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NEWSLETTER

HEGSEL® Corr 233

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in Heat Exchangers:
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Tube Bundles in Heat Exchangers: Critical Applications and Industry Insights

> High-Temperature Protective Coating

A tube bundle is a core component of a shell-and-tube heat exchanger, the most common type of heat exchanger used in heavy industries. It consists of a series of tubes arranged in a bundle, typically held together by baffles or spacers within a cylindrical shell. These tubes can be straight or U-shaped and are designed to allow one fluid to flow inside the tubes while another fluid flows outside the tubes (in the shell), facilitating heat transfer between the two fluids.



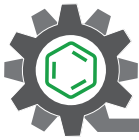
Fundamental Components of a Tube Bundle

Tubes, the primary heat transfer elements in a tube bundle, are made from durable materials like stainless steel, copper alloys, titanium, or corrosion-resistant alloys. They are built to endure high pressures, extreme temperatures, and corrosive fluids, ensuring efficient performance in industrial processes.

Tube Sheets are thick metal plates that hold tubes in place, ensuring the structural integrity of the bundle. They create a leak-proof barrier between tube-side and shell-side fluids, preventing cross-contamination and maintaining efficient heat transfer.

Baffles guide shell-side fluid in a zigzag pattern, increasing turbulence for better heat transfer efficiency. They also reduce vibrations, stabilizing the structure and extending the heat exchanger's lifespan.

Headers, or end covers, are located at the ends of the tube bundle. They distribute fluid evenly as it enters and exits the tubes, ensuring consistent flow and uniform heat exchange for reliable performance.



Key Application Areas for Tube Bundles in Heavy Industrial Heat Exchangers

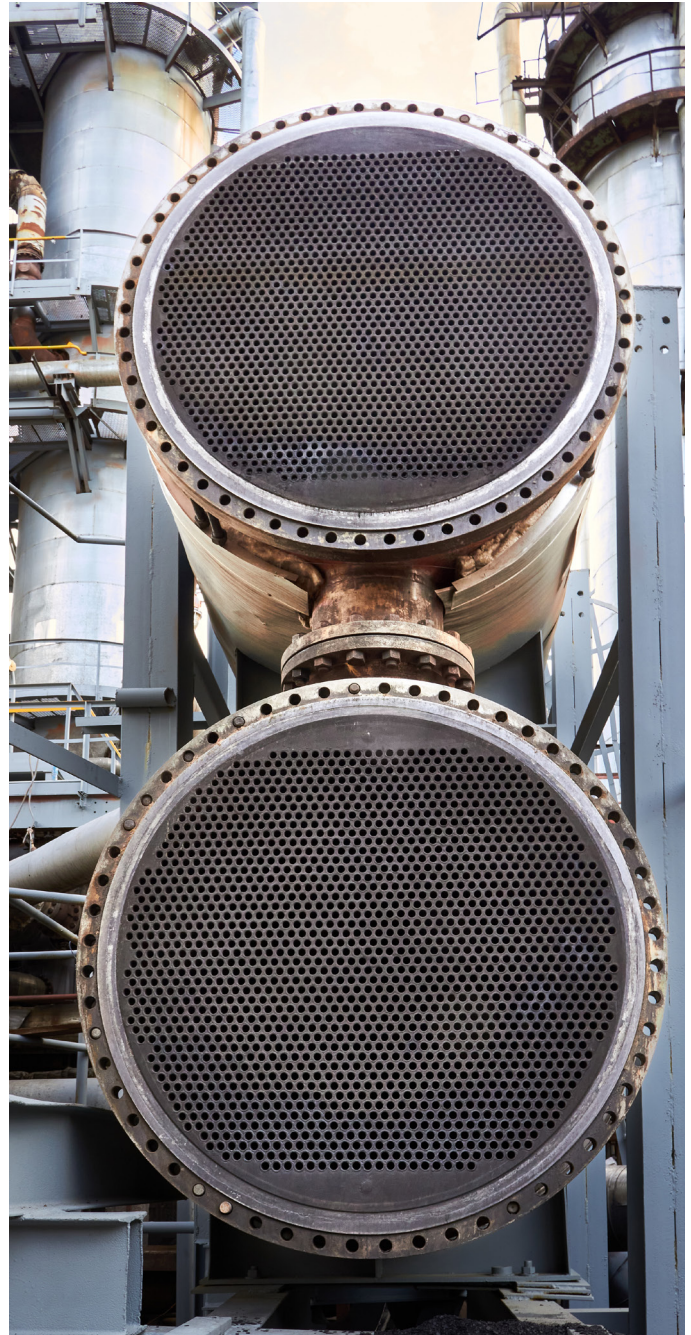
In heavy industrial applications, particularly in the oil and gas sector, shell-and-tube heat exchangers equipped with tube bundles are indispensable for various critical processes. These devices enable efficient heat transfer under extreme conditions, ensuring optimal performance across a range of operations. Below are key application areas where tube bundles play a vital role:

Refining processes depend on tube bundles for crude oil preheating, cooling in fractionating columns, and heat recovery in catalytic reforming. Their reliability ensures consistent performance under extreme temperature and pressure conditions.

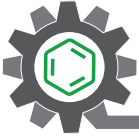
Gas processing employs tube bundles for condensing hydrocarbons, cooling natural gas, and heat management in gas sweetening units like amine absorbers. Their ability to resist corrosive gases and temperature fluctuations is critical in this sector.

Upstream production relies on tube bundles for heat exchange in separators and scrubbers, key for oil and gas extraction. They are also crucial in glycol dehydration units, preventing freezing and corrosion by removing moisture from natural gas.

Petrochemical manufacturing utilizes tube bundles to regulate temperatures in reactors and ensure precise thermal control for steam generation and superheating in complex chemical processes.



Offshore platforms use tube bundles to maintain thermal conditions in compression systems. Their robust design withstands harsh marine environments, ensuring reliable operation in vital applications.



Extreme Process Conditions for Tube Bundles in Industrial Heat Exchangers

Tube bundles in heat exchangers are designed to endure some of the most extreme process conditions encountered in heavy industries. From intense thermal and pressure demands to exposure to corrosive chemicals and abrasive materials, these components are engineered to ensure consistent performance in highly challenging environments.

Temperature ranges for tube bundles typically span from -50°C to $+600^{\circ}\text{C}$, with advanced designs capable of withstanding extremes up to 900°C . This versatility makes them reliable for processes requiring significant thermal resilience.

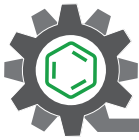
Pressure conditions often exceed 100 bar, especially in upstream Oil and Gas operations. Tube bundles are constructed to maintain integrity and efficiency under these high-pressure environments, ensuring safe and effective heat exchange.

Chemical exposure is a key factor, as tube bundles regularly face substances like hydrogen sulfide (H_2S) in sour gas streams, carbon dioxide (CO_2) in gas or oil processing, and a variety of chlorides, hydrocarbons, amines, and acids. These corrosive agents necessitate the use of specialized materials and protective measures to extend service life.



Abrasive exposure arises from particulates and debris in crude oil as well as solid contaminants in gas streams. Tube bundles must be resistant to erosion and wear, ensuring long-term durability in abrasive conditions.

Industrial processes relying on tube bundles include amine gas treating for acid gas removal, crude oil distillation with heat recovery, hydrocracking and hydrotreating under extreme conditions, and desalination through multi-effect or multi-stage flash units. These processes underscore the critical role of tube bundles in managing the demanding operational conditions of heat exchangers in industrial applications.



Corrosion Mechanisms and Their Consequences

Corrosion in tube bundles arises from various mechanisms, each influenced by specific environmental and operational conditions, and can lead to significant performance and safety challenges in heat exchangers.

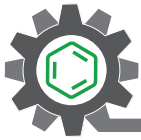
Chemical Corrosion in tube bundles occurs due to exposure to aggressive agents such as hydrogen sulfide (H₂S), chlorides, and acids. H₂S in sour gas streams causes sour gas corrosion, forming brittle sulfide layers that weaken the metal. Chlorides lead to localized pitting corrosion, particularly in stainless steel tubes, while acidic environments accelerate material degradation, especially in hydrocarbon and chemical processing systems.

Erosion Corrosion combines the mechanical effects of abrasive particles with chemical reactions, leading to accelerated material loss. Abrasive particulates, such as sand or debris in crude oil or solid contaminants in gas streams, erode protective layers on tube surfaces, while corrosive fluids intensify the damage. Tube bundles in upstream production units and gas scrubbers are highly susceptible to this mechanism.

Galvanic Corrosion occurs when dissimilar metals in the tube bundle or between the tube and the shell contact an electrolyte. Electrochemical reactions accelerate the degradation of the less noble metal. For instance, carbon steel headers paired with stainless steel tubes can corrode rapidly in the presence



of moisture or process fluids, particularly in heat exchangers exposed to humid or corrosive environments.



Stress Corrosion Cracking (SCC) arises when tensile stresses combine with chemical exposure, such as chlorides, in environments where temperatures are elevated. This mechanism leads to crack initiation and propagation, particularly in stainless steel tubes used in seawater cooling systems or desalination plants. The elevated temperatures accelerate these reactions, compromising the structural integrity of the tubes.

High-Temperature Oxidation affects tube bundles operating at temperatures above 500°C. Metals react with oxygen to form oxide layers, which initially act as a protective barrier. However, thermal cycling during start-ups and shutdowns causes these layers to crack and spall, exposing fresh metal surfaces to further oxidation. This is a common issue in catalytic reformers, where frequent high-temperature cycles reduce tube efficiency and lifespan.

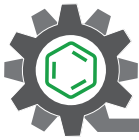
Sulfidation occurs in environments containing sulfur compounds, such as H₂S, at temperatures between 300 - 900°C. This mechanism forms porous sulfide scales on the metal surface, which fail to provide adequate protection. Tube bundles in heat exchangers handling sulfur-rich crude oil or sour gas streams, often seen in refining and upstream production, are especially prone to rapid material degradation from sulfidation.

Thermal Fatigue Cracking results from frequent temperature fluctuations during operational cycles. Expansion and contraction caused



by these changes generate thermal stresses, leading to microcracks in tube bundles. Over time, these cracks grow, allowing corrosive agents to penetrate, worsening localized corrosion and structural damage. Tube bundles in power generation systems and industrial heat exchangers are particularly vulnerable to this issue.

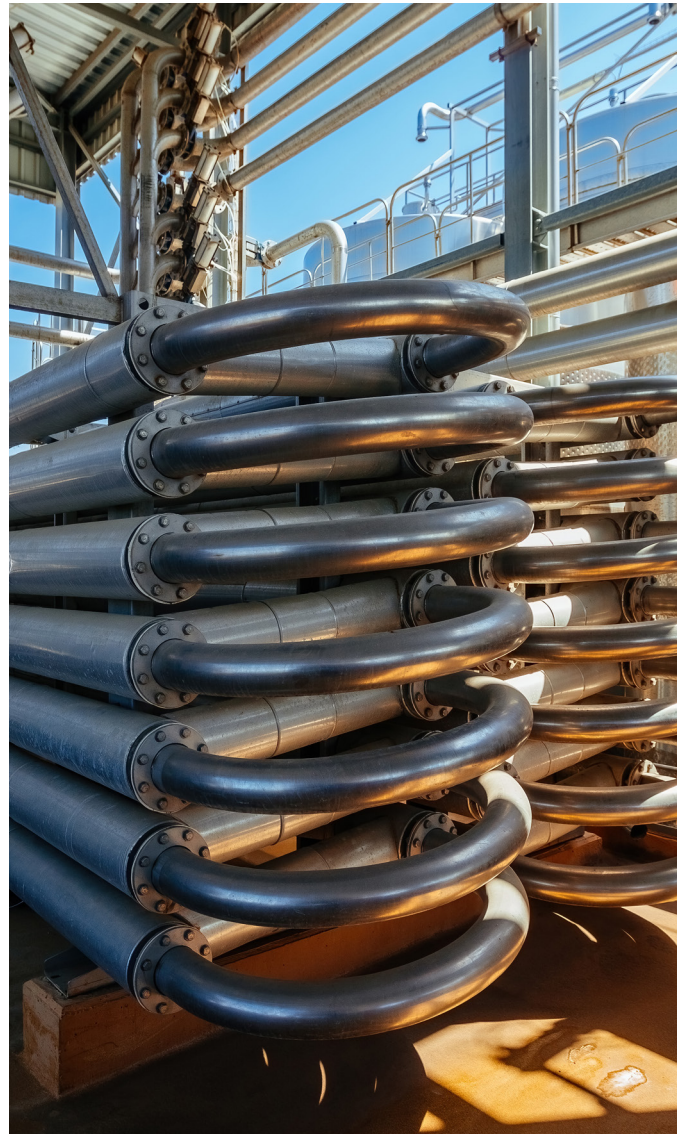
Metal Dusting is a high-temperature mechanism affecting tube bundles exposed to reducing environments containing hydrocarbons or carbon monoxide. Occurring at temperatures between 450 - 850°C, this process disrupts the protective oxide layer, causing the underlying metal to disintegrate into fine particles. Tube bundles in syngas or hydrogen production systems are highly susceptible, leading to rapid material loss and system failures.



Sedimentation and fouling occur when particulates and chemical residues in process fluids settle on tube surfaces, creating localized areas for under-deposit corrosion. The trapped agents cause pitting, crevice corrosion, and reduced heat transfer efficiency. Tube bundles in heat exchangers handling fluids with high particulate content, such as crude oil preheaters, are particularly affected by these issues.

Consequences of Corrosion in Tube Bundles significantly affect the performance and safety of heat exchangers. Fouling and corrosion deposits reduce thermal efficiency by impeding heat transfer. Corrosion-induced leaks can cause cross-contamination between fluids, disrupting process integrity. In severe cases, corrosion leads to equipment failure, resulting in costly repairs, unplanned downtime, and serious safety risks, such as the release of hazardous substances like H₂S.

Properly addressing these mechanisms is essential to maintaining reliable and safe operations.



The Necessity of Corrosion Protection

Corrosion protection is essential for ensuring the longevity and reliability of heat exchangers in demanding industrial environments. Effective strategies prevent equipment degradation, enhance durability, and minimize maintenance, ensuring efficient and uninterrupted operation in critical applications.

One critical approach is **material selection**, where corrosion-resistant alloys like Inconel, Hastelloy, or titanium are employed to withstand harsh conditions, including exposure to corrosive chemicals and extreme temperatures. **Cathodic protection** systems, such as sacrificial anodes or



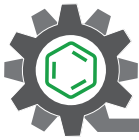
impressed current systems, are another vital method, mitigating galvanic corrosion and protecting metal surfaces from electrochemical reactions.

Additionally, the use of **corrosion inhibitors** in process fluids helps neutralize aggressive agents like hydrogen sulfide (H₂S) and chlorides, reducing the risk of chemical degradation. Regular **inspection and maintenance**, including non-destructive testing (NDT), are also indispensable for detecting early signs of corrosion or damage, enabling timely repairs and minimizing operational disruptions.



To combat the challenges of corrosion, one of the most effective strategies is the application of **coatings and linings**, which act as a durable barrier against chemical attacks, high temperatures, and erosion. These protective layers shield tube bundles from corrosive agents and abrasive wear, preserving their integrity and performance in harsh environments. The choice of coating or lining depends on operating conditions, including fluid type, temperature, and pressure. Advanced solutions like epoxy phenolic coatings excel in high-temperature environments by maintaining their protective properties under thermal stress, while PTFE or fluoropolymer coatings provide superior resistance to aggressive chemical exposure. For highly abrasive conditions, glass flake coatings or reinforced linings enhance surface durability, protecting tube bundles from mechanical wear. By carefully selecting and applying these measures, industries can ensure long-lasting efficiency and reliability of tube bundles in heat exchangers.

A notable example of such advanced solutions is **HEGGEL Corr 233**, which provides comprehensive corrosion protection. It combines high-temperature anti-corrosion performance with reliable mechanical features, ensuring exceptional durability and efficiency in demanding industrial applications.



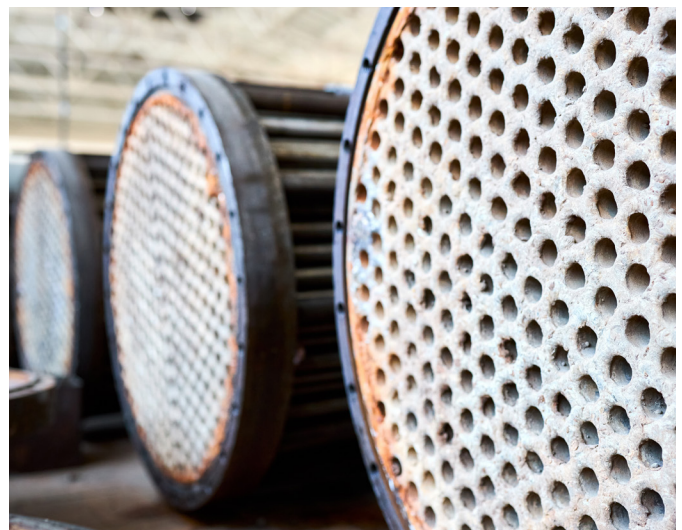
Advanced Anti-Corrosion Coating for Extreme Conditions

HEGSEL Corr 233 is an advanced, single-component coating system meticulously designed to deliver superior high-temperature anti-corrosion protection. Its innovative formulation ensures outstanding adhesion to both metallic and refractory surfaces, making it highly versatile for use in demanding industrial applications. Additionally, it offers exceptional resistance to hot acidic gases, providing robust and reliable protection in chemically aggressive and thermally challenging environments.



Versatile Chemical Resistance and Functional Design

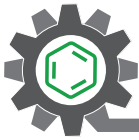
HEGSEL Corr 233 offers exceptional chemical resistance, effectively withstanding exposure to water, algae, oil, grease, and weak acids and alkalis. Its smooth, semi-gloss finish not only provides an enhanced visual appearance but also delivers practical advantages, such as increased surface durability and resistance to fouling. Furthermore, its self-priming nature simplifies the application process, ensuring efficient, long-lasting protection across a variety of substrates in challenging industrial environments.



Superior Thermal and Mechanical Performance

HEGSEL Corr 233 is engineered to withstand extreme thermal conditions, with an intermittent temperature resistance of up to +650°C. Its outstanding durability is further reinforced by exceptional resistance to impact, abrasion, and thermal shock, making it ideal for high-stress industrial environments.

Although the coating cures at ambient temperature, it requires gradual heating to reach its optimal operational performance. Additionally, its UV-resistant properties enhance its suitability for outdoor applications, providing reliable and long-lasting protection in a wide range of industrial settings.



Application Areas

Exhaust Vents:

Protecting systems that channel exhaust gases.

Stacks:

Ensuring durability in vertical discharge systems exposed to corrosive gases.

High-Temperature Structures:

Safeguarding components operating under extreme thermal conditions

Generators:

Enhancing corrosion resistance in power generation equipment.

Turbines:

Providing protection for critical rotating machinery.

Heat Exchangers:

Ensuring long-term performance in thermal transfer systems.

Technical Data	Value	Unit
Abrasion Resistance ASTM D4060 (Taber CS-17/1kg/1000 cycles)	43	mg weight loss
Salt Spray Test ASTM B117 (Tested on heat aged samples)	1000 No damage	hrs.
Adhesion Strength ASTM D4541 (Cohesive failure)	10	MPa
Temperature Cycling 5 cycles no damage	Ambient to 600	°C
Temperature Resistance	Continuous	°C
	Intermittent	