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Solutions Flash

Fast, economical Electric Arc Wire spray solutions are beneficial for coal-fired and waste-to-energy boilers

SF-0021.1 – October 2014

Today's situation

Coal-fired and waste-to-energy (WTE) boilers are exposed to complex corrosive and erosive surface mechanisms on the waterwalls, the superheaters and the flue gas desulfurization systems. In fact, boiler tubes are subject to some thirty different failure mechanisms [1], many of which are the result of some form of corrosion or erosion. These attacking mechanisms can lead to reduced operational efficiency and failures that result in unscheduled outages for component replacement. The industry has recorded more than 30,000 boiler tube failures, and 80 % of those failures have resulted in forced plant shutdowns. The material and installation costs, alone, to replace these components can cost more than one million U.S. dollars for a large boiler system.

But the greater cost can be measured in terms of lost revenues to the operating utility or company for plant downtime, which can be millions of U.S. dollars per day.

Surface protection for these boiler components can extend their useful service life, thereby reducing replacement costs and outage time. Many operators have turned to welded overlays of nickel-chromium alloys that help retard both corrosion and erosion, and are metallurgically bonded to the substrate material.

Such welded overlay coatings have proven successful, but are not without concern. First, welding is time-consuming to apply. Welding also causes base-metal dilution, can increase the potential for stress-induced corrosion cracking as a result of changes to the grain structure of the base metal. When improperly applied, weld overlays with through-hole pores can result in an attack site for accelerated crevice or pitting corrosion. Finally, as a result of base-metal dilution, the reapplication potential of welded overlays may be limited.

Common failure mechanisms in boiler waterwalls

As previously mentioned, there are many boiler tube failure mechanisms. Fireside surface protection can help manage or prevent a number of these mechanisms. Some of the more common mechanisms that can occur in boilers include:

- **Fireside corrosion fatigue:** Usually seen in coal-fired boilers as a series of circumferential cracks on tube ODs that appear as crazing or have an "elephant hide" appearance resulting from corrosion intensified by thermal stresses.
- **Fly ash erosion:** Caused as a result of fly ash impingement on tube walls, particularly in superheaters, that results in thinning of the tube wall.
- **Waterwall fireside corrosion:** Normally occurs in the lower part of the boiler, and may be associated with the combustion process. The result is thinning of the tube wall, leading to eventual failure.
- **Thermal fatigue:** Most often seen in the superheaters of coal-fired boilers, stresses result from thermal cycling and uneven thermal gradients in the components. Distortion in the components can set up a series of opposing compressive and tensile stresses that eventually result in cracking that can propagate to failure.
- **Erosion corrosion:** Metal corrosion that is accelerated by erosive fluid conditions. On the fireside of waterwalls, the erosion is caused by circulating gaseous media at high velocity, that carry the corroding media to the components. The result is generally pitting or ongoing erosion of the metal that is simultaneously undergoing corrosive attack.

A severely corroded waterwall tubes operated without surface protection.

A boiler tube that has a thin wall as a result of erosive conditions.

[1] Boiler Reliability Optimization Guideline, EPRI, Palo Alto, CA: 2001. 1004018

- **Falling slag erosion:** Large chunks of slag falling on waterwalls in the lower sections of the boiler cause impact damage.
- **Soot blower erosion:** High velocity compressed air or steam used to blow soot off of the superheater or waterwall surfaces can ultimately cause erosion and corrosion of those surfaces, thinning the walls of components.
- **Short-term / long-term overheating:** Overheating conditions generally characterized by longitudinal stress fracturing or splitting of the tube walls.
- **Chemical cleaning damage:** Corrosive caustic or acidic cleaning chemicals aggressively attack the metal causing damage that can lead to eventual failure. Such damage can be aggravated when rinsing of the cleaners is not performed quickly enough, causing pitting, or not thoroughly enough to get cleaning chemicals out of all pits and crevices.
- **Pitting corrosion:** Localized galvanic corrosion, that can occur as a result of chemical attack from the boiler atmosphere, such as with the use of sulfur-containing fuels or from coal ash constituents, etc.

These mechanisms, as well as others, can combine to cause very complex failure mechanisms of the boiler components.

Boiler tubes that have failed as the result of severe corrosion. Note the "elephant hide" appearance of the middle tube that may be the result of fireside corrosion fatigue.

The Oerlikon Metco solution

Electric arc wire thermal spray solutions from Oerlikon Metco can be applied to boiler components and systems significantly faster than weld overlays, reducing outage time.

Thermal spray is also less expensive to apply (application cost per unit area) than welded overlays, and the same nickel-chromium alloys used for welding can be applied using thermal spray. Coatings can be applied in the shop or on site. As thermal spray coatings bond to the substrate materials with an intrinsic mechanical bond, there is no possibility of base-metal dilution or detrimental changes to the substrate grain structure.

Electric arc wire spray is a relatively cool application process, eliminating concerns for waterwall distortion. When properly applied, these coatings provide full coverage and are well-bonded to the substrate.

Thermal spray coatings are long-lasting, offer excellent corrosion protection and can be reapplied to components throughout the effective service life of the component.

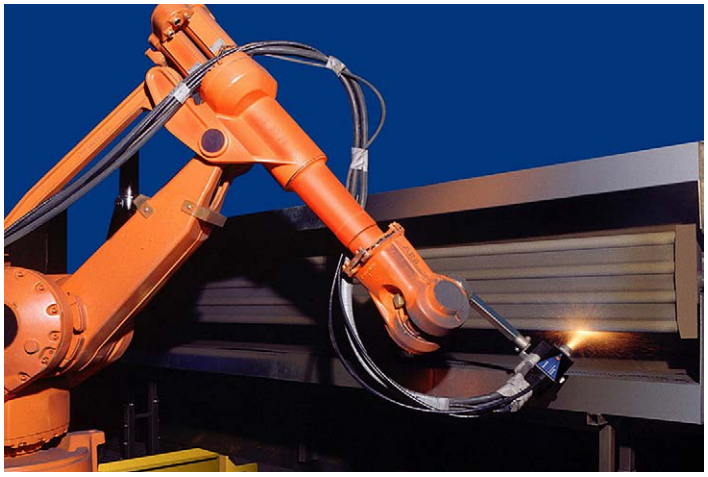
In those situations where a component must be repaired by welding, thermal spray coatings are weld-compatible and can be applied over the welded area.

Solution description and validation

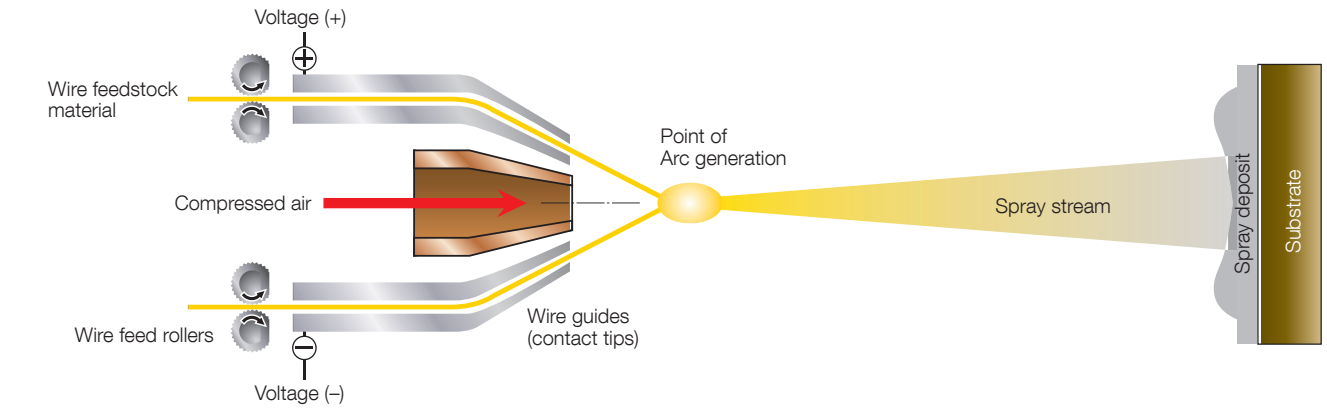
The Electric Arc Wire spray process

The Electric Arc Wire thermal spray process is renown for its simplicity and portability. Spray units are compact, requiring only electrical service and clean, compressed air to operate.

The process uses two metallic wires, usually of the same composition, as the coating feedstock. The two wires are electrically charged with opposing polarity and are fed into the arc gun at matched, controlled speeds. When the wires are brought together at the contact point, the opposing charges on the wires create enough heat to continuously melt the tips of the wires. Compressed air is used to atomize the now molten material and accelerate it onto the work-piece surface to form the coating.



A Oerlikon Metco Smart Arc system robotically spraying a boiler waterwall section in shop.



Principle of Electric Arc Wire Spray

FlexiArc 300 for on site coating work

The Oerlikon Metco FlexiArc 300 electric arc wire unit is designed for on-site work. Optional long-length hose packages and wire stands can be used to allow for convenient placement of the power supply unit remotely from the wire feed and spray gun. The FlexiArc 300 is capable of spraying the hard nickel-chromium alloy or composite wires best suited for boiler applications.

FlexiArc 300 is designed for long spray runs with consistent coating results. The unit is simple to use and low maintenance.

Although hand spraying can be used, for the best coating results on large areas with even coating thickness, the use of X-Y traverse units are recommended for spray gun manipulation.

The Metco FlexiArc 300 electric arc wire unit is recommended for on-site coating application for boilers.

Recommended surface protection materials for boiler applications

The materials applied by electric arc wire spray for boiler applications are chemically the same as those used for weld overlay. These materials are proven performers for erosion and corrosion resistance.

Product	Chemistry	Application area	Comments
Metco 8452	Ni 50Cr (cored wire)	Waterwalls for coal-fired or WTE boilers	Coatings exhibit high strength and corrosion resistance
Metco 8622	Ni 21Cr 14Mo 3W 2.5Fe (solid wire)	Waterwalls for coal-fired boilers	Good resistance to corrosion, erosion and thermal cycling. Niobium-free composition with excellent resistance to sulfur ion corrosion attack
Metco 8625	Ni 21Cr 9Mo 4(Nb+Ta) (solid wire)	Waterwalls for WTE boilers	Good resistance to corrosion, ion and thermal cycling. For use in sulfur-free environments; more economical than Metco 8622

Thermal spray coated boiler tubes. Left: coated and ready for installation. Right: after one year in service.

Electric Arc Wire spray vs. Weld Overlay

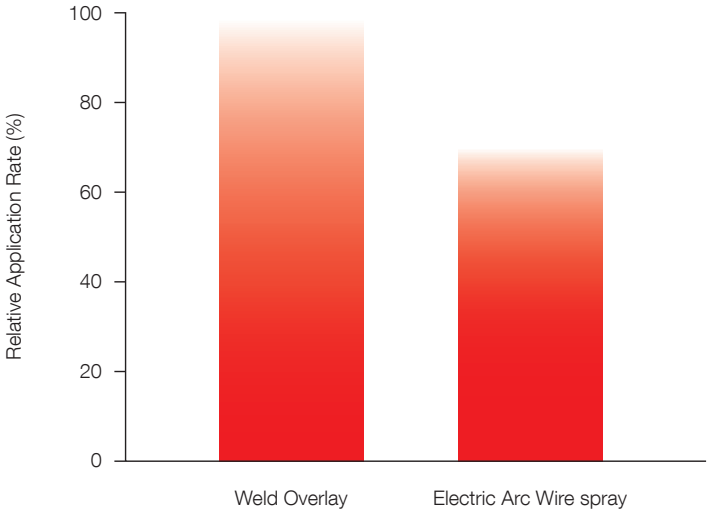
Coatings applied using Electric Arc Wire spray offer many cost and performance advantages over coatings applied using welded overlay. The two processes are compared in the following table:

Characteristic	Electric Arc Wire Spray	Weld Overlay
Surface preparation	Grit blast with aluminum oxide	Grit blast with aluminum oxide
Substrate temperature	Cool (no distortion)	Hot (melted substrate surface)
Target deposited thickness	1.0 – 1.25 mm (0.040 – 0.060 in)	1.5 – 1.75 mm (0.060 – 0.070 in)
Bonding mechanism	Strong mechanical bond	Metallurgical bond
Post-deposit substrate effects	None	Dilution, HAZ, grain distortion
Permeability	Not permeable	Not permeable
Application distance sensitivity	Not sensitive: ± 13 mm (± 0.5 in)	Very sensitive: ± 2.5 mm (0.1 in)
Post-deposit finishing	None required	May require TIG wash pass

Application time comparison

Most customers have reported that the total application time to apply electric arc wire coatings is 30 % to 40 % less than the application of welded overlay coatings.

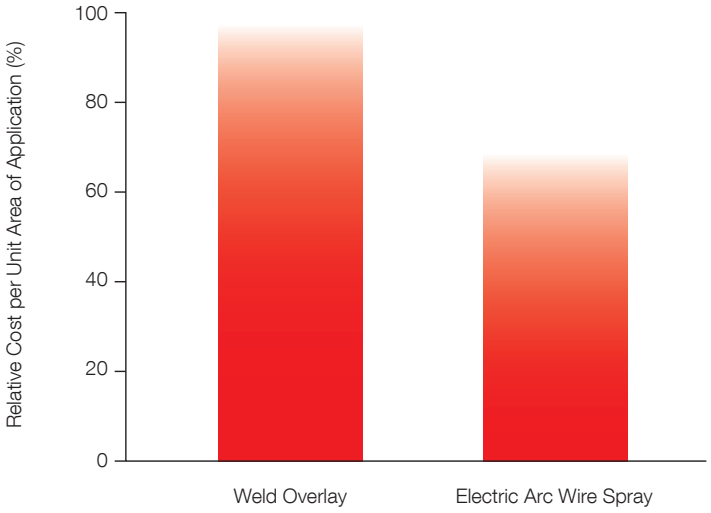
For a large utility boiler, this can signify completion of the surface protection application from 2 to 4 days faster using electric arc wire spray. This can mean millions of U.S. dollars in additional revenue generation as a result of reduced outage time.



Cost comparison

The cost to apply protective coatings using electric arc wire spray is considerably less than welded overlays. Wire material usage for thermal spray is approximately 3/5 that of weld overlay. Labor costs are lower because of the faster application time for electric arc wire spray compared to welded overlay.

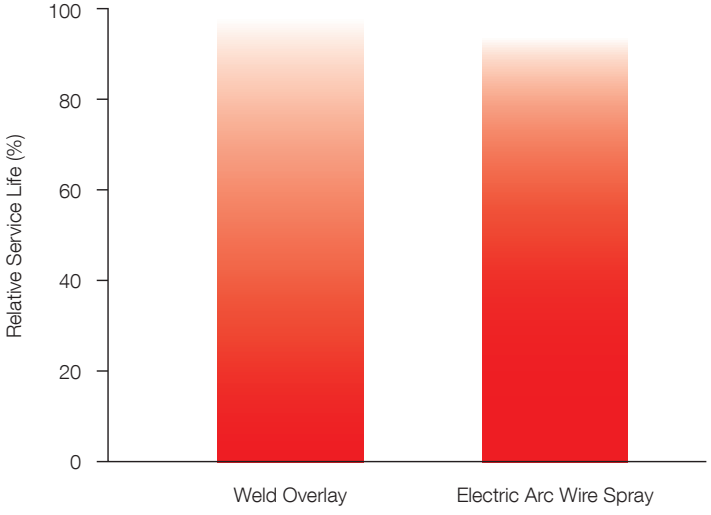
Furthermore, electric arc wire spray requires only electric, periodic change out of some inexpensive spray gun parts and compressed air; whereas welded overlay requires electric, welding gases and other consumables, depending on the welding process that is used. Overall, the costs for electric arc wire are 30 % to 40 % lower than that of welded overlay.



Service life comparison

Service life for the protective coatings will vary significantly depending on the boiler type, areas coated and the plant operating conditions.

Both electric arc wire spray coatings and welded overlays can be very long-lasting. However, the very nature of welded overlays can actually contribute to tube failure in ways that electric arc wire coatings do not. Dilution and HAZ (heat affected zone) changes to the base material grain structure can lead to premature tube failure as a result of unfavorable internal stress distributions or distortion from weld processing. Further, variations in the grain structure of the welded overlay from the metallurgical bond to the topmost deposits can initiate sites for cracking and micro-corrosion. Lastly, accidental through-hole pores in the weld can lead to premature attack of the base metal.



On-site application of electric arc wire spray

Electric arc wire spray is one of the most transportable of the thermal spray processes. The equipment can be arranged so that the spray controller and power supply are located outside of the boiler, while the feedstock material, wire feed unit, spray gun and cabeling are all that is needed to apply the coatings within the boiler. These elements easily fit through the tight manways of many boiler facilities. The spray gun has the ability to start and stop wire feed.

On site, manual electric arc wire spraying of a coal-fired boiler waterwall.

Customer benefits

- Effectively manages many of the fireside erosion and corrosion mechanisms that lead to boiler tube failures
- Provides long-lasting, surface protection for coal-fired and WTE boilers
- Significantly lower cost to apply than welded overlays
- Coating application is significantly faster than welded overlay, reducing outage time and minimizing revenue losses
- Does not distort or dilute base metal substrate
- Mechanical bonding does not produce a heat affected zone
- No through-hole pores that can act as sites for accelerated corrosion
- Requires no post-cost finishing or stress relief
- Coatings can be mechanically removed and reapplied without detriment to boiler components
- Single supplier for coating equipment and materials simplifies sourcing
- Flexible material choices depending on boiler type, operating conditions and location within the boiler
- Coatings are easily applied in shop or on site
- Process is easily automated for very consistent coating results and coating thickness
- Simple set up of equipment for on site work

SF-0021.1 – Electric Arc Wire Boiler Coatings

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www.oerlikon.com/metco
info.metco@oerlikon.com