Corrosion Resistant Flowlines Installed by Reel-lay

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Corrosion Resistant Flowlines Installed by Reel-lay

Industry trends

- Deeper water
- Long tiebacks
- Deeper reservoirs
- Higher pressures and temperatures
- More corrosive reservoir fluids

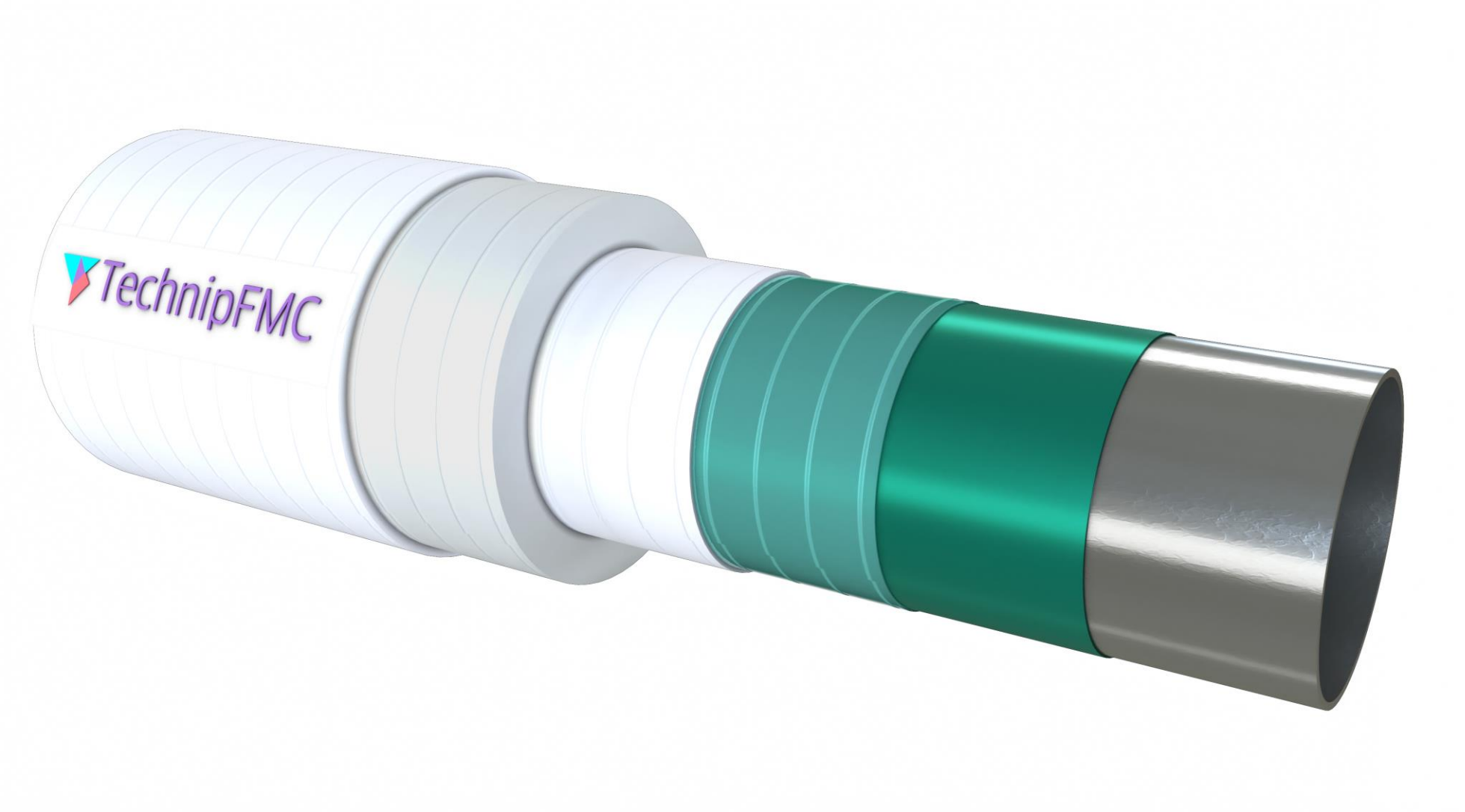
Subsea flowlines

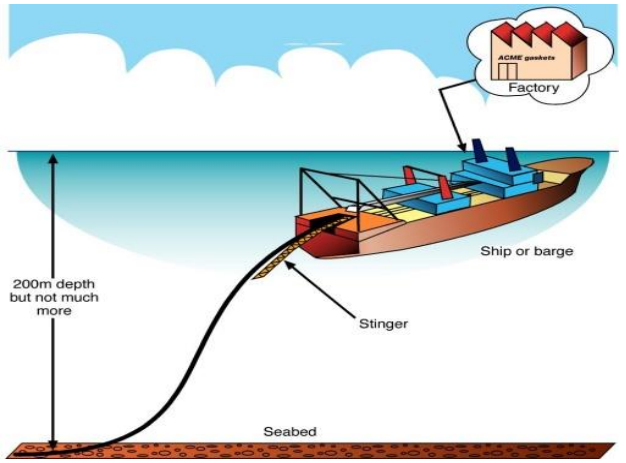
- Tieback flowlines are small diameter
- Reel-lay is most competitive solution for rigid flowlines
- Corrosive reservoir fluids require CRA flowlines

Cost-effective reeled CRA flowlines required

Reel-lay Flowlines

Rigid Flowlines

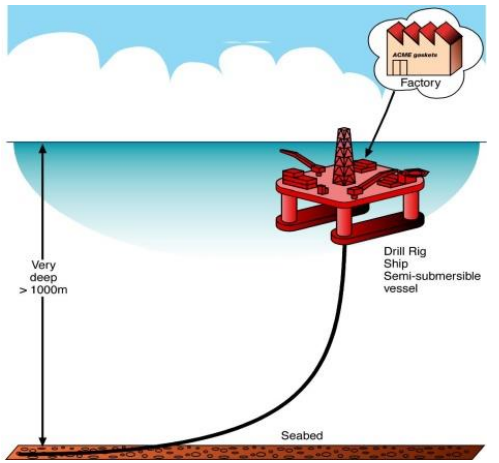




- **S-lay**

  Offshore fabrication on a horizontal firing line

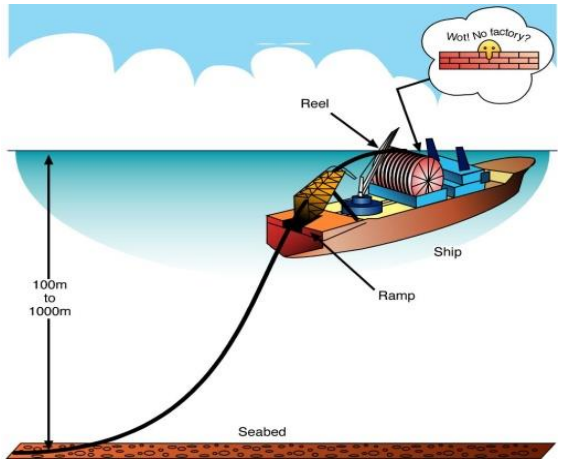
  Traditional offshore pipeline installation method, suitable for shallow water



- **J-lay**

  Offshore fabrication on a (near) vertical firing line

  Suitable for deep water, high top tension



- **Reel-lay**

  Onshore fabrication onto a storage reel on the vessel

  Suitable for small diameter ≤ 18” OD

Reel-Lay

Onshore fabrication

- High quality welding, inspection and assembly

Rapid offshore installation

- Vessel time is minimised

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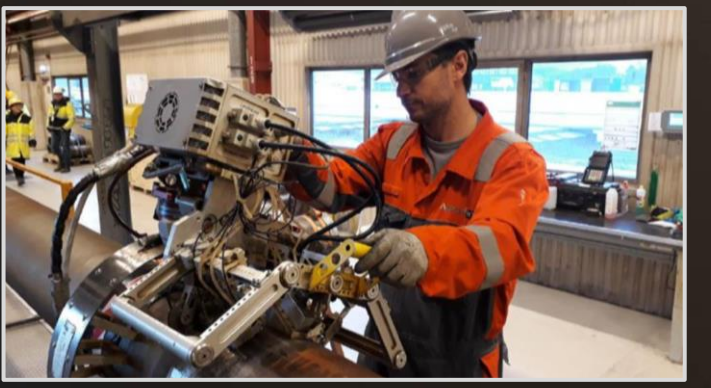
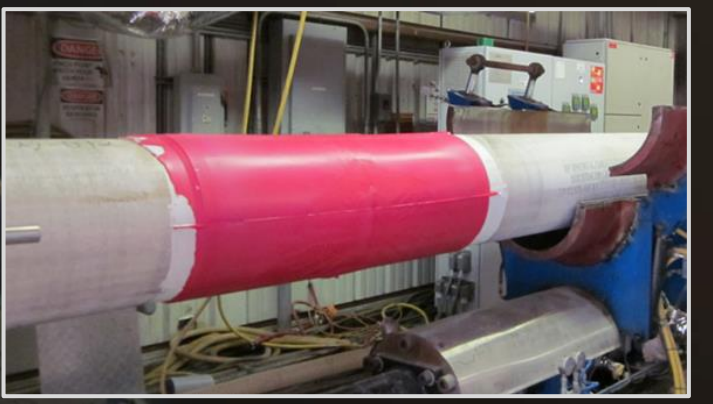
Assembly

- Pipe joints are prepared, welded, inspected, and field-joint coated
- Pipe stalks (typically 1 km in length) are stored on the pipe racks





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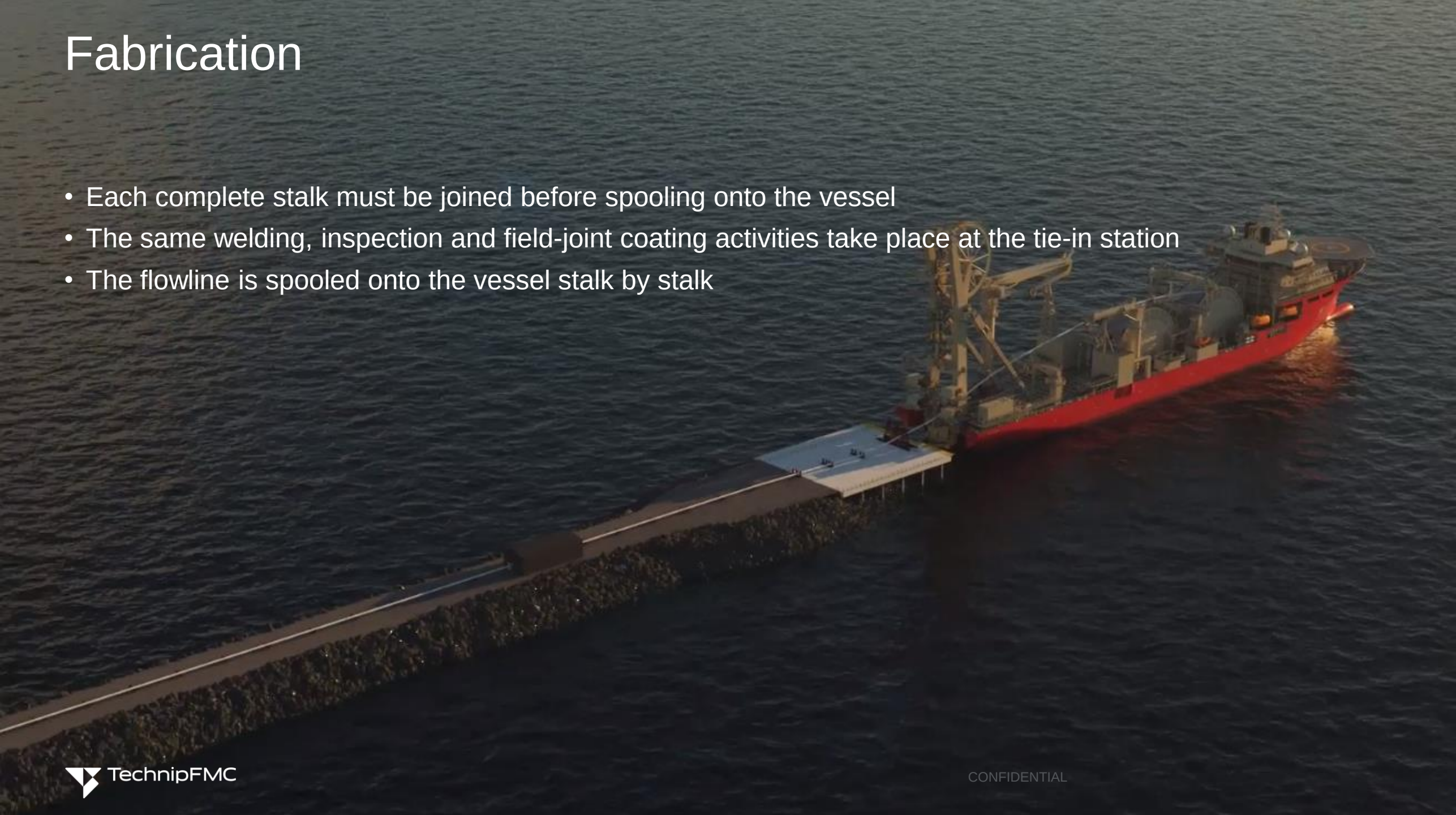
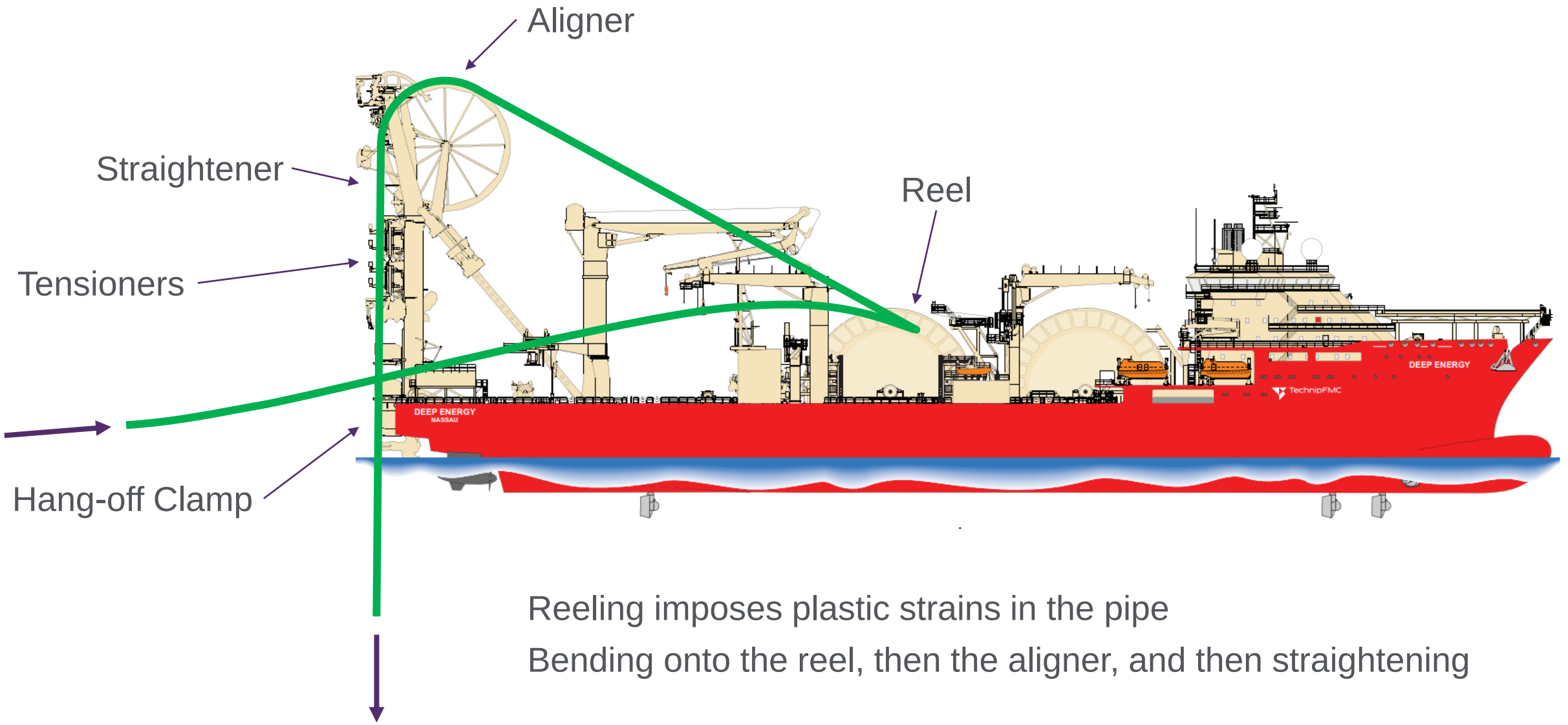
Fabrication



- Each complete stalk must be joined before spooling onto the vessel
- The same welding, inspection and field-joint coating activities take place at the tie-in station
- The flowline is spooled onto the vessel stalk by stalk

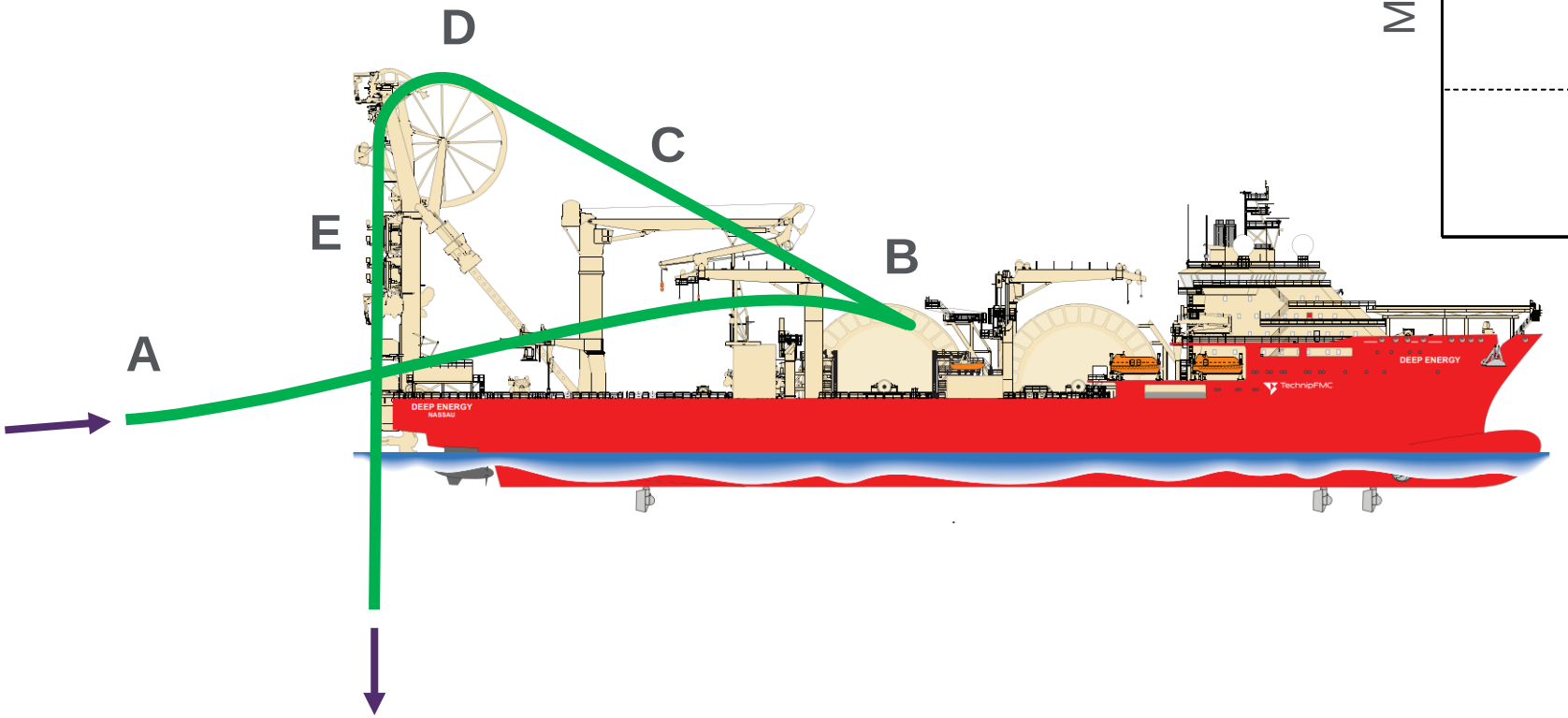
Reel-Lay

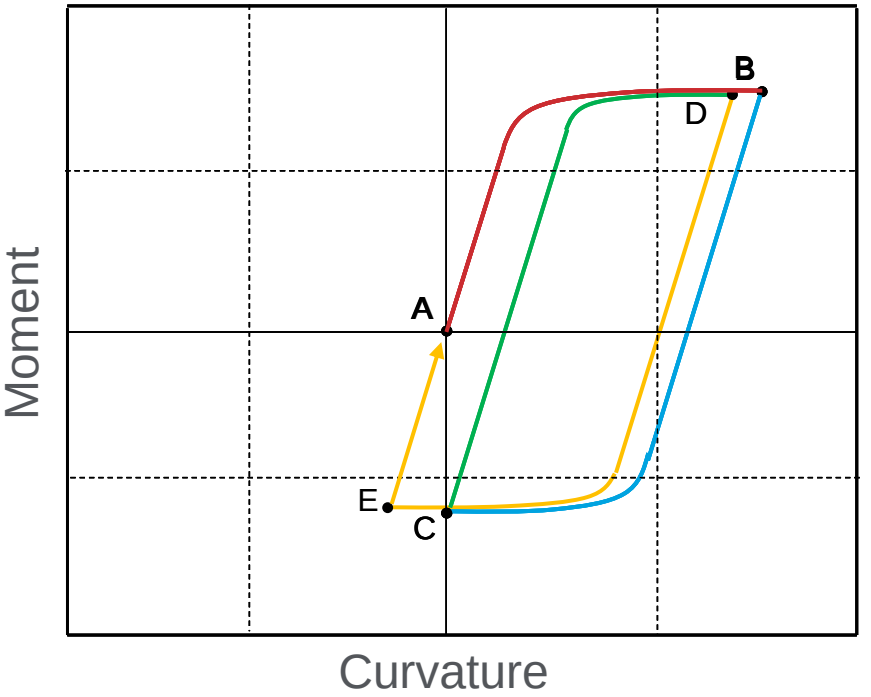


Reeling imposes plastic strains in the pipe

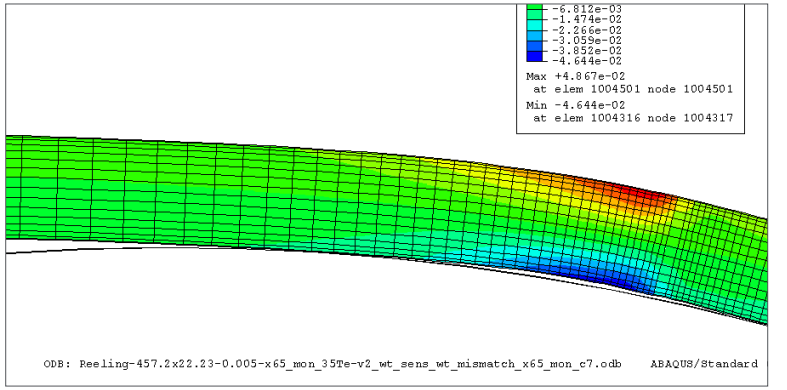
Bending onto the reel, then the aligner, and then straightening

Reel-Lay





Engineering Challenges



Strain localisation

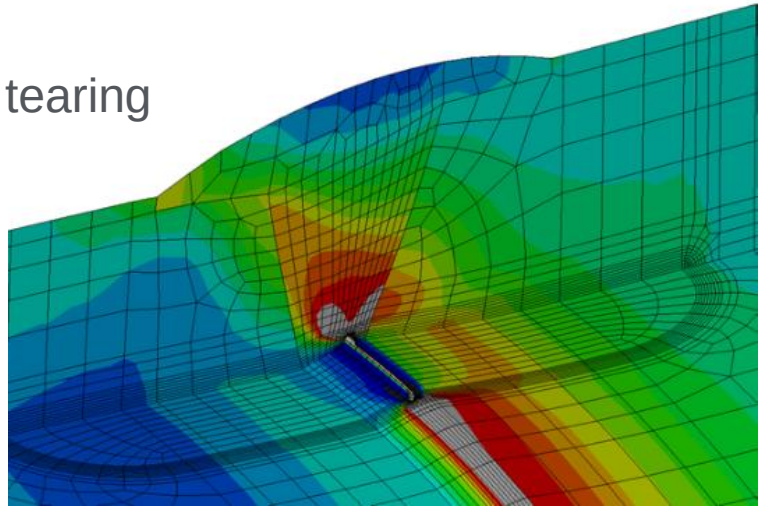
- High local strains caused by variability (size and strength) between pipe joints

Ovalisation

- Ovality caused by high bending strains

Defect growth

- Growth of weld defects through tearing



Linepipe materials

Material Selection

Carbon steel

Low alloy steels

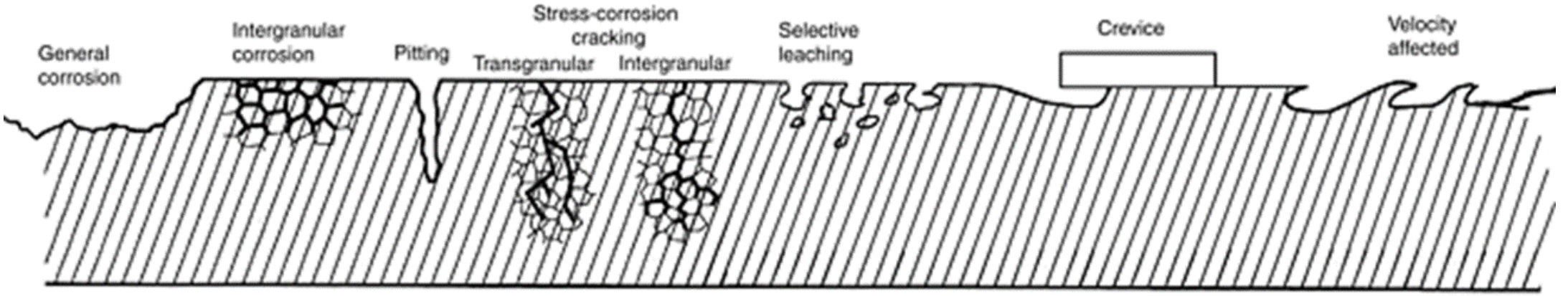
High alloy steels

Increasing corrosion resistance… and cost

General corrosion (metal loss)

Cracking (high-risk)

Corrosion mechanism	Carbon and low alloy steel
CO_2 and H_2S corrosion	Yes
MIC	Yes
SSC/SCC caused by H_2S	Yes
HIC/SWC	Yes
ASCC	Yes
SCC without H_2S	No



Material Selection

Super-martensitic stainless steels

- 13 Cr

Duplex (austenitic-ferritic) stainless steels

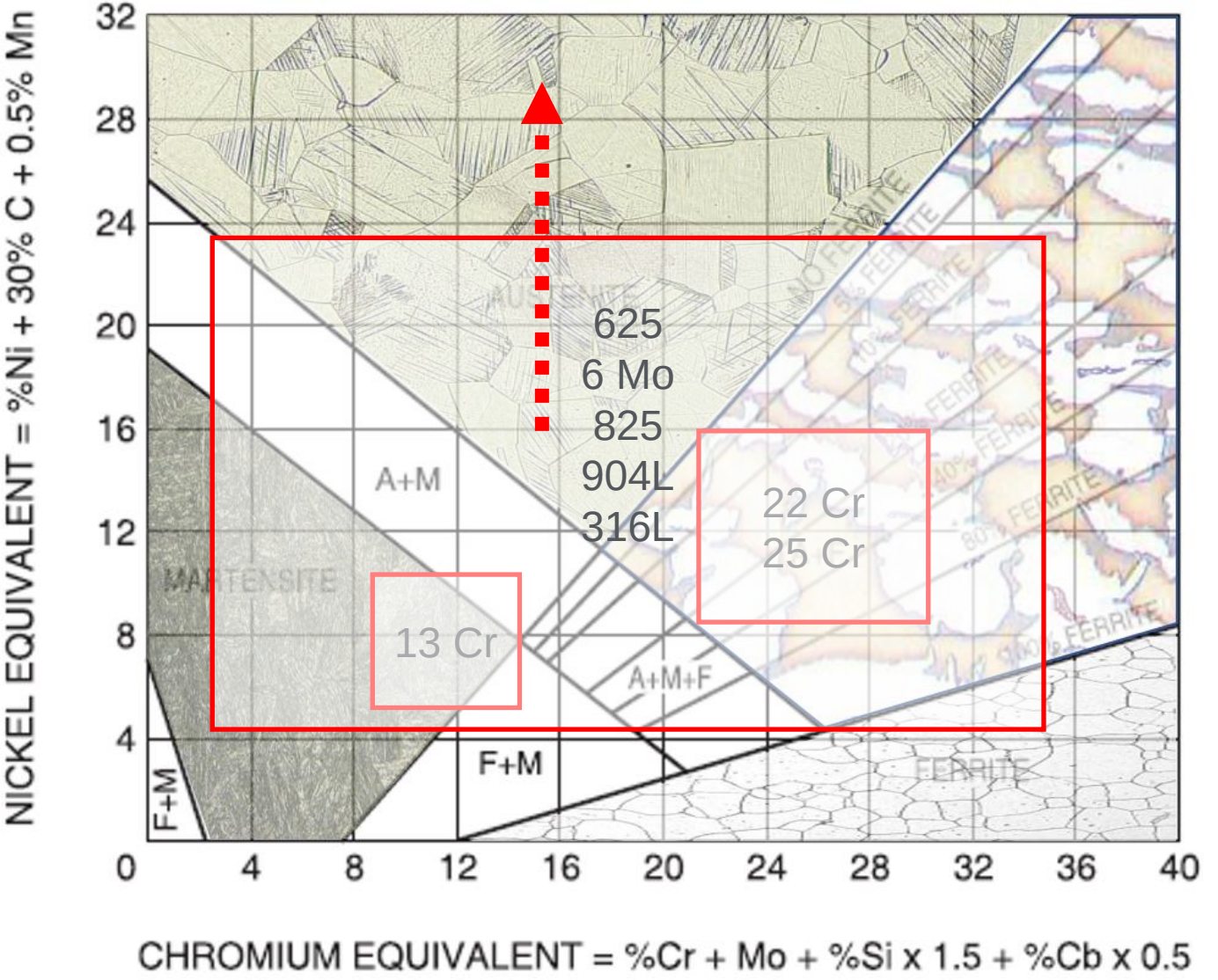
- 22 Cr (Duplex)
- 25 Cr (Super Duplex)

Austenitic stainless steels

- 316L & 317L
- 904L
- 6 Mo

Ni-base alloys

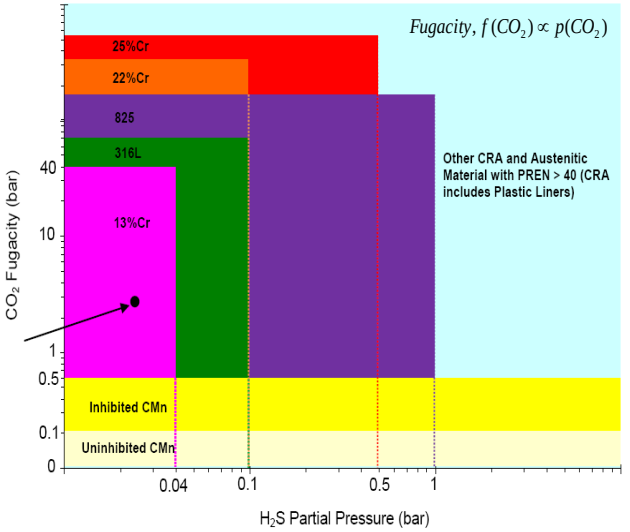
- Alloy 825
- Alloy 625



Material Selection

Selection

- ISO 15156 (Parts 1, 2 & 3), EFC 16, EFC 17, Norsok M-001
- Depends on H_2S, Cl-, pH, temperature, O_2, pressure, material condition



CRA Grade	UNS	Application	PREN (1)	Yield Strength (MPa), Min	Approximate CRA Price ($/kg)
13Cr	UNS S41426	Solid CRA	13	550	10
22Cr	UNS S31803	Solid CRA	35	450	25
25Cr	UNS S32760	Solid CRA	40	550	33
316L	UNS S31603	Bi-Metallic (MLP/HRB)	26	207	12
317L	UNS S31703	Bi-Metallic (MLP/HRB)	28	207	14
904L	UNS N08904	Bi-Metallic (MLP)	35	220	25
Alloy 825	UNS N08825	Bi-Metallic (MLP/HRB)	30	240	33
6 Mo	UNS S31254	Bi-Metallic (MLP)	42	320	33
Alloy 625	UNS N06625	Bi-Metallic (MLP/HRB)	45	276	55

(1) PREN > 40 is required for raw seawater corrosion resistance.

CRA with higher strength

Solid CRA

CRA with lower strength

MLP

HRB

Applications

Solid CRA

13Cr, 22Cr, 25Cr

- High strength alloys - used as solid linepipe
- Good corrosion resistance to production fluid

Manufacturing processes:

- **13Cr**: Seamless process (plug & mandrel mills)
- **22Cr & 25Cr:** Seamless (plug & mandrel mills or hot extrusion), or seam welded pipes (JCO)

Reel-lay application:

- Straightforward to install by reel-lay (significant reel-lay track record)
- Duplex (22Cr) and super duplex (25Cr) becoming less common due to high material cost
- Lower cost 13Cr remains popular in market

Seamless pipe

Duplex stainless steel pipes. © Butting

Bi-metallic Bonded Pipe

Low strength, high corrosion resistance alloys

- 316L, 904L, 6Mo, Alloy 825 & Alloy 625

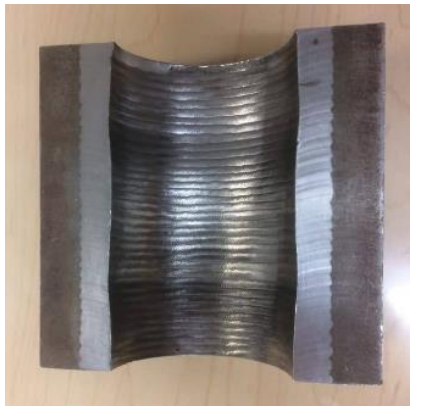
Hot-Rolled Bonded Pipe, HRB

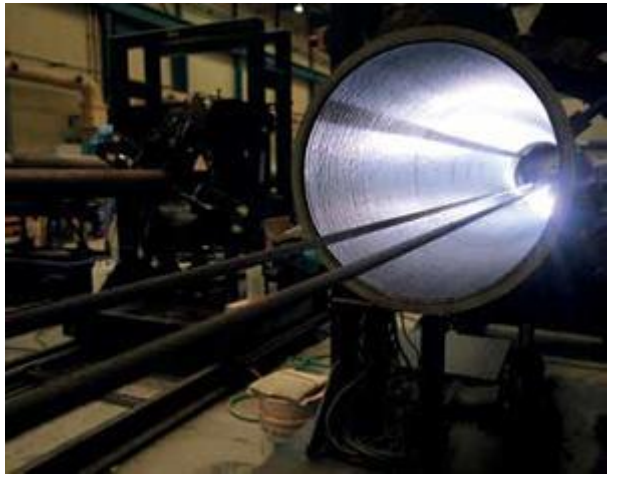
- Seam-welded linepipe manufacture from bi-metallic plate
- Metallurgical bond between liner and carbon steel parent pipe
- Straightforward to install by reel-lay
- Increasing reel-lay track record

Hot-rolled bonded pipe

Weld overlay pipe (WOL)

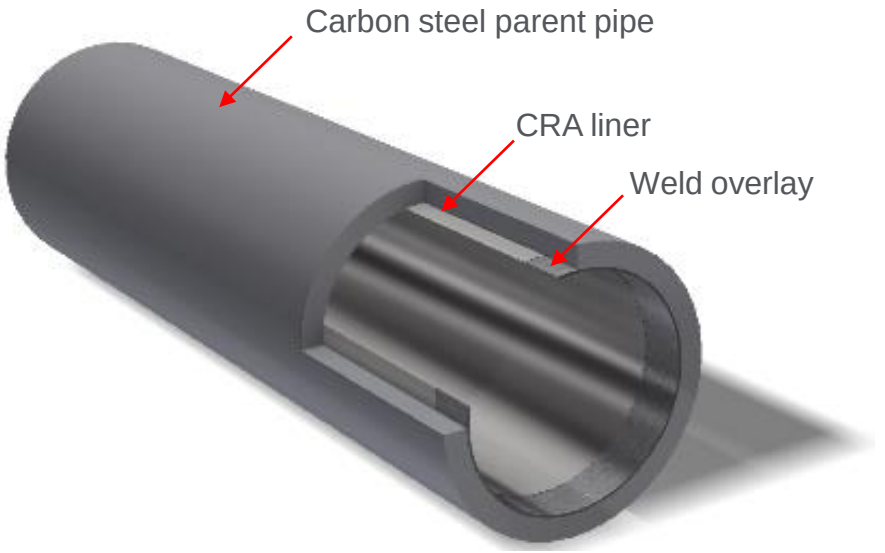
- Cladding applied by overlay welding (mainly Alloy 625)
- Metallurgical bond with carbon steel parent pipe
- Expensive to manufacture, lower productivity
- Suitable for short lengths only





Weld overlay pipe

Mechanically-Lined Pipe, MLP



Low strength, high corrosion resistance alloys

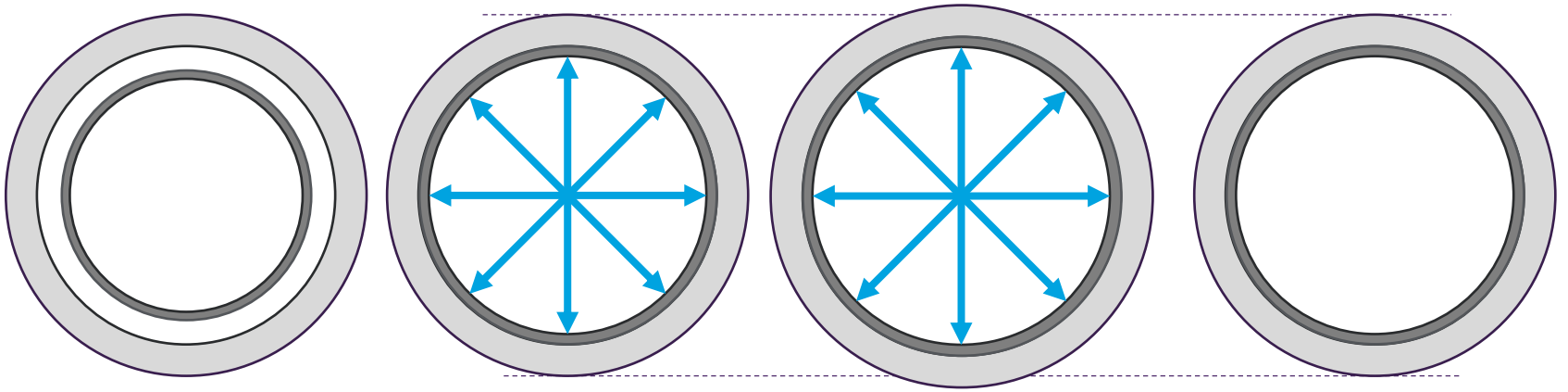
- 316L, 904L, 6Mo, Alloy 825 & Alloy 625

Manufacture by insertion and hydraulic expansion of CRA liner

Mechanical interference fit between liner and carbon steel parent

Cheaper product compared to HRB or weld overlay pipes

Growing reel-lay track record



Insertion of liner

Expansion of liner under hydraulic pressure

Expansion of liner and parent pipe under hydraulic pressure

Partial relaxation of both pipes

Mechanically-lined pipe

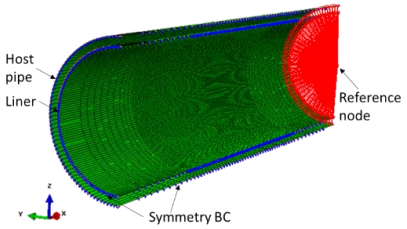
Reel-Lay MLP

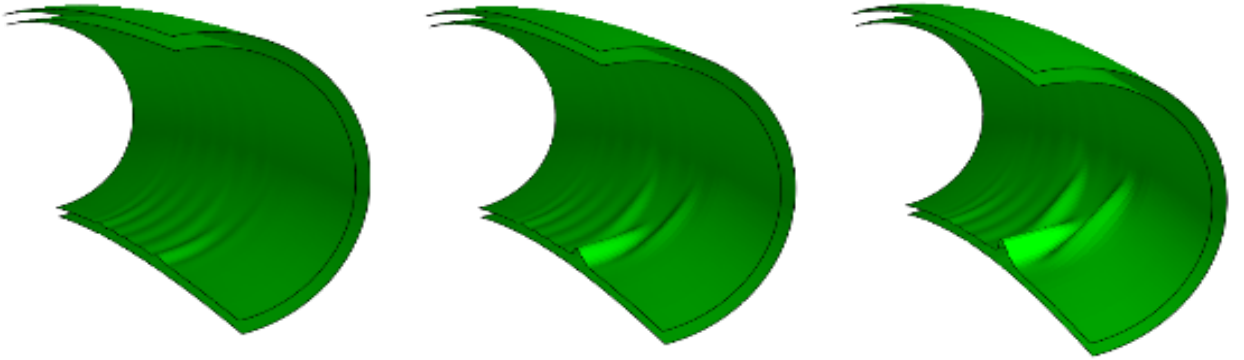
Liner held in place through residual expansion

Risk of liner wrinkling under high reeling strains

A nominal 3 mm liner is likely to wrinkle for MLP > 6” inside diameter

Strain capacity must be increased to allow reel-lay





Reel-lay MLP

Increased liner thickness

- Stability ensured by increasing the liner thickness
- Suitable for medium diameter flowlines and lower cost liner alloys (e.g. 316L)

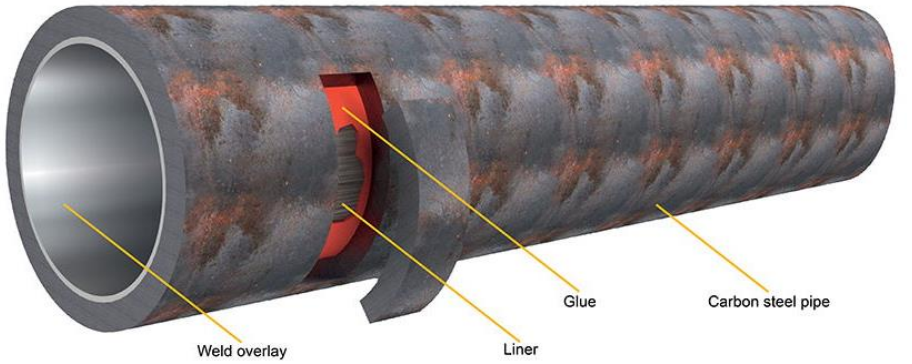
Install under internal pressure

- Stability ensured by flooding the pipe and reeling under internal pressure
- Suitable for large diameter flowlines (>10”) and higher cost liner alloys

Bonded liner – Glubi

- Stability ensured by bonding the liner pipe to the parent pipe
- Suitable for larger diameter flowlines and higher cost liner alloys

BUTTING



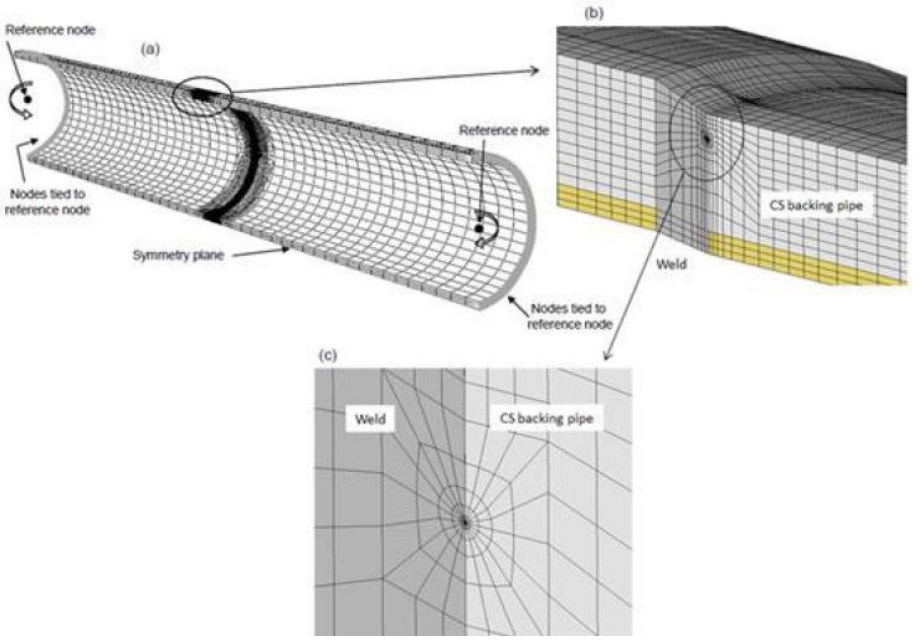
Reel-lay MLP

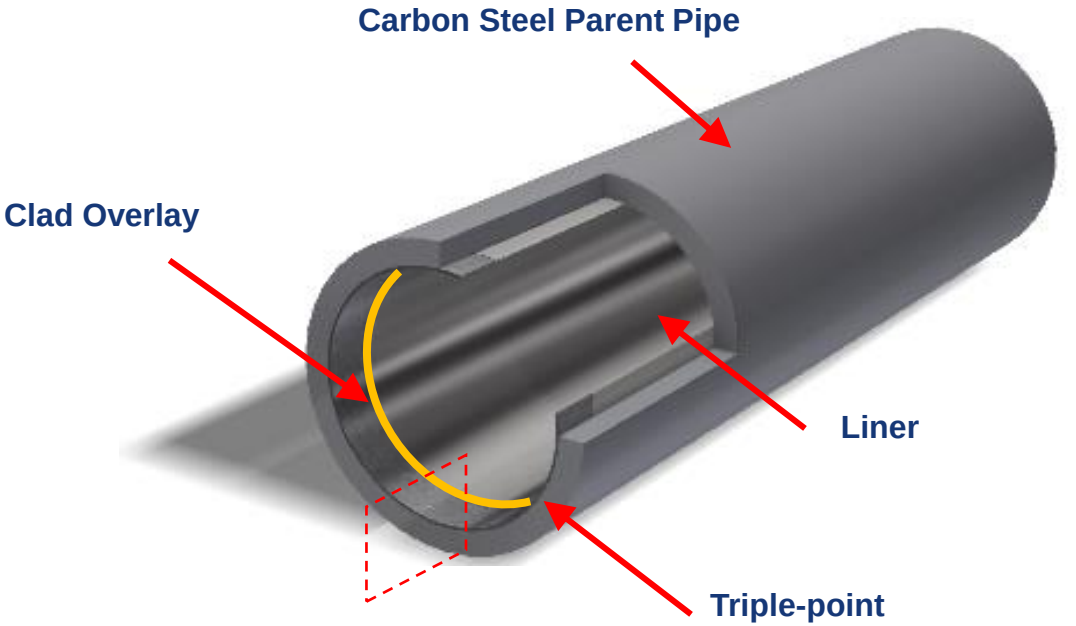
MLP “triple-point”

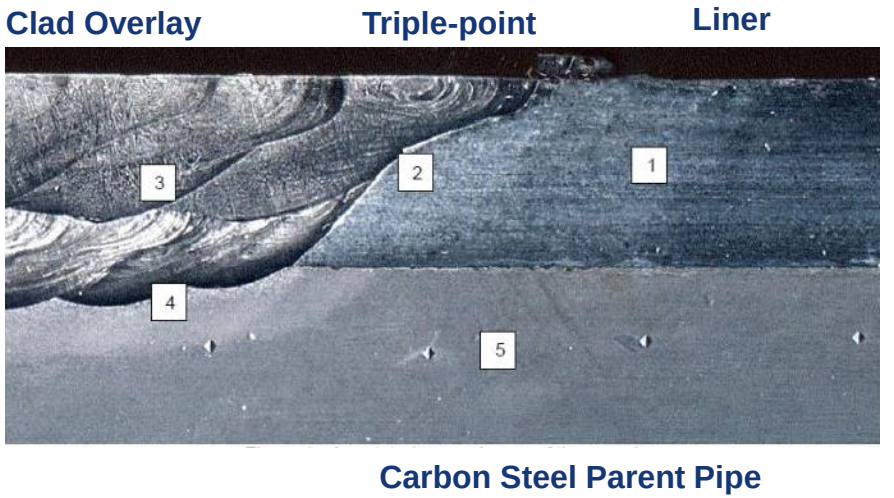
- Intersection of the liner, clad overlay and parent pipe

Significant focus of attention

- Liner separation during reeling
- Residual defects during manufacture
- Defect growth during reeling and installation







Plastic Liners

Plastic-Lined Pipelines

Steel parent pipe with polymer liner

Low cost corrosion solution, widely used onshore for water supply

Extensive reel-lay track record for water injection service

- Liner insertion into each stalk at the spoolbase

Hydrocarbon service?

- Gases permeate through the liner during service
- Gases build-up in the annulus
- The liner may collapse on depressurisation

Qualified solutions are now available to manage permeation for low corrosive conditions

Conclusions

Corrosion resistant subsea flowlines applications are increasing

Reel-lay is the primary installation method for rigid flowlines

Optimised engineering solutions are available for the installation of cost-effective CRA flowlines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