
EC-007 · MODULE 7 OF 22

Closes the first rung

Transformers: Principles, Types, and Applications

Recognition + light arithmetic - the math, the types, the nameplate.

EXTERNAL CORROSION TRACK

FOUNDATION TIER

ELECTRICAL BASICS FOR CP

~30 MINUTES

BY THE END OF THIS MODULE

You'll be able to -

- Explain how a transformer steps voltage up or down using the turns-ratio relationship.
- Identify whether a CP rectifier transformer is single-phase or three-phase by counting AC input terminals.
- Identify air-cooled vs. oil-immersed (and explosion-proof oil-immersed) housings on sight, and explain when each is specified.
- Read the six standard fields on a CP rectifier transformer nameplate to identify what is installed at a site.
- Reason about which transformer type fits a given installation based on phase, cooling, and step direction.

PRE-INSTALLATION INSPECTION - DE-ENERGIZED, ON THE BENCH

A new CP rectifier just came off the truck

Cover off, no power connected, fresh out of the crate. The biggest physical thing inside the cabinet - the heavy chunk of iron and copper - is the transformer. On the front of the transformer's case there is a small metal nameplate.

CP RECTIFIER TRANSFORMER - NAMEPLATE

PRI	240 V · 1-PHASE · 60 Hz
SEC	0-32 V · 30 A · 1.0 kVA
COOLING	DRY-TYPE · CLASS B
SER. NO.	2026-XXXXX

WHAT IS THE NAMEPLATE TELLING YOU?

Decode it before you install it

Reading that label tells you what service voltage the rectifier needs from the utility, how much current it can deliver to the structure, what kind of cooling it has, and whether it is a single-phase or three-phase unit. If you can read it.

EC-007 is about reading that nameplate, knowing the principle behind what the transformer does, and recognizing the types you'll see in the field. The math stays light - one relationship, the turns ratio. The recognition is the work.

One piece of math (**turns ratio**),
three type-distinctions (**phase, cooling, step direction**),
six nameplate fields.

That's the working level.

1

PIECE OF MATH

Turns ratio

3

TYPE-DISTINCTIONS

Phase · Cooling ·
Step direction

6

NAMEPLATE FIELDS

Primary V · Secondary V ·
Phase · kVA · Cooling ·
Frequency

MODULE ROADMAP

Five sections, in order

01**Step up,
down, isolate**

What a transformer can do;
why CP is nearly always
step-down.

02**Turns ratio**

The one piece of math
worth knowing - voltage
ratio = turns ratio.

03**Single or
three-phase**

Matches the AC service
available; recognition cue
at the cabinet.

04**Cooling type**

Air-cooled, oil-immersed,
explosion-proof oil-
immersed.

05**Reading the
nameplate**

Six fields that identify any
CP rectifier transformer on
sight.

BEFORE ANY WORK INSIDE AN ACTIVE RECTIFIER

Follow the Electricity - safety practice

CP rectifiers contain BOTH AC and DC voltage simultaneously.

- **PPE is not optional.** Insulated rubber gloves and insulated tools any time you are working on or around an energized unit.
- **Calibrated, high-impedance multimeter.** Tech uses their own meter, not the cabinet panel gauges. Built-in voltmeters and ammeters are not considered accurate or reliable for working readings.
- **Voltage indicator** with detection threshold no greater than 30 V for cabinet-safety verification.
- **Leads connected with the unit OFF, hands out, then energize** to take the reading. Build it into habit.
- **Working alone is not recommended.**

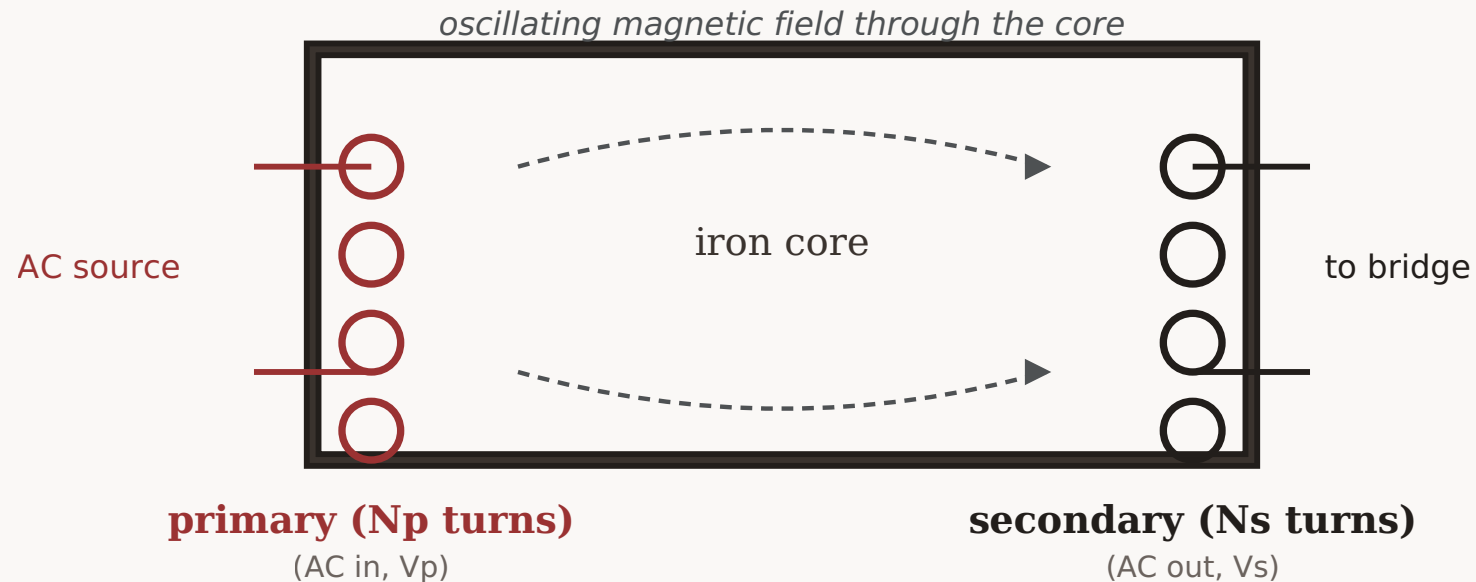
Source: "CP Rectifier Troubleshooting: Follow the Electricity" - Field Notes from RCS.

RECAP FROM THE PRIOR MODULE

**Before transformer types -
the principle the prior module set
up**

FROM THE PRIOR MODULE

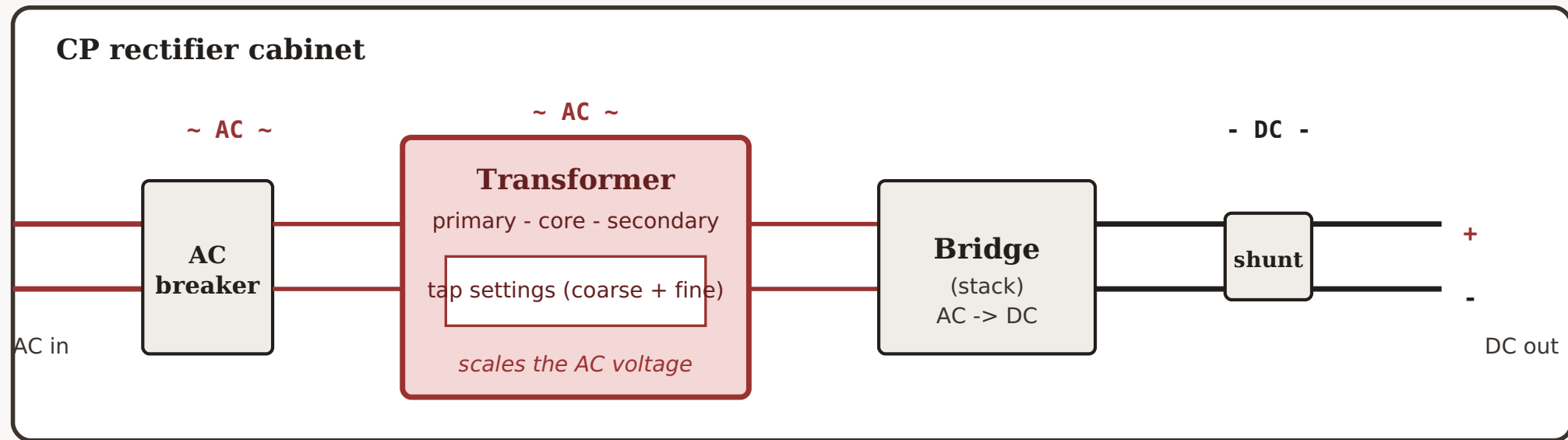
A changing magnetic field induces a voltage



Two coils on an iron core. AC in the primary winding creates a changing magnetic field; the changing field induces an AC voltage in the secondary. With steady DC, the field stops changing - and so does the secondary output.

FROM THE PRIOR MODULE

Where the transformer sits in the rectifier



EC-007 focus: the transformer

AC input lugs - AC breaker - **transformer** - bridge or stack - panel shunt - DC output terminals. EC-007 zooms in on the transformer; the bridge gets a deeper treatment in another module later in the catalog.

THE TRANSFORMER-RECTIFIER FRAMING

"Transformer-rectifier" is the actual unit

In CP work, what we call a "rectifier" is really a **transformer-rectifier unit**. It contains a step-down transformer, a means of adjusting the voltage, a rectifier (the bridge) to change AC to DC, plus controls and supporting components.

Two halves to the unit: the transformer (this module) and the bridge (another module later in the catalog). The transformer scales the AC voltage from utility level down to a working level. The bridge converts that AC to DC for the structure.

Some smaller modern rectifiers use solid-state circuitry instead - "switchmode rectifiers." Less common in standard impressed-current CP, but worth recognizing if you encounter one.

STEP UP · STEP DOWN · ISOLATE

Three things a transformer can do to AC voltage

TYPE DISTINCTION #1 - STEP DIRECTION

Step up, step down, or isolate

STEP UP**Lower to higher V**

Primary has fewer turns than secondary.
Common on the utility distribution side; rare on CP rectifiers themselves.

STEP DOWN**Higher to lower V**

Primary has more turns than secondary.
Standard configuration for nearly every CP rectifier transformer. Utility 120/240/480 V down to a working AC voltage for the bridge.

ISOLATE**Same V both sides**

No electrical connection between the two coils. Used in some specialized rectifier setups; not a typical adjustment in the field.

Turns Ratio · The Math

The one piece of math worth knowing

URNS RATIO = VOLTAGE RATIO

Two ratios that have to match

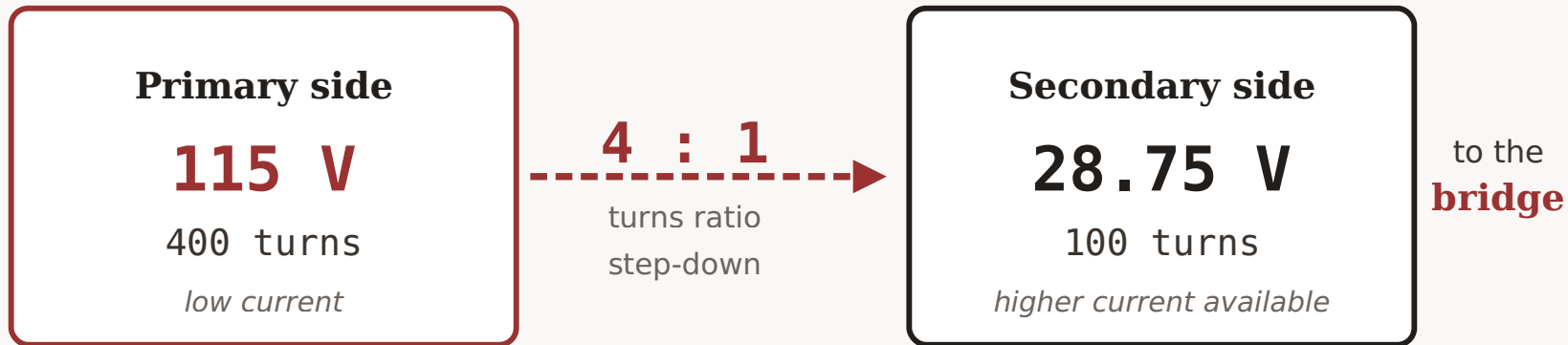
$$\begin{aligned} \text{Primary V} / \text{Secondary V} \\ = \text{Primary turns} / \\ \text{Secondary turns} \end{aligned}$$

The ratio of the primary voltage to the secondary voltage equals the ratio of the primary turns to the secondary turns.

One footnote. The relationship is exact under no-load conditions. Real-world losses inside the transformer (in the core and the windings) reduce the secondary voltage slightly below the no-load value when current is flowing. For recognition work, the no-load model is the right one.

WORKED EXAMPLE – TURNS-RATIO MATH

115 V primary, 400:100 turns to 28.75 V



115 / 4 = 28.75 V — voltage down by 4x, current up by about 4x

Read it out loud: 115 volts in. 400 turns on the primary, 100 turns on the secondary. That ratio is 4 to 1. So the primary voltage is 4 times the secondary voltage. 115 divided by 4 equals **28.75 V AC** on the secondary.

CURRENT GOES THE OPPOSITE WAY

Voltage down to current up. No math needed.

When a transformer steps the voltage down by 4x, the current available on the secondary goes *up* by roughly 4x. When it steps the voltage up, the current available goes down by the same ratio.

*A transformer doesn't make energy.
It trades voltage for current at a fixed ratio.*

Recognition cue. Look at the wiring. Primary connections on a step-down transformer are smaller wire (low current). The secondary side terminates at heavy bus bars (high current). That's why - the secondary is carrying the higher current that the lower voltage trades for.

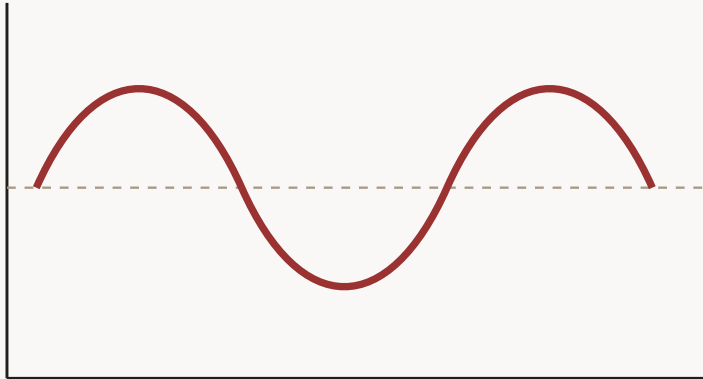
TYPE DISTINCTION #2 · PHASE

Single-phase or three-phase

MATCH THE AC SERVICE AVAILABLE AT THE SITE

Count the AC input terminals

Single-phase service

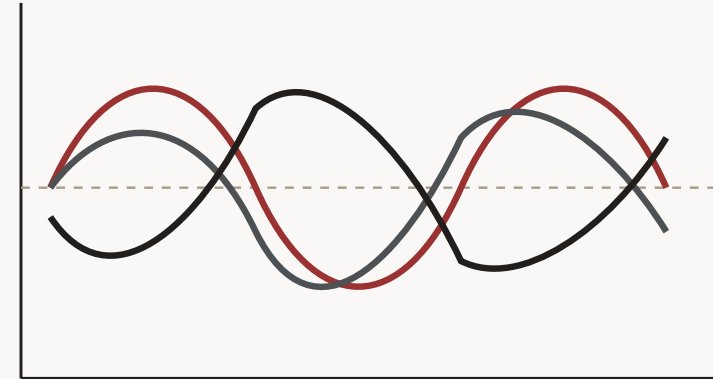


2 lines · 115/120 V or 230/240 V · most CP rectifiers

Single-phase

Two power-carrying lines plus ground. Common voltages: 115, 120, 230, 240 V. The typical North American single-phase standard is 120/240 V. Most CP rectifiers in the field are single-phase units.

Three-phase service



3 lines · 208/240/480 V · larger installations

Three-phase

Three power-carrying lines plus ground. Common voltages: 208, 240, 480 V. Three-phase service is most often found at larger industrial and oil-and-gas sites. Required for larger CP installations where the loads justify it.

WHAT DRIVES THE CHOICE

Available service + cost study

The choice between a single-phase and a three-phase rectifier comes down to two practical things: the type of power available at the site, and the economic comparison of overall costs.

Three-phase power may be available at only a few locations along a pipeline. Where it is available, the choice between single-phase and three-phase comes down to a cost study. For large installations, three-phase units tend to win out.

Practical rule: three-phase is more efficient and tends to win on larger installations, but you can only specify it if the service is on hand.

TYPE DISTINCTION #3 · COOLING

**Air-cooled or
oil-
immersed**

THREE OPTIONS ACROSS THE INDUSTRY

Air-cooled, oil-immersed, explosion-proof

STANDARD**Air-cooled
(ventilated)**

Steel enclosure with vents or louvers; convection air cooling. Wall, pole, or pedestal mount. **Most pipeline CP applications.** Lower cost, lighter weight.

HARSH-DUTY / CLASSIFIED**Oil-immersed**

Sealed steel tank, transformer and bridge fully submerged in transformer oil. Pedestal-mounted on a concrete pad. Used at hazardous-location sites and harsh environments.

HAZARDOUS AREAS**Explosion-proof oil-immersed**

Modified oil-immersed unit with rated seals and conduit fittings on every cable entry. For Class I, Division 1 or 2 locations and similar classified facilities.

THE CLASSIFICATION DRIVER - WHAT MOST CP TECHS SEE

Compressor stations + refineries = oil unit

The largest share of oil-immersed rectifiers a CP technician sees in the field aren't there for environmental reasons. They are at sites where the National Electrical Code applies a **hazardous-area classification**:

Class I, Division 1

Flammable gases or vapors normally present, or present often during normal operation. Compressor station relief vents, parts of refineries, fuel-handling areas.

Class I, Division 2

Flammable atmosphere only present abnormally - during a leak, vent release, or off-normal event.

Either rating disqualifies a standard air-cooled rectifier from being installed inside the classified area. Spark-producing components (breakers, diodes, contactors) cannot be open to the atmosphere. Oil-immersion seals them in transformer oil; the explosion-proof version adds rated seals and fittings to fully meet the code.

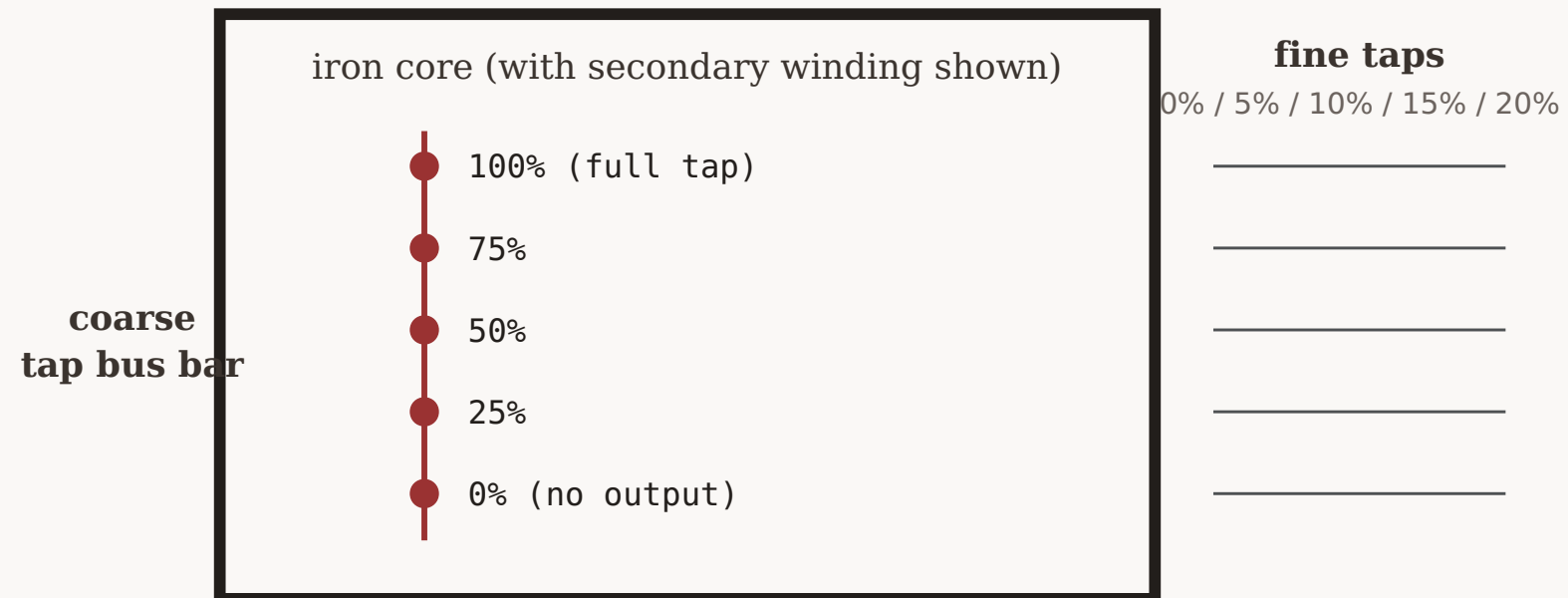
Environmental durability and heat dissipation are real benefits too - but the classification driver puts most oil units into the field.

TAP SETTINGS · THE TECHNICIAN'S ADJUSTMENT LEVER

How a tech tunes the DC output without changing the unit

CONNECTION POINTS ALONG THE SECONDARY WINDING

Move the tap, change the active turns count



moving the tap connector changes the active turns count - and therefore the secondary AC voltage

THE TECHNICIAN'S ADJUSTMENT LEVER

Tap up over time as the ground bed ages

From Peabody on rectifier sizing — useful field context. *"The output voltage rating should be sized 15-25% over the design-calculated value to allow for any change in ground bed [resistance] with age."* The tap settings live above the rated working point on purpose - so the unit can be tapped up over time as the ground bed ages and resistance climbs.

Field tie-in. Step C of the "Follow the Electricity" diagnostic procedure measures AC across these tap settings. Even voltage steps from low to high tap = transformer is delivering. Wrong or absent reading = the transformer is the likely problem.

NAMEPLATE READING · THE RECOGNITION PAYOFF

Six fields tell you everything you need to know

STANDARD CP RECTIFIER TRANSFORMER NAMEPLATE

Read the unit before you measure anything

Primary voltage	What AC service the unit needs from the utility. Single-phase: 115/120/230/240 V. Three-phase: 208/240/480 V. Sometimes shown as "120/240" - field-wirable for either.
Secondary voltage range	AC output across the tap settings. Usually shown as "0-X V" where X is the full-tap secondary voltage. Sets the rectifier's max DC output (just below X after the bridge).
Phase	"1-PHASE" for single-phase, "3-PHASE" for three-phase (sometimes written with a Greek-letter abbreviation). Must match the AC service.
kVA rating	Apparent power capacity. Roughly the rectifier's max AC output voltage times its max current, divided by 1,000. Sets the size class of the transformer.
Cooling type	"DRY-TYPE" for air-cooled, "OIL-COOLED" or "OIL-IMMERSED" for oil units. Often paired with an insulation class (Class B, Class H).
Frequency	60 Hz on US utility power; 50 Hz on most non-North American grids.

WALKING THE HOOK NAMEPLATE END TO END

From label to identification, in six reads

CP RECTIFIER TRANSFORMER - NAMEPLATE**PRI** 240 V · 1-PHASE · 60 Hz**SEC** 0–32 V · 30 A · 1.0 kVA**COOLING** DRY-TYPE · CLASS B

Identification: a small, dry-type, single-phase, step-down CP rectifier transformer suitable for a modest impressed-current installation on a North American site with standard 240 V single-phase service. About what you'd expect for a typical buried-pipeline test station rectifier or a small distribution-line CP unit.

PUTTING THE THREE TYPE-DISTINCTIONS TOGETHER

A deep-anode site - what type fits?

The site: deep-anode groundbed for impressed-current CP on a midstream natural-gas gathering line. Designer's spec: **80 V × 40 A DC output** (about 3.2 kW). 480 V three-phase service available at the meter pole. On a concrete pedestal pad **inside the compressor station's Class I Division 2 classified area**, with the deep-anode well a short distance away.

QUESTION 1**Phase?**

The site has 480 V three-phase available; the unit is in the size range where three-phase efficiency starts to pay off; the cost study favors three-phase for larger installations.

QUESTION 2**Cooling?**

Sits inside the compressor station's Class I Division 2 classified area; continuous load near rated capacity; concrete-pad mount available.

QUESTION 3**Step direction?**

Utility delivers 480 V; secondary needs to deliver up to ~80 V AC for the bridge to convert to 80 V DC at full tap.

THREE PICKS - ONE FOR EACH DISTINCTION

Three-phase + oil-immersed + step-down

PHASE

Three-phase

480 V three-phase service is on hand and the load size justifies the upfront cost. More efficient than a single-phase unit at this output level.

COOLING

Oil-immersed

The Class I Division 2 classification mandates oil-immersed (or explosion-proof oil-immersed) equipment. Heat dissipation at this load level is a real secondary benefit.

STEP DIRECTION

Step-down

Roughly $480\text{ V} / 80\text{ V} = 6$, so the primary winding has about 6 turns of wire for every 1 turn on the secondary - and that ratio shifts as the tech moves the tap settings.

Field tie-in. Once installed and energized, the "Follow the Electricity" troubleshooting practice will measure AC at this transformer's tap settings (Step C) when something is not right. The taps are how the field tech adjusts DC output as the deep anode resistance changes over the years.

MODULE 7 OF 7 · SERIES COMPLETE

The Electrical Basics for CP series is now closed

EC-001**Circuit shapes**

Series, parallel, series-parallel

EC-002**Ohm's Law**

$V = I \times R$ math

EC-003**V/I/R**

Measurement scenarios

EC-004**AC vs DC**

Two regimes in CP work

EC-005**Power & energy**

P, kWh, heat losses

EC-006**Electromagnetism**

Field induction principle

EC-007**Transformers**

Recognition + types

The certificate that closes this series covers all seven modules - **EC-001 through EC-007** - and represents a working tech's foundation in the electrical side of the job.

WHAT TO WALK AWAY WITH

Recognition - the working level for a CP tech

- **Turns ratio = voltage ratio.** $V_p/V_s = N_p/N_s$. The 115 V to 28.75 V worked example (4:1 step-down).
- **Step up, step down, or isolate.** CP rectifiers are nearly always step-down.
- **Single-phase vs three-phase** matches the AC service. Count input terminals.
- **Three housing types:** air-cooled (standard, most common), oil-immersed (most often at hazardous-classified sites), explosion-proof oil-immersed (the strictest hazardous-location spec).
- **Tap settings change the active turns count** on the secondary. Step C of "Follow the Electricity" measures here.
- **Six nameplate fields** identify any unit on sight: primary V, secondary V range, phase, kVA, cooling type, frequency.

Bundled with this module: a PDF of the "CP Rectifier Troubleshooting: Follow the Electricity" article. Save it, print it, take it to the field.

- **CP Rectifier Troubleshooting: Follow the Electricity** — Field Notes from RCS article on systematic rectifier diagnostics; included with this module as a PDF supplement.
- **Cathodic Protection Rectifier Manual** — Nelson, C.M. — authoritative on rectifier internals, types, and field practice.
- **AUCSC Short Course Materials** — pipeline-corrosion technician training curriculum.
- **Peabody's Control of Pipeline Corrosion** — long-standing field reference on CP systems and rectifier sizing.
- **NFPA 70 (National Electrical Code)** — hazardous-location classification standards.