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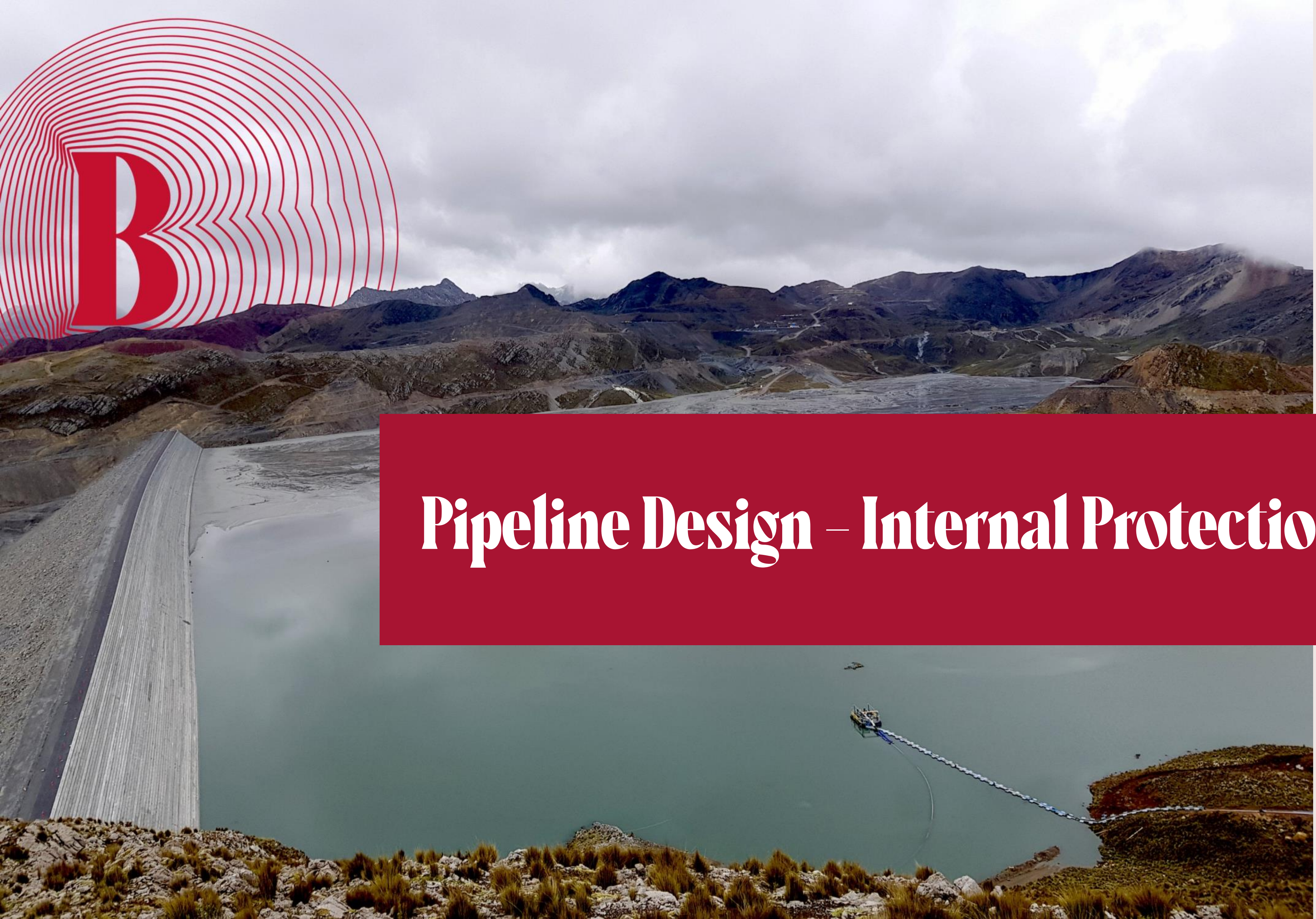
# 1st International Seminar

## on Design and Operation of Long-Distance Transportation Pipeline Systems

26th & 27th September 2024

# Pipeline Design – Internal Protection



# Pipeline Design – Internal Protection

In the mining industry, pipelines are widely used to transport water as a process solvent or as a medium for transporting solids, known as slurries (such as concentrates and tailings), over vast distances.

As such, the pipeline internal walls are in direct contact with the carrier fluid and that can lead to wear through corrosion and/or abrasion. Addressing this inherent characteristic is tantamount to ensure the pipeline integrity during its lifespan.

# Pipeline Design – Internal Protection

Depending on the fluid and its characteristics, this can be addressed via providing a barrier (coating, liner, or other type of physical barrier) or via a corrosion/abrasion wall thickness allowance.

# Main Pipeline Characteristics

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Influence of field conditions (elevation changes) and length

**Pressure Range**

Determined via the Pressure Range (including collapse) and fluid characteristics

**Wall Thickness / Material Selection**

Result of the design through put or flow

**Diameter**

Maximum speed of **3 m/s** for normal operations

**In line velocity**

# Pipeline Design – Internal Protection

The internal protection selection is closely related to the cost (CAPEX/OPEX), as there might exist various alternatives that can solve the corrosion/abrasion issue.

Normally, this is addressed via a Trade Off Study (TOS) in which the available solutions are compared.

Nonetheless, there are some factors that are subjective, and a risk workshop might be recommended to further expose each alternative strengths and weaknesses, while compromising on a final selection with which the risks are agreed upon.

# Pipeline Design – Internal Protection

The choice of internal protection typically depends on the type of fluid being transported.

- Pipeline
  - Water
    - Bare Steel
      - Corrosion Allowance
      - Corrosion Allowance + Chemical Inhibitors
    - FBE
    - HDPE Liner
  - Slurry
    - Bare Steel – Wear Allowance
    - HDPE Liner
    - Cement Mortar

Typically, if the corrosion/wear allowance is higher than 0,2 mm/year (8 mpy) internal protection is required for a lifespan of 20-year operation.

# Internal Protection – Bare Steel

Fluid must be characterized and coupons for corrosion rate estimation must be carried away if no prior information is available.

Care must be taken to monitor for the presence of bacteria in the fluid, especially Iron Reducing Bacteria (IRB). Samples and analyses should be conducted meticulously to ensure that the samples are valid and representative of the fluid that will actually be used.

# Internal Protection – Bare Steel

Bacteria do not cause corrosion in a uniform or distributed manner, as seen with pseudo-homogeneous corrosion. Instead, they form localized clusters that lead to pitting or localized corrosion. Because this type of corrosion, which  is highly localized, standard corrosion allowances are insufficient to mitigate the risk. Addressing this issue typically requires the use of chemical treatments, periodic pigging, or physical barriers, such as liners

# Internal Protection – Bare Steel

Main advantages of this type of protection (additional thickness) are:

- Doesn't impact on construction schedule (only on the welding as there is an increase in thickness).
- Easy repairs, only fitting and welding is required.
- Easy inspections (via ultrasound, intelligent PIGs, etc).
- Less restrictions on layout and construction (slopes, bends, anchors, etc).
- Lower CAPEX as flanges and couplings are not required (pipe is fully welded).
- Less susceptible to internal plugging.

# Internal Protection – Bare Steel

Main disadvantages:

- Contamination can accelerate corrosion beyond the level covered by the provided corrosion allowance, drastically reducing the pipeline's lifespan.
- It is essential to accurately assess all characteristics of the water to be used, taking into account seasonal fluctuations in the source conditions.
- Requires periodic pigging to improve pipeline roughness and reduce friction losses.
- Chemical cleaning, if needed, accelerates pipe material loss and reduction of wall thickness.

# Internal Protection – FBE

Fusion Bonded Epoxy (FBE) is a protective barrier applied to pipes during manufacturing. It is applied by electrostatic spraying onto a preheated pipe. This coating method is not applicable for slurry transport application.

It provides a physical barrier against corrosion and chemical attacks carried by the transported fluid.

Its application requires the surface to be prepared (cleaned, roughened, preheated) prior to the application of the FBE powder.

# Internal Protection – FBE

After application, curing time is needed, in which the coating hardens and forms the protective layer.

Normal coating thickness is about 500 to 625 um.

Due to its stringent application requirements, pipes are often purchased with the FBE coating already applied and delivered to the site. This requires careful handling and storage of the coated pipes before they are installed in the construction process.

# Internal Protection – FBE

Once in site, construction is similar to bare pipe, but since the welding of pipes is done at site, the coating at the interior of the welding zone must be carried at site. Inspection of the field application of the FBE is critical where most failures occur.

Given that FBE application is complicated, at times LBE (liquid bonded epoxy) is used for the internal coating of the pipe. For both (FBE and LBE) the same steps must be carried away, only for LBE no preheat is necessary.

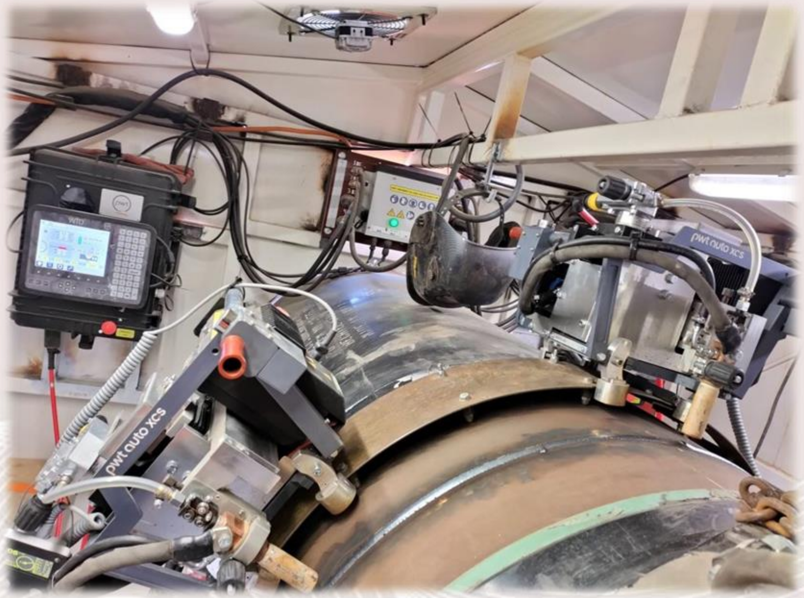
# Internal Protection – FBE

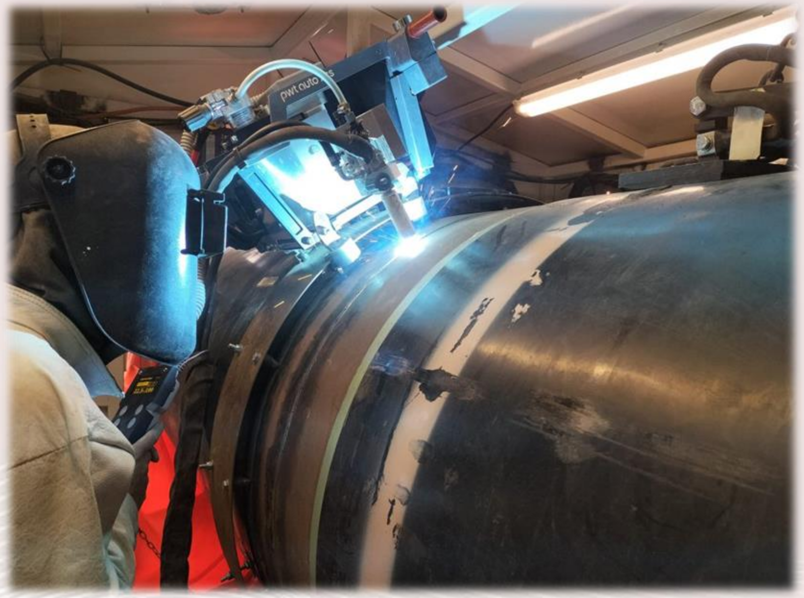
Additional welding considerations must be taken into account during the construction:

- Maximum penetration of 1/16”
- Good quality of the weld
- Clean cutback (no rust), so welding must be at most 24 hours after surface preparation and 24 hours prior to coating. This stresses coordination between welding front and coating front.
- Quality of the pipe (ovality)

# Internal Protection – FBE

Since there are strict requirements for the welding (penetration and quality), normally this is done by robotic machineries in a controlled environment to reduce quality rejects.

Welding might comply with API 1104, but still not be coatable.

# Internal Protection – FBE

Also, to minimize field welds, double joints are recommended, so pipes are welded at camp site under more favorable conditions, and then laid (24 m pipes).

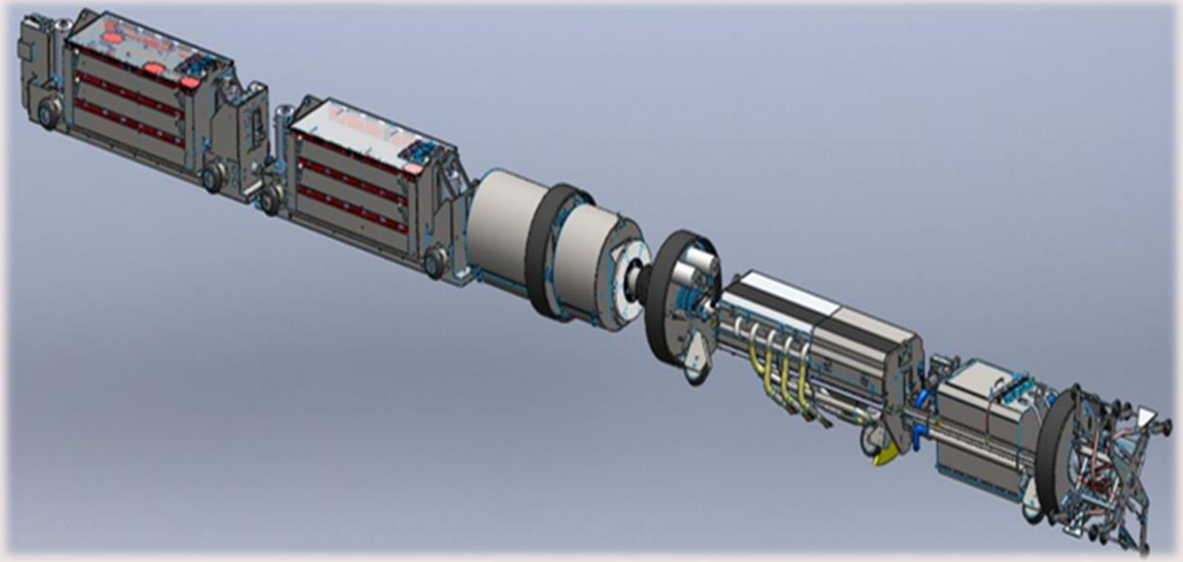
If FBE is to be used on the welding coatings trench needs to consider appropriate width for preheating element or coated prior to its lowering on the trench.

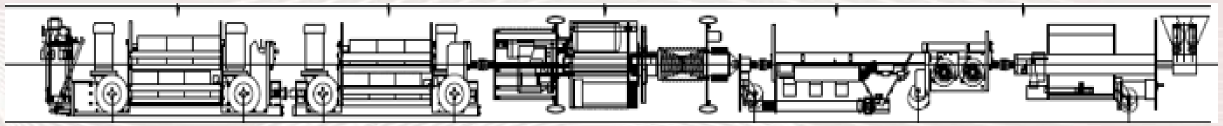
# Internal Protection – FBE

Field welds and camp welds require coating at site, typically performed by robots. To maintain the welding front efficiently—given that the welding speed is 12 meters per minute and the robots have a battery life of 5 to 10 hours—two or more robots may be needed per welding front. This requirement should be considered during the design stage, particularly given the maximum allowable pipe slope of 9% and the maximum bend of 1.5° per pipe diameter.

Also, mechanical joints might be used at some parts as a construction strategy, as robot only has a reach of 1 km.

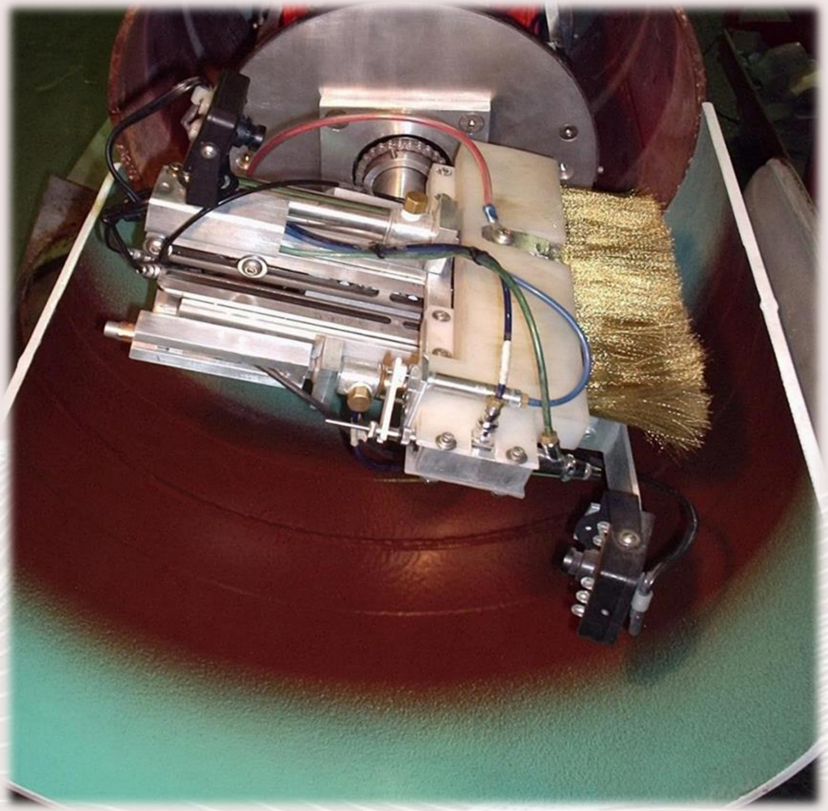
# Internal Protection – FBE





# Internal Protection – FBE

After application and curing time has passed, quality assurance is carried away via a holiday detector and the coating thicknesses is recorded (DFT or dry film thickness).



# Internal Protection – FBE

Main advantages of this form of protection (FBE) are:

- FBE comes applied on the pipe (no field work besides the welds). Depending on lifespan might be cheaper or more expensive than bare pipe.
- Good and stable barrier.
- No spare parts required (only paint and application equipment)
- Lower energy consumption as the friction coefficient is lower.

# Internal Protection – FBE

Main disadvantages:

- Quality of application can impact on disbandment.
- Damage on the coating will produce a focalized point of corrosion.
- Field repairs will require flange connections and design modifications.
- Presence of solids in the water can impinge and damage the coating.
- No lifespan assurance by vendors.

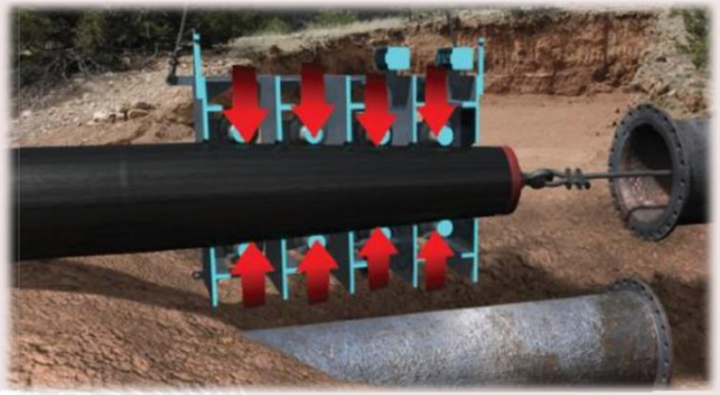
# Internal Protection – HDPE liner

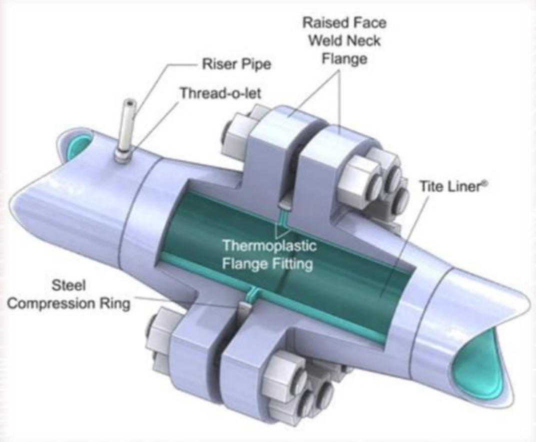
HDPE liner uses an internal pipe that is inserted inside a steel pipe.

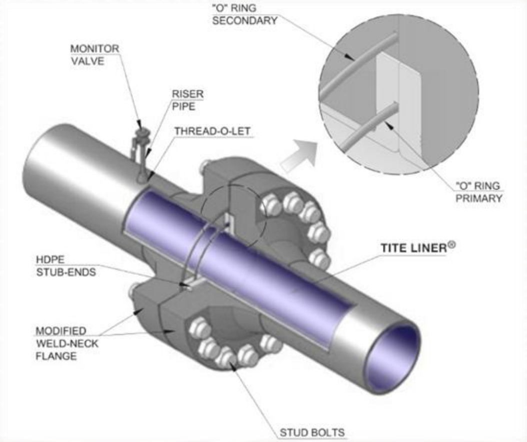
As such, the HDPE protects the steel, and structural capacity is provided by the steel pipe. Images presented in this section are extracted mainly form United Pipeline website (unitedpipeline.com) and used only for showcasing this technology.

# Internal Protection – HDPE liner

The HDPE pipe is inserted on a finished steel pipe which length can be between 600 m and 1,5 km depending on the curvature of the section (‘threaded’). Each end is flanged (Welding neck, RF).






# Internal Protection – HDPE liner

The HDPE liner is anchored at each flanges end and constrained in the pipe via an interference fit achieved via the initial deformation during installation (on elastic range).

Thickness of the liner can be modified as necessary between a minimum to withstand vacuum pressure (not collapsing) and recommended maximum of ¾” so as to keep the lengths from shortening excessively.

It’s installed with 2 ports (threadolets), one besides each flange to extract the air during insertion, which can then be used for inspection.

# Internal Protection – HDPE liner

Main advantages of this form of protection (HDPE liner) are:

- No interaction with welding front.
- Good and stable barrier.
- Lifespan of 25 years guaranteed by vendor.
- High abrasion resistance given to its low abrasion coefficient.
- Lower energy consumption as the friction coefficient is lower.

# Internal Protection – HDPE liner

Main disadvantages:

- Higher Capex.
- HDPE based, so compatibility with fluids must be considered (hydrocarbons presence).
- Repairs and modifications require especial spare parts (flanges are machined and particular to each diameter/thickness/ASME Rating).
- Temporary repairs can be done with specialty spare parts.
- Steel thickness can't be measured via PIGs because of the liner.
- Susceptible to plugging in case of liner failure.

# Internal Protection – Cement Mortar

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Cement mortar is a liner which produces a wear and corrosion resistant protection.

Its main characteristics are its corrosion resistance, smoothness (transport efficiency), lifespan, similar temperature behavior to steel (expansion). Its self-healing for hairlines type cracks and damage.

Its main weaknesses is its thickness, as it reduces the internal diameter, difficulty to apply in bends, so a less flexible from a constructability standpoint, it's a very labor-intensive liner and at high pressure can produce cracks that jeopardize the integrity of the protection as steel has more elastic range than cement.

It has to be applied on site by skilled labor and specialized equipment.

# Final Words

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3 different possibilities were reviewed:

- Bare Steel
- FBE liner
- HDPE liner

All of them are used to ensure a safe and continuous operation of pipeline systems.

Depending on the situation and system characteristics one might be the best fit for each design.

# Internal Protection – Final Words

As an example, for freshwater application, bare steel or FBE will meet the required lifespan expectancy with lower costs. However, for sea water application, bare steel might not be enough as corrosion rate may be excessive in the absence of proper chemical treatment.

A corrosion rate of the fluid is necessary to achieve a good result on the TOS, the same with abrasion on slurries, in which normally a miller number test is carried away to check whether a HDPE liner is recommended.

As stated before, a risk analysis is recommended as subjective elements might outweigh technical elements, as more communicational or political factors can be involved (nearby communities, landmarks, environmental sites, etc).

# Thanks! Questions?