IC-001 · MODULE 1 OF 8

Introduction to Internal Corrosion

Types and consequences. Orientation before mechanism. The opener for the IC track.

INTERNAL CORROSION TRACK   BASICS & THEORY   CORROSION MECHANISMS   ~20 MINUTES

BY THE END OF THIS MODULE

You'll be able to —

- Define internal corrosion in plain English and explain how it differs from external corrosion in cause map and program.
- Name the four big drivers of internal corrosion at survey level — and point at the module ahead that teaches each one in detail.
- Connect pipeline service type to likely threat profile — production, gathering, transmission, facilities, storage.
- State why IC work matters across safety, asset value, and regulatory compliance.
- Describe the three-role frame, the IC tech's day, and the four essential questions that organize the rest of the track.

FIRST TIME AT THE PIG RECEIVER

Fluids and solids in front of you. Decisions to make.

A cleaning pig comes through. The receiver opens up: dark sludge, water with a faint smell, scale flakes, maybe a tang of sulfur. Now you're standing there with a sample bottle and a chain-of-custody form, deciding what to test on-site, what to send to the lab, and what to tell them to look for.

For most techs, this is the moment internal corrosion stops being abstract. Outside of a planned dig, you don't get to look at the metal. You get a sample in your hand and a list of questions you don't yet know how to ask.

THE RACE AGAINST CHEMISTRY CHANGE

What's in the bottle is changing as you hold it

Dissolved gases start escaping. Oxygen creeps in. Bacteria die or multiply depending on what you put them in. The lab gets a sample that doesn't quite represent what was in the pipeline an hour ago.

Field testing on-site catches the fluids before that change. That's the race. It runs through the rest of this set of modules and beyond — we'll come back to it on sampling, monitoring, and inspection.

TWO CAUSE MAPS, ONE OUTCOME

External and internal corrosion are different jobs

EXTERNAL

Follows the outside of the pipe

Soil · Coating · CP system

INTERNAL

Follows what's inside the pipe

Fluids · Chemistry · Flow

CONVERGENCE

Same kind of failure outcome

Different programs, different tools, often different teams. RCS works both sides.

MODULE ROADMAP

Six sections, in order

01
What internal corrosion is
Definition, IC vs EC, water everywhere, threat vs problem.

02
The four big drivers
CO_2, H_2S, oxygen, microbes — named at survey level.

03
Where it shows up
By pipeline service, with a quick-scan recognition map.

04
Why it matters
Safety, asset value, regulatory compliance.

05
How IC work gets done
Three roles, the tech's day, the four essential questions.

SECTION 1 · WHAT INTERNAL CORROSION IS

Inside, in plain English

WORKING DEFINITION

Internal corrosion follows the fluids

Deterioration of pipe metal driven by the chemistry of the fluids inside the line. The inside part is what makes it a separate animal from external corrosion.

External corrosion follows the soil, the coating, and the outside surface. Internal corrosion follows what's flowing through, what's settling out, and what's reacting with the steel.

> Same kind of failure outcome. Completely different cause map.

PIPELINE OPERATORS MANAGE BOTH FAMILIES

IC inside, EC outside — two programs, often two teams

The IC program

Samples fluids and solids at pig receivers, drips, sampling points. Runs coupons and probes in fluid contact. Inhibits the wet phase. Pigs to remove deposits.

The EC program

Reads pipe-to-soil potentials. Tunes the CP system. Inspects coatings. Manages stray current. Walks the right-of-way.

This track is the IC half. RCS also offers a full EC track if your work covers both sides.

THE COMMON DENOMINATOR

If there's water collecting, there's a place corrosion can happen

Pipelines are seldom completely dry:

- Water vapor condenses on cool pipe walls
- Producers have liquid upsets that show up downstream as a slug of water in "dry" gas lines
- Sales-quality crude still carries a fraction of a percent of BS&W
- Tank bottoms hold water that eventually moves into connected pipelines
- The dehy unit isn't perfect

> **Starting question:** where can water collect on your line? Answer that and you've narrowed where IC will do its work by a lot.

TWO WORDS WORTH PINNING DOWN

A threat could damage. A problem has damaged.

Threat

A mechanism that could damage the asset. Possibility — not yet a problem.

Problem

When that threat damages the asset to the point it can't safely do its job.

The whole job of IC work is keeping threats from becoming problems — through **assessment**, **mitigation**, and **monitoring**. That's the spine of the track.

SECTION 2 · THE FOUR BIG DRIVERS

Named only.
The set ahead teaches them.

ONE SENTENCE EACH. DEEP DIVES AHEAD.

Most IC problems are one of these four — or a combination

CO_2 · SWEET

Carbonic acid

Dissolves in water to form a weak acid that's surprisingly aggressive against carbon steel. Most common acid-gas corrosion in upstream production and wet-gas gathering. Deep dive in IC-003.

H_2S · SOUR

Acid plus hydrogen damage

Forms another weak acid in water — and lets atomic hydrogen enter the steel itself, driving a whole family of cracking and blistering on top of metal loss. Deep dive in IC-004.

O_2 · OXYGEN

The intruder

Has no business in most of these lines, but sneaks in through upsets, leaks, tank breathing, injection chemicals. Even ppb levels can be aggressive — and amplifies most other drivers. Deep dive in IC-005.

MICROBES · MIC

The living driver

Microbes live in produced fluids, soil, water, even on the inside of pipelines. Some produce H_2S.

Some produce organic acids. Some trap moisture and create concentration cells. Deep dive in IC-006.

RECOGNITION CUES THAT SHOW UP ALONGSIDE THE FOUR

Two more patterns to name now

Erosion-corrosion

High-velocity fluid, sometimes with entrained solids, peels off the protective film that would otherwise slow the corrosion reaction. Mechanical and chemical mechanisms feed each other.

- Common at elbows, tees, valve outlets, pump discharges
- Deep dive: IC-007

Top-of-line corrosion (TLC)

Wet-gas-only phenomenon. Water vapor condenses on the cool top of a horizontal pipe, dissolves CO_2, and corrodes the 12 o'clock position aggressively. Inhibitor at the bottom can't reach it.

- Common in cool wet-gas transmission and offshore segments
- Deep dive: IC-008

TWO BIG PATTERNS AT SURVEY LEVEL

Uniform metal loss vs. localized attack

Uniform metal loss

The pipe wall gets thinner more or less all over.

- Easier to predict
- Easier to manage with a corrosion allowance
- Easier to catch with wall-thickness inspection

Localized attack

Pits, cracks, mesa-shaped patches concentrated in spots.

- Harder to predict
- Harder to find
- Disproportionately dangerous — all the damage gets concentrated in a small area of pipe

IC doesn't always look like rust on the outside. Sometimes it's a deep pit under a deposit.

SECTION 3 · WHERE IT SHOWS UP

By pipeline service type

HIGHEST THREAT PROFILE OF ANY SERVICE

Production and gathering — every driver in play

Wet, mixed fluids: water, oil, gas flowing together. Water cut starts low when a field is young and rises over the field's life. Once water wets the pipe surface, every driver from Section 2 is potentially in play.

- **CO_2 corrosion** if produced gas has CO_2
- **H_2S corrosion** in sour service
- **MIC and under-deposit attack** anywhere water and solids accumulate
- **Cracking damage** where H_2S is high enough
- **Oxygen** is usually rare here (reservoir is anaerobic) — but can sneak in through leaks upstream of pumps or with injected fluids

Most variable of any service category. Every well, every pad, every gathering system has its own chemistry, flow regime, and operating pattern.

SALES-QUALITY FLUID, LOWER BASELINE THREAT

Transmission — mostly clean, but upsets matter

Tariff agreements limit the corrosive constituents. Industry-typical orientation numbers:

GAS

Tight specs

CO_2 low single-digit mol%, H_2S single-digit ppmv, water vapor in single-digit lb/MMscf, O_2 below 0.5%.

CRUDE OIL

BS&W limits

Generally a fraction of a percent. Tight but not zero.

REFINED PRODUCTS

Similar order

Product-by-product BS&W limits at the same magnitude.

> **Always work from your company's actual tariff** for the line you're on. The numbers above are just orientation magnitudes. Upset conditions, drips, slug-through, pressure cuts, and black powder all still matter.

STAGNANT SECTIONS, TANK BOTTOMS, UTILITY LINES

Facilities, processing, and storage tanks

Facilities & processing

Some piping flows constantly. Some is shut-in (operational dead leg). Some is permanent dead leg from removed equipment that was never disconnected.

- Stagnant sections are MIC and under-deposit magnets
- Utility lines (methanol, glycol, process chemicals) have their own profiles
- Often non-piggable — pushes the work toward chemical injection plus monitoring

Storage tanks & tank lines

Above-ground tanks accumulate water and sediment in the bottom over time. The water is the corrosion threat, not the oil above it.

- Floating-roof tanks take in rainwater (carries dissolved O_2)
- Tank bottoms get water, sediment, biofilm — with poor mixing
- Tank facility lines sit stagnant most of the time

WHERE TO LOOK ON ANY LINE

Eight places to scan first

6 o'clock of horizontals — water and solids settle here

Low points in elevation — water collects, pigging misses accumulate

Dead legs and bypass lines — no flow, biofilms thrive

Drips on gas lines — designed liquid catches that don't always get cleaned

Tank bottoms — water and sludge layer above the steel

Top of cool wet-gas lines — TLC at the 12 o'clock

Downstream of pressure cuts — temperature drops into condensation territory

Recently opened sections — possible O_2 excursion after maintenance

SECTION 4 · WHY THIS MATTERS

Safety, asset value, regulation

SLOW LEAKS FOUND EARLY ARE THE WORK

Most IC failures aren't catastrophic — and that's the point

They're slow leaks discovered during routine inspection. That's exactly what makes inspection programs valuable. The tech's job is finding developing problems before they become release events.

> **The rare incidents are the reminder of the stakes.** Bellingham, WA, 1999 — gasoline line ruptured, spill ignited, three killed including two ten-year-olds playing near a creek. Carlsbad, NM, 2000 — natural gas transmission line ruptured, twelve killed. NTSB attributed the Carlsbad failure specifically to internal corrosion.

Day-to-day, IC work happens before any of that. The tech is the one taking the samples, pulling the coupons, walking the sites — finding the small problems while they're still small.

PIPELINES ARE LONG-LIVED CAPITAL ASSETS

Catch it cheap, or pay to fix it

The asset side

A buried transmission line is engineered for decades. IC takes years off the back end of that life. Replacement before end-of-design-life is millions per mile that wasn't in anyone's plan.

The headline numbers

2002 FHWA study: ~$276B direct cost of corrosion / ~$552B total in the U.S.

2016 IMPACT study: ~$2.5T globally per year, with 15–35% saveable through better-practice control.

Per-incident: replacement, downtime, cleanup, penalties, insurance. A significant leak on a major line can run into tens of millions before counting lost throughput.

THE RULES REQUIRE THE WORK

Federal regulation requires IC programs

49 CFR Part 192

Gas pipelines. Subpart O requires gas-transmission operators to identify, assess, and mitigate internal corrosion threats on covered lines.

49 CFR Part 195

Hazardous liquids pipelines. Equivalent integrity-management framework on the liquids side.

> **PHMSA** — the federal Pipeline and Hazardous Materials Safety Administration — audits these programs and issues enforcement when they fall short. None of the compliance work happens without IC techs in the field. The rules require the work; the techs do the work.

SECTION 5 · HOW IC WORK ACTUALLY GETS DONE

The roles, the day, the place

THREE PEOPLE WHO DON'T ALWAYS SIT IN THE SAME ROOM

Who does what in IC work

CORROSION TECH

Collects, executes, feeds back

Samples · Coupons · Field data · Mitigation execution

INTEGRITY ENGINEER

Designs the program, makes the calls

Inhibitor · Biocide · Dose · Pigging cadence · Monitoring plan

OPERATIONS

Runs the line, sees it daily

"Something looks different than usual." Front-line signals from people who live with the system.

THREE WORDS

Sample. Observe. Document.

Field hands, gloves, a sampling kit, a notebook. Fluids and gas at sampling points and pig receivers. Watching pig runs and drip-station blowdowns. Bacteria swabs. Coupons in and out, often under pressure. Lab reports. Walking compressor stations with operators. Driving between locations.

> If any of that sounds familiar from your current work, you're already partway in.

A lot of techs come to IC work having already done pieces of it without calling it that. This track gives you the framework for what you've already been around — not a foreign topic, a more deliberate way of doing what you already see.

THE BASIN WE KNOW BEST

The Appalachian shale-gas region

Wet gas. Intermittent flow. Cool winter soil. Plenty of CO_2. The occasional sour pocket. A steady drip-station rhythm. That's the work as we see it day to day.

The physics is the same wherever steel pipe carries fluid, but the combination of drivers in each basin is different. If you're in this region, the examples in this track will match what you see on your sites. If you're elsewhere, the principles still apply — translate the local conditions, swap out the basin-specific details, and the framework holds.

SECTION 6 · THE FOUR ESSENTIAL QUESTIONS

The spine of the work

ASK THESE IN ORDER. THE REST IS TECHNIQUE.

What organizes the whole field

Q1 · This module sets up

Is there potential for an IC problem in the asset?

What's the line carrying? What's the chemistry? Where can water collect? What drivers could be in play?

Q2 · The rest of this set

Can the cause be defined?

What driver is doing the work? CO_2? H_2S? Oxygen? Microbes? Some combination?

Q3 · Mitigation tier

How can it be prevented or mitigated?

Inhibitors, pigs, dehydration, materials, biocides, operational adjustments. Designed by the integrity engineer; executed by the tech.

Q4 · Assessment & IM tiers

Is the mitigation effective?

Coupons, probes, in-line inspection, fluid sampling, surface analysis. Closing the loop back to Q1.

Assess, mitigate, monitor, repeat. That's the spine of every IC program — and of this track.

THE TRACK ROAD MAP

Where this module sits

YOU ARE HERE

Basics & Theory tier

The entry tier — 22 modules in 3 sets. You're in the first set: **Corrosion Mechanisms in Pipeline Fluids** (IC-001 through IC-008). Two more sets close out the tier — Environmental & Flow Factors and System Differences & Risk Foundation. Tier medal lands when all three are clear.

NEXT TIER

Assessment tier

How to know what's happening. Sampling methods, coupon procedures, microbial monitoring, in-line inspection, gas analysis, the lab side of the work.

TIER AFTER

Mitigation tier

How to control it. Inhibitors, biocides, scavengers, pigging programs, design choices. Integrity engineer designs; tech delivers.

CAPSTONE

Integrity Management

Putting it all together. How a corrosion control program lives across years and changing operating conditions.

Built for techs who want to do the work, not pass a test.

KEY TAKEAWAYS

What to carry forward

- **IC is the inside problem.** Different cause map than EC; needs sampling, monitoring, and inspection to find at all.
- **Four big drivers.** CO_2, H_2S, O_2, microbes. Most IC problems are one of these or a combination.
- **Three roles.** Tech collects and executes; integrity engineer designs the program; operations runs the line.
- **Four essential questions.** Is there potential, what's the cause, how to mitigate, is mitigation working.

UP NEXT

IC-002 — Corrosion Chemistry in Pipeline Fluids

The chemistry foundation. Four ingredients, four solute categories, the indirect → direct → mitigation data-flow chain. Where the technical density picks up.

BOOKS

- **Internal Corrosion Field Guide**
- **Peabody's Control of Pipeline Corrosion**

FEDERAL & INDUSTRY

- 49 CFR Parts 192 & 195
- NACE SP0106 · SP0775 · TM0194
- API RP 1160 · API RP 80

STUDIES & REPORTS

- 2002 FHWA Cost of Corrosion
- 2016 IMPACT Study
- NTSB Bellingham (1999) & Carlsbad (2000)