EC-014 SUPPLEMENTAL READING

The Evans Diagram

Potential against current, the point where the two lines cross, and what cathodic protection does to that point.

ROBERTS CORROSION SERVICES FIELD NOTES FROM RCS ELECTROCHEMISTRY SERIES ~9 MIN READ

Adapted from Field Notes from RCS — ‘Evan’s Diagram’. Edited for this module. Originally published at **newsletter.rcswv.com** in February 2026. Included with EC-014 as supplemental reading for the Electrochemistry & the Galvanic Series set. Save it, print it, take it to the field.

> **Adapted from Field Notes from RCS — 'Evan's Diagram'. Edited for this module.**
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> Edits to voice, length and structure are unmarked. Every change to a technical claim, number, standard or recommendation is marked in the text as an **[RCS note]**. The article's web-hosted figures are not reproduced here; the drawing they were carrying is redrawn natively below.

Why This Drawing Is Worth Knowing

The Evans diagram plots electrode potential against current density for the anodic and cathodic reactions happening on one metal surface. It is a kinetics picture, and that is what makes it useful.

A potential table tells you which way a reaction wants to go. This tells you how fast it is going, and what happens to that rate when you push current onto the surface. That second question is the one that matters the moment a rectifier is in the circuit.

Reading the diagram is what ties polarization data, corrosion rate and cathodic protection settings into one story instead of three unrelated ones. You will not be asked to construct one on a job. You should be able to look at one and say where an unprotected structure is living, which way protection moves it, and why a modest shift in potential buys a large cut in metal loss.

What the Diagram Plots

Corrosion is two reactions running at once on the same surface: metal giving up electrons and going into solution, and something in the electrolyte taking those electrons up. The diagram puts both of them on one set of axes.

Potential (E) runs up the vertical axis, more negative toward the bottom. Current density (i) runs along the horizontal, plotted logarithmically — each step to the right is ten times more current, not one more unit.

- **Anodic curve.** Metal atoms losing electrons and dissolving into the electrolyte. Current density climbs as the potential moves in the positive direction.
- **Cathodic curve.** The reduction that consumes those electrons — oxygen reduction in most buried service, hydrogen evolution where conditions are acidic or the potential is driven far down. Current density climbs as the potential moves in the negative direction.

The two curves slope toward each other and cross. At that crossing the anodic rate and the cathodic rate are equal, no net current flows in or out, and the metal sits there.

One intersection names two numbers. The **corrosion potential (E_{corr})** is what a meter reads with no current applied — the natural corrosion tendency of that metal in that environment. The **corrosion current density (i_{corr})** is proportional to how fast the metal is actually being consumed.

> **Read the direction before you read the diagram.** *On every Evans diagram — this one and every other one you will ever meet — potential runs* **positive at the top and negative at the bottom**. *That is upside down from the survey plots you are used to, where more negative usually runs up the page. Same numbers, opposite direction. Getting this straight once saves reading the whole picture backwards.*

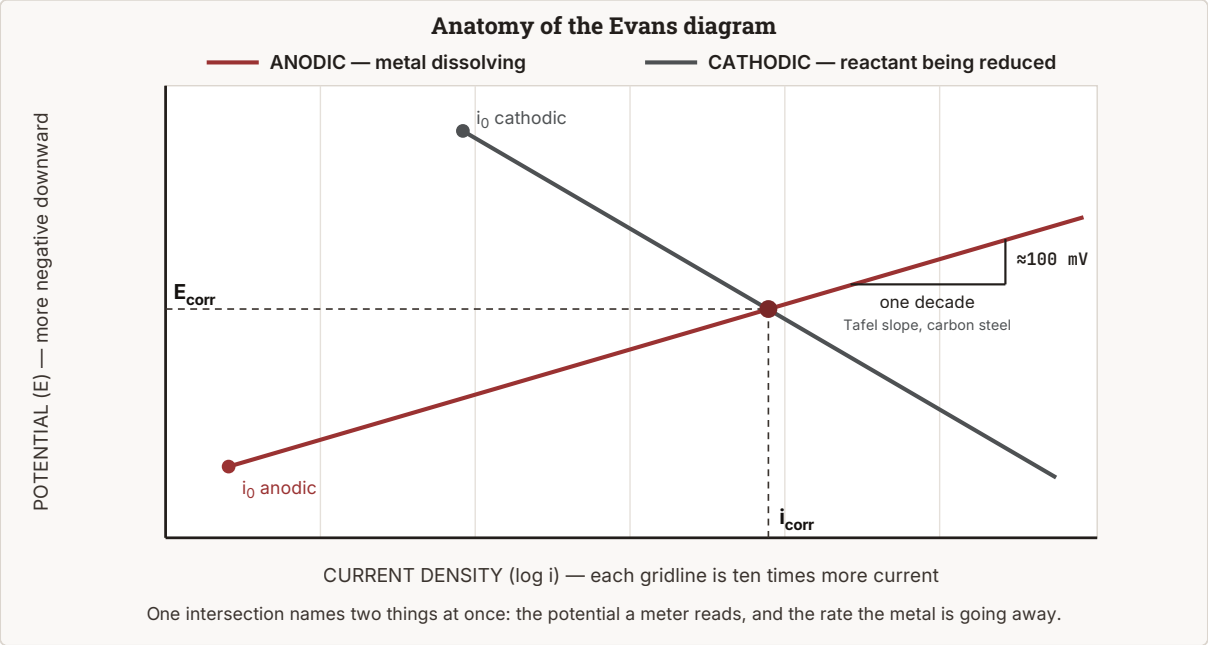

Figure 1. Redrawn for this reprint in place of the article's web-hosted diagram.

The Parts, One at a Time

Electrode potential (E)

Potential is the driving force for the reaction, and it is always read against a reference — a copper/copper sulfate cell in buried work. It describes the energy state at the metal-electrolyte interface, not a fixed property of the metal by itself.

Move it positive and you are polarizing anodically, toward oxidation. Move it negative and you are polarizing cathodically, toward reduction.

Current density (i)

Current density is electron flow per unit area of exposed surface, and it converts directly into metal loss. It is plotted on a log scale because the rates involved span orders of magnitude; on a linear axis everything worth looking at would pile up against the left edge.

Exchange current density (i_0)

At the equilibrium potential of a half-reaction, forward and reverse run at the same rate. Net current is zero, but nothing has stopped — the reaction is turning over in both directions at a rate called the exchange current density.

It depends on the metal, the condition of its surface, and the reaction itself. A high i_0 means the reaction is easy to drive: less potential is needed to get current out of it, so it polarizes less.

Tafel slopes (β_a and β_c)

Along the straight portion of each curve, potential and log current move together at a fixed rate. That rate is the Tafel slope, quoted in millivolts per decade — millivolts of potential change per tenfold change in current.

For carbon steel the anodic slope is roughly 100 mV per decade. That figure is worth carrying, because it is where the hundred-millivolt polarization criterion comes from.

> THE RELATIONSHIP THAT PAYS OFF IN THE FIELD
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> 100 mV of shift = one decade = corrosion current cut by a factor
> of 10
> ```

Extending the straight portions back to where they intersect is how corrosion rate gets pulled out of polarization data in a laboratory. In the field you inherit the result rather than run the test.

Reading the Diagram

- **Corrosion potential (E_{corr}).** The potential where anodic and cathodic currents are equal. The metal's resting point in that environment.

- **Corrosion current density (i_{corr}).** The current density at E_{corr}, proportional to the corrosion rate.
- **Polarization.** Any displacement of potential away from E_{corr} caused by current crossing the surface.
- **The cathodic protection effect.** Applied current moves the potential negative, and the anodic current density falls with it.

What Cathodic Protection Does to the Picture

Cathodic protection works by refusing to let the metal sit at the crossing point.

Electrons are supplied from somewhere else — a sacrificial anode, or a rectifier and an anode bed — and the potential is dragged down from E_{corr} to a more negative value. Call it E_{cp}.

Read the anodic curve at that new potential and the anodic current density sits far below where it was. The metal is still dissolving. It is dissolving at a small fraction of the former rate.

Read both curves at E_{cp} and they no longer meet. The gap between them at that potential is the current you have to supply from outside, and that is what the rectifier output is buying.

Because the horizontal axis is compressed, the return is not proportional. A couple hundred millivolts of shift does not trim the corrosion current. It drops it by factors of ten, and that is the whole reason cathodic protection is practical at the scale we use it.

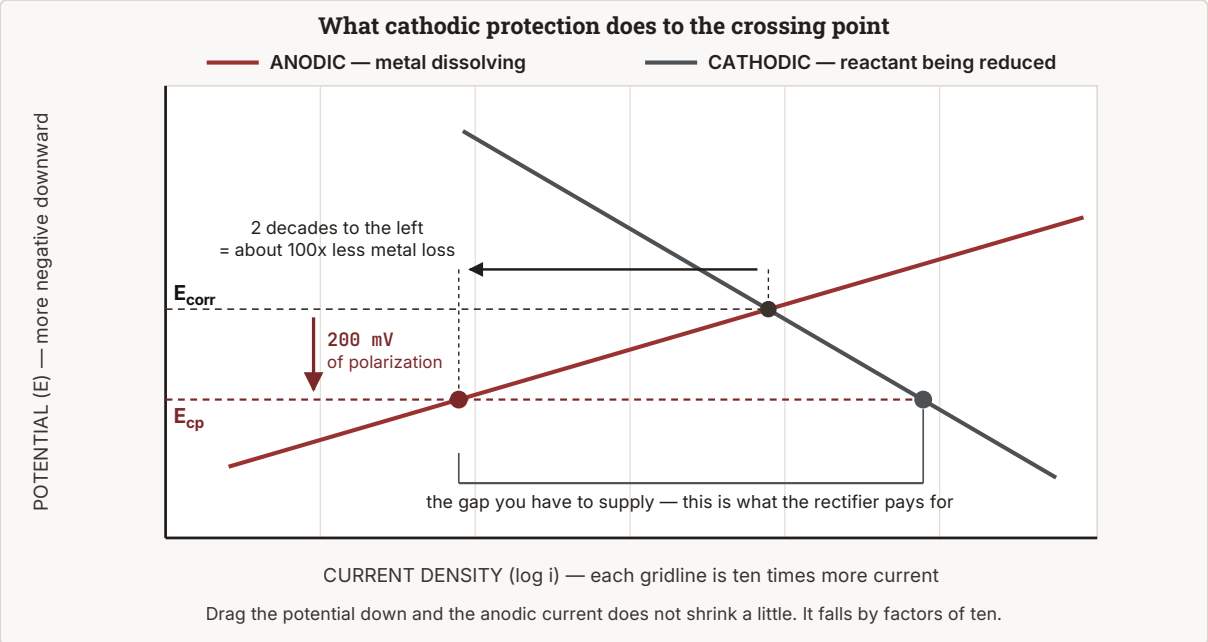

Figure 2. The same two curves, read at a protected potential. Redrawn for this reprint.

Three Kinds of Polarization

Polarization does not come from one mechanism. Three different things slow the reactions at a metal surface, and each one bends the curves in its own way.

Activation polarization

The charge-transfer step itself is sluggish. Electrons crossing between the metal and the things in the electrolyte have to get over a hump, and driving that reaction faster costs potential. This is what dominates when reactant is plentiful and the current is modest.

Concentration polarization

The reaction runs short of something to react with. In buried service the usual bottleneck is oxygen: the surface consumes it faster than fresh oxygen can work its way in. The rate stops being set by the metal and starts being set by delivery. Stagnant or dilute conditions bring it on early.

Environmental polarization

The current changes the chemistry right at the surface, and the changed chemistry helps. Cathodic reactions leave the film against the metal more alkaline than the bulk electrolyte, and that film is a less hospitable place for corrosion to proceed. Some of the protection you paid for with current ends up maintaining itself.

[RCS NOTE]

The fourth quantity, and why it is not on this list

This article names three kinds of polarization — activation, concentration and environmental. The module names the same three, so the two are not disagreeing with each other.

What the module adds is a fourth quantity handled separately: **resistance drop**, the IR term. Current flowing through the resistance of the electrolyte produces a voltage, and a reference cell sitting out in that electrolyte reads it along with everything else. It is not polarization in the chemical sense — nothing at the metal surface has changed, and it vanishes the instant the current stops — but it rides on every on-potential you take.

It is left off the list above because it does not belong on it, not because either source overlooked it. Three kinds are real. The fourth is a measurement artifact, and telling it apart from the other three is most of the work.

What Moves the Curves in the Field

None of these curves are fixed. Change the environment and they move, which moves the crossing point, which changes both the resting potential and the corrosion rate. The original article made this point with a family of plots, one variable at a time. The table gathers the same variables in one place.

Condition	What changes at the surface	What it looks like from the truck
Oxygen concentration	More dissolved oxygen means more reactant for the cathodic reaction, so the cathodic curve supports higher current density.	Current demand goes up. Well-drained, aerated ground is thirstier than saturated clay, and the same rectifier setting will not hold the same shift in both.
Aeration versus deaeration	With oxygen largely absent at neutral pH, the cathodic reaction is starved and the crossing point moves toward much lower current.	Oxygen-starved ground consumes carbon steel far more slowly than aerated ground at the same acidity. Two identical pipes, two different rates.
Temperature	Warmth speeds up both reaction kinetics and the diffusion feeding them, pushing the crossing point toward higher current.	A line that holds its numbers in February can slip in August with nothing on the system changed. Weather before faults.
Movement of the electrolyte	Flow carries reactant in and sweeps product away, which erases concentration polarization and lifts the cathodic curve.	A creek crossing does not behave like a hilltop. Where water moves, demand goes up.
Acidity (pH)	Acidity governs which cathodic reaction dominates — hydrogen evolution in acid conditions, oxygen reduction near neutral — and shifts the cathodic curve accordingly.	Different soils polarize differently at the same output. The setting that works on one stretch is not automatically the setting for the next.
Metal ion concentration	Ions already in solution shift the anodic equilibrium potential and move the anodic curve with it.	Tight, undisturbed ground around a coating holiday does not behave like freshly opened backfill.

Table added for this reprint in place of the article's web-hosted curve families.

Summary and Key Takeaways

- The Evans diagram is the standard way to picture the kinetics of corrosion — the balance between metal dissolving and the reaction consuming the electrons it releases.
- Where the anodic and cathodic curves cross, the two rates are equal. That single intersection names both the corrosion potential and the corrosion rate.
- Cathodic protection moves the potential negative and the corrosion current falls with it — not in proportion, but by factors of ten, because the current axis is logarithmic.
- Tafel slopes and exchange current densities are the parameters that put numbers on all of it. For carbon steel, roughly 100 mV of shift is one decade, which is where the hundred-millivolt criterion comes from.
- Three mechanisms produce real polarization: activation, concentration and environmental. Resistance drop is not one of them, but it shows up on your meter as though it were.
- The curves move when the environment moves. Oxygen, aeration, temperature, water movement, acidity and dissolved metal ions all shift the crossing point, which is why the same setting reads differently season to season.
- Measurement technique and environmental conditions have to be accounted for before any of this is interpreted. The diagram is only as honest as the numbers you feed it.

Referenced Standards

- **NACE SP0169** — Control of External Corrosion on Underground or Submerged Metallic Piping Systems. Criteria and methods for corrosion control and cathodic protection assessment.
- **ASTM G59** — Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements. Supports polarization data collection.

[RCS NOTE]

Three changes to this reference list

Removed. The original list cited **NACE TM0177**, Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments. That is a materials-qualification standard for sour service. It has no bearing on reading an Evans diagram or on the polarization behavior this article describes, and it has been taken out.

Corrected. The original cited **ASTM G61** under the title "Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements." That title belongs to **ASTM G59**; G61 is the cyclic potentiodynamic test for localized corrosion susceptibility, a different subject. The citation now reads G59, which is what the original description was pointing at.

Trimmed. The original gave an edition year for SP0169. RCS house style cites standards without edition years, so it is listed bare here — the standard itself is unchanged.