IC-004 · MODULE 4 OF 8

H_2S (Sour) Corrosion Mechanisms and Effects

Sour service taken end to end: why H_2S is a two-part threat, the one number that flips a line into sour service, the three ways it damages steel, and how you carry the read up the chain. The fourth module of the Corrosion Mechanisms in Pipeline Fluids set.

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

A NEW ROW ON A FAMILIAR GAS ANALYSIS

"Little bit of sour now — we'll watch it"

A line you've always read as sweet comes back with **hydrogen sulfide, 180 ppm** — a rounding error next to the methane. The operator figures it's the CO_2 line plus a little extra.

It isn't. That small number switches on a second kind of damage — one that can crack or blister the wall with the thickness gauge still reading full — and it can quietly flip the line into a different materials category.

You can't treat sour like "the CO_2 line, plus a little extra." By the end of this module, that 180 ppm reads very differently.

BY THE END OF THIS MODULE

You'll be able to —

- Explain why H_2S is a two-part threat: acid metal loss plus hydrogen driven into the steel.
- Recognize the H_2S chemistry chain and the hydrogen-charging "fork" at its center.
- Calculate H_2S partial pressure and judge a line against the 0.05 psia sour-service threshold.
- Tell the three damage modes apart — uniform loss, HIC/blistering, and SSC.
- Read black FeS scale for what it is, and know why a thickness gauge can miss sour damage.
- Treat sour as a moving target and carry the signal up the data chain to a clean handoff.

PART 1 · WHAT "SOUR" MEANS

One gas, two separate threats

THE WHOLE VOCABULARY

"Sour" just means H_2S is in the gas

Gas that carries hydrogen sulfide is **sour** — named off the rotten-egg smell. Gas without it is **sweet**.

That one difference isn't a matter of degree. A sweet line has one corrosion story to tell: it thins until it can't hold pressure. A sour line has two — running at the same time, on different clocks.

> **Safety aside:** H_2S is also acutely toxic. That's a safety-course topic; here we're strictly on what it does to the steel.

EVERYTHING IN THIS MODULE HANGS OFF THIS FRAME

H_2S does two jobs at once

JOB ONE · METAL LOSS

Dissolved H_2S is an acid; like any acid on a wet wall, it eats iron. This part behaves like corrosion you already know.

JOB TWO · HYDROGEN IN THE STEEL

H_2S drives loose hydrogen into the metal, where it cracks and blisters from within — damage that owes nothing to how much wall was lost.

The second job is what makes sour dangerous out of all proportion to the metal it removes. A tech trained only on wall loss will read a sour line wrong.

Cracking sounds like an outside-the-pipe problem. In sour service it comes from the inside — the hydrogen is made by the reaction on the inside wall.

Same family of damage, opposite surface. It's why a sour line can look clean outside while it's in trouble within.

PART 2 · THE CHEMISTRY, IN FIELD TERMS

Acid, iron, and the hydrogen fork

RECOGNIZE IT — YOU DON'T NEED TO BALANCE IT

H_2S dissolves and lets go of hydrogen

Dry gas touches nothing; the trouble needs liquid water on the wall. Then H_2S dissolves and comes apart:

THE ACID GAS DISSOLVES AND DISSOCIATES

$$H_2S \rightleftharpoons H^+ + HS^- \rightleftharpoons 2\ H^+ + S^{2-}$$

The H^+ is the acid; the bisulfide/sulfide left behind is what builds the scale.

THE ACID ATTACKS THE STEEL

$$Fe + 2\ H^+ \rightarrow Fe^{2+} + H_2\uparrow$$

Iron leaves the wall as a dissolved ion; hydrogen forms at the surface. Same iron-loss event any acid drives.

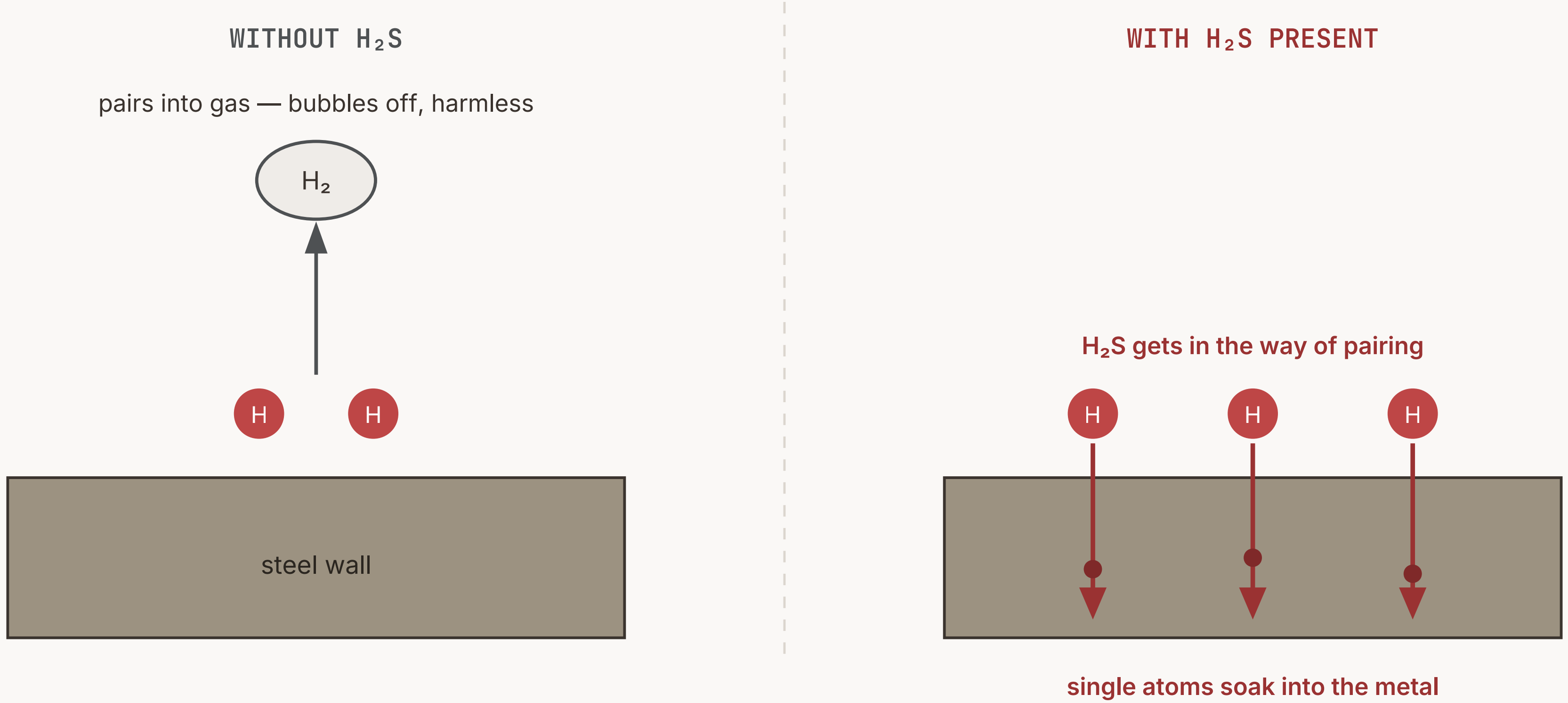
THE SINGLE MOST IMPORTANT IDEA IN THE MODULE

Where the hydrogen goes

Normally the hydrogen forming at the wall pairs into gas and bubbles off, harmless. **H_2S gets in the way of that pairing** — so a share of it stays as single atoms, small enough to soak between the iron atoms and into the steel. The more H_2S, the bigger that share.

> H_2S doesn't make the hydrogen — the acid attack does. H_2S changes where it goes, feeding it into the metal. That charged-in hydrogen is the source of every cracking mode ahead.

Why the hydrogen ends up inside the steel



The acid attack makes the hydrogen either way. H_2S just changes where it goes.

THE LEFTOVER SULFIDE MEETS THE DISSOLVED IRON

And a black scale builds

THE SCALE THAT FORMS

$$Fe^{2+} + S^{2-} \rightarrow FeS$$

Iron sulfide — the black scale on a sour line.

It's tempting to read scale on the wall as protection. On a sour line, don't — and we'll see why when we get to field signatures. For now: acid loss, hydrogen charging into the steel, and a black scale, all from the same wet-wall chemistry.

PART 3 · THE WORKING NUMBER

H_2S partial pressure, and the sour-service line

THE RAW PPM ISN'T THE NUMBER THAT MATTERS

The working number is partial pressure

What matters is the share of the total line pressure that H_2S is carrying — the same idea as any acid gas.

THE ONE CALCULATION IN THIS MODULE

$$P_{H_2S} = (\text{ppm } H_2S \div 1{,}000{,}000) \times \text{total pressure (psia)}$$

psia = psig + 14.7. The gauge reads above atmosphere; the chemistry feels the absolute pressure.

Pressure is what pushes gas into water. The same ppm at higher pressure carries more push behind it.

WHERE SOUR PARTS WAYS WITH SWEET

Sour service trips at a tiny number

Sweet corrosion doesn't get serious until a few psia. Sour service trips at about **a hundred times smaller**.

THE SOUR-SERVICE THRESHOLD

$P_{H_2S} \geq \sim 0.05$ psia (≈ 0.003 bar)

Set by the industry materials standard. At or above it, sour-service rules for steel, welds, and hardness take over.

Why a measured threshold, not a yes/no? How much hydrogen works in scales with how much H_2S is present — more H_2S, more charging. The 0.05 psia line is where that rising risk changes the rules.

IS THIS LINE SOUR SERVICE?

The same calc, run once

THE LINE

Wet gathering line, **600 psig**, gas analysis shows **300 ppm H_2S**.

THE MATH

$600 + 14.7 = 615$ psia

$(300 \div 10^6) \times 615 \approx \mathbf{0.18}$ **psia**

0.18 psia against a 0.05 threshold — more than 3× over. Sour service. The same 300 ppm at 100 psig is only 0.034 psia — not sour. Partial pressure classifies the line, not the ppm.

PART 4 · THREE WAYS SOUR DAMAGES STEEL

Uniform loss, HIC, and SSC

TELL THEM APART — THEY FAIL AND ARE FOUND DIFFERENTLY

One gas, three failures

LOSS

Uniform corrosion

General wall thinning under the black scale. A gauge can track it.

CRACK · NO STRESS

HIC / blistering

Hydrogen tears the steel from inside. No outside stress needed.

CRACK · STRESS

SSC

Hard, stressed steel goes brittle and cracks. Welds first.

Two of the three come straight out of the charged-in hydrogen from the fork — and only the first shows up on a routine thickness check.

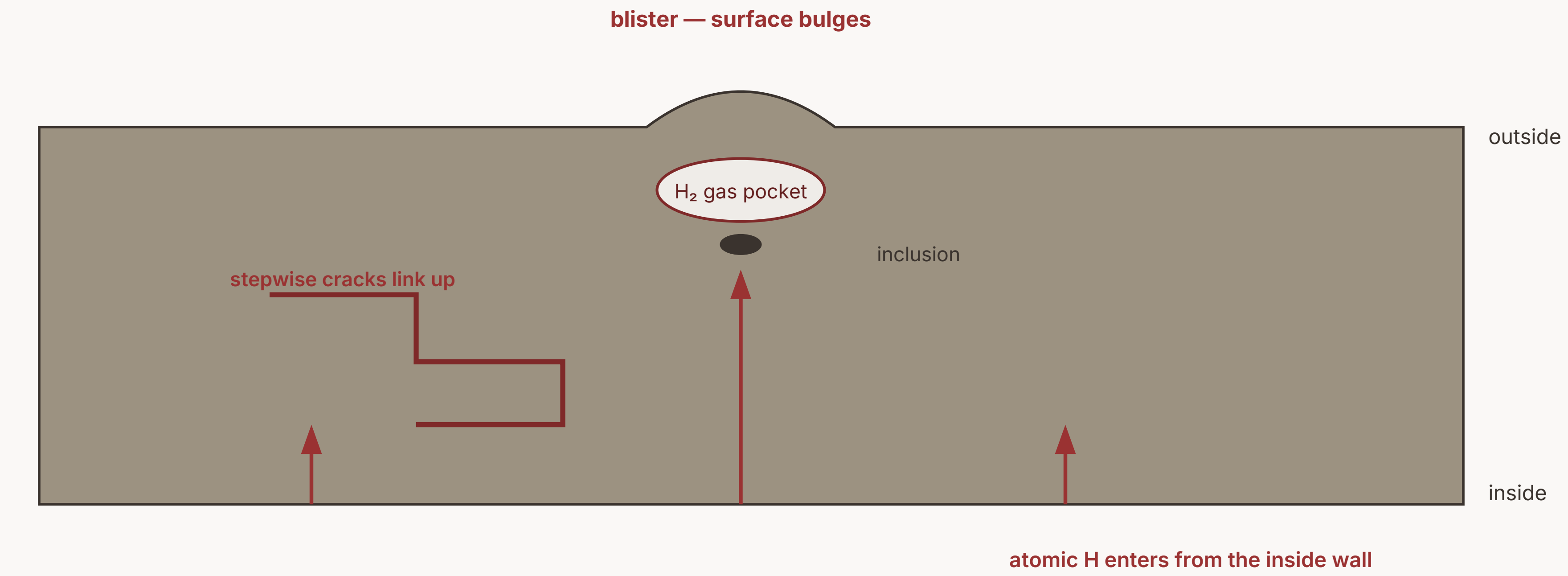
THE ACID-ATTACK SIDE

Uniform corrosion — the familiar one

General thinning of the wall wherever sour water sits against steel, usually under and around the black iron-sulfide scale.

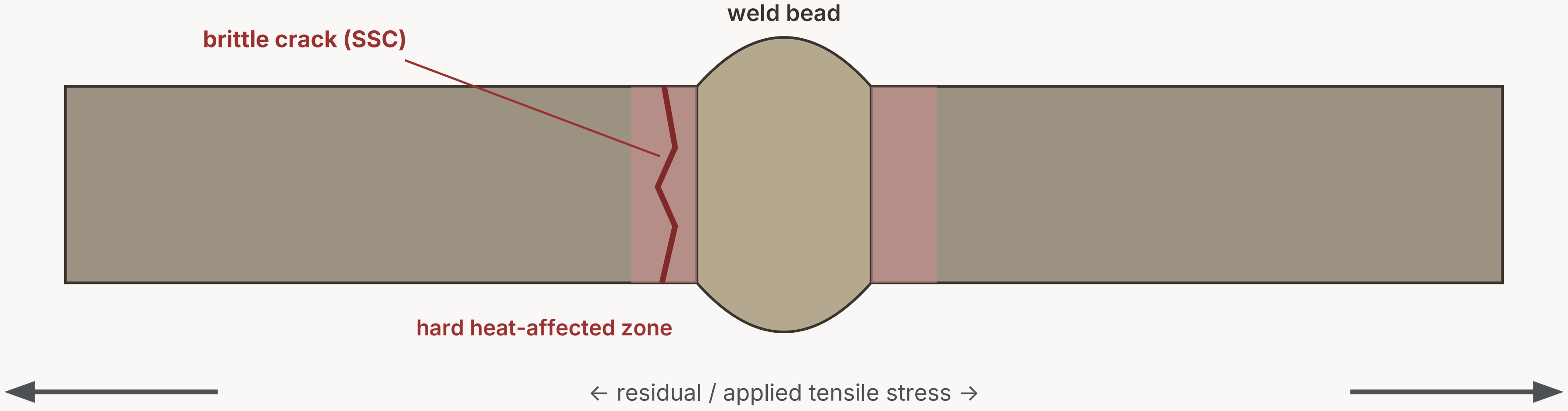
It behaves the way metal loss always does — metal leaves, the wall gets thinner, a thickness gauge follows it. If this were the only thing H_2S did, sour would be a manageable problem. It isn't, because of the next two.

Hydrogen-induced cracking — damage from the inside, no outside stress



The wall can read near full thickness while all this happens inside it.

Sulfide stress cracking — hard steel + stress + charged-in hydrogen



Fast and brittle — and welds carry both the hardness and the locked-in stress.

THE CLEAN WAY TO DISTINGUISH THEM

Three modes, three triggers

UNIFORM

Thins the wall

A loss problem. Needs only sour water on steel. Gaugeable.

HIC + BLISTERING

Tears from inside

Hydrogen builds at internal flaws. **No stress required.**

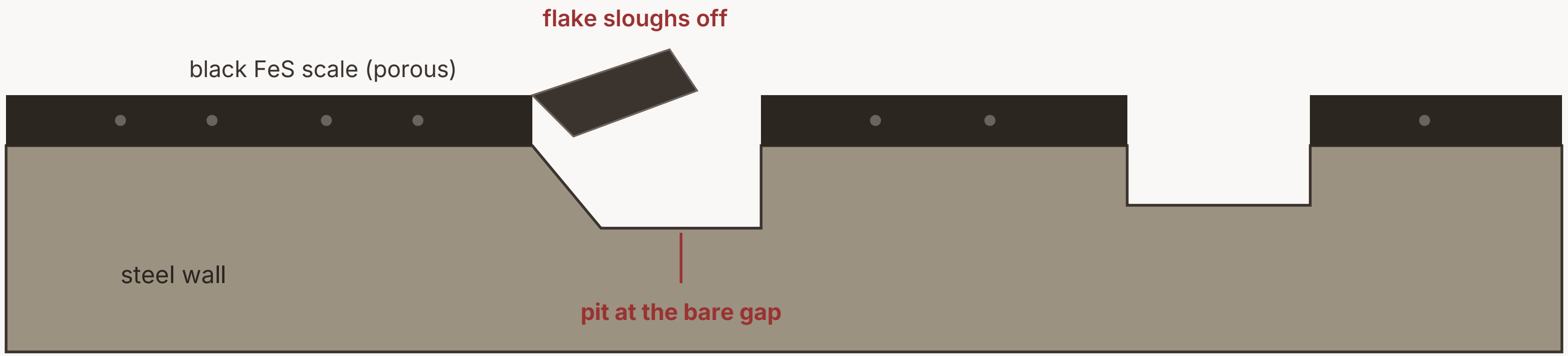
SSC

Brittle cracking

Needs **hard steel** and **tensile stress** both. Welds are the classic spot.

> **Where the metallurgy lives:** which grades qualify and how welds are kept soft is material-selection work, set by the sour-service materials standard and taught upstream. Your job here is the recognition.

Black iron-sulfide scale — porous, flaking, and no protection



A good-looking black coat is not a coping line — look under and between the flakes.

THE SENTENCE THAT MAKES EXPERIENCED HANDS RESPECT SOUR

A full thickness reading can still be trouble

HIC and SSC remove almost no metal — a stepwise crack or a brittle weld crack can be advanced and dangerous with the wall reading near nominal.

Finding it takes tools built for it: a crack-detection in-line inspection run (a "smart pig" down the line), or specialized ultrasonic at a dig. The ordinary metal-loss pig shares the gauge's blind spot — catching cracks takes a tool built for cracks.

> On a sour line, a good thickness number is not a clean bill of health. The deep methodology lives in the assessment modules; the instinct lives here.

PART 5 · WHERE IT HIDES, AND THE PLAN

A moving target, and the data chain

SOUR CLASSIFICATION IS ABOUT CURRENT SERVICE

A sweet line can turn sour

Microbes in the water can produce H_2S over the years — a process called souring. A system that tested clean at startup can cross the sour-service threshold from the inside, with no change in the gas from the ground. (The microbes themselves are their own module later in this set.)

> **Where sour concentrates:** sour gas reservoirs and gathering lines, separators and scrubbers, amine units — and the quiet spots: low points, dead legs, and stagnant zones under deposits. Start where the water stops moving. Appalachian shale systems have a track record of starting sweet and trending sour as they mature.

THE SPINE OF THE WHOLE TRACK

Five steps, and where you sit in them

01
Indirect data
Gas, pressure, water, smell, bacteria.

02
Repeatability gate
Two consecutive reads that agree.

03
Direct data
Coupons for loss; crack tools for cracking.

04
Materials + model
Run upstream on your numbers.

05
Mitigation
Designed upstream, executed by you.

This module is the literacy that makes step one worth anything — and the flag, at step one, that a line has crossed into sour service.

READING THE LINE FOR H_2S

Build the picture, then clear the gate

- **Gas + pressure** → partial pressure → sour service or not.
- **The water** — pH down, dissolved iron up, sulfide present.
- **Field signs** — rotten-egg smell at a sample point, black scale on a coupon or pig catch.
- **Bacteria checks** — is anything souring the line further from the inside?

One aggressive sample is a note in the file. Two consecutive reads telling the same story is a signal worth acting on.

WHEN THE SIGNAL CLEARS THE GATE

Coupons, crack tools, and whose model it is

DIRECT DATA

Coupons go where sour concentrates — they read the loss rate and pitting well, but track cracking poorly. HIC and SSC need the crack-detection tools.

PREDICTION + MATERIALS

Models and standards turn your numbers into rate estimates and material requirements — the integrity engineer's and specialist's work, far up the track.

The model and the material call are only as good as the field data feeding them. The tech who catches the sour-service crossing makes those upstream calls possible.

DESIGNED UPSTREAM, EXECUTED BY YOU

Three families of response

CHEMICAL

Inhibitors + scavengers

Corrosion inhibitors, and H_2S scavengers dosed to pull H_2S out before it does its two jobs.

OPERATIONAL

Run it drier, cleaner

Drying, cleaning pigging, keeping water from collecting where it sours.

MATERIAL

Qualified steel + welds

Sour-service grades and controlled-hardness welds for the parts that live in it.

Which lever, which product, what dose is the specialist's design. The tech runs it and keeps the samples coming — follow-up data is what proves the fix is holding.

CARRY THESE OFF THE MODULE

What to remember

- **Back to the hook:** 180 ppm at 850 psig is 0.16 psia — over 3× the threshold. Sour service. "A little bit of sour" was never the read.
- **One gas, two threats:** acid metal loss plus hydrogen driven into the steel. The second is what makes sour dangerous.
- **The fork:** H_2S gets in the way of hydrogen pairing off, so a share soaks in — the source of every cracking mode.
- **The one number:** P_{H_2S} = (ppm ÷ 10^6) × psia; sour service at ~0.05 psia. Partial pressure classifies, not ppm.
- **Three modes:** uniform (gaugeable) · HIC/blistering (no stress) · SSC (hard steel + stress). Black FeS scale is a false friend, and a full thickness reading isn't a clean bill of health.
- **Moving target:** souring can turn a sweet line sour — classify on current service, and carry the signal up the chain.

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 (Part 2)
- **Corrosion Basics: An Introduction**
- **ISO 15156 / AMPP MR0175** — materials for H_2S service; sour-service classification and hardness limits
- **AMPP TM0177** — lab testing for SSC/SCC resistance in H_2S
- **49 CFR Part 192** — gas-pipeline internal corrosion control

UP NEXT

Oxygen corrosion

A gas that doesn't belong in a sealed pipeline at all, and does its worst where it sneaks in — often an intrusion, not an ingredient. Same four ingredients, same one reaction, a new way in.