IC-002 · MODULE 2 OF 8

Corrosion Chemistry in Pipeline Fluids

The chemistry under every internal-corrosion mechanism - what has to be true inside a line for the steel to corrode, and what makes it run faster. The second module of the Corrosion Mechanisms in Pipeline Fluids set.

INTERNAL CORROSION TRACK   BASICS & THEORY   CORROSION MECHANISMS IN PIPELINE FLUIDS   ~30 MINUTES

BY THE END OF THIS MODULE

You'll be able to -

- Run the four-ingredient check on any segment - water on the wall, an aggressive solute, steel, and conditions that let them meet.
- Recognize the one reaction every mechanism feeds - iron leaving the wall as dissolved ions.
- Read the levers that make pipeline water aggressive - pH, chlorides, dissolved gases, temperature, flow.
- Name the four chemistry drivers (CO_2, H_2S, O_2, bacteria) and what each does to the water.
- Explain the carbonate buffer - why the same gas corrodes one line and spares another.
- Separate the water you sample from the water on the wall, and walk the data chain from a reading to a plan.

FEBRUARY, A RIDGETOP PAD IN THE APPALACHIAN BASIN

Is this line corroding right now?

A wet-gas flowline, wellhead to separator. Gas off the wellhead at ~95 °F; the winter ground around it at ~45 °F. About 2% CO_2, 30 ppm H_2S, a 5% water cut, slow stratified flow.

You can't look - the damage, if any, is on the inside wall of a buried line that's staying in service. The only witnesses you get are the fluids. If you can read the chemistry, the fluids will tell you what the steel is going through.

Internal corrosion is the inside problem - you can't walk it down. So you learn to read the water.

This module is the chemistry under every mechanism in the set: what has to be true for the steel to corrode, and what makes it run faster.

FIVE SECTIONS, IN ORDER

How we'll build the read

01
The four ingredients
What corrosion needs to run.

02
The one reaction
And what makes water aggressive.

03
The four drivers
CO_2, H_2S, O_2, bacteria.

04
Amplifiers & buffer
Temperature, sources, alkalinity.

05
Reading the line
Bulk vs wall, sample to plan.

SECTION 1 · WHAT CORROSION NEEDS TO RUN

The four ingredients

ALL FOUR, SAME PLACE, SAME TIME

Take one away and it essentially stops

Water

Liquid water touching the steel - not just water in the line.

Aggressive solute

CO_2, H_2S, O_2, or bacterial acids dissolved in it.

Steel

The pipe - the iron available to give up.

Conditions

Temperature, flow, a low spot that holds water on the wall.

Walk every segment in this order. Miss any one ingredient, no significant internal corrosion. All four present, it's possible - and worth your attention.

THE FIRST QUESTION, EVERY TIME

Does water reach this pipe wall?

Of the four, water on the wall is the one that gates everything. All the chemistry lives in liquid water against the steel - no water there, and the gases and bacteria have nothing to work in.

> A genuinely dry sweet-gas line can carry CO_2 for decades with little damage. Let water into that same line and it can light up. So before the lab work, before the coupons: **does water get here, and where?**

SECTION 2 · THE REACTION, AND WHAT FEEDS IT

One reaction, many ways to feed it

RECOGNIZE IT - YOU DON'T HAVE TO DERIVE IT

Iron leaving the wall

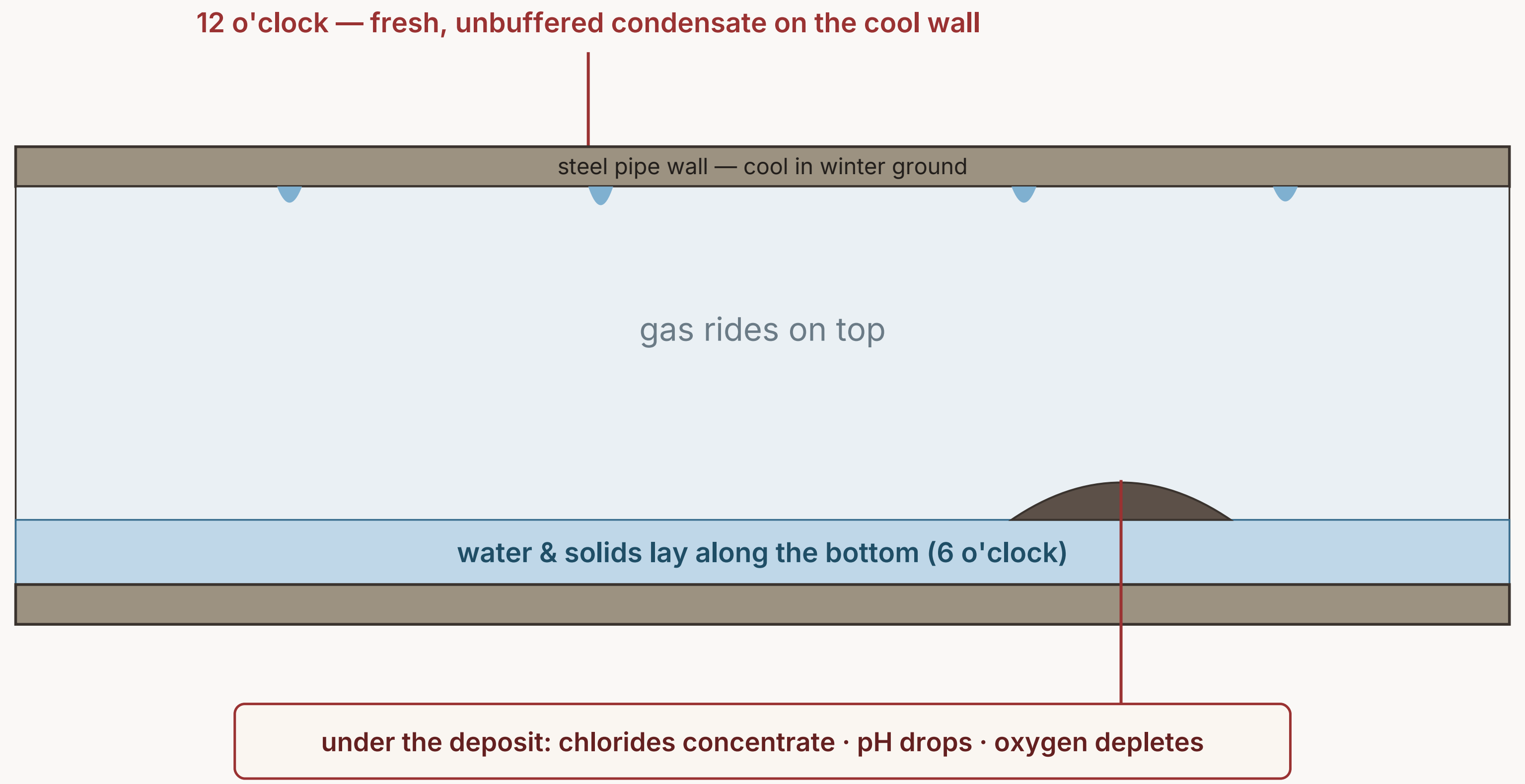
$$Fe \rightarrow Fe^{2+} + 2e^-$$

solid iron leaves the pipe wall as a dissolved ion

Every mechanism in this set drives this same reaction - CO_2, H_2S, oxygen, and bacteria are just different ways of keeping it fed and running. Dissolved iron in a water sample is a receipt: that metal came off a wall somewhere upstream.

THE WATER YOU SAMPLE VS THE WATER ON THE WALL

Read the wall, not just the tap



The water you sample is the bulk average — the wall sees something else.

THE LEVERS OPERATING CONDITIONS CAN PULL

Five levers

pH

Acidity

Below ~6 the protective films dissolve.

Cl^-

Chlorides

Past a few hundred mg/L, damage turns to pitting.

gas

Dissolved gases

CO_2, H_2S, O_2 - each a different chemistry.

°

Temperature

An amplifier on almost everything else.

flow

Flow

Decides where and how long water works on the wall.

Carbon steel armors itself with thin films - as long as the water lets them survive. Above about pH 6 they hold; below, they dissolve; below 5, attack runs fast.

Most mechanisms ahead are, at bottom, ways of pushing the wall's pH down.

SECTION 3 · THE FOUR AGGRESSIVE SOLUTES

CO_2, H_2S, oxygen, bacteria

TWO THAT ARRIVE WITH THE GAS

CO_2 sweet, H_2S sour

SWEET

Carbon dioxide

Dissolves into water and makes carbonic acid - mild, but manufactured around the clock. Pushes pH down, dissolves the films, eats steel.

$CO_2 + H_2O \rightarrow H_2CO_3$

SOUR

Hydrogen sulfide

Another weak acid - plus a second problem: it lets atomic hydrogen into the steel, cracking and blistering pipe from inside the metal. Leaves black iron-sulfide scale.

> Each gets its own module ahead - the sweet-corrosion module takes CO_2 end to end, the sour-corrosion module takes H_2S and its hydrogen damage. Here we just name them.

TWO THAT DON'T ARRIVE WITH THE GAS

Oxygen and bacteria

THE INTRUDER

Oxygen

Formation fluids come up oxygen-dead, so O_2 is an intruder - in through tank vents, worn packing, opened lines. Aggressive at trace levels, and it amplifies almost everything else. Finding it is itself a finding.

THE CHEMISTRY FACTORIES

Bacteria

Alive, and they make chemicals: acid producers drop local pH, sulfate reducers make H_2S in place, slime-formers build biofilms that trap water and shut treatment out.

> Oxygen corrosion and microbial corrosion (MIC) each get their own module later in this set. Survey now, depth ahead.

SECTION 4 · AMPLIFIERS, SOURCES, AND THE BUFFER

What turns the chemistry up

AN AMPLIFIER, NOT A HAZARD GAUGE

Ask what the temperature does to the chemistry

- **Reaction speed** - roughly doubles per 10 °C of rise. Same chemistry, faster.
- **Microbes** - most do their best work in a middle band, roughly 20-40 °C.
- **Scales flip sides** - some protective films get denser when hot; others destabilize.
- **Gradients make water** - warm gas on a cool wall condenses water right onto the steel.

The right question isn't "is it hotter?" - it's "what is this temperature doing to the chemistry the steel sees?"

THE SOURCE TELLS YOU THE CHEMISTRY

Not all pipeline water is the same water

Produced water

Up from the formation - salty, mineral-loaded, oxygen-dead, often carrying built-in buffer. High chlorides, but some armor.

Condensed water

Dropped out of the gas onto a cool wall - essentially distilled. Fresh, clean, and no armor at all.

> Injection/disposal water, hydrotest residual, and atmospheric ingress round out the list. The hook flowline carries produced water **and** makes condensate against its cool wall - two chemistries, one half mile of pipe.

THE MOST UNDER-READ LINE ON THE LAB REPORT

Alkalinity is the water's armor

Alkalinity - dissolved bicarbonate and carbonate - is the water's shock absorber against acid. Buffered produced water soaks up the acid the CO_2 makes before the pH can fall far.

Same gas over unbuffered condensate has no cushion - the pH drops hard and the wall pays full price. Same gas, different result, and the difference is the water, not the gas.

SECTION 5 · READING THE LINE

From a sample to a plan

THE WATER YOU SAMPLE IS NOT THE WATER ON THE WALL

Bulk is the average; corrosion is local

What the tap reads

The bulk fluid - the average of what's flowing by. pH, chlorides, iron, bacteria counts.

What the wall sees

Under a deposit: chlorides concentrated, oxygen gone. Inside a biofilm: local pH two to three units below the bulk.

> A clean-looking bulk sample never closes the case. The IC tech's eye stays on the metal surface, not the sampling tap - which is exactly where direct-measurement tools end up living.

READ IT, DON'T JUST RECORD IT

Six numbers, one story

A receiver sample: pH 4.8 · iron 25 mg/L · oxygen 12 ppm · SRB none of five vials · APB four of five vials · chloride 8,000 mg/L.

What it says

Acid-driven attack (pH well below 6) with a microbial contribution (APB up), actively shedding iron, pitting-prone (high chloride).

What to chase

The 12 ppm oxygen shouldn't be in produced water - air ingress, or an aerated sample. Run the door down and tighten sampling.

> One coherent picture, and three follow-up actions that wrote themselves. **That's reading.**

HOW A READING BECOMES A PLAN

Indirect, then direct, then act

01
Indirect data
Samples, field tests, lab - corrosion is possible.

02
Repeatability gate
Two positives that agree - a real signal.

03
Direct data
Coupons on the wall - corrosion rate, pitting rate.

04
Mitigation
Designed upstream, built on your data.

05
Execute
Run it, keep sampling - does it work?

> This module is the literacy that makes step one worth anything - so the indirect data you collect actually means something.

YOUR ROLE IN THE CHAIN

Collect it, understand it, execute it

The mitigation plan usually comes together with a corrosion specialist or integrity engineer leading the design. Your role is the one that makes that plan worth building: collect the data, understand what it's telling you, run the program, and keep sampling to prove it's working.

> On a bigger operator those are different people; on a smaller outfit, the same person may do both. The split isn't about rank - it's about making sure the plan gets built on real data and a real read, not guessed at ahead of them.

FEBRUARY, THE APPALACHIAN RIDGETOP

Now you can work the question

Four ingredients, all present: water (a 5% cut plus condensate on the cool wall), two acid gases, steel, and slow stratified flow that lets it all settle. Corrosion is possible - emphatically.

> The honest answer isn't "yes it's corroding" - nobody can say that from the surface. It's: **everything this line needs is present, here's where the attack would live, and here's exactly what I'd collect to find out.**

The four-ingredient check is the diagnostic you'll run for the rest of your career. Reading a water analysis for what it's telling you is the skill the whole set builds on.

Get those, and every mechanism ahead slots into a place you already understand.

WHAT THIS MODULE GAVE YOU

Read the water, and the pipe tells you its story

You hold the four-ingredient check, the one reaction every mechanism feeds, the levers that make water aggressive, the buffer that explains why identical gas treats two lines differently, the bulk-versus-wall rule, and the data chain that turns a reading into a plan.

The next module turns up the resolution on the first driver - sweet corrosion.

WHAT TO WALK AWAY WITH

The frame, in six lines

- **The four-ingredient check** - water on the wall, an aggressive solute, steel, conditions that let them meet. Miss one, it stops.
- **One reaction under everything** - iron leaving the wall ($Fe \rightarrow Fe^{2+} + 2e^-$); every mechanism feeds it.
- **pH ~6 is the tipping point**; chlorides past a few hundred mg/L push damage toward pitting.
- **Four drivers** - CO_2 (sweet), H_2S (sour, plus hydrogen damage), O_2 (intruder), bacteria (chemistry factories).
- **Temperature amplifies; alkalinity armors.** Same gas corrodes one line and spares another - read the water.
- **Bulk is the average; corrosion is local** - and the data chain runs indirect → gate → direct → mitigation.

WHY THIS MODULE IS THE FOUNDATION

Read the water, read the threat

Every mechanism in this set is a different way of feeding the same iron-dissolution reaction. Learn the chemistry that decides whether it runs, and the rest of the set is turning up the resolution on a picture you already have.

The water tells the story. This module taught you to read it.

WHERE THIS SET GOES NEXT

Each module is one driver, end to end

- **Sweet corrosion (CO_2)** - carbonic-acid attack, where it lives, and what the numbers mean.
- **Sour corrosion (H_2S)** - acid attack plus hydrogen damage in the steel.
- **Oxygen corrosion** - the intruder, how it gets in, and why trace levels matter.
- **Microbial corrosion (MIC)** - the bacteria that make their own chemistry.
- **Erosion-corrosion and top-of-line corrosion** - flow and condensation as the drivers.

FURTHER READING + THE NEXT MODULE

Sources used + where this goes

- **Internal Corrosion Field Guide** - the canonical field reference for this track
- **Field Guide to Internal Corrosion Mitigation and Monitoring for Pipelines**
- **Internal Corrosion: Sweet and Sour** - Field Notes from RCS
- **Influencing Factors: Temperature, Oxygen & Relative Movement** - Field Notes from RCS
- **Corrosion Basics: An Introduction**
- **NACE SP0106** - Control of Internal Corrosion in Steel Pipelines and Piping Systems
- **49 CFR Part 192** - gas-pipeline internal corrosion control
- **API RP 1160** - Managing System Integrity for Hazardous Liquid Pipelines

UP NEXT

The first driver - sweet corrosion (CO_2)

The next module takes CO_2 end to end - turning up the resolution on the chemistry frame you just built.