

GREEN/BLUE HYDROGEN



Leader in High Value-Added Industrial Solutions

At **Tubacex**, we are leaders in the manufacturing of high value-added industrial products, utilizing advanced stainless steels and special alloys for the energy and mobility sectors.

As a provider of comprehensive solutions, we ensure seamless integration across the entire value chain, from research and development to final delivery and installation of our advanced industrial products and services, which include high-precision machining. We achieve profitable growth and create significant value for our stakeholders through a fully integrated and sustainable business model.

Our integrated value chain guarantees cutting-edge technology, exceptional quality, and a constant focus on sustainability and circularity, setting new industry standards. Our extensive experience in advanced stainless steels and special alloys offers exceptional corrosion resistance (CRA), designed to excel in the most corrosive environments and deliver superior performance under extreme conditions. Our products are capable of withstanding high temperatures and pressures effortlessly.

Tubacex 2030 Program

Pioneering Decarbonization

Leading the Way in Carbon Reduction

Tubacex's ambitious 2030 program strategically aligns with global decarbonization efforts by incorporating advanced material solutions for Carbon Capture, Utilization, and Storage (CCUS) and hydrogen technologies. This initiative signifies a major shift towards sustainability, leveraging Tubacex's investments and expertise to better support carbon-intensive industries in reducing their emissions.

Integrated Low-Carbon Solutions

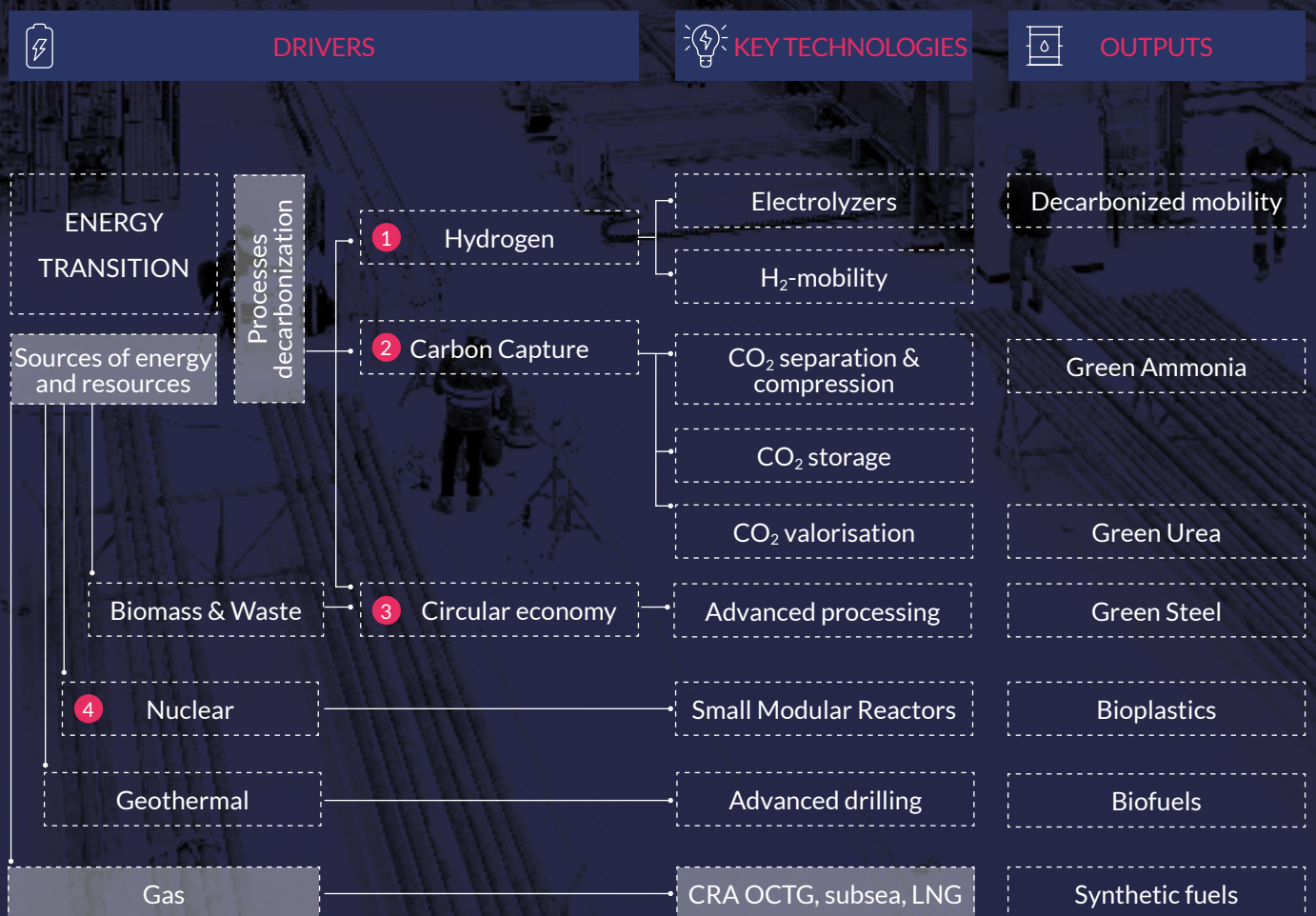
The integration of low-carbon segments into Tubacex's portfolio enhances our comprehensive solutions and strengthens our all-inclusive strategy. Through continuous innovation in materials and processes, we aim to reduce greenhouse gas emissions in both our operations and those of our clients, fostering a sustainable industrial landscape.

Commitment to Low-Carbon Solutions

Our dedication to Low-Carbon Solutions, combined with our expertise and scale, positions us as leaders in the energy transition. By advancing hydrogen supply and expanding CCUS applications, we support our clients in achieving their emission reduction goals, playing a crucial role in global decarbonization efforts.

Both conventional and low carbon technologies require materials that are highly resistant to corrosion, temperature and pressure.

Energy transition for Tubacex



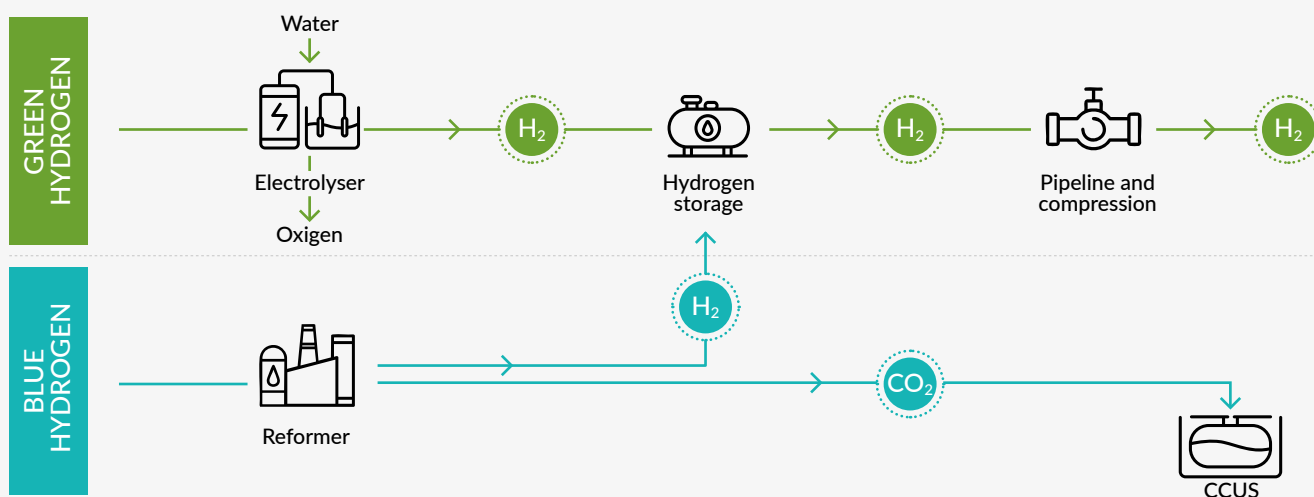
HYDROGEN GENERAL APPLICATIONS

Hydrogen is a clean and sustainable energy source that is currently considered to be one of the best potential substitutes to fossil fuel. Hydrogen value chain including production, process, distribution and storage presents significant challenges for materials requiring resistance to hydrogen embrittlement, high mechanical properties to withstand high pressures and microstructure stability to resist cryogenic conditions or high temperature resistance. Stainless steels are perfect candidates to fulfil these requirements.

Tubacex is a transversal supplier to the whole hydrogen value chain. From gas production, in the case of grey or blue hydrogen, through all the generation technologies, liquefaction, transport, and most of the applications, our products are used.

As one stop shop supplier, we are producers of Steel, pipes, tubes and fittings, in a fully integrated way. In addition, we provide a broad spectrum of services associated with or without products, in order to better service our customers, and reduce the overall cost.

Carbon dioxide is a by-product of the process, which is subsequently captured and stored in a carbon storage facility—a key factor that defines it as blue hydrogen.



01

Steam reforming

This is the most conventional and widely used method to produce hydrogen. To reduce CO₂ emissions, new concepts and designs such as CCUS or more efficient designs are being developed. Tubacex produces different high-temperature grades for these applications, and in collaboration with VDM, the new 699XA grade provides outstanding performance for the highly reducing atmospheres present in recuperative designs.

Materials for hydrogen applications

Current projects being developed for the different hydrogen-related technological challenges

OVERVIEW OF HYDROGEN STRATEGIES

ENHANCE CURRENT OFFERING BY:

- Optimizing precision tubing capacity worldwide.
- Adding and promoting new alloys.

EXPLORE NEW MATERIALS SOLUTIONS:

- Materials for electrolyzer stacks.
- Ceramic coatings.
- Bimetallic tubes.

DEVELOP NEW BUSINESS MODELS:

- Serial production of tubular components for electrolyzers.
- Technology partnerships (e.g.: Waste to H₂).

Austenitic stainless steels are the most commonly used materials in GREEN/BLEU HYDROGEN electrolyzers and Green/Blue Hydrogen gas separation/recovery section . In particular, Tubacex supplies customized, engineered on scale of economy pipes, fittings, and precision tubing for balance of plant and process instrumentation.

New business models.

Components for electrolyzers.

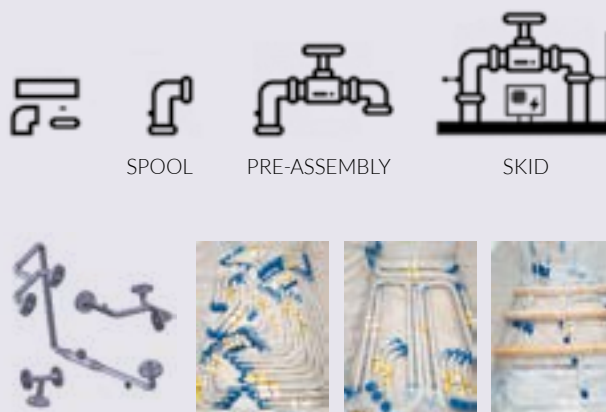
Geared up for delivering value to main electrolyzer oems.

VALUE PROPOSITION

- Cost reduction is a high priority need to achieve large scale in Green/Blue Hydrogen production
- After the technology efficiency and the cost of raw materials, the most important factor for cost reduction is to do serial production in highly efficient and lean industrial facilities
- By applying lean manufacturing concepts, and engineering for manufacturing, our first estimation is that savings in the range of 30% can be achieved in the tubular systems of the electrolyzers

PROTOTYPE / FEW UNITS SERIAL PRODUCTION

PRODUCT	Tubes / pipes off-the-shelf	Functional parts
SERVICE	Stock	Just in Time
QUALITY	Standards	Total Quality Management Zero defects Integrated process Validation for plug&play
DESIGN	Conventional	Co-Design Total cost reduction Easy to assemble
COST	High	Total cost >20% lower



Hydrogen storage and high-pressure conditions are the key features of this application. Tubacex is one of the leading companies in high-precision tubing. Additionally, our offering includes high-pressure tubes, with a low diameter-to-thickness ratio, for the most demanding mechanical conditions.

The 316 series with various variants is generally used, but Tubacex offers a complete portfolio of alloys that can be tailored to meet particular specifications.

TX 316/316L

TX 316/316L, the low carbon version of 316, is a molybdenum alloyed austenitic stainless chromium nickel steel. It has very high immunity from sensitization. The austenitic structure gives these grades excellent toughness, even down to cryogenic temperatures. TX 316/316L is an excellent material to be used in hydrogen service due to its resistance to hydrogen embrittlement. For electrolyzers it is used as substrate for bipolar plates in due to the combination of corrosion resistance, electrical conductivity, and high strength.

The added molybdenum (>2.5%) of TX 316/316HMo improves pitting and crevice corrosion resistance compared to standard 316/316L chemistries with typical molybdenum contents around 2,1%.

With higher strength at elevated temperatures, it is sometimes used for structural and pressure containing applications at temperatures above about 500°C.

TX S20910 (XM19)

TX S20910 is a nitrogen-strengthened and manganese alloyed austenitic stainless steel with better corrosion resistance than stainless steel grades 316 and 317 and higher mechanical strength, about twice the yield strength at room temperature. In addition, TX S20910 has very good mechanical properties at both elevated and subzero temperatures. Unlike many austenitic stainless steels, TX S20910 does not become magnetic when cold worked or cooled to sub-zero temperatures. Moreover, TX S20910 has excellent hydrogen embrittlement resistance in comparison with 316L, even at high pressurized hydrogen gas at lower temperature.

Other materials

- NI 200/201 for chlorine electrolyser technology
- ALLOY 690/601 for waste heat recovery boilers in blue hydrogen/blue ammonia production
- ALLOY 800H for inlet /outlet manifolds for blue hydrogen/blue ammonia production
- ALLOY 400 for blue Hydrogen/Blue ammonia production

Alloy 699 XA®

A nickel-based alloy with superior resistance to metal dusting.

Metal dusting is a high-temperature corrosion phenomenon occurring in carbonaceous environments at temperatures between 400 and 800 °C. These conditions inevitably occur in some industrial processes such as synthesis gas production, iron ore reduction, and ammonia or methanol plants.

An example of application of Alloy 699XA® tubes is as catalyst tubing of a convective heat exchange reformer located adjacent to the primary reformer of some hydrocarbon processing plants. This parallel equipment uses the high heat level of the effluent of the primary reformer to reform additional feed. This special reformer reduces the emissions and can increase the total hydrogen capacity of the plant by 20-30%.



Under metal dusting conditions, vulnerable materials are disintegrated in high amounts of coke mixed with metal, metal carbides and metal oxides.

*Material Data sheets available upon request

TUBACEX LOW CARBON SOLUTIONS GREEN/BLUE HYDROGEN

Hydrogen plays a crucial role in our strategy as a viable, low-emission fuel source that meets the growing demand for energy with **zero emissions** at the point of use. Its versatility makes hydrogen an essential element in various industrial applications, significantly impacting sectors such as steel, cement, and other hard-to-abate industries where CO₂ is integral to their processes.

Hydrogen is a clean and sustainable energy source that is currently considered one of the best potential substitutes for fossil fuels. The hydrogen value chain, which includes production, processing, distribution, and storage, presents significant challenges for materials that require resistance to hydrogen embrittlement, high mechanical properties to withstand high pressures, and microstructural stability to endure cryogenic conditions or high-temperature resistance. Stainless steels are perfect candidates to meet these requirements.

Tubacex is a cross-cutting supplier for the entire hydrogen value chain. From gas production, in the case of gray or blue hydrogen, through all generation, liquefaction, transportation technologies, and most applications, our products are utilized. As a comprehensive supplier, we produce steel, pipes, and fittings in a fully integrated manner. Additionally, we offer a wide range of associated services, with or without products, to better serve our customers and reduce total cost.

Green/Blue Hydrogen Value proposition

Thesis

01

Cost reduction is a high priority need to achieve scale in Green/Blue Hydrogen production.



02

After the technology efficiency and the cost of raw materials, the most important factor for cost reduction is to do serial production in **highly efficient and lean industrial facilities**.



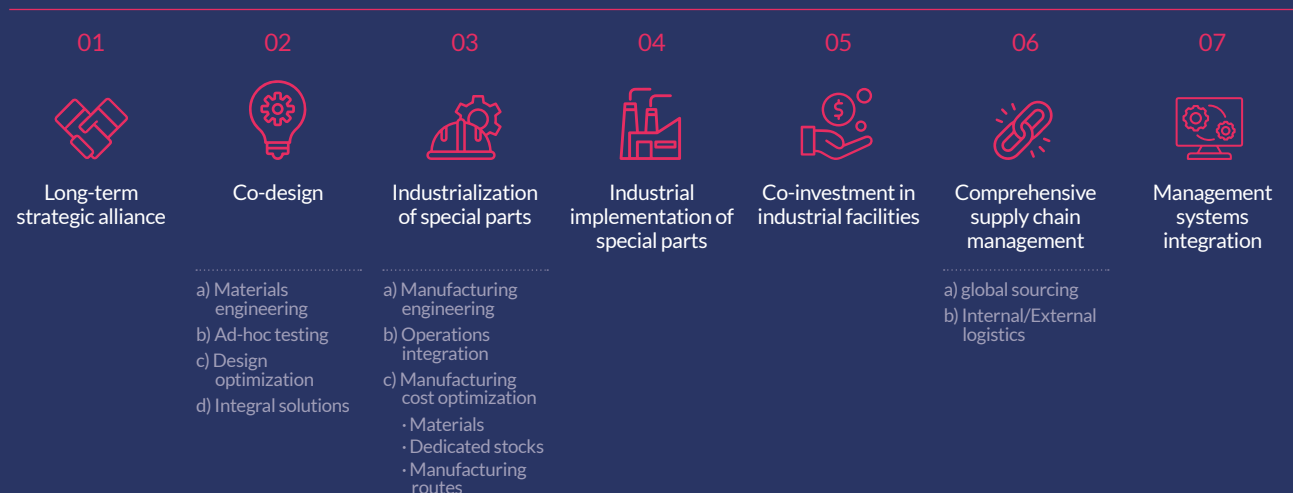
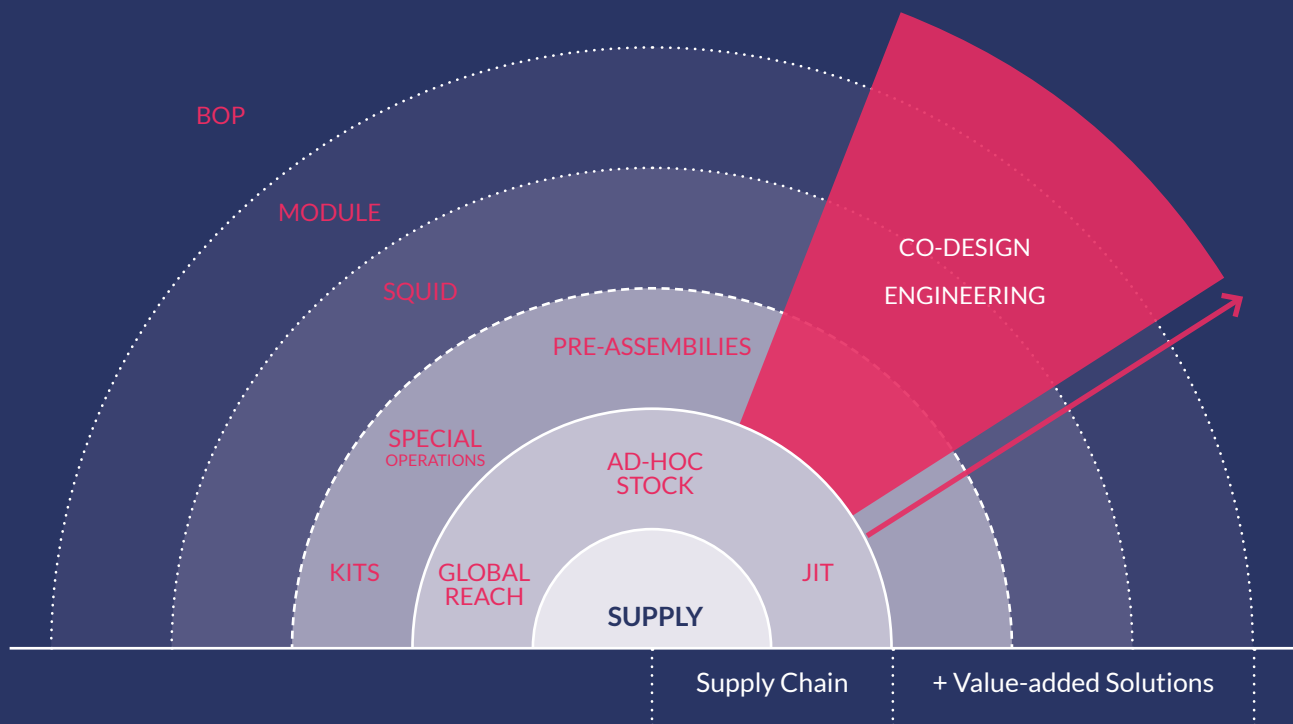
03

By applying lean manufacturing concepts, and engineering for manufacturing, our first estimation is that **savings** in the range of **30%** can be achieved **in the tubular systems** of the electrolyzers.



Overall aim

Becoming your **industrial partner for tubular systems**, with a comprehensive, collaborative and transparent approach, to **reduce costs and accelerate scaling-up**.



TUBACOAT TECHNOLOGY

Tubacoat is a **unique solution widely used in downstream refining industry** for improved unit life cycle, better reliability, improved heat transfer and reduced carbon footprint.

Based on innovative ceramic coatings, Tubacoat's disruptive technology was developed by the Tubacex Group in response the inherent challenges of corrosion, fouling and extreme temperatures.

Our proprietary production process allows the application of a thin layer (Avg 0.20 mm) of Tubacoat to the inner or outer surface of tubular products (pipe, tube and fitting) made of different substrates, including carbon steel, low alloys and stainless steels in outer diameters ranging from 1" to 12", and lengths up to 40'.

Unlike other coating technologies, Tubacoat's sintering process produces chemical and mechanical bonding with the base material, extending the service life of critical equipment.

Efficiency enabler

01

OPEX

Reduced
OPEX

02

CAPEX

Reduced
CAPEX

03

RELIABILITY

Reliable
operations

04

EMISSIONS

Reduced fuel
gas/emissions

05

THROUGHPUT

Increased
throughput

Solution advantages

Profitable



- Avoids profit loss caused by shutdown for cleaning or replacement.
- Reduced OPEX due to easier and less frequent cleaning.
- Increased heat transfer efficiency reduced heating costs.
- Extended cycle lengths between online spalling, steam-air decoking, and pigging operations, delivering significant economic value.
- Increased throughput for enhanced operational efficiency.
- Reduced CAPEX through extended base metal tube lifespan, thanks to Tubacoat's protective layer.

Safe



- Corrosion resistant.
- Reduced number of shutdowns & start-ups.
- Slower tube temperature increase.
- Avoids hotspots.

Clean



- Increased Heat transfer efficiency.
- Reduced fuel consumption and CO₂ emissions.
- Longer tube life.

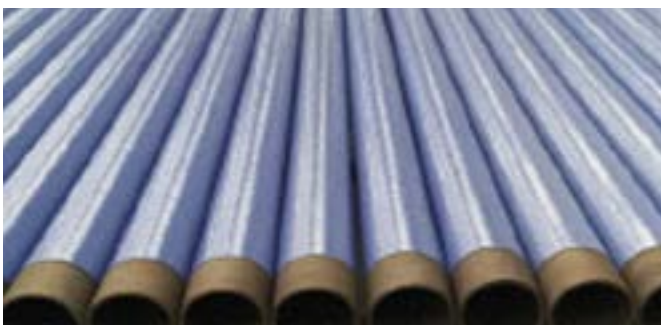
Key properties

Value-added products with...

- **Outstanding Anti-fouling** properties reduce deposition and increase heat transfer.
- **Chemical inertness** minimizes coke formation and reactions with base steel.
- **Excellent corrosion resistance** in different media and thermal conditions.
- **Abrasion resistance** based on hardness 4 times higher than base material.

Specifically developed to...

- Provide **long term reliable & competitive solutions** to industrial applications under **high temperatures**, severe working conditions and extreme environments.



Engineering, industrial development and commercialization of tubular solutions based on advanced innovative coatings.

Chemical inertness and coking resistance study. Anti-coking solution for fired heaters.

When the coating is applied to the inner surface of heater tubes

- Minimizes coke formation (chemical inertness).
- Minimizes coke deposition (anti-fouling).

Fired heater with coating applied will obtain

- Longer run lengths.
- Lower fuel consumption.
- Increased safety and reliability.

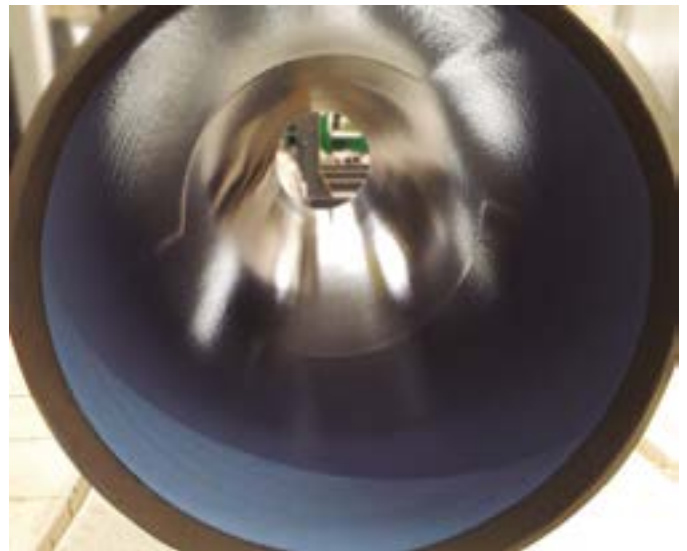
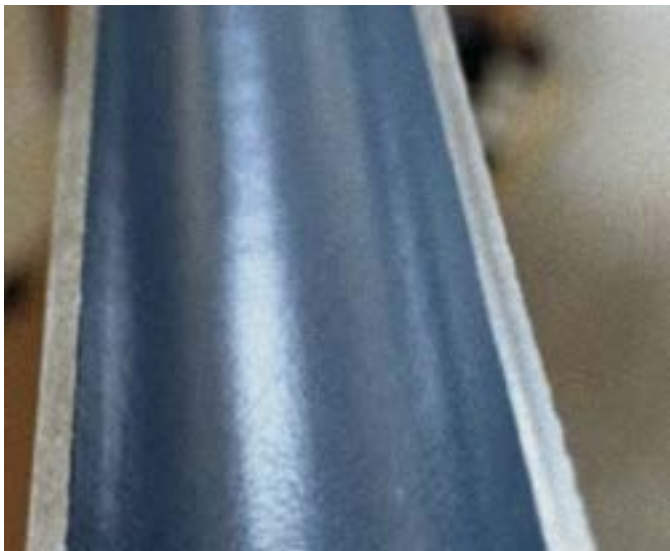
Tubacoat for biomass/biofuels application

Potential issues in processing biomass in refineries

- **Corrosion:** Biomass contains corrosive components that can degrade equipment and pipelines.
- **Fouling/plugging:** Biomass processing can lead to the formation of deposits on heat transfer surfaces, reducing efficiency.
- **Chemical Attack:** Biomass processing may involve aggressive chemicals that can attack and degrade equipment.

Role of Tubacoat

- **Corrosion Resistance:** Tubacoat can protect equipment surfaces from corrosive elements in biomass.
- **Anti-Fouling / anti-plugging Properties:** Tubacoat can prevent the buildup of deposits on heat transfer surfaces.
- **Chemical Resistance:** Ceramic coatings can withstand exposure to aggressive chemicals used in biomass processing.



Tubacoat is a commercially proven advanced coating solution, trusted by over 100 customers worldwide as the preferred supplier to leading global companies.



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