EC-012 · MODULE 5 OF 7

Faraday's Law & Corrosion Rates

Current into pounds, pounds into years. The arithmetic that prices every anode, reads every coupon, and turns "the anode corrodes" into a number you can stand behind.

EXTERNAL CORROSION TRACK   FOUNDATION   ELECTROCHEMISTRY & THE GALVANIC SERIES   ~30 MINUTES

BY THE END OF THIS MODULE

You'll be able to —

- State Faraday's Law — metal consumed is exactly proportional to charge passed — and name the constant that makes it work: 96,485 coulombs per mole of electrons.
- Use the exchange rate: one amp-year dissolves about 20 pounds of steel — and recall the four consumption rates worth knowing cold.
- Read anode capacity in amp-hours per pound, and explain why actual capacity runs below theoretical (current efficiency).
- Run the chain — pounds × capacity ÷ draw ÷ 8,760 — from a shunt reading to an anode-life estimate.
- Recognize the rate-to-current equivalence on iron (1 mpy ≡ 2.17×10^{-6} A/cm^2) and what an external coupon's known area makes measurable.
- Explain cathodic protection in Faraday's terms: the metal bill doesn't vanish — it moves to the sacrificial side, priced and planned.

BACK AT THE TWO TANKS

The question that ends most tailgate meetings

Hilltop — magnesium

soil	dry silty loam
resistivity	~8,000 Ω·cm
drive	~0.6 V — the strong pusher

Right metal for hard dirt. You made this call last module, and it held up.

Creek bottom — zinc

soil	wet gray clay
resistivity	~400 Ω·cm
drive	~0.25 V — steady push

Right metal for easy dirt. Same reasoning, opposite answer.

Then the operator asks: **“So how many years does each anode last?”**

Last module we told the truth: that's arithmetic we haven't done yet. Today we do it.

Every electron is bookkeeping. Count the charge and you've counted the metal — current into pounds, pounds into years — forward to price an anode, backward to read a corrosion rate.

One law does all of it, and it fits on one line.

PART 1 OF 5

From counting electrons to weighing metal

YOU ALREADY HAVE THIS

Counting charge is counting metal

Every iron atom that leaves the wall leaves as Fe^{2+} — and every one hands off exactly **two electrons**. No exceptions, no partial credit.

That looked like chemistry trivia when you learned it. It's actually the foundation of corrosion accounting: if every atom ships with a fixed number of electrons, then the charge that flows is a running total of the metal that left.

The mass of metal consumed is proportional to the charge passed — proportional the way a scale ticket is proportional to what's on the truck.

THE ONLY TIME YOU'LL SEE IT FULLY DRESSED

Faraday's Law

$$m = (I \times t \times M) \div (n \times F)$$

The current side

I — current, amps
t — time, seconds
One coulomb = one amp for one second.

The metal side

m — grams consumed
M — atomic weight, g/mol
n — electrons per atom (iron: 2).

The constant

F = **96,485** coulombs per mole of electrons. Many references round to 96,500 — at field precision, either is fine.

Same number for every metal, every couple, every soil, every job. You never solve for F — it's the posted conversion rate between electrons and amp-seconds.

WHY YOU ONLY RUN IT ONCE

The industry did the algebra decades ago

You'll work the full equation exactly once in this module — then never again.

Every metal a corrosion crew will ever meet has already been run through Faraday's Law, and the answers were written down as constants: pounds per amp-year for structures, amp-hours per pound for anodes.

We run it once so the constants aren't magic. After that, we use the constants like everyone else in the trade does — on a phone calculator, on a tailgate.

PART 2 OF 5

The twenty-pound year

THE ONE FULL RUN — EVERY UNIT SHOWN

One amp, one year, on steel

TIME		CHARGE		FARADAY'S LAW		METAL
31,536,000 s	→	**31,536,000 C**	→	**(1 × t × 55.85) ÷ (2 × 96,485)**	→	**≈ 9,130 g**
365 d × 24 hr × 3,600 s		1 A × the seconds		iron: M = 55.85 · n = 2		= 9.1 kg = **20.1 lb**

The two electrons in the denominator are the same two from the oxidation half-reaction. Chemistry in, pounds out.

THE EVERYDAY CURRENCY OF THIS TRADE

What a stray amp costs

One amp, one year, twenty pounds of steel. That's the exchange rate.

20 lb

1 A leaving a pipeline at one spot, for one year

10 lb

half an amp — same spot, same year

2 lb

100 mA — small, until you remember it doesn't take pounds to make a leak

WHAT THE LAW DOESN'T TELL YOU

The law says how much. The circuit says where.

Spread — a whole bare surface

One amp across an entire tank bottom is a haze of surface rust nobody will ever measure. Twenty pounds as paperwork.

Concentrated — a few holidays

The same amp funneled to three quarter-size coating holidays delivers the same twenty pounds to three addresses. Now you're cutting out pipe.

Faraday counts the pounds; the current distribution picks the address. Same arithmetic, different geometry — and the geometry is what leaks.

FOUR NUMBERS WORTH KNOWING COLD

Pounds per amp-year — theoretical

METAL	LB / A-YR	READ IT AS
Carbon steel	≈ 20.1	the structure you're protecting
Zinc	≈ 23.6	pays out more metal for the same current
Magnesium	≈ 8.8	punches above its weight per pound
Aluminum	≈ 6.5	lightest bill of the four

Lighter atoms and more electrons per atom mean fewer pounds per amp. The field form is this table with the algebra pre-chewed: `W = K × I × T` — pounds = rate × amps × years.

PART 3 OF 5

Amp-hours per pound: the anode's fuel gauge

THE SAME CONSTANT, FLIPPED

A battery rating for a bar of metal

For anodes, don't ask how many pounds an amp consumes — ask how many amp-hours of charge live inside one pound.

1,000	372	?
A-hr per pound — magnesium, theoretical	A-hr per pound — zinc, theoretical	what a buried bar actually delivers — next slide

That's how suppliers publish anode data, and it's the form the life calculation wants.

THE TAX ON BEING ACTIVE

Theoretical vs. actual

A buried anode doesn't spend every electron on your structure. Part of its surface runs little corrosion cells of its own — metal dissolving locally, electrons round-tripping on the bar, doing nothing for the tank at the end of the wire.

METAL	THEORETICAL	ACTUAL	CURRENT EFFICIENCY
Magnesium	1,000 A-hr/lb	≈ 500 A-hr/lb	≈ 50%
Zinc	372 A-hr/lb	≈ 335 A-hr/lb	≈ 90%

Magnesium gives you half of what the chemistry promises; zinc gives you ninety cents on the dollar. Neither is a defect — it's a property of each metal, already folded into every honest life estimate in the industry.

Quote anode life off **actual** capacity, never theoretical.

An estimate built on theoretical magnesium is wrong by a factor of two — and wrong in the direction that gets remembered, because the system dies ten years before the paperwork said it would.

PART 4 OF 5

Back at the hilltop: the operator's answer

WHERE THE NUMBER COMES FROM

Read the shunt, let Ohm's Law do the rest

Nobody hands you “50 milliamps.” You earn it at the test station.

> 5.0 mV across a 0.1-Ω shunt → I = V ÷ R = **50 mA**

- **The polarity is information** — it tells you the bar is feeding the structure, not the other way around.
- **An amp clamp gets you the same number** when there's one on the truck — but every tech carries a multimeter, and the shunt is already wired.
- **Fifty milliamps is modest, and modest is the point** — dry 8,000 Ω·cm loam is why the strong pusher got this job.

THE CHAIN, START TO FINISH

One 17-lb magnesium bar at 50 mA

THE BANK	→	THE DRAW	→	THE HOURS	→	THE YEARS
8,500 A-hr		**0.050 A**		**170,000 hr**		**≈ 19.4**
17 lb × 500 A-hr/lb		off the shunt		8,500 ÷ 0.050		÷ 8,760 hr/yr

On the tailgate, out loud: “Call it nineteen years, give or take how wet the seasons run.”

Four lines, no lookup tables, nothing you can't do in the truck.

WHAT COMES WITH THE ANSWER

Nineteen years, with honesty attached

The 2× trap

Run the same chain on theoretical capacity and you'd promise **39 years**. The difference between an estimate and an apology is one factor of two, applied up front.

Estimate, not expiration

Output wanders with soil moisture and season. The number tells you which **decade** to plan the replacement in — that's its job.

The 85% line

Crews don't wait for zero — near 85% consumed, the stub can't hold dependable output. Design sheets carry it as a **utilization factor**.

And the creek-bottom zinc? Same chain, different numbers — 335 A-hr/lb in the bank and a bigger draw in that easy clay. It's waiting in the Apply lesson, and this time you're the one at the tailgate.

PART 5 OF 5

The law in reverse — and why CP works at all

WHICH DIRECTION YOU MEET DEPENDS ON WHERE YOU WORK

Forward in the field, backward in the lab

The lab move — internal side

Weigh a coupon before and after exposure; walk mass loss through density, area, and time; out comes mils per year. IC coupons ride inside the line and come out on schedule with retrieval tools. If your career runs the IC path, you'll meet it properly there.

The field move — external side

External coupons go in the ground beside the pipe and **stay buried**. Nobody's mailing them to a lab. What they give you, they give you alive — next slide.

A BARE SPOT WITH A BIRTH CERTIFICATE

The one thing no real holiday has: a known area

An external coupon is a bare piece of steel wired to the pipe through the test station — a stand-in coating holiday whose size you actually know.

- **Read its shunt, divide by its area** — and you're holding current density, the number CP design speaks in. Measured, not assumed.
- **It gives honest potentials too** — one reason we've called coupons the closest thing to asking the steel directly.
- **Procedures live later** — what matters now is what the known area makes possible.

WORTH RECOGNIZING ON SIGHT

Rate ↔ current density, on iron

$$1 \text{ mil per year} \equiv 2.17 \times 10^{-6}\ \mathrm{A/cm^2} \equiv \text{about } 2\ \mathrm{mA/ft^2}$$

A mil is a thousandth of an inch; metric reports quote the same rates in mm/yr (1 mpy ≈ 0.025 mm/yr).

You don't need to derive it. You need to recognize it — it's the line that turns a measured current density into wall language, and wall language into current.

THE BLOCK ABOVE, DOING A DAY'S WORK

Same number, threat or receipt

THE COUPON	→	THE SHUNT	→	CURRENT DENSITY	→	IN STEEL LANGUAGE
10 cm²		**22 µA**		**2.2 µA/cm²**		**≈ 1 mpy**
known area, by design		measured at the test station		22 ÷ 10		via the equivalence

On a freely corroding bare spot, that's the wall it would lose. On a protected coupon, that's the bill your anodes are paying on its behalf. Faraday's Law is what makes the translation honest.

THE QUIET IDEA UNDER THE WHOLE TRADE

The pounds don't vanish. They move.

If a structure's corrosion cells are drawing current — pounds leaving on schedule, per the exchange rate — then supplying that current from somewhere else means the structure stops paying. Faraday's Law keeps the books balanced either way.

> Cathodic protection doesn't cancel corrosion. It redirects the bill — to metal you chose, priced, and planned to replace.

Galvanic: the payer is magnesium or zinc, budgeted in advance. Impressed current: a rectifier drives the circuit, and the anodes — high-silicon cast iron, mixed metal oxide, graphite — are picked because they spend almost nothing.

WHERE YOU'LL MEET THIS MATH FOR THE REST OF YOUR CAREER

Every quote, every report, same law

- **Galvanic CP quotes** end in a Faraday line item — anode count, anode size, expected life. That's this module's arithmetic, priced by the pound.
- **Internal-corrosion coupon reports** convert mass to rate with the same law, run backward.
- **External coupon readings** turn shunt current and known area into measured current density.
- **ICCP consumption estimates and rectifier sizing** lean on the same constants, downstream.

The tech who can run the chain reads those documents instead of taking them on faith — catches the theoretical-capacity mistake before it ships, answers the operator without calling the office.

That's the difference between running the survey and understanding the system — the first step from technician thinking toward designer thinking.

It costs four lines of arithmetic.

PIN THIS ONE TO THE DASH

Shunt to years, in four moves

1 · READ
mV ÷ Ω
shunt drop → amps (Ohm's Law)

→

2 · BANK
lb × A-hr/lb
actual capacity, never theoretical

→

3 · HOURS
bank ÷ draw
amp-hours ÷ amps

→

4 · YEARS
÷ 8,760
hours in a year

Forward for anode life. From the middle for remaining life. Backward for rates. One chain, every direction.

CARRY THESE OUT THE DOOR

Key takeaways

- **Faraday's Law is exact bookkeeping** — m = (I × t × M) ÷ (n × F), with F = 96,485 C per mole of electrons. Run once; constants carry it from there.
- **One amp-year ≈ 20 lb of steel** — and the four rates: steel 20.1, zinc 23.6, magnesium 8.8, aluminum 6.5 lb/A-yr.
- **The law counts pounds; the circuit picks the address** — spread is haze, concentrated is a leak.
- **Capacity: Mg ≈ 500, Zn ≈ 335 A-hr/lb actual** — quote life off actual, never theoretical (the 2× trap).
- **The chain: read · bank · hours · years** — a 17-lb bar at 50 mA is 19.4 years, said out loud on a tailgate.
- **1 mpy ≡ 2.17 × 10^{-6} A/cm^2** — and an external coupon's known area makes current density a measured number.
- **CP moves the bill** — the “expected life” line on a galvanic quote is this module's arithmetic, priced.

MODULE 5 OF 7 · ELECTROCHEMISTRY & THE GALVANIC SERIES

You can answer the operator

You came in able to call the anode in any couple. You leave able to bill it — current into pounds, pounds into years, forward for anode life and backward for corrosion rates.

The quiz is ten questions, eighty percent to pass — and you've already done everything it asks. Complete all seven modules in this set and the certificate for Electrochemistry & the Galvanic Series is yours. Two to go after today.

NEXT IN THE SET

Reference electrodes

Every number today leaned on a measured potential — and every potential is measured against something. Next: why a copper-sulfate cell holds still, and why the same pipe can read two different numbers against two different cells.