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Crude Oil Pipeline Repair

بابەتی توێژینەوە

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١ Abstract

Maintaining the integrity of crude oil pipelines is crucial for environmental protection and uninterrupted energy flow. This abstract explores two common methods for repairing damaged pipelines while they remain operational: Type A and Type B sleeves and composite sleeves.

٢ Introduction

Pipelines are vital infrastructure for transporting oil, gas, water, and other fluids. However, they are susceptible to damage from corrosion, mechanical impact, and other factors. Timely and effective repair is essential to maintain pipeline integrity and prevent leaks or ruptures.

Traditional pipeline repair methods often involve excavation, line cutting, and hot work like welding. These methods can be disruptive, expensive, and pose safety hazards.

The purpose of this document is to provide the required technical information and references to main standards and codes for the installation of steel sleeves, Type B Sleeve, and filling of epoxy resin (sleeves type A) and Composite Wrapping.

٣ Codes and Standards Reference

Sr #	Document Number / Link	Title / Description
١	API ٥L	Specification for Line pipe
٢	API ١١٠٤	Welding of Pipelines and Related Facilities (Annex B)
٣	ASME PCC-٢	Repair of Pressure Equipment and Piping
٤	ASME B٣١,٤	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
٥	ASME B١٦,٥	Pipe Flanges and Flanged Fittings
٦	ASME B٣١G	Manual for Determining the Remaining Strength of Corroded Pipelines
٧	ASTM E٧٩٧	Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method
٨	ASTM E١٤٤٤	Standard Practice for Magnetic Particle Testing
٩	API RP ٢٢٠٠	Repairing Hazardous Liquid Pipelines
١٠	PRCI L٥٢٠٤٧	Pipeline Repair Manual
١١	API ٥L	Specification for Line pipe
١٢	API ١١٠٤	Welding of Pipelines and Related Facilities (Annex B)
١٣	ASME PCC-٢	Repair of Pressure Equipment and Piping
١٤	ASME B٣١,٤	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

Sr #	Document Number / Link	Title / Description
١٥	ASME B١٦,٥	Pipe Flanges and Flanged Fittings

٤ Steel sleeves that are used to repair defects.

٤,١ Corrosion Defects:

- **Internal Corrosion:** This is the most prevalent defect, caused by the deterioration of the pipe wall due to reactions with the oil and impurities within it. Refer to the previous explanation of "Metal Loss" for details on the causes and effects of internal corrosion.
- **External Corrosion:** External factors like acidic soil or stray electrical currents can also eat away at the pipeline from the outside.

٤,٢ Mechanical Defects:

- **Cracks:** These can develop due to manufacturing defects, ground movement (stress on the pipe), or external damage from excavation work.
- **Dents:** These are permanent deformations in the pipe wall caused by blunt impacts or external pressure. While not always critical, significant dents can reduce the pipe's strength and increase the risk of leaks.
- **Gouges:** These are grooves or scrapes on the pipe wall, typically caused by external mechanical damage during construction or maintenance activities. Severe gouges can weaken the pipe and pose a leak risk.

٤,٣ Weld Defects:

- Welds are critical points where pipe segments are joined. Poor quality welds, incomplete penetration, or cracks in the weld zone can create weak points susceptible to leaks or even complete failure.

٤,٤ Manufacturing Defects:

- Imperfections introduced during pipe manufacturing, such as voids (air bubbles) or inconsistencies in the steel composition, can create weak spots prone to future problems.

٤,٥ Third-party Damage:

- Accidental damage caused by excavation equipment or other external activities can puncture or damage the pipeline. This is a major concern, and pipeline operators often work closely with local authorities to mark pipeline locations and prevent such incidents

- Other anomalies such as coating damages, buckle, etc.

The repair system consists of seam welding two half-section pipes with an inner diameter equal or larger than the outer diameter of the pipe around the damaged section and composite wrapping.

١. Type A sleeves which are only seam welded without welding the ends to the carrier pipe, Sealant putty will used to seal both end once it hardens the epoxy material will

be used to fill the annular space between the sleeve and the carrier pipe. Moreover, sacrificial Anodes are usually used for type A sleeves,

٢. Type B sleeves which are welded at the ends contributing to a full pressure containment around the damage,

٣. Girth weld sleeves which are used for defect located in existing girth weld. This sleeve contains a bulge to accommodate the existing girth weld crown and it is a tight fit to the carrier pipe as Type B and fillet welded both ends to carrier pipe.

٤. Composite wrapping is a technique used to repair and reinforce pipes, most used for crude oil pipelines. It's a non-intrusive solution that offers several advantages over traditional methods like excavation and replacement.

٥ Pipeline Repair

٥,١ Type-A - Epoxy-filled sleeve.

٥,١,١ **Definition**

This type of sleeve is centred around the pipeline with a stand-off distance that may vary between ٥ mm and ٢٠ mm. The diameter of the sleeve for Epoxy–filled sleeve shall be greater than that of the carrier pipe between ٥ mm and ٢٠ mm to fill this annular space with Epoxy resin.

The shell is placed on the defective pipe, and bolts are used to centre it. The side seams are then welded, and the gaps at the ends are sealed with quick curing putty or epoxy-based resin seal. Ensure the putty is pushed into the cavity between ٢٥-٥٠mm. Apply an additional layer of putty leaving a ٣٠° fillet between the sleeve front face and pipeline. After these seals have hardened, epoxy is pumped into the annular space until it comes out of an overflow hole at the top of the sleeves.

Figure ٥-١ Type A Sleeve- The gaps at the ends are sealed with quick curing putty

Figure ٥-٢ The putty is pushed into the cavity between ٢٥-٥٠mm

Figure ٥-٢ Epoxy is pumped into the annular space until it comes out

Once the epoxy filler has hardened, the radial bulging tendency of the defect is restrained by the epoxy.

Measures shall be taken to prevent the sleeve seam weld metal from being deposited on the pipe. The grouting pressure shall be controlled to prevent damage to the pipeline.

The principle of the epoxy-grouted sleeve is to prevent the damaged section of the pipe from bulging radially at the location of the defect.

Protection against external corrosion like External Coating shall be provided after installation of the sleeve.

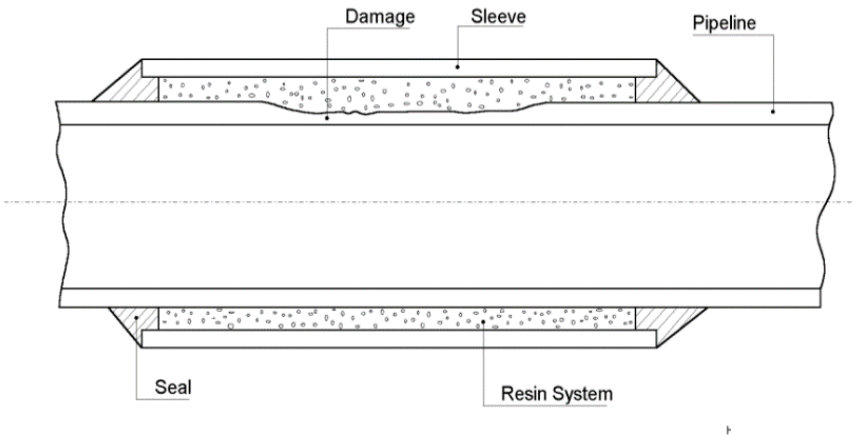

Figure ٥-٤ Epoxy-grouted sleeve (Type A)

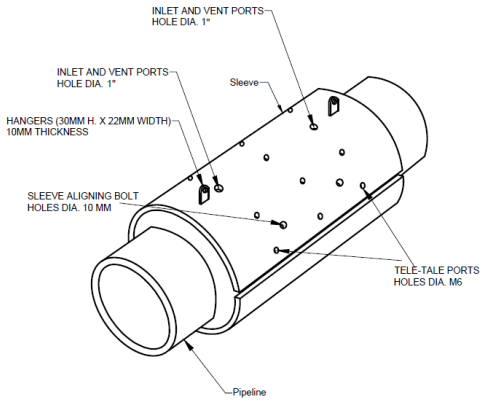

Figure ٥-٥ Epoxy-grouted Sleeve (Type A)- Sleeve isometric view

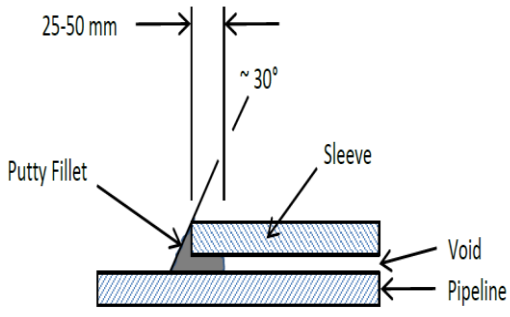

Figure ٥-٦ Epoxy-grouted Sleeve (Type A)- Sleeve Side view

٥,١,٢ **Design:**

A cylindrical steel sleeve with a longitudinal seam weld but no welds at the ends. Imagine a half-pipe wrapped around the damaged area.

Here are some key considerations for designing a Type A sleeve for crude oil pipeline repair:

٥,١,٢,١ Pipe and Defect Characteristics:

Pipe diameter and wall thickness: The sleeve's dimensions need to exactly match the pipe it is reinforcing. This ensures a proper fit and optimal load distribution.

Defect size and location: The sleeve should encompass the entire damaged area, extending past the defect by a certain distance on both ends. This "extra" length depends on code requirements and engineering judgement.

Material properties: The sleeve material should be compatible with the pipeline steel. Typically, high-strength steel with similar or slightly higher yield strength than the pipe is chosen.

٥,١,٢,٢ Design Parameters:

Pressure rating: While Type A sleeves don't have end welds and aren't suitable for high-pressure leaks, consider the maximum pressure the pipeline operates under to ensure the sleeve provides adequate reinforcement.

Temperature fluctuations: Crude oil pipelines experience temperature variations. The sleeve material needs to be suitable for the expected operating temperature range to avoid strength or dimensional changes.

Corrosion resistance: The sleeve material should be resistant to internal crude oil corrosion and any external environmental factors that might contribute to corrosion.

٥,١,٢,٣ Engineering Considerations:

Strength calculations: The sleeve needs to be designed to withstand the internal pressure of the crude oil and any external loads it might encounter during installation or operation. Engineering calculations will determine the required sleeve thickness based on these factors.

Fatigue life: Crude oil pipelines experience cyclic pressure variations. The sleeve design should consider fatigue life to ensure it doesn't crack or fail prematurely due to repeated stress.

Installation method: Since Type A sleeves don't involve welding, consider the chosen installation method (e.g., mechanical clamps) and ensure the sleeve design facilitates a secure and efficient installation process.

- **Application:** Ideal for situations requiring reinforcement against corrosion, minor cracks, or dents. Not suitable for leak repair due to the absence of end welds.

- **Advantages:**
    - Easier and faster to install compared to Type B sleeves as it requires only one weld.

- Cost-effective solution for minor to moderate pipeline defects.
- Maintains some flexibility due to the absence of end welds.

- **Disadvantages:**
  - Not suitable for high-pressure pipelines or leak repair.
  - Offers less structural reinforcement compared to Type B sleeves.

٥,٢ Type-B Sleeves

٥,٢,١ **Definition**

Type B sleeve can be used to repair leaks and to strengthen circumferentially oriented defects. In fact, a Type B sleeve has been used in place of a girth weld to make a tie-in on a pipeline. Because a Type B sleeve may contain pressure and/or carry a substantial longitudinal stress imposed on the pipeline by lateral loads, it should be designed to carry the full pressure of the carrier pipe. Additionally, it should be carefully fabricated and inspected to ensure its integrity.

Type B sleeves should be designed to the same standard as the carrier pipe. This usually means that the wall thickness of the sleeve will be equal to that of the carrier pipe and that the grade of

the sleeve material also will be equal to that of the carrier pipe. The diameter of the sleeve is usually designed slightly greater than that of the carrier pipe, so it fits over the carrier pipe. In

addition, in case the defects area located around Girth weld joint, the size of bend to be considered or sleeve to be bent at girth weld joint. The material and other properties of the sleeve

are designed according to the requirement also considering the dynamic loading in the operation at the location of installation.

Figure ٥-V Longitudinal weld – connection of the two sleeves

Figure ٥-٨ Circumferential weld – Sleeve type B is welded directly to carrier pipe-in-operation-٣٦ Inch Kurdistan pipeline- Erbil

Figure ٥-٩ Sleeve type B (direct welding)- -٣٦ Inch Kurdistan Pipeline- Erbil

٥,٣ Full-encircling pressure-containing sleeve

This type of sleeve is tight-fit sleeve except that the ends are fillet-welded to the pipeline, see Figure ٦, and this type of sleeve can be designed to contain pressure (the tight-fit sleeve cannot). WPS for Type B sleeves at circumferential welds shall be qualified in accordance with API ١١٠٤, Annex B, In-service Welding.

Main design code for the full-encircling pressure-containing sleeve is ASME B٣١,٤, since the full-encircling pressure-containing sleeve may contain pressure, it shall be designed, fabricated, and installed in accordance with the same requirements as specified for the pipeline. A UT check shall be performed on a ١٠٠ mm wide band centred on the circumferential sleeve to the pipe weld location to ensure that the minimum wall thickness is complied with.

The minimum required nominal wall thickness and steel grade of the sleeve shall be based on the wall thickness design factor and equation as required for the pipeline.

As for the tight-fit sleeve, the sleeve thickness shall be increased to compensate for the groove accommodating backing strips or seams of the pipeline.

The sleeve should extend at least ٥٠ mm (٢ inches) beyond both ends of the defect. Adjacent sleeves should not be placed closer than one-half pipe diameter from each other. Oversleeves may be used to protect areas adjacent to or between sleeves. These shall be welded to the original sleeve using qualified welding procedures. Protection against external corrosion like External Coating shall be provided after installation of the sleeve.

Note: The Internal diameter of the sleeve for Type B is slightly greater than that of the carrier pipe so it fits over the carrier pipe.

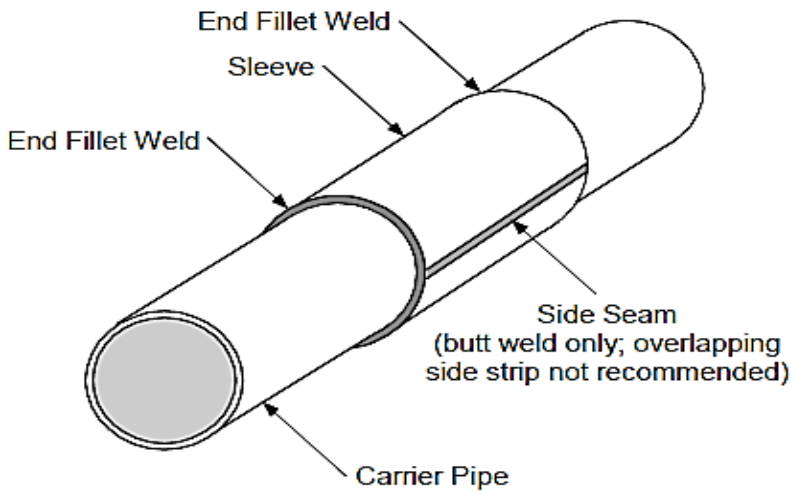

Figure ٥-١٠ Full- Encircling pressure-containing Sleeve (Type B)

٥,٣,١ **Design:**

A cylindrical steel sleeve with a longitudinal seam weld and complete circumferential welds at both ends to the pipeline. Imagine a full pipe section encasing the damaged area.

Here's a breakdown of what to consider specifically for a Type B sleeve designed to repair a crude oil pipeline:

٥,٣,١,١ Oil Properties:

Temperature: Crude oil temperature can affect the material selection for the sleeve and the welding process. High temperatures can weaken some steels and require specific welding procedures to avoid welding defects.

Compatibility: The sleeve material needs to be compatible with the crude oil being transported. Some crudes can contain corrosive elements that could degrade certain materials over time.

٥,٣,١,٢ Pipeline Environment:

External Loads: Consider any external stresses the pipeline might encounter in its location. This could include seismic activity, ground movement, or uneven settling. The sleeve design should be able to handle these additional loads along with the internal pressure.

Environmental Factors: For buried pipelines, consider factors like soil type, moisture content, and potential for corrosion from external sources. These can influence the selection of corrosion-resistant coatings for the sleeve.

٥,٣,١,٣ Regulatory Requirements:

Pipeline Codes: In addition to general design standards like ASME B٣١,٤ for pipeline transportation systems, there might be specific codes applicable to crude oil pipelines in your region. Ensure the Type B sleeve design adheres to these codes.

٥,٣,١,٤ Additional Considerations:

Fatigue Life: Crude oil pipelines experience cyclic pressure variations during operation. The Type B sleeve design should consider fatigue life to ensure it can withstand these pressure fluctuations for the expected lifespan of the pipeline.

Non-Destructive Testing (NDT): Specifying the type and extent of NDT for the sleeve material and welds is crucial to ensure their integrity after fabrication and installation.

- **Application:**
  Suitable for a wider range of repairs, including leaks, cracks, corrosion, and punctures. Offers superior structural reinforcement for compromised pipelines.

- **Advantages:**
  Provides a stronger and more pressure-resistant repair compared to Type A sleeves. Effective for leak sealing due to the complete enclosure around the damaged area.

Offers superior structural reinforcement for weakened pipelines.

- **Disadvantages:**

A more complex and time-consuming installation process due to the additional welds. Higher cost compared to Type A sleeves. Reduces pipeline flexibility due to the rigid encasement.

٥,٤ Girth Weld sleeve.

٥,٤,١ **Definition**

A girth weld sleeve is a type of sleeve used to reinforce or repair girth welds on pipelines. Girth welds are the welds that connect two sections of pipe together along the length of the pipe. Girth weld sleeves are typically made of steel and are available in a variety of sizes and thicknesses.

A girth weld sleeve, also sometimes called a full encirclement sleeve, is a specific type of Type B sleeve used for repairing crude oil pipelines. Here is what to consider for its design:

- **Pipe Properties:** Diameter, wall thickness, and material grade of the pipe.
- **Damage Assessment:** Type and severity of damage (corrosion, crack, etc.)
- **Pressure Requirements:** Pipeline operating pressure and relevant codes (ASME B٣١,٤).
- **Material Selection:** High-quality carbon steel meeting ASTM specifications, considering temperature and oil compatibility.
- **Weld Design:** Full circumferential weld - ensure strong and leak-proof repair.
- **Fit-up:** Tightness of the fit between sleeve and pipe for optimal performance.
- **Design Standards:** Follow ASME PCC-٢ for design, fabrication, and installation.

Additional Considerations for Girth Weld Sleeves on Crude Oil Pipelines:

- **Strength & Stiffness:** The girth weld sleeve needs to be strong enough to withstand the internal pressure of the crude oil and any external loads the pipeline encounters. Stiffness is also important to maintain the pipeline's overall rigidity.
- **Corrosion Resistance:** Select a sleeve material and potentially a corrosion-resistant coating that can handle the specific corrosive elements present in the crude oil and the external environment.
- **Fatigue Analysis:** Perform a fatigue analysis to ensure the sleeve can withstand the cyclic pressure variations experienced in crude oil pipelines over its lifespan. This analysis considers factors like material properties, weld details, and operating pressure.
- **Field Welding:** Girth weld sleeves are typically installed in the field. The design should consider the limitations and procedures for field welding to ensure a high-quality weld. Preheating and post-weld heat treatment might be necessary depending on the material selection.
- **End Geometry:** The ends of the girth weld sleeve can be designed with a bevel or other features to facilitate smooth welding with the pipe.

٥,٤,٢ **Benefits of using girth weld sleeves:**

- They can be installed without shutting down the pipeline, which can save time and money.
- They can be used to repair a variety of girth weld defects, including leaks, cracks, and corrosion.
- They can help to extend the life of a pipeline.

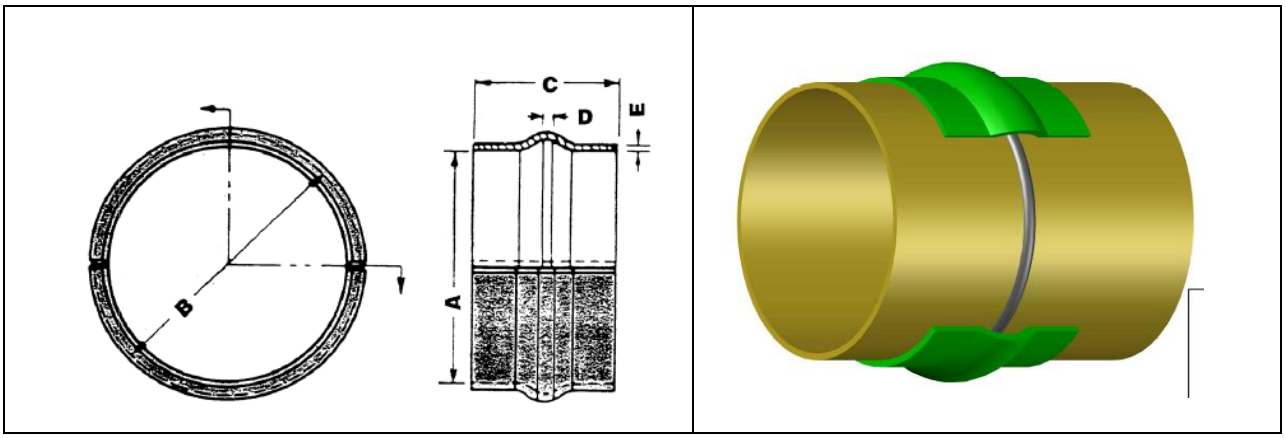

Figure ٥-١١ Full- Encircling pressure-containing Sleeve (Type B -Gerth weld)

٦ Which Sleeve to Use?

٦,١ Choosing Between Type A and B Sleeves:

The selection between Type A and B sleeves depends on the severity of the pipeline damage and the desired repair outcome. Here's a general guideline:

- **Use Type A sleeves for:**
  - Minor corrosion
  - Small cracks or dents
  - Reinforcement needs where flexibility is somewhat important.
- **Use Type B sleeves for:**
  - Leaks
  - Major cracks or punctures
  - Situations requiring high structural reinforcement.
  - High-pressure pipeline

٦,٢ Additional Considerations:

- **Pipe diameter and wall thickness:** Sleeve selection considers the size and strength of the pipeline being repaired.
- **Pipeline material:** Compatibility between the sleeve material and the pipeline material is crucial.

- **Regulatory requirements:** Specific industries may have regulations dictating sleeve type selection for pipeline repairs.

٦,٣ Composite Wrapping

Wrapping systems are a popular method for repairing crude oil pipelines. They offer a non-intrusive solution to address corrosion, leaks, and other forms of damage. Here's a breakdown of how these systems work:

٦,٣,١ **Materials:**

- **Composite material:** The core component is a composite material, typically fiberglass reinforced plastic (FRP). FRP is strong, lightweight, and resistant to corrosion.
- **Resin and hardener:** The FRP comes in a resin and hardener combination. When mixed, they cure to form a tough shell around the pipe.
- **Additional layers:** Depending on the specific system and repair needs, additional layers like epoxy putties or anti-corrosion coatings may be used.

٦,٣,٢ **Repair Process:**

١. **Surface preparation:** The damaged area of the pipeline is thoroughly cleaned and prepped to ensure proper adhesion of the wrapping material.

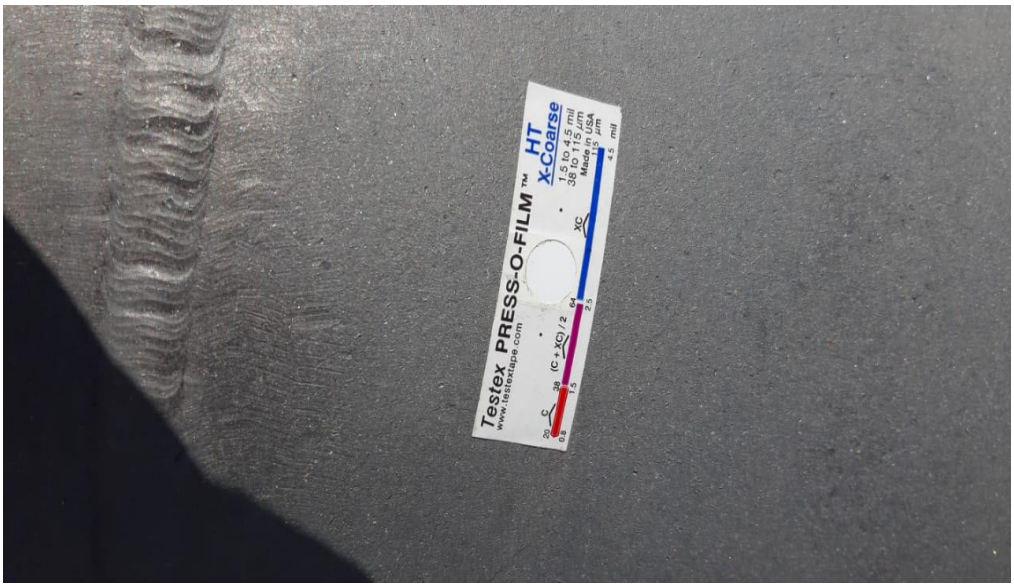

Figure ٦-١ Cleaning pipeline thorough Sand blasting

٢. **Resin application:** The resin is mixed and applied to the pipe surface, often followed by a layer of reinforcing fabric.

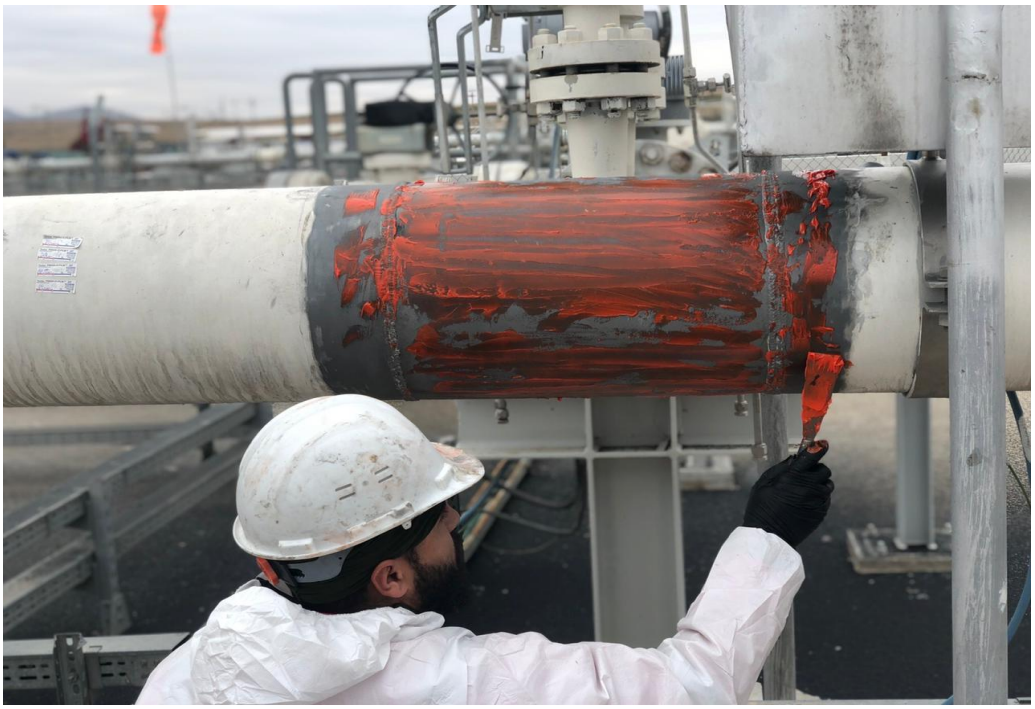

Figure ٦-٢ Apply Epoxy Resin on the pipe surface

Figure ٦-٣ Apply Epoxy Resin on the Fiber Reinforced Polymer

٣. **Wrapping:** The FRP wrap is saturated with the resin mixture and meticulously wrapped around the pipe in multiple layers to achieve the desired thickness and strength.

Figure ٦-٤ Apply and Wrapping Fiber Reinforced Polymer on the Pipe

٤. **Curing:** The resin is allowed to cure, solidifying the composite shell and reinforcing the pipe.

٦,٣,٣ Benefits of wrapping systems:

- **Minimally invasive:** The repair can be done without extensive excavation, reducing downtime and environmental impact.
- **Cost-effective:** Compared to traditional excavation and pipe replacement, wrapping systems can be a more economical solution.
- **Durable:** Properly installed composite wraps can extend the lifespan of a pipeline for many years.
- **Versatility:** Wrapping systems can address a variety of pipe damage including leaks, corrosion, and cracks.

٦,٣,٤ Things to consider when choosing a wrapping system:

- **Severity of the damage:** Different wrap systems are designed for varying degrees of repair needs.
- **Pipe diameter and pressure rating:** The wrap system needs to be compatible with the size and pressure requirements of your pipeline.

- **Environmental conditions:** Some wrap systems are better suited for specific temperature ranges or underwater applications.

٧ Conclusion

Type A and B sleeves offer effective solutions for pipeline repair. Understanding their design, applications, and limitations allows for informed decisions based on the specific repair needs. Consulting with pipeline repair professionals is recommended to determine the most suitable sleeve type for your situation.

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