Internal Corrosion Monitoring for Gas Pipelines

38th Annual Corrosion Short Course

EnhanceCo Inc

Lance Barton

Tom Pickthall

2026

Why Do We Need To Monitor Gas Pipelines

Upsets Occur

I have dry gas, so I don't have corrosion argument no longer works

High profile accidents recently with gas pipelines lead to:

Additional Regulations

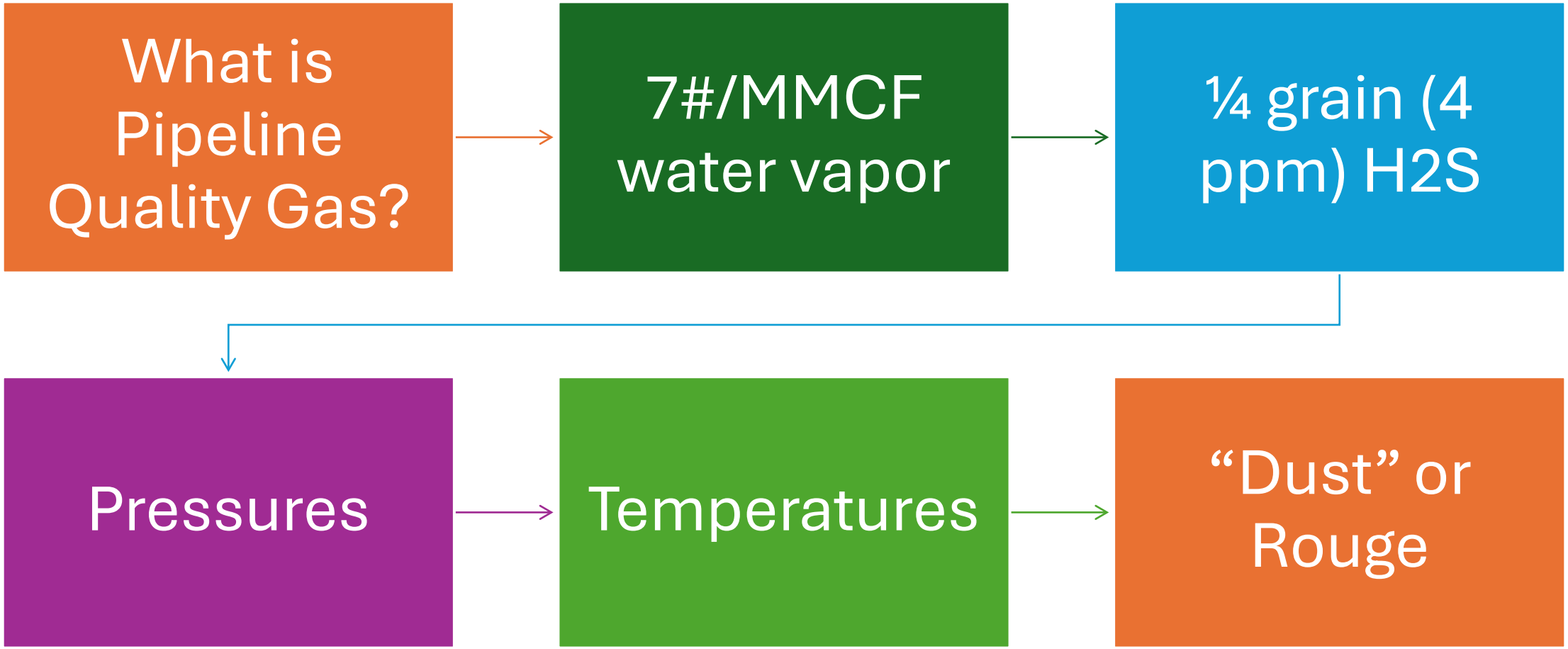
How Can We Monitor Gas Pipelines?

PRODUCT QUALITY

INDIRECT MEASUREMENTS

DIRECT MEASUREMENTS

Product Quality

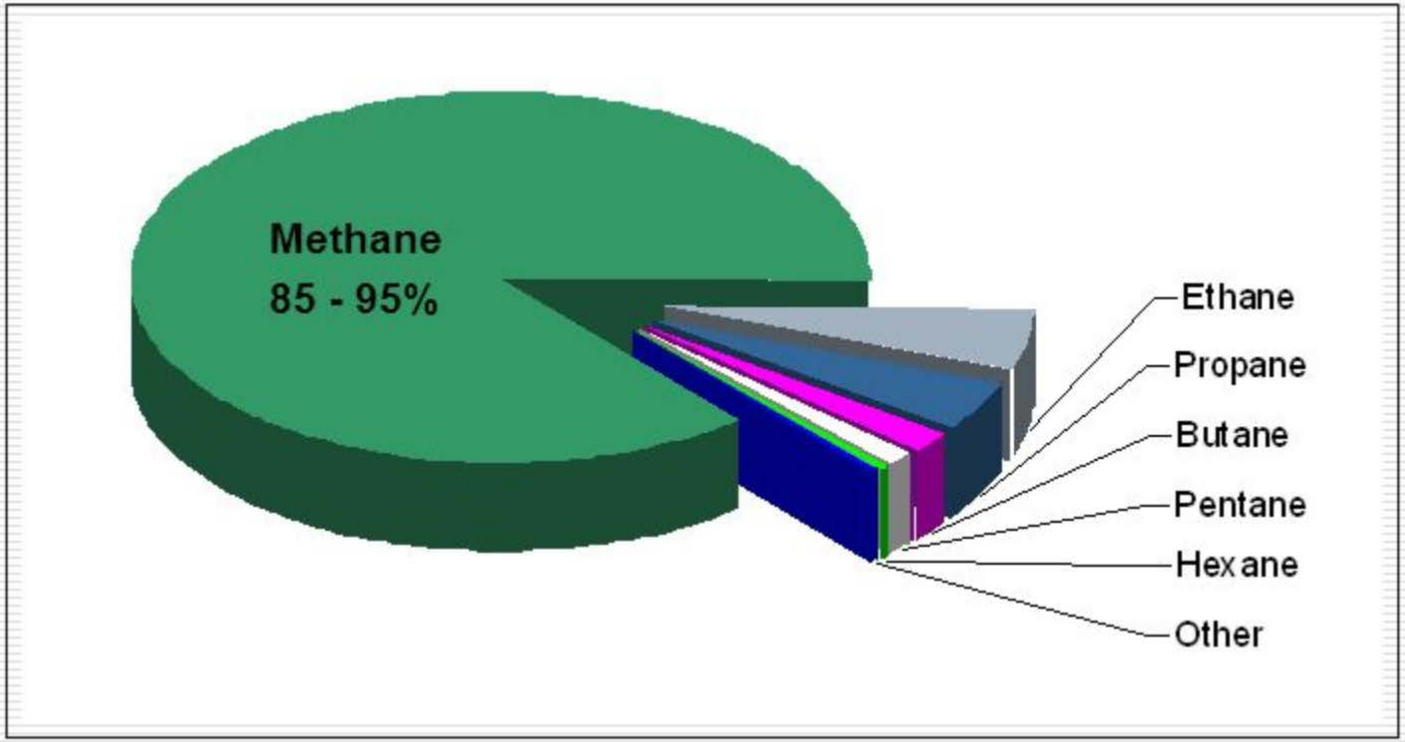


Specifications for Pipeline Quality Gas

Major Components	Minimum Mol%	Maximum Mol%
Methane	75	None
Ethane	None	10
Propane	None	5
Butanes	None	2
Pentanes and heavier	None	0.5
Nitrogen and other inerts	None	3
Carbon dioxide	None	2–3
Total diluent gases	None	4–5
Trace components		
Hydrogen sulfide	0.25–0.3 g/100 scf (6–7 mg/m^3)	
Total sulfur	5–20 g/100 scf (115–460 mg/m^3)	
Water vapor	4.0–7.0 lb/MM scf (60–110 mg/m^3)	
Oxygen	1.0%	
Other characteristics		
Heating value (gross, saturated)	950–1,150 Btu/scf (35,400–42,800 kJ/m^3)	
Liquids	Free of liquid water and hydrocarbons at delivery temperature and pressure	
Solids	Free of particulates in amounts deleterious to transmission and utilization equipment	

Source: Engineering Data Book (2004).

Pipeline Natural Gas composition

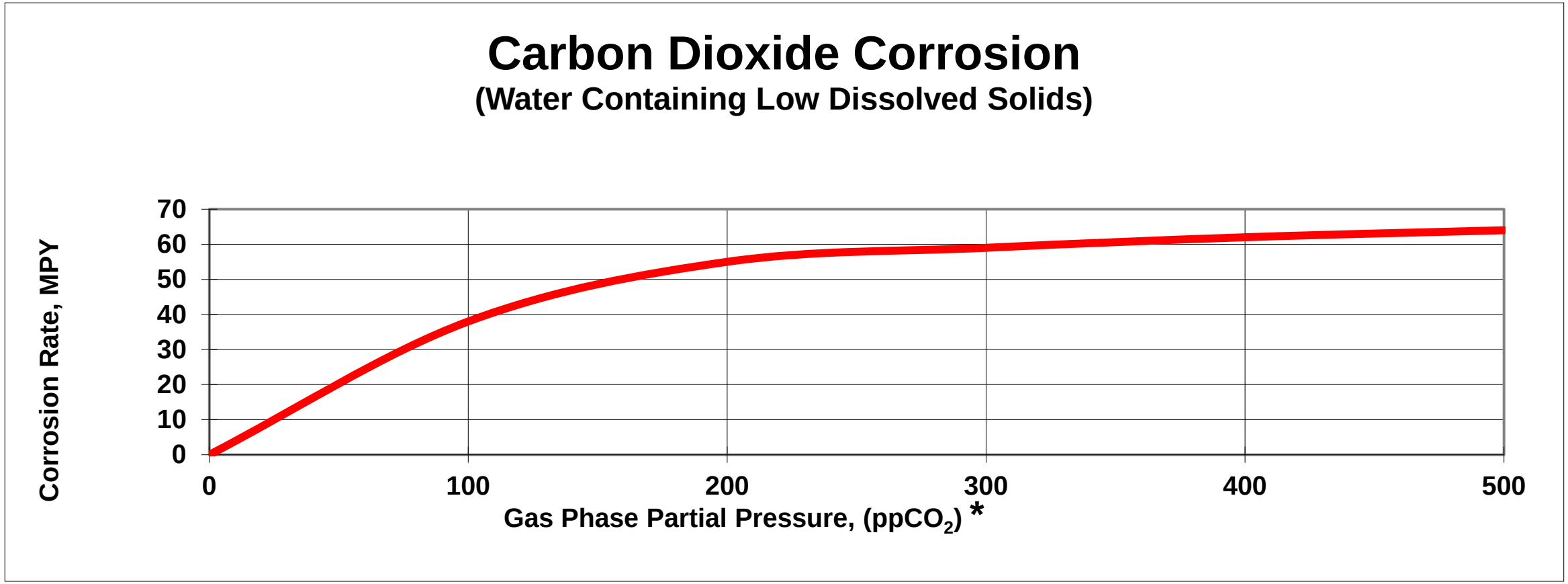


In the ground, natural gas contains a wide range of compounds. During well-head cleaning and processing, gas quality is improved to pipeline standards. Gas in the pipeline has a range of acceptable compositions. Typical pipeline gas would be as shown.

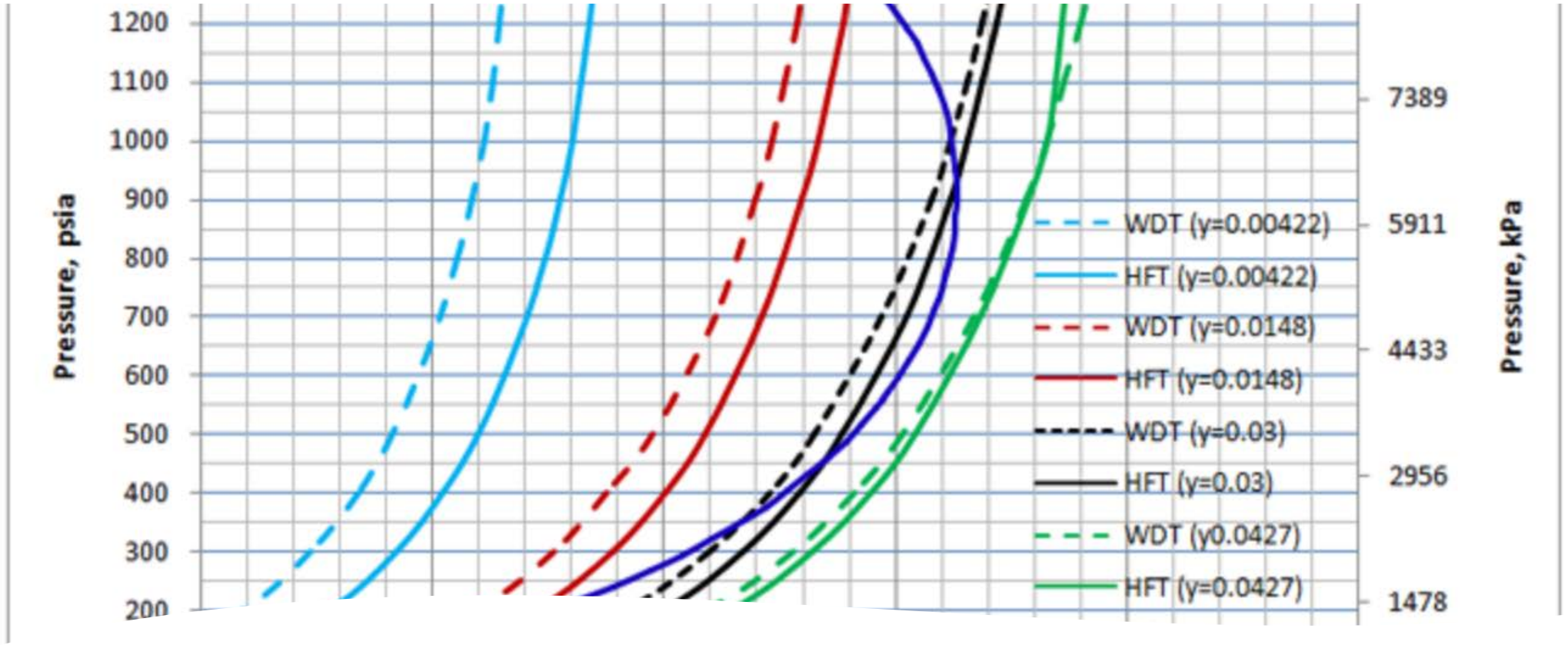
How Much Oxygen is 1%?

- 1% = 10,000 ppm
- All we need for corrosion is 10-50 ppb
- 10,000 ppm = 10,000,000 ppb!
- So any moisture is BAD

What About the Partial Pressure of Carbon Dioxide



- http://www.jmcampbell.com/tip-of-the-month/2011/01/what-is-the-impact-of-water-content-on-the-dew-point-and-hydrate-phase-behavior/



At What Point Do We Form Water?

- http://www.jmcampbell.com/tip-of-the-month/2011/01/what-is-the-impact-of-water-content-on-the-dew-point-and-hydrate-phase-behavior/

The NPRM Requirements are Covered by Three Sections for Internal Corrosion

192.710
Pipeline Assessments

192.935
What additional preventive and mitigative measures must an operator take?

§ 192.710 - Pipeline Assessments

Internal corrosion. To address the threat of internal corrosion on a low stress segment, an operator must—

- Conduct a gas analysis for corrosive agents at least twice each calendar year;
- Conduct periodic testing of fluids removed from the segment.
- At least once each calendar year test the fluids removed from each storage field that may affect a segment;

§ 192.710 - Pipeline Assessments

- At least every seven (7) years, integrate data from the analysis and testing required by paragraphs (ii)(A)-(ii)(B) with applicable internal corrosion leak records, incident reports, safety-related condition reports, repair records, patrol records, exposed pipe reports, and test records,

- And define and implement appropriate remediation actions.

§ 192.935 What additional preventive and mitigative measures must an operator take?

- Monitor for, and mitigate the presence of, deleterious gas stream constituents.
- At points where gas with potentially deleterious contaminants enters the pipeline, use filter separators or separators and continuous gas quality monitoring equipment.
- At least once per quarter, use gas quality monitoring equipment that includes, but is not limited to, a moisture analyzer, chromatograph, carbon dioxide sampling, and hydrogen sulfide sampling.

§ 192.935 What additional preventive and mitigative measures must an operator take?

- Use cleaning pigs and sample accumulated liquids and solids, including tests for microbiologically induced corrosion
- Use inhibitors when corrosive gas or corrosive liquids are present

§ 192.935 What additional preventive and mitigative measures must an operator take?

Address potentially corrosive gas stream constituents as specified in § 192.478(a), where the volumes exceed these amounts over a 24-hour interval in the pipeline as follows:

- Limit carbon dioxide to three percent by volume
- Allow no free water and otherwise limit water to seven pounds per million cubic feet of gas; and
- Limit hydrogen sulfide to 1.0 grain per hundred cubic feet (16 ppm) of gas. If the hydrogen sulfide concentration is greater than 0.5 grain per hundred cubic feet (8 ppm) of gas, implement a pigging and inhibitor injection program to address deleterious gas stream constituents,
- including follow-up sampling and quality testing of liquids at receipt points.

Indirect Measurements

CORROSION COUPONS AND PROBES

GAS SAMPLES

SOLIDS

LIQUIDS

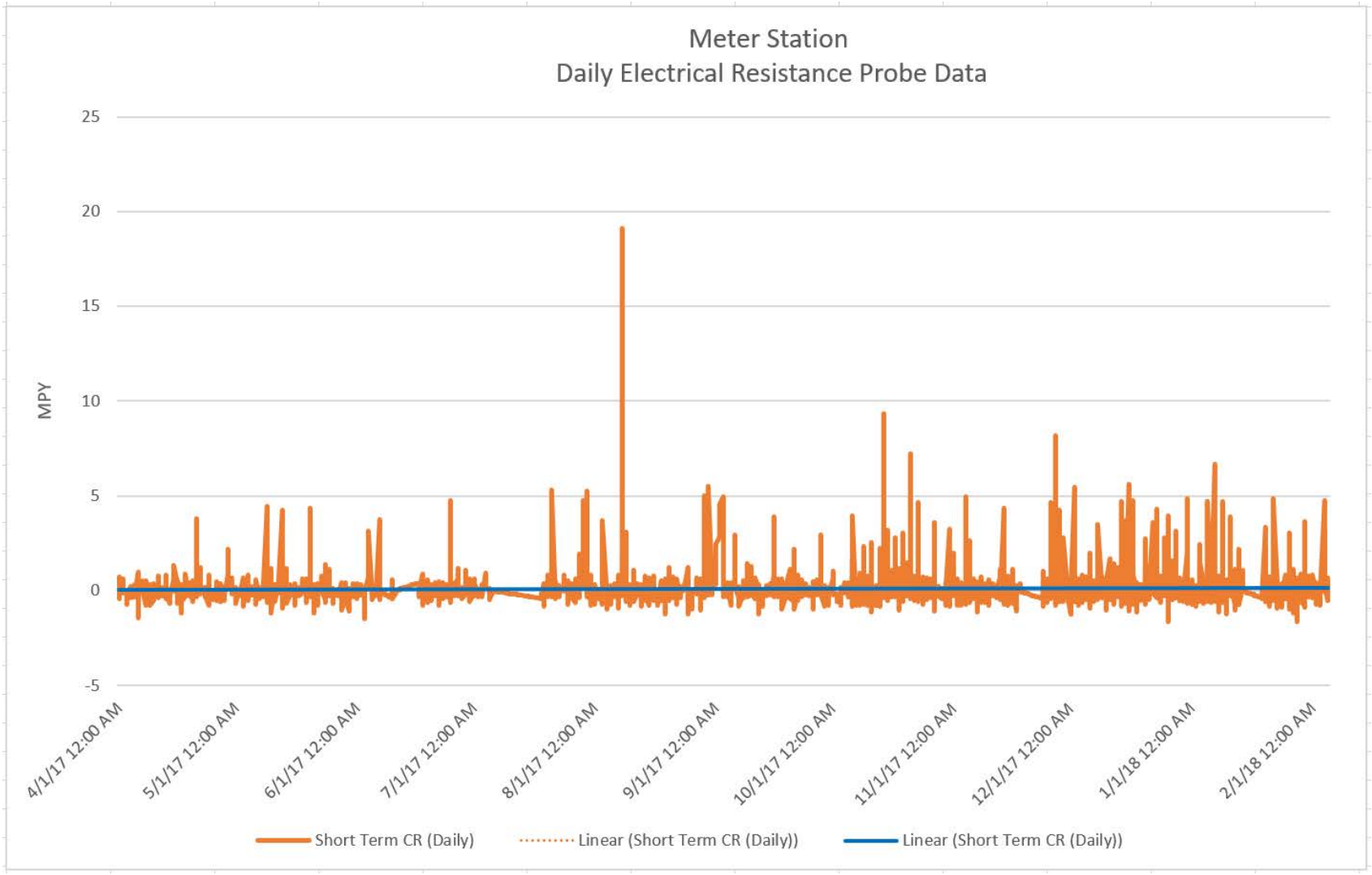
(HYDROCARBON AND WATER)

MICROBIOLOGY

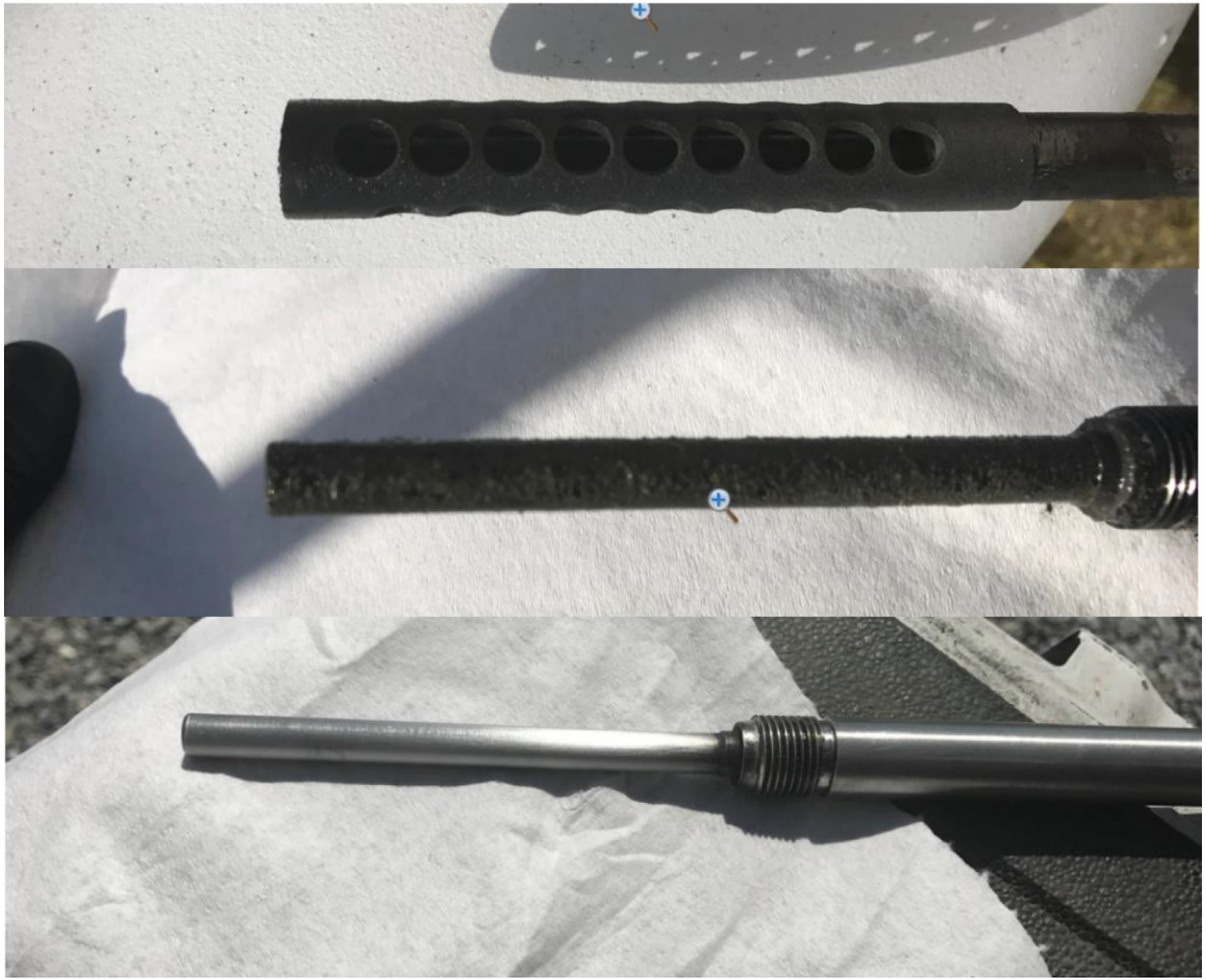
REVIEW

Electrical Resistance

On Line Corrosion Rate Readings



What We Found



Coupons and Holders

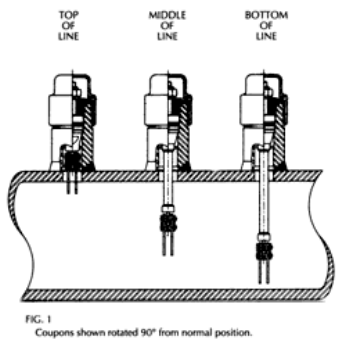
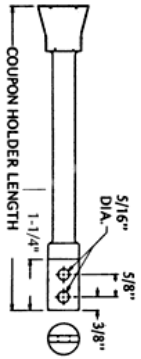


FIG. 1
Coupons shown rotated 90° from normal position.



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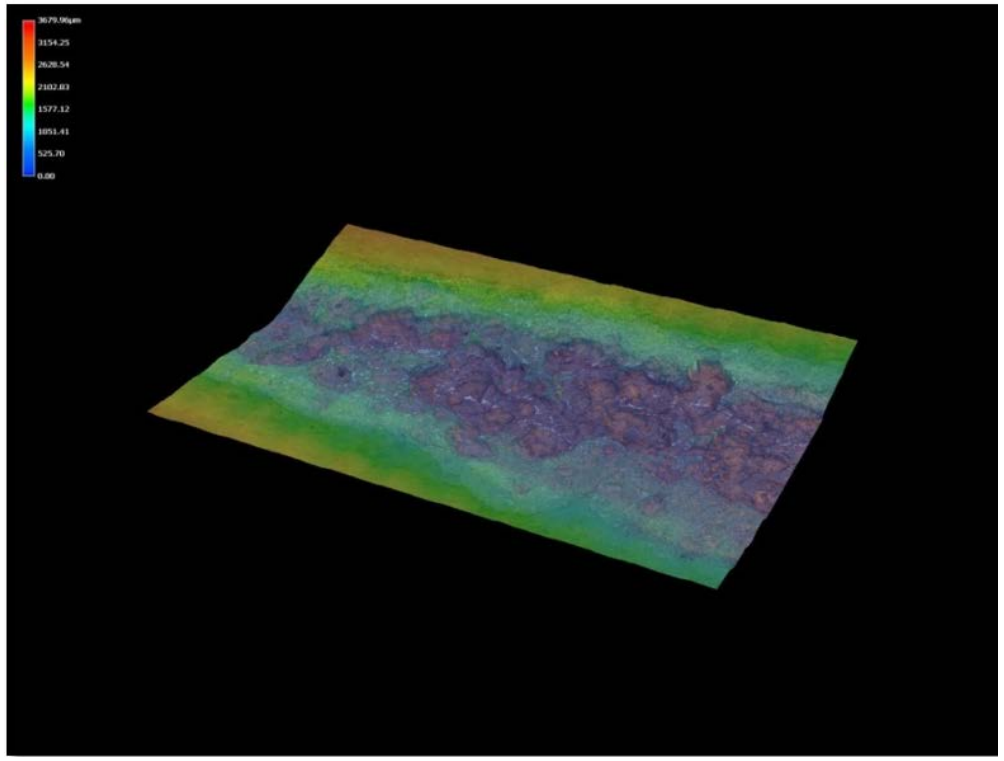
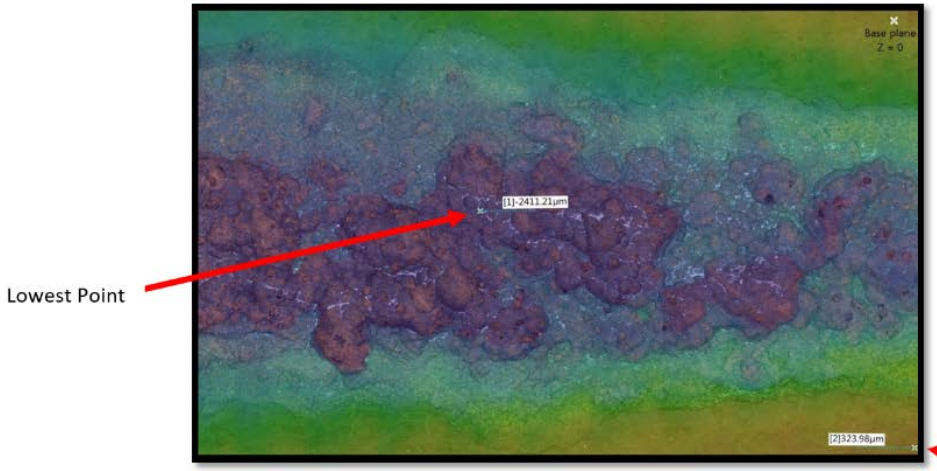
Structured Light Inspection

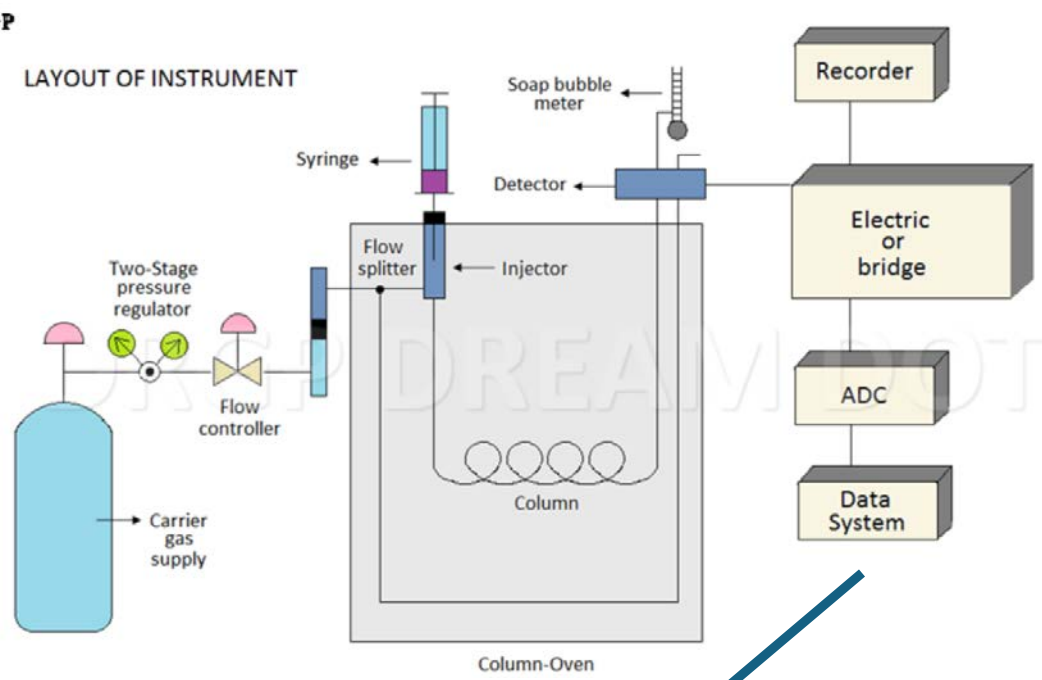




Lowest Point

Highest Point

Gas Sampling



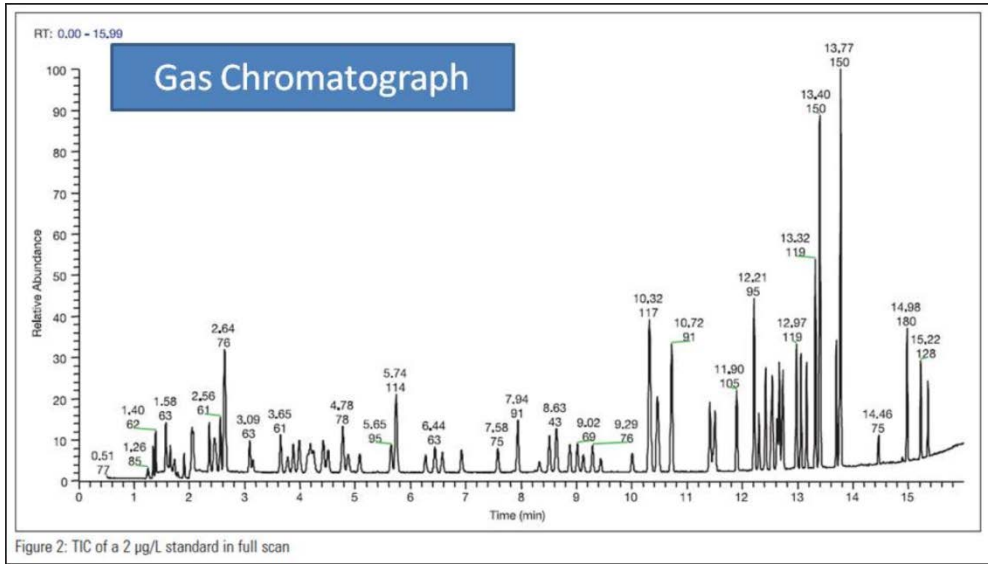


Figure 2: TIC of a 2 µg/L standard in full scan

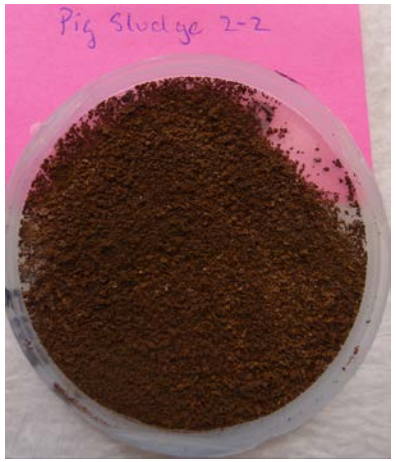
What Components of the Gas should I Sample?

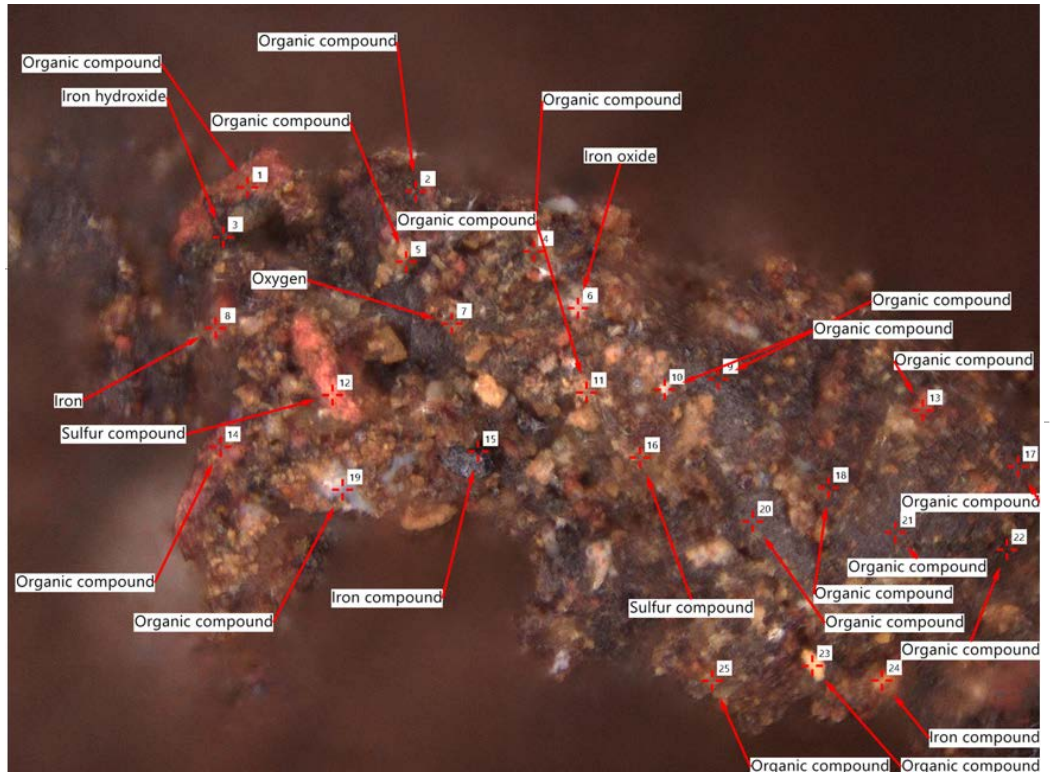
- Oxygen
- Carbon Dioxide
- Hydrogen Sulfide
- Moisture

Solids Sampling

What Do I need to Know?	Where Do I Get the Sample?	Are There Any Special Precautions?
• Elements • Compounds	• Pig Returns • Meter Runs • Gas Filtration	

Solids Analysis





Multi-point analysis by [wt%]

No.	Presumed material	C	S	O	Fe	H
1	Organic compound	30.0%	23.7%	21.9%	21.3%	3.1%
2	Organic compound	44.6%	0.0%	34.0%	21.4%	
3	Iron hydroxide	0.0%	0.0%	49.0%	44.4%	6.6%
4	Organic compound	51.4%	0.0%	25.7%	19.6%	3.3%
5	Organic compound	31.5%	0.0%	34.4%	23.8%	
6	Iron oxide	0.0%	0.0%	51.0%	49.0%	
7	Oxygen	0.0%	0.0%	100.0%	0.0%	
8	Iron	0.0%	0.0%	0.0%	100.0%	
9	Organic compound	56.0%	17.3%	22.8%	0.0%	3.9%
10	Organic compound	29.9%	21.5%	23.8%	8.4%	2.9%
11	Organic compound	47.1%	0.0%	32.9%	15.5%	4.5%
12	Sulfur compound	15.9%	54.6%	0.0%	0.0%	
13	Organic compound	34.4%	32.9%	14.7%	0.0%	2.6%
14	Organic compound	44.2%	0.0%	37.7%	18.1%	
15	Iron compound	26.9%	23.9%	17.9%	29.1%	2.2%
16	Sulfur compound	22.9%	77.1%	0.0%	0.0%	
17	Organic compound	53.0%	0.0%	23.1%	20.3%	3.6%
18	Organic compound	50.5%	0.0%	26.2%	19.0%	4.3%
19	Organic compound	36.7%	0.0%	33.4%	10.4%	3.5%
20	Organic compound	38.8%	0.0%	15.6%	25.7%	2.2%
21	Organic compound	54.0%	28.3%	14.4%	0.0%	3.3%
22	Organic compound	42.3%	0.0%	35.8%	21.9%	
23	Organic compound	46.9%	0.0%	32.3%	20.8%	
24	Iron compound	0.0%	61.8%	0.0%	38.2%	

Liquids Analysis

What Do I need to Know?

- Water?
  - pH
  - Anions
  - Cations
  - Compounds
- Hydrocarbon?
  - FTIR /chemical Makeup
  - Carbon Chains

Where Do I Get the Sample?

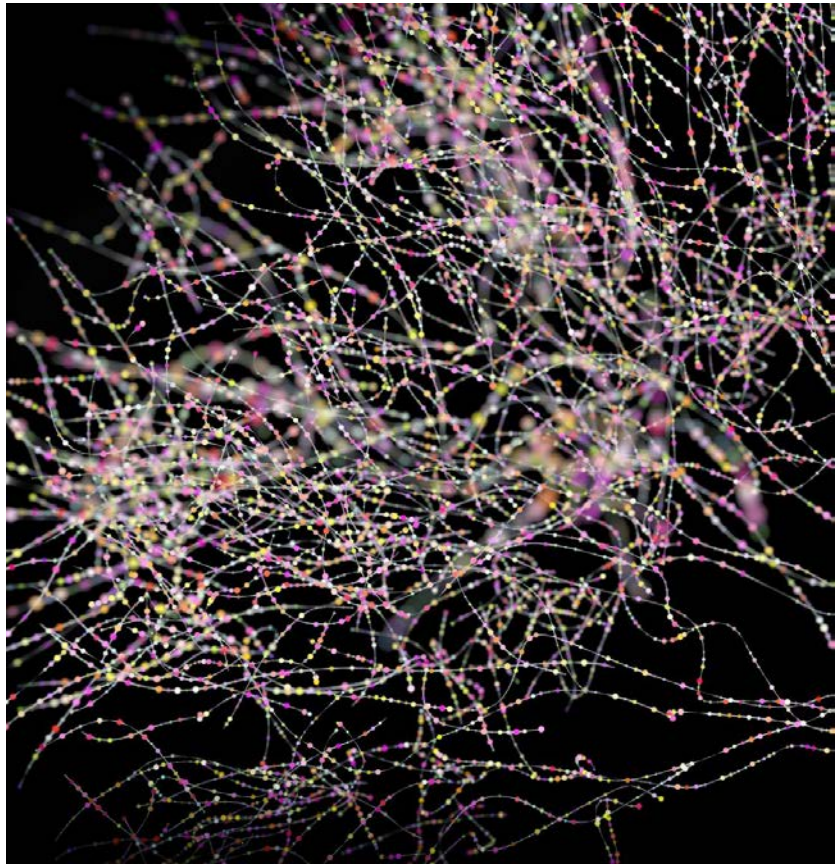
- Pig Returns
- Drips
- Filter Separators

Are There Any Special Precautions?

Bacteria Testing and MIC Control

Nature of Bacteria

- Bacteria are single celled microorganisms that exist everywhere. They are generally prokaryotes that lack a nucleus and true organelles. Eukaryotes are multicellular organisms that have nucleus and organelles. That said, there are multicellular bacteria……
- Bacteria grow rapidly when conditions are suitable for growth.
- Bacteria can utilize a wide range of nutrients, both organic and inorganic
- Bacteria can change to adapt to their environment
- There are other life forms (yeast/mold/fungi/eukaryotes) that can cause corrosion issues



Bacteria Problems
Oil and Gas Industry

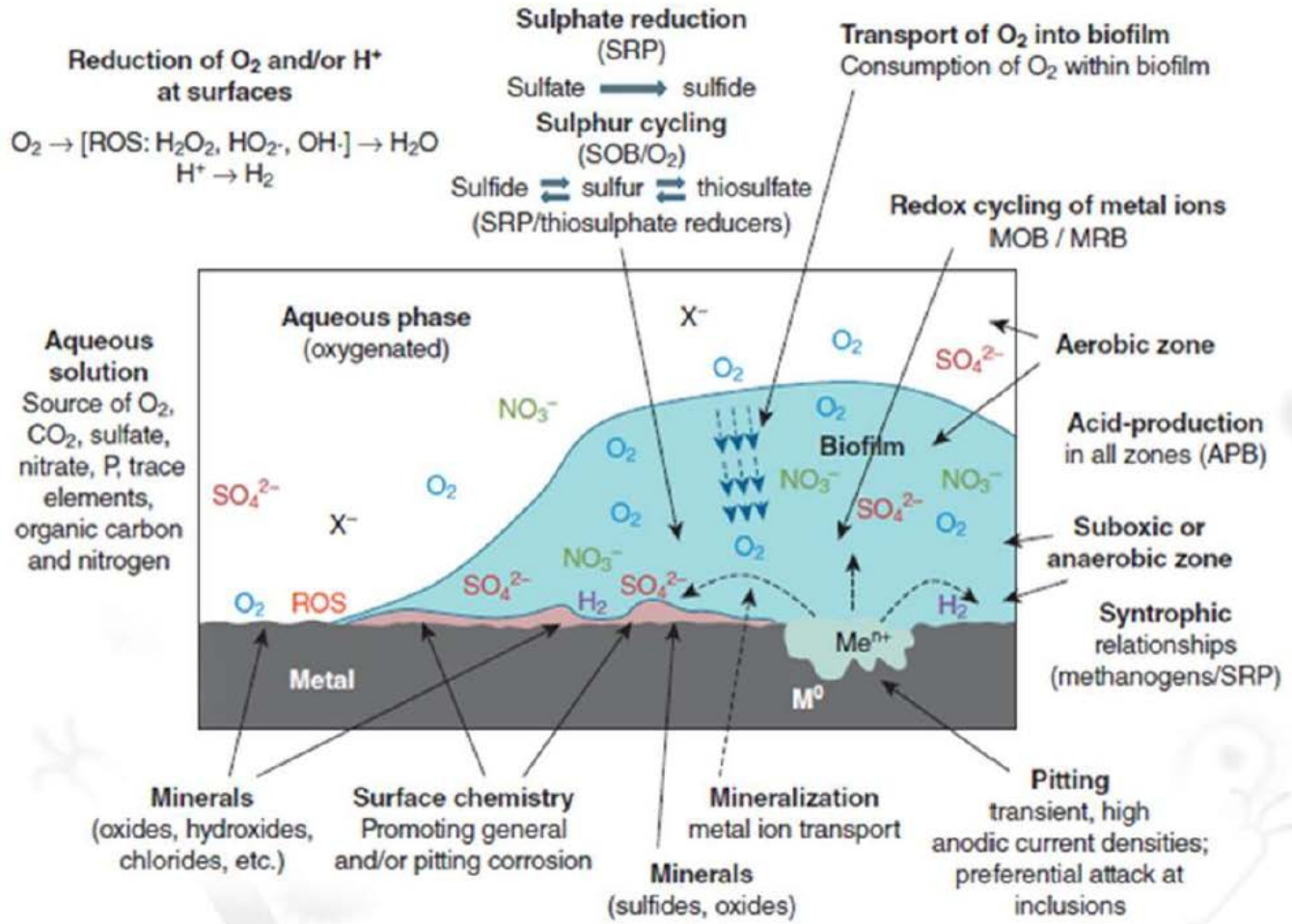
- Plugging of Filters, Vessels and Injection Wells with Biomass and/or Iron Sulfide
- Microbial Influenced Corrosion (MIC)
- Souring of Reservoirs with Hydrogen Sulfide
- Degradation of Polymer or Coating
- Emulsion Stabilization
- Increase Total Cost of Operation

General Types of Bacteria that are tested for

- *Sulfate Reducing*
- *Acid Producing*
- *Slime Forming*
- *Iron Reducing*
- Iron Oxidizing
- Nitrite Reducing
- Nitrite Oxidizing
- ETC……

Why do we care?

How do they cause damage?



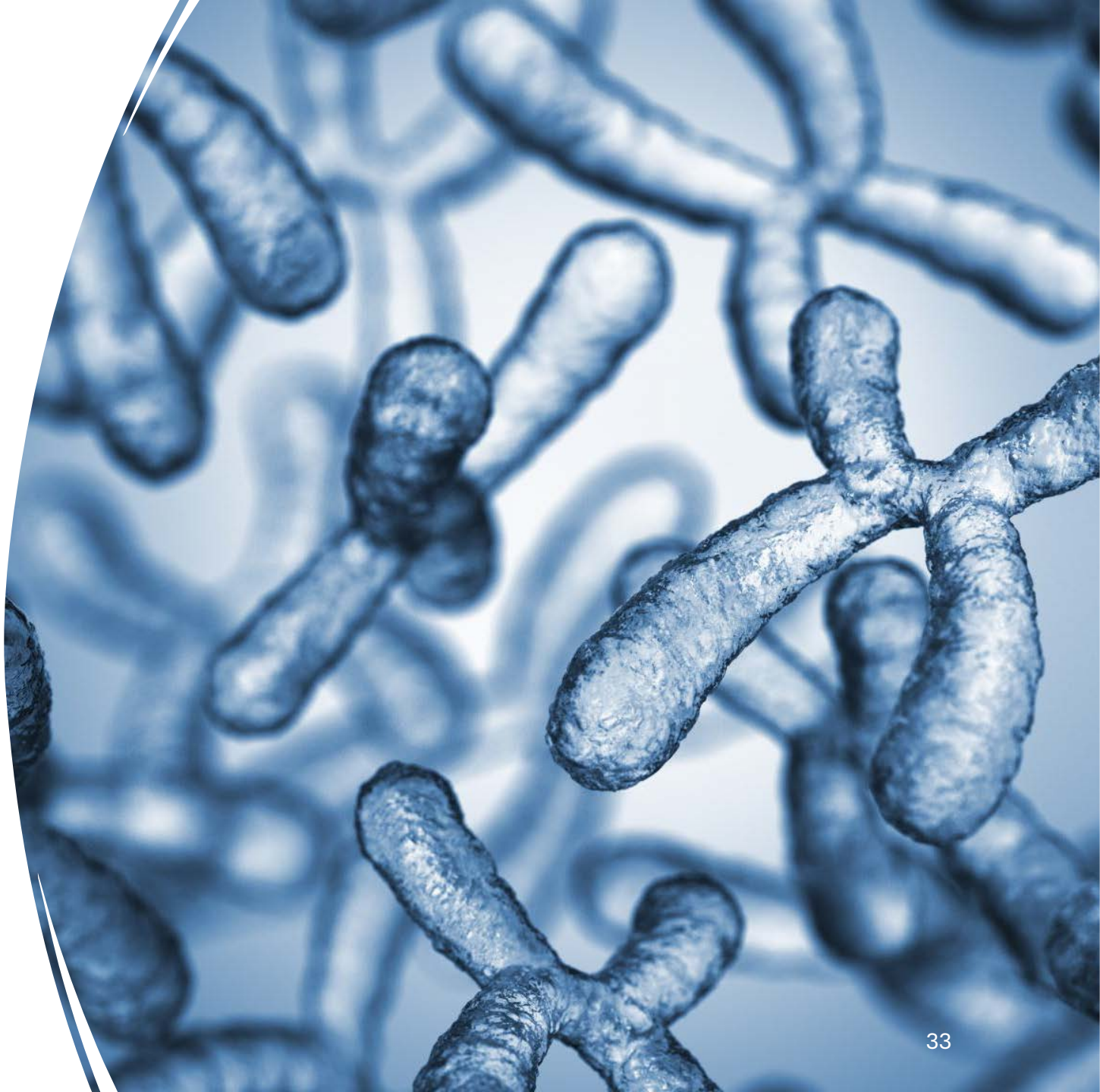
Bacteria Primer

Planktonic vs. Sessile

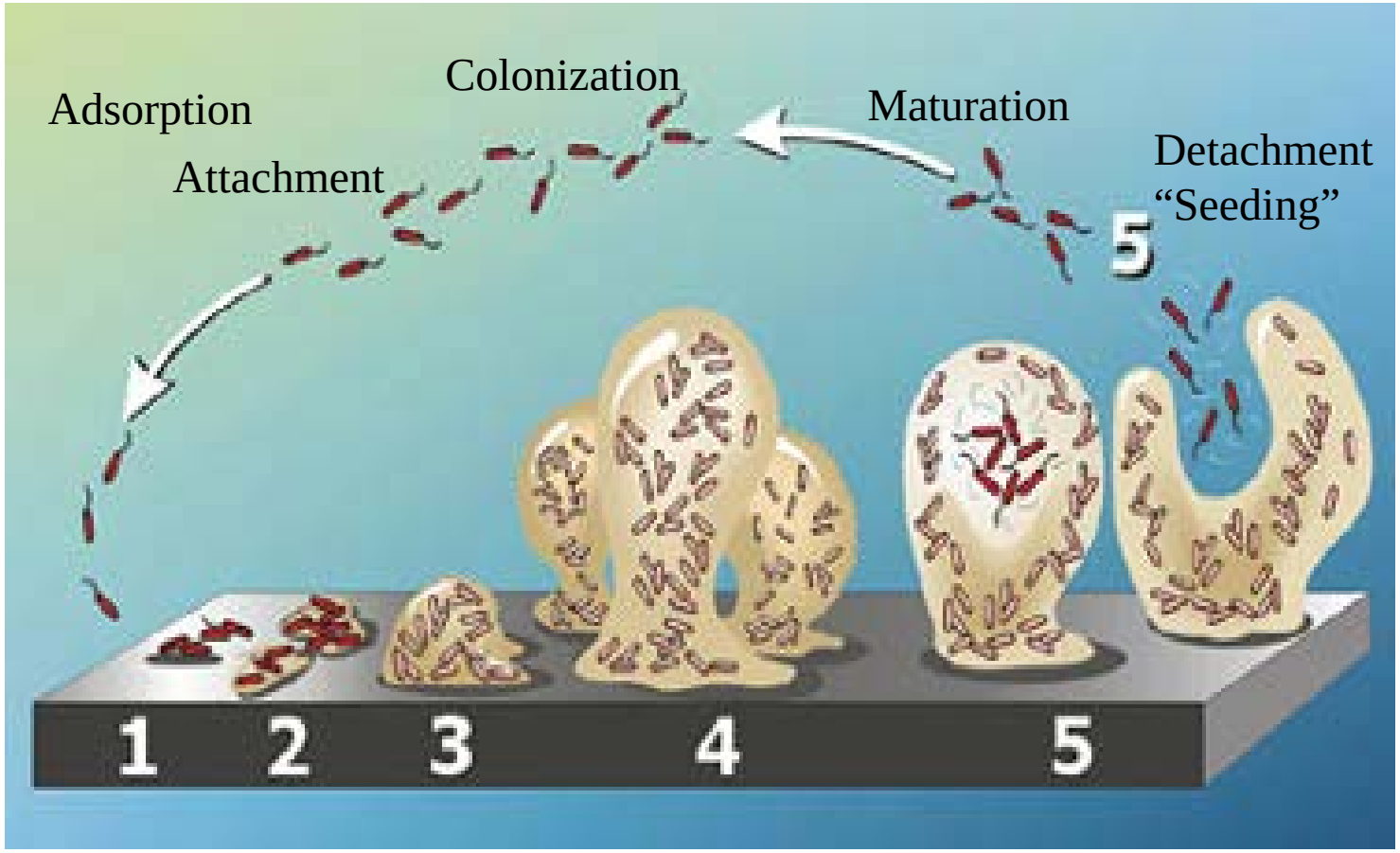
Aerobic vs. Anaerobic vs. Facultative

What is a Biofilm?

- Biofilm is a Matrix of Microbial (Bacteria) Cells
- The Cell Walls are Loosely Bound Together by a Produced Exopolymer
- Exopolymer is a Polysaccharide (Sticky Sugar) Material



Biofilm Formation (How Do They Spread?)



Sulfate Reducing Bacteria

Tend to be anaerobic

Reduce sulfate or sulfite to sulfide

Can cause plugging, solids deposition and under-deposit corrosion

DESUFOVIBRIO DESULFURICANS is a common oilfield SRB

NACE RP-38 is a guideline for testing procedures for SRB's

Acid Producing Bacteria

Can be either Aerobic or Anaerobic

Produce Acids as a byproduct - organics such as acetic, citric, propionic and inorganics such as sulfurous, carbonic, nitric

Are Synergistic

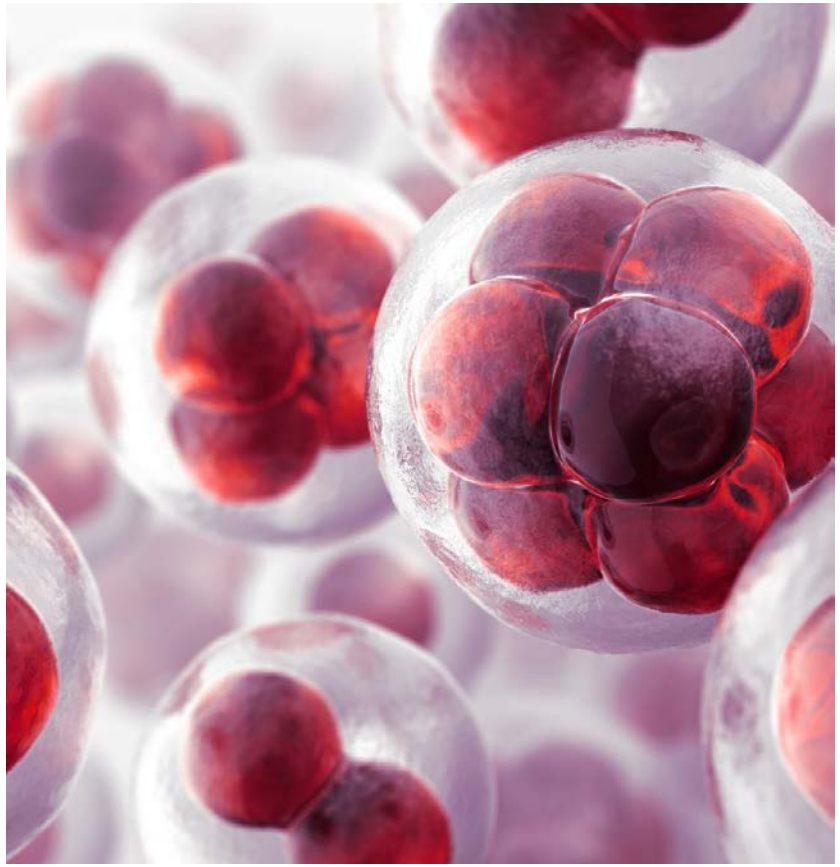
Can cause Rapid Pitting

Slime Formers

- Produce dense masses of slime which sticks to solid surfaces
- Contribute to corrosion by forming a Shielding Layer of slime
- Can be Aerobic or Anaerobic
- Are commonly called Marine Bacteria
- Pseudomonas is a common Marine Bacteria
- Are Synergistic

Iron Reducing Bacteria

- Form Turbucles or Deposits of Ferric Hydroxide from the Soluble Iron in the water
- Can cause Corrosion and Plugging
- Create Concentration Cells
- Are typically Aerobic
- Gallionella is a type of Iron Bacteria
- Are Synergistic



Why Worry?

Sessile Bacteria Old Vs. New Colony Theory

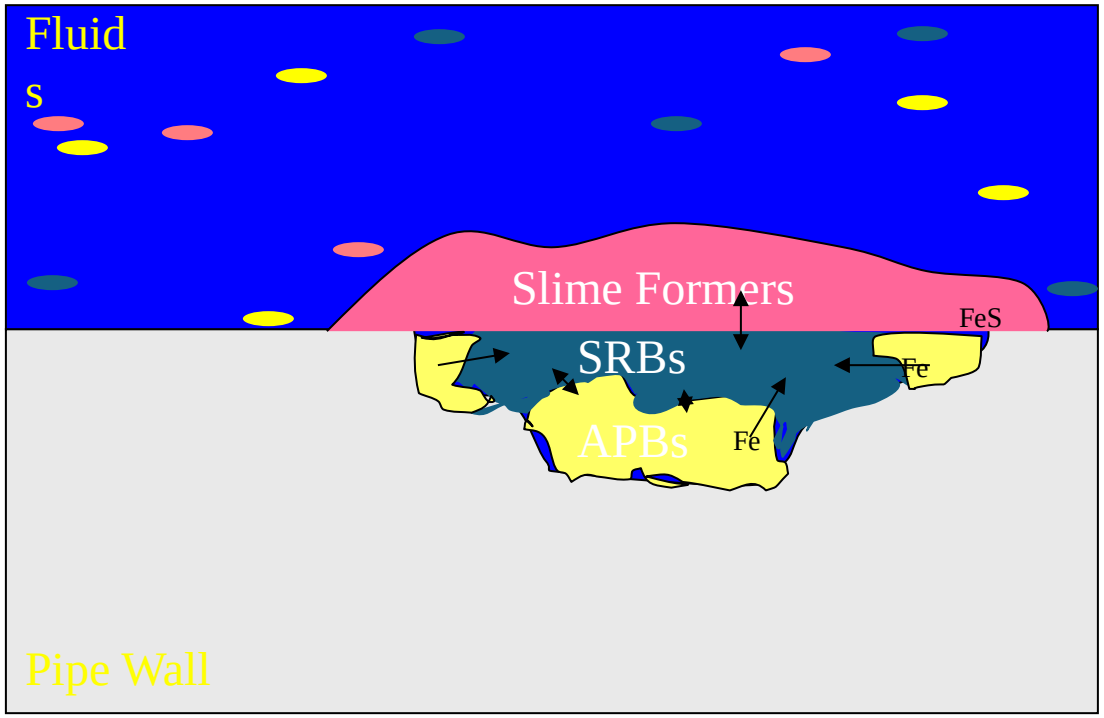
Old

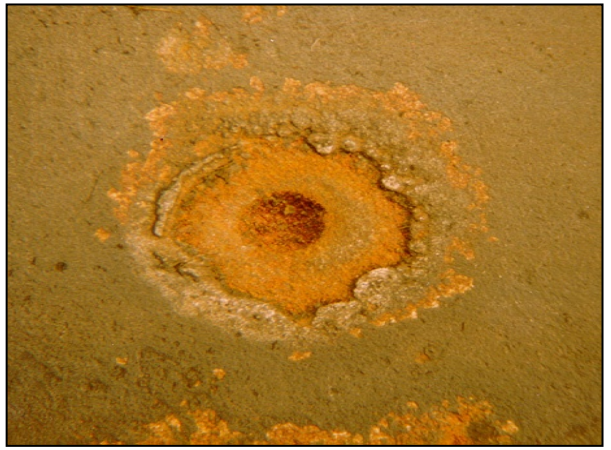
- Layers

New

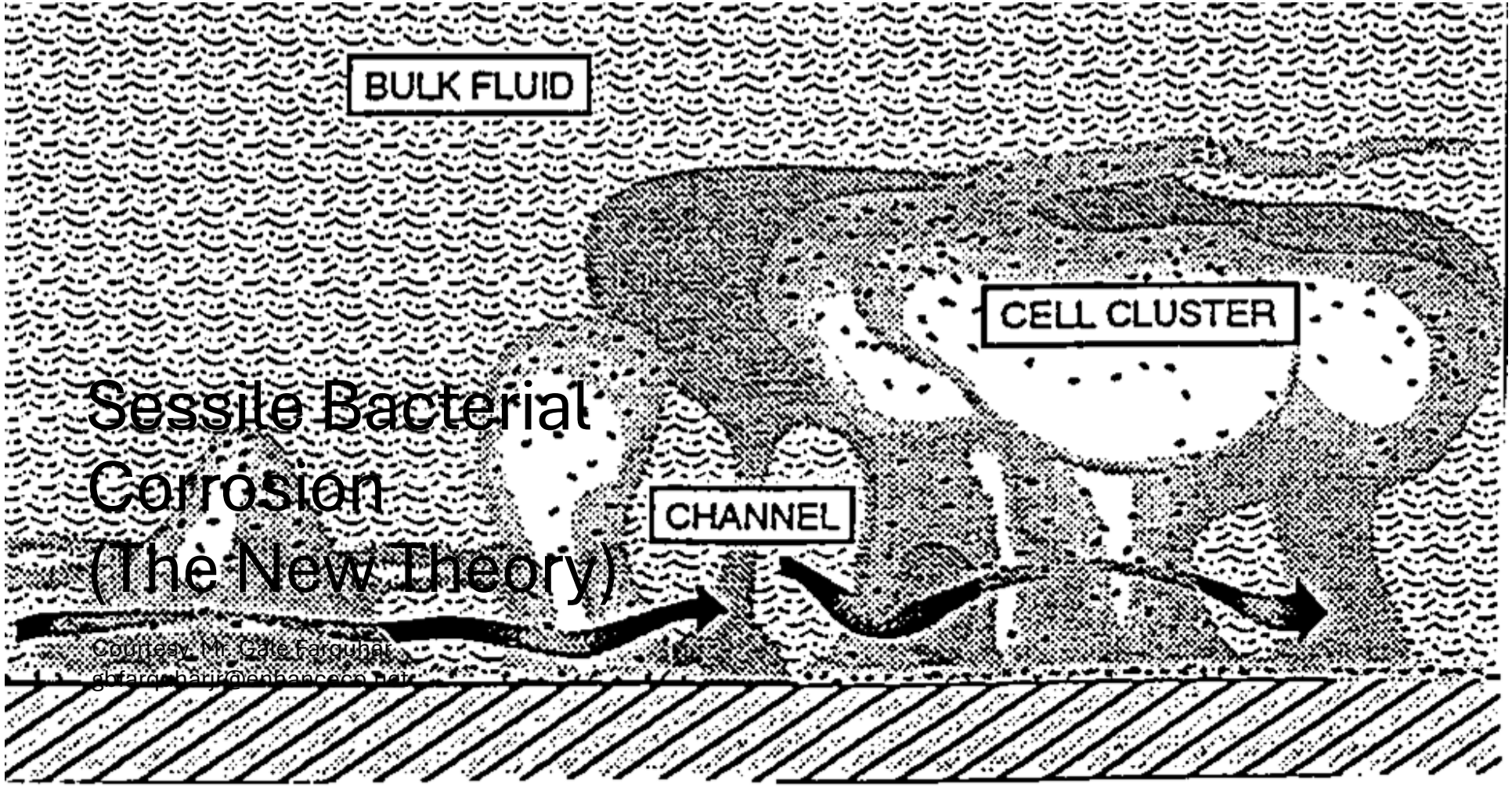
- Cell Clusters
- (Univ. of Montana Studies)

Sessile Bacterial Corrosion (The Old Theory)





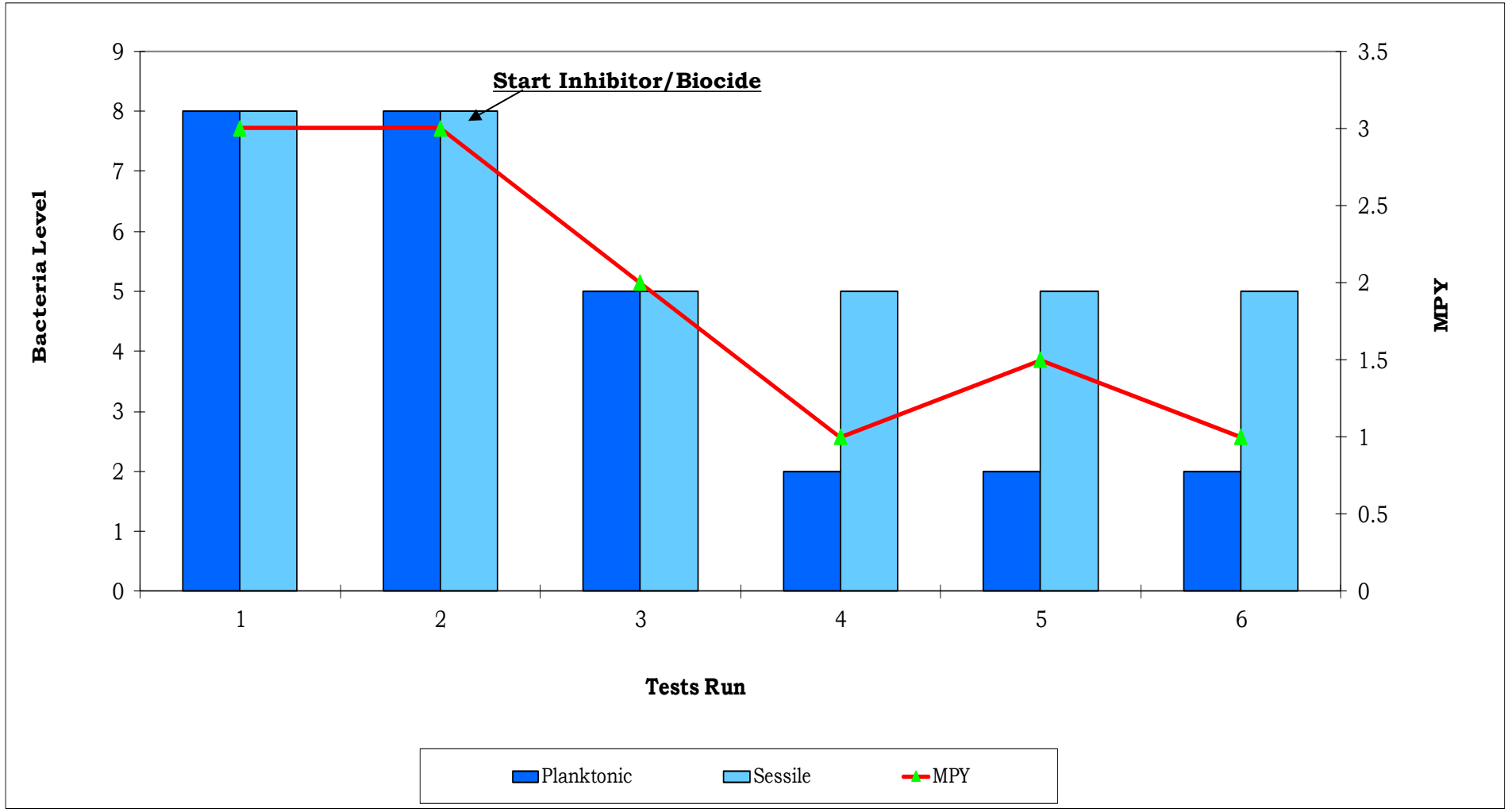
Sessile Bacterial Corrosion (The New Theory)



BIOFILM - NEW CONCEPTUAL MODEL

Courtesy: Mr. Gale Farquhar
gbfarquharjr@enhancecp.net

Sessile Vs. Planktonic
With an Inhibitor/Biocide



“New” Discoveries

- Bacteria become more resistant to biocides when they go from Planktonic to Sessile
- Bacteria can be made to dislike or avoid certain things
- Cell to Cell Communications Studies

Where is Work ongoing?

- Medical Field
- Paint and Coatings Field
- Research Organizations
- **DNA**
- Aerospace Industry
- Bio-Remediation Industry

Down the Rabbit Hole with DNA

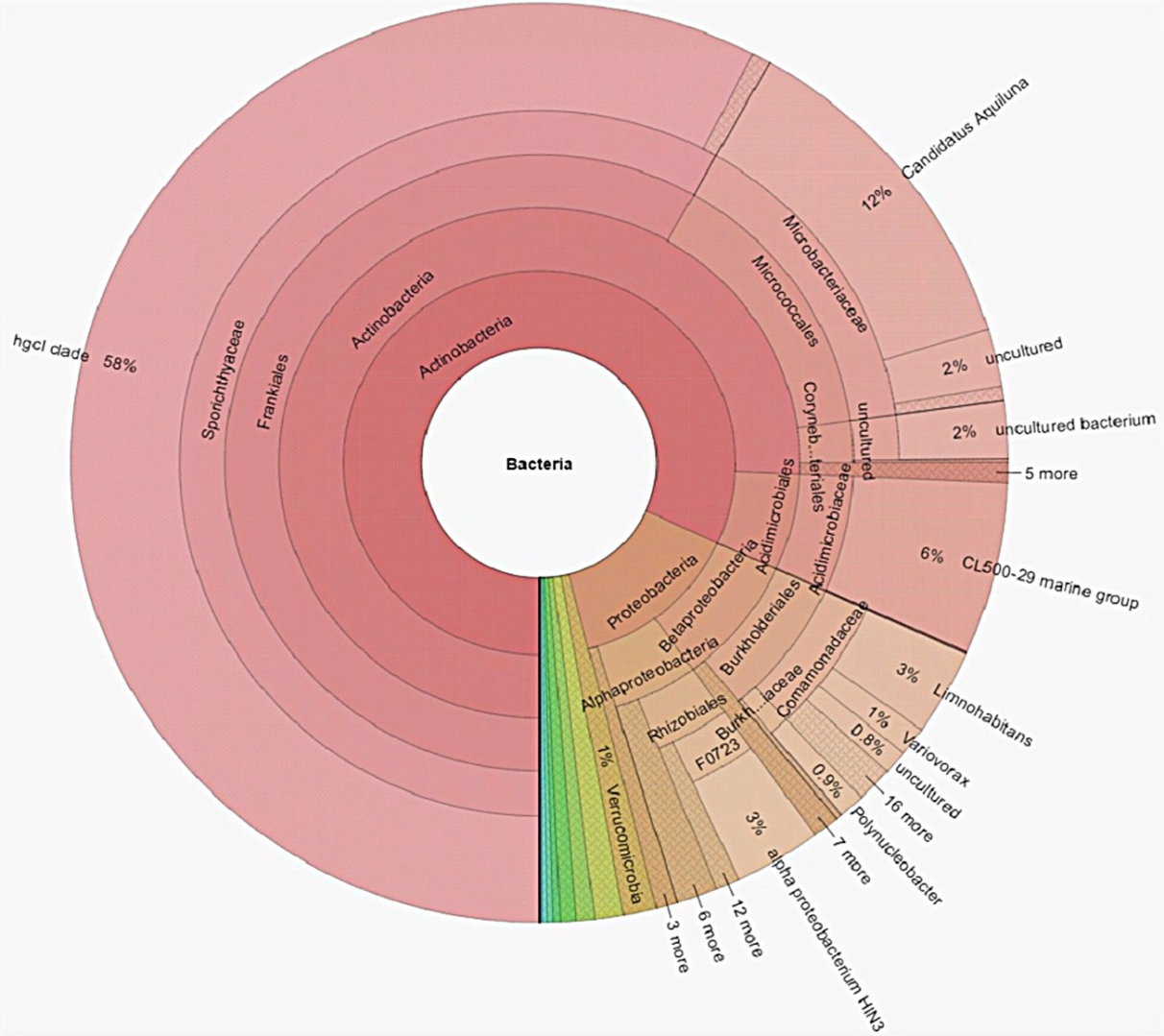
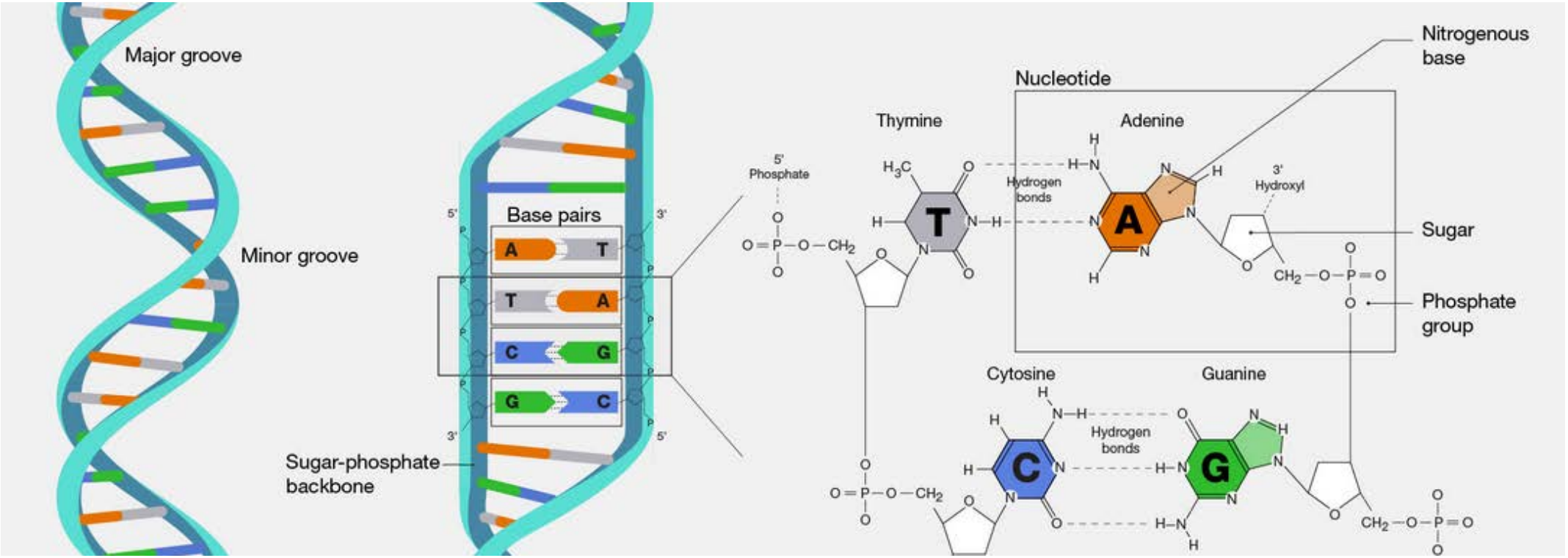


Figure 2. Bacterial composition

What is DeoxyRibonucleic Acid (DNA)?

https://www.genome.gov/genetics-glossary/Deoxyribonucleic-Acid



What YOU can learn with DNA

Table 1. Bacterial composition

Genus	Abundance	Metabolism/Habitat
Sporichthyaceae(hgcI clade)	57%	Environmental fresh water bacteria
Candidatus Aquiluna	12%	Environmental sea water bacteria
Acidimicrobium ferrooxidans	6%	Iron oxidizer
Limnohabitans	3%	Environmental fresh water planctonic bacteria
Alpha proteobacterium HIN3	3%	Environmental fresh water bacteria
Microbacteriaceae	2%	Nitrate reducer
Corynebacteriales	2%	Hydrocarbon degrading
Variovorax	1%	
Polynucleobacter	1%	
Unclutured Betaproteobacteria (Comamonadaceae family)	1%	
Uncultured Actinobacteria	1%	
Haloferula	1%	
Albidiferax	1%	
Armatimonas	1%	Environmental fresh water bacteria
Smithella	1%	Propionate-degrading

Sampling Techniques

Select a Representative Location

- Pipelines and Flow Lines have sample points on top, bottom and sides of lines – find the water for a sample
- Stagnant Areas are good breeding grounds for bacteria

Use Clean, Sterile Container

- Preferably Sterile Glass, Polyethylene or Polypropylene
- Fill Sample Bottle Completely (SRB are anaerobic)

Key Points

- The most common method of detecting bacteria only tells whether you can grow them – NOT if they are contributing to corrosion
- Planktonic testing alone will not always give a true picture
- You should strive to find **evidence** of **Microbiologically Influenced CORROSION** –not just growth in a bottle of media
- Detection and Mitigation of MIC is part of the overall integrity of the pipeline.

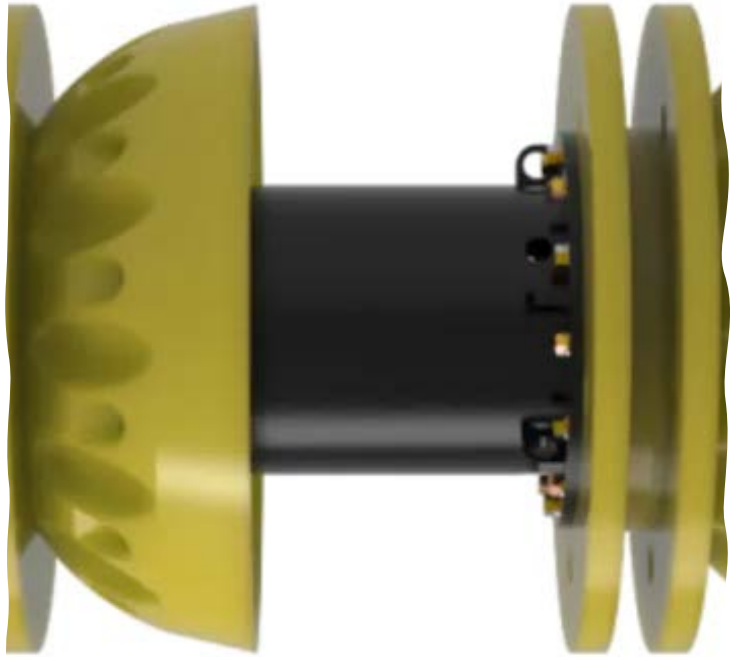
Maintenance Pigging and Cleaning

Where Do I Begin?

- PIG TYPES (FOAM, BRUSH, MAGNETIC, SMART)
- ROLE OF PIGGING IN CORROSION PREVENTION
- PIGGING FREQUENCY AND PLANNING
- PIG RUN DATA ANALYSIS

Pig Types –Which One Do I Choose?

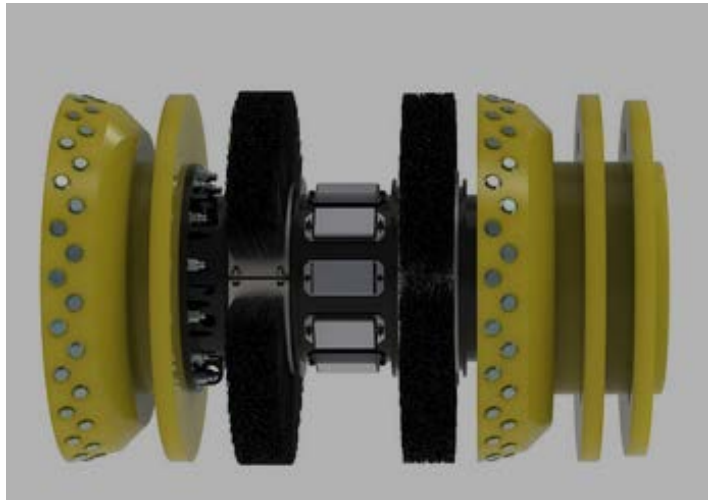
- Foam
- Solid Cast
- Mandrel
- Ball
- Specialty
  - Spray
  - Stud
  - GEL
  - Custom



Pig “accessories”

- Sizing Plates
- Scrapers
  - Fingers
  - Needles
  - Wiping Cups
- Cups
- Discs
- Magnets
- Specialty
  - Spray Nozzles and back pressure valves
  - Speed Controlled
  - Tracking Devices
  - “Flushing” holes

https://www.tdwilliamson.com/solutions/pigging-solutions/pipeline-pigs



https://www.enduropls.com/cleaning

Can I Run This Pig?

- Pig Launchers and Receivers
- Product needed to Push the Pig
- Short diameter bends and intrusions in then pipeline (less than 3 X Diameter may be a problem)
- Manpower Needed
- Will I Overwhelm the Plant with Fluids/ Cause Other Operational Problems
- What will I do if a Pig gets Stuck?

Role of Pigging in Internal Corrosion Control Programs

- Cleaning and Removing Contaminants
- Identify Dents
- De-Watering
- Breaking up Solids
- Effectively Spreading Corrosion Inhibitor and Biocides
- Isolating Batches to Prevent Cross Contamination

https://www.istockphoto.com/photos/broom?utm_medium=cpc&utm_source=GOOGLE&utm_campaign=US_Tail_Photo_EN_DSA_RLSA-Plus&utm_content=Photo_SRP_DSA_RLSA&utm_term=DYNAMIC+SEARCH+ADS&is_click_id=CjwKCAjwu9fHBhAWEiwAzGRC_7ZOvB-pVb4w5BAnr8R-rXKZQuhla1dGjw5mdo4Iqf35-d0NyhyKPxoCQWsQAvD_BwE&gclsrc=aw.ds&gad_source=1&gad_campaignid=15167493777&gclid=CjwKCAjwu9fHBhAWEiwAzGRC_7ZOvB-pVb4w5BAnr8R-rXKZQuhla1dGjw5mdo4Iqf35-d0NyhyKPxoCQWsQAvD_BwE

Pigging Frequency and Data

- What are you trying to accomplish?
- How Much is Too Much?
- Evidence Based Vs. Calendar Based
- Do you have enough FLOW?
- Do you have TOO MUCH FLOW?
- Can the flow be maintained throughout the pig run?

Pigging Frequency and Data

- What Data Do I need to Gather?
  - Flow Velocity
  - Time of Run
  - Wear and Damage
  - Quantity of Solids and Liquids brought in

Pig Run Data Analysis

IDENTIFICATION OF SOLIDS (ELEMENTAL AND COMPOSITIONAL ANALYSIS)

IDENTIFICATION OF LIQUIDS PARAMETERS (PH, ALKALINITY, CHLORIDES ETC –IS THE FLUID CORROSIVE)

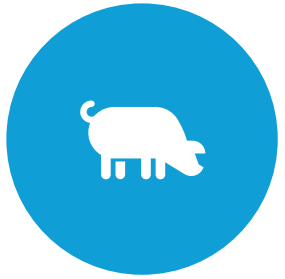
IDENTIFICATION OF ENTRAINED GASSES (OXYGEN, CARBON DIOXIDE, HYDROGEN SULFIDE

IDENTIFICATION OF BIOLOGICAL CONTAMINATION

How Do I use All Of this?

FIND OUT WHAT NORMAL IS –AND LOOK FOR ABNORMAL

TRACK ALL OF THE PARAMETERS_THIS CAN GET YOU AHEAD OF THE GAME



IDENTIFY ROADBLOCKS IN GETTING THE PIGS LAUNCHED

MONITOR INTERNAL CORROSION

Chemical Treatment

What is our Ultimate Goal?

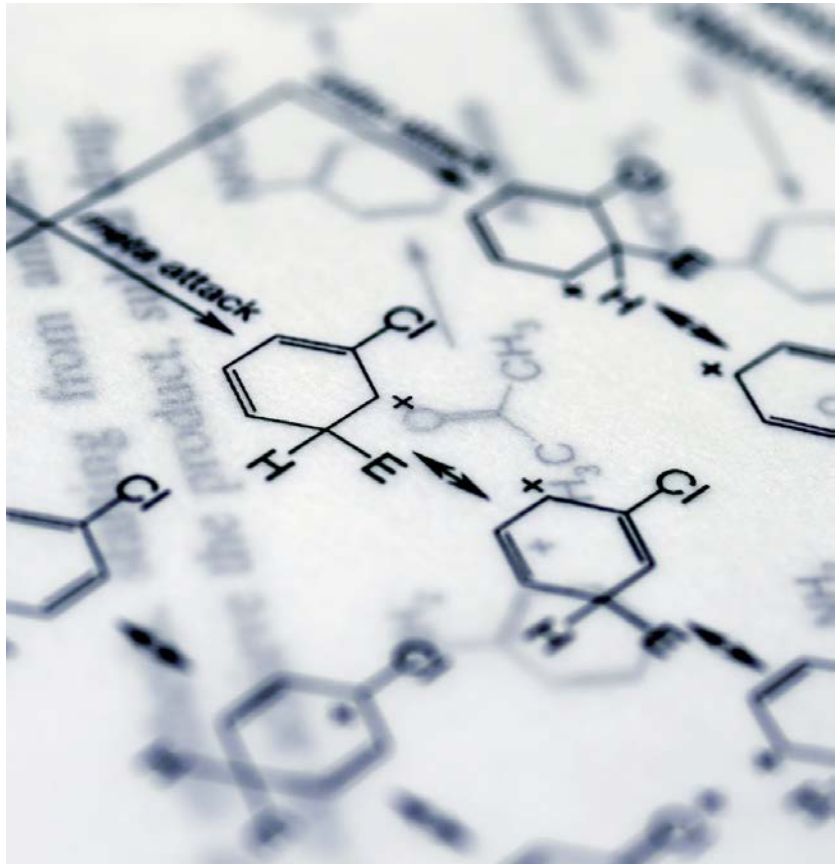
- Operate Safely
- Keep the product in the pipe
- Maintain profitability
- Continue to be employed

Why would I use Chemistry?

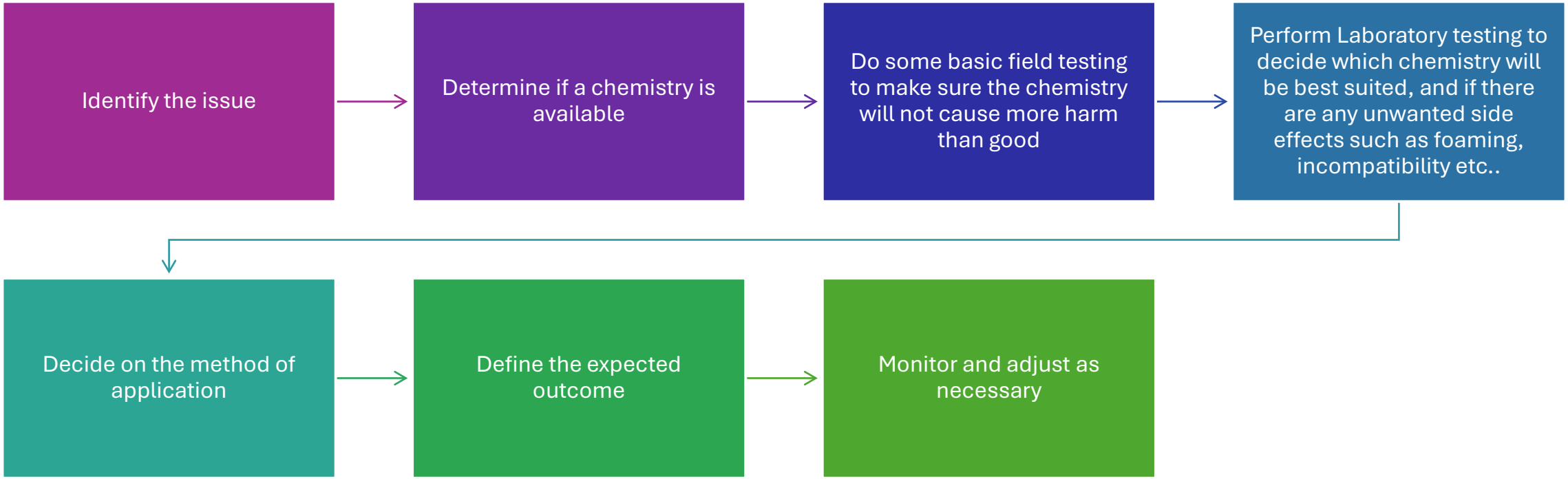
- To Reduce the Risk of Corrosion
- To Reduce Microbiological Growth and Reproduction
- To enable more product movement with the same horsepower, or the same product movement with less horsepower
- To provide a protective layer between the pipeline steel and the fluids
- To assist in cleaning the pipeline and breaking down solids
- To assist in production

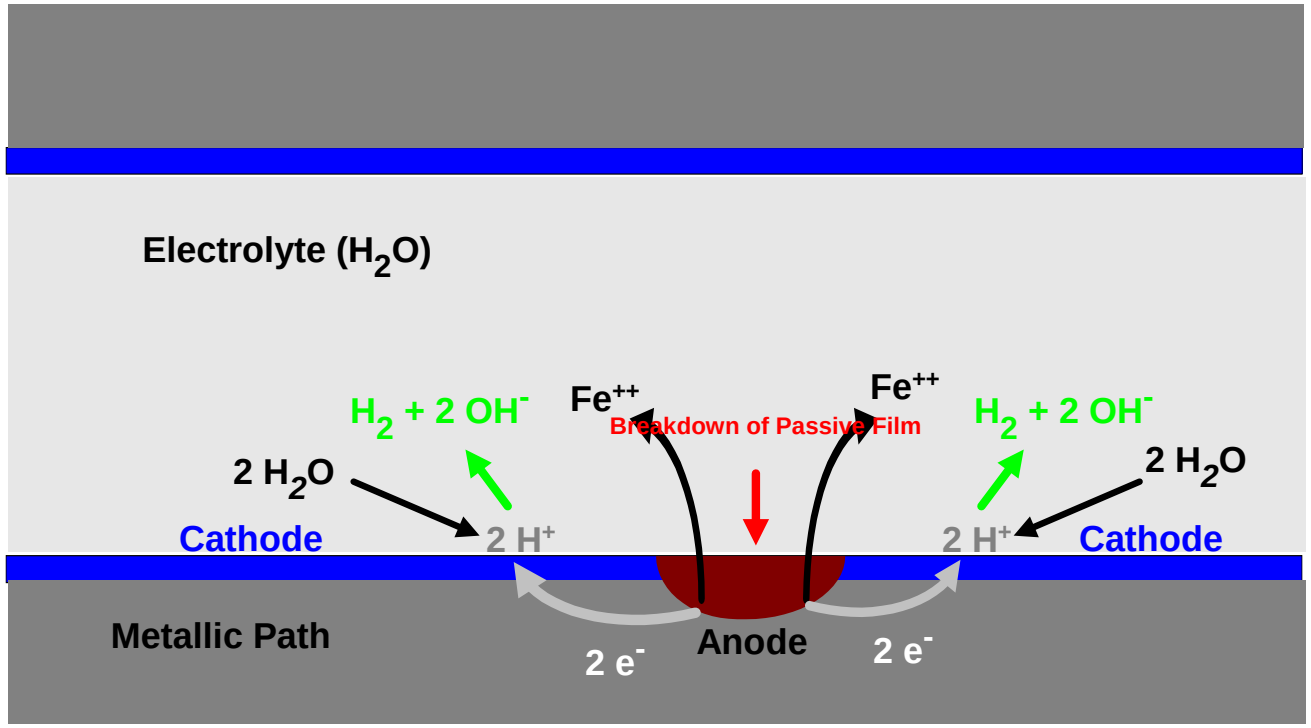
What Kind of Chemistries are Available?

- Corrosion Inhibitors
- Biocides
- Scale inhibitors
- Surfactants and Cleaning Chemicals
- Chemicals to form Gels
- Drag Reducing Agents
- Chemicals to change the pH or alkalinity
- Chemicals to keep anions and cations from sticking to each other by breaking or forming other bonds (Iron Chelant, H2S scavengers etc..)
- Chemicals to absorb water (methanol, glycol etc..)
- Pickling or Hydrotest Chemistries (often a combination chemistry)
- Vapor Phase Chemistries



How Do I Pick the right one?

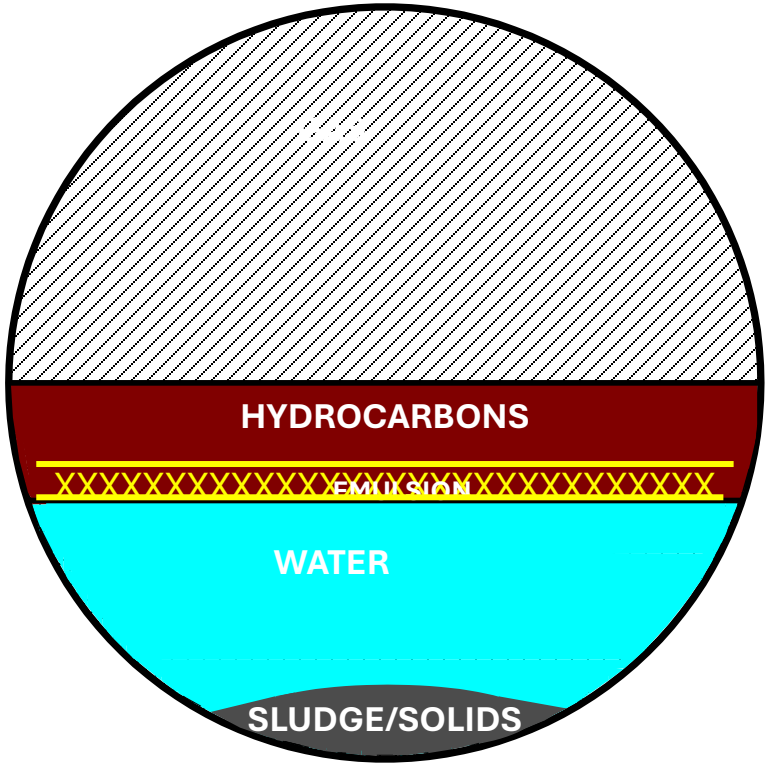




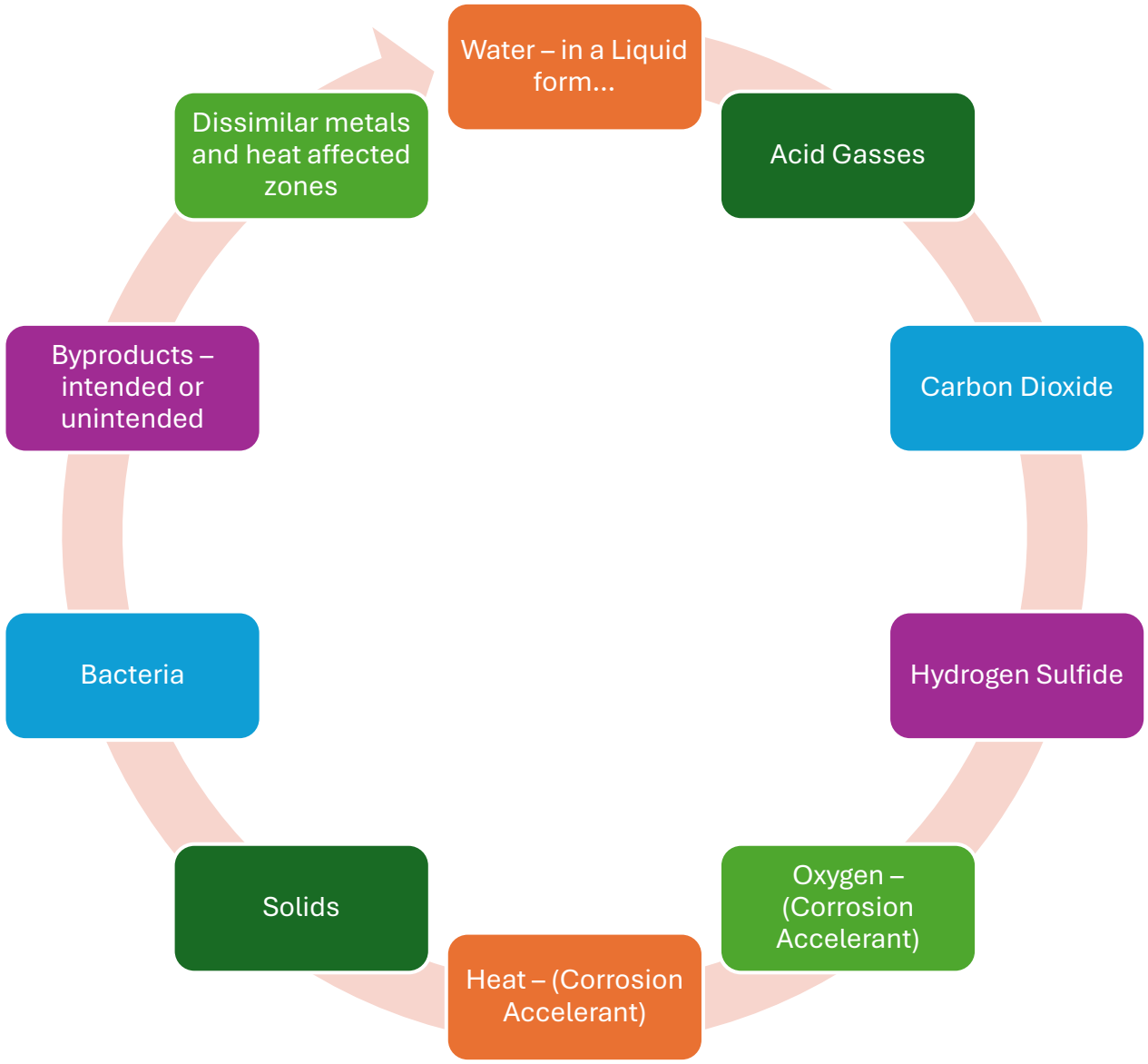
Remember the Corrosion Process…

INTERNAL PIPELINE ENVIRONMENT

Where do I Want my Chemistry to Go?



What Causes Corrosion?



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Lance Barton
EnhanceCo Inc.
LanceBarton@Enhanceco.net
417.204.1614 Cell
281.499.4426 Office

THANK YOU FOR
YOUR LISTENING

DO YOU HAVE
ANY QUESTIONS?

Tom Pickthall
EnhanceCo Inc.
tomp@Enhanceco.net
713.906.4841 Cell
281.499.4426 Office