# Seleção de materiais resistentes à corrosão (CRA) para dutos flexíveis

**Roberta Pires**

Intercorr Conference, held in Búzios, 18 Maio 2016

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# Seleção de materiais resistentes à corrosão (CRA) para dutos flexíveis

## Agenda

- An introduction to flexible pipes
- Material in contact with the fluid: the carcass
- Carcass Materials
- Corrosion Mechanisms
- Selecting the right material
- Carcass Corrosion Test
- Future conditions and its materials

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# An Introduction to Flexible Pipes

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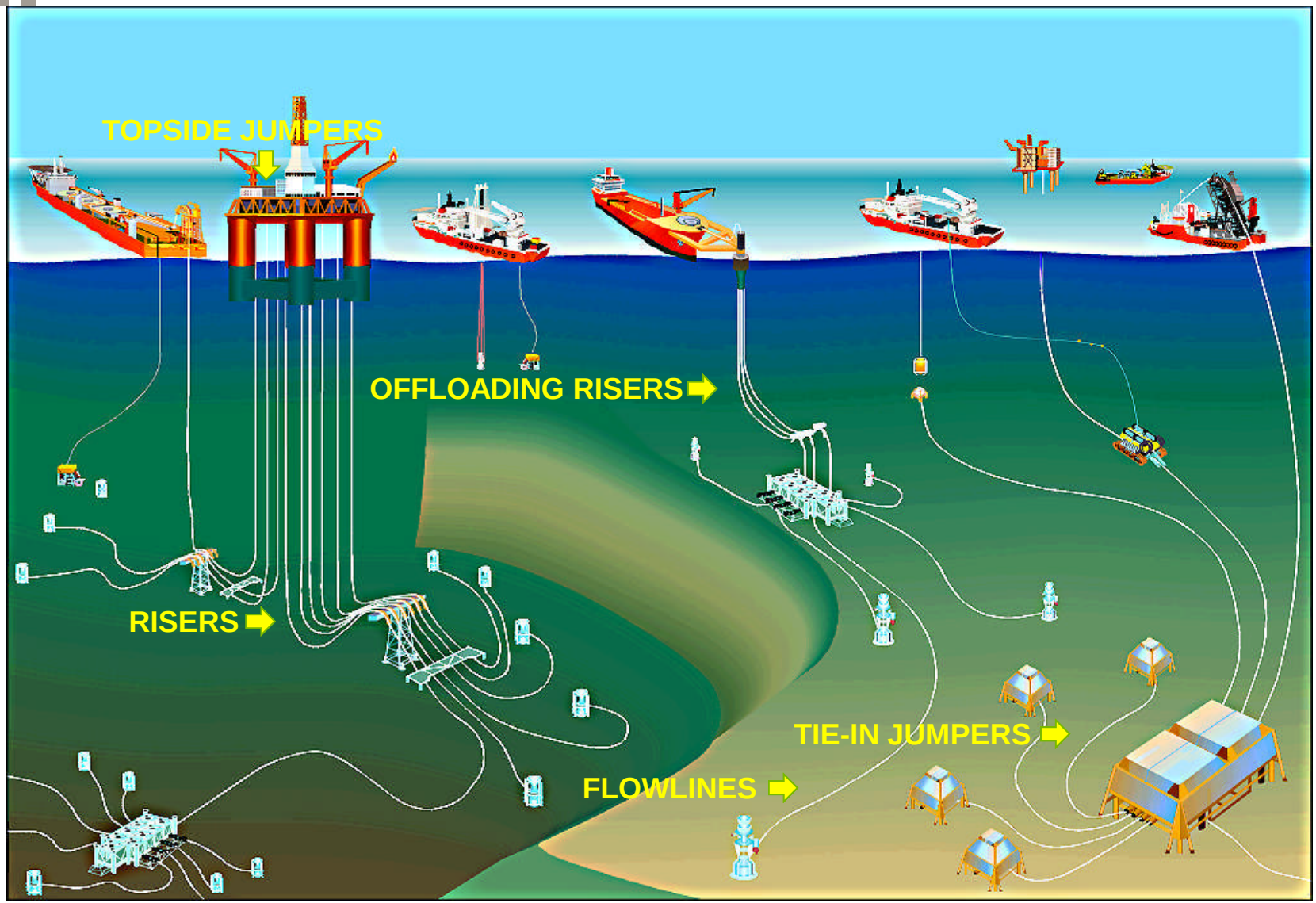
# Types of flexible pipes

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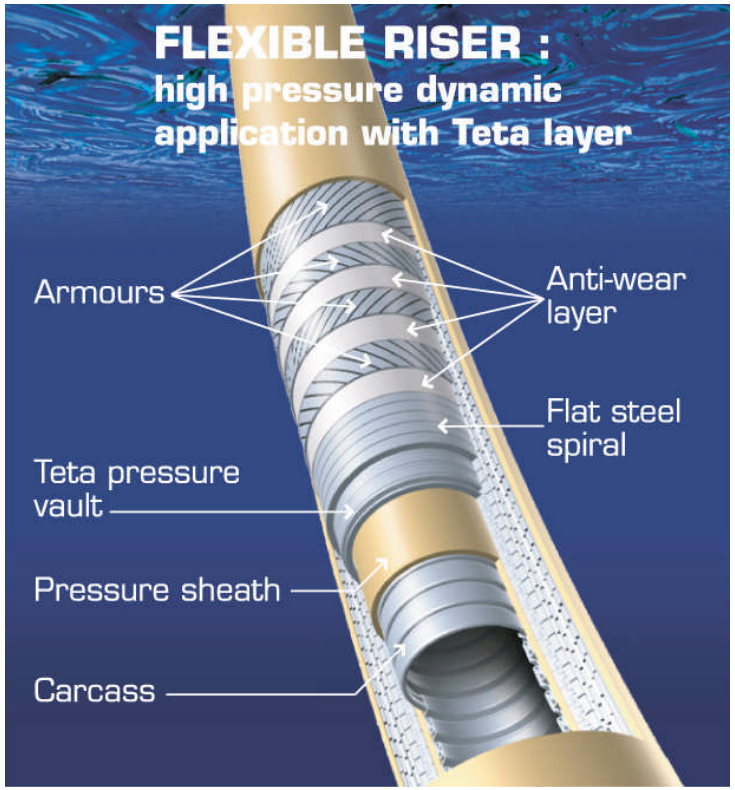
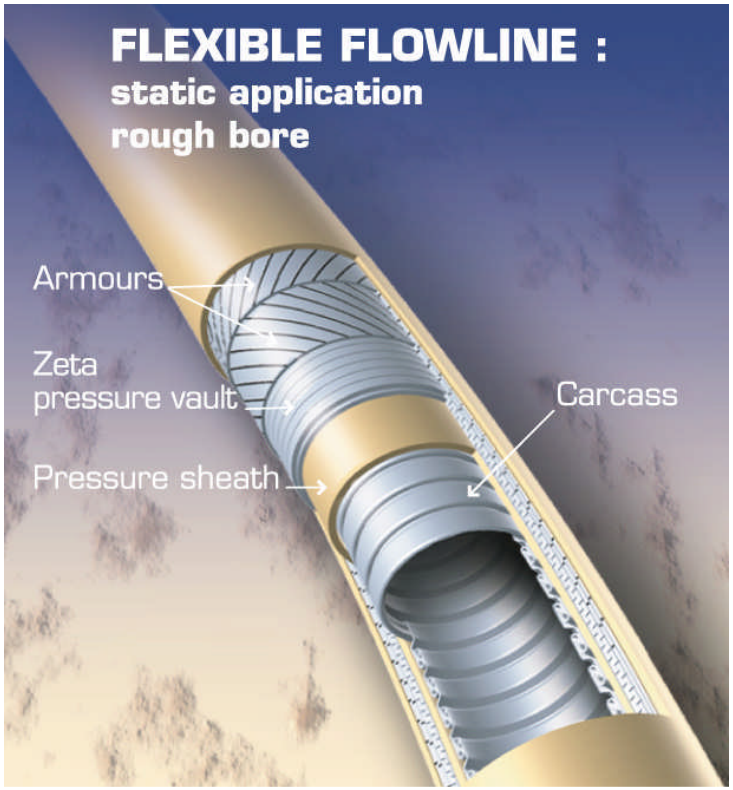
# Dynamic / Static application

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# Material in Contact with the Fluid: the Carcass

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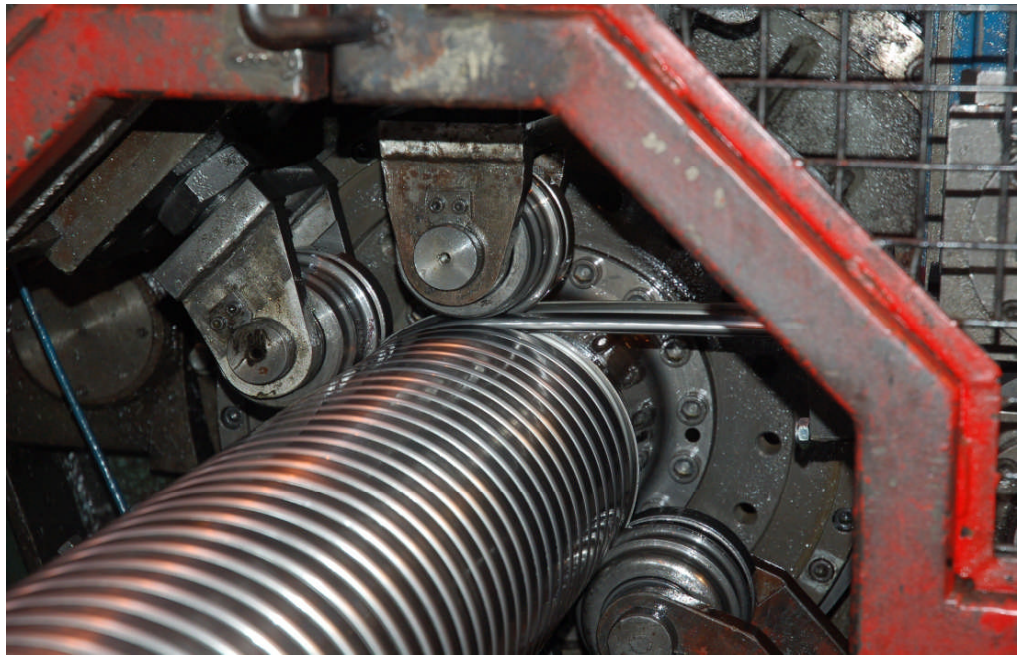
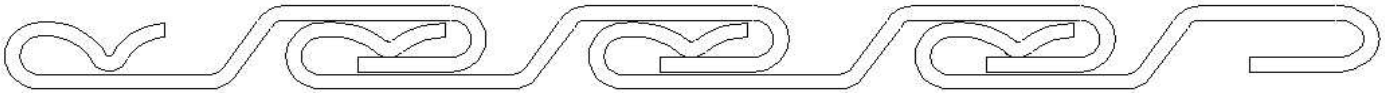
# Material in contact with fluid: the carcass





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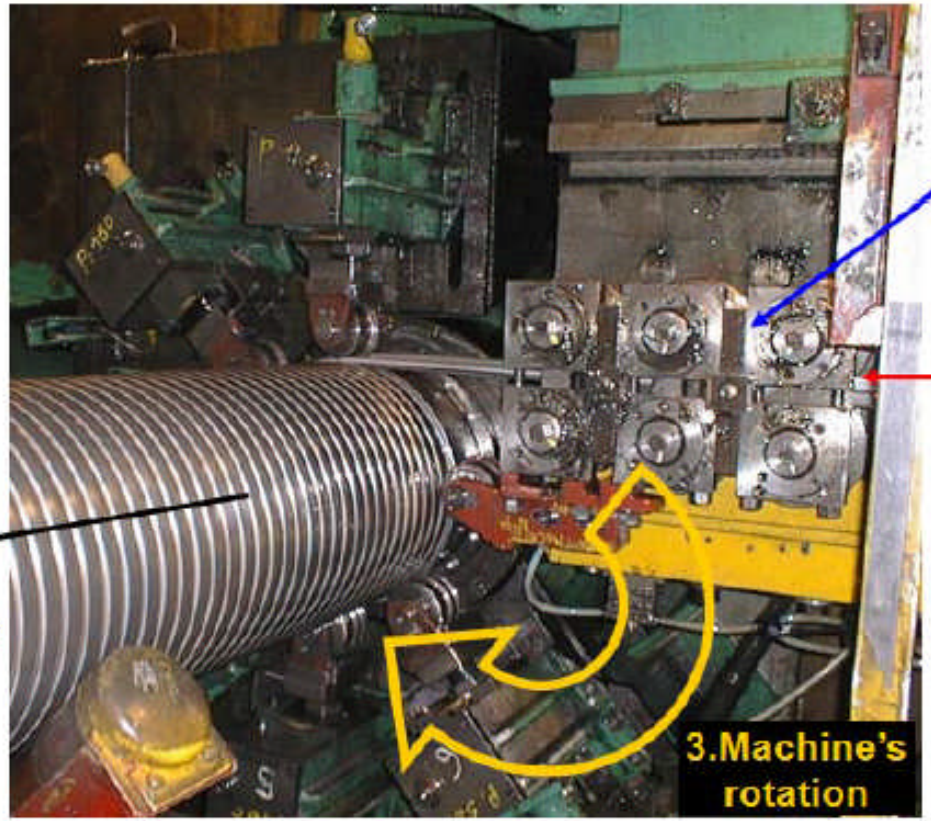
# Material in contact with fluid: the carcass

- Profiling and spiraling




2. Successive rolls to deform the strip and obtain the staple shape

1. Stainless steel strip's entrance

4. Flexible pipe's advance

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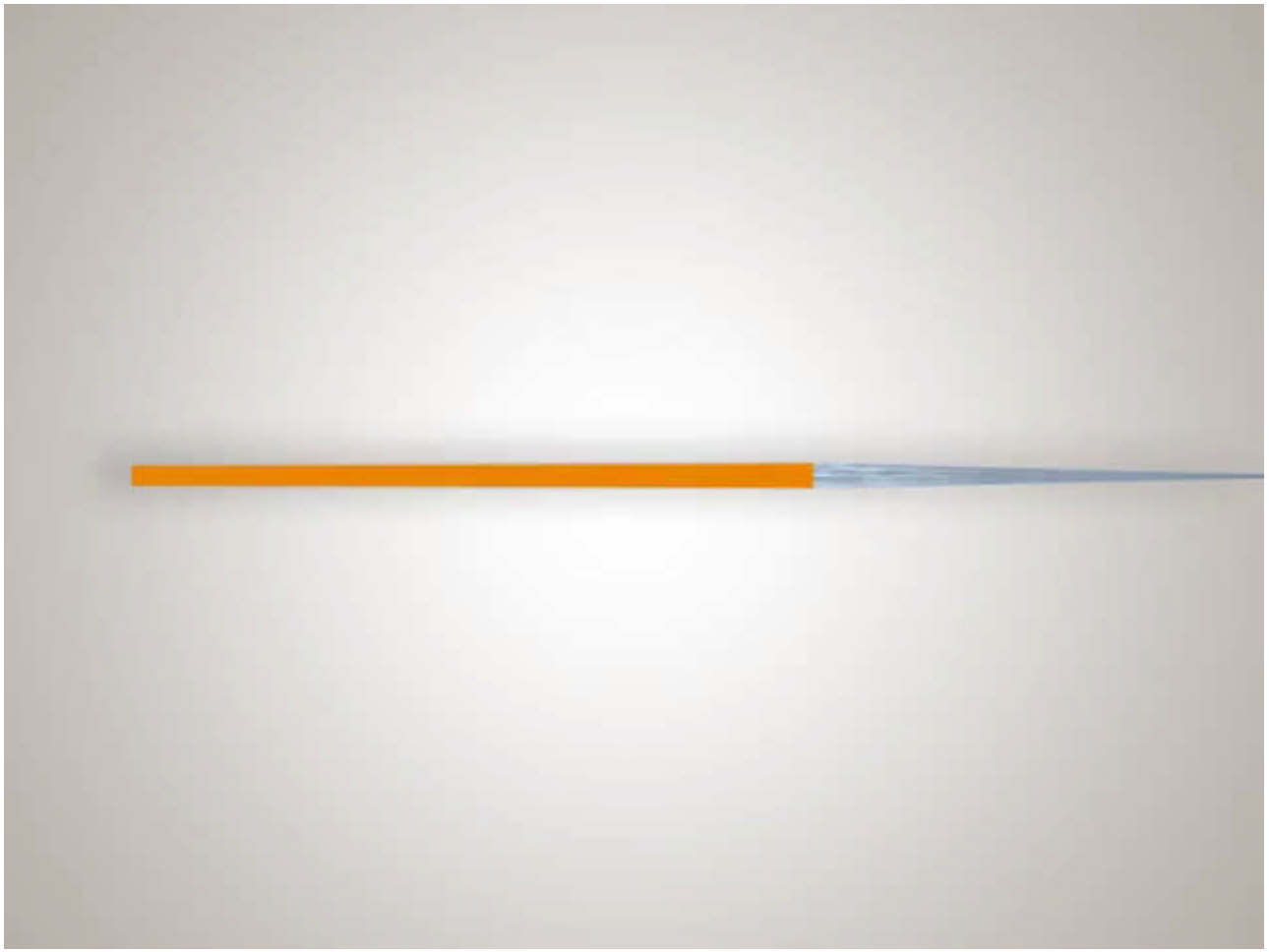
# Material in contact with fluid: the carcass



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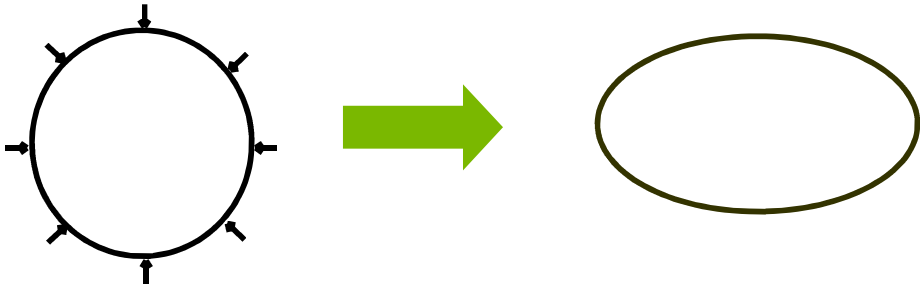
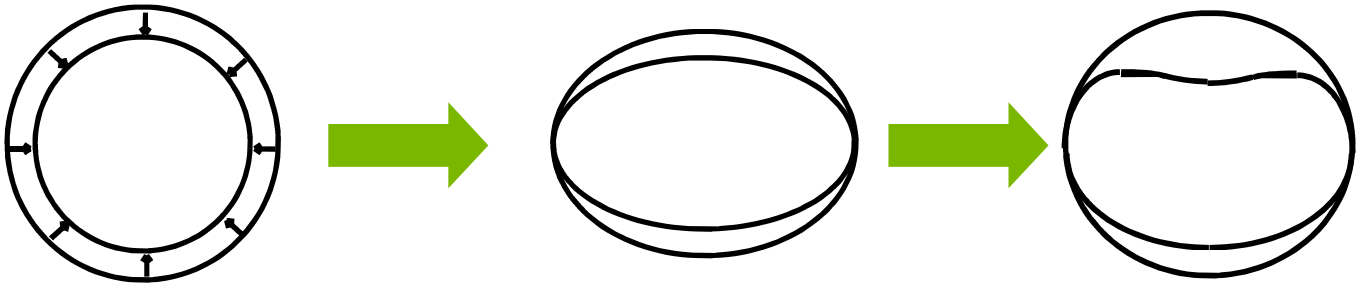
# Mechanical behavior

## External pressure

- **Hydrostatic collapse**
  - 1 vault



  - 2 vaults



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# Mechanical behavior

- **Installation vessel**
  - Vertical Laying system
  - Pulley

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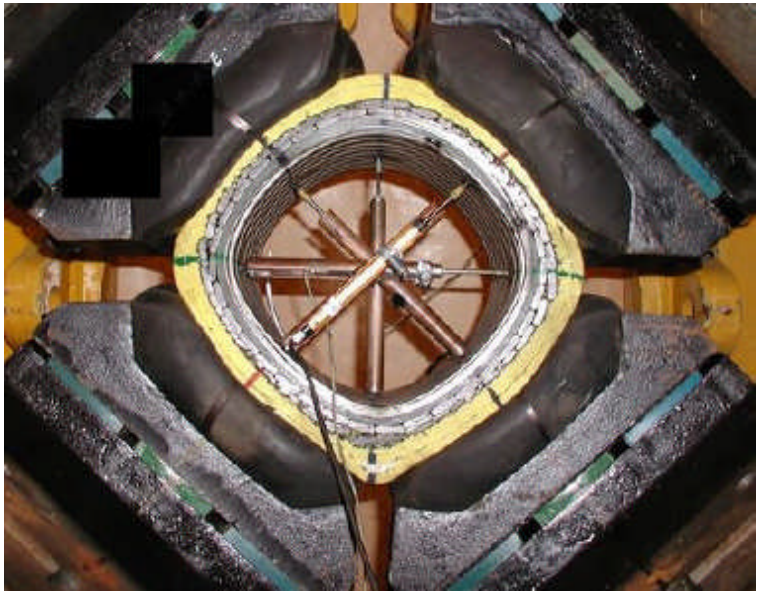
# Mechanical behavior



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# Material in contact with fluid: the carcass

- **Functions:**

  - Transport of fluids: it is in direct contact
  - Prevents:
    - Collapse due to external hydrostatic pressure during operation and installation
    - Over ovalization due to crushing during installation
    - Damage on the plastic pressure sheath with tools used for work in wells

- **Many stainless steels grades, selected regarding:**
  - Mechanical properties
  - Corrosion resistance
  - Cost


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# Carcass Materials

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# Carcass Materials

- **Austenitic stainless steels (Fe-Cr-Ni)**: 16 to 26 % Cr and 7 to 22 % Ni.

  ex.: 304, 304L (18 % Cr / 8 % Ni),

  316, 316L (18% Cr / 10% Ni / 2 % Mo)

- **Duplex stainless steels: austenitic and ferritic phases.**

  ex.: 2205 = S32205 (22 % Cr / 5 % Ni / 3 % Mo)

  2304 = S32304 (23 % Cr / 4 % Ni)

- **Super duplex stainless steels:** duplex stainless steels + high contents of Mo, Cr and N .

  ex.: 2507 = S32750 (25% Cr / 7 % Ni / 4 % Mo)

- **Alloy 31:** Fe-Ni-Cr-Mo alloy

**More noble**

US standards

(usual) UNS Nb

(2507) S32550
(2507) S32750

(2205) S31803
(2205) S32205

(2304) S32304

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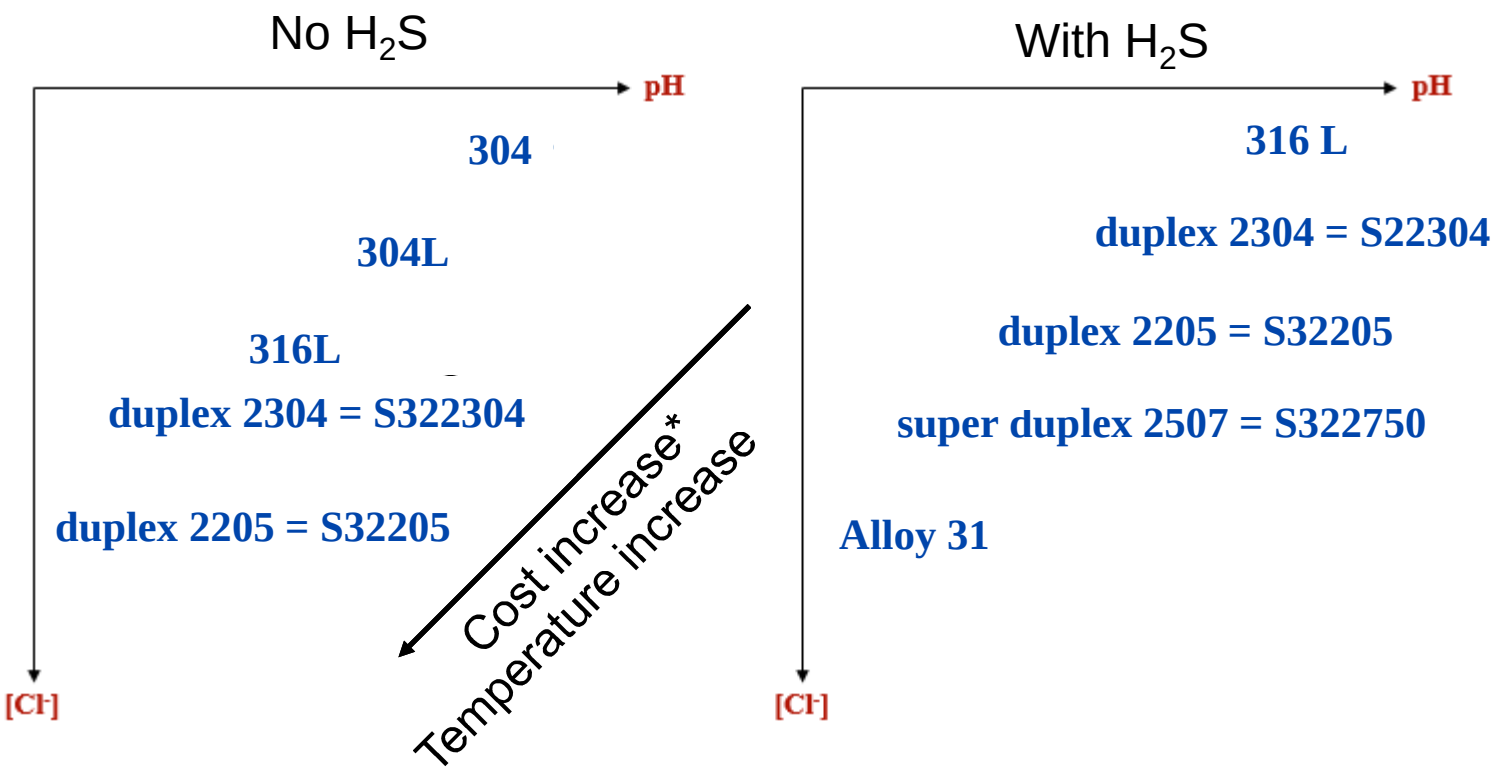
# Carcass Materials




US standards

(usual) UNS Nb

(2507) S32550
(2507) S32750

(2205) S31803
(2205) S32205

(2304) S32304

*indication only as it varies a lot with market

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# Selecting the Right Material

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# Selecting the Right Material

**NACE standard MR0175 / ISO 15156 not applicable for carcass selection**

**Carcass deformed during spiralling, hardness increase (autoclave tests necessary)**

Operator usually does not directly determines material.

Operator issues a technical specification containing:

- Water composition, including chlorides, carbonates and any molecule that can affect pH
- Oil chemical composition, including $H_2S$ and $CO_2$ acid gases
- Pressure,
- Temperature.

Flexible pipe manufacturer calculates fug$H_2S$ and pH

Flexible pipe manufacturer checks its tests database and selects the right material.

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# Corrosion Mechanisms

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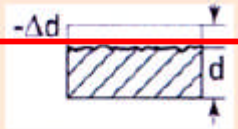
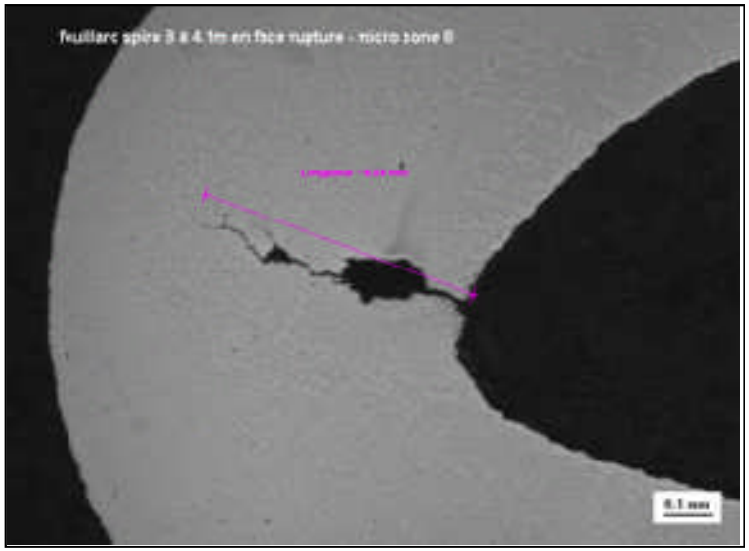
# Corrosion Mechanisms

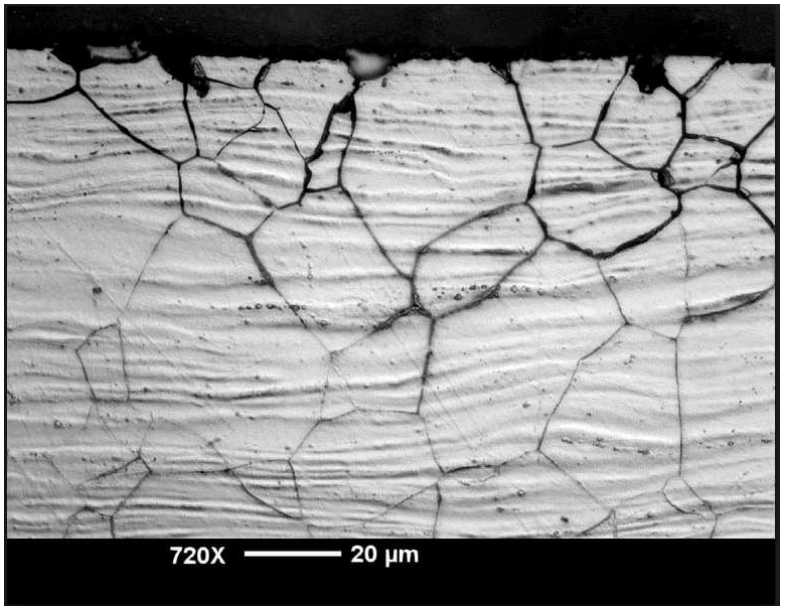
| Type of corrosion | | Aspect |
|---|---|---|
| Uniform corrosion (general attack) | |   |
| Localised corrosion | Pitting |  |
| | Crevice |  |
| Intergranular | |  |
| Stress corrosion | |   |

Not an issue

Stress Corrosion Cracking (SCC)



Intergranular Corrosion

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# Corrosion Mechanisms

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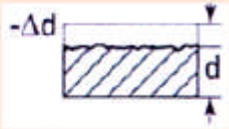
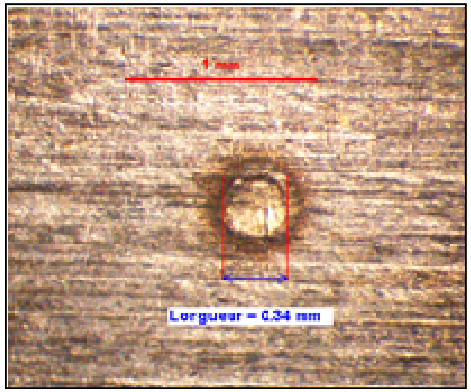
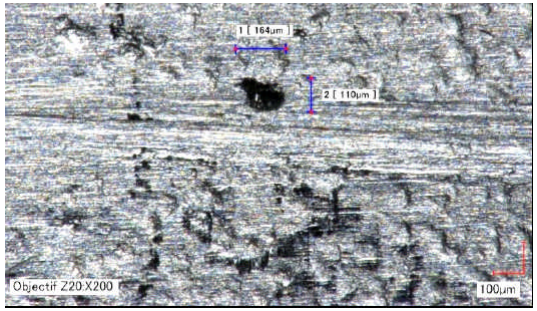
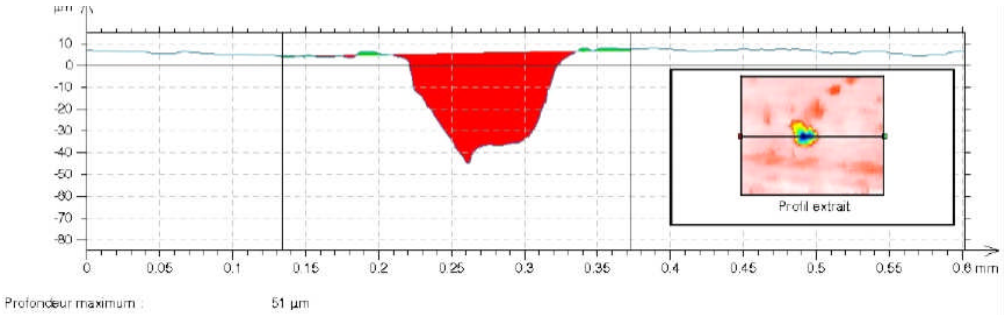
| Uniform corrosion (general attack) | |   |
| Localised corrosion | Pitting |  |
| | Crevice |  |
| Intergranular | |  |
| Stress corrosion | |   |

Pitting

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# Carcass Corrosion Test

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# Carcass Corrosion Test : Autoclave Tests

- **Test procedure:**
  - Samples are cut in a formed carcass
  - Residual stresses due to profiling
  - Samples contains welds
  - Exposure to the environment in autoclave
  - No electrical contact between samples: avoiding galvanic corrosion
  - Duration = 720 h


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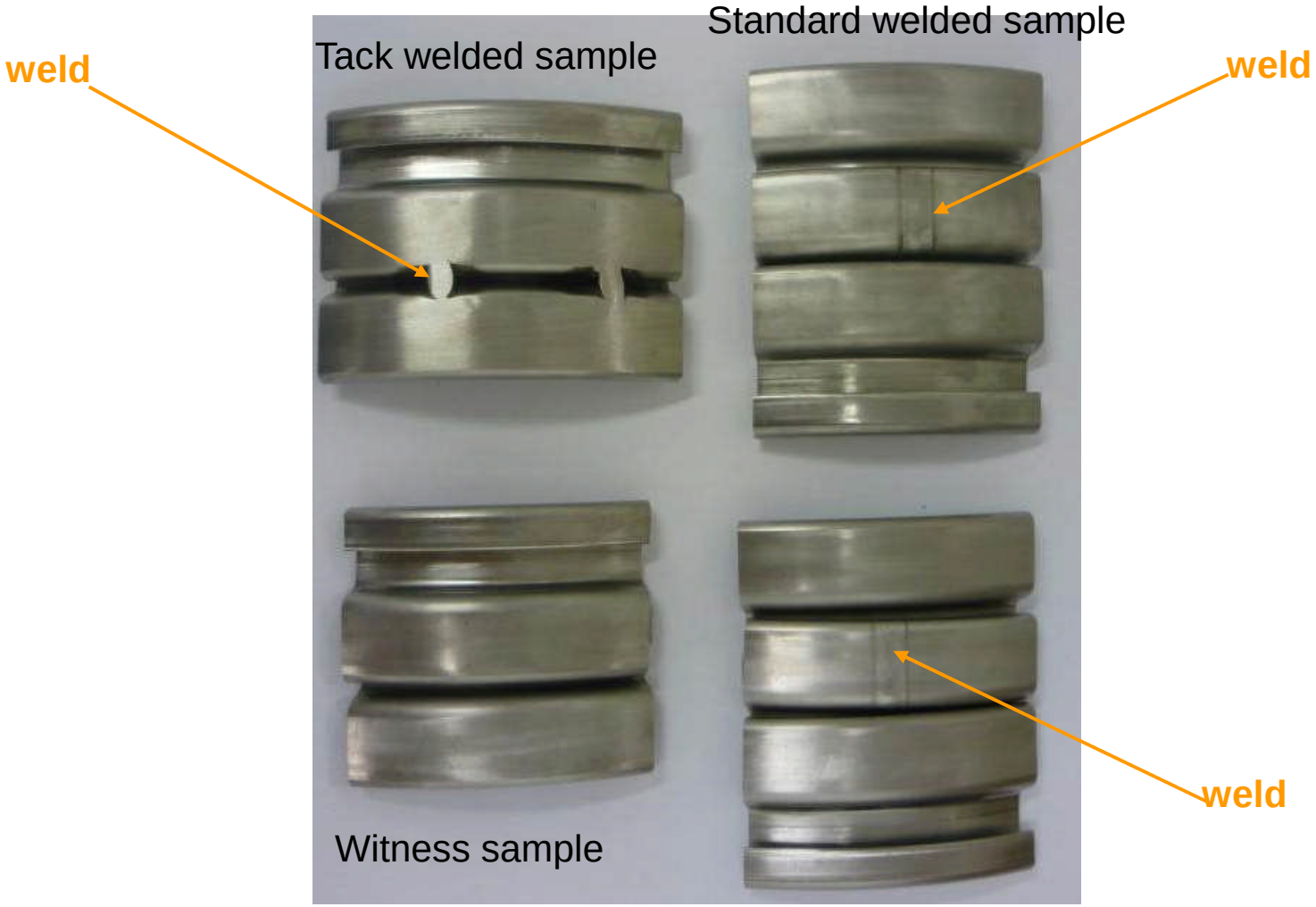
# Carcass Corrosion Test : Autoclave Tests

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# Carcass Corrosion Test : Autoclave Tests

View of a basket with samples


View of sample holder

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# Carcass Corrosion Test : Autoclave Tests

- **Test conditions:**
  - Test performed in deaerated deionized water ($O_2$<10 ppb): $N_2$ bubbling
  - Temperature
  - pH
  - Fug$H_2S$
  - Chloride content


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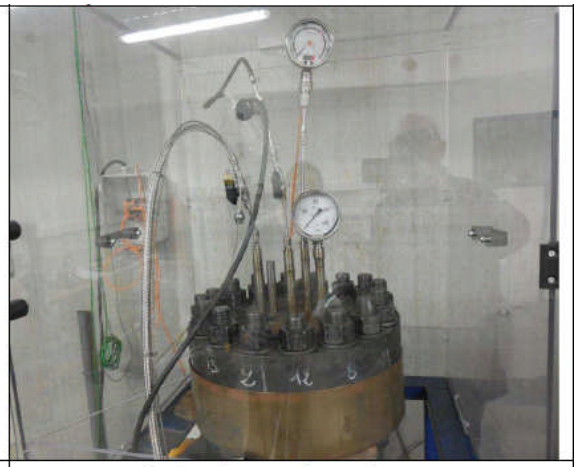
# Carcass Corrosion Test : Autoclave Tests

Autoclave open



Autoclave closed

High pressure autoclaves
Up to 1380 bar
Up to 400°C

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# Future Conditions and its Materials

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# Future Conditions and its Materials

**Technip has a solution for current and future conditions**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 130 | 130 | 110 | 90 | 90 | 90 | 90 |
| pH | 4,70 | 3,70 | 3,60 | 3,80 | 2,85 | 2,82 | 2,83 |
| Fug$H_2S$ (mbar) | 148 | 61 | 10 | 15 | 18 | 35 | 65 |
| Chloride content (mg/l) | 140300 | 123000 | 161900 | 131000 | 0 | 0 | 0 |

Corresponds to **1200 ppmv (!)**

at 1 bar and 40°C

**Real Projects covered**

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# Future Conditions and its Materials

**Developments:**

**Increase in carcass colapse resistance by increasing thickness and mechanical resistance while keeping as much as possible corrosion resistance.**

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# Thank you

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