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REDUCE OPEX AND CAPEX IN REFINING PROCESS UNIT FIRED HEATERS USING CERAMIC COATING TECHNOLOGY

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ABSTRACT

Ceramic coating “A” is a unique disruptive technology for refining, chemical, and petrochemical critical applications, a game-changer for the industry to reduce OPEX and CAPEX. This Innovative and customized silica-based inert coating technology provides anti-fouling, anti-corrosion, and anti-coking properties for the harsh environments and extreme temperatures (700ºC/1300ºF) applications, making the ceramic coating “A” useful in almost all refineries and petrochemical applications, focusing on delayed cokers, visbreakers, cracking, vacuum distillation unit furnaces and similar units.

In most refining conversion units such as delayed coker and others, unscheduled shutdowns, high maintenance, higher fuel consumption, and throughput reduction due to furnace tube coking, fouling and corrosion is widespread problem. Ceramic coating technology minimizes formation, deposition, and plugging due to coke/carbon in addition to the reduction in fouling, corrosion, and fuel usage. The use of the ceramic coating technology in these applications leads to longer runs, the incremental life cycle for equipment, reliable operations, reduced fuel consumptions, and hence significant savings in OPEX and CAPEX.

This presentation covers the properties and advantages of resistance of ceramic coated tubes to various forms of coking, corrosion, fouling, scaling, and the expected cost savings. Results and case studies from various commercial field trials and runs with major US, European, and Asian refineries and further developments and new applications are also covered in this presentation.

Keywords: anti-coking, ceramic coating, stainless steel,

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INTRODUCTION

The formation of carbon deposits and fouling of tubes is one of the most common operational issues regarding the operability and lifetime of materials at an industrial scale. Several billion dollars are spent worldwide on annual basis to upgrade/change materials apart from revenue loss on account of production halt and additional costs incurred in maintenances. Particularly, the carbon deposition in the refining process is an evitable and undesired factor. Most refineries worldwide have vacuum distillation, delayed cokers, visbreakers, or thermal cracking units where coke formation occurs faster due to high temperatures used in the process. Therefore, unscheduled shutdowns are required, or throughput is reduced due to tube de-coking. From an economic point of view, stainless steel is the most frequently used material, but sometimes more expensive metals are required. The coating of the internal surface with a ceramic layer is useful for preventing the formation of deposits and extending the lifetime of the tubes. This innovative solution not only helps fight fouling, erosion, and corrosion but also helps in an overall reduction of cost, reliable plant operations with improved energy efficiency.

In this sense, a thin layer of the innovative ceramic coating “A” is proposed, which reduces the deposition of this carbon (fouling) and allows operating at severe conditions with a better thermal transfer, thus avoiding the need for more expensive materials and significant costs on maintenance operations. This advanced ceramic coating is a unique disruptive technology for refining, chemical, and petrochemical applications, which is bound to be a game-changer for the industry. This proprietary technology has been developed by a premium advanced tubular solutions manufacturer over the past 10 years with significant investment and R&D resources. Its exclusive production process applies a thin layer (Avg 0.20 mm) of the ceramic coating to the inner or outer surface of tubular products (pipes, tubes, and fittings made from different substrates, such as carbon steel, stainless steel, and metal alloys), to improve their properties. It has excellent resistance to coking, erosion, and corrosion at extreme conditions and high temperatures up to 800°C (1472°F) in critical refinery and petrochemical process equipment. Ceramic coated tubes also minimize coke formation, deposition, and plugging due to their chemical inertness in delayed coker, visbraker, vacuum distillation unit, resid hydrocracker, and other refinery unit furnaces. These benefits improve unit run lengths, unit reliability, heat transfer efficiency, and tubes life cycle without the same level of need for decoking, and they increase throughput and reduce the carbon footprint for both new and aging plant equipment.

Dimension range and coating procedure

Ceramic coating “A” is factory applied on the internal or external surface of tubes and fittings. It can be supplied for a dimension range from ¾” up to 10” OD. Fittings such as return bends, reducers, elbows, and flanges can also be coated.

Regarding the coating procedure, the following steps are followed: Firstly, the base material is inspected to verify that meets all specific project requirements. Secondly, the surface is sandblasted to remove any contaminant and increase tube roughness for optimum coating application. After this, the coating is applied on the steel surface using advanced techniques that provide homogeneous thickness along the tube length. Finally, tubes are thermal treated which provides glass properties to the coating and enhances adherence between coating and base material.

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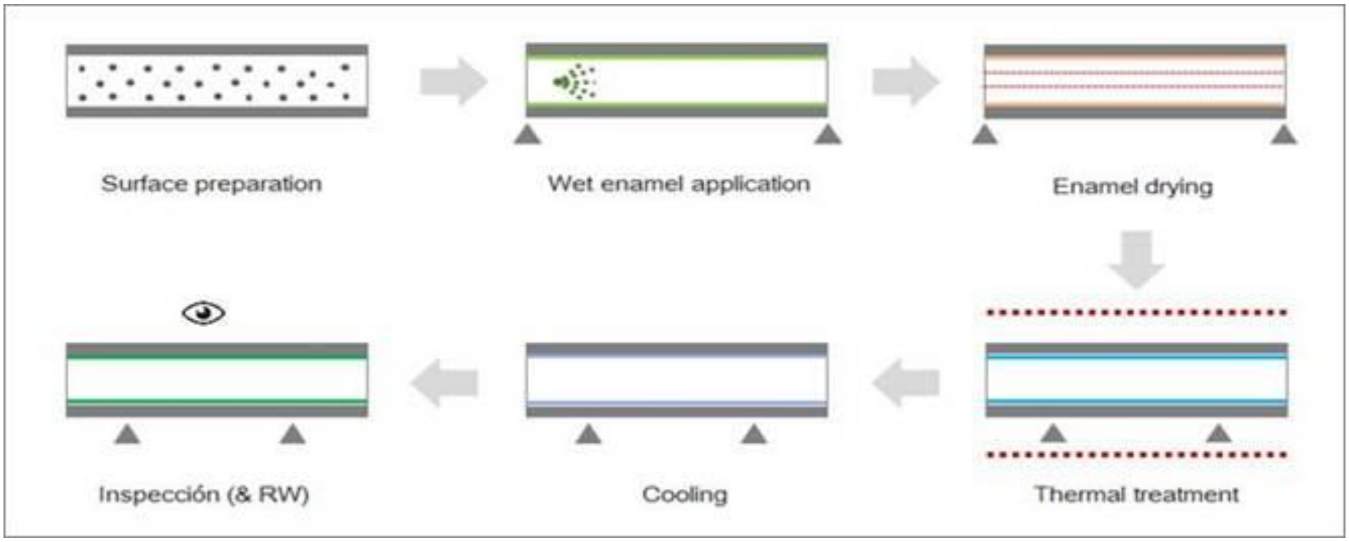

Figure 1. Coating procedure.

Quality inspection

Coated tubes are inspected to verify optimum thickness, roughness, and porosity. Visual inspection is performed through the whole length using a boroscope when the coating is on the internal surface. Roughness is measured in both tube ends, and it is controlled that all dosing parameters remain constant during the process. Porosity is measured by a holiday detector through the whole length, by means of isolated lances coupled to detectors and moved along the inner side of the tubes. Magnetic Induction Method is used to measure ceramic coating thickness on carbon steel tubes, whereas Eddy Current Method is used for measurements on stainless steel tubes.

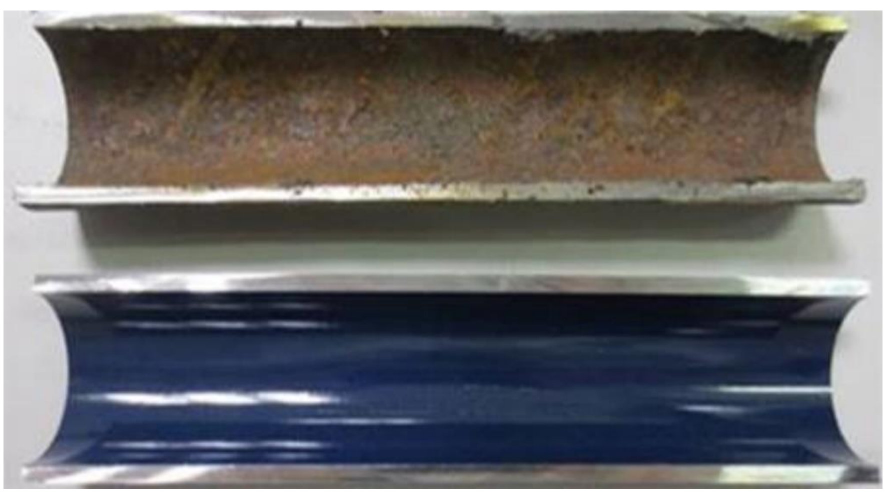

Figure 2. Uncoated Vs. Coated Tube:
uncoated vs. coated tube after one year in refinery process service.

Key properties

The coating is a continuous, homogeneous layer. This premium advanced solutions manufacturer can control the thickness of the layer across the pipe in a unique way, based on suspension parameters and rheological properties. There is a 97% drop in roughness from the uncoated to the coated tube,

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minimizing particle adhesion. As we know, the smoother the surface, the less resistance there is to the flow. After 10,000 cycles there is a 94% decrease in mass loss between the uncoated and coated tubes. In service, the structure and composition of ceramic coatings affect the elastic properties of the coated tubes. The elasticity of the coated tubes increases, allowing up to 1.5% better elongation. The surface hardness of the ceramic coating is about four times higher than the surface hardness of the bare steel tubes, which improves the erosional resistance properties.

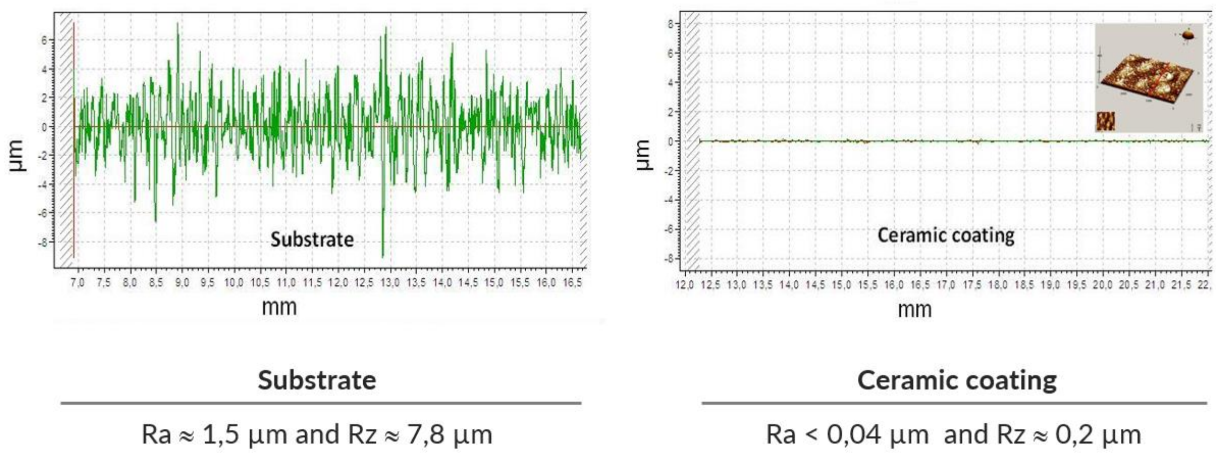

Figure 3. Roughness. Ra and Rz decrease >97% minimizing particle adhesion

Ceramic coating provides long-term reliable and competitive solutions to industrial applications under high temperatures, severe working conditions, and extreme environments. The coating offers 1) outstanding anti-fouling properties that reduce deposition and increase heat transfer; 2) Chemical inertness that minimizes coke formation and reactions with the base metal; 3) Excellent corrosion resistance in different media and thermal conditions and abrasion resistance based on hardness 4 times higher than the base metal.

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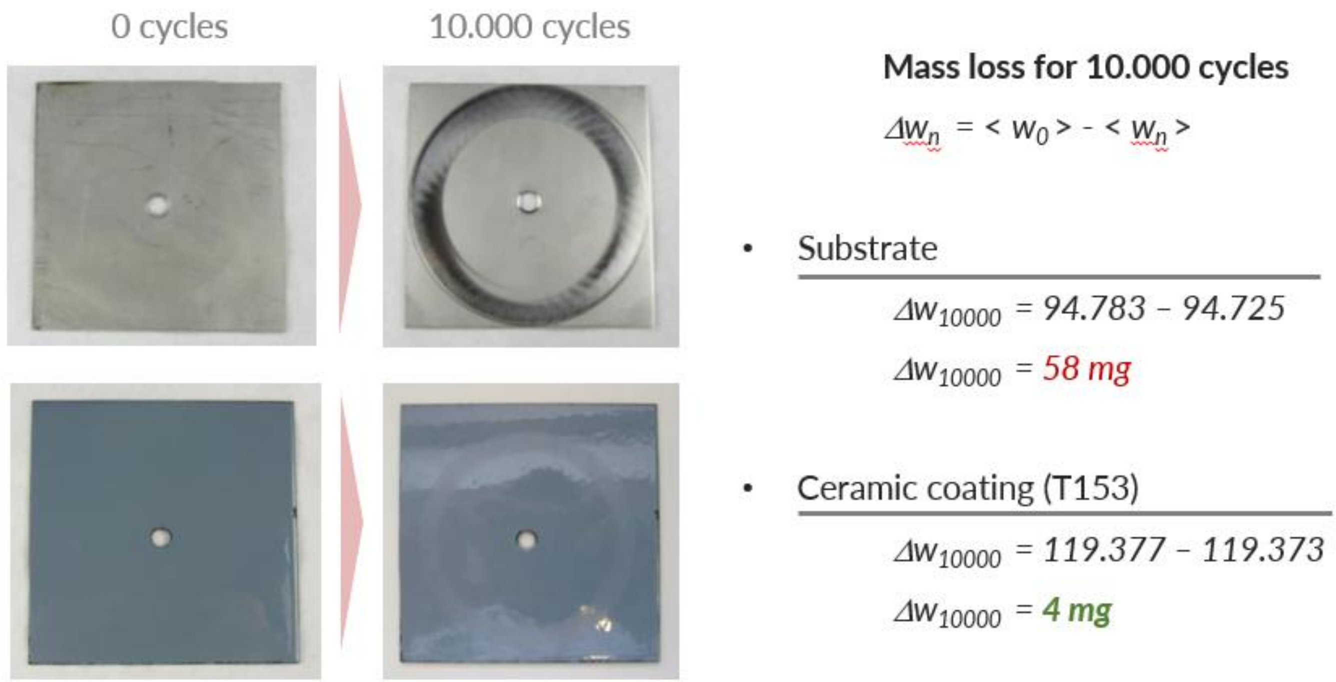

Figure 4. Abrasion resistance. ≈ 94% decrease in mass loss

Thermal Resistance of coating was tested up to 800 ^{O}C by thermal cycling (30 minutes) and rapid water cooling (20 ^{O}C) with no damage to coating confirming thermal stability of coating as shown in Figure 5. Coating is thermally stable in commercial operations indicated in commercial trial results indicated below. Future study is planned for maximum temperature resistance and thermal stability of coatings at a temperature above 800 ^{O}C for a longer duration.

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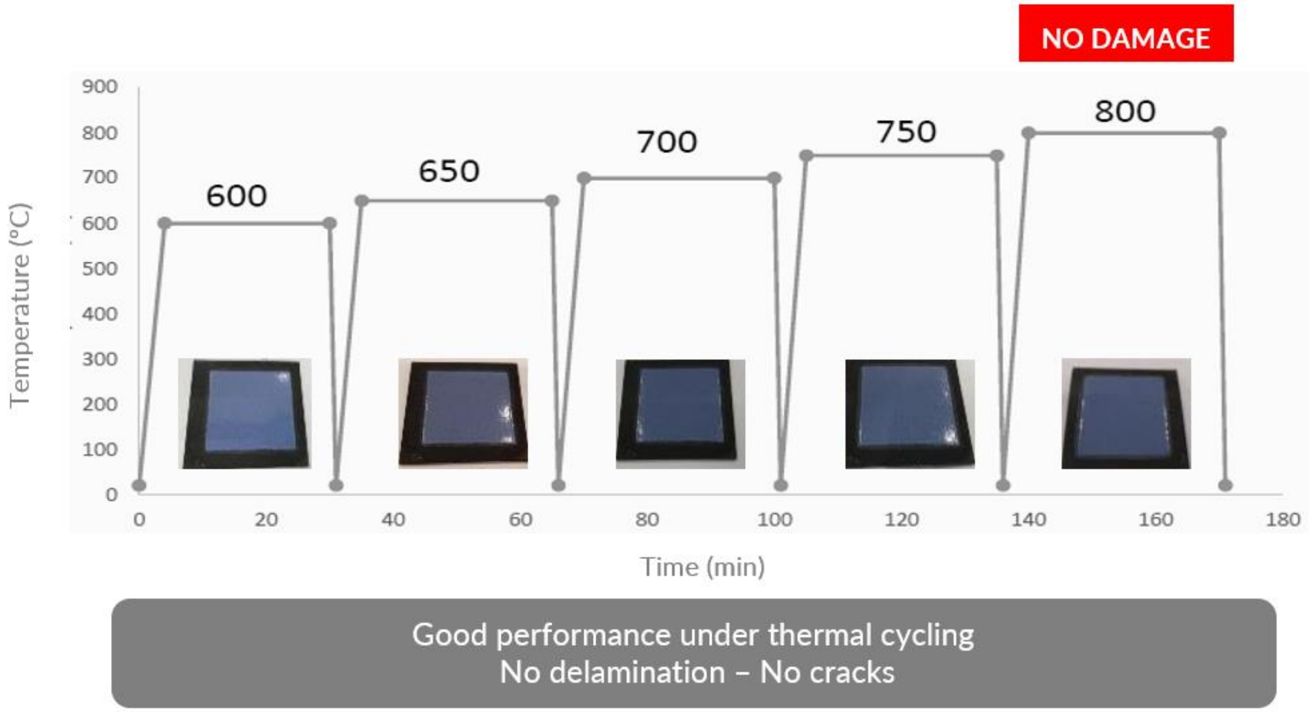

Figure 5. Thermal cycling (30min) + Rapid water cooling (20ºC)

Benefits

This technology is based on an innovative customized silica-based inert enamel with inorganic metal oxides to provide anti-fouling, anti-corrosion and anti-coking properties in harsh environments and extreme temperatures, making the ceramic coating useful in almost all refineries and petrochemical applications, focusing on delayed coker, visbreaker, thermal cracking, and vacuum distillation unit furnaces. With an automated manufacturing process developed fully in-house and quality control to offer a product of optimum quality, the ceramic coating becomes the best ally in refining processes. This innovative solution reduces coke formation and deposition by 75% in furnace tubes, with run times 3 to 4 times longer in DCU, VDU, and visbreaker units and reducing unscheduled furnace cleaning operations and shutdowns by 50-70%. Energy consumption is reduced by 2-3% due to increased heat transfer efficiency, leading to lower CO_2 emissions. A delayed coker or visbreaker unit with a capacity of 20,000 BPD can save an average of US $3 million/year due to various improvements, including increased throughput and reliability.

EXPERIMENTAL RESULTS

The ceramic coated tube has shown significantly better performance in the carbon deposition-removal tests done at the University of the Basque Country Dep. of Chemical engineering as evidenced by the following facts *and indicated in chart below.*

- The chemical inertness of the coated tube surface avoids the parallel reactions occurring in the active sites present on the non-coated tube
- The carbon deposition-removal cycles can be repeated without observing deterioration on the coated surface in contact with the gases

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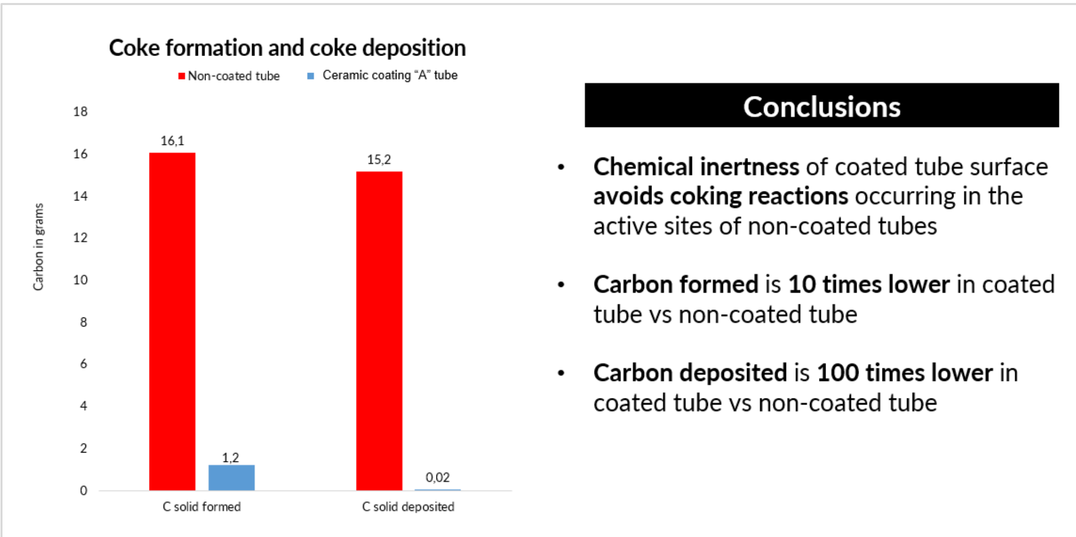
- The carbon formed on the coated tube is one order magnitude lower than on a non-coated tube due to the absence of parallel reactions forming soot (Boudouard reaction and CH_4 decomposition)
- The amount of carbon deposited on the coated tube is a two-order magnitude lower than on the noncoated tube, and its percentage referred to as carbon degraded is a three-order magnitude lower than on the non-coated tube.



REFINERY PROCESS UNITS RESULTS

Outstanding results have been achieved in a European Refinery with coke deposition problems inside the tubes of the visbreaker unit causing frequent shutdown for pigging, constantly taken out of service due to coke accumulation or high fuel consumption because of tube deformation, resulting in high OPEX. For that challenging application, Ceramic coating proposed an innovative solution based on inner coated tubes, bends, and flanges installed at the furnace outlet line to prove anti-fouling properties. The outstanding performance of the coated products used exceeded customer expectations. In 10 months of trials, coke deposition was reduced to 75% with a reduction in cleaning and maintenance, with estimated savings of 1.5 Million USD per year.

In 2020, a refinery in Asia installed this Ceramic Coating technology in one of the world's largest delayed coker units. This unit required frequent decoking, with pigging and online spalling operation every 3 months and every 30-4 days in 2 passes/furnace, respectively. After 8 months in operation, the refinery has seen several benefits including reduced fuel consumption (by 3% due to increased effective heat transfer), effective spalling in coated tubes, and temperatures after spalling 15ºC lower than uncoated tubes. The coker was much easier to remove and takes less time to remove. An incremental benefit of 10 million USD/year is expected by this customer on account of these benefits including extended run length.

Another example was the installation of this specific ceramic coating solution in a VDU furnace in a refinery in Canada in October 2020. This furnace was subjected to frequent decoking operations by mechanical pigging due to plugging and polythionic acid stress corrosion cracking, leading to tubes being replaced every 6 months. Tubes coated with this Ceramic Coating were installed and are in service for

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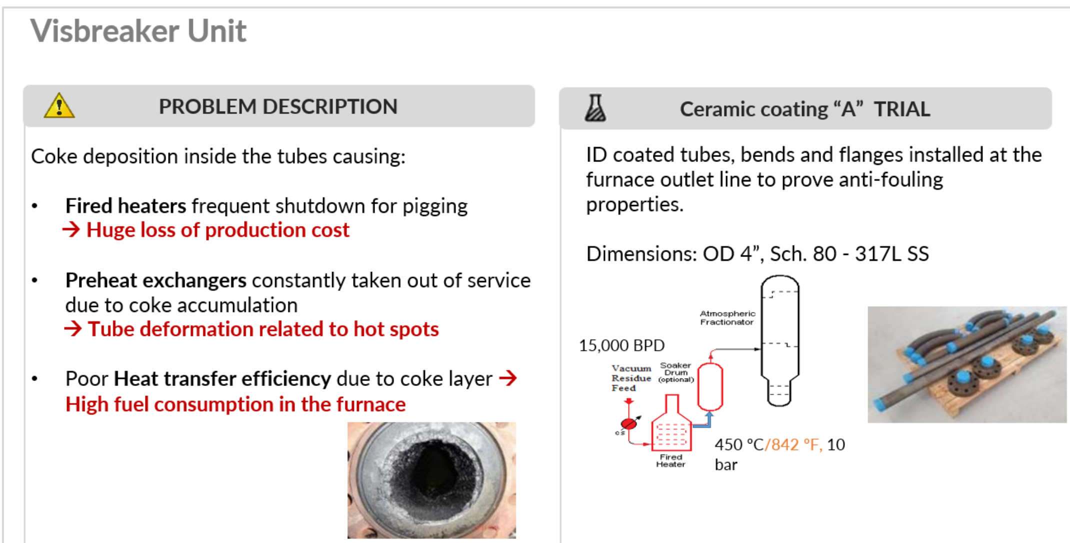
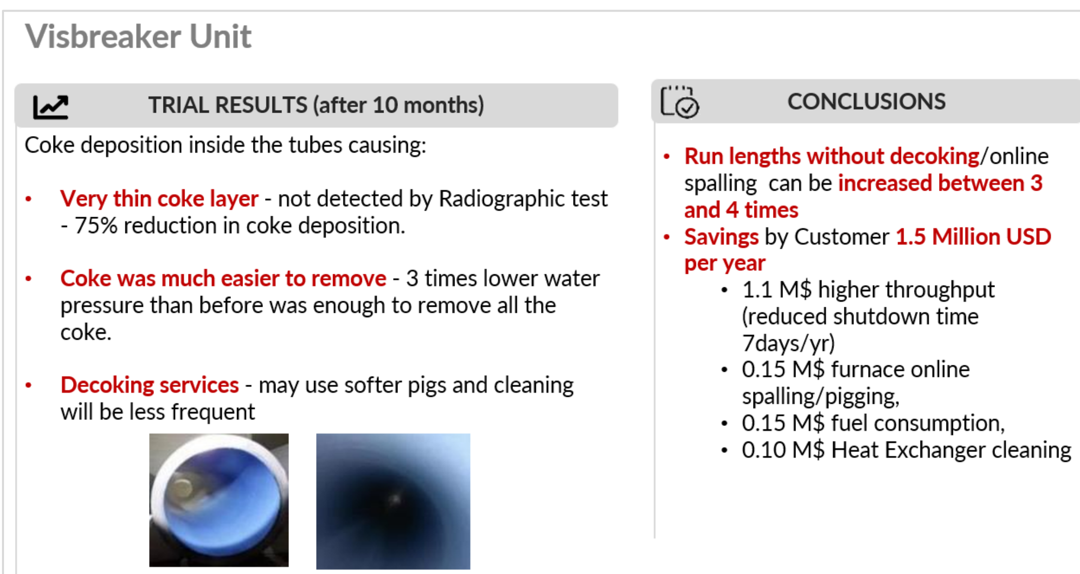
10 months with no plugging or need for replacement of tubes confirming the outstanding performance of tubes.

Another results from Refinery A Delayed Coker unit in USA indicated below resulted in following outcome after 10 months in operation. After online spalling furnace temperature with Tubacoat coated tubes went to back to start of run temperature indicating coated tube efficiency. Coated Tube start of run temperatures were 50 dec lower than uncoated tubes giving addition 10% increase life between spalling and increasing throuput.





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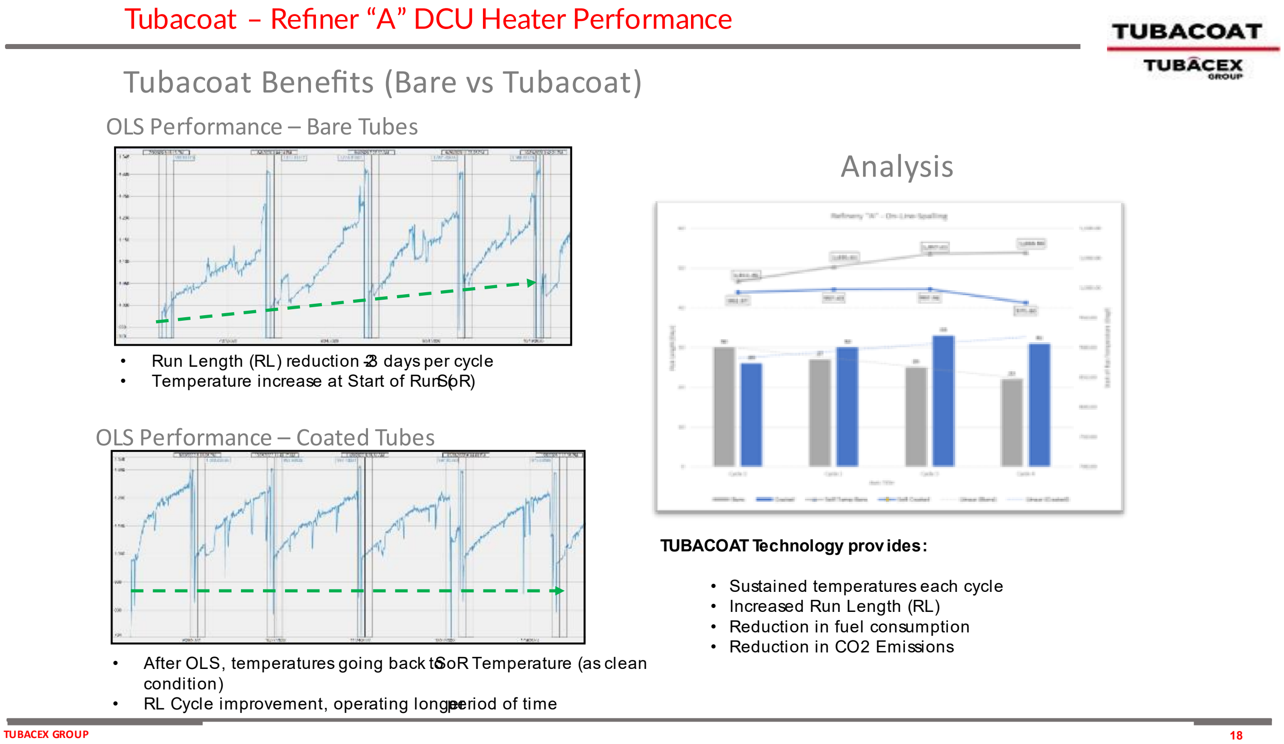

CONCLUSIONS

To sum up, ceramic coating technology has been commercially proven and is ready for wider adoption and application in the market becoming the answer to improved operations and reliability in key refining and petrochemical units. Applying inner coating in refinery process unit heater tubes is profitable, showing longer run lengths and easier and much less frequent cleaning operations; safe, with Increased safety by reducing the number of shutdowns and start-up operations and avoidance of hotspots; clean, Reduced fuel consumption due to increased heat transfer efficiency and CO_2 reduction; and reliable, with major Oil & Gas players using it successfully coating layer brings additional protection to the existing base material.

Definitions:

DCU: Delayed coker unit which cracks the heavy, long-chain hydrocarbon molecules of the residual oil into coker gas oil and petroleum coke.

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Visbreaker: A refinery process to convert residual oil to middle distillates (clean fuels) by thermal cracking.
RHC: Refinery Hydrocracker to convert heavy gas oil into distillates.
VDU: Vacuum distillation unit to convert heavy crude residue into distillates.
Boudouard reaction: redox reaction of a chemical equilibrium mixture of carbon monoxide and carbon dioxide at a given temperature. It is the disproportionation of carbon monoxide into carbon dioxide and graphite or its reverse:
Thermal Cracking: Refinery process to thermally crack refinery heavier hydrocarbon feeds into lighter hydrocarbon molecules.
CH4 Decomposition: Methane decomposition reaction to carbon and hydrogen.
Spalling: online cleaning service to remove coke from DCU furnace tube.
Pigging: Offline cleaning service to remove coke from DCU furnace tubes.

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