

The background features a collection of 3D-rendered spheres and organic, liquid-like shapes in various shades of blue and purple. The spheres vary in size and are scattered across the frame. The organic shapes are more complex, with smooth, rounded edges and a gradient of colors from light blue to deep purple. The overall composition is abstract and modern.

Corrosion of Oil Transmission Pipelines

BY

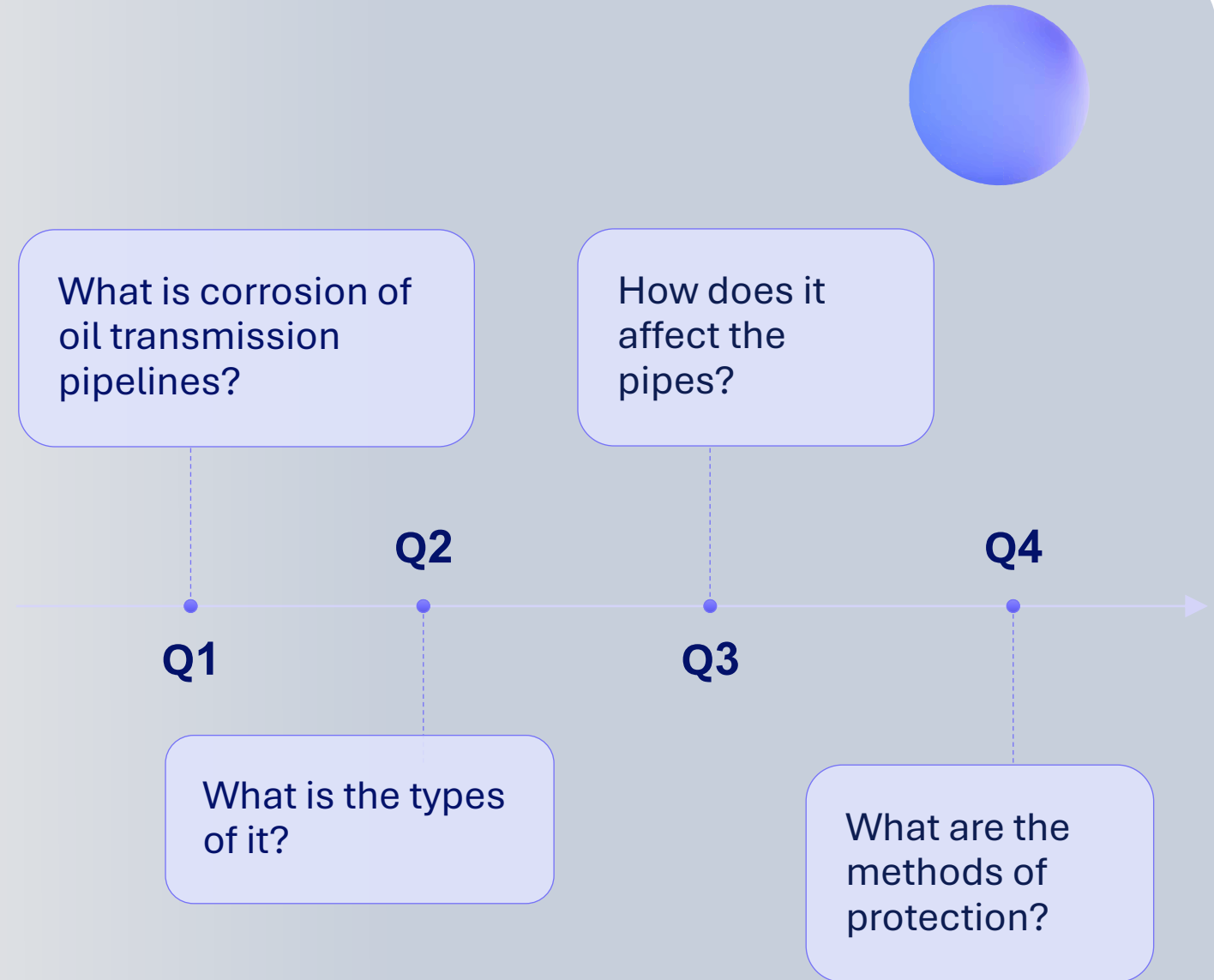
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Agenda

- CORROSION OF OIL TRANSMISSION PIPELINES
- TYPES OF CORROSION IN OIL TRANSMISSION PIPELINES
- THE EFFECT OF EACH TYPE AND METHODS OF PROTECTION FROM IT
- TECHNIQUES USED TO DETECT CORROSION IN OIL TRANSMISSION PIPELINES

INTRODUCTION

Corrosion is defined as the deterioration of a material that alters its properties due to a chemical or electrochemical reaction with the surrounding environment. The corrosion of oil transmission pipelines is a complex topic that requires a comprehensive understanding of the environmental, chemical, and physical factors affecting the pipelines. Corrosion is considered one of the biggest engineering and economic problems in the oil sector and one of the most widespread issues in the world, primarily due to the significant impact this problem has on oil facilities. These facilities exposed to corrosion include thousands of kilometers of pipeline networks, underground storage tanks, oil transmission lines, and other installations.



Corrosion of Oil Transmission Pipelines

Corrosion of oil transmission pipelines is one of the major challenges facing the oil and gas industry today. The transportation of crude oil and petroleum derivatives over long distances exposes these pipelines to various chemical and environmental factors that lead to their gradual corrosion. This corrosion can cause severe damage, including the leakage of hydrocarbons, posing a direct threat to the environment and adversely affecting the economy and public safety. With the advancement of technologies and the emergence of new solutions, monitoring corrosion and finding ways to mitigate it have become urgent necessities to maintain pipeline efficiency and reduce potential risks.

Types of Corrosion in Oil Transmission Pipelines

1. UNIFORM CORROSION
2. GALVANIC CORROSION
3. INTERGRANULAR CORROSION
4. PITTING CORROSION
5. STRESS CORROSION CRACKING (SCC)
6. CREVICE CORROSION
7. BIOCORROSION (MICROBIAL CORROSION)

1. Uniform Corrosion

Uniform corrosion is a type of localized corrosion that appears on the external or internal surface of the pipelines. It primarily occurs when the metal surface is exposed to a specific environment that allows for a chemical or electrochemical reaction to take place, leading to the corrosion of the surface layer. In the case of oil transmission pipelines, the pipes are subjected to harsh conditions such as a mixture of water, salts, sulfides, and oxygen, which react with the metal surface of the pipe, resulting in surface corrosion.

Factors Affecting Surface Corrosion in Oil Transmission Pipelines

Several factors influence the extent and rate of surface corrosion in oil pipelines, including:

1. High concentrations of chlorides and salts: The presence of chlorides and salts enhances corrosion, especially if the pipelines transport seawater.
2. Presence of sulfur dioxide and hydrogen sulfide (H₂S): These gases contribute to the formation of sulfur compounds that increase the severity of corrosion.
3. Temperature: Higher temperatures accelerate electrochemical reactions and increase the corrosion rate.
4. Flow within the pipes: High flow rates increase corrosion due to friction and cause the removal of natural protective layers that may form.

Mechanisms of Surface Corrosion

There are two primary mechanisms for surface corrosion in oil transmission pipelines:

A. General Corrosion: Occurs uniformly across the entire internal surface of the pipe, and the corrosion rate is often slow but continuous.

B. Localized Corrosion: Appears in specific areas more concentrated than others, with examples including pitting corrosion, which manifests as small, deep pits in certain areas. This type of corrosion is the most dangerous to pipelines as it leads to the formation of voids and structural weakness in the pipe walls, potentially resulting in holes and leaks.

2. Galvanic Corrosion

Galvanic corrosion is a type of corrosion that occurs when two different metals come into electrochemical contact in a conductive environment (such as water or salts), leading to the formation of an electrochemical cell between them. In this case, the more active metal (or less noble) becomes the anode, corroding rapidly, while the more noble metal acts as the cathode, remaining less affected by corrosion.

How Galvanic Corrosion Occurs in Oil Pipelines

In oil transmission pipelines, galvanic corrosion can occur due to the presence of a mixture of different metals or as a result of connections between various piping materials, such as pipe joints or welds. When these different metals are exposed to a conductive environment, such as a mixture of oil and saline water inside the pipes, an electrochemical cell forms, initiating the galvanic corrosion process.

Example: When connecting a carbon steel pipe to a stainless steel fitting, the carbon steel (less noble) becomes the anode and corrodes at a higher rate, while the stainless steel (more noble) remains the cathode and is protected.

Factors Increasing Galvanic Corrosion

Several factors can affect the extent and rate of galvanic corrosion, including:

1. The difference in electric potential between the metals: The greater the difference, the greater the intensity of corrosion.
2. Presence of saltwater: Salts act as an electrolyte solution that helps transfer the electrochemical current between the metals.
3. Distribution and contact between the metals: The degree of direct contact between different metals and the surface area of each affects the corrosion rate.
4. Temperature: Higher temperatures increase electrochemical activity and enhance corrosion.

Mechanism of Galvanic Corrosion in Pipelines

Role of Anode and Cathode: In the galvanic cell, the anode continuously corrodes due to the loss of electrons. These electrons transfer to the cathode through the conductive solution (or environment) that provides a path for ion movement, leading to gradual corrosion of the anode. **Resulting Effects:** Areas acting as anodes corrode much faster, resulting in localized weakening that may lead to leaks or holes in the pipe.

Methods of Protection Against Galvanic Corrosion

To reduce the risks of galvanic corrosion, several preventive strategies are employed, including:

- A) **Insulating metals:** Insulating materials are used at contact points between different metals to prevent the formation of an electrochemical cell.
- B) **Cathodic protection:** Cathodic protection is applied to the pipelines, so the less noble metal is not subject to corrosion by using sacrificial anodes connected to the metal to be protected.
- C) **Choosing homogeneous materials:** Attempting to use materials with a uniform composition, so all parts of the pipe are made of the same material, reduces the likelihood of galvanic corrosion.
- D) **Using corrosion inhibitors:** Adding inhibiting materials into the oil to reduce the corrosion rate.

Practical Examples of Galvanic Corrosion in Oil Pipelines

In some cases, galvanic corrosion is a particular problem in pipes connected to pumps or other equipment containing different metal parts. Pipelines are sometimes exposed to an environment containing a mixture of oil, water, and salts, increasing the likelihood of forming electrochemical cells at connection points, causing rapid localized corrosion in the less noble materials. This way, we can understand how galvanic corrosion occurs and the importance of addressing it in oil transmission systems, as neglecting it may lead to significant losses in equipment and infrastructure, as well as environmental damage in the event of an oil spill.

3. Intergranular Corrosion

Intergranular corrosion is a type of localized corrosion that occurs along the boundaries between crystal grains in metals, where the grain boundaries become more susceptible to corrosion than the rest of the metal. This type of corrosion happens due to chemical or structural differences between the grain boundaries and the internal areas of the grains.

Mechanism of Intergranular Corrosion in Oil Transmission Pipelines

Intergranular corrosion typically occurs when the metal is exposed to certain environmental conditions, such as high temperatures or high concentrations of chemicals that cause changes in the chemical composition of the grain boundaries. In oil transmission pipelines, repeated exposure to substances such as water, chlorides, and sulfides can stimulate this type of corrosion, especially at elevated temperatures. In metals like stainless steel, intergranular corrosion can occur at specific temperatures due to the formation of chromium carbides at the grain boundaries. This results in chromium depletion in those areas, making them more susceptible to corrosion.

Mechanisms of Surface Corrosion

Several factors contribute to intergranular corrosion, including:

1. **Thermal Changes:** Repeated heating and cooling, especially in the temperature range of 450–850 °C, lead to the formation of chromium carbides in stainless steel, increasing the likelihood of corrosion.
2. **Presence of Contaminants like Chlorides and Sulfides:** These substances significantly affect the grain boundaries and increase corrosion rates.
3. **Chemical Composition of the Metal:** Steel types with high levels of chromium and carbon are more susceptible to intergranular corrosion if not subjected to proper heat treatment.
4. **Mechanical Stresses:** Stresses accumulated due to operation or thermal expansion may also contribute to an increased occurrence of intergranular corrosion.

Effects of Intergranular Corrosion in Pipelines

Intergranular corrosion leads to a loss of metal toughness, making the pipes brittle and weak along the grain boundaries. This corrosion can lead to internal cracking in the pipe, which may develop over time and cause leaks in the oil or even pipe failure.

Methods of Protection Against Intergranular Corrosion

To prevent or reduce intergranular corrosion in oil pipelines, several preventive measures are implemented, including:

- A) **Proper Heat Treatment (Solution Annealing):** This method involves heating the metal to specific temperatures and then rapidly cooling it, which helps dissolve chromium carbides and redistribute chromium in the metal.
- B) **Using Low-Carbon Alloys:** Using types of stainless steel that contain low levels of carbon (such as 316L stainless steel) reduces the formation of chromium carbide and thus decreases intergranular corrosion.
- C) **Adding Corrosion-Inhibiting Elements:** Some elements like titanium or niobium can be added to the alloys to stabilize carbon and prevent the formation of chromium carbides.
- D) **Choosing More Corrosion-Resistant Materials:** Using advanced alloys resistant to intergranular corrosion in harsh environments reduces the likelihood of this type of corrosion.
- E) **Controlling the Operating Environment:** Reducing the concentration of chlorides and sulfur compounds in the pipeline environment decreases the chances of intergranular corrosion.

Practical Examples of Intergranular Corrosion in Oil Transmission Pipelines

In some oil transmission pipelines, particularly those made of stainless steel, intergranular corrosion can be observed in areas of joints or welds, where these areas are exposed to high temperatures during welding operations, leading to the deposition of chromium carbide at the grain boundaries in those regions. Over time, small cracks may appear along these boundaries, leading to pipe weakness and potentially causing oil leaks

4. Pitting Corrosion

Description: Appears as small holes or deep pitting on the surface, and it grows rapidly if not detected.

Causes: Concentration of certain ions, such as chlorides, or a lack of oxygen in a specific area.

Locations of Occurrence: In marine environments or in pipes exposed to chloride ions.

Prevention: Regularly applying protective coatings and monitoring water or fluids to ensure there are no harmful ion concentrations.

5. Stress Corrosion Cracking (SCC)

Crevice corrosion is a type of corrosion that results from a complex interaction between corrosion and mechanical stresses, whether internal or external. This type of corrosion occurs in the form of fine cracks that begin at the surface and extend into the metal, often affecting metals subjected to static stresses and corrosive environments simultaneously. This type of corrosion is one of the most dangerous because it can lead to sudden metal failure and may be difficult to detect.

Mechanism of (SCC) in Oil Transmission Pipes

In oil transmission pipes, the pipes are often exposed to harsh environments containing water, salts, chlorides, sulfur dioxide, and hydrogen sulfide gas, creating a highly corrosive environment. With stresses caused by internal oil pressure or thermal expansion and contraction, cracks begin to appear in areas where these stresses accumulate. Crevice corrosion occurs in stages:

1. **Initial Crack Formation:** Cracking starts from the surface due to high stresses at specific points.
2. **Crack Propagation:** As the metal continues to be subjected to stress and corrosion, the crack slowly expands inward, interacting with corrosive elements in the environment.
3. **Metal Failure:** Eventually, significant crack propagation may lead to the collapse of the pipe or leaks at the crack locations.

Factors Leading to (SCC) in Oil Pipes

Several factors contribute to the occurrence of crevice corrosion in pipes, including:

1. **Mechanical Stresses:** Residual internal stresses from manufacturing processes, or stresses resulting from internal oil pressure.
2. **Presence of Chlorides:** Especially in marine pipes exposed to saline water, as chlorides exacerbate corrosion.
3. **Presence of Sulfur Gases:** Such as hydrogen sulfide (H_2S) and sulfur dioxide (SO_2), which create a corrosive environment.
4. **Temperature:** Elevated temperatures increase electrochemical reactions and promote crack formation.

Mechanism of Interaction Between Stress and Corrosion

Crevice corrosion occurs due to a combination of mechanical stress and chemical corrosion. Mechanical stress helps open the cracks while chemical corrosion weakens the metal in the open areas, and together they accelerate crack propagation.

Crevice corrosion is particularly common in stainless steel and carbon steel alloys in the presence of chloride ions, where cracks start from the metal surface and extend dangerously inward.

Methods of Protection Against (SCC) To protect pipes from crevice corrosion

several strategies are employed:

- A) **Reducing Mechanical Stresses:** Relieving residual stresses in the pipes through heat treatment or applying mechanical processes to remove stresses.
- B) **Using Resistant Alloys:** Selecting corrosion- and crack-resistant alloys, such as low-carbon stainless steel or alloys containing chromium and molybdenum.
- C) **Using Corrosion Inhibitors:** Adding chemical inhibitors that help reduce corrosion in the pipe environment, especially in areas containing chlorides.
- D) **Cathodic Protection:** This method reduces electrochemical corrosion and helps protect the metal from corrosive environmental effects.
- E) **Controlling the Environment:** Reducing the levels of chlorides and sulfur compounds in the oil or the surrounding medium of the pipes may decrease the severity of corrosion.

6. Crevice Corrosion

Crevice corrosion does occur in oil transmission pipes, especially in areas where the conditions are suitable for its occurrence. This type of corrosion is considered one of the common problems in pipe environments containing corrosive fluids and chemicals.

How Does Crevice Corrosion Occur in Oil Transmission Pipes?

Crevice corrosion occurs when corrosive liquid, such as chloride containing water, accumulates within small cracks or crevices in the pipes. These crevices may be present in:

- Areas where parts connect, such as pipe joints and flanges.
- Underneath deposits or accumulations of materials like sand or soil.
- Beneath insulating materials; external insulation of the pipes may trap moisture and create an ideal environment for crevice corrosion

In these enclosed or tight areas, there is a lack of ventilation, and the concentration of corrosive ions, such as chlorides, begins to rise, increasing the acidity of the liquid and rapidly enhancing corrosion at these points.

Importance of Crevice Corrosion in Oil Transmission Pipes

Crevice corrosion is dangerous because it occurs locally and is difficult to detect, which may lead to a loss of metal thickness in specific areas, resulting in holes and leaks. This increases the risk of oil spills and leads to financial losses and environmental damage.

Methods of Protection Against Crevice Corrosion in Oil Pipes

To protect pipes from crevice corrosion, the following measures can be taken:

- A) Using Corrosion-Resistant Alloys: Such as stainless steel containing molybdenum, which provides additional resistance to crevice corrosion.
- B) Designing Pipes to Prevent Crevices and Gaps: Avoiding tight angles and gaps that can trap liquids.
- C) Regular Cleaning and Maintenance: To ensure the removal of deposits and dirt that may cause crevice corrosion.
- D) Using Moisture-Resistant Insulating Materials: Insulating pipes with moisture-resistant materials reduces the accumulation of corrosive liquids

Stress Corrosion Cracking (SCC) is considered a type of crevice corrosion but differs in details and causes.

The Difference Between Stress Corrosion Cracking and Crevice Corrosion

1. Stress Corrosion Cracking (SCC):

Occurs as a result of the interaction between mechanical stresses and a specific corrosive environment, leading to surface cracks that propagate inward. SCC typically manifests under conditions that combine static stresses and chemical factors, such as chlorides or sulfides. This type is dangerous because it can lead to deep cracks and sudden structural failure.

2. Crevice Corrosion:

Occurs in enclosed or narrow crevices where corrosive liquid accumulates. Due to the lack of ventilation and accessibility, the corrosive liquid within the crevice causes rapid localized corrosion, often occurring in cracks between pipe sections or beneath deposits. However, it does not necessarily require mechanical stresses as seen in stress corrosion cracking.

This means that stress corrosion cracking is a form of corrosion that may involve cracks, but it is linked to the effect of mechanical stresses with the corrosive environment. In contrast, crevice corrosion is localized corrosion that occurs in tight spaces and does not depend on mechanical stresses.

7. Biocorrosion (Microbial Corrosion)

Biocorrosion is a type of corrosion resulting from the biological activity of microorganisms, such as bacteria and fungi, that grow in oil environments and affect metals. These microorganisms produce corrosive substances that weaken metals and accelerate their corrosion, potentially causing leaks in pipelines and significant problems in oil transmission systems.

How Does Biocorrosion Occur in Oil Transmission Pipes?

In oil pipelines, small amounts of water and impurities accumulate on the walls of the pipes, especially in the lower areas, creating a suitable environment for the growth of microorganisms such as:

- **Sulfate-Reducing Bacteria:** These bacteria convert sulfates into hydrogen sulfide (H_2S), which is highly toxic and corrosive. The hydrogen sulfide gas produced by the activity of these bacteria causes severe corrosion of the metal.
- **Iron Bacteria:** These bacteria convert iron ions into iron oxides and hydroxides, leading to the deposition of layers on the surface that promote corrosion.
- **Other Anaerobic and Aerobic Bacteria:** They produce organic acids such as acetic acid and formic acid, increasing the acidity of the environment and accelerating the rate of corrosion.

Mechanism of Biocorrosion

Biocorrosion occurs through several processes carried out by microorganisms, such as:

1. **Production of Corrosive Chemicals:** Such as sulfuric acid and hydrogen sulfide, which react with the metal surface and initiate corrosion.
2. **Formation of Biofilms:** Microorganisms adhere to the metal surface and form sticky layers. These layers prevent oxygen flow and concentrate corrosive chemicals in specific areas, leading to severe localized corrosion.
3. **Production of Organic Acids:** Some types of bacteria produce organic acids that lower the pH, thereby increasing the rate of corrosion.

Factors That Increase Biocorrosion in Oil Pipelines

- A. **Presence of Water and Impurities:** The presence of small amounts of water allows bacteria to thrive.
- B. **Oxygen Deficiency in Some Areas:** Such as the bottom of the pipes, which encourages the growth of anaerobic bacteria.
- C. **Suitable Temperature:** Most microorganisms causing biocorrosion grow best at moderate temperatures (20-50 degrees Celsius).

Damage Caused by Biocorrosion in Oil Pipelines

Biocorrosion causes significant damage, including:

1. **Holes and Leaks:** Localized corrosion caused by microorganisms leads to severe weakening and erosion of the pipe.
2. **Significant Financial Losses:** Due to the need to repair or replace damaged pipes.
3. **Environmental Pollution:** If oil spills occur as a result of biocorrosion, the surrounding environment may be contaminated.

Preventive Measures Against Biocorrosion in Oil Pipelines

To reduce biocorrosion and maintain the integrity of oil pipelines, several measures can be implemented, including:

- A) **Using Biocidal Materials:** Such as injecting chemical biocides into the pipes to inhibit microbial growth.
- B) **Proper Pipe Design:** Designing pipes to prevent the accumulation of water and impurities reduces the likelihood of microbial growth.
- C) **Regular Cleaning of Pipes:** Removing deposits and organic materials that may encourage biofilm growth.
- D) **Choosing Corrosion-Resistant Alloys:** Using alloys or treated materials that resist the effects of hydrogen sulfide and organic acids.
- E) **Controlling Water Content:** Separating water and impurities at processing stations before oil reaches the pipes reduces the chance of microbial growth.

Techniques Used to Detect Corrosion in Oil Transmission Pipelines

Certainly. Here's a brief list of techniques for detecting corrosion in oil transmission pipelines:

1. Ultrasonic Imaging.
2. Smart Inspection Devices.
3. Eddy Current Technology.
4. Magnetic Flux Leakage Analysis.
5. X-ray Imaging.
6. Nuclear Magnetic Resonance Technology.
7. Thermal Imaging.
8. Electrochemical Analysis Techniques.
9. Integrated Corrosion Sensors.

The techniques vary depending on the type of corrosion, the size of the pipe, and the type of material. However, using a combination of these techniques helps achieve a comprehensive and accurate assessment of the condition of the pipes in oil transmission environments.

Thank you

The background features several abstract 3D shapes and spheres in shades of blue and cyan. On the right side, there is a large, complex, multi-lobed shape with a gradient from light blue to a darker blue. Scattered around it and across the rest of the page are various sized spheres, some with a gradient and others with a uniform color. The overall aesthetic is clean and modern.