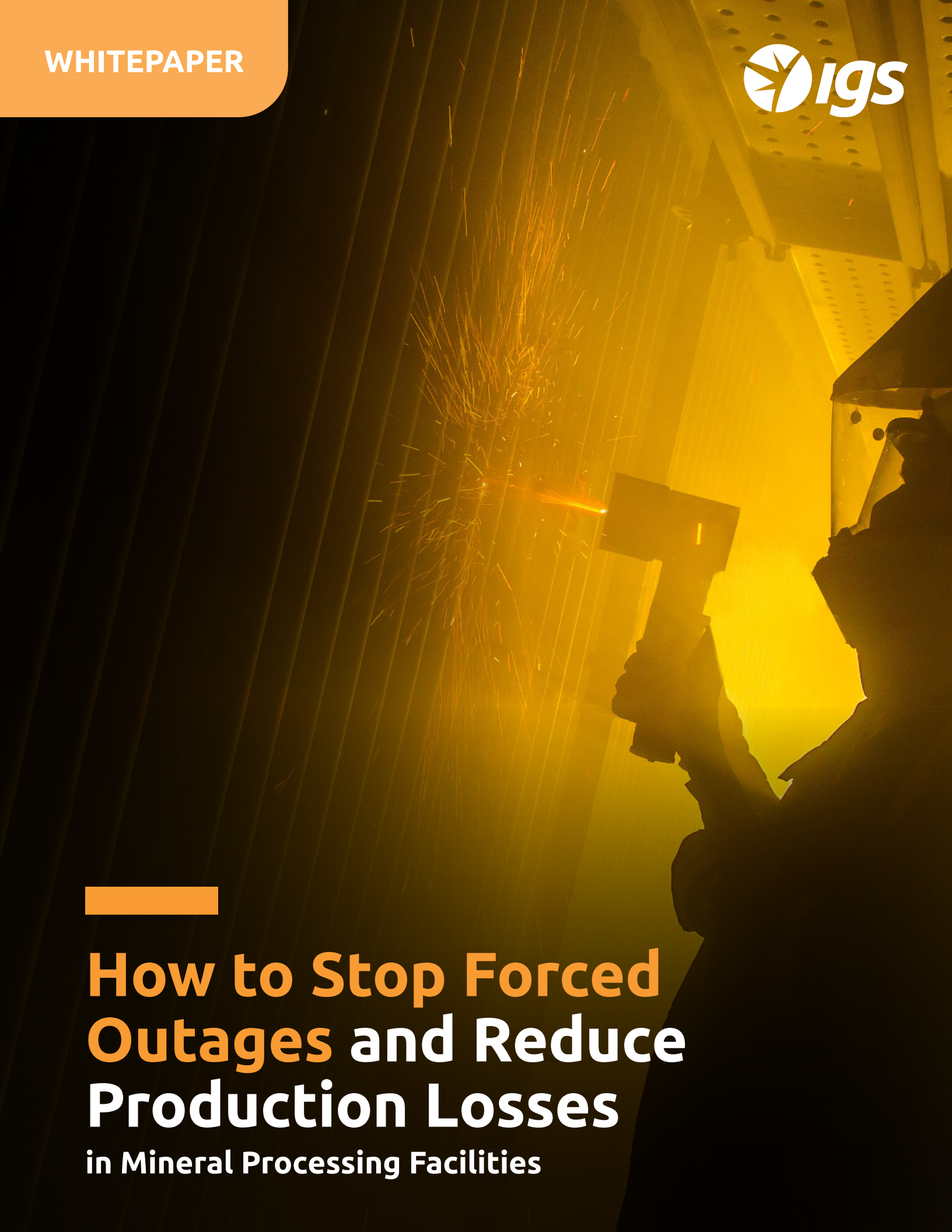
WHITEPAPER



How to Stop Forced Outages and Reduce Production Losses

in Mineral Processing Facilities

Contents

Mineral processing facilities refining and smelting copper, alumina, ferronickel, platinum and steel experience metal wastage within their mission-critical equipment, including converter furnaces, smelter furnaces, and off-gas ducting.

Problem Areas

Metal surfaces in these high-temperature environments suffer from hot corrosion, acid attack, solid particle erosion, and acid dew point corrosion, among other wastage mechanisms. Frequent replacement and welding repairs can become costly, lead to forced outages, and significant production losses.

Any delay in permanently solving corrosion and erosion problems can lead to costly maintenance cycles as well as operational losses. Furthermore, corrosion and erosion problems can lead to environmental concerns, contributing to pollution and can ultimately lead to penalties.

Equipment Specific Issues

Corrosion causes metal wastage issues anywhere across the metals and mining site, but it is specifically troublesome in the following equipment:

- Heat Recovery
- Waste Heat Boilers (Steam Recovery Heat Generators)
- Baghouses
- Off-gas Ducting
- Pyrometallurgical Furnaces
- Cooling Parts (Cooling Components of Pyrometallurgical Furnaces)
- Stacks

Damaged boiler tube

Waste Heat Boiler (WHB) Corrosion

The waste heat boilers are equipped with membrane walls, bulkheads and bundle heating surfaces.

Waste Heat Boilers often suffer from:

- Solid particle erosion
- Acid dew point corrosion
- High-temperature sulfidation
- Tremendous slagging

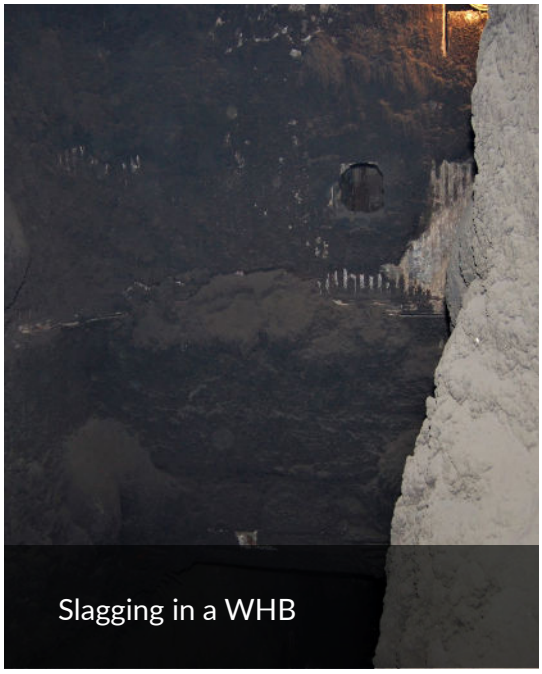
These processes are caused by the presence of a combination of sulfur, halides and water vapor within a high-temperature environment.

On the right is a WHB example that gets replaced every 24 months due to rapid degaradation of the pressure parts.

The Science

The flue gas stream within a metallurgical WHB has a high dust content. It may either slag on the surface, depending on its melting point temperature, or erode waterwall, as it mainly consists of a variety of metal oxides.

Dew Point corrosion in metal-air preheaters leads to rapid corrosion and breakdown of plates and tubes. This results in decreased energy efficiency and performance of WHBs. To avoid asset failure, preventative action should be taken to ensure efficiency and prevent costly unplanned shutdowns.



Slagging in a WHB

Typical WHB tubes with a membrane view before corrosion sets in

WHB Corrosion Solutions

Replacement

Some plants elect to replace the whole waste heat boiler periodically. This can happen as frequently as every 24 months due to the aggressive nature of the feedstock and process.

Replacement offers a certain performance guarantee. The new boiler is manufactured to the exact specification. There is also an element of predictability. When the market conditions are stable the new boiler will arrive and be installed within the agreed timeframe with no issues.

Replacement does carry a significant inherent cost implication. With a global fight on waste, the maintenance and operations team may question the status quo and consider reliability initiatives to prevent replacement or prolong the lifetime of their WHB.

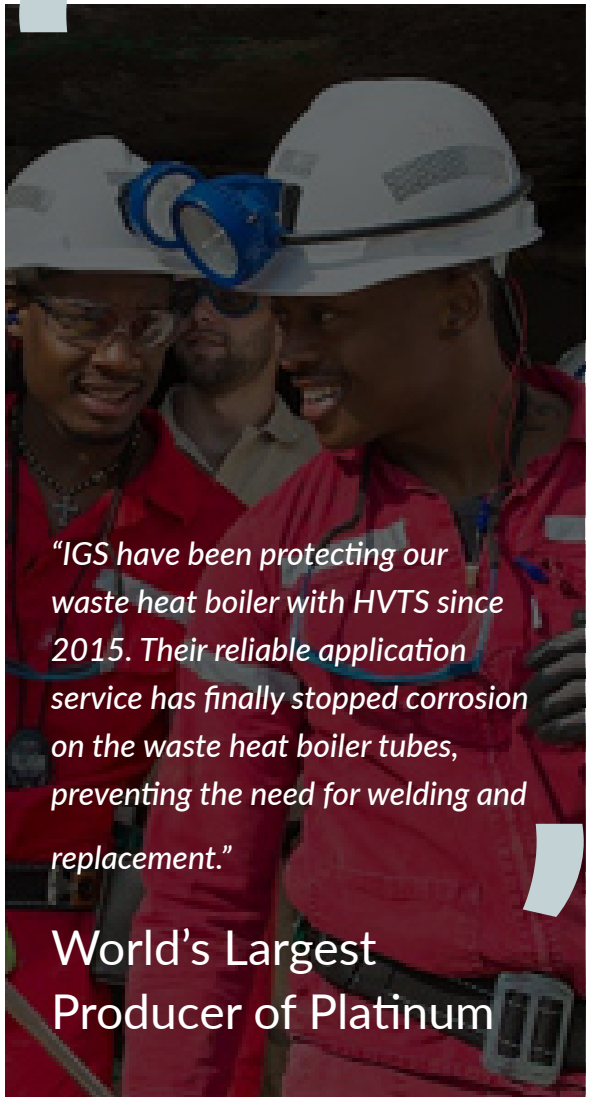
Welding

Welding is a tried and tested solution. It adds structural integrity and has an ability to improve the metallurgy of the substrate. Welding carried out in a controlled workshop environment is an optimum solution for asset life extension.

Not all welding can be carried out in a workshop. Field welding can also be performed, but it is not without its challenges. It is a relatively slow process which can cause issues during a tight turnaround. Welding boiler pressure parts, depending on the surface area can also become prohibitively expensive.

New WHB ready for installation

Boiler field welding



HVTS (High Velocity Thermal Spray)

Developed for safe on-site application, IGS HVTS encompasses a high nobility alloy deposited onto the surface using a High Velocity Thermal Spray. It is widely used to permanently stop metal wastage in waste heat boilers, preventing the need to cut and replace the metal parts or continuously reapply low-performance coatings.

HVTS has been engineered at the IGS Technology Research Center. Specifically designed for the mining and mineral processing industry, it ensures excellent bond strength and corrosion resistance. HVTS helps non-ferrous pyrometallurgical plants to prevent forced outages and increases maintenance-free periods.

Baghouse Corrosion

Acid gas corrosion affects baghouses and leads to rapid degradation. The economic impact of baghouse corrosion includes:

- Unplanned shutdowns
- Reduced efficiency
- Costly maintenance
- Loss of containment
- Environmental fines

Baghouse Corrosion Mechanism

Carbon steel corrodes when exposed to high temperatures, wet, and acid flue gases. Stainless steel will experience corrosion if the gases contain chlorides. Corrosion that ultimately leads to equipment failure affects not only baghouses, but also ESPs, Stacks, and Ducts.

Solutions - Conventional Coatings

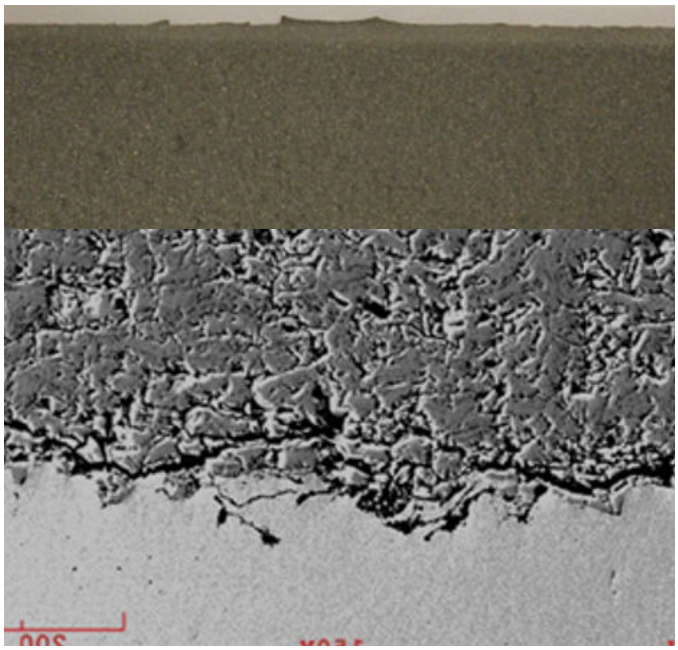
Typical epoxy-based, silicone, acrylic and alkyd coatings do not withstand normal operating temperatures. Blistering is soon followed by delamination from the steel surface. These coatings suffer from abrasion, permeation, and poor adhesion, leading to premature failure.

Some coatings that offer better performance are available but can only be applied in a workshop under strict environmental controls.

MRP System

The IGS MRP system is a metal-reinforced polymer. It is not susceptible to uniform corrosion patterns and is thus significantly more resistant to mechanical damage. The appropriate metallurgy is specified for the specific process condition and environment. Its thickness is optimized for maximum protection and integrity of the metal cladding.

IGS MRP system leverages 20-plus years of metal cladding and polymer applications experience to provide a surface protection solution that is significantly more robust and reliable than traditional organic and inorganic coatings. MRP delivers a barrier against high-temperature corrosive media, including H_2SO_4, HCl, H_2S and other corrosive and abrasive compounds.



Off-Gas Ducting Corrosion

Off-gas ducting systems commonly experience:

- Acid dew point corrosion
- Accelerated corrosion attack
- Corrosion-erosion due to particulate in high-temperature gas streams

Conventional Solutions

Failing organic coatings, frequent metal replacement, and welding repairs can become costly and lead to forced outages, production losses, and environmental concerns.

IGS HVTS Cladding Solution

Dew point corrosion, high-temperature sulfidation, slagging, acid attack, and solid particle erosion can be effectively mitigated with IGS High Velocity Thermal Spray (HVTS).

Developed for safe on-site application, IGS HVTS can be used to permanently stop metal wastage. This prevents the need to cut and replace the metal parts or continuously reapply low-performance coatings.

"IGS has helped us to finally solve the problem and reduced our critical path schedule by 3 days. We have achieved short- and long-term cost savings as a result." – International Gold Mining Company

Cooling Part Corrosion

Sulfidation of cooling parts in metals and mining processing facilities may occur, exacerbated by HCl gas. Corrosion rates as high as 80 mm/y can be observed when the metal is exposed to the sulfide gas at 110°C/ 230°F. This observation suggests that sulfide alone can cause severe corrosion even at moderate temperatures. When HCl is added, the corrosion rate is enhanced above 112°C/ 233°F, and pitting corrosion is observed.

IGS HVTS Cladding Solution

Dew point corrosion, high-temperature sulfidation, slagging, acid attack and solid particle erosion can be effectively mitigated with IGS HVTS.

"IGS have been applying their HVTS protection to our cooling parts since 2009, protecting them against sulphur vapour corrosion. Their service and speed of application have helped shorten and prevent many outages in our plant." - Leading International Precious Metals Mining Company

Stacks and ESPs

Stacks and chimneys are exposed to combustion gases, moisture, and acidic compounds. The top area of the stack can experience severe corrosion and failure, especially around flanged joints. The unlined carbon steel stack will require frequent and costly part replacement.

Increased sulfur in fuel and alternative fuel sources have all contributed to the corrosion problems. Following 4 or 5 years of uncontrolled corrosion, a stack can face wall thickness loss, causing the structure to become unsafe.

Smelters can experience significant production time losses due to poorly performing electrostatic precipitators (ESP) handling process gas. Rapid deterioration of the ESPs leads to a reduced performance and a steady increase of fugitive fume emissions inside the plant. These emissions raise concerns regarding the health and safety of workers.

IGS HVTS Cladding Solution

Developed for safe on-site application IGS HVTS can be used to permanently stop metal wastage, preventing the need to cut and replace the metal parts or continuously reapply low-performance coatings.

Comparison Chart	IGS High-Velocity Thermal Spray (HVTS)	Weld Overlay (WOL)	Organic Coating (Non-Metallic)
Corrosion Resistance	Yes	Yes	Yes (Temperature and organic material dependent)
Erosion Resistance	Yes	Medium (depending on alloy)	Temperature and organic material dependent
Typical Alloys Utilized	Modified 625 alloy, C-276 hastelloy and monel alloys	316, 625, 622, 52, monel, hastelloy with Fe dilution	NA
Bond	Mechanical and chemical (>3h MPa)	Metallurgical	Mechanical and chemical (>15 MPa)
Typical Thickness Spec.	500 microns nominal	2-3mm (dillution issue below 2mm)	
PWHT Requirement	No	Yes (required for most applications or HAZ becomes weak corrosion resistance area)	No
Dillution into Base Material	No	Yes	No
HAZ	No	Yes	No
Stress/Distortion of Base Material	No	Yes	No
Application Speed	3-6 m²/shift/machine	0.5-2 m²/shift/machine	5-10 m²/shift/gun + VARIABLE curing time
Repairability	Blast prep, build up and/or reapply locally	Blast prep, grind and reweld if not cracked/contaminated locally possible	Blast, surface preparation and re-application
Replacement/Removal	Possible aggressive blast removal	Grind-out for removal	Locally impossible aggressive blast removal
Durability	Metallic cladding - mechanically tough and temperature resistant	Metallic cladding - mchanically tough	Organic coating - fragile and susceptible to damage mechanically or by heat
Steam Out Resistance	Yes	Yes	No
Thermal Resistance	Metallic cladding - high temperaturte capability (>500C)	Metallic cladding - high temperaturte capability (>500C)	Organic coating - low immersion temperature capability (typically (<90C)
Curing Requirements	Metallic cladding - no cure	Metallic cladding - no cure	Organic coating - chemical reaction required to cure organic systems (cure rate dependent upon environmental conditions)
Application Requirements	Metallic cladding - minimum environmental controls required	Metallic cladding - minimum environmental controls required	Organic coating - strict environmental controls required (temperature, humidity, surface salts, amine bloom, solvent release etc.)
External Inspection Capability	Yes	Yes	No

Project Execution

IGS provide a turnkey application of the internal HVTS cladding for our clients, utilizing highly experienced and certified operations team. The IGS engineered solution considers all aspects necessary to effectively protect the asset internal surface including provision for the nozzles and manways. The entire process is controlled by the IGS Quality Management System (QMS) which includes the HVTS cladding procedure, Inspection Test Procedures (ITP's), environmental requirements,

surface acceptance criteria (including the evaluation of the existing cladding integrity, its restoration and mechanical remediation methodology), surface preparation requirements, as well as site applied production test plate creation and evaluation. All IGS personnel support the delivery of the QMS, the application technician, shift foreman, quality manager and project manager, each critical requirement is checked and verified multiple times during the project execution in close coordination with the client, following the IGS Standard Operating Procedures (SOPs).

The project engineering package was successfully delivered, including the project plan, method statement, inspection test plan, project safety analysis, risk assessment and mitigation plan and the job-specific safety data sheets. The project scope was completed on time.

Material Science

IGS material is a high velocity thermal sprayed metal cladding suited for a broad spectrum of both low and high temperature erosion/corrosion environments. The alloy has been specifically designed for use in high erosive and abrasive boiler, ducting and vessel environments. NiCr binder composition, with high Cr content makes it particularly resistant to high temperature sulfidation conditions. The alloy also has good high temperature oxidation resistance. A thermal expansion coefficient at the midpoint between carbon and stainless steels makes it well suited to both as substrate materials. The material has good erosion resistance due to effective Boron and Carbon induced hard-phase integration in a ductile binder.

The IGS cladding has excellent erosion resistance. Although it is a hard cladding system, it has greater ductility and can be repaired and rebuilt easily. It is widely used for erosion/corrosion protection in process equipment. The erosion/corrosion protection of the underlying metal substrate with the IGS cladding system will increase the service life of the asset, eliminate unplanned downtime, and increase the efficiency of the plant.

Case Studies:
Asset Owners Experience with HVTS

FURNACE PRESSURE PART LIFE EXTENSION DELIVERS 3X SAVINGS

PROBLEM

Due to the aggressive nature of the converter furnace and high temperature process environment, the furnace panels required frequent replacement or repair during the turnaround every two years. The time required for the weld repairs, together with any potential new panel installation in areas of damage, caused extended turnaround schedules and associated production losses.

SOLUTION

The IGS HVTS Cladding is a NiCr-based alloy that is specifically designed for use in high temperature furnaces/boilers. This material offers a low stress, very dense corrosion resistant layer of nominally 20 mils / 500 µm thickness to mitigate corrosion.

APPLICATION

Failures of the base metal and welds were observed in the converter furnace during their 2013 inspection. Considering the relatively fast application rates and no curing time associated with the IGS HVTS process, a decision was made to apply IGS HVTS cladding on the furnace roof section (an area encapsulating a total of 20m^2).

The converter furnace tubes were extensively evaluated after significant substrate damage had been determined. This furnace historically formed part of the critical path for the outage due to the extensive repair time needed. An IGS HVTS cladding solution was chosen over a

weld metal overlay solution due to significant T/A impact in terms of time savings and the lack of need for post-weld heat treatment, reducing T/A complexity and downtime.

INSPECTION / INTEGRITY ASSESSMENT

Final inspection of the work scope involved the generation of a cladding thickness record with mapped electromagnetic lift-off gauge readings on a defined reference grid across the area lined. This record will continuously be used for future inspection and verification of cladding integrity. HVTS cladding systems can be readily inspected visually for any signs of deterioration and thickness measurements taken with a magnetic lift-off gauge. The converter furnace was inspected again in August 2016 and 2020 with the IGS HVTS cladding found to be intact with no apparent thickness loss identified.

VALUE PROPOSITION

IGS' ability to protect the converter furnace panels and limit production losses was a key driver for the Maintenance and Turnaround Managers. The use of the IGS HVTS process was deemed more economical when compared to weld metal overlay due to time sensitivity. The cost of the weld metal overlay would have been approximately three (3) times more than the cost of the IGS HVTS cladding solution, thus saving the plant a considerable amount of money on the corrosion resistant material installation. Significant cost savings were realized due to reduced outage time related to repairs, inspection and turnaround time savings of repeated re-installation/repair of the failed tube sections.

OFF-GAS DUCT PROTECTED FROM ACID DEW POINT CORROSION

PROBLEM

Acid dew point corrosion in an off-gas duct has lead to its thinning. This resulted in the loss of efficiency, high replacement costs associated with frequent replacement and safety concerns.

SOLUTION

The fluctuating process conditions in the furnace contributed to the generation of corrosive sulfur and halide based species. The IGS HVTS Cladding material was applied to the water-cooled duct, consisting of seven 3.785 m lengths, each segment consisting of 72 welded pipes. The IGS HVTS was applied to the tubes to protect from acid dew point corrosion, high temperature sulfidation, oxidation and erosion, caused by the sulfur and water environment.

The total area coated was 109m2. The IGS HVTS cladding system acts as a barrier that prevents the gaseous sulfur and chloride components from contacting the base metal, thereby preventing high temperature corrosion.

TURN AROUND DECISION PROCESS - RISK MITIGATION

Failures of the base metal and welds were observed at the metals and mining facility during their 2015 inspection of the off-gas duct. This furnace historically formed part of the critical path for the outage due to the extensive repair time needed. Considering the relatively fast application rates, no curing time, reduced T/A impact in terms of time savings and the lack of need for post-weld heat treatment, reducing scope T/A complexity and downtime, a decision was made to apply IGS HVTS cladding on the entire off-gas duct.

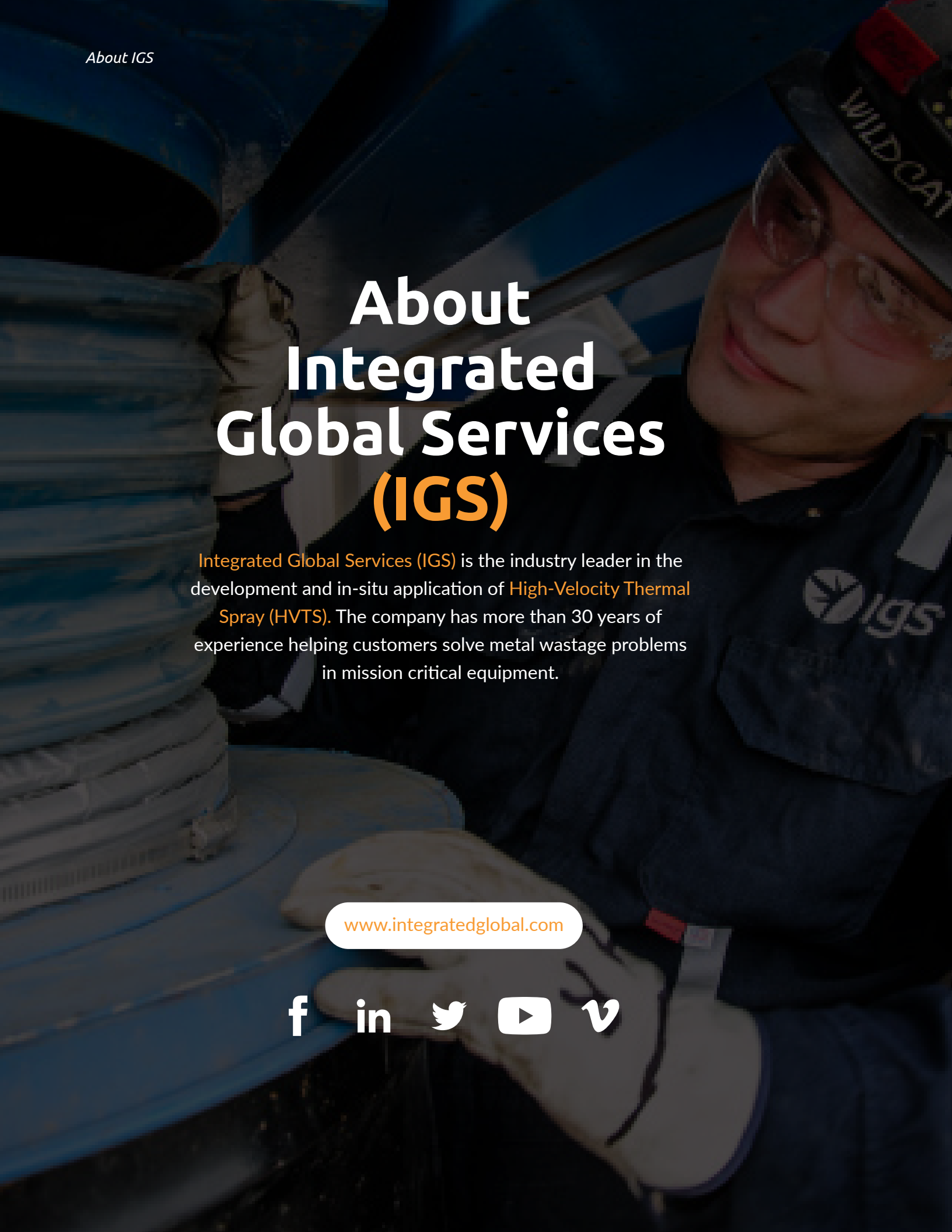
INSPECTION / INTEGRITY ASSESSMENT

The off-gas duct was inspected in 2016 and then again annually with the IGS HVTS cladding found to be intact with no apparent thickness loss identified.

Summary

Corrosion protection is critical for long-term asset performance and a comprehensive mitigation strategy should be in place at the beginning of the conversion process.

A preventative maintenance plan will ensure that asset life is prolonged, the risk of costly unplanned outages is reduced, and performance and efficiency are maximized.



About Integrated Global Services (IGS)

Integrated Global Services (IGS) is the industry leader in the development and in-situ application of High-Velocity Thermal Spray (HVTS). The company has more than 30 years of experience helping customers solve metal wastage problems in mission critical equipment.

www.integratedglobal.com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