness measurement on every 5^{th} or 10^{th} tube. This type of screening will speed up measurements. If thin areas are found, more detailed measurements can be taken on every tube in the affected area.
- If NDE is inconclusive, a sample should be removed to determine the material thickness in the area of interest. If it should turn out to be critically thin, replacement of the eroded or corroded area should be performed, using a tube-to-tube weld on each end or a “Dutchman.”

2.5.2 Determination of the Base Material Type

Base material composition must be identified to ensure that proper welding procedures are followed. Satisfactory identification methods have been described in Section 2.4.

2.5.3 Preparation for Repair

Many types of NDE can be used to evaluate the integrity of individual tubes or entire panels. The methods discussed here are suggested in the order in which they should be used. Prior to any NDE, a good surface cleaning should be performed. This can be accomplished using high-pressure water blasting or a local grit blast. If the deposit is not too thick, adequate cleaning can be accomplished by light grinding or power wire brushing. Where they exist, grind the scarfs, cracks, or nicks to provide a groove suitable for welding. Clean the area of all slag, dirt, or debris by grinding or wire brushing.

2.5.4 Filler Metal Selection

The weld metal that is chosen for repairs should have the same chemical and physical properties as the base metal. Table 2-4 offers recommendations based on weld metal that is traditionally used to weld the listed tubing base metals.

Table 2-4
Tube Materials and Typical Repair Weld Filler Metals (SMAW shown, corresponding GTAW products can be used)

P-NUMBER	TUBE MATERIAL	PREHEAT	ELECTRODE
P1	SA 178	50°F (10°C)	E7018
P1	SA 210	50°F (10°C)	E7018
P3	SA 209-A1	50°F (10°C)	E7018-A1
P3	SA 213-T2	50°F (10°C)	E7018-A1
P4	SA 213-T11	250°F (120°C)	E8018-B2
P4	SA 199-T11	250°F (120°C)	E8018-B2
P5A	SA213-T22	400°F (205°C)	E9018-B3
P5A	SA 199-T22	400°F (205°C)	E9018-B3

Welds in boiler waterwalls and superheat/reheat (SH/RH) tubing are frequently performed in the vertical position. Where burnthrough concerns exist due to thinning, welding in the vertical down progression should be considered to reduce penetration. Downhill welding usually results in a thinner deposit and lower residual stresses.

Challenges can exist with downhill welding. Low hydrogen filler metal generally used for boiler repairs employs fast freeze iron powder fortified EXX18-XX flux formulations specifically designed for increased deposition during out-of-position welding. This fast-freezing flux may trap impurities in the weld metal when welding downhill. One way to minimize this problem is to use EXX15-XX coatings. The flux is normally thinner, and less iron powder is available to create unmanageable weld puddle geometries.

Use of EXX15-XX formulations can also help with burnthrough. This is of additional interest in systems where the system contains copper tubing in the feedwater heaters or condenser. Copper can plate out on the ID of the boiler tubing. When welding, copper can migrate into the weld and cause copper embrittlement, which results in failure of the repair weld.

Most procedures qualified by utilities are done with an uphill progression. If a downhill progression or a more downhill friendly filler metal is used, a new welding procedure may be required.

2.5.5 Welding Parameters and Variables

Welding procedures appropriate for the material involved and qualified in accordance with ASME IX must be used for the repair. Variables including preheat, interpass temperature, and PWHT must be observed.

Weld metal should be selected as recommended in Table 2-2 unless otherwise qualified or indicated on approved drawings.

2.5.6 Weld Sequence

If a through-wall leak results in a forced outage, a Dutchman should be considered if at all possible. When using a Dutchman, good welding practice requires grinding the ID of all existing tubing prior to installing the Dutchman. If a Dutchman cannot be used, see Section 2.8.

Downhill or vertical down progression is recommended for thin tubes. However, if more than one pass is to be welded, allow sufficient time for the surface to return to the initial specified preheat temperature. Upon verification of the specified preheat, uphill or vertical up weld progression should be performed in accordance with the welding procedure specification (WPS).

2.5.6.1 Cracked, Scarfed, or Nicked Tubes

Cracks should be removed by grinding prior to repair welding. If the groove depth is within 0.100" (2.5 mm) of through wall, the first pass must be done using GTAW or GMAW processes, or the SMAW process using the vertical down progression.

2.5.6.2 Eroded Tubes:

Tubes eroded below 0.100" (2.5 mm) should be replaced. If tubing cannot be replaced, see Section 2.7.

After installing a Dutchman or performing weld repairs to the base metal, the area should be cleaned by grit blasting or another suitable method before applying the corrosion-resistant overlay.

2.5.7 Final Inspection

All repair areas should be inspected, identified, and documented in accordance with the original code of construction or National Board Inspection Code (NBIC).

2.6 Corrosion-Resistant Overlay for Wastage (Original Application)

This information is intended to apply to application of a CRO to tubing that does not contain a previously applied CRO. If the tubing has already had a CRO applied that needs to be repaired, see Section 2.7. If the tubing is below minimum wall thickness and a CRO is desired, see Section 2.5 first.

2.6.1 Inspection Prior to CRO

Inspection prior to CRO should be conducted as stated in Section 2.4. A flow chart for this type of repair is shown in Figure 2-2.

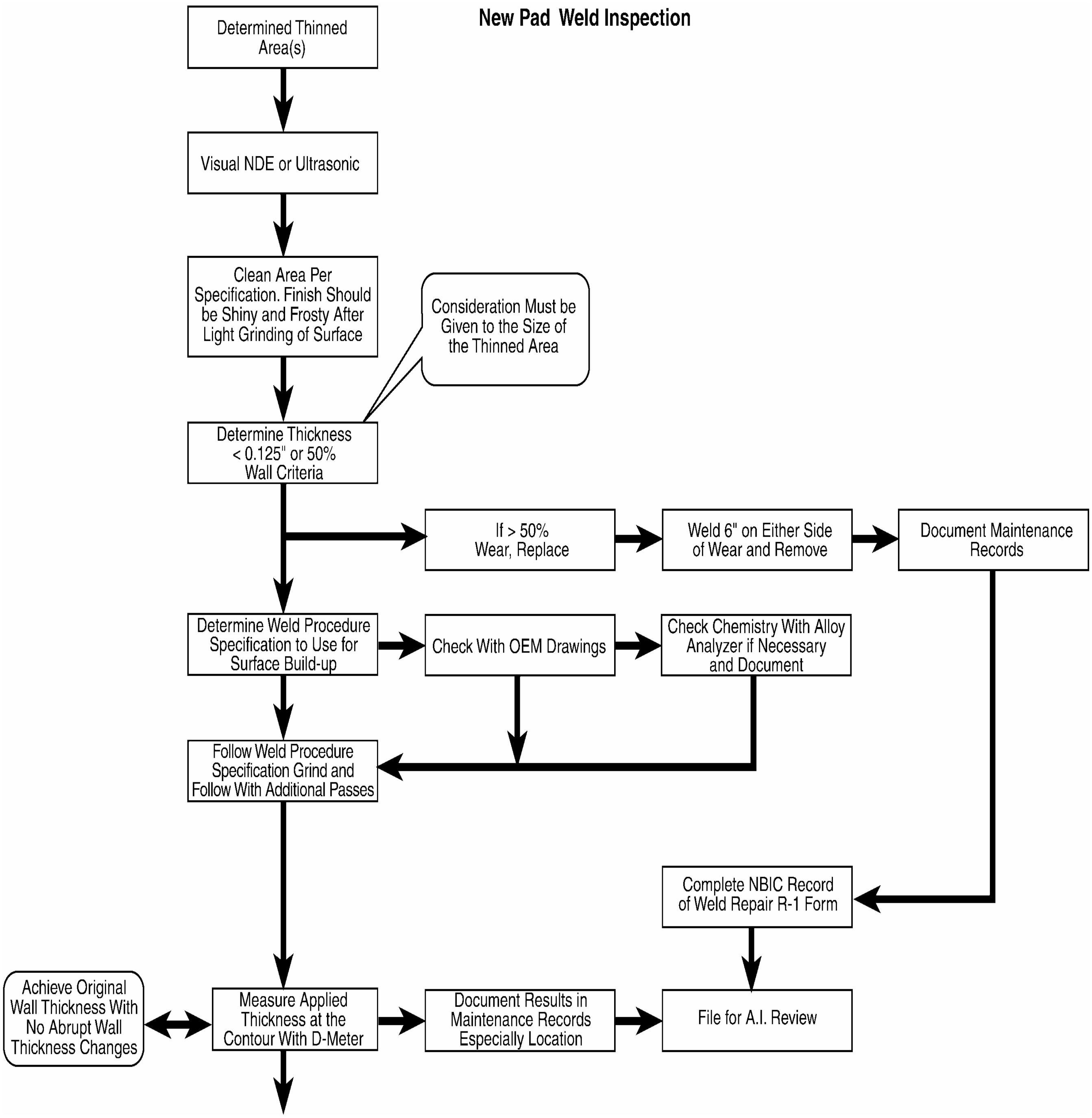

Figure 2-2
Flow Chart for the Restoration of Wasted Tubing

2.6.2 Determination of the Base Material Type

Base material composition must be identified to ensure that proper welding procedures are followed. Satisfactory identification methods have been described in Section 2.4.

2.6.3 Preparation for Repair

Many types of NDE can be used to evaluate the integrity of individual tubes or entire panels. The methods discussed here are suggested in the order in which they should be used. Prior to any NDE, a good surface cleaning should be performed. This can be accomplished using high-pressure water blasting or a local grit blast. If the deposit is not too thick, adequate cleaning can be accomplished by light grinding or power wire brushing. Where they exist, grind the scarfs, cracks, or nicks to provide a groove suitable for welding and repair according to Section 2.4 above. Clean the area of all slag, dirt, or debris by grinding or wire brushing. If the area was previously pad welded, replace the affected tube with a new Dutchman.

2.6.4 Inspection Prior to Repair

Inspection prior to repair should be conducted as outlined in Section 2.5.

2.6.5 Filler Metal Selection

Weld metal to be used for the weld overlay can range from stainless steel to nickel-based alloys. Weld overlay materials are selected because of their performance. See Table 2-5 and Figures 2-3, 2-4, and 2-5. All of the alloys shown have greater than 20% chrome in their analysis, a key factor in limiting subsequent service-induced damage. Another consideration is the coefficient of thermal expansion between materials to be welded. The nickel-based alloys are a closer match with carbon and low alloy steels than are the stainless steels, as shown in Figure 2-6. When choosing a filler metal, you should consider this physical property because similar thermal expansion coefficients assist in reducing spalling of the clad from the tubing substrate.

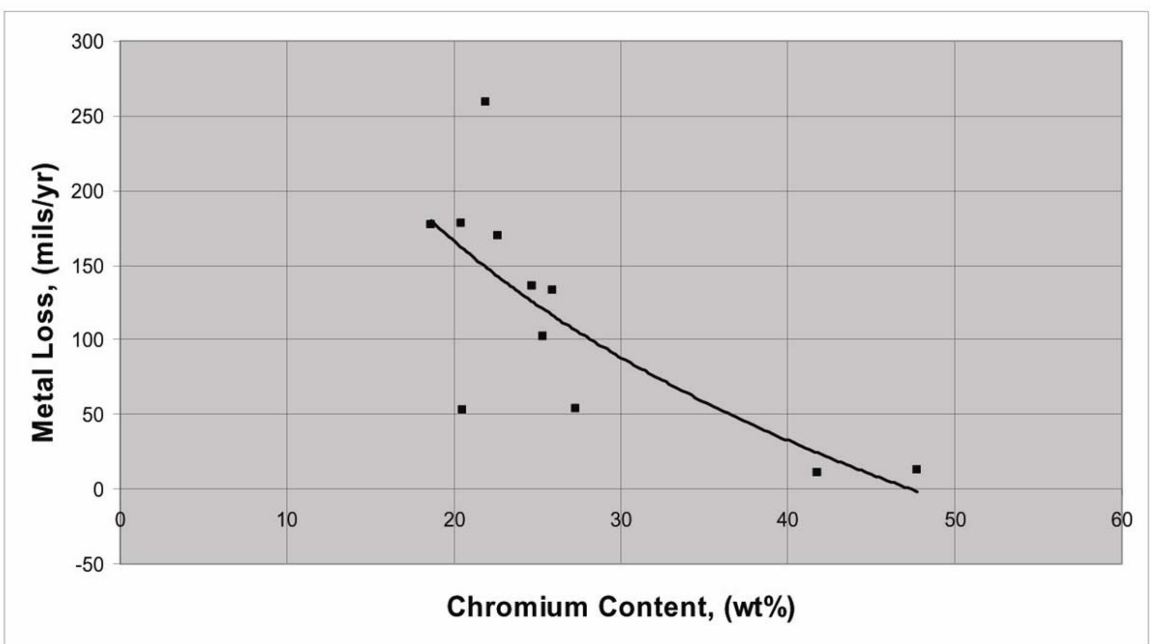

Figure 2-3
Influence of Chromium Content on Metal Loss or Wastage [8]

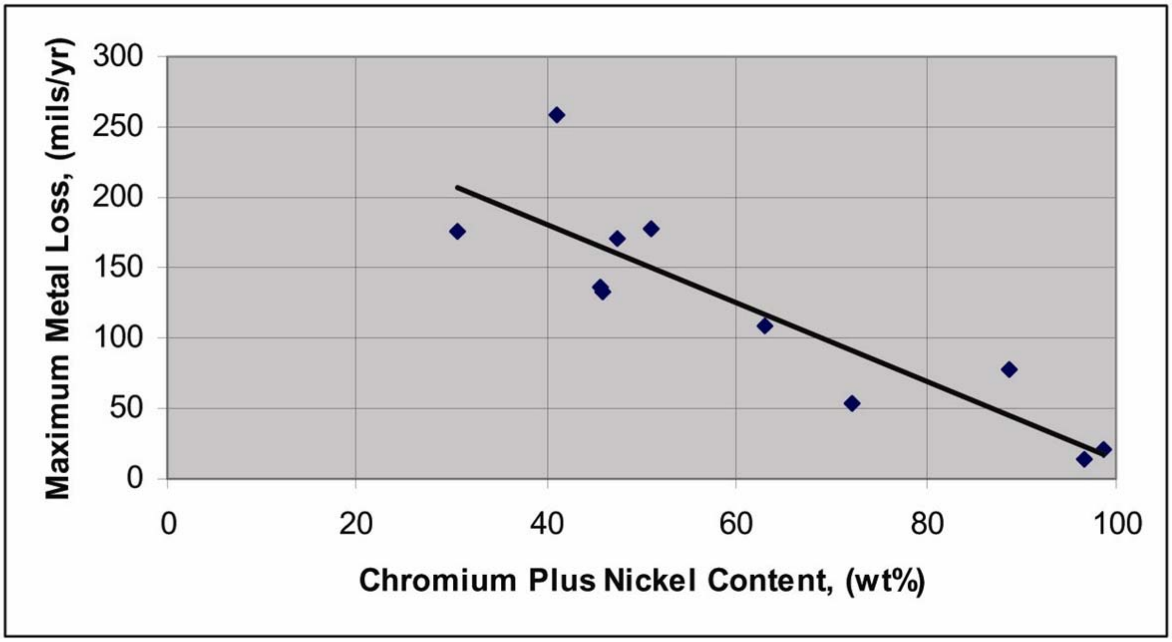

Figure 2-4
Cr+Ni Effect on Metal Loss or Wastage [8]

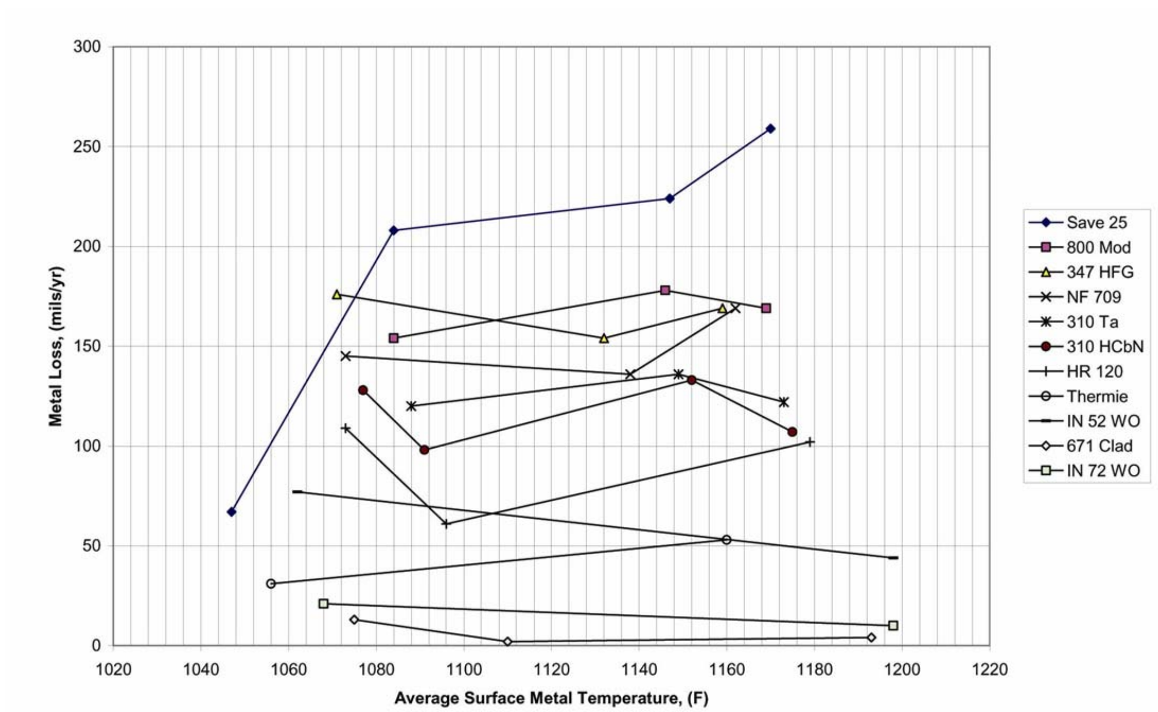

Figure 2-5
Effect of Surface Metal Temperature with Alloy and Corresponding Metal Loss [8]

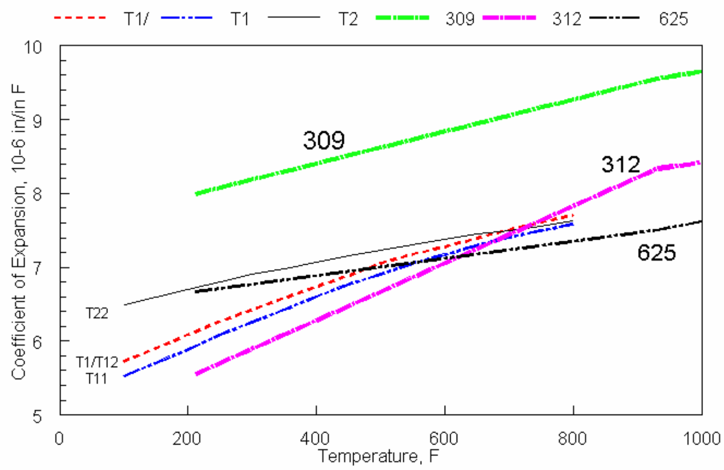

Figure 2-6
Comparison of Coefficients of Expansion [9]

Popular weld overlay alloys are shown in Table 2-5. Past performance suggests that alloys 622, 52, and 33 will offer good `service in supercritical boiler waterwalls, whereas alloys 33 and 72 are best suited to superheater and reheat tubing. Alloy 309 may be suitable for overlays in subcritical boiler waterwalls where the operating temperature will not have as much effect on the total thermal expansion as higher temperature supercritical waterwalls.

Special care should be given subcritical waterwalls because of concerns of internal damage (that is, hydrogen damage) and distortion of the internal surface that can lead to deposits forming on the ID surface (see Section 2.2).

Table 2-5
Alloys Used for Weld Overlay [1, 8, 9, 10]

Alloy	Composition	Approx. Life	Temperature Limits	Comments
309	24Cr, 13 Ni	4–6 yrs. Some cracking	900°F–? (482°C–?)	Not popular for supercriticals
312	30Cr, 9Ni	3–6yrs. Scarce data	885°F–? (474°C–?)	Solidification cracking?
625	64Ni, 21Cr, 9Mo, 3.5Nb	1.5–6 yrs.	1100–1150°F (593–621°C)	5–15 mpy (mils per year) loss
622	59Ni, 22.2Cr, 14Mo, 3W	> 7 yrs.*	1000–1100°F (538–593°C)	No cracking, 2–3 mpy loss
72	56Ni, 43Cr, 0.6Ti	> 3 yrs.*	1000–1300°F (538–704°C)	Insufficient data, 3–4 mpy loss
52	59Ni, 30Cr, 9Fe	Insufficient Data*	1000–1300°F (538–704°C)	Insufficient data
53MD	60Ni, 30Cr, 5Fe, 3Al	No Data*	1100–1300°F (593–704°C)	No data
33	31Ni, 33Cr	Insufficient Data*		
Chromized Steel	Fe	2–4 yrs.	-	Not effective in some low No_x
Steel	Fe	1 yr.	-	120 mpy loss

*As of June 2004.

Comparative cost information for overlay weld metals is shown in Table 2-6. Costs vary widely based on alloy surcharges, international monetary exchange rates, and quantity ordered.

Table 2-6
Comparison of Overlay Alloys (10 lb. Quantity Pricing, Late 2004)

Overlay Alloy	Process	Electrode	Cost per Lb.
309	GTAW/GMAW	ER309L	$8.57
309	SMAW	E309L-16	$8.31
312	GTAW/GMAW	ER312	$11.00
312	SMAW	E312-16	$9.15
622	GTAW/GMAW	ERNiCrMo-10	$32.65
625		ERNiCrMo-3	$27.03
52		ERNiCrFe-7	$34.94
72		Unassigned	$71.08

2.6.6 Welding Parameters and Variables

All welding parameters and qualified procedures should be supplied by the overlay contractor. Procedures should include, as a minimum, welding procedure qualifications, welding procedure specifications, and technique/workmanship instructions.

Field weld overlays performed during an outage should be done with water circulation in the tubing to prevent extreme warpage and wall geometry problems. Water circulation reduces residual stress and minimizes ID surface distortion and chances of burnthrough. Field weld overlays have been applied with no water circulation and have exhibited extensive distortion and residual stress. Control of welding is also more difficult when welding without water in the tubing because as the tube surface heats up, welding parameters (amperage, travel speed, weave width, and dwell) must be altered to minimize burnthough and control the weld shape.

2.6.7 Weld Sequence

Weld sequencing is very important in the weld overlay process. Early waterwall overlay attempts using a weld sequence like the one shown in Figure 2-7 resulted in cracking in the crown of the tube. This type of weld sequence also results in a thick buildup on the crown of the tube. Because most of the alloys used for CRO have lower thermal conductivity than carbon or low alloy steel, this thick overlay may result in high metal temperature at the surface, which can lead to premature failure of the overlay or tube material.

Revised weld sequences shown in Figure 2-8 have resulted in better service.

Parameters	Membrane Bead 1	Sides of Tube Bead 2	Crown Pass Beads 3 & 4
Amps	180–220	180–220	180–220
Volts	24–28	24–28	24–28
Travel Speed	16–18	22–27	22–27
Wire Feed	425–450	375–425	375–425

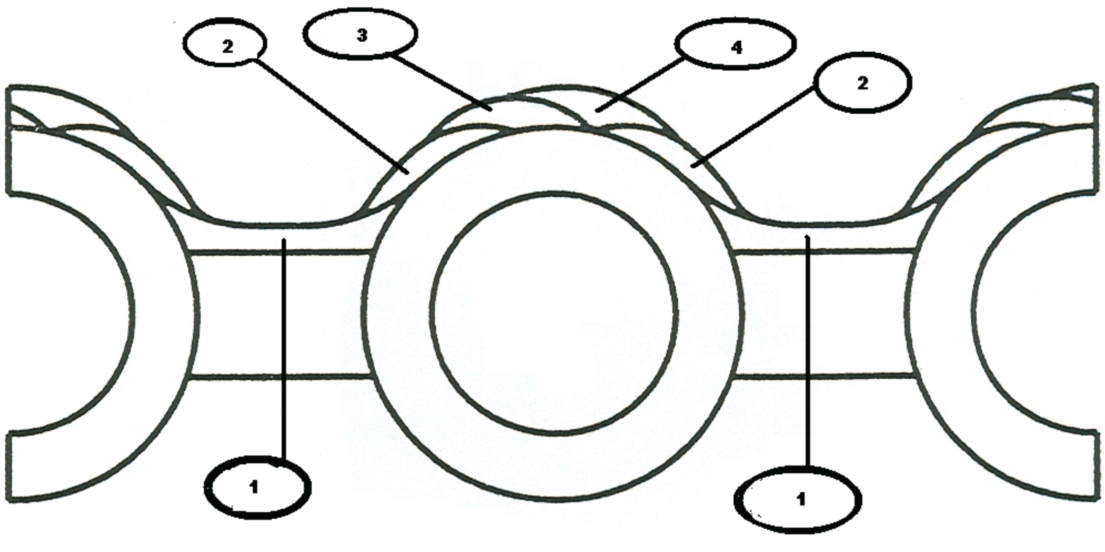

Figure 2-7
Early Weld Sequence

Parameters	Membrane Bead 1	Sides of Tube Bead 2	Crown Pass Beads 3 & 4
Amps	180–220	180–220	180–220
Volts	24–28	24–28	24–28
Travel Speed	13–18	18–26	18–26
Wire Feed	425–525	425–525	425–525

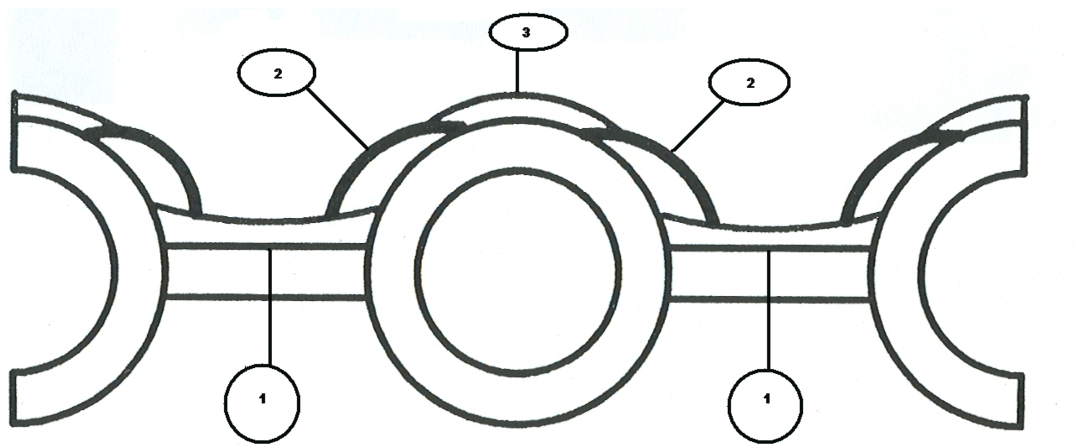

Figure 2-8
Improved Weld Bead Sequence

2.6.8 Final inspection

All repair areas should be inspected, identified, and documented in accordance with the original code of construction or NBIC.

2.7 Repair of Corrosion-Resistant Overlay (CRO)

This section applies to waterwalls and tubes that have previously had a CRO applied that needs to be repaired. Previously applied weld overlay may require repair due to wastage, embrittlement, or thermal cycling effects. Figure 2-9 shows a flow chart for this type of repair.

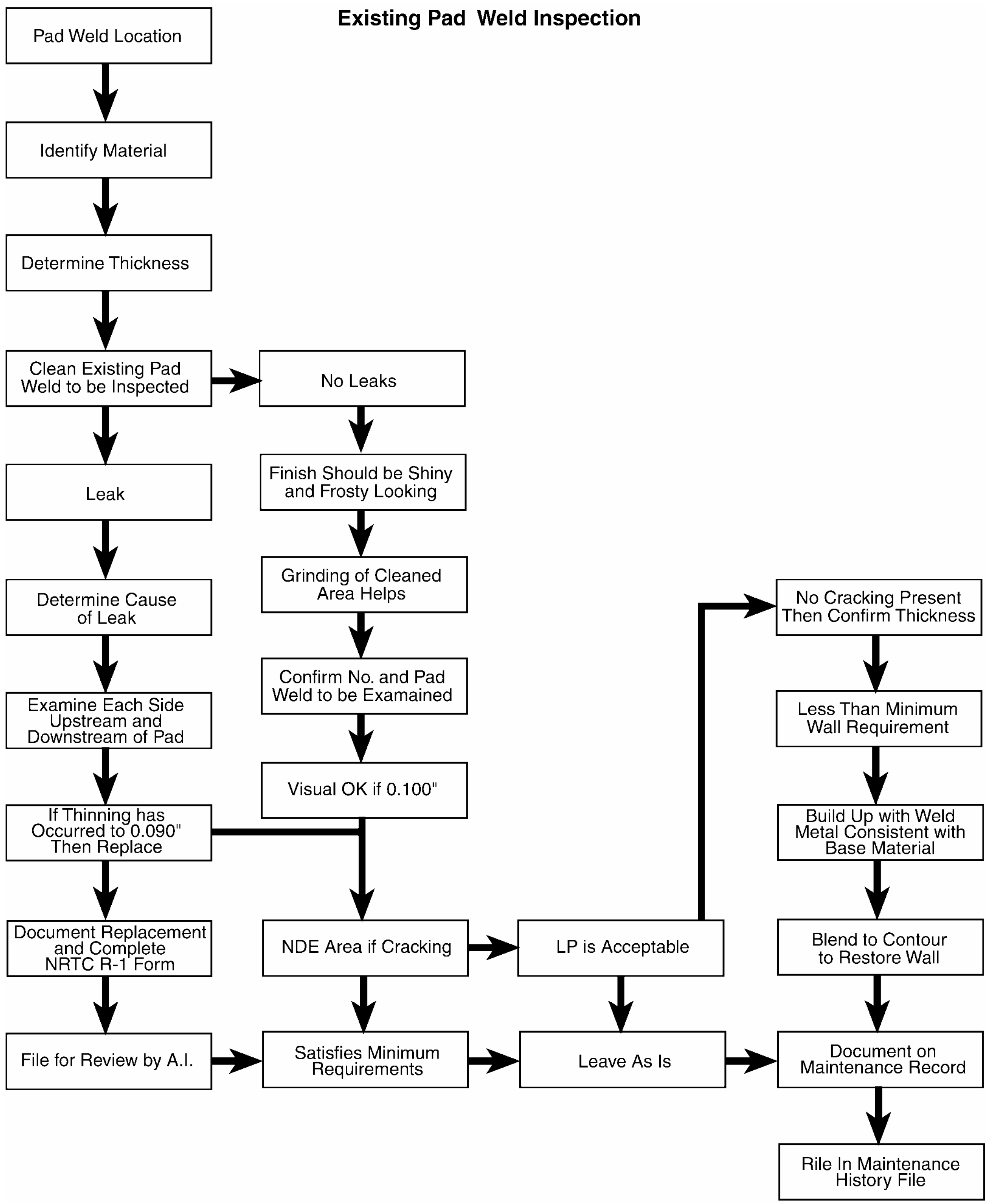

Figure 2-9
Flow Chart for Repair of CRO

2.7.1 Inspection Prior to Overlay Repair

Repair of areas in question found by NDE (see Section 2.5.1) should be evaluated and staged for repair or subsequent replacement. The areas that are not leaking and exhibit wastage should be checked for thickness to ensure a successful weld repair of the existing overlay. Leaking areas should be replaced with a Dutchman.

2.7.2 Damage Assessment

The primary damage mechanism for waterwall panels prior to installation of a CRO is wastage. This is not a large concern for panels after installation of a CRO. The enhanced chromium content of modern overlays seems to be adequate for corrosion protection. The primary damage mechanism for installed CROs is cracking. The cause of the cracking varies depending on the material used for the overlay. Among the concerns are corrosion of the dendrite structure (due to weld solidification), embrittlement, residual stresses, and lack of coverage of the original base metal. Many boilers are operating with embrittled overlay material without cracks, and other installations have had cracking problems related to embrittlement. The exact relationship between embrittlement and failure is not well understood.

Before repairs can be successfully completed, an inspection for damage should be completed and a root cause analysis performed.

Cracking orientation appears to be location-specific. Vertical cracking occurs on the crown of the tubing or at the interface of the membrane to the tube. Such cracking may be at the toe of the weld or at the weld centerline. Many of these cracks have been traced back to the original installation and are influenced by surface cleanliness.

Horizontal cracking is generally related to the weld metal being used, solidification structure, and thermal excursions during boiler operation. When extensive horizontal cracking is observed, significant time and money can be expended to make the area crack-free. Weld economics vs. tube or panel replacement will be a large factor when deciding whether to repair or replace. Horizontal cracks seem to be prevalent, especially in alloy 625.

Thermal stresses from sootblowing and use of water cannons may also contribute to horizontal cracking as has occurred in base metals. The effect of water cannons is ongoing under separate research in the EPRI Materials & Repair Program.

Horizontal cracking may also be influenced by residual stresses. When areas of CRO are extended, the residual stress from the subsequent CRO application can cause cracking in the existing CRO. The possibility of this cracking occurring can increase if any embrittlement has occurred during service. To minimize this, if a small band (2" to 4" [5 to 10 cm]) of un-overlaid tube is left until all other CRO application has been completed and then this small area is overlaid, residual stresses in the old CRO can be minimized.

2.7.3 Determination of Base Material and Overlay Type

Determination of base material and CRO should be conducted as outlined in Section 2.4.

2.7.4 Preparation for Repair

If the area to receive the CRO has suffered from material wastage that has not penetrated the tube base metal, it should be cleaned, and additional CRO applied with filler metal that matches the original CRO or an upgraded filler metal. It is generally OK to apply nickel-based filler metal over austenitic filler metal, but austenitic filler metal should not be applied over nickel-based filler metal.

If wastage is severe enough to require restoration of tube base metal, the tubing should probably be replaced with tubing that has received a shop-applied CRO or bare tubing and a field-applied CRO applied.

Field weld overlay performed during an outage should be done with water circulation in the tubing to prevent extreme warpage and wall geometry problems. Water circulation reduces residual stress and minimizes ID surface distortion and chances of burnthrough. Field weld overlays have been applied with no water circulation and have exhibited extensive distortion and residual stress. Control of welding is also more difficult when welding without water in the tubing because as the tube surface heats up, welding parameters (amperage, travel speed, weave width, and dwell) must be altered to minimize burnthough and control the weld shape.

Cracking, if localized and not too frequent, can be repaired using a thin wheel in a grinder or carbide burr. Care must be taken to open the crack up, being careful not to grind through the overlay and into the original tube wall. NDE should be performed before the welding repair to verify that the entire crack has been removed. The gas tungsten arc welding (GTAW) process should be used in the initial pass of the repair, using filler metal that matches the original CRO. After the cracks are repaired, additional overlay can be applied with any welding process including gas metal arc (GMAW), shielded metal arc (SMAW), or continue with the GTAW process if the repair area is not too large.

2.7.5 Filler Metal Selection

Field weld overlay repair should be done with compositions as close as possible to the original overlay. When selecting repair filler materials for existing overlays, although austenitic and nickel-based filler metals provide good ductility in the as welded condition, the nickel-based alloys may be a better choice for repairs because they have closer thermal expansion to the tube base metal. Additionally, nickel-based filler metals can be successfully used to weld austenitic base metals but not vice-versa. See Section 2.5 for discussion of weld filler metal options.

2.7.6 Welding Parameters and Variables

When making repairs to CROs, it may be unclear what type of welding procedure should be used. One school of thought suggests that the original welding procedure for placing the weld overlay on the water wall should be used. Alternatively, because the existing weld overlay may be considered to be the base metal, a procedure for a base metal with the same chemistry as the nickel or stainless material overlay material may be required. This question must be addressed on a case-by-case basis.

2.7.7 Weld Sequence

Weld sequencing is very important in the weld overlay process. See the weld sequence discussion in Section 2.6.

2.7.8 Final Inspection

All repair areas should be inspected, identified, and documented in accordance with the original code of construction or post-construction code.

2.8 Repair of Leaking Tubing (Pad Welding)

Repair of leaking tubing is called “pad welding”. Pad welding is not recognized as a permanent repair and generally results in repeated tube failure. Such a repair should be removed and the tube replaced at the earliest possible time [11]. Tubing left in service for extended time with a pad weld in place often results in repeat failures and forced outages. The primary reasons for this are the lack of cleanliness and control of welding operations and the inability to properly perform failure mechanism/root cause analysis. Without proper failure mechanism/root cause analysis, proper repair is generally not possible.

Pad welding should never be attempted when damage is ID initiated or if the failure is a thick-walled failure. These types of failures generally result from waterside failure mechanisms or material degradation. Repairs to tubing that suffers from ID tube failure mechanisms or material degradation will not provide adequate service life.

Tubing that has eroded from the outside may provide service until the next available outage when more permanent repairs can be completed. Even with this type of repair, concern exists that the failure mechanism may not be adequately known or that other circumstances will result in premature failure. One area of concern is in feedwater systems that contain copper. If copper from inside the tube melts and solidifies in the weld metal, embrittlement and lower strength may occur. Other deposits on the inside of the tubing may behave similarly.

2.8.1 Determination of Base Material Type

Base material composition must be identified to ensure that proper welding procedures are followed. Satisfactory identification methods are described in Section 2.4.

2.8.2 Preparation for Repair

All water must be drained from tubes and headers prior to welding. Inspection of areas should follow the logic outlined in the flow charts offered in Figures 2-7 and 2-8.The area should be mechanically cleaned (brushing, grinding, etc.) and be free from dirt, oxidation, scale, grease, or other deleterious materials.

The best option for the repair of leaking tubing or those tubes experiencing a high degree of ID erosion is to selectively replace the tube with a short section or “Dutchman.” Dutchman replacement lengths should not be less than 6–8" (15–20 cm) with additional consideration given to existing welds in the area. Most plants replace the damaged area with an additional length of about 6" (15 cm) on each end of the tube so that replacement welds will be in undamaged tubing. This results in replacement Dutchmen in the 15–18" (38–46 cm) length.

Stacking numerous welds, one on top of the other, should be avoided. Minimizing the number of welds lessens the chances of failure in the future. If there are additional welds in the area, the Dutchman length should be increased to remove as many of the existing welds as possible. Flow disturbances from multiple welds may lead to waterside failure mechanisms being active.

Where the existing tubing must be used, the following should apply.

2.8.2.1 Cracked, Scarfed or Nicked Tubes

Grind the scarf, crack, or nick to provide a groove suitable for welding.

2.8.2.2 Eroded Tubes

Clean the area of all slag, dirt, or debris by grinding or wire brushing. If the area was previously pad welded, a replacement Dutchman is strongly recommended.

2.8.3 Filler Metal Selection

Weld filler metal selection and welding procedures must be consistent with the existing tubing and/or weld overlay. Table 2-2 offers recommended filler metals for alloys that may be encountered.

2.8.4 Welding Parameters and Variables

Welding procedures appropriate for the material(s) involved and qualified in accordance with ASME IX should be used for the repair. Variables including preheat, interpass temperature, and PWHT should be observed.

Weld metal should be selected in accordance with Table 2-2 unless otherwise indicated on the approved drawings.

2.8.5 Weld Sequence

Downhill or vertical down progression is recommended for pad welding thin tubes. However, if more than one pass is required, allow sufficient time for the pad welded surface to return to the initial specified preheat temperature. Upon verification of the specified preheat, uphill or vertical up weld progression should be performed in accordance with the WPS.

Weld sufficient passes to restore the surface to the original contour or to the specified wall thickness. No weaving of the weld passes is permitted; however, the amount of oscillation permitted for each bead is three electrode diameters.

2.8.5.1 Cracked, Scarfed, or Nicked Tubes

If the groove depth is within 0.100" (2.5 mm) of through wall, the first pass must be done using the GTAW or GMAW process, or the SMAW process using the vertical down progression.

2.8.5.2 Eroded Tubes

Tubes eroded below 0.100" (2.5 mm) should have the first pass welded using 3/32" (2.4 mm) diameter or smaller rods, low amperage, stringer beads, or the GTAW process.

2.8.6 Final Inspection

All repair areas should be inspected, identified, and documented in accordance with the original code of construction or post-construction code.

2.9 Documentation

Record keeping is very important to help you to understand wear patterns and to provide a confidence factor in which overlay decisions are working. Field-welded overlaid areas should be identified by their start and stop elevations, as well as by the tube numbers that were overlaid. Areas of concern should be specified in an elevation drawing or sketch by tube number and elevation. Drawings of this type serve as a maintenance tool for future predictions and document repairs to show the Authorized Inspector (AI) what work was performed.

Records should include the following:

- Repair organization performing the repairs
- Surface preparation procedures
- Welding procedures
- Welder and welding procedure qualification records
- Preheat
- PWHT
- Filler metal
- Process
- Thickness applied
- NDE procedures

2.10 Life Assessment and Future Repair/Replacement Plans

Performing weld overlays to enhance boiler performance is a dynamic situation. Application and evaluation are typically conducted based on either emerging research or trial and error. This is compounded by the fact that no two boiler/fuel combinations are the same. Conventional wisdom and sound engineering judgment suggest that elevated chromium alloys should offer better performance. This is being disproved in selected instances as alloys believed to be resistant to wastage are failing by other mechanisms such as embrittlement or selective wastage of dendrite cores. Most evaluations of service performance are confounded by varying fuel supply characteristics, emerging burner technology, and changes in environmental rules.

EPRI is working on a separate project to have CRO included in the wall thickness and pressure boundary calculations. This change, when approved, should provide substantial savings on membrane fireboxes and also allow the use of overlays in tangent tube fireboxes where physical dimensions may currently not allow overlays of existing tubes. If approved, the weld overlay and the remaining original tube wall thickness would be counted into the wall thickness calculations as a homogeneous thickness.

The following sections provide specifications to aid utilities in contracting for shop- and field-applied weld overlays.

3
WELDING SPECIFICATION FOR SHOP-WELD OVERLAYS

1.0 Purpose

This specification provides general information, tube/panel preparation, welding, and inspection requirements. Further details are included for welding consumables, shielding gases, welder training and qualification, repairs, and documentation.

This guideline is presented to demonstrate areas that should be considered for a successful overlay job. A utility requesting an overlay proposal should examine each item individually and determine what items are appropriate for their use.

2.0 General

2.1 Overview

A. This specification identifies quality parameters necessary for boiler fireside tube buildups and corrosion-resistant weld metal overlays.

B. Further, this specification defines Plant (Owner) and Contractor responsibilities and accountabilities pertaining to required supervision, labor, tools, equipment, consumables, and other related services.

C. It is the intent of this specification to establish quality and technical requirements for the application of weld metal and/or corrosion-resistant overlay protection to the fireside of boiler tubes. It is not the intent of this document to completely specify all the details of the welding operation. However, all work shall be completed within the limits of this document shall conform to accepted utility and industry standards.

2.2 Definitions

A. Weld metal overlay (build-up) – One or more layers of weld metal applied to the substrate of a base metal to obtain desired properties and/or dimensions.

B. Corrosion-resistant weld metal overlay – Dissimilar weld metal deposits on base metals and weld metals to deter the effects of corrosion.

C. *In situ* techniques – Method for in-field application in place.

D. Plant – The utility Owner and/or its responsible management.

E. Contractor – The weld overlay contractor or vendor.

F. Work scope – The amount of weld overlay identified and approved by the Plant for the Contractor to perform.

G. MSDS – Material Safety Data Sheet.

H. CMTR – Certified Material Test Report.

I. UTT – Ultrasonic thickness testing.

J. PWHT – Post-weld heat treatment.

2.3 Safety

The Contractor shall have their own safety/drug protection program and conduct safety meetings as required

All Contractor personnel required to be on the Plant site are required to wear safety glasses, steel-toed safety shoes, and cotton clothing. The Contractor shall comply with industry safety practices and any requirements imposed by the Plant.

2.4 Provided Services

A. Labor and supervision for planning, mobilization, work scope, and final documentation.

B. Daily cost and schedule reporting for firm price or cost plus work scopes.

C. Tools and equipment to perform weld overlay work scope.

D. Materials (tubing, etc.) and consumables such as grinding equipment, welding wire, welding consumables, shielding gas, etc.

E. MSDSs and CMTRs shall be maintained at the work site and provided to the Plant in the final document package.

F. Final project summary (no later than two weeks after shipping the overlayed product) to include the actual itemized costs for supervision, labor, tools, consumables, and equipment.

G. Boiler tube(s) surface preparation.

H. Tube wall pre-heat if needed.

I. All required donnage, shipping, and handling apparatus.

2.4.1 Welding Consumables and Shielding Gas(es)

Welding consumables including manual shielded metal arc (SMAW) electrodes, bare filler wire for gas tungsten arc welding (GMAW) and/or shielding gas(es) shall be procured by either the Plant or Contractor.

2.4.1.1 Where provided by the Plant, the following shall apply:

- The Contractor shall be notified during the bidding process what welding consumables and/or weld deposits will be procured/required to ensure that the successful bidder will have the appropriate welding procedure qualifications and specifications, as well as welders and welding operators who are available to perform the work.
- The Contractor shall provide any special procurement information at job award to the Plant to ensure that appropriate welding consumables, shielding gas and/or gas mixtures, and estimated quantities are procured and available. When specified by the Contractor as necessary for satisfactory welding, items including surface finish, cast, helix, composition limits, trace element limits, delta ferrite, diameter, spool size(s), and packaging requirements will be provided by the Plant.
- Material presented to the Contractor that does not meet the prespecified requirements shall relieve the Contractor from schedule delays resulting from incorrect welding consumables and shielding gas(es).

2.4.1.2 Where provided by the Contractor, the following shall apply:

- The Contractor shall procure welding consumables and shielding gas(es) to provide weld deposits in accordance with the bid specification.
- The Contractor shall ensure that adequate quantities of material are available to support the Plant schedule.
- Problems or issues resulting from welding consumables and/or shielding gas(es) shall be the responsibility of the Contractor.

2.5 Pre-Job Planning

The Contractor and the Plant project management, including site supervision, will determine the scope of work, outage dates, duration, etc., during a pre-job planning meeting.

The welding Contractor shall provide supervision, labor, equipment, and materials to apply 0.070" (0.180 cm) thick (minimum) machine weld metal overlay to the surface of the boiler tubes and/or water wall panel(s). Weld metal thickness should be measured at several areas around the tubing so area of minimum thickness can be determined. The following information is required for the planning of the overlay job:

Tube Diameter (OD):		___________"
Minimum Wall:		___________"
Base Material:	SA-	___________
Membrane Width:		___________"
Membrane Material:	SA-	___________
Overlay Material:	ER-	___________
Overlay Height:		___________ Ft.
Width of Tubes:		___________ Ft.
Overlay Square Footage:		___________ Ft^2

Weld overlay is priced by the amount of actual surface area applied, taking into account the curvature of the tubes (often referred to as *flat footage*). Overlay square footage can be calculated using the formula for surface area calculation as follows:

Surface Area = [(π(O.D.)/2) + membrane width)](number of tubes)(length of tubes) For example, the applied surface area of sixty 1.375" (3.49 cm) tubes with 0.625" (1.59 cm) membrane, 10' (3.048 m) long would be:

Surface Area = $[(\pi\,(1.375")/2) + 0.625")](60)(120")(1\ ft^2/144\ in^2) = 139.2\ ft^2$

The work scope will be performed in accordance with the requirements of ASME Boiler and Pressure Vessel Code and National Board Inspection Code (NBIC). The NBIC is generally accepted by the regulatory agencies, (referred to as the jurisdictions—the state or local government or agency that regulates boiler repair—and normally the state government in which the plant is located) as the basis for repairs to existing plants. The NBIC has no specific requirements for the minimum wall thickness required in an existing plant. Section I of the ASME Boiler and Pressure Vessel Code is the specification usually imposed by the jurisdictions for new construction. Section I includes the formula for determining minimum tube wall thickness for new construction based on material specification and design temperature and pressure. This formula results in a wall thickness with a safety factor of 4; although. for lower temperature applications, ASME has recently reduced the safety factor to 3.5. The Foreword of Section I contains a statement to the effect that design validation to Section I ensures a margin for deterioration in service to enable a reasonably long period of usefulness. Since fireside waterwall wastage will result in leaks within the furnace enclosure that would minimize personnel safety concerns, the NBIC would rely on the Owner's interest and possible insurance concerns to repair eroded tubes before failures occur. The general practice is to measure thickness and to forecast when the wall thickness will be some percentage of the minimum wall thickness and make the repairs before that occurs. The specific percentage is set by the utility in conjunction with its insurance company. A major boiler OEM has issued a recommendation that, for supercritical waterwalls, repair or replacement should be performed if the wall thickness measurements are less than 85% of the minimum thickness. The requirement for subcritical boilers would result in repair or replacement if measurements were 70% of minimum.

The overlay material must be specified by the Owner/Plant. The more commonly used materials are ER309, ERNiCrMo-3 (Alloy 625), ER312, or ERNiCrMo-10 (Alloy 622). Proprietary alloys, such as Special Metals' 686CPT and Thyssen-Krupp's Alloy 59, are also considered for use.

ER309 is an austenitic stainless steel with an expansion coefficient that is about 30% greater than the base metal t which may lead to problems from cyclic operation if large thermal gradients occur. Figure 3-1 compares the coefficient of expansion of various waterwall tube materials with selected weld metal cladding. ERNiCrMo-3 and ERNiCrMo-10 have experienced selective corrosion attacks due to inherent segregation. ER312 provides a two-phase weld deposit with substantial percentages of ferrite in an austenite matrix. The ferrite undergoes 885°F (474°C) embrittlement in service. Toughness is high at service temperature when the material is heated above its FATT (Fracture appearance transition temperature). Severe thermal cycling and hydrostatic testing have indicated that the embrittlement does not affect service performance. The cost of ERNiCrMo-3 or ERNiCrMo-10 is at least twice that of ER312, but this cost may result in only about a 20% increase in total costs on a large overlay.

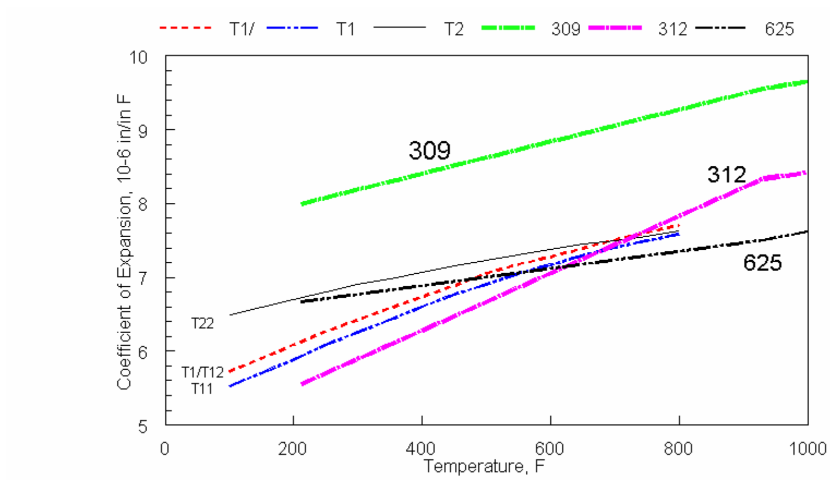

Figure 3-1
Coefficient of Expansion Comparisons

3.0 Codes and Standards

The following Codes, Standards, and Specifications apply to this specification. The latest edition and addendums in force at time of purchase shall apply:

A. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code
   a. Section I - Power Boilers
   b. Section II Parts A, B, C, and D
   c. Section V – Article 9- Visual Examination
   d. Section VIII- Division 1 Pressure Vessels
   e. Section IX - Welding & Brazing Qualifications

B. National Board Inspection Code (NBIC) - Repair/Alteration

C. American Society of Nondestructive Testing (ASNT)
   1. SNT TC-1A Recommended Practice for Nondestructive Testing, Personnel Qualification and Certification

D. American Welding Society (AWS)
   1. A2.4 Welding Symbols
   2. A3.0 Terms and Definitions

E. ASME "S" Certificate of Authorization [or "A", as appropriate]

F. ASME/NBIC "R" Certificate of Authorization

G. American National Standards Institute
   1. Z49.1 Safety in Welding and Cutting

4.0 Quality Assurance Program

The Contractor shall submit for review to the Authorized Inspector (and Owner when required) the following:

A. ASME Control Traveler
B. Welding Procedure Specifications
C. Supporting Procedure Qualification Records
D. Welder or Welding Operator Qualification Records
E. Welder Continuity Logs
F. QC Personnel Certifications
G. Documentation
   1. CMTRs for filler metal.
   2. Base metal ultrasonic thickness test reports
   3. Weld metal ultrasonic thickness test reports
   4. Distortion measurements

Note: In addition to the above, the Contractor QA and/or Site Manager will present a bead sequence/parameter deposition profile designed specifically for this application. All Contractor operational personnel will be advised of the parameters and bead sequence.

After authorization to proceed has been obtained from the Authorized Inspector, personnel may begin the weld overlay process.

5.0 Plant/Owner Access

5.0 The Owner/Plant shall have free access to Contractor facilities to:

5.0.1 Review any relevant procedures and verify compliance to the requirements of the Contractor quality program or to the Owner/Plant requirements.

5.0.2 Witness any portion of the welding process, equipment calibration, welding procedure qualifications, welder and welding operator performance qualifications, or nondestructive examination activities or personnel.

6.0 Contractor Personnel

6.1 QA/QC/Supervision

6.1.1 The Contractor shall provide a qualified lead quality control representative during the work scope. The Contractor's quality control personnel shall remain assigned to the work scope until the work is completed and shall be released only by the Owner's quality assurance representative.

6.1.2 The lead quality control representative shall administer the Contractor's quality control program and ensure conformance to the program requirements.

6.1.3 The lead quality control representative shall also be the weld technician unless the Owner approves additional weld technicians prior to the award of the contract.

6.1.4 Additional weld technicians, when specified in the contract, shall report to the lead quality control (QC) representative or as designated in the Contractor's program.

6.1.5 The Contractor's lead QC representative shall have at least two years of quality assurance and/or quality control experience with one year focused on boiler tube corrosion-resistant weld metal overlays.

6.1.6 Resumes of prospective candidates shall be submitted to the Owner's quality assurance representative at least one week before commencement of the job.

6.2 Welding Technician

The Contractor shall provide a quality control representative per shift who shall also perform welding technician responsibilities during the work scope. Quality control/welding technician personnel shall remain assigned to the work scope until completion of the work. If required, additional welding technicians for multi-shifts shall be specified in the contract agreement.

6.2.1 Welding technicians' duties shall include, but not be limited to, the following:

1. Participate in welder assignments.
2. Supervise filler metal and material control.
3. Inspect welding and related activities.
4. Maintain and submit applicable documentation.
5. For shop overlay panels, verify Cr content using a metal analyzer. Provide a minimum of five random readings per panel.
6. For shop single tube overlays, verify Cr content using a metal analyzer. Provide a minimum of two random readings per individual tube.
7. Regarding paragraphs 5 and 6 above, any Cr readings below 19.5% shall be brought to the immediate attention of the Owner's QA rep, and no work shall continue until released by the Owner's QA rep.

6.2.2 Welding technicians shall meet the following requirements:

1. AWS - Certified weld inspector (CWI) or
2. AWS - Certified associate weld inspector (CAWI) who has successfully passed the CWI examination but lacks the full five years of experience (written verification required) or
3. Quality control representative/welding technician who is a full-time employee of the company performing the overlay process and is certified in accordance with the company's visual weld inspection program

6.2.3 A copy of the individual's current certification records shall be submitted for review by their first day of work at the job site.

6.3 Inspection Personnel

All QA/QC personnel who perform visual and dimensional examinations are to be certified to an approved QA program that uses ASNT SNT TC-1A as a guide. The Contractor shall certify all QA/QC personnel, and records shall be provided to the utility.

6.4 Welders and Welding Operators

The Contractor shall qualify all welders and welding operators in accordance with its QA and ASME Section IX requirements. Welder qualifications shall comply with the following:

6.4.1 Contractors performing weld metal overlay shall have the option to use welder’s current qualification records if proof can be obtained by the Contractor of the welder having welded for them within the last six months.

6.4.2 Welder or welding operator performance qualification records shall be fully documented to the satisfaction and approval of the Authorized Inspector and the Owner.

6.4.3 Welder performance qualification tracking system welder status report shall be documented to the satisfaction and approval of the Authorized Inspector and the Owner.

6.4.4 The Owner or Authorized Inspector reserves the right to retest any welder plus audit welder qualification records and the welder tracking system at the site and/or record facility.

6.4.5 Contractor welders assigned to perform weld metal overlay who do not have current qualification records and have not welded for the Contractor within the last six months must re-certify on Company property and be in full compliance with paragraphs 6.4.1 through 6.4.5.

6.4.6 The Contractor's welding technician shall obtain all necessary copies of the welder’s performance qualifications. These shall be submitted to the Owner prior to the start of welding.

6.4.7 Contractor welder and welding operator qualification testing shall comply with the following:

6.4.7.1 The Contractor's welding technician shall administer the welder qualification tests.
6.4.7.2 The Owner reserves the right to witness or inspect any phase of the welder qualification test.
6.4.7.3 The coupon shall be tacked at the welding station into the designated position.
6.4.7.4 Once the coupon is tacked into position, it shall not be removed from that position until completion of the test.
6.4.7.5 The Contractor's welding technician shall make periodic checks during the test to verify usage of the proper filler materials and techniques. All grinding, filing, or brushing on the coupon after tacking shall be performed in the designated test position and is considered as part of the test.

6.4.8 Upon completion of the test, the Owner's quality assurance representative and the Contractor's QC representative/welding technician shall perform visual inspection of the test coupon prior to submittal for examination and testing.

Failure to meet the following criteria shall result in rejection of the test coupon:

- Lack of penetration
- Surface undercutting exceeding 1/32" (0.794 mm)
- Crown reinforcement exceeding 1/8" (0.318 cm)
- Abrupt valleys between passes with depths exceeding 1/32" (0.794 mm)
- Excessive weld splatter on the hard-facing surface that would affect visual examination
- Burning through the tube

6.4.9 Acceptance criteria shall be as per ASME Section IX, QW-453 for welders' coupons and Contractor's approved weld procedure specification.

- A welder whose test coupon fails to meet the acceptance criterion is permitted to take one, two-coupon retest.
- A welder who fails the two-coupon retest is not permitted to take any further tests for that procedure for the duration of the contract.

Upon initial acceptance of the coupon, it shall be marked with the contractor's identification letter, the welder's security number, and the appropriate weld-type identification letter before being submitted for liquid penetrant examination of the weld surface and destructive testing. (After surface conditioning to the minimum thickness specified in the WPS, the corrosion-resistant surface shall be examined by the liquid penetrant method and shall meet the acceptance standards as specified in QW-195. Following the liquid penetrant examinations, the test coupon shall be sectioned to make two guided side-bend test specimens perpendicular to the welding direction.)

7.0 Technical Requirements

7.1 General

The Contractor shall apply corrosion-resistant weld overlay to the fireside of existing tubing, tube panels, and/or new tubes, membranes, and panels in accordance with the Contractor's QA program. All repairs and/or alterations shall be performed in accordance with ASME Section I, and NBIC. All welding shall be performed in accordance with ASME Section I, NBIC, and ASME Section IX, as applicable. The Contractor shall be accredited by the National Board of Boiler and Pressure Vessel Inspectors for repairs and alterations of pressure-retaining items with an "S" Symbol Stamp accreditation. The Contractor's authorized inspection agency shall ensure that all jurisdictional requirements are met and that this information is provided to the Utility.

7.2 Mapping and Identification

A grid type method, specifying location by elevation and panel area within the boiler, shall be used to identify repairs, clad areas, and test results.

7.3 Minimum Tube Thickness and Testing

After surface preparation and prior to welding, the Contractor QA personnel shall perform UTT measurements on the tubes to be overlaid. At the option of the Plant, Plant personnel or a subcontractor may perform tube wall thickness testing. Plant personnel and the Contractor shall agree upon the test matrix prior to commencing any thickness measurements. All testing shall then be in accordance with the Contractor's specification.

7.4 Surface Preparation and Coatings

Tube surfaces shall be prepared for welding in accordance with the Contractor's specification. Surface preparation shall be performed by the Contractor.

In all cases, the Contractor shall be responsible for the acceptance of surface preparation.

The tube surface after grit blasting shall be to a "white metal" finish. Prior to the application of any surface protection, the tube surfaces shall be visually examined according to the inspection section to ensure that all tube surfaces are acceptable for welding. Any defects that require metal removal and result in the base metal tubing's being below the minimum wall thickness shall be repaired with filler metal with chemical composition matching the base metal before application of the corrosion-resistant overlay.

If there will be substantial time between the grit blasting process and the start of the overlay welding, surface protection such as a deoxaluminate coating may be applied. Care must be utilized to apply a thin coat that is free of runs and excessive buildup. This protective coating must be completely consumed during the welding operation. The Contractor shall supply the MSDS data sheets for this consumable product.

Under certain conditions of limited access or surface tube condition, it may be necessary for the Contractor to grind the tube surface rather than grit blast. In these conditions, the surface shall be ground to bright metal with only minimum metal removed to ensure adequate weld deposition.

7.5 Tube Wall Displacement

The Contractor shall measure and benchmark tube walls and monitor tubing displacement before, during, and after weld overlay application and proactively inform the Plant representative and make recommendations as work is being performed to prevent unacceptable wall distortion.

Acceptable wall distortion shall be agreed upon between the Plant and the Contractor prior to the start of welding.

All data shall be included in the final document package.

7.6 Weld Repairs

7.6.1 Restoring Tube Minimum Wall Thickness

Base metal repairs required to restore the pressure boundary to minimum thickness before application of the corrosion-resistant overlay shall be performed with filler metal matching the chemistry of the base metal unless an alternative is agreed upon by the Plant, Contractor, and Authorized Inspector. Welding for repairs shall be performed with a qualified procedure according to ASME Section IX. All repair welds shall be in accordance to NBIC. After performing weld repairs to the base metal, the area shall be cleaned by grit blasting or other suitable method prior to application of corrosion-resistant overlay. All repair areas shall be inspected, identified, and documented.

7.6.2 Repair of Existing Cladding or Overlay

Repairs to existing cladding resulting from embrittlement or cracking phenomena (thermal cycling, coefficient of expansion differences) require that they be blended by mechanical means and/or the flaw completely removed and verified by surface examination techniques. Care shall be observed not to encroach on the tube material by removal of material beyond the overlay thickness. If this occurs, see paragraph 7.6.1 above.

Cladding or overlay thickness shall be restored using qualified procedures and weld metal of similar deposited composition unless otherwise directed by the plant. All restored locations shall be inspected, identified, and documented.

7.7 Weld Overlay Application

Contractor employees shall receive training prior to the start of all overlay activities to ensure continuity and adherence to bead sequence and deposition parameters. Parameters outlined for the specific application shall be thoroughly tested for field use and confirmed with laboratory evaluations. The parameter set/bead sequence shall be designed by the Contractor to provide maximum weld metal deposition in the shortest time while minimizing weld metal dilution, maximizing surface chemistry, and affording low heat-affected zone hardness.

The preheat shall be in accordance with the Welding Procedure Specification (WPS). The method of preheat will be at the Contractor's discretion.

7.8 Weld Overlay Deposit

7.8.1 Deposit Composition

Contractor personnel shall ensure that the filler metal used for deposition conforms to the Welding Procedure Specification requirements. If required, the Contractor can analyze the surface of the overlay using an x-ray fluorescence system such as Texas Nuclear Alloy Analyzer (TNAA), Niton, or similar device.

Dilution shall be measured during the welding procedure qualification and recorded because measuring actual weld metal dilution in the shop is not practical. Since dilution is affected by factors including preheat, electrode extension, voltage, mechanical travel, and position field cladding composition, acceptability shall be determined by measuring deposited chromium content. Table 3-1 provides satisfactory properties for various alloys.

Table 3-1
Satisfactory Properties for Selected Cladding Weld Metals

Alloy	Minimum Cr	Max HAZ Hardness on T11Tubing	Max HAZ Hardness on T22 Tubing
ER309L			
ER312L			
ERNiCrMo-3			
ERNiCrMo-10			

7.8.2 Delta Ferrite

For weld overlays using Type 309 or 312 SS, delta ferrite in the deposited weld metal should be measured on the surface of the weld. Measurements shall be performed using a Fischer Feritscope or equivalent.

Percent delta ferrite should be within the range of that qualified during qualification of the welding procedure. Factors including dilution, position, and cooling rate in actual production can influence delta ferrite formation. In the absence of values in the welding procedure qualification, the percent ferrite shall be between 20 and 40%.

Weld metal overlays using Type 309L or 309LSI may have the delta ferrite measured to ensure consistent application and reduce the potential for cracking of the weld deposit. Ferrite readings should remain within the range of that qualified by the WPS/PQR. In the absence of a qualified range of ferrite in the welding procedure, the ferrite should be in the range of 2.5 to 10 FN. Ferrite should not fall to 0 FN.

7.8.3 Hardness

Maximum heat-affected zone (HAZ) hardness in the tubing resulting from the cladding operations shall not exceed the values shown in Table 3-1.

7.8.4 General Acceptance Criteria

7.8.4.1 The Contractor shall submit a completed manufacturing sequence or traveler that includes all major fabrication operations, testing, and shipping information. Witness points will be assigned by the Owner based on this documentation.

7.8.4.2 Any burnthrough must be immediately reported to the Owner. The Owner will determine the resolution. All resolution costs will be to the account of the Contractor.

7.8.4.3 Panels shall be rejected for any of the following:

- Excessive arc strikes
- Any crack or crack-like indication
- Lack of fusion
- Weld undercut greater than 1/32" (0.794 mm)
- Incorrect weld bead sequence

7.8.4.4 Overlay thickness shall be between 0.070–0.090" (0.178–0.229 cm).

7.8.4.5 Acceptance values provided in Table 3-1 are required. Failure to obtain these criteria will require rework at the Contractor’s expense.

7.8.4.6 All panels/tubes shall be flat and/or true in all directions. Any deviation greater than 1/8" (0.318 cm) shall be cause for rejection and repair at the Contractor’s expense.

7.8.4.7 Finished width, center to center between the two side tubes, shall be within ± 1/8". Overall panel length shall be ± ¼ inch

8.0 Post Weld Heat Treatment (PWHT)

8.1 All panels shall receive a PWHT following weld metal overlay. The PWHT temperature and soak time shall be in accordance with ASME Section I.

8.1.1 The heating rate above 600°F shall be no greater than 400°F per hour.

8.1.2 The cooling rate above 600°F shall be not greater than 400°F per hour. This cooling rate must be performed while the panels are still within the furnace. Below 600°F, cool in still air.

8.2 No PWHT is required on single overlaid tubes, unless instructed by the Owner or as specified in the Contractor’s Welding Procedure Specification.

8.3 Stainless steel tubing shall be solution annealed prior to weld overlay.

9.0 Hydrostatic Testing

None, unless special requirements apply.

10.0 Painting

10.1 Painting shall be performed on the cold side of panels only.

10.1.1 A rust preventive coating shall be applied to the cold side of the panel, except as noted in paragraph 10.l.2 below.
10.1.2 No paint shall be applied within 3 inches of all weld preparations, within 1 inch all around toggle slots, on each side of a tube for its entire length, and on any nameplate.
10.1.3 Areas described in paragraph 10.1.2 shall be coated with deoxaluminate (or similar) to a 1–2 mil dry film thickness.
10.1.4 All tube ends, either panel or straight tubing, shall be coated with deoxaluminate to a 1 to 2 mil dry film thickness on the inside and outside of each tube for a minimum distance of 1 inch.
10.1.5 Straight tubes require no paint, except as noted above.

11.0 Clean-Up

The Contractor shall be responsible for clean up after completion of the job including, but not limited to, vacuuming out all grit blast media, rags, grinding debris, welding spatter, welding consumables, etc. If the boiler ash system can be utilized for blast media removal, this shall be approved by the Plant prior to job start.

12.0 Final Project Report and QA Package

After completion of the work scope, a final report package shall be provided to the Owner/Plant. This report shall include at a minimum the following:

A. Welding Procedure Specifications (ASME Form QW-482 or equivalent)

B. Procedure Qualification Records (ASME Form QW-483 or equivalent)

C. Welder's Performance Qualification (ASME Form QW-484 or equivalent

D. Welder continuity log

E. QC personnel certifications

F. Equipment calibration records for measurement equipment

G. Base metal and weld filler metal CMTRs

H. Deposit chemical analysis results

I. Ultrasonic thickness data for base metal and weld metal overlay

J. Displacement/distortion data

K. ASME control traveler

L. P-4 forms, as appropriate.

M. Detailed fabrication drawings.

N. Tube blow-through locations including remediation measures

13.0 Shipping

13.1 All panels shall be shipped with overlay side “up”.

13.2 Delivery of panels shall be by flatbed-type truck.

13.3 Panels, if stacked on the truck, shall be done so using hardwood spacers that are thick enough to permit fork truck forks to slide under each panel with no interference.

13.4 A 24-hour delivery notice is required.

13.5 The documentation package shall be received within three days of final shipment.

13.6 Receipt inspection will be performed at the Plant. Any discrepancies found will be repaired at the Contractor’s expense.

13.7 Any damage during shipment will be the responsibility of the Contractor. Damage will be repaired by the Contractor at no cost to the Plant/Owner.

14.0 Price, Terms, and Conditions

A pricing schedule similar to Attachment 1 should be completed with the cost associated with the weld overlay project unless the work scope is to be conducted on a lump-sum basis.

A daily (or weekly) project update will be forwarded to the Plant indicating work completed, percentage of project complete, current schedule, and labor hours for the project, as appropriate or per the contract.

Attachment 1

PRICING SCHEDULE (Example)

ID	Type	Description	Contract Typ	No. Craftsme	Hours / Shift	No. Shifts	Total Hours	Rate / Hour	Dollars
		Mobilization							
1	Labor	Unload Tools & Equipment & Stage To Work Area	Pri					$	$
2	Labor	Travel Pay (No. Craftsmen x Travel Hours S/T Only)	Pri					$	$
3	Labor	Supervision & QA/QC	Pri					$	$
4	Other	Freight - Tools & Equip To Plant	Sub						$
						Mobilization Sub Total			
		Outage - Weld Overlay Workscope							
5	Supv	Supervision, Safety, Productivity, Quality & Cost	Pri					$	$
6	Supv	Inspections, Start, During & Final	Pri					$	$
7	Labor	Boiler Tube Wall Displacement, Meas., Rigging, Adjust	Pri					$	$
8	Labor	Weld Overlay Buildup (Sq. Ft ____ x $ _____ Sq. Ft)	Pri					$	$
9	Labor	Weld Overlay Corrosion (Sq. Ft ____ x $ _____ Sq. Ft)	Pri					$	$
10	Other	Grit Blast Tube Wall Surface (Detail _____)	Sub						$
11	Other	Weld Wire Overlay Buildup Alloy Type: ___ Lbs: __	Pri						$
12	Other	Weld Wire Overlay Corrosion Alloy Type: __ Lbs: __	Pri						$
13	Other	Misc Supplies (Provide detailed list)	Sub						$
14	Other	Per Diem (Detail _____)	Pri						$
						Outage - Weld Overlay Workscope Sub Total			$
		DeMobilization							
15	Labor	Clean Work Area & Disassemble Equipment	Pri					$	$
16	Labor	Tools & Equipment - Stage From Work Area & Load Out	Pri					$	$
17	Labor	Travel Pay (No. Craftsmen x Travel Hours S/T Only)	Pri					$	$
18	Labor	Supervision & QA/QC	Pri					$	$
19	Other	Vac Clean Lower Boiler Furnace Area (Detail _____)	Sub						$
20	Other	Freight - Tools & Equip From Plant	Sub						$
						DeMobilization Sub Total			$
						Mob, Outage & DeMob Total			$

Pri = Primary Weld Overlay Contractor

Sub = Subcontracted Service or Material Procurement Provided by Primary Weld Overlay Contractor @ Markup %

4
WELDING SPECIFICATION FOR FIELD-WELD OVERLAYS

1.0 Purpose

This specification provides general information, boiler access, scaffolding, sandblasting, welding, and inspection requirements. Further details are included for welding consumables, shielding gases, welder training and qualification, repairs, and documentation.

The specification also identifies which services may be supplied by the Plant or Contractor. This guideline is presented to demonstrate areas that should be considered for a successful overlay job. A utility requesting an overlay proposal should examine each item individually and determine what to provide and what items the contractor should provide. Sub-contractors may be used to handle specific work scopes. Examples of this are scaffolding, grit blasting, and UTT.

2.0 General

2.1 Overview

A. This specification identifies necessary parameters for boiler fireside tube buildups and corrosion-resistant weld metal overlays.

B. This specification also defines Plant (Owner) and Contractor responsibilities and accountabilities pertaining to required supervision, labor, tools, equipment, consumables, and other related services.

C, It is the intent of this specification to establish quality and technical requirements for the application of weld metal and/or corrosion-resistant overlay protection to the fireside of boiler tubes using *in situ* techniques. It is not the intent of this document to completely specify all the details of the welding operation. However, all work shall be completed within the limits of this document shall conform to accepted utility and industry standards.

2.2 Definitions

A. Weld metal overlay (build-up) – One or more layers of weld metal applied to the substrate of a base metal to obtain desired properties and/or dimensions.

B. Corrosion-resistant weld metal overlay – Dissimilar weld metal deposits on base metals and weld metals to deter the effects of corrosion.

C. *In situ* techniques – Method for in field application in place.

D. Plant – The utility Owner and or its responsible supervision.

E. Contractor – The weld overlay contractor.

F. Work scope – The amount of weld overlay identified and approved by the Plant for the Contractor to perform.

G. MSDS – Material Safety Data Sheet.

H. CMTR – Certified Material Test Report.

I. UTT – Ultrasonic Thickness Testing.

J. PWHT – Post-weld heat treatment.

2.3 Safety

The Contractor shall have their own safety/drug protection program and conduct safety meetings as required. The Contractor shall submit their program to Plant personnel for acceptance for use on-site. The Plant will inform the Contractor of all security requirements. Plant safety procedures shall be reviewed with the Contractor and any sub-contractors before employees can start work at the job site. Safety measures for welders and welding operators involved in welding and cutting shall be in accordance with American National Standards Institute Z49.1.

The Contractor shall provide all safety equipment for their employees including but not limited to:

A. Safety glasses

B. Gloves

C. Flashlights/batteries

D. Respirators

E. Welding helmets

F. Welding leathers

G. Safety harnesses and lanyards

H. Hearing protection

All Contractor personnel, while on site, are required to wear safety glasses, steel-toed safety shoes, and cotton clothing. The Contractor shall comply with industry safety practices and any requirements imposed by the Plant.

2.4 Support Services

2.4.1 Plant Provided

A. Boiler and equipment de-energized and properly tagged and ready for entry and ensuing work.

B. Scaffolding and lighting to access and perform work scope as identified.

C. Electrical source service for lighting and work scope tools and equipment.

D. Water for work scope and potable drinking water for labor.

E. Break and restroom facilities.

F. One contact person to ensure proper coordination.

G. If a fork truck is required for equipment staging, the Plant shall supply the fork truck and operator.

2.4.2 Contractor Provided

A. Coordination and communications to identify required Plant-provided services.

B. Labor and supervision for planning, mobilization, work scope, and demobilization.

C. Daily cost and schedule reporting for firm price or cost plus work scopes.

D. Tools and equipment to perform weld overlay work scope.

E. Materials and consumables such as grinding equipment, welding wire, welding consumables, and shielding gas.

F. MSDSs and CMTRs shall be maintained at the job site and provided to the Plant as requested.

G. Final project summary (no later than two weeks after demobilization) to include actual itemized costs for supervision, labor, tools, consumables, and equipment.

H. Boiler tube grit blasting if required.

I. Tube wall pre-heat if needed

J. Boiler cleanup using industrial vacuum process if needed.

K. The Contractor shall supply all rigging and lifting equipment necessary to position welding equipment within the boiler. The Contractor shall provide all necessary personnel for operating the hoisting and lifting equipment.

2.4.3 Welding Consumables and Shielding Gas(es)
Welding consumables including manual shielded metal arc electrodes (SMAW), bare filler wire for gas tungsten arc welding (GMAW), and/or shielding gas(es) shall be procured by either the Plant or Contractor.

2.4.3.1 Where provided by the Plant, the following shall apply:

- The Contractor shall be notified during the bidding process what welding consumables and/or weld deposits will be procured/required to ensure that the successful bidder will have the appropriate welding procedure qualifications and specifications, as well as welders and welding operators who are available to perform the work.
- The Contractor shall provide any special procurement information, at job award, to the Plant to ensure that appropriate welding consumables, shielding gas and/or gas mixtures, and estimated quantities are procured and available. When specified by the Contractor as necessary for satisfactory welding, items including surface finish, cast, helix, composition limits, trace element limits, delta ferrite, diameter, spool size(s), and packaging requirements will be provided by the Plant.
- Material presented to the Contractor that does not meet the prespecified requirements shall relieve the Contractor from schedule delays resulting from incorrect welding consumables and shielding gas(es).

2.4.3.2 Where provided by the Contractor, the following shall apply:

- The Contractor shall procure welding consumables and shielding gas(es) to provide weld deposits in accordance with the bid specification.
- The Contractor shall ensure that adequate quantities of material are available to support the Plant schedule.
- Problems or issues resulting from welding consumables and/or shielding gas(es) shall be the responsibility of the Contractor.

Table 4-1 may be used to help document provided services that the Contractor and Plant shall supply.

Table 4-1
Typical Support Providers

REQUIRED SUPPORT ITEM:	Supplied by:	
	CONTRACTOR	PLANT
1. Copy of Original Manufacturer Data Report		X
2. Boiler and Equipment De-Energized And Tagged		X
3. Authorized Inspector		
4. Plant Contact Person		X
5. Safety/Hole Watch(s)		
6. Fire Watch and Extinguisher(if required)		
7. Scaffolding (if required)		
8. Abrasive Blast Equipment and Media		
9. Air Compressor and Fuel		
10. Electrical Power		X
11. Shielding Gas		
12. Welding Filler Metal		
13. Consumables (grinding wheels, rags)		
14. Contractor Safety Equipment	X	
15. Main Power Cable and Connection		
16. Non-Potable Water		X
17. Forklift, Elevator, Crane		
17. Lighting		
18. Sanitary Facilities		
19. Container for Trash and Debris		
20. Area for Job Site Trailer		X
21. Weather Protection		
22. Primary Surface Preparation		
23. Preheating		

2.5 Pre-Job Planning and Mobilization

The Contractor and the Plant project management, including site supervision ,will determine the scope of work, outage dates, duration, boiler access, scaffold requirements, etc. during a pre-job planning meeting.

The welding Contractor shall provide supervision, labor, equipment, and materials to field apply 0.070" (0.178 cm) thick (minimum) machine weld metal overlay to the surface of the existing boiler tubes. Weld metal thickness shall be measured at several areas around the tubing so areas of minimum thickness can be determined. The following information is required for planning of the overlay job:

Tube Diameter (OD):	__________"
Minimum Wall:	__________"
Base Material:	SA-__________
Membrane Width:	__________"
Membrane Material:	SA-__________
Overlay Material:	ER-__________
Overlay Height:	__________ Ft.
Width of Tubes:	__________ Ft.
Overlay Square Footage:	__________ Ft^2

Weld overlay is priced by the amount of actual surface area applied, taking into account the curvature of the tubes (often referred to as *flat footage*). Overlay square footage can be calculated using the formula for surface area calculation as follows:

Surface Area = [(π (O.D.)/2) + membrane width)](number of tubes)(length of tubes) For example, the applied surface area of sixty, 1.375" (3.49 cm) tubes with 0.625" (1.59 cm) membrane, 10' (3.048 m) long would be:

Surface Area = [(π (1.375")/2) + 0.625")](60)(120")(1 ft^2/144 in^2) = 139.2 ft^2

The work scope will be performed in accordance with the requirements of ASME Boiler and Pressure Vessel Code and National Board Inspection Code (NBIC). The NBIC is generally accepted by the regulatory agencies, (referred to as the jurisdictions and normally the state government in which the plant is located), as the basis for repairs to existing plants. The NBIC has no specific requirements for the minimum wall thickness required in an existing plant. Section I of the ASME Boiler and Pressure Vessel Code is the specification usually imposed by the jurisdictions for new construction. Section I includes the formula for determining minimum tube wall thickness for new construction based on material specification and design temperature and pressure. This formula results in a wall thickness with a safety factor of 4; although, for lower temperature applications, ASME has recently reduced the safety factor to 3.5. The Foreword of Section I contains a statement to the effect that design validation to Section I assures a margin for deterioration in service to enable a reasonably long period of usefulness. Since fireside waterwall wastage will result in leaks within the furnace enclosure that would minimize personnel safety concerns, the NBIC would rely on the Owner’s interest and possible insurance concerns to repair eroded tubes before failures occur. The general practice is to measure thickness and to forecast when the wall thickness will be some percentage of the minimum wall thickness and make the repairs before that occurs. The specific percentage is set by the utility in conjunction with its insurance company. A major boiler OEM has issued a recommendation that, for supercritical water walls, repair or replacement should be performed if the wall thickness measurements are less than 85% of the minimum thickness. The requirement for subcritical boilers would result in repair or replacement if measurements were 70% of minimum.

The utility must decide on what will be contracted with the overlay Contractor. Existing companies that perform NDE and sandblasting may be more efficient than boiler tube overlay companies. Also boiler repair firms are normally more effective than the overlay contractor in replacing tubes or tube sections.

The overlay material must be specified by the owner/plant. The more commonly used materials are ER309, ERNiCrMo-3 (Alloy 625), ER312 or ERNiCrMo-10 (Alloy 622). Proprietary alloys, such as Special Metals' 686CPT and Thyssen-Krupp's Alloy 59, are also considered for use.

ER309 is an austenitic stainless steel with an expansion coefficient that is about 30% greater than the base metal that can be a problem if large thermal gradients occur. Figure 4-1 compares the coefficient of expansion of various waterwall tube materials with selected weld metal cladding. ERNiCrMo-3 and ERNiCrMo-10 have experienced selective corrosion attack due to inherent segregation. ER312 provides a two-phase weld deposit with substantial percentages of ferrite in an austenite matrix. The ferrite undergoes 885°F (474°C) embrittlement in service. Toughness is high at service temperature. Severe thermal cycling and hydrostatic testing have indicated that the embrittlement does not affect service performance. The cost of ERNiCrMo-3 or ERNiCrMo-10 is at least twice that of ER312, but this cost may result in only about a 20% increase in total costs on a large overlay.

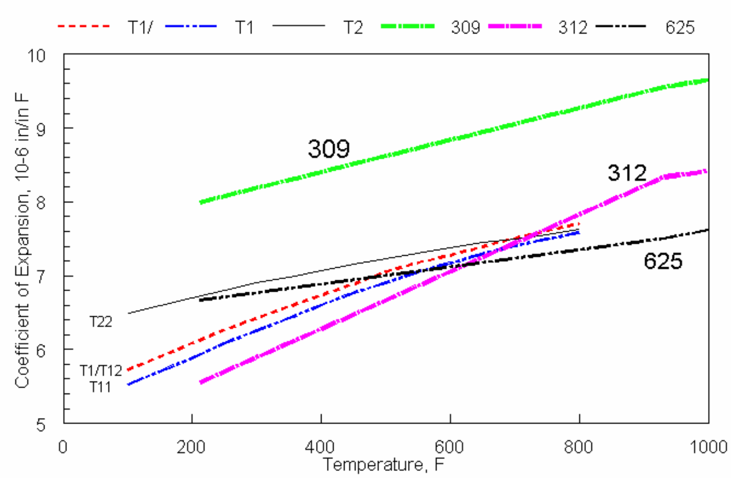

Figure 4-1
Coefficient of Expansion Comparisons

2.6 Scaffolding

Scaffolding shall be provided by the Plant and shall comply with Contractor, Plant, and OSHA safety requirements plus Contractor equipment clearance requirements.

A. Type of scaffold: Quick-erect bricklayer scaffolding is <u>not</u> acceptable.

B. Suppliers: Safeway or patent scaffolding is recommended.

C. Distance from walls: 26" (66.04 cm) minimum; 40" (101.6 cm) maximum

D. Decks: One deck every 7–8' (2.13–2.44 m). Decks shall be a minimum of 2' (60.96 cm) wide along each wall to be overlaid
   a. Toe-boards shall be provided on all sides.

E. Ladders: Stairs are preferred.
   a. Ladders are acceptable.
   b. Ladders shall be staggered and shall not run straight up.

F. Open bay: Open bay(s) shall be provided for the full height of the scaffold.
   a. Handrails and toe-boards shall be provided on all sides.

G. Side Brackets: Two-foot knee braces (side braces) shall be supplied every 8'.

H. Roof: When work is to be carried out above the scaffold, the scaffold shall have a hard roof. This roof shall be sealed to prevent debris from falling and injuring the workers below. The roof shall also prevent contaminants from falling into the weld area.

I. Safety Requirements: All scaffolding shall meet OSHA requirements.

2.7 Lighting

The Plant will provide lighting in the boiler for the overlay job. Adequate lighting shall be provided to allow for safe working conditions. Lighting shall be provided at different elevations of the scaffolding in order to prevent unsafe areas. Lighting during visual examination shall be in accordance with ASME Section V, Article 9, T-952.

2.8 Electric Power

Electric power shall be supplied by the Plant. In the event that an on-site feed is not available and portable generation is required, voltage, frequency, and phasing shall be suitable for satisfactory operation of the weld overlay welding power sources and controls plus nondestructive testing apparatus. Contractor requirements shall be supplied to the Plant within 10 days after the award of the contract.

2.9 Plant Compressed Air

The Plant shall provide compressed air for surface preparation and operation of air tools during the work effort. Contractor requirements shall be supplied to the Plant within 10 days after the award of the contract.

3.0 Codes and Standards

The following Codes, Standards, and Specifications apply to this work scope. The latest edition and addendums in force at time of award shall apply:

A. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code
   a. Section I - Power Boilers
   b. Section II Parts A, B, C, and D
   c. Section V – Article 9- Visual Examination
   d. Section VIII- Division 1 Pressure Vessels
   e. Section IX - Welding & Brazing Qualifications

B. National Board Inspection Code (NBIC) - Repair/Alteration

C. American Society of Nondestructive Testing (ASNT)
   1. SNT TC-1A – Recommended Practice for Nondestructive Testing, Personnel Qualification and Certification

D. American Welding Society (AWS)
   1. A2.4 Welding Symbols
   2. A3.0 Terms and Definitions

E. ASME "S" Certificate of Authorization [or "A", as appropriate]

F. ASME/NBIC "R" Certificate of Authorization

G. American National Standards Institute
   1. Z49.1 Safety in Welding and Cutting

4.0 Quality Assurance Program

The Contractor shall submit for review to the Authorized Inspector (and Owner when required) the following:

A. ASME Control Traveler
B. Welding Procedure Specifications
C. Supporting Procedure Qualification Records
D. Welder or Welding Operator Qualification Records
E. Welder Continuity Logs

F. QC Personnel Certifications
G. Documentation
   1. CMTRs for welding consumables.
   2. Base metal ultrasonic thickness test reports
   3. Weld metal ultrasonic thickness test reports
   4. Distortion measurements

NOTE: In addition to the above, the Contractor QA and/or Site Manager will present a bead sequence/parameter deposition profile designed specifically for this application. All Contractor operational personnel will be advised of the parameters and bead sequence.

After authorization to proceed has been obtained from the Authorized Inspector, personnel may begin the weld overlay process.

5.0 Plant/Owner Access

5.1 The Owner/Plant shall have free access to Contractor facilities to:

5.1.1 Review any relevant procedures, verify compliance to the requirements of the Contractor quality program or to Owner/Plant requirements.

5.1.2 Witness any portion of the welding process, equipment calibration, welding procedure qualifications, welder and welding operator performance qualifications, or nondestructive examination activities or personnel.

6.0 Contractor Personnel

6.1 QA/QC/Supervision

6.1.1 The Contractor shall provide a qualified lead quality control representative during the installation. The contractor's quality control personnel shall remain on-site until completion of the work and shall be released only by the Owner's quality assurance representative.

6.1.2 The lead quality control representative shall administer the Contractor's quality control program and ensure conformance to the program requirements.

6.1.3 The lead quality control representative shall also be the weld technician unless the Owner approves additional weld technicians prior to the award of the contract.

6.1.4 Additional weld technicians, when specified in the contract, shall report to the lead quality control (QC) Representative.

6.1.5 The Contractor’s lead QC representative shall have at least two years of quality assurance and/or quality control experience with one year focused on boiler tube corrosion-resistant weld metal overlay maintenance outage activities at fossil fuel plants.

6.1.6 Resumes of prospective candidates shall be submitted to the Owner’s quality assurance representative at least one week before mobilization.

6.1.7 The Contractor’s lead QC representative and additional weld technician, if specified, shall be on site per the contract agreement.

6.2 Welding Technician

The Contractor shall provide a quality control representative per shift who shall also perform welding technician responsibilities during the installation. Quality control/welding technician personnel shall remain on site until completion of the work and shall be released by the Owner’s quality assurance representative. If required, additional welding technicians for multi-shift activities shall be specified in the contract agreement.

6.2.1 Welding technicians duties shall include, but not be limited to the following:

1. Participate in welder assignments.
2. Supervise filler metal and material control.
3. Inspect welding and related activities.
4. Maintain and submit applicable documentation.
5. For shop overlay panels, verify Cr content using a metal analyzer. Provide a minimum of five random readings per panel.
6. For shop single tube overlay, verify Cr content using a metal analyzer. Provide a minimum of two random readings per individual tube.
7. Regarding paragraphs 5 and 6 above, any Cr readings below 19.5% shall be brought to the immediate attention of the Owner's QA rep, and no work shall continue until released by the Owner's QA rep.

6.2.2 Welding technicians shall meet the following requirements:

1. AWS - Certified weld inspector (CWI) or
2. AWS - Certified associate weld inspector (CAWI) who has successfully passed the CWI examination but lacks the full five years of experience (written verification required) or
3. Quality control representative/welding technician who is a full time employee of the company performing the overlay process and is certified in accordance with the company’s visual weld inspection program.

6.2.3 A copy of the individual’s current certification records shall be submitted for review by their first day of work at the job site.

6.3 Inspection Personnel

All QA/QC personnel who perform visual and dimensional examinations are to be certified to an approved QA program that uses ASNT SNT TC-1A as a guide. The Contractor shall certify all QA/QC personnel, and records shall be provided to the utility.

6.4 Welders and Welding Operators

The Contractor shall qualify all welders and welding operators in accordance with their QA manual and the National Board "R" stamp program. Welder qualifications shall comply with the following:

6.4.1 Welders shall be qualified as a minimum in the 2G (horizontal) and 3G (vertical) positions. **Note:** In the vertical position, the welding in the specified AWS classification, for example. ER309L or ERNiCrMo-10 progression, shall be vertical down.

6.4.2 Contractors performing weld metal overlay shall have the option to use welder's current qualification records if proof can be obtained by the Contractor of the welder having welded for them within the last six months.

6.4.3 Welder or welding operator performance qualification records shall be fully documented to the satisfaction and approval of the Authorized Inspector and the Owner.

6.4.4 Welder performance qualification tracking system welder status report shall be documented to the satisfaction and approval of the Authorized Inspector and the Owner.

6.4.5 The Owner or Authorized Inspector reserves the right to retest any welder plus audit welder qualification records and the welder tracking system at the site and/or record facility.

6.4.6 Contractor welders assigned to perform weld metal overlay who do not have current qualification records and have not welded for the Contractor within the last six months must re-certify on Company property and be in full compliance with paragraphs 6.4.1 through 6.4.5.

6.4.7 The Contractor's welding technician shall obtain all necessary copies of the welder's performance qualifications. These shall be submitted to the Owner prior to the start of welding.

6.4.8 On-site welder qualification testing shall comply with the following:

6.4.8.1 The Contractor's welding technician shall administer the welder qualification tests.
6.4.8.2 The Owner reserves the right to witness or inspect any phase of the welder qualification test.

6.4.8.3 The coupon shall be tacked at the welding station into the designated position.

6.4.8.4 Once the coupon is tacked into position, it shall not be removed from that position until completion of the test.

6.4.8.5 The Contractor's welding technician shall make periodic checks during the test to verify usage of the proper filler materials and techniques. All grinding, filing, or brushing on the coupon after tacking shall be performed in the designated test position and is considered as part of the test.

6.4.9 Upon completion of the test, the Owner's quality assurance representative and the Contractor QC representative/welding technician shall perform visual inspection of the test coupon prior to submittal for examination and testing.

Failure to meet the following criteria shall result in rejection of the test coupon.

- Lack of penetration
- Surface undercutting exceeding 1/32" (0.794 mm)
- Crown reinforcement exceeding 1/8" (0.318 cm)
- Abrupt valleys between passes with depths exceeding 1/32" (0.794 mm)
- Excessive weld splatter on the hard-facing surface that would affect visual examination
- Burning through the tube

6.4.10 Acceptance criteria shall be as per ASME Section IX, QW-453 for welders' coupons and Contractor's approved weld procedure specification.

- A welder whose test coupon fails to meet the acceptance criterion is permitted to take one, two-coupon retest.
- A welder who fails the two-coupon retest is not permitted to take any further tests for that procedure for the duration of the contract.

Upon initial acceptance of the coupon, it shall be marked with the contractor's identification letter, the welder's security number, and the appropriate weld-type identification letter before being submitted for liquid penetrant examination of the weld surface and destructive testing. (After surface conditioning to the minimum thickness specified in the WPS, the corrosion-resistant surface shall be examined by the liquid penetrant method and shall meet the acceptance standards as specified in QW-195. Following the liquid penetrant examinations, the test coupon shall be sectioned to make two guided side-bend test specimens perpendicular to the welding direction.)

7.0 Technical Requirements

7.1 General

The Contractor shall apply corrosion-resistant weld overlay to the fireside of existing tubing, tube panels, and/or newly installed tubes, membrane and panels in accordance with Contractor's QA program. All repairs and/or alterations as such shall be performed in accordance with ASME Section I, and NBIC. All welding shall be performed in accordance with ASME Section I, NBIC, and ASME Section IX, as applicable. The Contractor shall be accredited by the National Board of Boiler and Pressure Vessel Inspectors for repairs and alterations of pressure retaining items with an "R" Symbol Stamp accreditation. The Contractor's authorized inspection agency shall ensure that all jurisdictional requirements are met and this information provided to the Utility.

7.2 Mapping and Identification

A grid type method, specifying location by elevation and panel area within the boiler, shall be used to identify repairs, clad areas, and test results.

7.3 Minimum Tube Thickness and Testing

Tubes below 0.120" (0.305 cm) in thickness may require carbon steel build-up or replacement prior to weld overlay. These repairs will be performed on a Time and Material basis. In addition, any repairs on tubes below the defined thickness will be performed on a best-effort basis. Any replacement costs that are necessary will be borne by the customer. See paragraph 7.6.1.

After surface preparation and prior to welding, Contractor QA personnel shall perform UTT measurements on the tubes to be overlaid. At the option of the Plant, Plant personnel or a subcontractor may perform tube wall thickness testing. Plant personnel and the Contractor shall agree upon the test matrix prior to commencing any thickness measurements. All testing shall then be in accordance with the Contractor's specification.

Contractor QC personnel shall utilize a UTT and data recording system. Data shall be taken in accordance with the required grid pattern before welding. If any of the data indicate the tubes to be excessively thin, the results shall be reported to the Plant representative for corrective action. After completion of welding, the Contractor personnel shall record the actual weld deposit thickness and provide the Plant with a final report indicating initial wall thickness and final weld deposit thickness. **Note:** With an austenitic or duplex material over a ferritic material, the acoustic velocity difference of the materials makes absolute measurements questionable. However, benchmarks at well-defined locations can be of benefit for future efforts to determine wastage rates. Calibration should be performed on calibration blocks using the same base metal and weld metal combinations as actual materials.

CAUTION:

If Plant data indicates and if Contractor data confirms that tubes to be overlaid are excessively thin (< 0.120" [0.305 cm] for vertical-down applications and < 0.125" [0.318 cm] for overhead applications), it is recommended that either the tubes be removed and replaced or a waiver signed by the Contractor and Plant acknowledging that the *in situ* weld overlay application will be performed on a best-effort basis. If tubing replacement is necessary, it shall be handled outside this specification.

7.4 Surface Preparation and Coatings

Prior to grit blasting, the Plant shall arrange for deslagging of the boiler via appropriate means including soot blowing and water lancing. This shall include removal of refractory insulation if required.

Tube surfaces shall be prepared for welding in accordance with the Contractor’s specification for grit-blast surface preparation. Surface preparation shall be performed using equipment provided by the Contractor including grit-blasting equipment, breathing equipment, blast media, air compressors, and safety equipment. At the option of the Plant, compressed air may be supplied by the Plant.

If agreeable to both the Contractor and the Plant, grit blasting may be sub-contracted. All surface preparation personnel shall be trained in the safe use of this equipment. If the grit blast preparation is subcontracted, Contractor supervision shall be responsible for personnel, equipment, schedule, and adherence to the specification requirements.

In all cases, the Contractor shall be responsible for acceptance of surface preparation.

In lieu of the Contractor’s specification for grit blasting, the Contractor shall remove any and all slag, thermal spray coatings, corrosion product or surface contaminate. The tube surface after grit blasting shall be to a “white metal” finish. Prior to the application of any surface protection, the tube surfaces shall be visually examined according to the inspection section to ensure all tube surfaces are acceptable for welding. Any evidence of circumferential cracking will require local grinding to remove the embedded contaminates and the surface cracks. In addition, if weld crowns are >3/16" in height, grinding will be necessary. Furthermore, any and all surface attachments on the tube walls that interfere with the machine weld head will require removal prior to welding. Any defects that require metal removal and result in the base metal tubing’s being below minimum wall thickness shall be repaired with filler metal with chemical composition matching the base metal before application of the corrosion-resistant overlay.

If there will be substantial time between the grit blasting process and the start of the overlay welding, surface protection such as a deoxaluminate coating may be applied. Care must be utilized to apply a thin coat free of runs and excessive buildup. This protective coating must be completely consumed during the welding operation. The Contractor shall supply MSDS data sheets for this consumable product.

Under certain conditions of limited access or surface tube condition, it may be necessary for the Contractor to grind the tube surface rather than grit blast. In these conditions, the surface shall be ground to bright metal with only enough metal removed to ensure adequate weld deposition.

7.5 Tube Wall Displacement

The Contractor shall engineer preferred welding location sequences to minimize tube wall movement that may occur during the overlay process.

The Contractor shall measure and benchmark tube walls and monitor tubing displacement before, during, and after weld overlay application, and proactively inform the Plant representative and make recommendations as work is being performed to prevent unacceptable wall distortion.

Acceptable wall distortion shall be agreed upon between the Plant and the Contractor prior to the start of welding.

All data shall be turned over to the Plant after completion, and any significant finds shall be highlighted to the Plant representative for review.

7.6 Weld Repairs

7.6.1 Restoring Tube Minimum Wall Thickness
Base metal repairs required to restore the pressure boundary to minimum thickness before application of the corrosion-resistant overlay shall be performed with filler metal matching the chemistry of the base metal unless an alternative is agreed upon by the Plant, Contractor, and Authorized Inspector. Welding for repairs shall be performed with a qualified procedure according to ASME Section IX. All repair welds shall be in accordance to NBIC. After performing weld repairs to the base metal, the area shall be cleaned by grit blasting or other suitable method prior to application of corrosion-resistant overlay. All repair areas shall be inspected, identified, and documented.

7.6.2 Repair of Leaking Tubing (Pad Welding)

Repair of leaking tubing by pad welding is not permitted in this specification. Where required, pad welding shall be accomplished only as specified and approved on a case-by-case basis by the Plant.

7.6.3 Repair of Existing Cladding or Overlay

Repairs to existing cladding resulting from erosion (wastage), embrittlement or cracking phenomena (thermal cycling, coefficient of expansion differences) require that they be blended by mechanical means and/or the flaw completely removed and verified by surface examination techniques. Care shall be observed not to encroach on the tube material by removal of material beyond the overlay thickness. If this occurs, see paragraph 7.6.1 above.

Cladding or overlay thickness shall be restored using qualified procedures and weld metal of similar deposited composition unless otherwise directed by the plant. All restored locations shall be inspected, identified, and documented.

7.7 Weld Overlay Application

Contractor employees shall receive training prior to the start of all overlay activities to ensure continuity and adherence to bead sequence and deposition parameters. Parameters outlined for the specific application shall be thoroughly tested for field use and confirmed with laboratory evaluations. The parameter set/bead sequence shall be designed by the Contractor to provide maximum weld metal deposition in the shortest time while minimizing weld metal dilution, maximizing surface chemistry, and affording low heat-affected zone hardness.

To obtain high production rate, low distortion, and correct chemical composition of the weld overlay, it is preferred that the tubing to be welded be filled with standing water. This will allow for improved economies and schedule, and allow for optimum bead sequencing and parameter deposition. If other work (for example, boiler inspection or tubing replacement) requires the tubing to be drained during the repair welding operation, special bead sequences and skip techniques may need to be utilized to provide optimum deposition with minimal displacement. If this impacts the schedule, the Contractor reserves the right to requote the project.

The preheat shall be in accordance with the Welding Procedure Specification (WPS). Method of preheat will be at the Contractor's discretion.

7.8 Weld Overlay Deposit

7.8.1 Deposit Composition
Contractor personnel shall ensure that the filler metal used for deposition conforms to the Welding Procedure Specification requirements. If required, the Contractor can analyze the surface of the overlay using an x-ray fluorescence system such as Texas Nuclear Alloy Analyzer (TNAA), Niton, or similar device.

Adherence to the bead placement and deposition parameters combined with proper alloy selection all but ensures optimum surface chemistry.

Dilution shall be measured during the procedure qualification and recorded because measuring actual weld metal dilution in the field is not practical. Since dilution is affected by factors including preheat, electrode extension, voltage, mechanical travel, and position field cladding composition, acceptability shall be determined by measuring deposited chromium content. Table 4-2 provides satisfactory properties for various alloys.

Table 4-2
Satisfactory Properties for Selected Cladding Weld Metals

Alloy	Minimum Cr	Max HAZ Hardness on T11Tubing	Max HAZ Hardness on T22 Tubing
ER309L			
ER312L			
ERNiCrMo-3			
ERNiCrMo-10			

7.8.2 Delta Ferrite

For weld overlays using Type 309 or 312 SS, delta ferrite in the deposited weld metal should be measured on the surface of the weld. Measurements shall be performed using a Fischer Feritscope or equivalent.

Percent delta ferrite should be within the range of that qualified during qualification of the welding procedure. Factors including dilution, position, and cooling rate in actual production can influence delta ferrite formation. In the absence of values in the welding procedure qualification, the percent ferrite shall be between 20 and 40%.

Weld metal overlays using Type 309L or 309LSI may have the delta ferrite measured to ensure consistent application and reduce the potential for cracking of the weld deposit. Ferrite readings should remain within the range of that qualified by the WPS/PQR. In the absence of a qualified range of ferrite in the welding procedure, the ferrite should be in the range of 2.5 to 10 FN. Ferrite should not fall to 0 FN.

7.8.3 Hardness

Maximum heat-affected zone (HAZ) hardness in the tubing resulting from the cladding operations shall not exceed the values shown in Table 4-2.

8.0 Hydrostatic Testing

After completion of welding operations, the boiler shall be hydrostatically tested according to NBIC RC02050. Test pressure shall be that agreed upon between the Plant, the Contractor, and the Authorized Inspector. Water used for hydrostatic testing shall be at a minimum of 60°F.

9.0 Clean-Up

The Contractor shall be responsible for clean up after completion of the job including, but not limited to, vacuuming out all grit blast media, rags, grinding debris, welding spatter, welding consumables, etc. If the boiler ash system can be utilized for blast medial removal, this shall be approved by the Plant prior to job start.

10.0 Final Project Report and QA Package

After completion of welding and visual examination, the boiler shall be subjected to hydrostatic testing in accordance with applicable Code requirements. After completion of hydrostatic testing, an R-1 form shall be prepared and signed by the Contractor representative and the Authorized Inspector.

After completion of the fieldwork, a final report package will be provided to the Owner/Plant. This report shall include at a minimum the following:

A. Welding Procedure Specification (ASME Form QW-482 or equivalent)

B. Procedure Qualification Records (ASME Form QW-483 or equivalent)

C. Welder's Performance Qualification (ASME Form QW-484 or equivalent

D. Welder continuity log

E. QC personnel certifications

F. Equipment calibration records for measurement equipment

G. CMTRs for welding consumables

H. Ultrasonic thickness data for base metal and weld metal overlay

I. Displacement/distortion data

J. ASME control traveler

K. NBIC R-1 forms

L. Map of waterwalls showing areas overlaid and tubing replacement

M. Tube blow-through locations including remediation measures

11.0 Price, Terms, and Conditions

A pricing schedule similar to Attachment 1 should be completed with the cost associated with the weld overlay project.

A daily project update will be forwarded to the Plant indicating work completed, percentage of project complete, current schedule, and labor hours for the project.

Attachment 1

PRICING SCHEDULE (Example)

ID	Type	Description	Contract Typ	No. Craftsme	Hours / Shift	No. Shifts	Total Hours	Rate / Hour*	Dollars
		Mobilization							
1	Labor	Unload Tools & Equipment & Stage To Work Area	Pri					$	$
2	Labor	Travel Pay (No. Craftsmen x Travel Hours S/T Only)	Pri					$	$
3	Labor	Supervision & QA/QC	Pri					$	$
4	Other	Freight - Tools & Equip To Plant	Sub						$
		Mobilization Sub Total							
		Outage - Weld Overlay Workscope							
5	Supv	Supervision, Safety, Productivity, Quality & Cost	Pri					$	$
6	Supv	Inspections, Start, During & Final	Pri					$	$
7	Labor	Boiler Tube Wall Displacement, Meas., Rigging, Adjust	Pri					$	$
8	Labor	Weld Overlay Buildup (Sq. Ft ____ x $ _____ Sq. Ft.)	Pri					$	$
9	Labor	Weld Overlay Corrosion (Sq. Ft ____ x $ _____ Sq. Ft.)	Pri					$	$
10	Other	Grit Blast Tube Wall Surface (Detail _____)	Sub						$
11	Other	Weld Wire Overlay Buildup Alloy Type: ___ Lbs: __	Pri						$
12	Other	Weld Wire Overlay Corrosion Alloy Type: __ Lbs: __	Pri						$
13	Other	Misc Supplies (Provide detailed list)	Sub						$
14	Other	Per Diem (Detail _____)	Pri						$
		Outage - Weld Overlay Workscope Sub Total							$
		DeMobilization							
15	Labor	Clean Work Area & Disassemble Equipment	Pri					$	$
16	Labor	Tools & Equipment - Stage From Work Area & Load Out	Pri					$	$
17	Labor	Travel Pay (No. Craftsmen x Travel Hours S/T Only)	Pri					$	$
18	Labor	Supervision & QA/QC	Pri					$	$
19	Other	Vac Clean Lower Boiler Furnace Area (Detail _____)	Sub						$
20	Other	Freight - Tools & Equip From Plant	Sub						$
		DeMobilization Sub Total							$
		Mob, Outage & DeMob Total							$

Pri = Primary Weld Overlay Contractor

Sub = Subcontracted Service or Material Procurement Provided by Primary Weld Overlay Contractor @ Markup %

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