Internal Corrosion Basics

Welcome and Introductions

Pipeline Internal Corrosion Agenda

Morning Session

8:30-11:30 a.m.

- Basics of Internal Corrosion
- Monitoring Equipment
- What Tests Should I Be Doing

11 a.m.-12:30 p.m. - Lunch

Afternoon Session

12:30 - 2:00 p.m.

- Tanks and Vessels
- The Chemical Dilemma: to Treat or Not to Treat
- Question and Answer

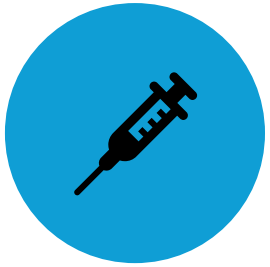
2:00 – 3:30 p.m.

- Southern Star – “What we do in the field” – Bryan Vierthaler and Jason Sparks

Pipeline Internal Corrosion Agenda

INDUSTRY OVERVIEW

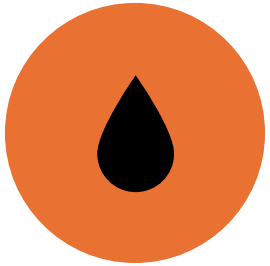
CORROSION BASICS



MONITORING EQUIPMENT

TESTING –WHAT SHOULD I DO?

TANKS AND VESSELS

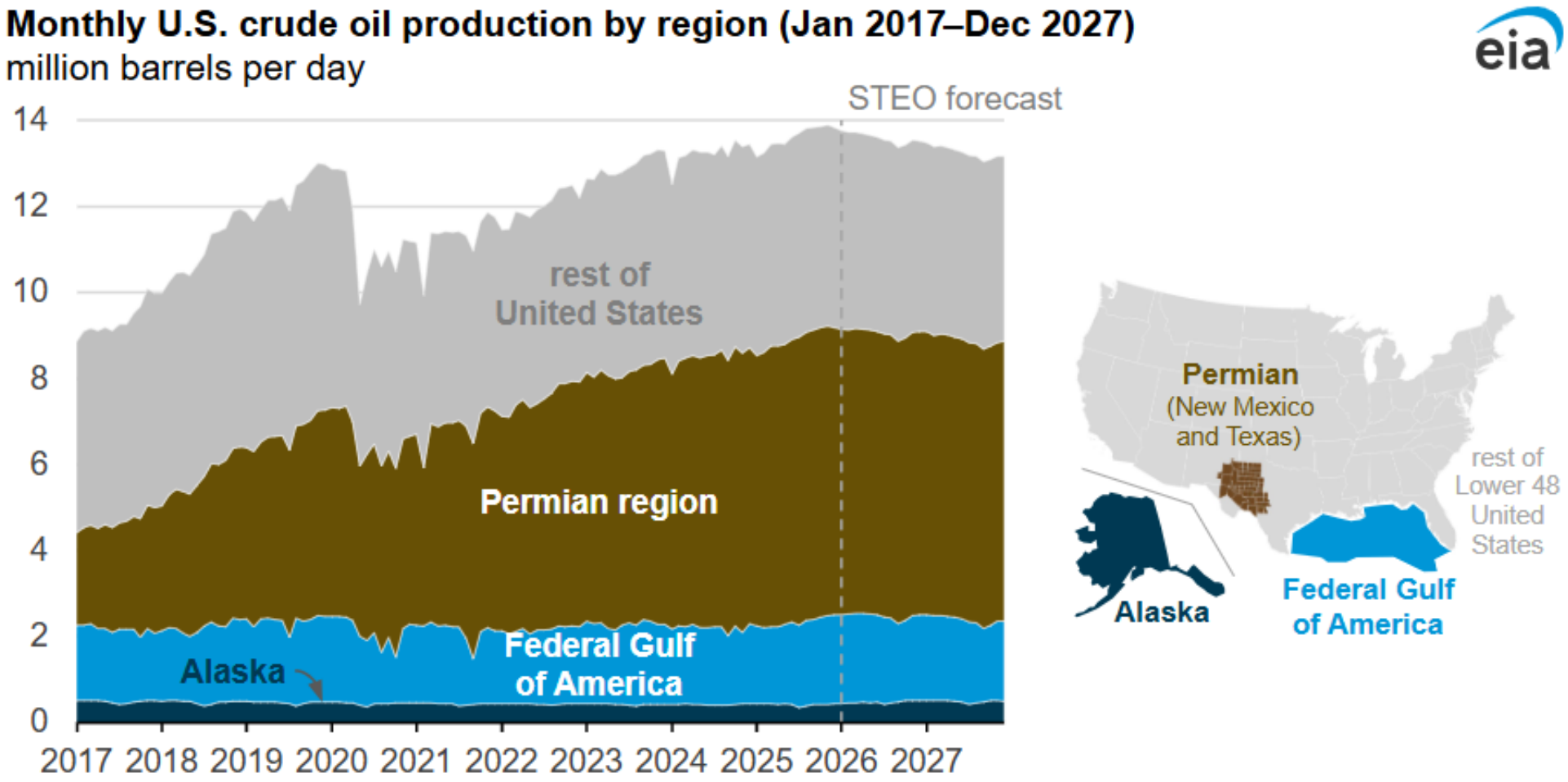


THE CHEMICAL DILEMMA

TO TREAT –OR NOT???

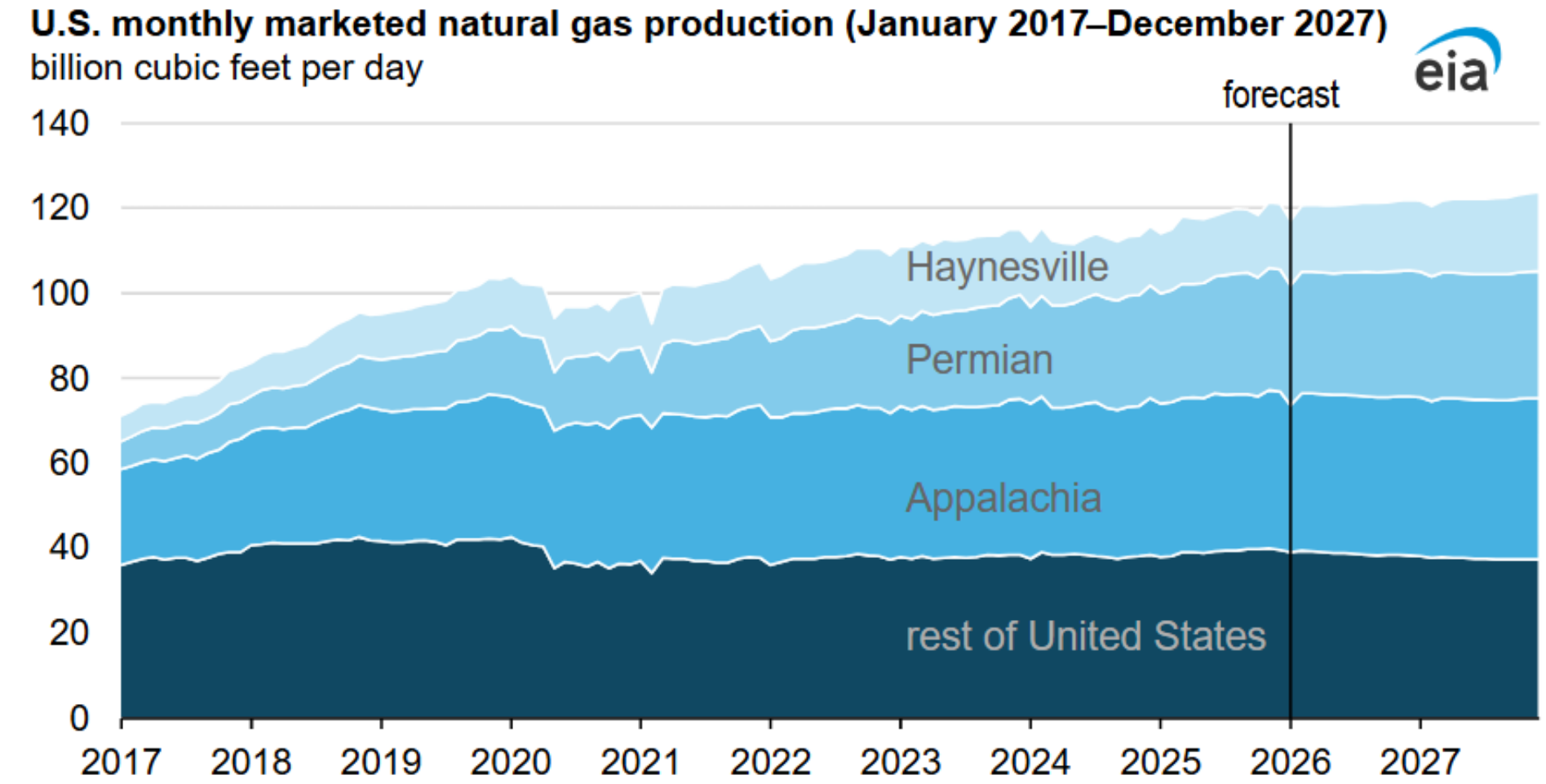
Production Industry Overview

Crude Oil Production (2017-2027)



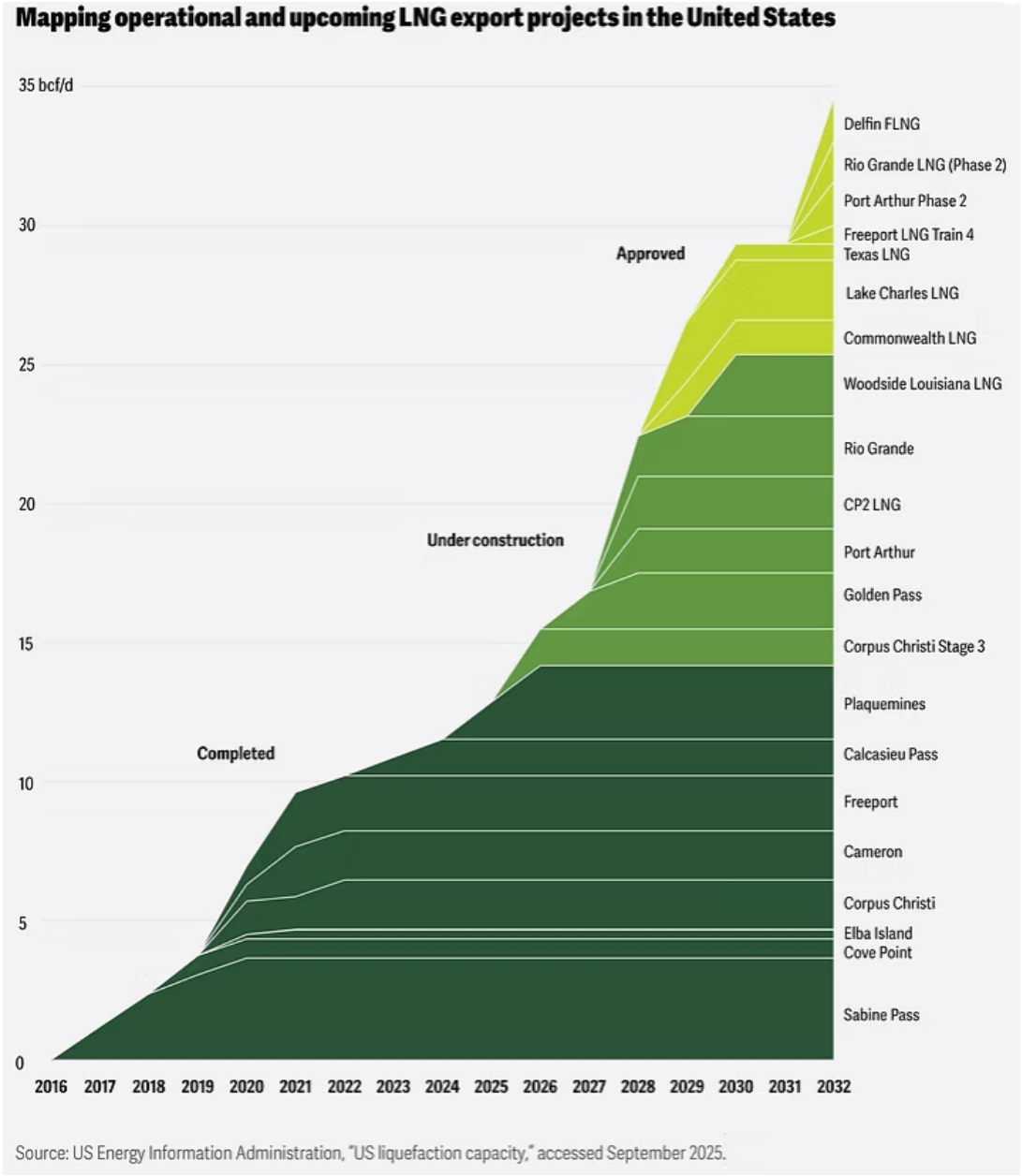
Data source: U.S. Energy Information Administration, *Short-Term Energy Outlook* (STEO), January 2026
Data values: U.S. Petroleum and Other Liquids Supply, Consumption, and Inventories

Gas Production (2017 - 2027)



Data source: U.S. Energy Information Administration, *Short-Term Energy Outlook*, February 2026

Why is the gas demand increasing?



LNG Export Expansions expected to double by 2030

Increased power demand

Increase in data centers

Change to cleaner/dependable power generation

- Operate Safely
- Keep the product in the pipe
- Maintain profitability
- Continue to be employed

What is our Ultimate Goal?

What is Corrosion

Degradation of a material

Carbon Steel

Plastic

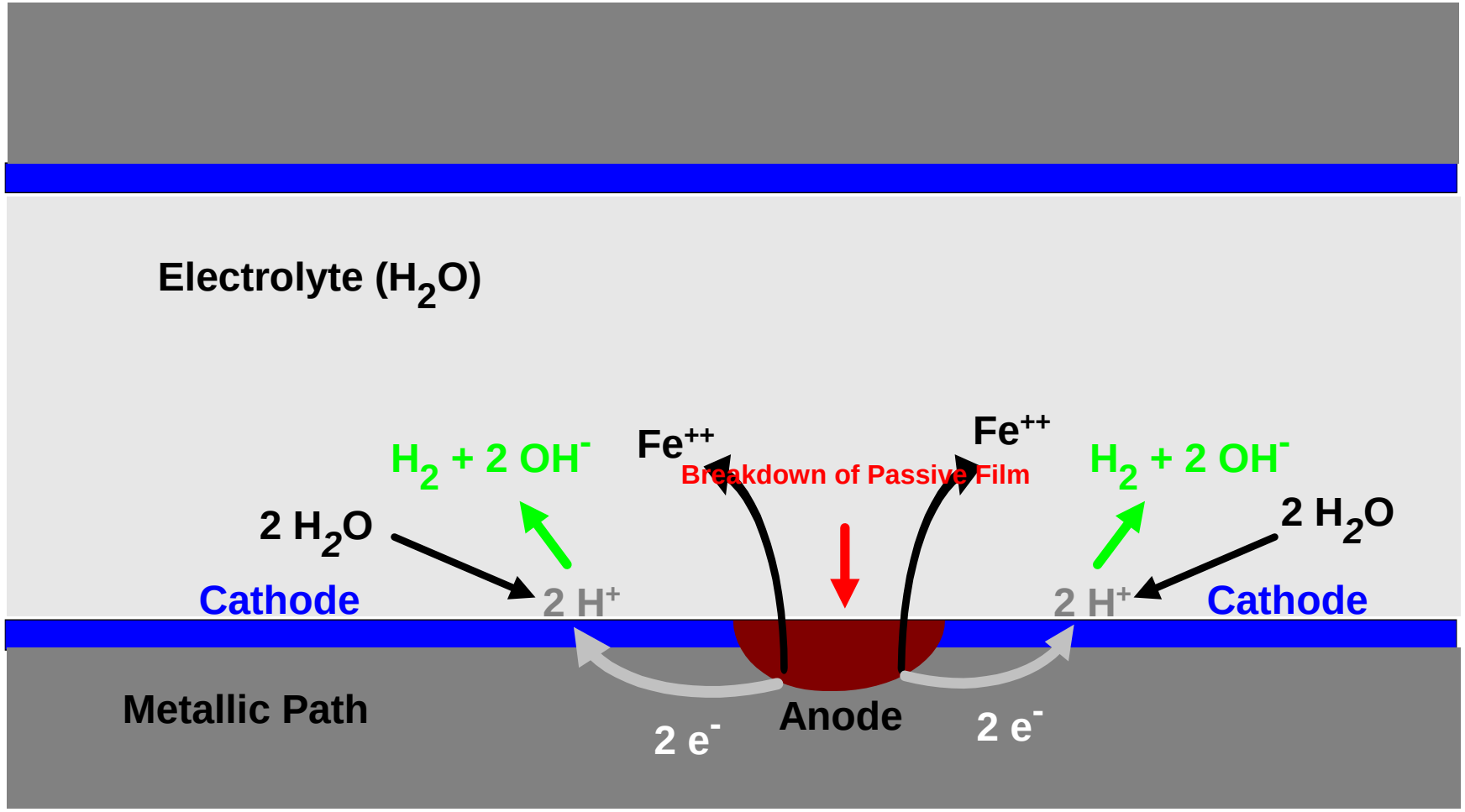
Wood

Skin

NACE definition - The degradation of a material, usually carbon steel, due to the reaction with its environment

- Eliminate one part of the circuit and corrosion stops.
- **ANODE** - More anodic (CP), CRA’s
- **Cathode** – Coating , inhibitor film, CRA’s
- **Metallic Path**- Use non metallic’s
- **Electrolyte** – Get rid of water, inhibitors, coatings.

Corrosion Circuit



Cathodic Reaction Involving Hydrogen Evolution

Electrochemical Reactions

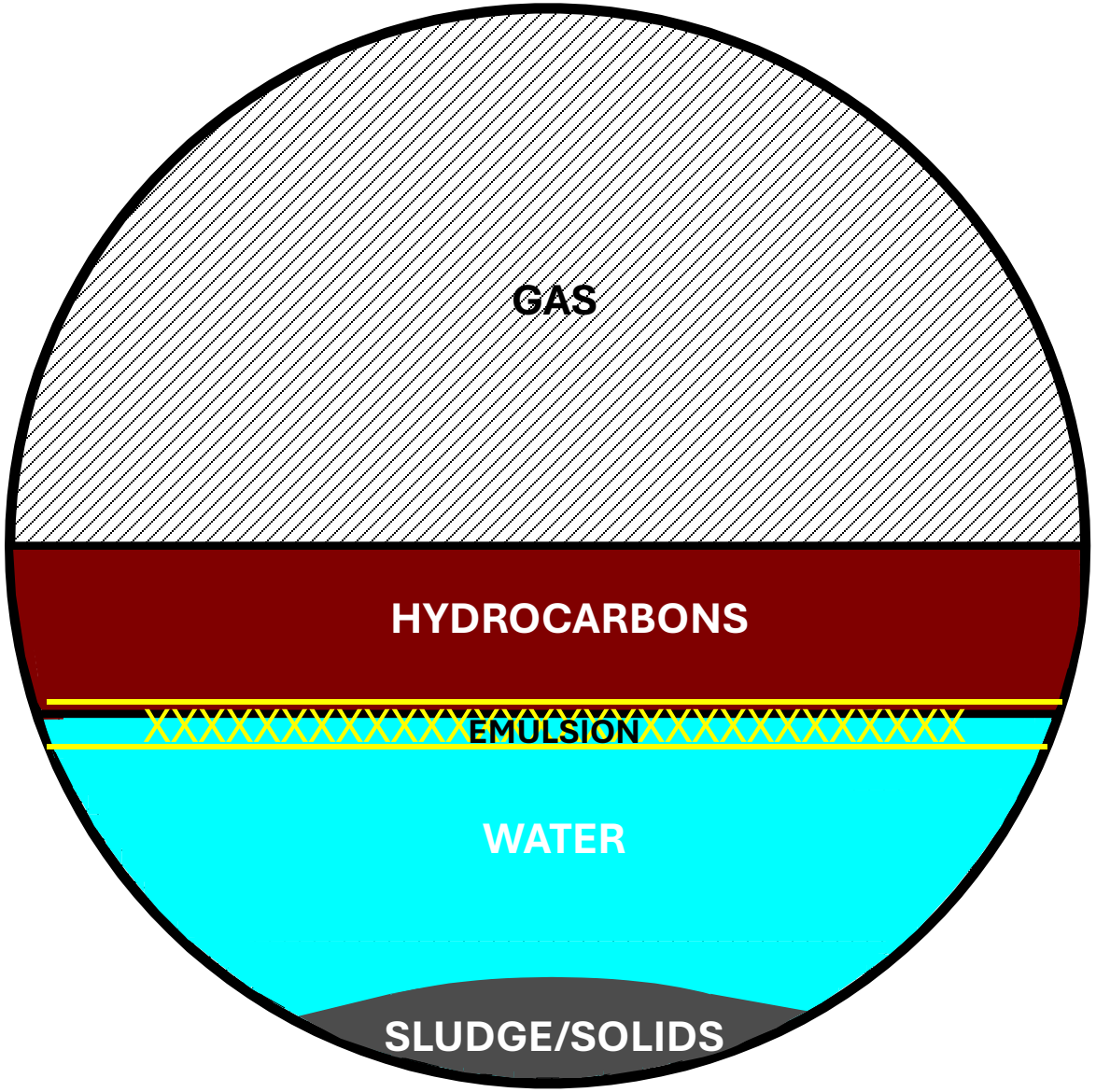
- Oxidation Reaction – *Corrosion of Iron*

$$\mathbf{Fe \rightarrow Fe^{++} + 2e^-}$$

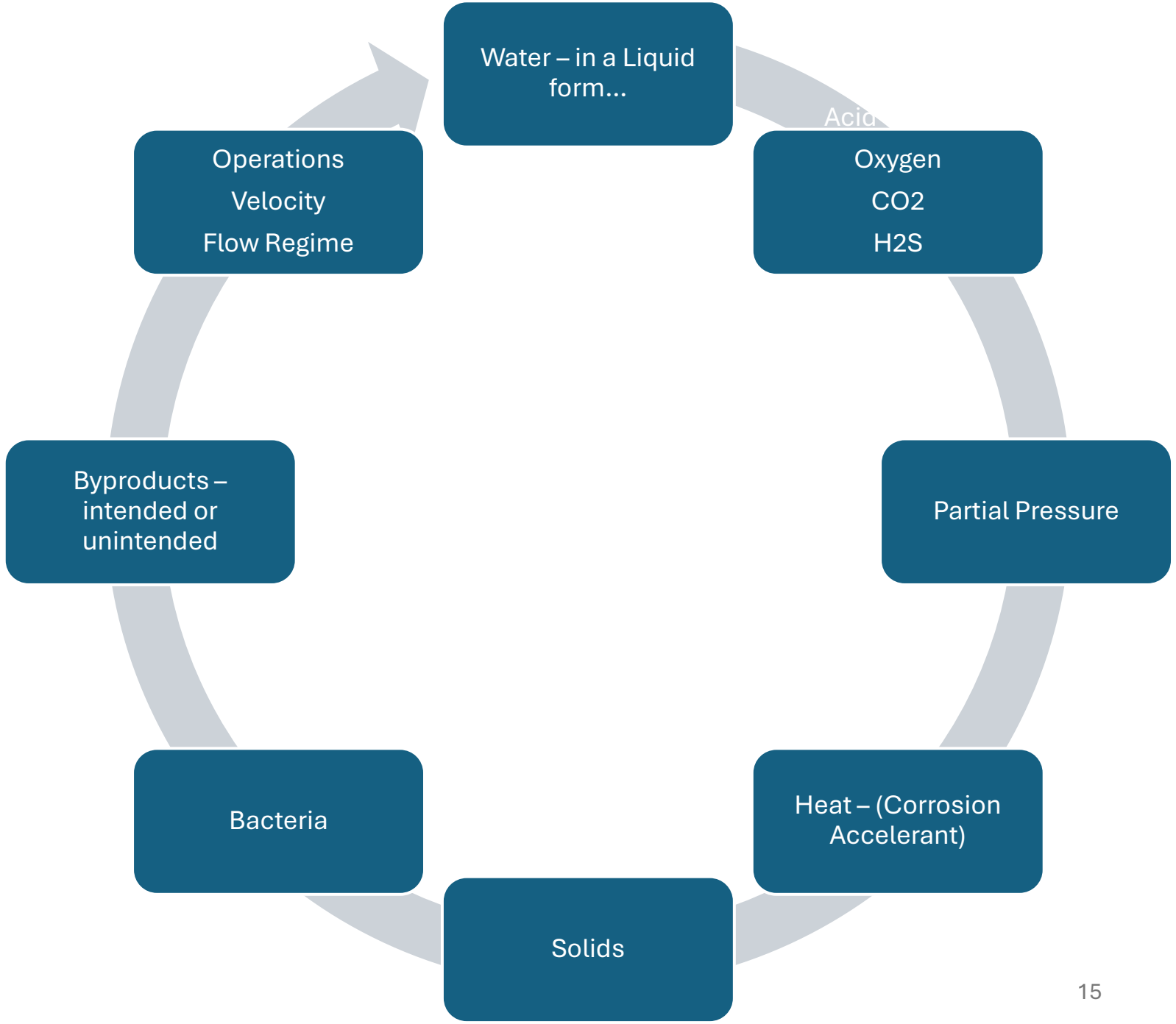
- Reduction Reaction – *Hydrogen Evolution*

$$\mathbf{2\,H_2O + 2e^- \rightarrow H_2 + 2\,OH^-}$$

INTERNAL PIPELINE ENVIRONMENT



What Causes Corrosion?



What Are The Components We Worry About?

GAS:

Moisture

Oxygen

CO_2

H_2S

Liquids:

Water Volume

Water Composition

Anions

Cations

pH

Alkalinity

Conductivity/Resisitivity

Scaling Tendencies

Water /Solids /Product Chemistry

Advantages:

- Gives an indication of corrosive components
- Shows changes in the quantity of potentially corrosive components over time
- Provides data on how potentially corrosive the system could be.
- Provides a method of monitoring product quality

Disadvantages:

- Some tests must be done on site to maintain accuracy
- Sample transportation and preservation is key to accurate results.
- Results can be difficult to interpret
- Requires an understanding of the Methods

Henry's Law – Partial Pressures, and Why They Are Important....

*At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the **partial pressure** of that gas in equilibrium with that liquid.*

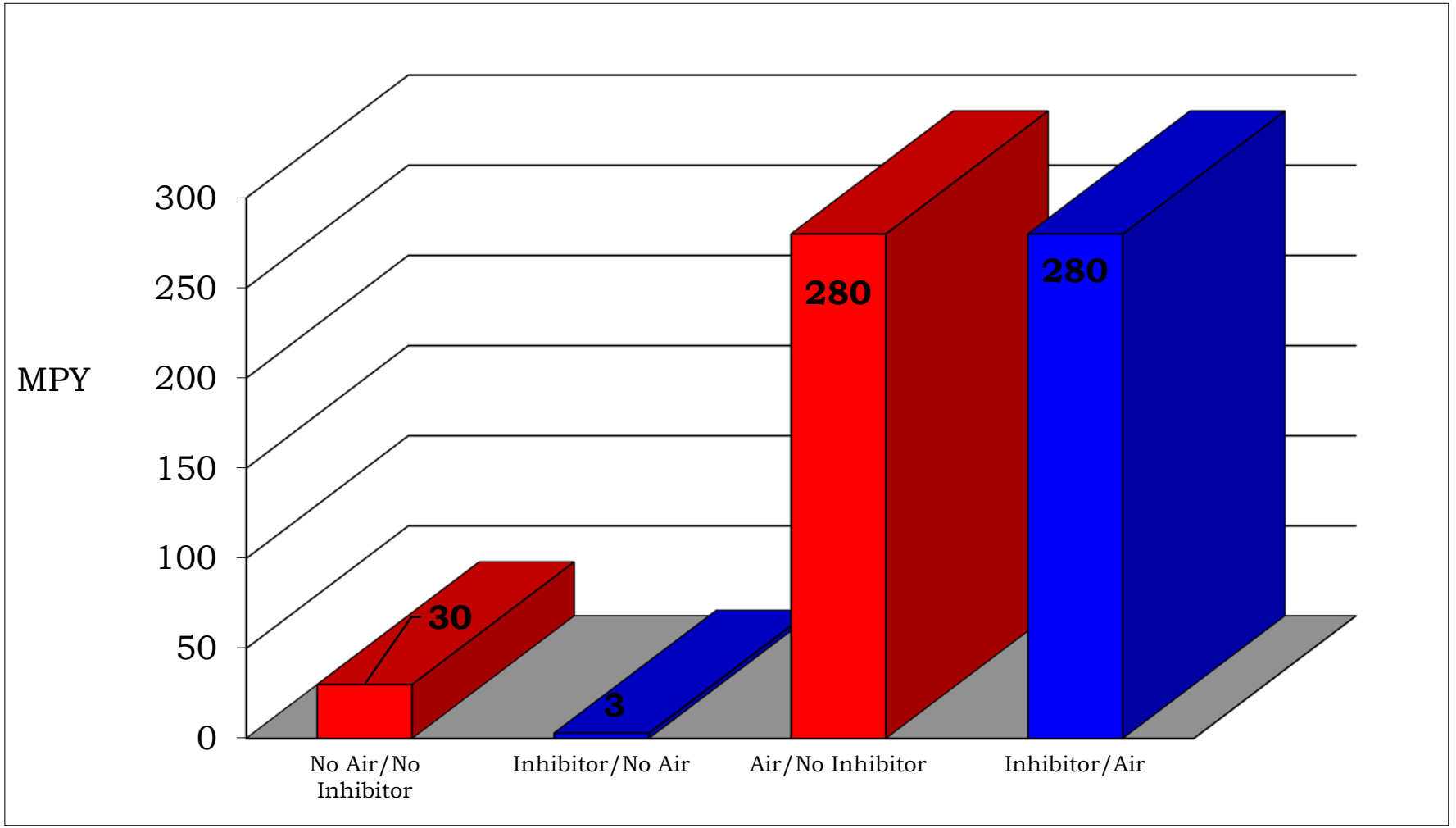
- More simply stated:
- The **solubility** of a gas in a liquid is proportional to the pressure *of that gas* above the liquid.

- $\mathbf{ppCO_2 = \frac{System\ CO_2\ (Mole\ \%)\ X\ (System\ Pressure + Atmospheric\ Pressure)}{100}}$

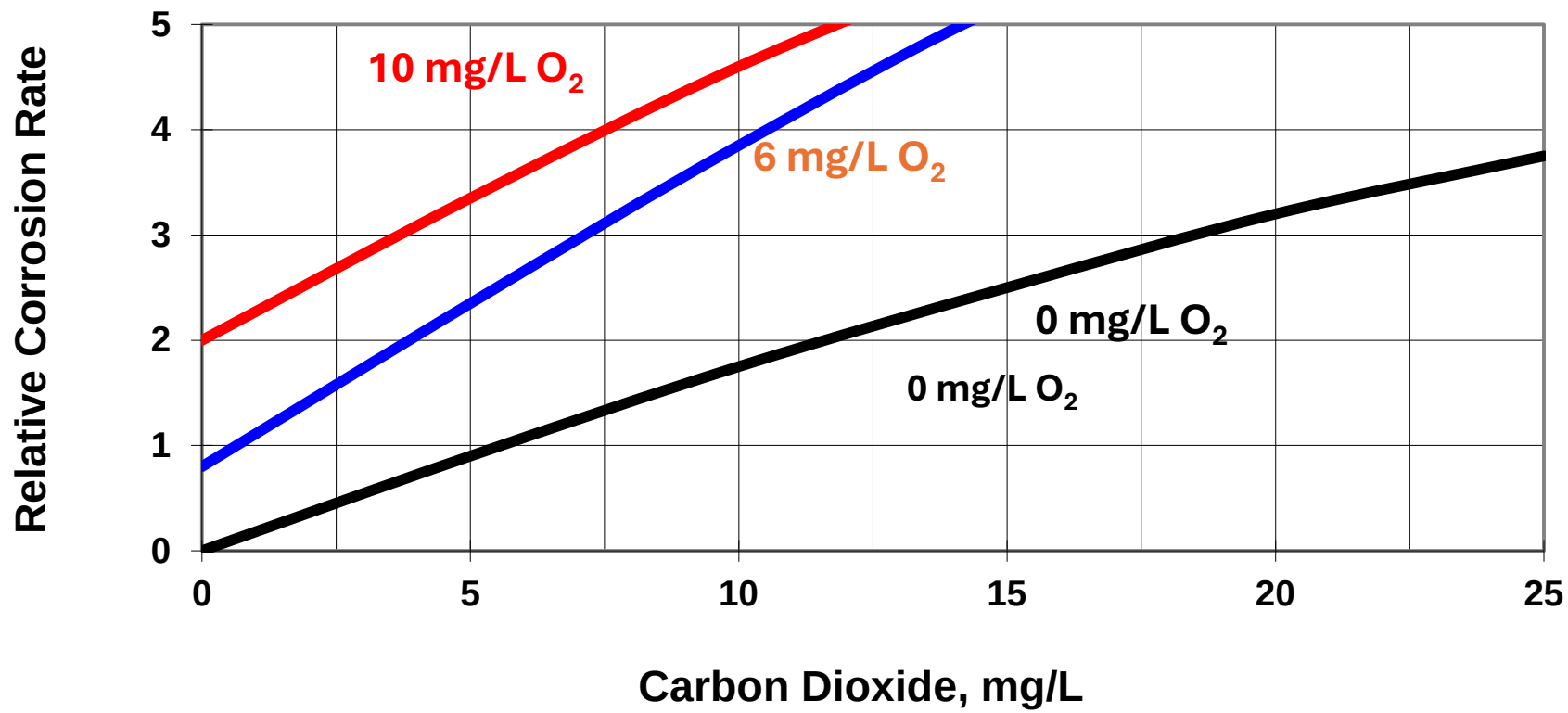
Acid Gases - Oxygen (O_2)

- Strong “Depolarizer”
- Forms deep pits
- Usually found in surface equipment where air has entry point.
- Can greatly accelerate other corrosive agents
- Usually caused by a mechanical problem (Seals, Thief Hatches, Packings, Open Valves etc.)

Effect Of O_2 On Sour Corrosion With And Without Inhibitor



Carbon Dioxide Corrosion Rates with the Addition of Oxygen in Surface Water



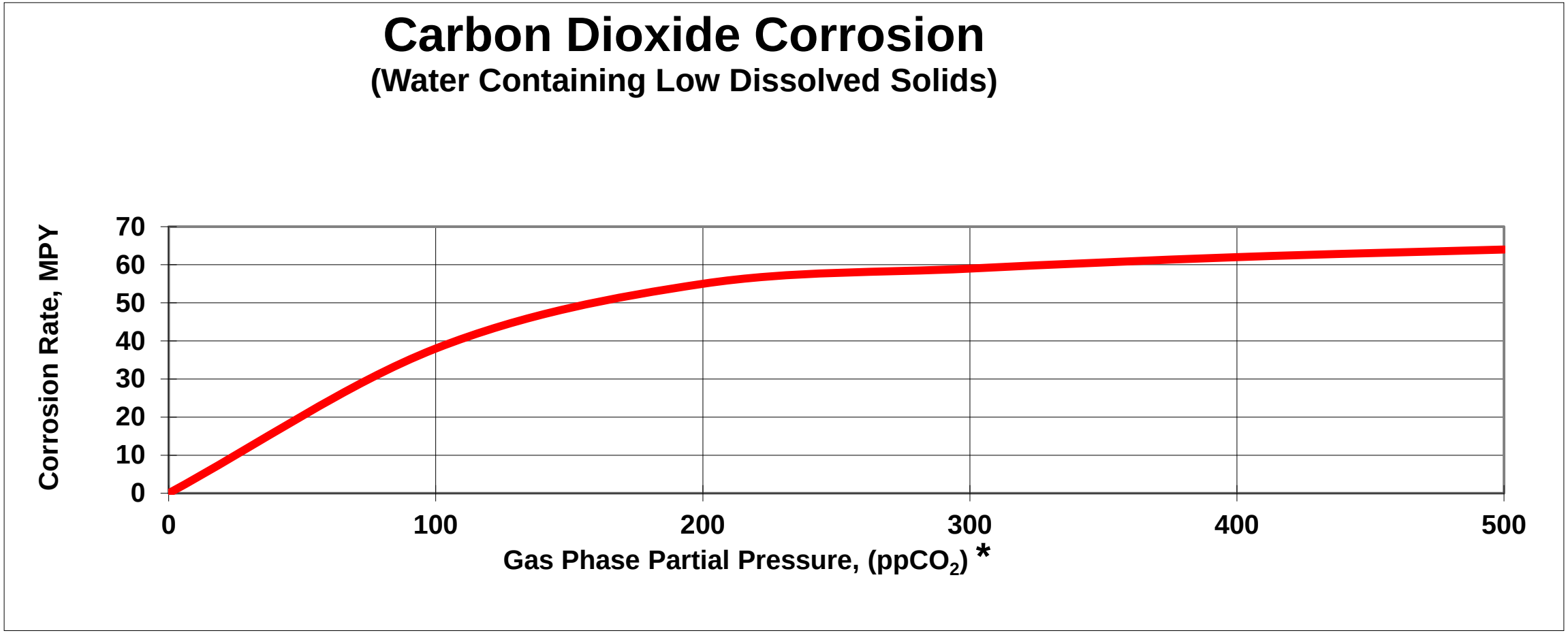
Estimation: ppm O_2 = 10 – 0.555 (X°F - 30°F), where X°F is the water temperature.

Acid Gases
Carbon Dioxide (CO_2)

$$CO_2 + H_2O \leftrightharpoons H_2CO_3 \leftrightharpoons H^+ + HCO^-_3$$

- CO_2 forms a weak acid that attacks metal
- Often takes the form of “Mesa” pitting type attack

Partial Pressure of Carbon Dioxide Vs. Corrosion Rate



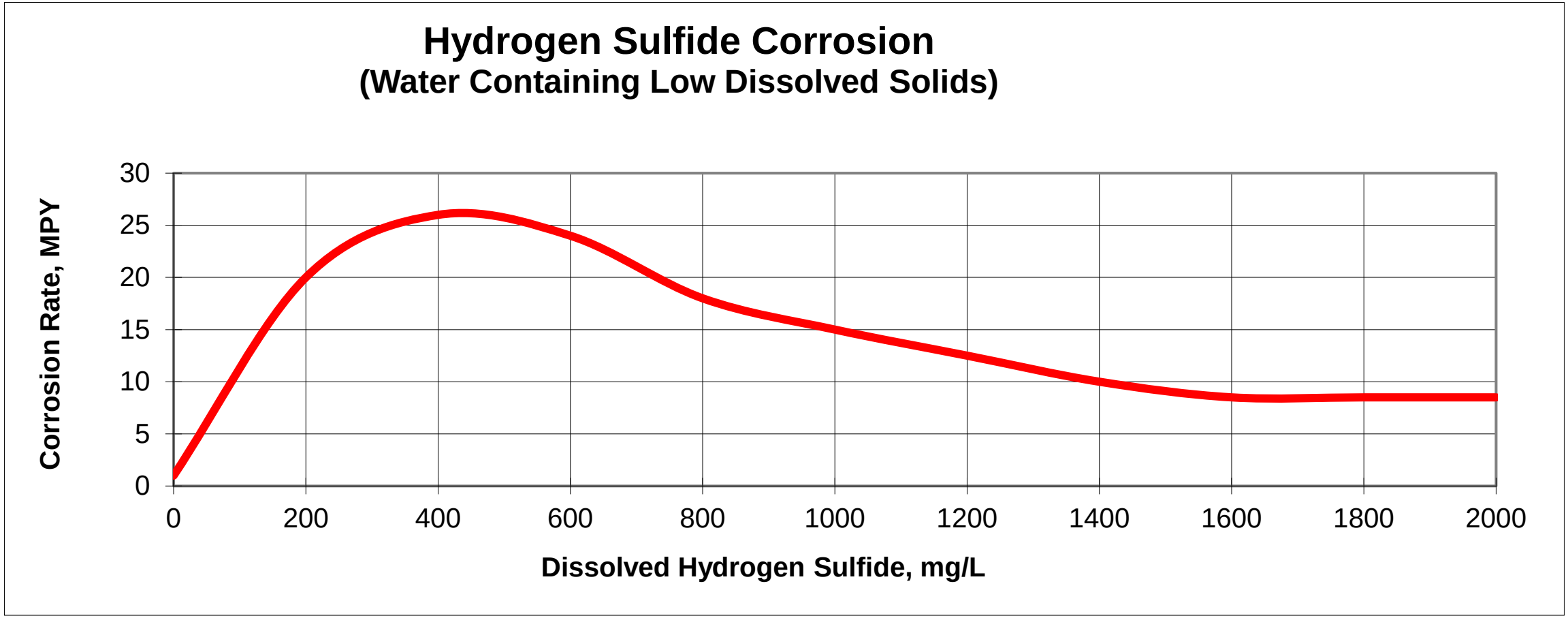
- $ppCO_2 = \frac{\text{System } CO_2 \text{ (Mole \%) X (System Pressure + Atmospheric Pressure)}}{100}$

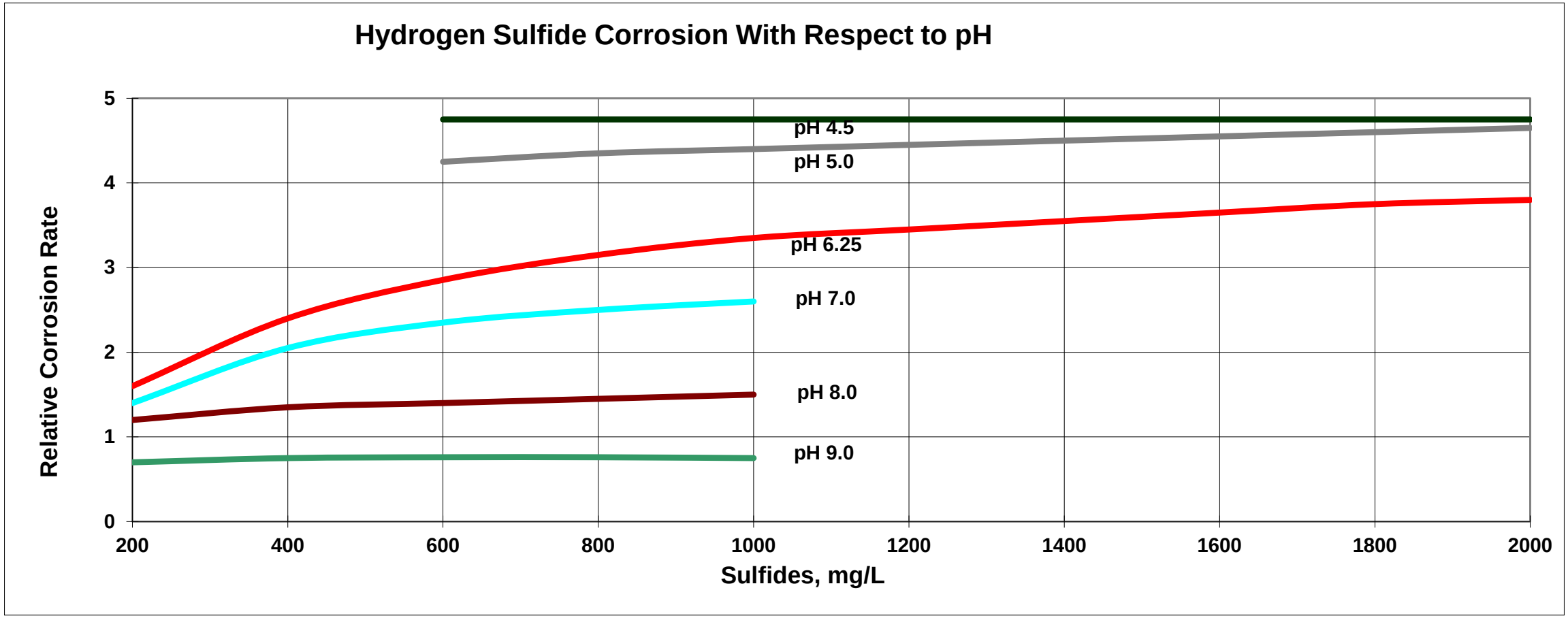
Acid Gas - Hydrogen Sulfide (H_2S)

$$H_2S + Fe = FeS + H_2$$

- Has characteristic “rotten egg” smell
- Creates a black deposit FeS
- Usually a shallow “dish” type attack, but may have pitting
- H2S forms a weak acid that attacks metal
- Usually has etching in the bottom of the pits

Courtesy- Corrosion of Oil and Gas Well Equipment, API cc 1958


Hydrogen Sulfide Corrosion
(Water Containing Low Dissolved Solids)
Corrosion Rate, MPY
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Dissolved Hydrogen Sulfide, mg/L


Hydrogen Sulfide Corrosion With Respect to pH
Relative Corrosion Rate
0
1
2
3
4
5
200
400
600
800
1000
1200
1400
1600
1800
2000
Sulfides, mg/L
pH 4.5
pH 5.0
pH 6.25
pH 7.0
pH 8.0
pH 9.0

Acid Gas “Worry Levels”

Sweet	Any amount of CO_2 with 5 ppm or less H_2S.
Sour	Any amount of CO_2 with 10 ppm or more H_2S.
Oxygen Assisted	Any amount of CO_2 and / or H_2S with 10 -20 ppb or more O_2.

- Levels relative to measurements made on fresh samples.
- Your “Worry Levels” may change with Temperature, Pressure and other corrosive constituents

Water /Solids /Gas / Product Chemistry

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Velocity Effects
Pipeline Flow Conditions - Water

Gas (ft/sec):	
0 - 7.5	Stratified
7.5 – 15	Slug
15 – 25	Annular Mist
> 35	Erosion

Liquids (ft/sec):	
0 - 3.5	Stratified
3.5 – 7	Slug
> 7.5	Turbulent

Temperature Effects

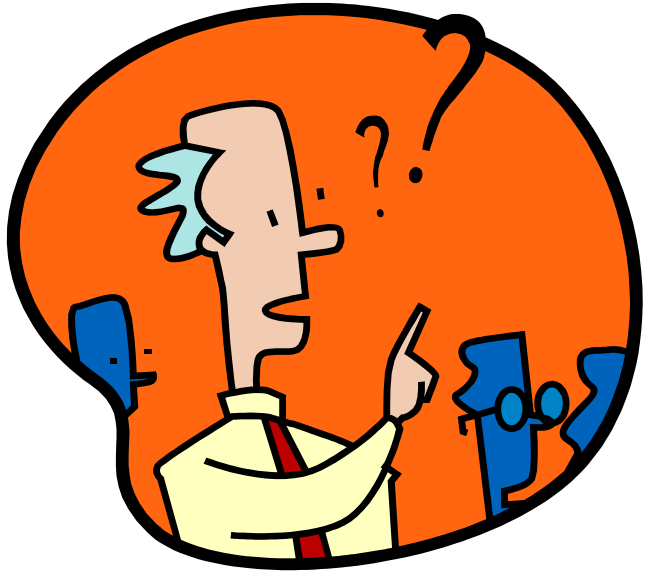
Rule of Thumb:

Corrosion rates double for every 10 C° (18 F°) increase in temperature.

Free Water and Solids

- Acid Gases
- Anions
- Cations
- pH
- Alkalinity
- Scaling Indices

Questions?



Thank you for your attention and for allowing me to present this information

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