White Paper

Mitigating Corrosion/Erosion in Waste to Energy and Biomass Boilers

Comparing the effectiveness of commonly used technologies, including refractory, weld overlay, thermal spray and high velocity thermal spray

Content

Corrosion in Waste to Energy Boilers

Problem Areas

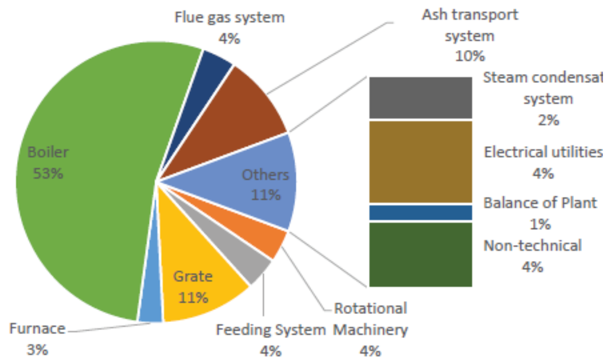
Boiler reliability has become one of the main challenges with the advent of efficiency advances in Waste to Energy industry. When operated at low pressure/low pressurized water temperature, the corrosion rate of the boiler waterwall is low. As a result, boilers can operate for decades without any corrosion protection. In order to generate power efficiently, the production of high-temperature steam with the highest pressure/temperature possible is required. The implementation of the Best Available Technology (BAT) required by the Industrial Emissions Directive 2010/75/EU under the EU BAT reference documents (BREFs) pushes the operators to optimize the performance of the lines where reliability becomes a key factor. This increase in temperature calls for a selection of materials that can withstand higher operating conditions in a more aggressive and complex environment, including chlorine and molten salts forming and condensing at various temperatures. Many readily available materials offer adequate resistance to high-temperature service or certain corrosive agents; however, few can perform reliably where a combination of corrosion mechanisms affects the boiler.

To ensure the highest percentage of operating availability, a solid preventive maintenance is required.

Unplanned outages, on the other hand, lead to unfortunate consequences:

1. Emergency work. The line is stopped, conditions to complete the repair under time constraints are unfavorable. Oftentimes, this extra work can occur in the middle of the night, on a weekend or during a holiday period, adding unnecessary stress for the operation and maintenance teams.
2. Financial losses. Several days are required to remedy the problem, leading to sizeable production losses.
3. Emissions. Stop-and-start phases are known as periods with higher emissions, since the gas filtration system doesn't operate within its design parameters. Exceeding emissions can potentially lead to losing the license to operate.
4. Faster aging of the unit. Frequent stops and starts create additional thermal cycles on the entire boiler for which it was not designed, accelerating the fatigue aging of the components under stress.

Root Cause Unplanned Outage

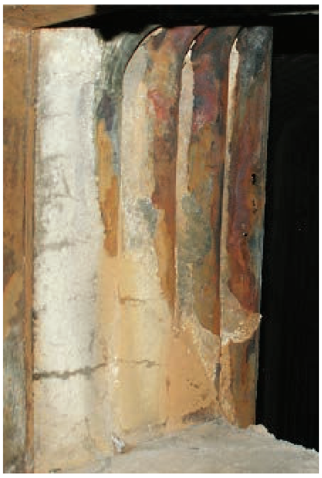


Evaluating Alternatives: Refractory

One of the most commonly used solutions for WtE boiler corrosion protection is refractory. There are different types of refractory readily available on the market: tiles, castable concrete, and shotcrete. The initial purpose of a refractory was to insulate the substrate from high temperatures, in the combustion or high-temperature areas. Research conducted with the aim of achieving better power generation efficiency, suggested that the heat needs to be transferred from the combustion area to water, generating steam for the turbine. As a result, materials have since evolved with the inclusion of more heat-conductive grades of refractory. Refractory effectively protects the waterwalls but, due to its low heat transfer, even the latest generation materials reduce heat transfer significantly. Moreover, refractories tend to be fairly thick, several centimeters at least. This can be useful for keeping temperature to maintain 850°C during 2 seconds in case of low load operation.

Refractory maintenance costs tend to be high and usually drive the duration of the outage. Refractory can also degrade and fall off in service, exposing unprotected boiler tubes to the severe operating conditions, leading to rapid failure. After the installation, drying times and heat ramp up are also critical.

Almost New Refractory



Refractory effectively protects the waterwalls but, due to its low heat transfer, even the latest generation materials reduce heat transfer significantly.

Material	W/m°K
Mono Tile	~16
Mortar	6-8
Carbon steel	~50

Evaluating Alternatives: Field Weld Metal Overlay

Weld overlay emerged as a new solution ~25-30 years ago, developed for WtE plants suffering from reduced waterwall tube life. Several materials were evaluated and alloy 625 provided the best results with relative ease of in-situ application and life extension reliability, despite its high cost. As the demand grew, several suppliers entered the market with different quality/price ratios. Competition and pressure from the end users have ultimately drove the prices down, leading to the reduction in quality. As a result, low-priced providers were selected with some disappointing results:

1. Shortened weld overlay life (high dilution)
2. Wall distortion due to weld generated stress (high heat input)
3. Execution time longer than planned (especially in cases of thin tubes)

Some operators prefer replacing thinned panels with workshop-applied weld overlay on new panels.

***Field services –** on site weld overlay*

Evaluating Alternatives: Shop Weld Metal Overlay

Many suppliers and OEMs integrated Shop Weld Overlay as a preferred solution due to its reliability and better-quality controls.

Nowadays, most boilers are designed and fabricated with weld metal overlay (WMO) installed in critical areas where a higher risk of corrosion is expected. Vast experience allows better prediction of expected lifetime, depending on the operating conditions and the limits of use.

One of the main limitations of alloy 625 overlay is its skin (material) temperature. Alloy 625 performs exceptionally well at temperatures up to 400°C/752°F. Above this temperature, the lifetime is reduced by half with every 10°C/18°F increase, an important factor with flue gas temperature. As a result, the lifetime on superheaters can vary significantly, since the material is being used at the edge of its capacity.

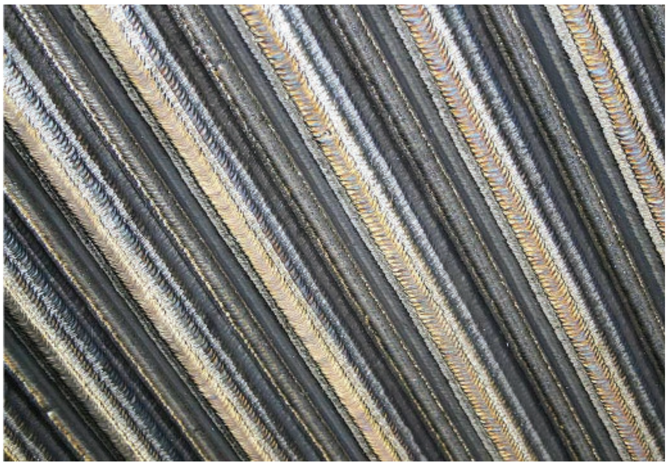
During the design of the boiler, its corrosion protection can vary depending on the warranty, expected lifetime and budget. The corrosion rate will typically follow the flue gas temperature - with high temperatures and corrosion rates in the first pass, followed by lower temperatures/ corrosion rates in the second pass, and even lower in the third pass.

After years in operation, unprotected waterwalls will corrode and tube thinning should be monitored. Before tube thickness becomes too low, cladding extension should be considered. Alternatively, tubes will have to be replaced with or without cladding depending on the return on investment.

After years in operation alloy 625 weld overlay will also age. Typically, the surface becomes “spongy”. Chromium forms chromium oxide layers to protect from corrosion, but this layer gets worn and reformed until the layer of alloy is “consumed”. The phenomenon is not uniform, consequently some areas will age faster than others.

Weld overlay can be repaired, provided that surface preparation can be carried out to remove the “aged” material. This operation, usually performed by grinding, is time consuming. It can be performed locally to “maintain” the barrier, but once the aged surface is too large, the replacement with new shop-applied weld overlay panels or other protection means needs to take place.

Shop weld metal overlay



Alloy 625 performs exceptionally well at temperatures up to 400°C/752°F. Above this temperature, the lifetime is reduced by half with every 10°C/18°F increase

Evaluating Alternatives:
Thermal Spray

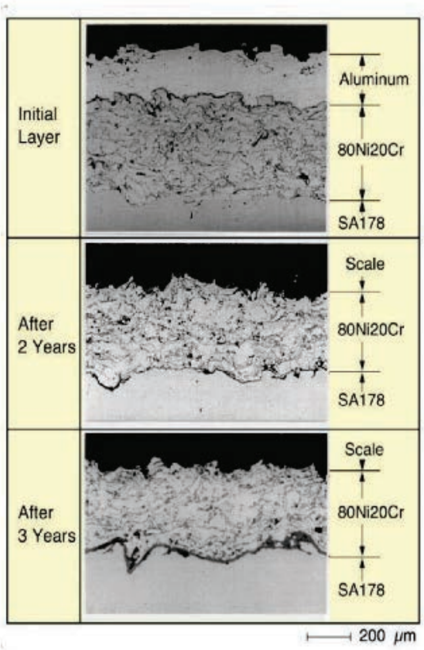
Thermal spray technology has been used for the application of erosion resistant alloys in the power industry since the 1980s. However, it was quickly understood that the thermal spray process itself negatively affects the properties of the alloy being sprayed and can be difficult to use for corrosion protection, with exception of TSA (Thermal Spray Aluminum), since it protects by the means of a cathodic sacrificial system.

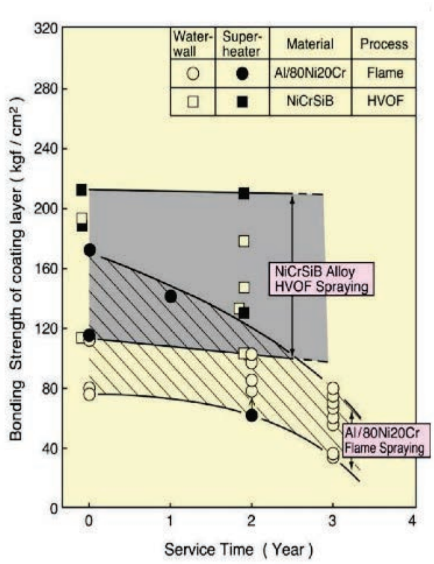
The resulting as-applied cladding, when using off-the-shelf metal alloy wires and conventional thermal spray equipment, was permeable. This endemic permeability as a result of the structure and as sprayed chemistry, weakened by high internal stress and low bond strengths with the base metal, created a unavoidable pathway for corrosion agents.

Once the corrosion agents reach the substrate, corrosion, sometimes even accelerated, can develop under the coating causing delamination from the substrate.

Some improvements have been unsuccessfully attempted with sealants or bonding layers, only lasting ~2-3 years in service.

HVOF (High Velocity Oxy Fuel) can be performed with better results, but the application is limited to shop only, due to safety and process control factors for manual application. As a result, annual maintenance is required to ensure lasting performance.



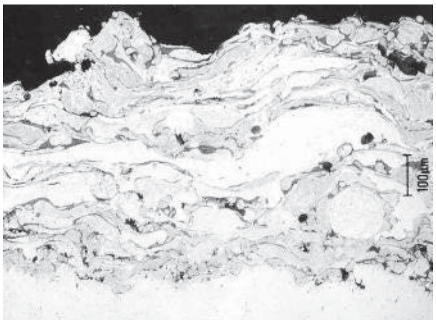


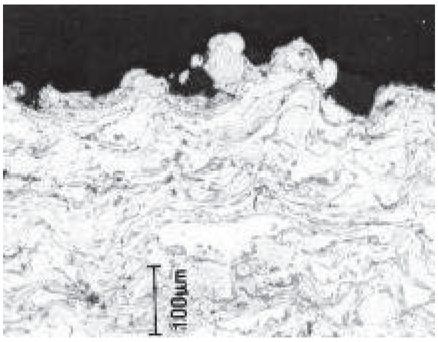
Thermal Spray Evolution: High Velocity Thermal Spray (HVTS) Alloy Cladding

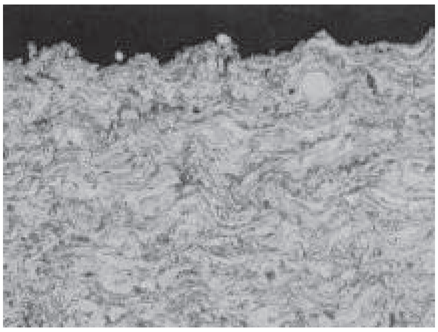
In the early 2000s, a handful of engineers and material scientists have successfully developed a solution to improve the quality of the cladding applied with Thermal Spray (TS). The aim was to keep the benefit of TS technology, including the low heat input to the substrate and high production rates, while avoiding permeability, stress and distortion. The key improvement to achieve the breakthrough technology are as follows.

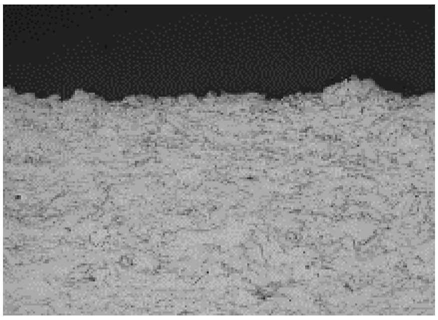
1.Creating an Impermeable Barrier

Traditional thermal spray processes create permeable layers, which manage to interconnect and create a path for the corrosive agents. The first priority for the development of this new technology was to apply a minimal permeability layer.
Increasing the propelling gas speed facilitated the metal droplets atomization in smaller particles with a more homogeneous size. In addition, these particles reach the substrate with higher velocities. However, melting metal alloys “in air” leads to the oxidation and sensitization of the particle surface, while replacing the air by an inert gas is not an option from the safety and cost perspective.
A clever solution has facilitated the reduction of oxide content below 1%.









2.Bond Strength

Creating an impermeable barrier is fundamental, with one condition. This layer needs to stay on the substrate. As opposed to welding, no substrate fusion occurs during thermal spray. Consequently, there is no dilution of the base metal into the applied Corrosion Resistant Alloy, nor is there any generation of a Heat Affected Zone (HAZ).

The Thermal Spray applied cladding is anchored by mechanical connections, mainly related to surface preparation and particle chemical properties. The bond strength is even more important with high operating temperatures. Applied CRA materials have similar coefficient of thermal expansion to the base metal, in order to reduce stress at the interface. The thickness of the CRA layer is also critical.

When corrosion develops at the interface, the bonding resistance disappears, since the iron oxides have no mechanical strength. Clean-blasting, in addition to removing the dust layer, will also generate mechanical forces to remove the non-bonded layer.

3.Quality Assurance and Control

Several workshop thermal spray vendors have ventured out into the on-site mission-critical asset application market and their inconsistent results have arguably damaged the reputation of thermal-spray-applied cladding as a whole. Weld metal overlay (WMO) has been successfully applied for decades as an engineered solution, with relevant quality control requirements for the technician/ operator (welder), the welding process, and the welding alloy. Welding on pressure part assets is typically considered to be a major repair according to Notified Bodies, forcing clients to submit a repair package file, often including a pressure test.

As a result, there are multiple procedures, standard practices, and controls that a client can follow to ensure the application standard and quality are appropriate.

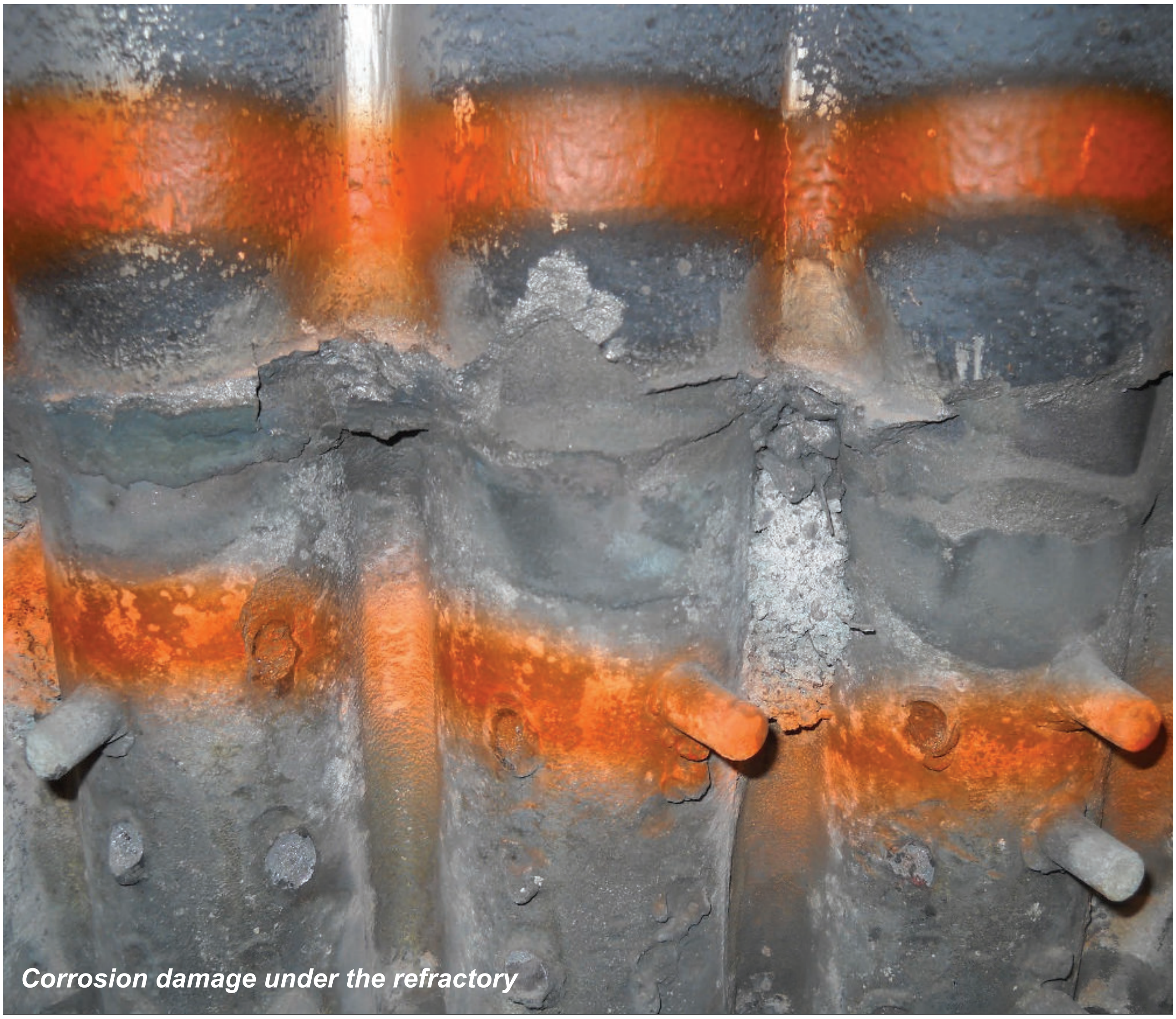
Thermal spray process does not alter the pressure part integrity, as a result there is no mandatory documentation nor tests required. Each vendor is, therefore, able to set their own quality procedures and practices, leading to a wide range of quality and performance outcomes.

IGS (Integrated Global Services), provider of High Velocity Thermal Spray (HVTS), developed multiple quality control systems, adapted from the established welding industry model, to ensure applications would not follow the thermal spray past experiences.

Innovation in Corrosion Protection

IGS subject matter expert on WtE and biomass boiler coatings, Cyril Narjoz, said:

"Some boiler operators believe that the application of alloy 625 weld overlay is the only solution available to protect boiler waterwalls from waste- or biomass-induced corrosion.
This was indeed the case for many years, but IGS has now proven the performance of HVTS in several independent tests and arduous practical applications.
With its on-site application being much faster and easier than weld overlay, HVTS has become the preferred corrosion protection option for many operators.
With IGS high velocity thermal spray (HVTS) applied alloy claddings our customers enjoy all the benefits of weld overlay without the drawbacks. Our application time is also significantly faster, at 3-6 m² per machine per shift."



Corrosion damage under the refractory

Extending the Lifetime of Existing Cladding

Many asset owners look for a solution to extend the lifetime of their weld overlay. The cladding can degrade overtime, leading to failure. It is difficult to evaluate the severity of the problem, as it will typically start with a local minor defect, while 95+% of the cladding is still in an acceptable condition.

However, this break in corrosion protection endangers the reliability of the operation. Most operators would attempt to extend the lifetime of their weld overlay, due to the costs of its replacement. Aged weld overlay can be repaired, requiring surface preparation by grinding. It can be easily executed on a localized spot, but when the quantity of these repairs increases or the quality of the inspection to define the repairs is under time and cost pressure, the reliability of the cladding drops.

The recommended solution is to replace the overlay area with new panels with overlay in a shop. This is an expensive and time-consuming project which should be evaluated with the return on investment, depending on the remaining lifetime of the equipment or the duration of the contract.

HVTS is a proven solution to extend the lifetime of aged weld overlay. The application is carried out quickly without the need for grinding. Temperature resistance of IGS 5000 series HVTS materials exceeds that of alloy 625 overlay. As a result, HVTS can offer lifetime longer than the initial projected life of alloy 625. HVTS can also be repaired, with no more panel replacement required.

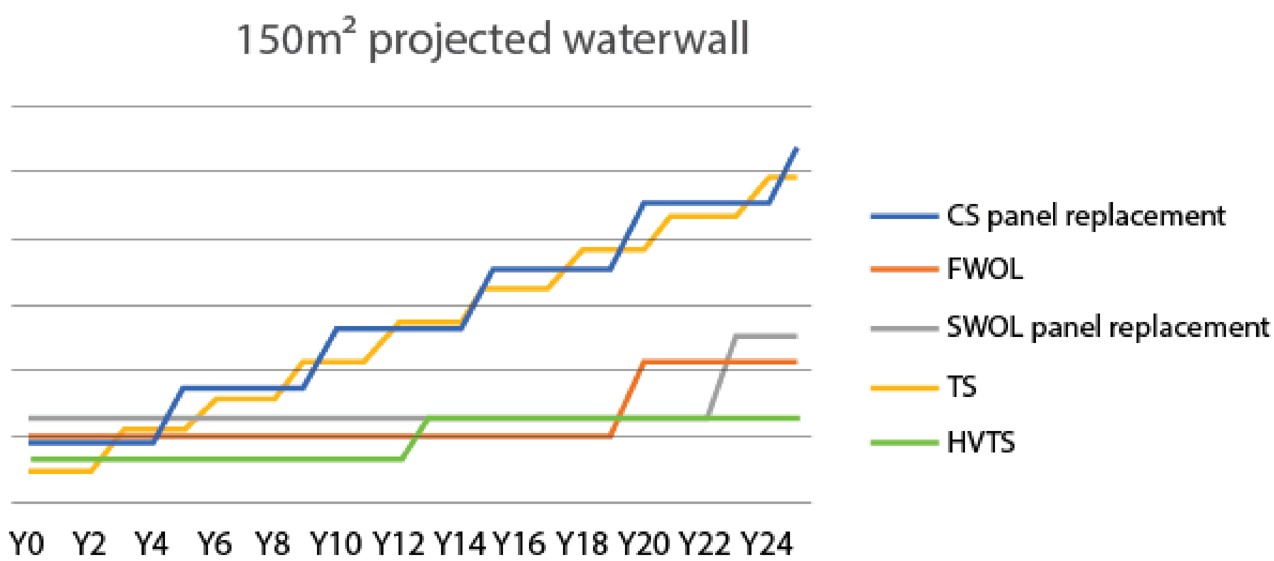
Many boilers are partially protected, either as part of their initial design by the OEM or later by the operator. Very often, after some time, the surface next to the protected area will corrode. The corrosion rate is lower with the cooling of the flue gas, therefore corrosion protection was not implemented on an area with the lifetime over 10 years. After 7-8 years in operation, significant thinning can be measured and the decision to replace with carbon steel (CS) panel or cladding extension must be taken.

No corrosion on area fitted with IGS 5000 Series cladding

Corroded weld overlay

It can also be a consequence of fuel evolution. In this case, the best solution should be evaluated depending on the cost of implementation, cost of maintenance, lifetime of corrosion protection, duration of the remaining lifetime of the equipment or operating contract and other parameters.

The following table gives indication of the cost versus return on investment of various solutions for a projected surface 150m² area. The cost can vary slightly based on the location, while the lifecycle may vary significantly based on location, fuel, boiler design and other influences. Life cycles for the different options relative to each other remain somewhat consistent though.



Case Study 1: Test Application 32 Months in Service

The test application of IGS HVTS was performed for one of the largest WtE plants that treats over 1.400.000 tons of waste per year. The plant was experiencing accelerated degradation of their weld overlay cladding in the 1st path, just above the refractory. Looking to avoid panel replacement, the plant has elected to trial two HVTS alloy cladding solutions, IGS8000 and IGS5000 series materials, in 2016 with a 15m² application.

Boiler parameters:

Fuel:	**33,6 t/h house hold waste**
Thermal capacity:	**93,3MW**
Steam output:	**102t/h**
Steam pressure:	**130 bar**
Steam temperature:	**420°C**
Outage cycle:	**Every ~2years**

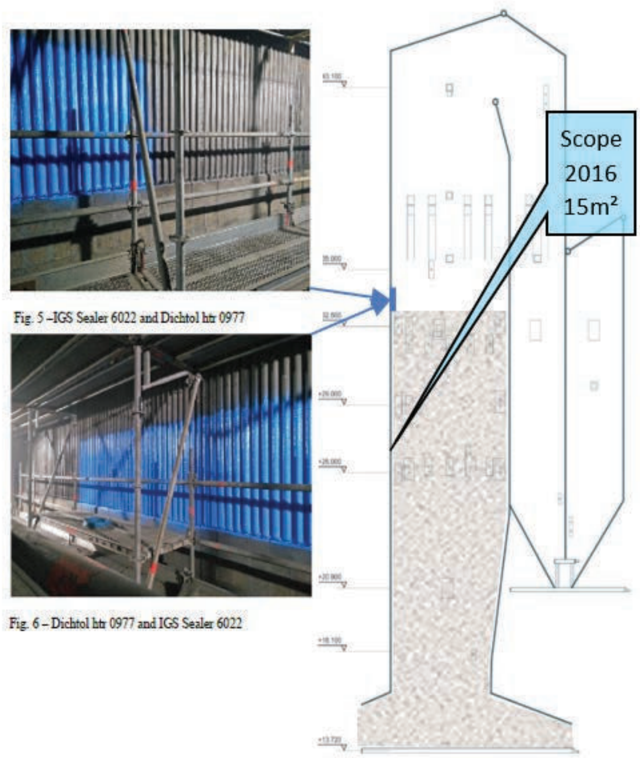


Fig. 5 –IGS Sealer 6022 and Dichtol htr 0977

Fig. 6 – Dichtol htr 0977 and IGS Sealer 6022

Inspection In 2019, After Three Years in Service

The inspection in 2019 has revealed:

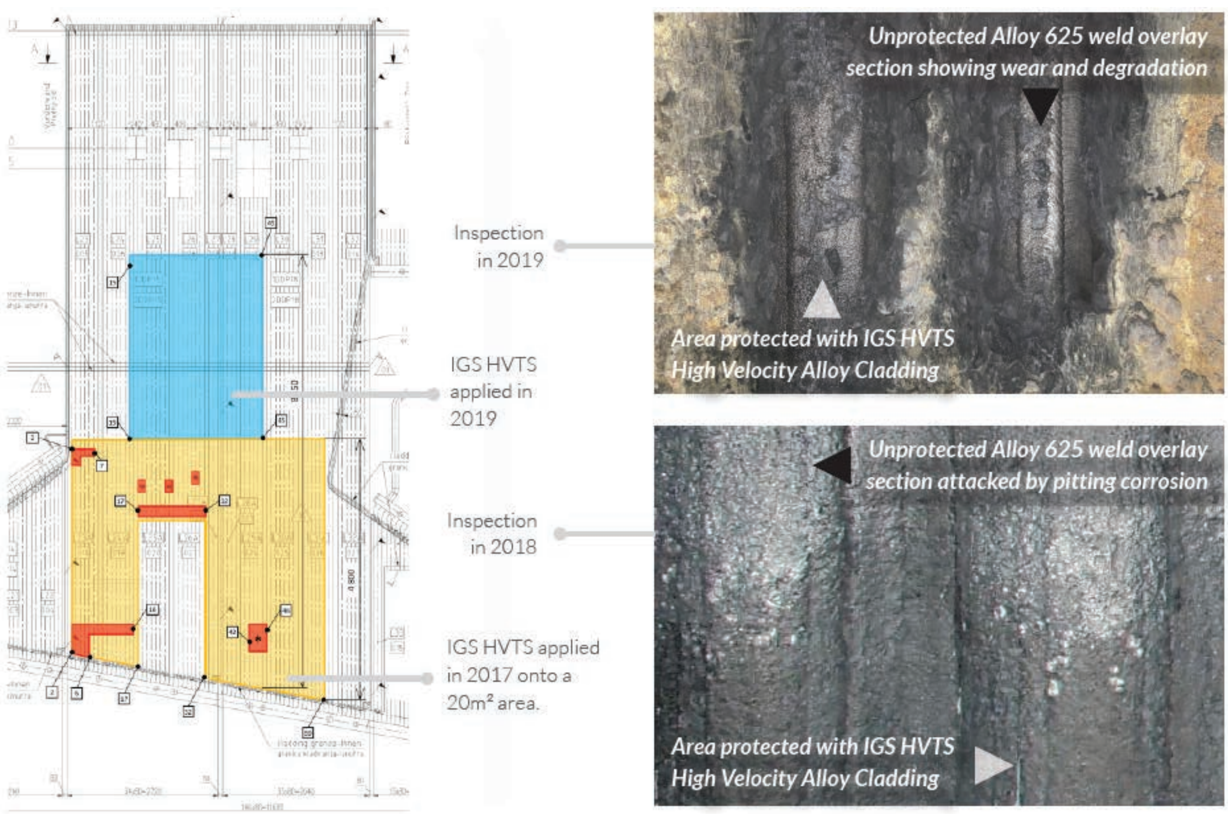
- Unprotected alloy 625 weld overlay continued to degrade, with through-wall defects on the membrane
- Alloy 625 areas protected with IGS8000 series, a material previously developed for the coal power sector, were exposed
- Alloy 625 areas protected with IGS5000 series, a material developed specifically for the WtE and Biomass industry in 2016, showed no signs of wear or degradation. IGS5000 series was unaffected with no spalling or degradation, even on the membranes, after 32 months in service.

Case Study 2: Trialing Four Thermal Spray Vendors in One Boiler

Renergia Waste to Energy plant in Switzerland went into operation in 2015. Hitachi Zosen Inova (HZI) furnace installed at Renergia is an inclined moving grate four-pass waste to energy boiler with an external economizer. The boiler's thermal capacity is 47MW with the steam flow of 58 t/h and steam pressure of 41 Bar at 410°C/770°F. Alloy 625 weld overlay was shop-applied on the fireside waterwall panels.

Rapid alloy 625 degradation was being observed on the waterwall panels after one year in operation. The plant needed to maintain a 98% availability and could only consider solutions that could be applied within tight turnaround schedules.

As a result, Renergia has elected to test four thermal spray vendors. Each was given a small area within the boiler, performance was evaluated after one year in operation, during the next turnaround. Two of the vendors who used a low velocity thermal spray process have failed as thir cladding delaminated and exposed alloy 625 to further degradation. IGS 5000 series and another cladding, both using the High Velocity Thermal Spray (HVTS) process have performed well. Due to the other vendor's capacity limitations, IGS was awarded the contract in boiler protection.



Case Study 3: Upgrade in Preparation for Fuel Change

IGS performed a High Velocity Thermal Spray (HVTS) application at E.ON Värme Sverige AB Åbyverket, Örebro, Sweden, on a steam boiler in 2017. ÅP5 is a 170 MW biomass-fired CFB boiler built in 1988 by Götaverken-Generator (currently Valmet Technologies Inc.) The steam conditions are 150 bar and 540°C/1004°F.

Åbyverket wanted to upgrade the previously installed erosion protection in preparation for the fuel change during the boiler revamp. 20m height of waterwalls were being changed on all 4 walls. IGS applied 993,5 m^2 (20m band) of HVTS during a 3-week period, working 24/7.

In August 2018, IGS conducted its first annual inspection of the cladding with no deviation on the HVTS cladding thickness. Inspection the following year was conducted, and the report stated: “No black areas were detected (bleed through), the cladding turned out to be completely intact and without material loss. Measurements taken showed results similar to those from the year of application.” Inspections in 2019 and 2020 showed no corrosion, ~1m2 (0.1% of the total area) was refurbished in 2019 and 2020 due to normal erosion near refractory and field weld areas.

Summary:

As the WtE and Biomass market rapidly grows, burning an ever-increasing variety of different fuels, boiler engineers will face more arduous corrosion and erosion metal wastage challenges.
IGS can provide an effective barrier to protect pressure parts in-situ, preventing further metal loss and waterwall panel replacement.

When selecting a thermal spray system as a corrosion barrier, one needs to be aware of the vendor-to-vendor differences in the design, technology, application, and performance of these systems.

Asset owners should always request suitable references, evidence of operator experience and test reports which should be thoroughly reviewed to ensure the as applied CRA barrier will perform as expected.

For more information, contact info@integratedglobal.com or visit integratedglobal.com

IGS HVTS succesfully protects hundreds of CFB, BFB, WtE, Biomass and coal-fired boilers worldwide.

IGS has performed over 4,000 site projects and installed millions of square feet of reliable HVTS metal cladding surface protection.

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