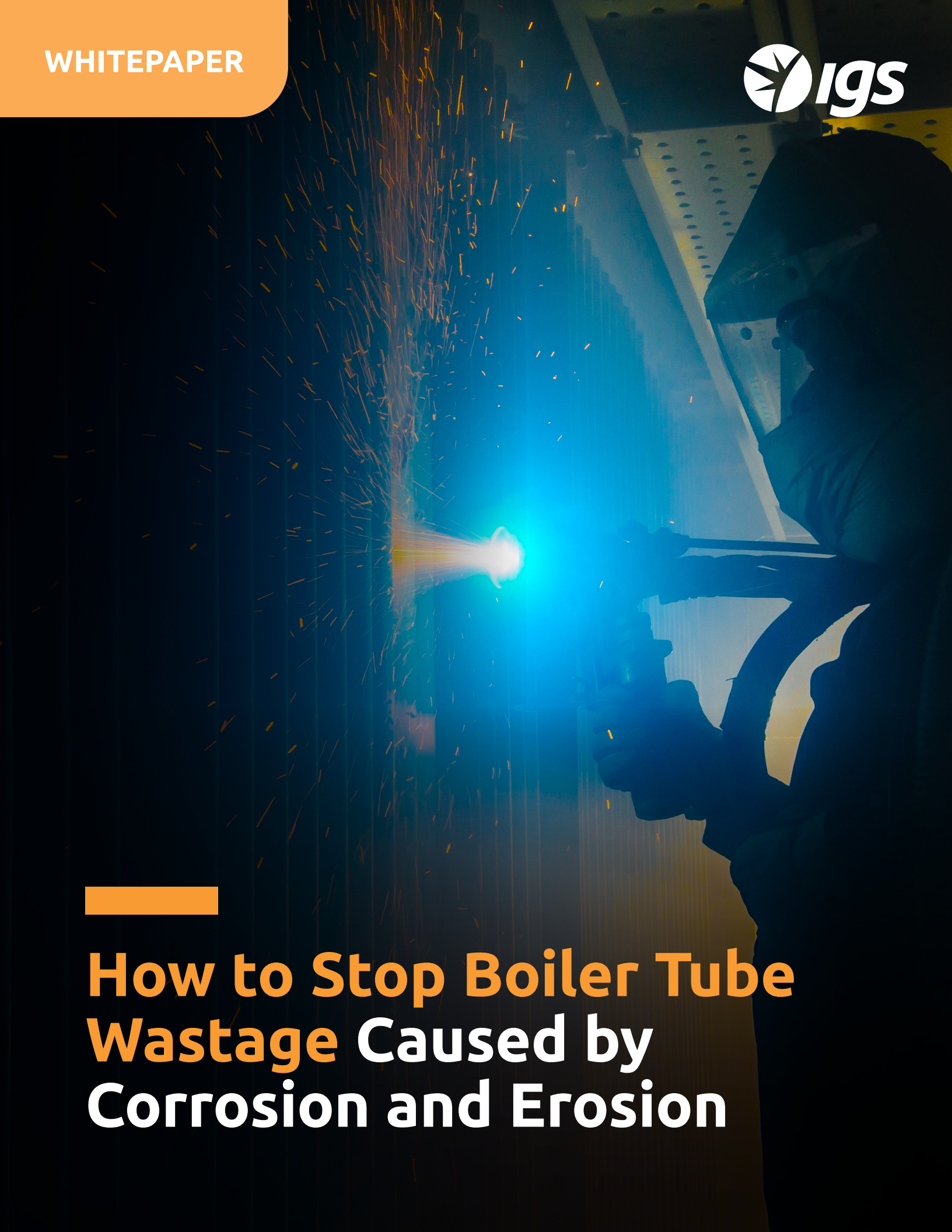
WHITEPAPER



How to Stop Boiler Tube Wastage Caused by Corrosion and Erosion

Contents

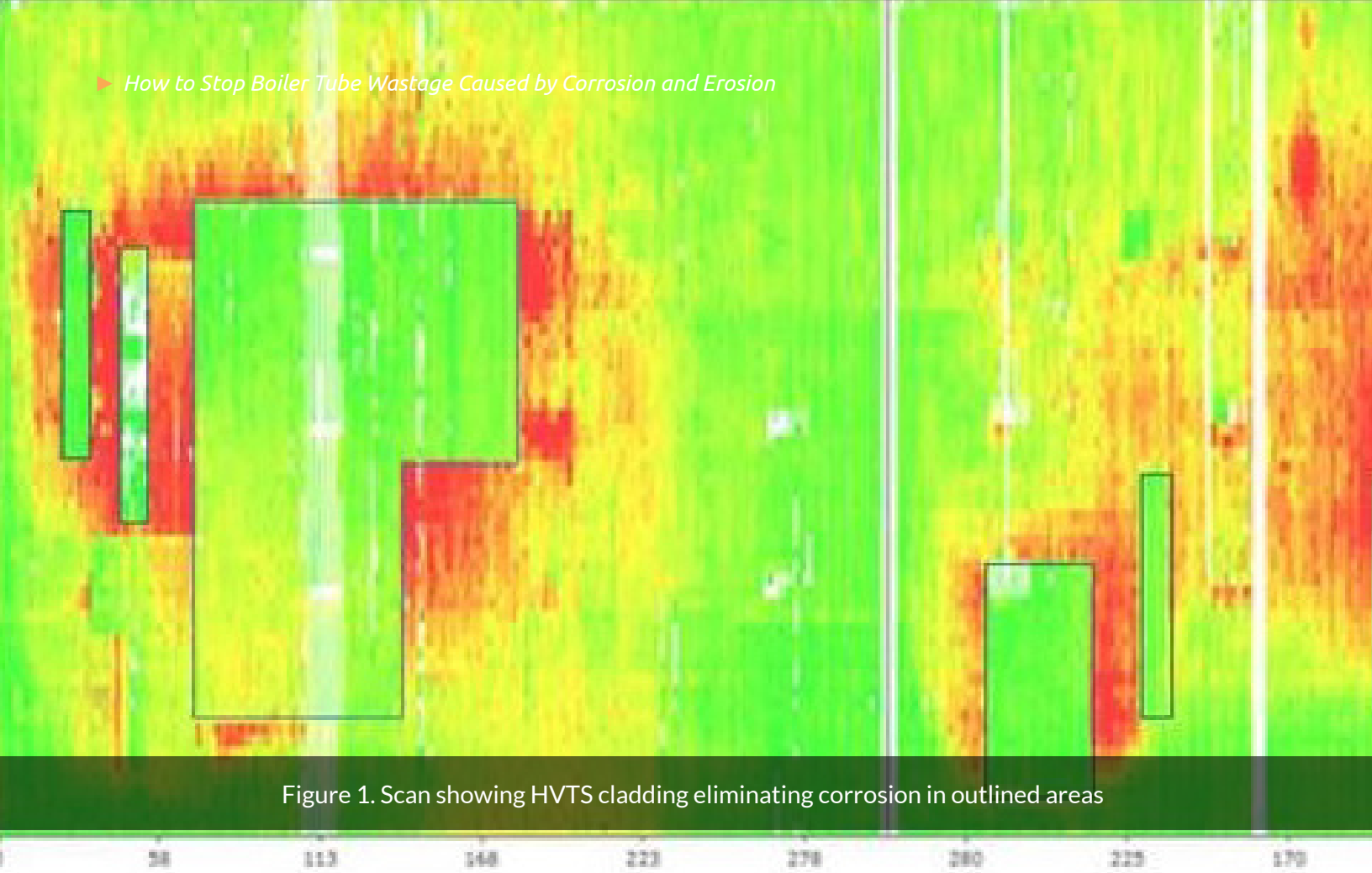


Figure 1. Scan showing HVTS cladding eliminating corrosion in outlined areas

Boiler tube wastage is a major problem that causes forced outages, unexpected major expense, affects unit availability, reliability, and ultimately will cost an owner a tremendous amount of money. There are two maintenance approaches boiler owners will take, proactive and reactive. Once tubes become too thin, caused by either corrosion or erosion, they need to be replaced.

Extending Tube Life with Added Material

Extending the life of the tube is possible with the use of added material to the OD surface of the tube, with Inconel Weld Overlay or High Velocity Thermal Spray (HVTS) Cladding. The purpose of adding material to the tube is to extend its useful life, ultimately preventing panel replacement.

About the White Paper

This paper will discuss HVTS Cladding being used to extend the life of boiler tubes experiencing severe corrosion and erosion. The HVTS Cladding system can be rapidly installed in-situ or on new panels and elements.

Damage Mechanisms

Erosion can be found in most CFB boilers, sootblower lanes (dual mechanism of corrosion-erosion), and backpass areas that experience fly ash erosion. The type of corrosion found will depend on the type of fuel, boiler configuration, and combustion atmosphere. The typical corrosion mechanisms include fireside corrosion and reduced atmosphere high temperature sulfidation (found mostly in boilers burning eastern bituminous coal) and circumferential cracking (also known as stress corrosion cracking, corrosion assisted thermal fatigue, quench cracking).

High Velocity Thermal Spray (HVTS)

- Addresses tube wastage caused by high temperature sulfidation/ reduced oxygen atmosphere / Low NOx firing
- Addresses tube wastage caused by erosion – soot blowers, IK/IR, fly ash
- Delivers long-term reliability by eliminating tube leaks and disruption to operations
- Is 3x to 5x faster compared to Inconel weld overlay
- Is 3x to 5x less expensive compared to panel replacement
- Delivers a 10+ year solution

Erosion

Fly ash erosion is the second most important cause for boiler tube failure (DOE, 1998). Tube erosion in a CFB combustor can never be stopped, but HVTS Cladding is proven to slow the wastage down. HVTS Cladding is 20 times more erosion-resistant compared to carbon steel. Thousands of square feet of surface area can be rapidly installed during a short outage. The HVTS Cladding is able to be refurbished during future outages, thus it is possible to extend boiler tubes' useful life indefinitely.

Erosion Resistance

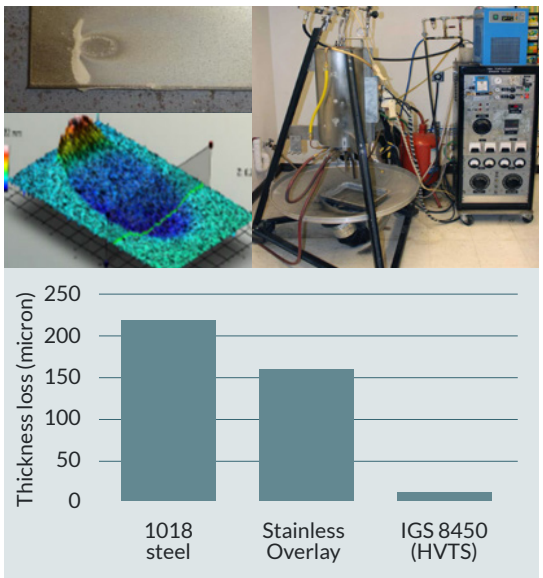


Figure 2. CFB Combustor boiler tubes protected with HVTS Cladding at the tube and refractory interface

Corrosion-General

Boiler tube corrosion causes material wastage, which eventually will lead to equipment failure due to hoop stress or the replacement of the material if the mechanism is not identified. The cost implications are significant. Even if a single tube failure requires only 24hrs of repair work (usually not the case), this results in high margin revenue losses.

The cost of boiler tube failures comprises of three main components:

1. cost of the repair;
2. cost of startup oil to return unit to service
3. cost of lost production (shut down, repair and startup time).

The extent and type of corrosion impacting boiler tubes can vary widely and is driven by a number of operational conditions. High temperature corrosion leading to boiler tube wastage does not follow the rules of wet chemistry and so is often misunderstood.

Also, mechanisms such as fly ash erosion can couple with corrosion by removing oxide scales, thus accelerating wastage rates from boiler tube corrosion. As another example, some corrosion phenomena, such as coal ash corrosion, only occurs at specific temperature ranges.

Figure 3. Zimmer EPRI Study, above photo as received, below photo after light sandblasting to reveal HVTS Cladding has protected the tube from fireside corrosion (no wall loss)

Corrosion-Reduced Atmosphere Fireside Corrosion

In the past decade, there has been a heavy focus on reducing environmental emissions. In order to reduce the production of NOx during the combustion, low-NOx retrofit burners are used in the boiler. These burners reduce the production of NOx by slowing down the combustion, lowering in this way the temperature of the combustion and taking the combustion away from the burners higher up into the furnace.

This is achieved by reducing the amount of oxygen in the area where the burners are (lower portion of the furnace) and injecting that oxygen higher up in the furnace using over-fire air ports. Low-NOx retrofit causes areas lower in the furnace to be oxygen starved or under reducing conditions (or in most severe cases, cycling between both).

Although the whole corrosion process is far more complex, it can be summarized as follows: in normal combustion with the presence of correct amount of oxygen (before low-NOx burners), the sulfur present in the fuel will combine with oxygen and remain in gaseous condition and exit the stack. In a combustion under reducing conditions (low oxygen), the sulfur will combine with hydrogen and deposit on the tube surface reacting with the iron of the tube material to form a scale of FeS, and repeat the cycle as more H2S deposits on the walls, causing significant tube thinning.

HVTS Cladding is ideal for long-term, reliable protection from the above-described typical wastage mechanisms. The cladding composition developed in the mid-2000s specifically for high temperature sulfidation environments with the understanding that permeation and oxide content should be below critical specified levels for long term cladding performance.

HVTS Cladding is low-stress, thermal sprayed metal coating specifically suited for boiler tube protection in combustion environments with aggressive sulfidation conditions up to 1800°F (980°C). It is highly protective against under deposit corrosion, when Sulfur together with Sodium, Potassium and Vanadium Oxides form low melting temperature pyro-eutectic salts.

The high Chromium content, together with performance enhancing elements provide a dense stable coating, with high bond strength due to micro-fusion sites on the substrate. 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 hard-phase integration.

The HVTS Cladding was also tested by Electric Power Research Institute (EPRI), in a 1300MW high sulfur coal, supercritical boiler with Low NOx burner retrofits. Several other cladding materials were also tested, and the HVTS Cladding was the only material to fully protect the substrate from corrosion during the 39,000 hour testing period.

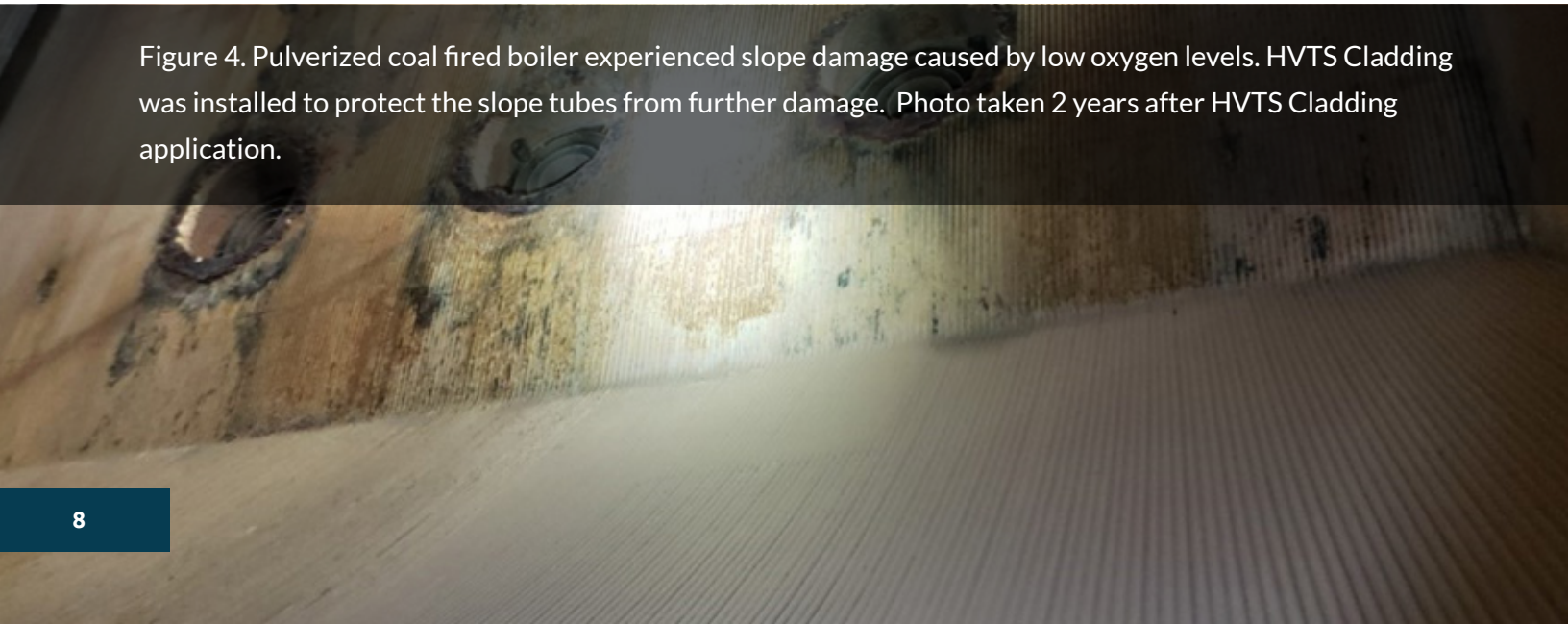
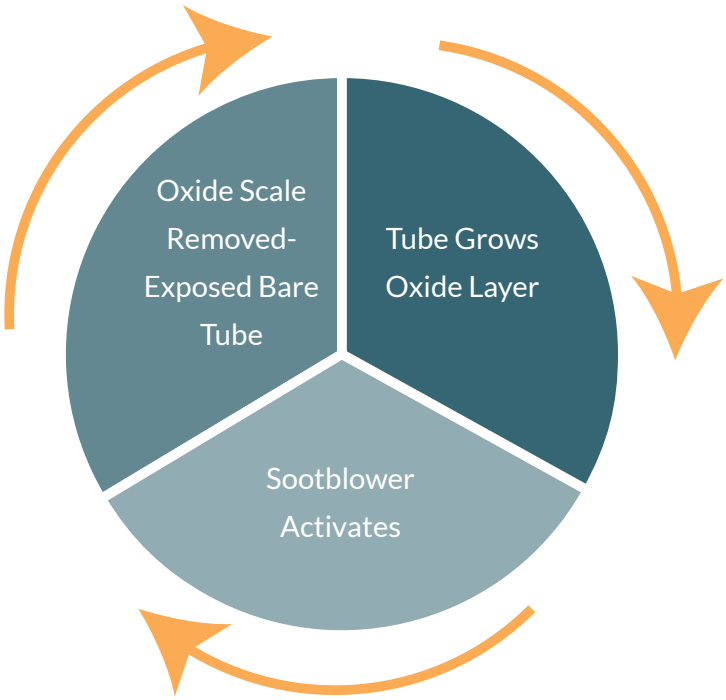


Figure 4. Pulverized coal fired boiler experienced slope damage caused by low oxygen levels. HVTS Cladding was installed to protect the slope tubes from further damage. Photo taken 2 years after HVTS Cladding application.

Corrosion and Erosion caused by Soot Blowers (dual wastage mechanism)

Plants that operate pulverized coal fired boilers normally use steam or air to clean boiler tubes. Sootblowers are installed at various boiler locations on the waterwalls, superheaters, reheaters, and economizers. Wall blowers and IK steam sootblowers (above the nose arch) cause the most damage. The root cause of the problem is not always 100% erosion. Corrosion starts the cycle. As the tube builds an oxide scale on the OD of the surface, the force of the sootblowing activity will remove the scale. After the scale is removed, the tube will grow more scale, restarting the cycle again.

IK steam stootblowers are notorious for spraying condensate at the start of the cleaning, which is hard on the nose arch tubes. HVTS Cladding is tough and erosion resistant, but the material is also very corrosion resistant. The HVTS Cladding will not grow an oxide layer which will result in no loss caused by the sootblowing process, ending the wastage cycle.



Circumferential Cracking (Corrosion assisted thermal fatigue, stress corrosion cracking, quench cracking)

Boiler tube cracking is a major problem for some of the Utilities that operate a boiler that burns sub-bituminous PRB or lignite coals and also use water cannons. This problem is also seen in boilers that burn high sulfur bituminous coal, but is less of a problem due to the primary tube loss being caused by fireside corrosion.

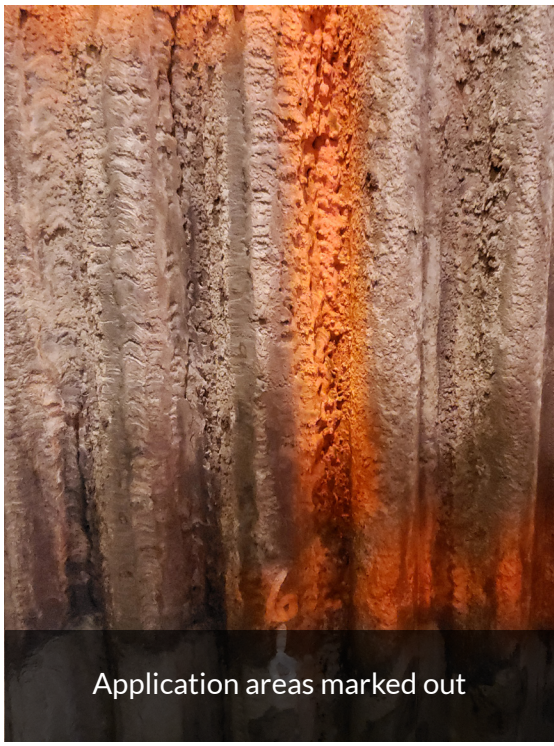
HVTS Cladding will prevent crack growth because it will stop fresh Sulfur from weakening the tube metal. It is well known the crack growth is a dual mechanism, so by removing one of the root causes, in this case the corrosion aspect, the crack will stop.

Case Studies: Asset Owners Experience with HVTS

RELIABLE BOILER PROTECTION SUPPORTED BY LONG-TERM EPRI STUDY

EPRI STUDY

In the mid 2000s, a US power utility owner and EPRI performed a long-term study to determine if thermal spray technology would protect the sidewall tubes (adjacent to burner levels) from thinning caused by reduced sulfidizing atmospheres. A test panel with thermal spray products from IGS and another thermal spray provider were installed. After a 5-year run, the study concluded the IGS alloy cladding performed well with no sign of deterioration at all. Other products experienced cracking and cladding delamination. The important key point to note is the IGS HVTS alloy cladding protected the tubing material under the cladding, resulting in zero loss of wall thickness on the outer surface.



Application areas marked out

PROBLEM

The boiler was experiencing tube wall thickness wastage caused by operating the boiler in a reducing atmosphere (low NOx burners) which results in sulfidation corrosion. This boiler is the newest of the 1300 mw units but experienced very similar corrosion problems to others in use across the industry. Typical of boilers retrofitted with low NOx burners, areas of concern are: Sidewalls adjacent to burner elevations, front and rear walls in between burners and coutant slope, convection pass floor wastage caused by coal ash corrosion, upper furnace corrosion assisted thermal fatigue (CATF), and economizer wastage caused by fly ash erosion.

IGS HVTS application

Boiler tubes protected

Application sealed with ceramic top-coat

SOLUTION

During the Fall of 2019, the plant was in a major planned outage. A full furnace scaffold was installed for boiler maintenance and a tube assessment was performed. During the inspection, new wastage was discovered on the upper front wall just below the wingwalls, near the right sidewall. As a result of the previous testing of IGS HVTS alloy cladding in the boiler, and IGS's status as a long-term, proven vendor, IGS was contracted to protect the damaged tubes on a very short notice. The IGS value is more than just protecting boiler tubes from wastage. IGS alloy cladding is a permanent solution that is rapidly installed and improves reliability. Clients who are proactive in their maintenance strategy can realize significant capital savings by utilizing the IGS solution and prevent not only forced outages but eliminate future tube panel replacements.

RAPID RESPONSE TO ADDRESS THE BOILER DAMAGE ZONE

SCHEDULED SHUTDOWN

The unit was in a scheduled outage in October 2019, at which time the fireside of the tubes in the boiler were inspected by robotic UT. Wastage was discovered on both sidewalls above the existing field applied overlay, rear wall slope and burners, and front wall slope and burners. The type of damage is typical for opposed wall fired pulverized coal boilers operating in a reducing atmosphere with low NOx burners.

Application areas marked out

RAPID RESPONSE

IGS was contracted to install 5450 EPRI Proven HVTS Alloy Cladding over the damage zones. IGS offered a rapid response and addressed the areas during the week of November 4, 2019. The IGS solution is a rather fast application - a total of 2,000 square foot of boiler tubing was protected with HVTS in 5 short days.

HVTS application

SAFETY FIRST

The project was executed in accordance with the IGS Safety Program. Safety is, and always will be Integrated Global Services' first and highest priority. Our Management Team is dedicated to becoming the industry leader in Health and Safety while our excellent safety record bears witness to this fact. A continuous improvement process is utilized that enables all levels of personnel to take part in identifying and fixing hazards associated within the workplace. This is marked by our Safety Committee that involves members of all areas and levels of IGS.

QUALITY

IGS Thermal Spray projects are performed in accordance with the IGS quality control standards which have been developed in to meet customer requirements. All site work will be executed in accordance to the accepted Quality Control Plan (ITP/QCP) and accompanying method statement. The final project QC package will be issued along with this report.

Completed application

References and Testimonials

References are available on request and can be obtained by getting in touch with your local IGS representative or emailing info@integratedglobal.com.

"We went from a varied scope and high man hours to lower man hours and a known scope, which is great for planning for an outage, especially for the budget. Because of our process and work with IGS we didn't need to replace pressure parts. When you start doing pressure part replacement in circulating fluidized bed boilers, you run into all kinds of issues because you have to do tube alignment. If the tube alignment is not done correctly, you're going to end up with erosion or gouging issues for the rest of the life of those pressure parts, that's extremely difficult to fix."

Joel Taylor, Boiler Engineering and Maintenance Specialist. Joel has ensured reliable operation of 7 Circulating Fluidized Bed Boilers between 4 Plants across his 15 Years of CFB Experience.

"IGS brings to table the technical expertise, the understanding of the boilers, the technical knowledge behind what the people in the field are doing and you're seeing the results. IGS spends a fair amount of time making sure that they've got a good base material and they actually quantify the finish and document that to ensure a sound product, a sound solution and a sound application. Cladding thickness measurements give you the ability to determine your wear rates and what millage you want to apply and need to maintain to be able to get you from one outage to the next."

Pete Kline, Plant Manager with 28 years CFB Experience, beginning with the initial utilization of CFB boiler Technology.

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 over 30 years of experience helping customers solve metal wastage problems in mission critical equipment.

IGS designs solutions that increase plant capacity, increase equipment availability, and reduce unplanned downtime. Customer references are extensive and include facilities operated by the world's largest energy companies in over 30 countries on 5 continents.

IGS' HVTS is applied on-site to address problems associated with erosion and corrosion in many types of boilers utilizing a wide variety of fuels.

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