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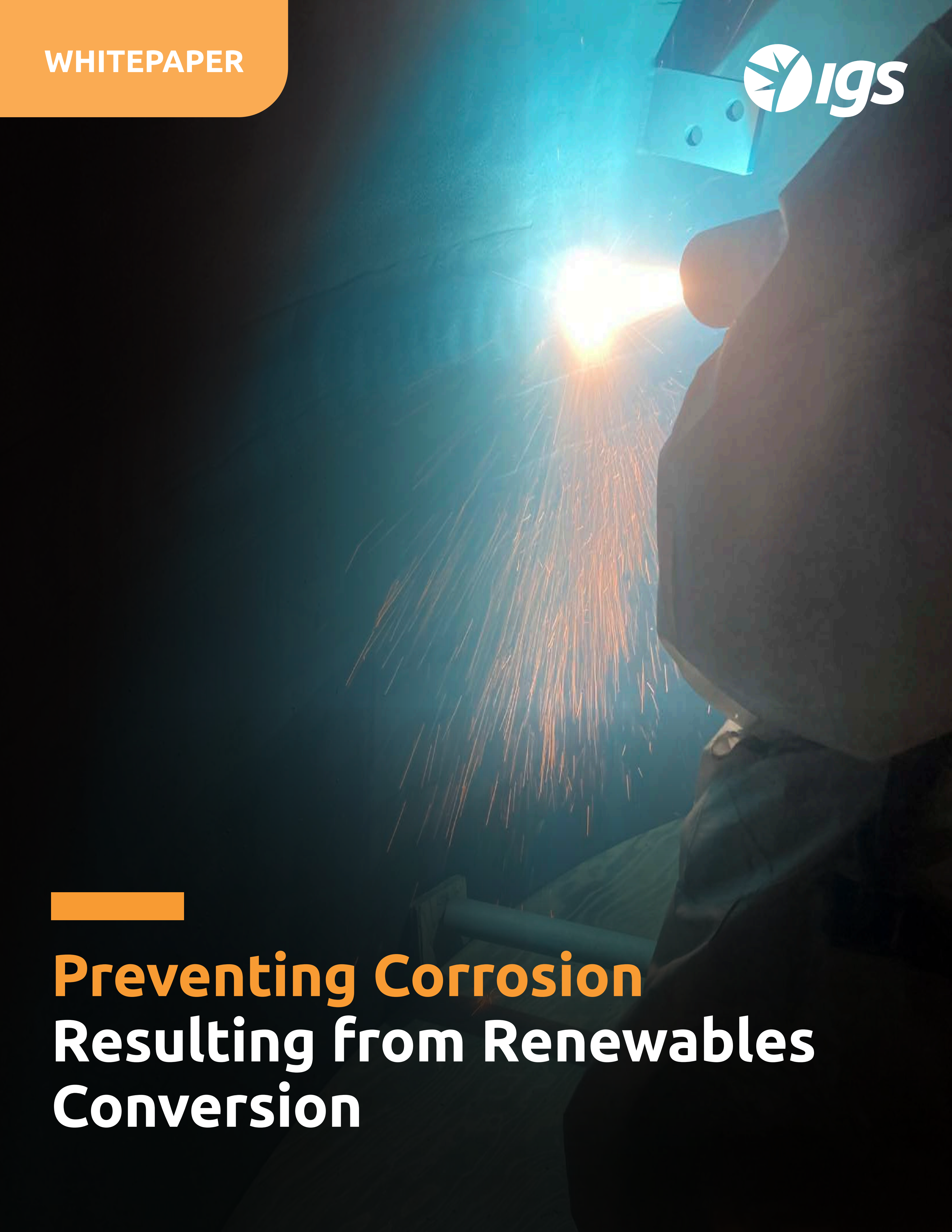

Preventing Corrosion Resulting from Renewables Conversion

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Many oil and gas companies are repurposing refineries to produce renewable diesel, sustainable aviation fuel, and other renewable biofuels and products. The replacement of fossil fuels will help to decrease greenhouse gas (GHG) and CO2 emissions.

To incentivize the production of renewable fuels, the US Environmental Protection Agency's *Renewable Fuel Standard (RFS)* Program requires that 36 billion gallons of renewable fuel replace or reduce the quantity of petroleum-based transportation fuel, jet fuel or heating oil by 2022.

Process equipment designed to refine crude oil products will now be faced with new chemical compositions, pressures, and temperatures. This new processing environment leads to new *corrosion mechanisms* which can all detrimentally affect existing carbon steel, stainless steel or internally clad reactors, drums, and other process equipment.

New Corrosion Mechanisms

Corrosion mechanisms in renewable diesel processing are unique. Conventional base materials of columns, towers, and reactors, as well as past corrosion mitigation strategies, are unsuitable in these new operating environments.

The processing of renewables, whether co-processing or switching to 100%, means that critical equipment, such as reactors, become susceptible to high temperature free fatty acids (FFAs). These are a type of carboxylic acid and will contribute to the acidification of the feed, increasing the total acid number (TAN), leading to corrosion. Other types of corrosion include CO_2 corrosion, wet chloride corrosion, sulphidation and stress corrosion cracking.

Damage Mechanism Concerns in Petroleum vs. Renewables vs. Co-processing

100% Petroleum	100% Renewables	Co-processing
• Sulphur is the major concern in the feed along with lower amounts of naphthenic acids and nitrogen • H_2/H_2S corrosion dominates in the hot section of the unit • Sulphur-to-TAN ratios can be leveraged to control corrosion of some materials • As the effluent cools, NH_4Cl and NH_4HS and wet H_2S damage can occur	• Fatty Acids are the major concern in the feed, resulting in Free Fatty Acid (FFA) corrosion • Pre-treatment of feeds may be necessary to remove catalyst poisons and extend run length • Pre-treating and lipid degradation can increase acid content; acids convert to CO_2 and water in the reactor • As effluent cools, CO_2 corrosion (carbonic acid corrosion) can occur	• Depending on the blend, H_2/H_2S corrosion and fatty acid corrosion could occur in hot sections of the feed • In the effluent, alkaline aqueous species help to mitigate CO_2 corrosion • Wet H_2S damage and salting (from chloride contamination) are still relevant mechanisms

Repurposed equipment is faced with risks to asset integrity due to new corrodents and damage mechanisms. The original equipment design and/or mitigation strategy may no longer be sufficient to deal with any combination of Free Fatty Acid (FFA), Naphthenic Acid, Carbonic Acid, Chlorides etc. in the effluent and associated streams. Revised mitigation strategies must account for the differences between the old and new damage mechanisms, for both the asset base material and cladding (if installed). Depending on the process conditions, 3XX SS alloy overlays may not be resilient enough for these more aggressive service conditions.

Cladding materials based on alloys with a known tolerance (e.g. NiCrMo/W/XX), can provide the necessary corrosion resistance for renewable fuel processing.

To protect the existing equipment base material and pressure boundary, a metallurgy upgrade is required to prevent corrosion and potential asset integrity failure. There are several options available to achieve this.

Available
Solutions

Replacement

This option involves replacing the existing assets with newly built equipment designed for the latest operating environment. Replacement of small items can be relatively quick and cost effective, but when operators consider medium/large processing equipment, such as pressure vessels, drums, reactors, columns etc., replacement becomes prohibitively expensive and slow, with lead times for the required high-nobility clad equipment often being many years.

Field Applied Weld Metal Overlay (WMO)

Welding is a commonly used solution in the wider oil and gas industry, both for rebuilding degraded areas of wall thickness and for providing a corrosion-resistant alloy barrier.

However, welding carries some fundamental drawbacks. A common issue is the potential damage of the vessel shell or any existing internal cladding, due to the heat input required for the welding process (preheating, welding (Heat Affected Zones) and post weld heat treatment or bake out).

The process also necessitates additional mechanical support for the equipment during the process to mitigate the structural integrity risks e.g., loosening any flanged connections, cranes or laying the column down horizontally. A high degree of stress gets added during welding, especially on thinner wall vessels, which can cause distortion or failure. Additionally, the weld procedure, code, or environmental conditions will typically require heat treatment prior to and after the application, adding further time and cost to the repair solution.

There is also the question of time and cost. Welding is a relatively slow process with an application time of 10 – 16 ft2 (1 – 1.5m2) per weld head per shift and can cause additional delays in bringing the asset back into service. Depending on the time frame available for converting to renewables, using the method of welding for corrosion protection can have a significant financial impact.

Field Applied High Velocity Thermal Spray (HVTS)

Developed by corrosion mitigation specialists Integrated Global Services (IGS) in the early 2000's following decades of field application experience, HVTS is designed to protect the base metal in high corrosion environments and involves the simple application of a non-porous high nobility metal alloy. This application upgrades the metallurgy of base materials, protecting them from new operating environments. Since the early 2000's HVTS has been successfully installed and the performance verified through inspection in hundreds of critical O&G process assets over thousands of square metres of internal surface.

The application process is considerably faster than welding and there are no stresses imposed on the base material during the application process, effectively for the substrate the application is a cold process. Furthermore, HVTS application does not generate any dilution (the process does not require fusion or a metallurgical bond).

Application Speed	32-64 ft² / 3-6m² per shift per HVTS machine
Heat treatment before / after Application	Not required
Bond:	Mechanical and Chemical (>35 MPa)
Thermal resistance	Over 1000°F / 537°C

Top Tips for Upgrading Vessel Internal Metallurgy for Renewables Conversion

Prequalifying the Solution

When selecting a contractor to protect mission-critical equipment from new processing environments, there are several things to consider. Firstly, the contractor should work with the EPC, asset owner and the licensor to deliver a comprehensive pre-qualification engineering package to govern the quality of the applied surface technology solution and ensure that the protection solution is suitable for the new harsh corrosion mechanisms. Rigorous testing should be performed by the provider to verify the suitability of the selected solution in advance of the application.

Delivering a Technical Package

A good surface solutions provider should deliver a complete technical package of services ensuring a turnkey site application within agreed timescales, including:

- Project Plan
- Method Statement
- Project Safety Analysis
- Risk Assessment and Mitigation Plan
- Job Specific Safety Data Sheets
- Material Selection
- Surface Preparation
- Utilization of the Application Process
- Critical QA/QC Controls
- Post Project Reports.

Case Study

50% Savings in Renewables Conversion achieved at a plant in Eastern Canada

Introduction

The former refinery in Eastern Canada was performing a site-wide conversion in preparation for refining 100% renewable feedstocks instead of 100% petroleum oils. The Canadian government was partly financing the conversion. The refinery will start processing Sustainable Aviation Fuel (SAF) in Summer 2022. Using SAF results in an up to 80% reduction in carbon emissions compared to the traditional jet fuel it replaces over the lifecycle of the fuel.

The Problem

The new damage mechanisms associated with switching the processing from petroleum to 100% renewable feedstock were a major concern for the existing 347SS (Stainless Steel) weld overlayed reactors and associated equipment.

The two reactors and two drums required a metallurgy upgrade due to new operating conditions. With renewables processing, reactors are susceptible to high temperature free fatty acid (FFA) corrosion, C02 or carbonic acid corrosion, wet chloride corrosion, and stress corrosion cracking.

The drums had possible damage mechanisms including wet CO2 corrosion, wet chlorides and potential NH4HS and NH4CL.

The Solution

The refinery, in conjunction with its EPC, elected to go with the Integrated Global Services (IGS) HVTS solution. Jason Lynn, IGS HVTS SME, said: “I would say that they probably saved half of their cost compared to automated welding. In terms of time, they saved a third of their time, so that was important.”

“Another reason why they didn’t choose automated welding, was the fact that it would require preheat, which again would take more time and resources. This was an important factor as the facility is in Arctic conditions.”

“The facility appreciated the fact that IGS could work turnkey. They didn’t want to have multiple vendors performing different tasks with one group doing preheating, another group welding with a third group potentially doing the post-weld heat treatment.”

Furthermore, much higher deposition rates, without dilution or needed “butter” / intermediate layers to achieve surface chemistry, made HVTS the solution of choice for this application.”

Material Science

Modified alloys specifically designed for field application using the HVTS process were prequalified and specified for the reactors and the drums. NiCrMoXX type materials were specified due to their excellent resistance to corrosion and erosion.

Prequalifying the Solution

The EPC, asset owner and the licensor required a comprehensive pre-qualification and adherence to a tight engineering standard to govern the quality of the cladding applied and ensure that the HVTS protection would hold up against the new harsh corrosion mechanisms. Numerous prequalification tests and application trials were performed on test panels and witnessed in the IGS laboratory in Richmond, Virginia to alleviate any concerns including, microhardness, bond strength, application standard, SEM/EDS analysis etc.

Iain Hall, IGS CTO, said: “While material selection is important, it is only a small part of the technical package required to ensure durable long-term performance in claddings systems. Careful attention to surface preparation and accessibility, utilization of High Velocity process and critical parameter control is necessary to ensure homogenous alloy cladding with the right mechanical properties. It also takes more than a coupon to qualify an application. Management of environmental conditions and monitoring of field quality control with real-time production test plate assessments is also required.”

Project Execution

IGS provide a turnkey application of the internal HVTS cladding for our clients, utilizing our 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 (SOP's).

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.

Summary

With the rise in renewable conversions, there are a multitude of issues to consider for oil and gas companies. 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.


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