Materials Selection - Basics

Subsea Pipelines

Basics of Materials Selection

- What is Materials Selection (SURF)?
- How it is Carried out?
- Examples
  - Carbon Steel & Corrosion Resistant Material
  - Corrosion Resistant Alloys
  - Cost / Availability Trend

Basics of Materials Selection

- Materials Selection
  - Mechanisms for Choosing Suitable Materials
    - Corrosion Resistance – Internal External Corrosion
    - Mechanical Properties – Yield Strength and Toughness
    - Easy of Fabrication/Installation – Weldability Formability Inspection

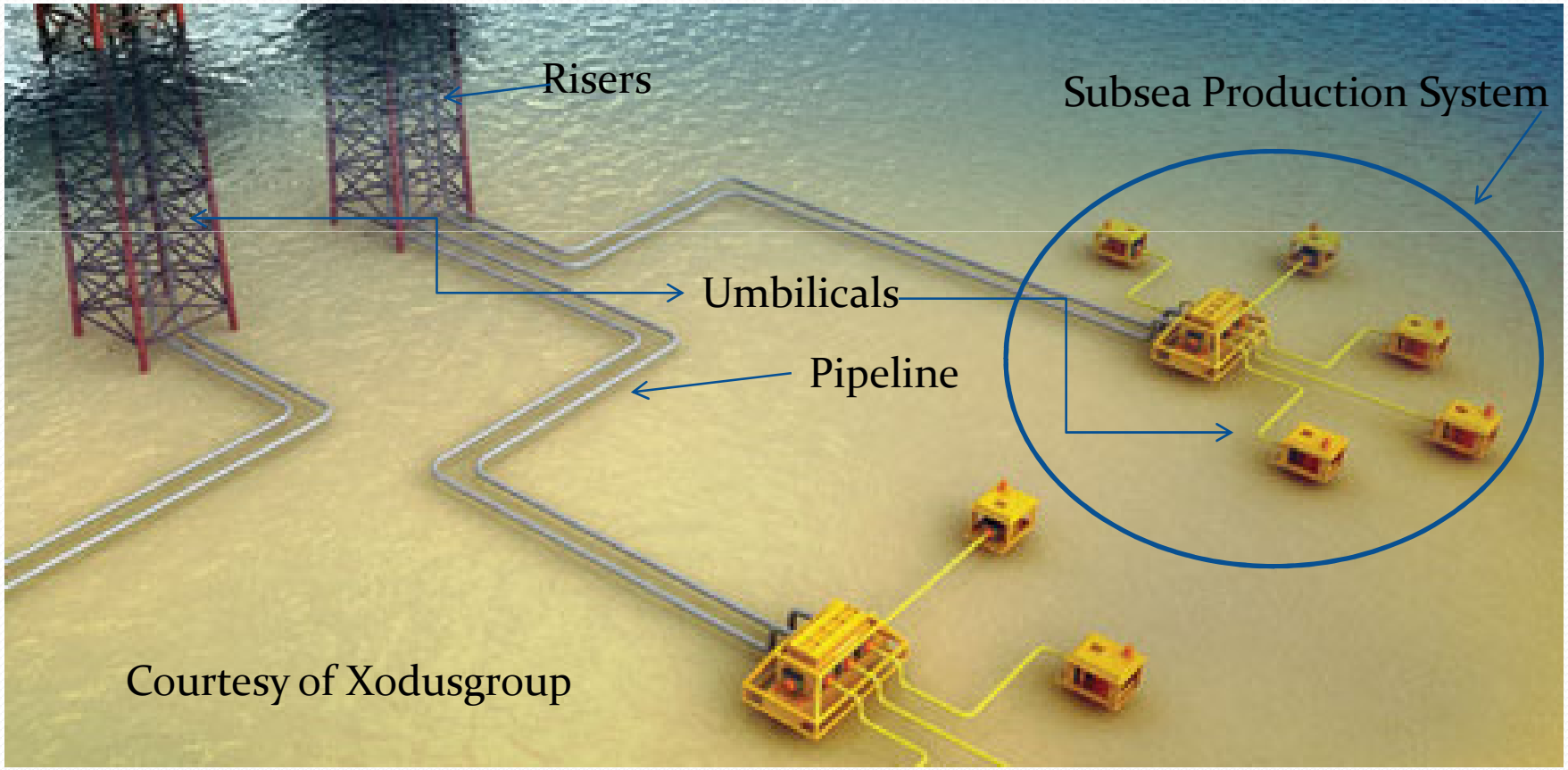
  - Establishing Cost of Selected Materials
    - Carbon Steel + Corrosion Inhibition
    - Corrosion Resistant Materials
    - Bimetallic Materials
    - Fabrication & Installation Costs

    CAPEX

    - Operation
    - Maintenance Costs

    OPEX

Basics of Materials Selection



Basics of Materials Selection

- Materials Selection – Subsea Pipelines
  - Selection Mechanism
    - Internal Corrosion
    - External Corrosion

2

Strength
Toughness

1

Flow Assurance
Operating & Design Data

  - Optimised Cost Based On
    - Procurement, Installation
    - Operation & Maintenance
    - Design & Regulatory Compliance
  - Existing Track Record & Contractor Capability
    - Welding
    - NDT
    - Installability

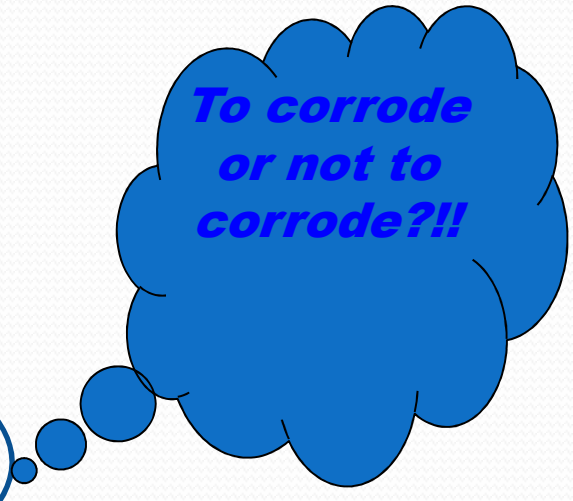
3

Basics of Materials Selection

- Material Selection
  - Corrosion
    - Subsea Pipelines -Saline Muds, Seawater & Process Fluids
      - Wet Acid gases (CO_2 H_2S) or O_2
      - Halide ions
      - Bacterial Activity
    - Corrosion - Process

$$Fe \rightleftharpoons Fe^{2+} + 2e^-$$

$$M \rightleftharpoons M^{n+} + ne^-$$



Basics of Materials Selection

- Several Relationships exist that predict corrosion rates based on
  - CO_2
  - H_2S
  - H_2O
  - O_2
  - Cl^-
  - pH level
  - Presence of Corrosion inhibitors
  - Flow velocity
  - Total System and Active Gas Partial Pressure
- Many different corrosion rate models available

Basics of Materials Selection

- Internal Corrosion – Carbon Steels & Low Alloy Steels
  - De Waard Milliams or Flow Chemistry
    - Shell - HydroCor
    - BP - Cassandra
    - TOTAL - Corplus
    - Intetech – ECE (Electronic Corrosion Engineer)
    - Norsok - M 506
    - Honeywell - PREDICT
    - IFE - KSC
    - OLI - SCORE
    - Scandpower - OLGA

Basics of Materials Selection

- Internal Corrosion – Corrosion Resistant Alloys
  - Flow Chemistry
    - Honeywell – SOCRATES
      - Selection of Corrosion Resistant Alloys Through Environment Specification
    - Intetech - ECE
    - Established Domains
    - Qualification Testing
  - Experience
    - Operator
    - Engineer

Basics of Materials Selection

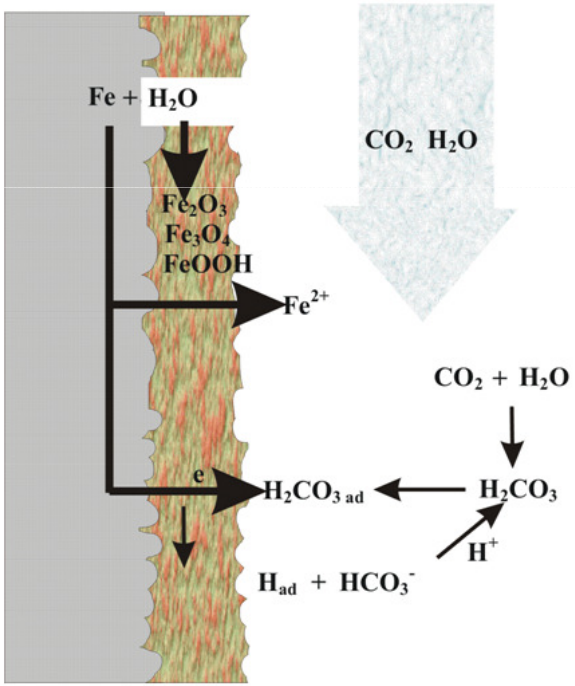
- Selection Mechanism – How It Is Done
  - Internal Corrosion
    - Collection of Information
      - Design & Operating Data
      - Flow Assurance & Production Profiles
    - Default Selection – Carbon Steel
      - Determine corrosion rates using known Algorithms
      - Establish if Inhibition is possible
      - Calculate Corrosion Allowance

$$CA = \left(CRinhibited\ x\ \frac{A\%}{100}\right) + CRuninhibited\ x\ (1 - \frac{A\%}{100})$$

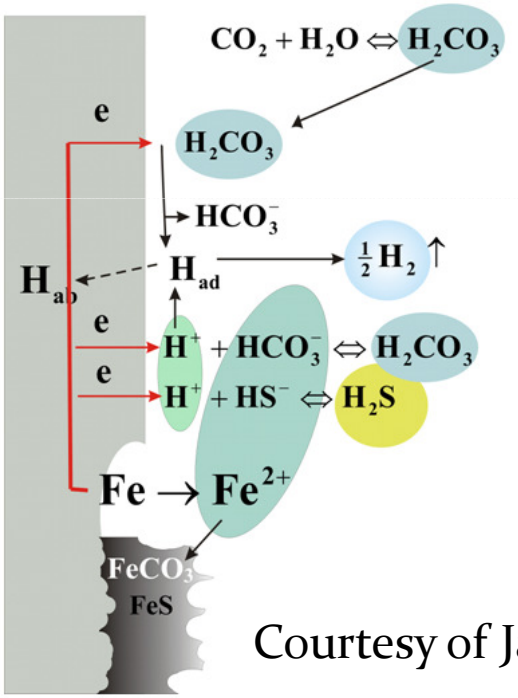
Basics of Materials Selection

Carbon Steels

Sweet Corrosion



Sour Corrosion



Courtesy of Jacek Banas

$$Fe + CO_2 + H_2O \longleftrightarrow Fe^{2+}(Z) + H_2$$

Basics of Materials Selection

De Waard Milliams

$$\frac{1}{Vcorr} = \frac{1}{Vr} + \frac{1}{Vm}$$

$$Vm = 2.45 \frac{U^{0.8}}{d^{0.2}} pCO2$$

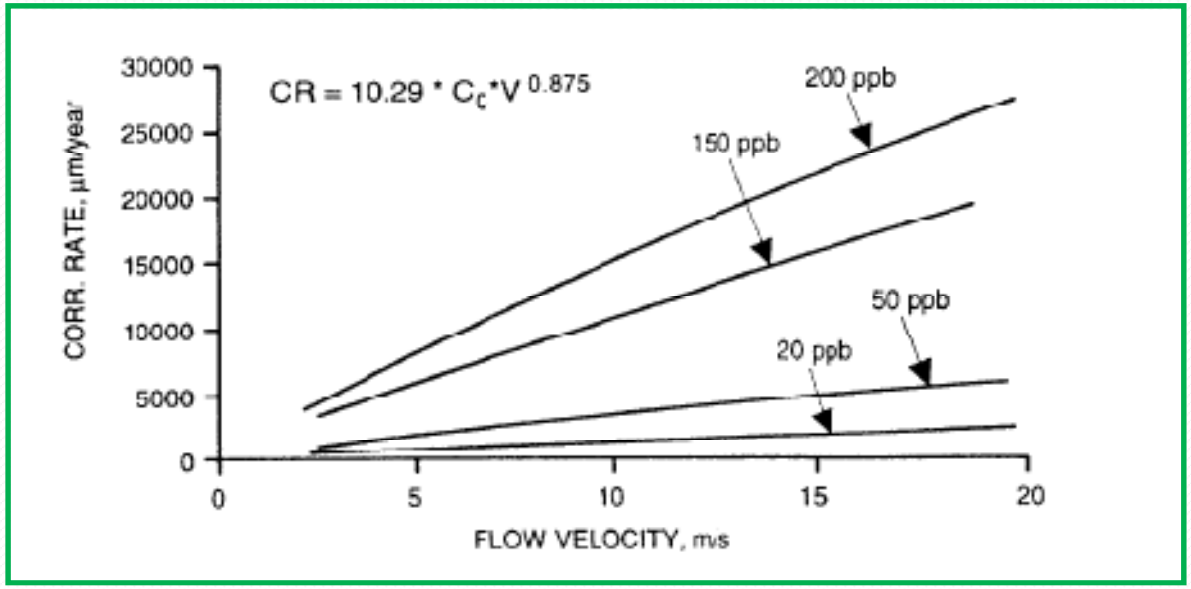
$$LogVr = 4.93 - \frac{1191}{(t + 273)} + 0.58 Log\, pCO2 - 0.34\,(pH\ actual - pHCO2)$$

$$LogVr = 5.8 - \frac{1710}{(t + 273)} + 0.67 Log\, pCO2$$

Basics of Materials Selection

Oldfield Swales & Todd

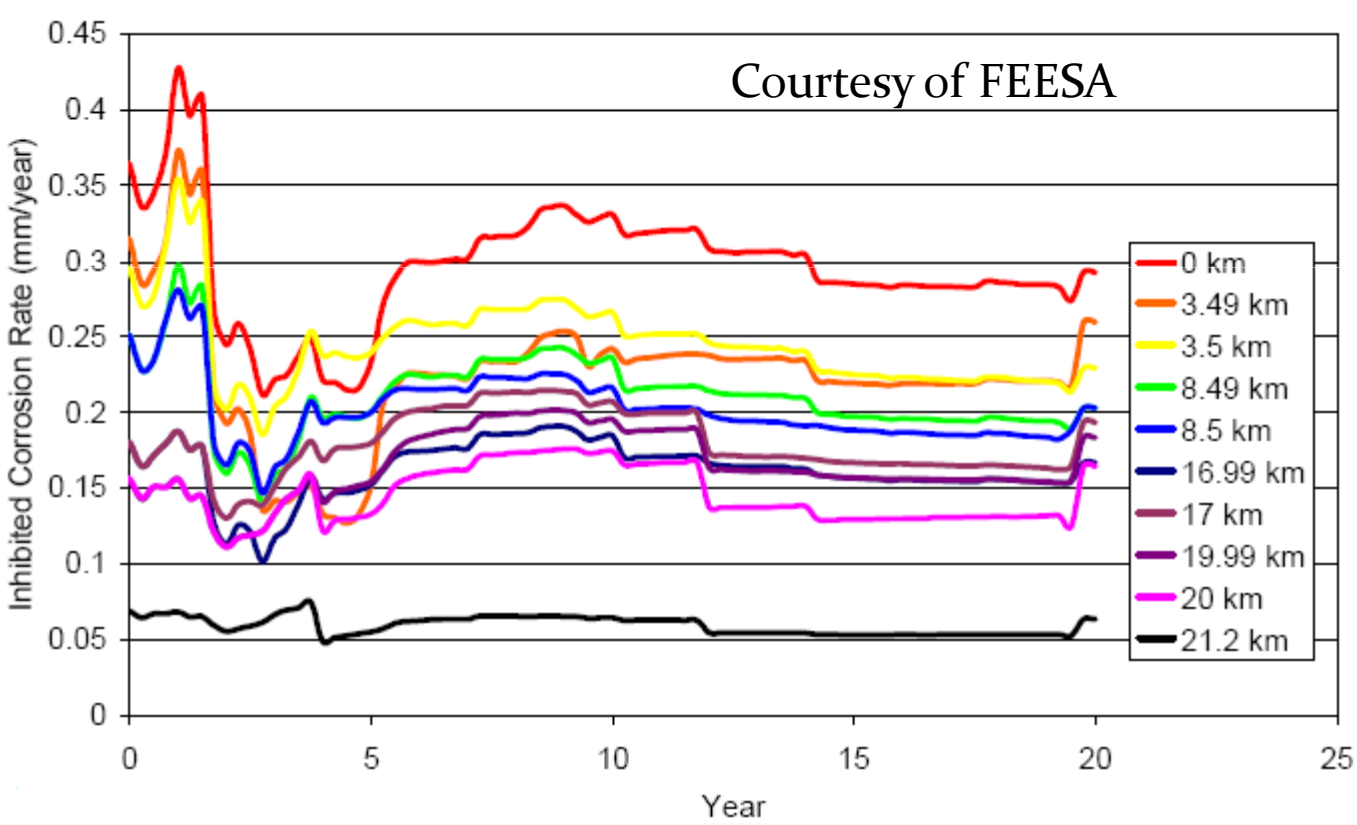
$$CR = \frac{0.0565 \times V \times C_o}{\mathrm{Re}^{0.125} \times \mathrm{Pr}^{0.750}} \qquad CR = \frac{0.0565 \times D^{0.75} \times V^{0.875}}{V_k^{0.125} \times d^{0.125}} \times C_o$$



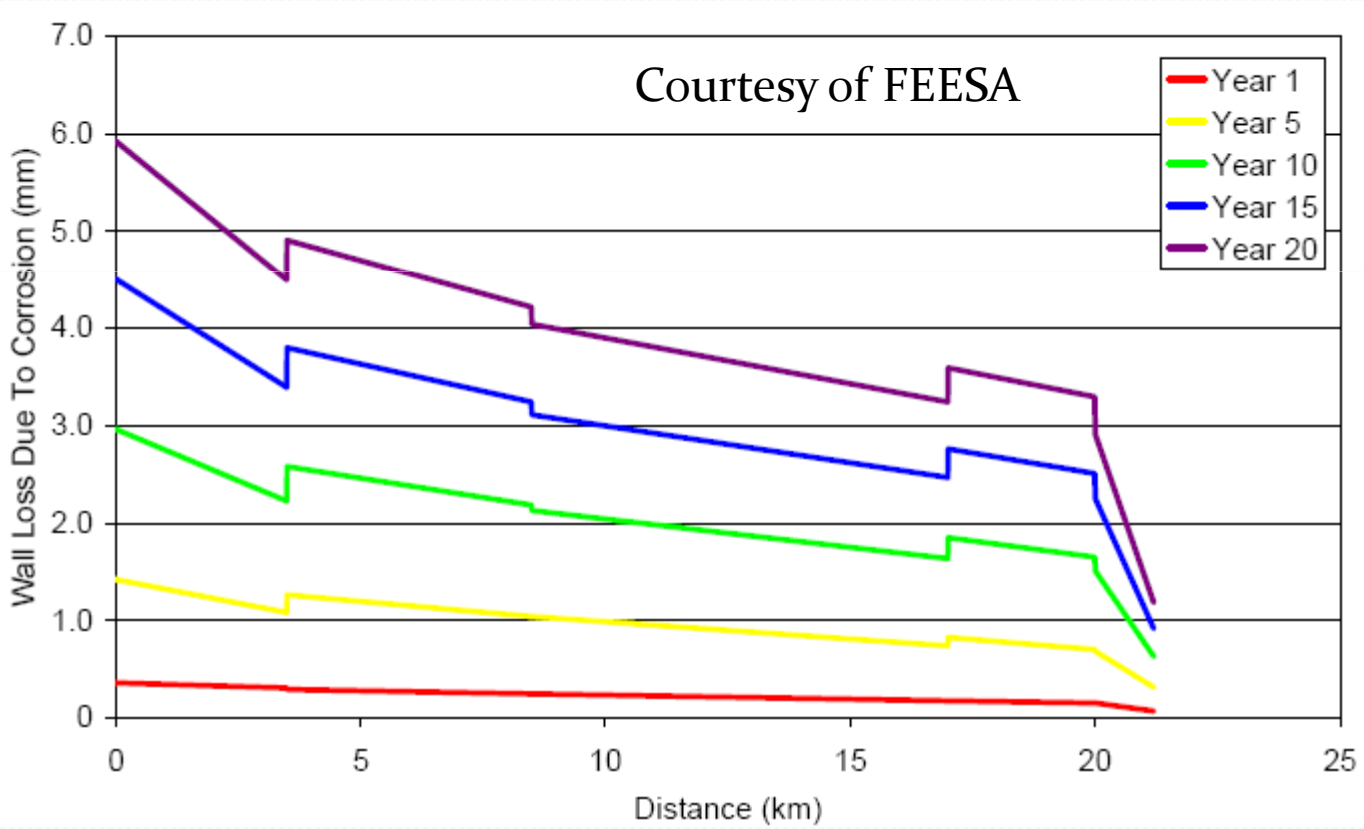
Basics of Materials Selection

- Cumulated Thickness Loss (CTL)
  - Establish Corrosion Rate at various location
  - Plot Corrosion rate against Time
  - Calculate Area under worst Trace
    - CTL
    - ATL (Acceptable Thickness Loss typically 3mm or 6mm)
    - L Design life
  - Consider
    - $CRmax\ x\ \frac{L}{CA}$ or $\frac{CTL}{ATL}$

Basics of Materials Selection



Basics of Materials Selection



Basics of Materials Selection

Courtesy of IFE

CTL/ATL	Likelihood of corrosion categories	Approximate Impact on system life for a new system
≤0.5	Negligible	System will last longer than required with no failures
>0.5 and ≤1	Low	System will reach its design life without a failure
>1 and ≤4	Medium	System will only reach 25% of its design life before a failure occurs, if no action is taken
>4	High	A failure will occur before the system reaches 25% of its design life, if no action is taken

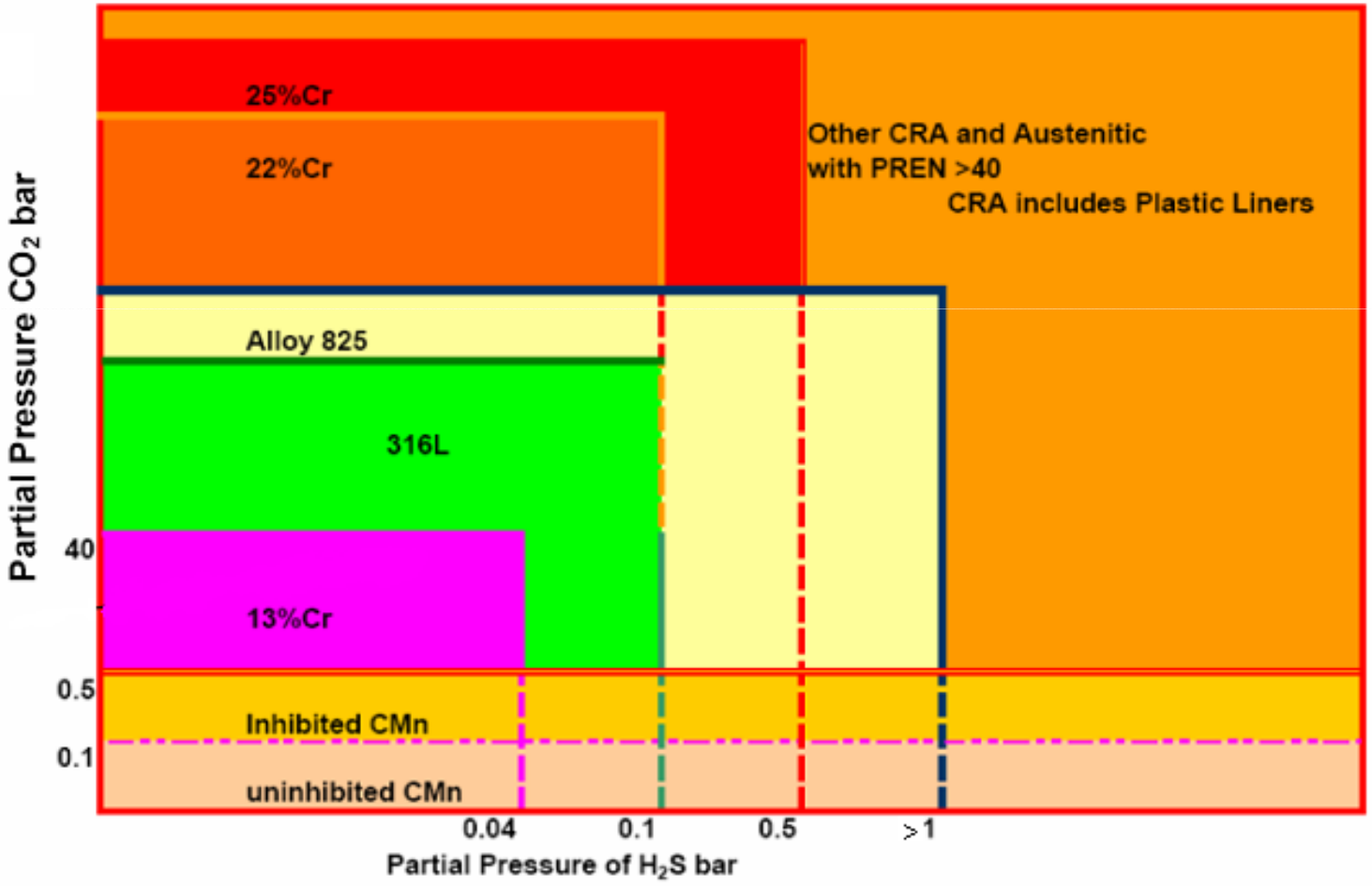
Basics of Materials Selection

- Decision
  - If $CRmax\ x\ \frac{L}{CA}$ or $\frac{CTL}{ATL}$ > 1
  - Carbon Steel is Risky; Select CRA
  - CS + CRA
    - Solid CRA
    - CRA – Clad or Lined
    - CRA - Plastic Liner

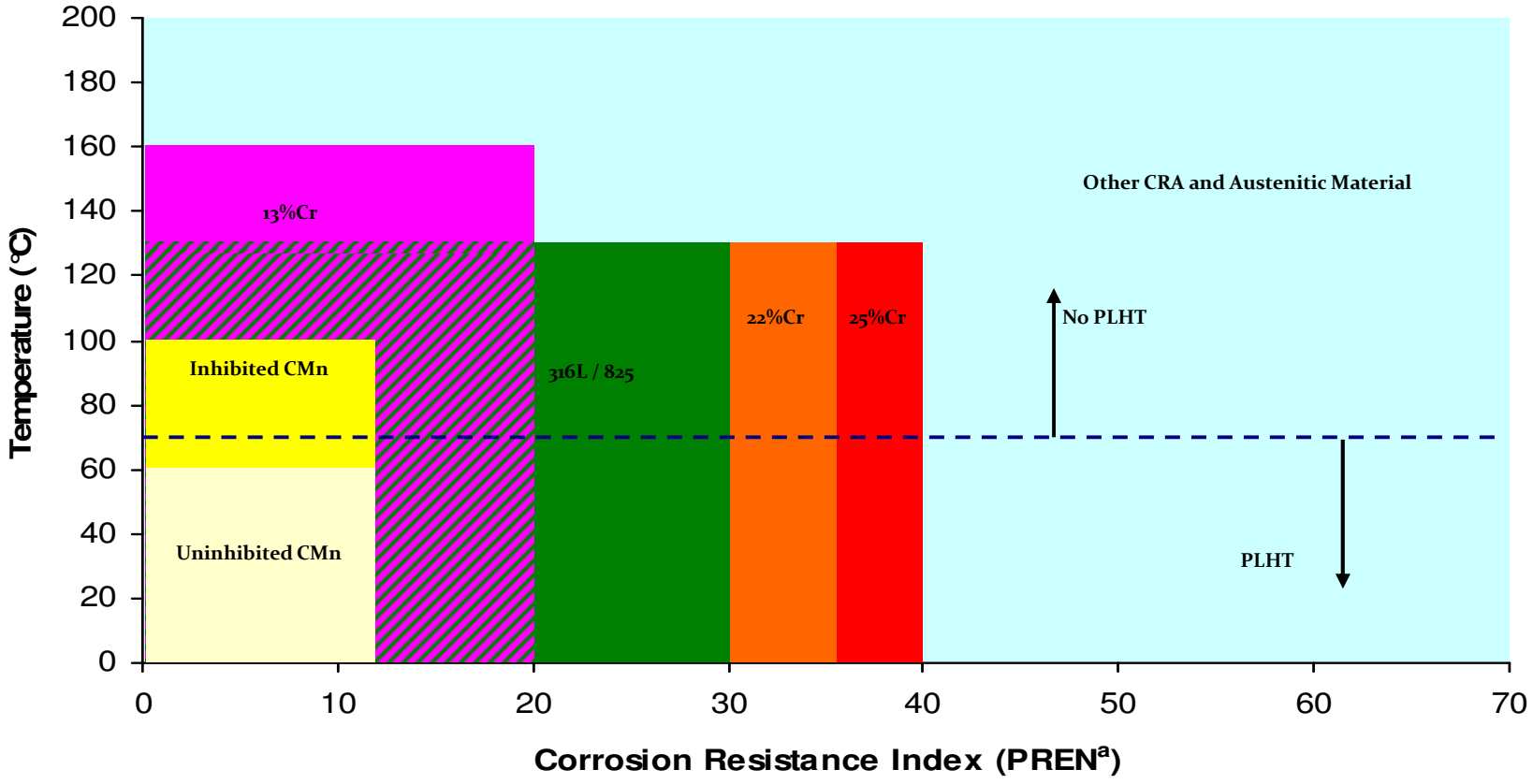
Basics of Materials Selection

Material	Selection Guide	Trigger Point	Issue
CMn	Predicted CO_2 corrosion rate is less than 0.3mm/yr.	Only used if corrosion rate is less than 0.30mm/yr and or process stream is dry otherwise CRA required.	Use inhibitors and model must be conservative otherwise prediction could be very optimistic
13%Cr	If corrosion rates predicted are > 0.30mm/yr and ppH_2S is less than 0.1 bar.	If corrosion in CMn is unacceptable and ppH_2S is generally less than 100mbar depending on the level of chlorides present.	Sensitive to HISC and SSC if ppH_2S /chloride levels are not properly assessed
316L Clad	More resistant than 13%Cr	If 13%Cr is unacceptable due to level of chlorides and or ppH_2S	Limited by its resistance to pitting in certain levels of ppH_2S/Cl^-. ppH_2S > 100mbar is acceptable for certain combinations of pH and chloride levels.
22%Cr & 25%Cr	More resistant than 316L. Exhibits very good SCC and SSC resistance than 316L	If 316L is not acceptable due to pitting in the presence of chlorides and H_2S	Relaxed ppH_2S & Temp levels in NACE MR 0175/ISO 15156-3. Yield strength de-rating may require more wall thickness at elevated temperatures than the other materials such as CRA clad CMn or 13%Cr.
Alloy 825 and 904L clad CMn	More resistant to SSC than 22%Cr or 25%Cr.	If SSC is considered i.e. 22%Cr and 25%Cr are not options due to ppH_2S.	If qualification programmes are undertaken it is possible that 316L, 22%Cr or 25%Cr can be viable options if service environments are assessed and welds qualified based on the intended installation method.
625 clad CMn	Resistant to both SSC and SCC	If ppH_2S is considerable and alloy 825 or 904L are not options	Very costly.

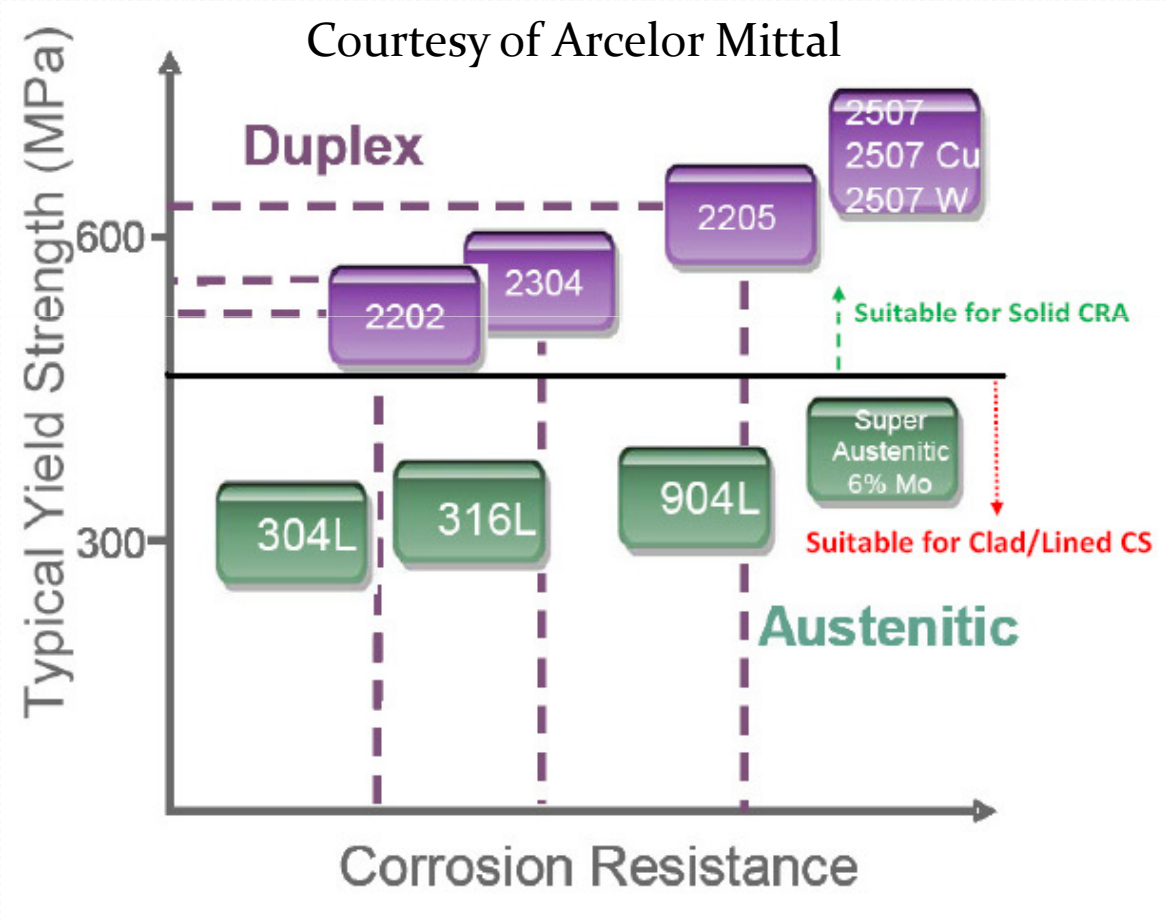
Basics of Materials Selection



Basics of Materials Selection



Basics of Materials Selection



Basics of Materials Selection

Relative cost ratings of alloys

Material	Cost factor (weight basis)
Carbon steel	1
13Cr for downhole tubing	1.1 - 1.8
Weldable martensitic stainless steels /Super 13Cr	2.2 - 3.5
AISI 316 (solid or clad)	3.5 - 4.5
22Cr Duplex	4.0 - 4.6
AISI 904L	4.2 - 4.8
25Cr Duplex	5.0 - 5.6
6Mo	5.0 - 5.6
Alloy 825 clad	5.2 - 5.5
Alloy 625 clad	5.4 - 6.0
Alloy 825 solid	7.5 - 8.5
Alloy 625	8.5 - 10.0
Higher nickel alloys	10.0 - 15.0

Basics of Materials Selection

- Q&A