Chapman Engineering

30 PLUS YEARS

**Hello, NACE/SSPC/AMPP Kansas Section! March 11, 2026**

# COPPER AND CARBON STEEL – A TALE OF TWO METALS

## (OR, "HOW DO GROUNDING & AC POWER GRID PLAY WITH PIPELINES & FACILITIES?"

Answer: Not So Nicely.)

**Cal Chapman, P. E.**
NACE-Certified Cathodic Protection Specialist
**Professional Engineer in TX, FL, LA, NM, ND, NY, OK, TN**
Boerne, Texas; Houston, Texas; Columbus, Montana, USA
US 830-816-3311

# LET'S LOOK ONLY AT A PIPELINE RECTIFIER, INSTALLED

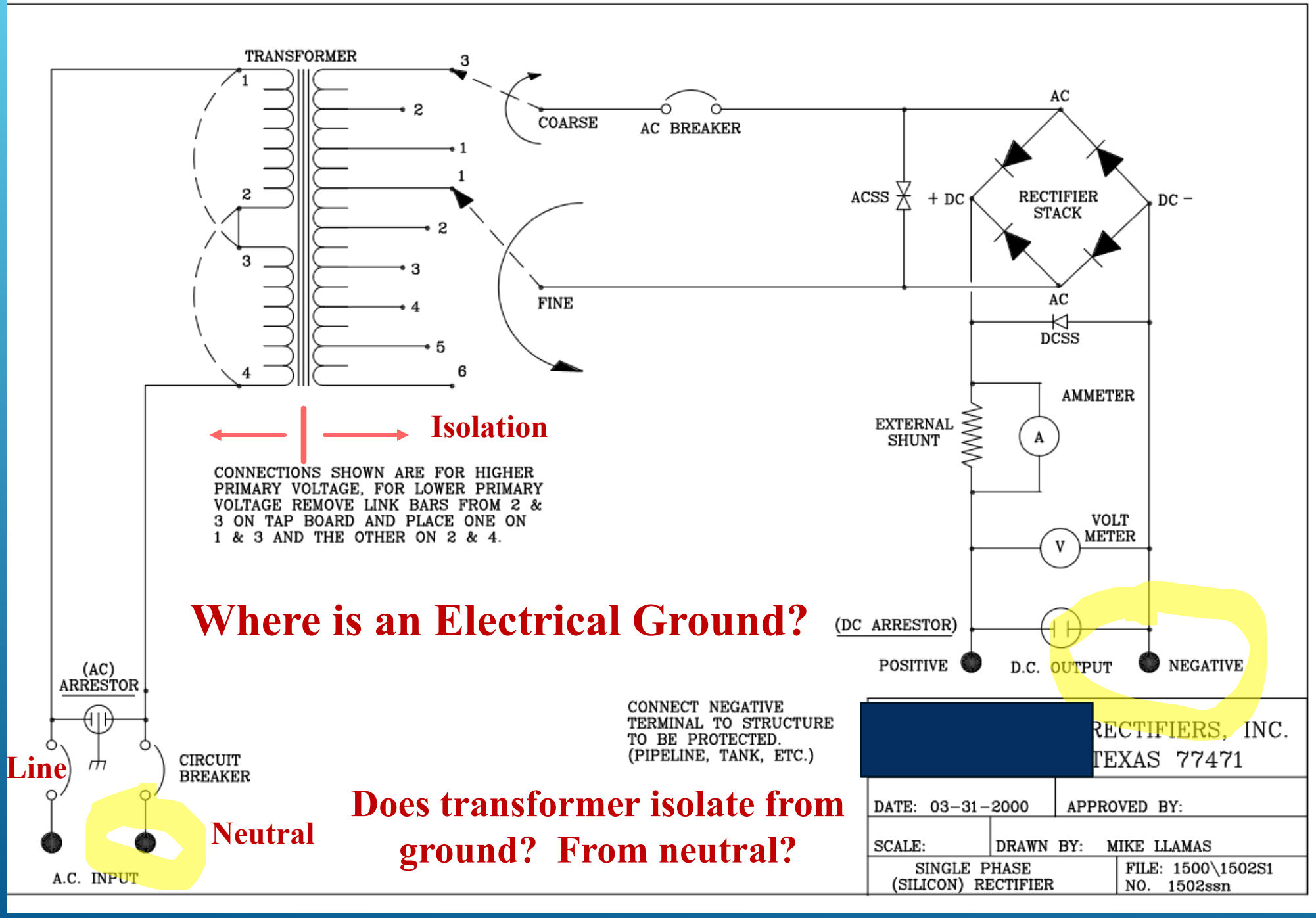

**AC Power comes in (for single-phase 230VAC) – one black wire (line/hot), one white wire (neutral), one green ground wire to rectifier case.**

**We have negative DC bond to pipeline (and positive to structure).**

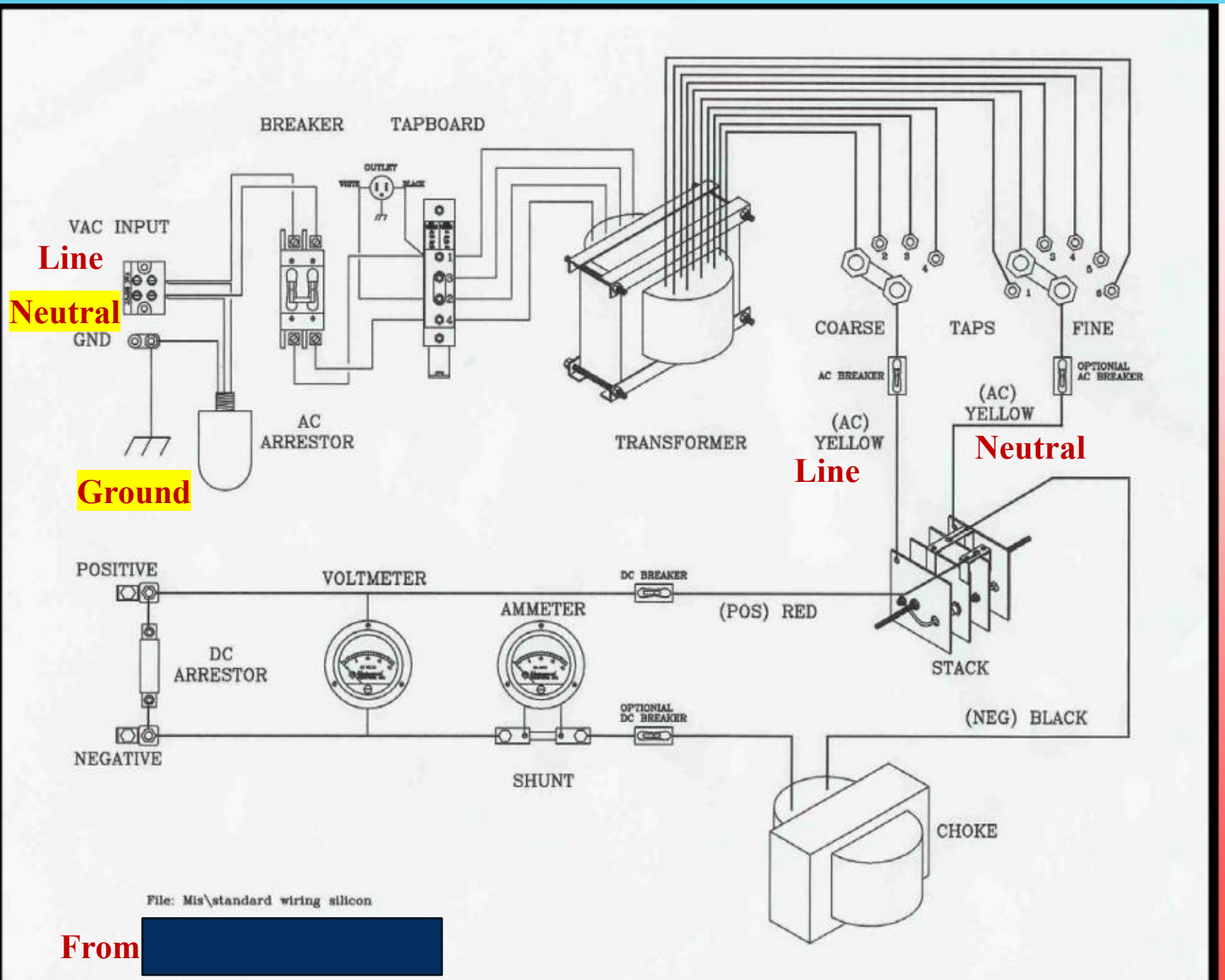
**There is Rectifier case ground, to a dedicated ground rod (or two).**

**There is AC neutral tie-back from local power service back to regional AC neutral leg, for safety and per US National Electrical Code (NEC). Don't mix these systems (except that NEC requires the ground-to-neutral combination).**

# RECTIFIER SCHEMATIC INFORMS US ON MOST OF THESE CIRCUIT PORTIONS.



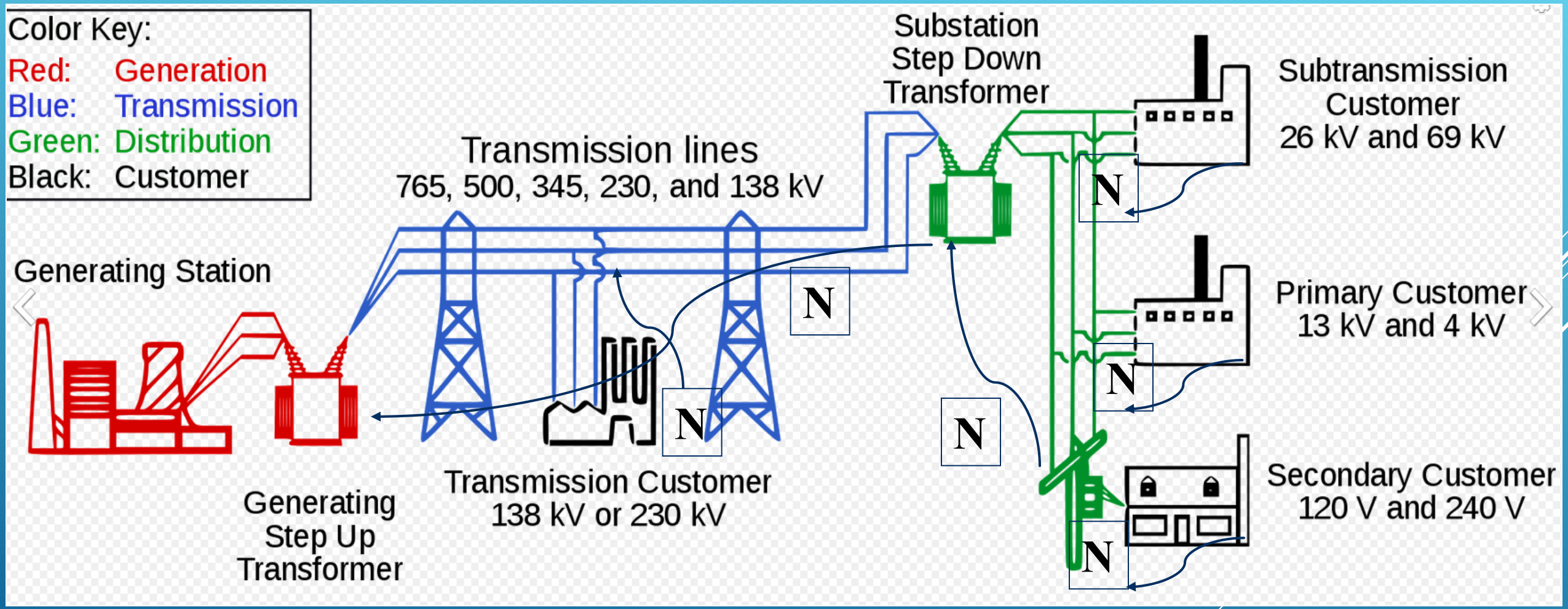
# RECTIFIER SCHEMATIC WITH DIFFERENT "ONE-LINE" LAYOUT. NEUTRALS AND GROUNDS ARE WHERE?



# AC POWER SYSTEM OVERVIEW

**Power Generation Feeds Transmission Power Lines. Transmission Lines Feed Substations,**

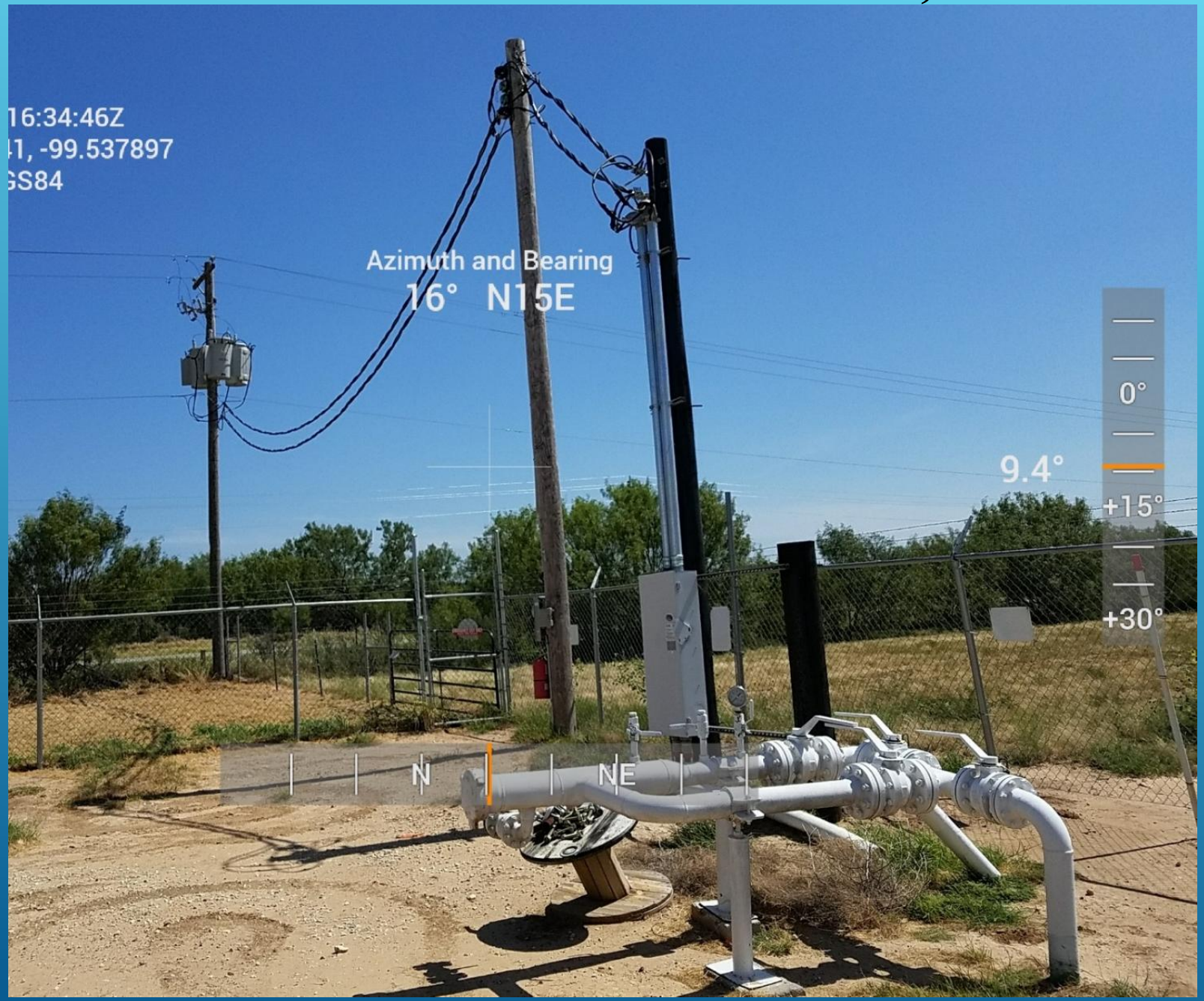
**Which Transform Voltages Down to Regional Lines, and on to Local Substations/Transformers/Distribution.**




Drawing Courtesy of Wikipedia

**Where is a neutral wire? Neutral system? Butt grounds?**

# AC WIRING – LIVE WIRES, NEUTRALS AND GROUNDS




- Service to Facility – three-phase power in, neutral tie back out;
- LOCAL Grounding Should be Separated from Neutrals on Site;
- We hope that large copper surface areas are not lying too close to our structure(s) needing CP (facility ground wires, ground rods on site);
- Look for electric substations, big facilities with electrical ground grids, dense AC power distribution grids around and near each asset/facility.
- Adjacent facilities get joined BY COPPER very readily!

# WHAT TIES FACILITIES TOGETHER? AC NEUTRAL.

NORTH DAKOTA, USA, 2016


**Try to convince these eight operators that all assets are common, that all CP needs synchronized interruption. That's for bulk tanks, overland pipelines, and maybe even facilities farther away.**

**And electric provider needs to help . . .**

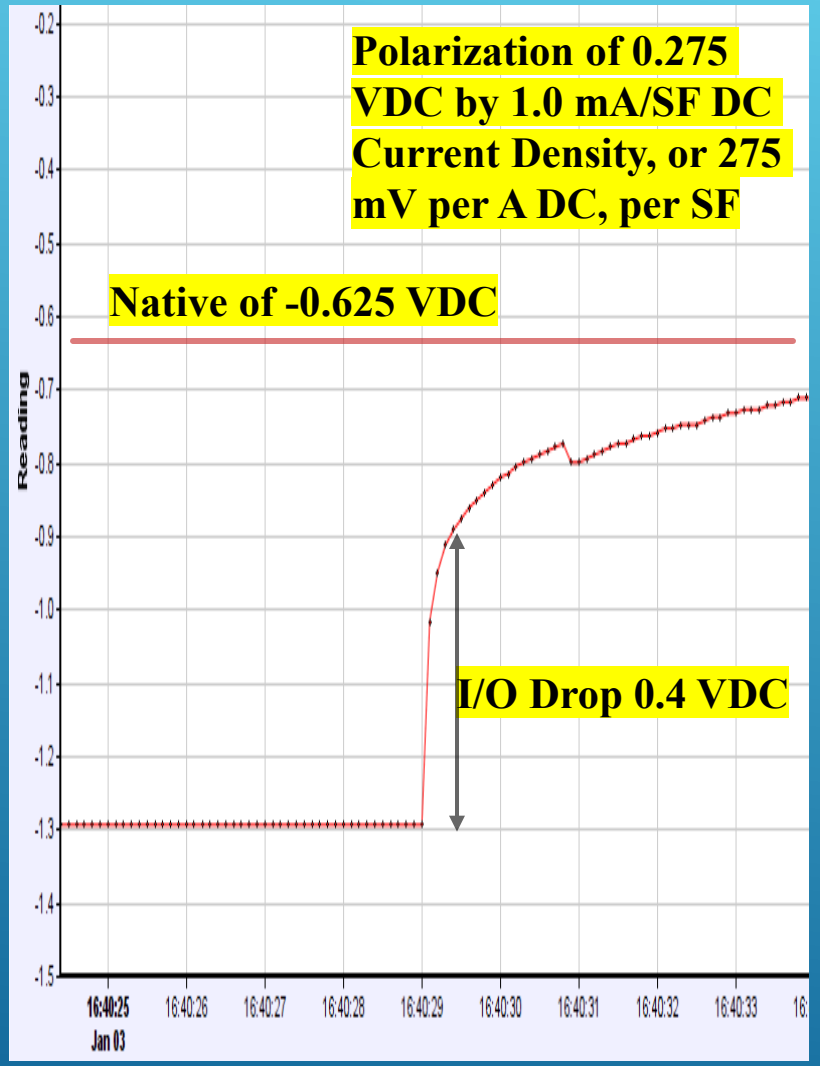
# What is US NEC (NFPA 70) requirement for electrical grounding? (Or equivalents?)

- Every electrical ground must have total resistance of 25 ohms or less;
- In most conditions, we want to see 5 ohms or less – virtually always obtainable in broad river valley regions, steppes, coastal flats, but not in rocky geographies or semi-desert and desert conditions;
- If you have 240 VAC and 5-ohm resistance, fault current flow will be about 48 amps. Yes, we think breaker will trip – but how soon?
- What is the AC neutral system's magnitude? What is local grounding's size and extent?

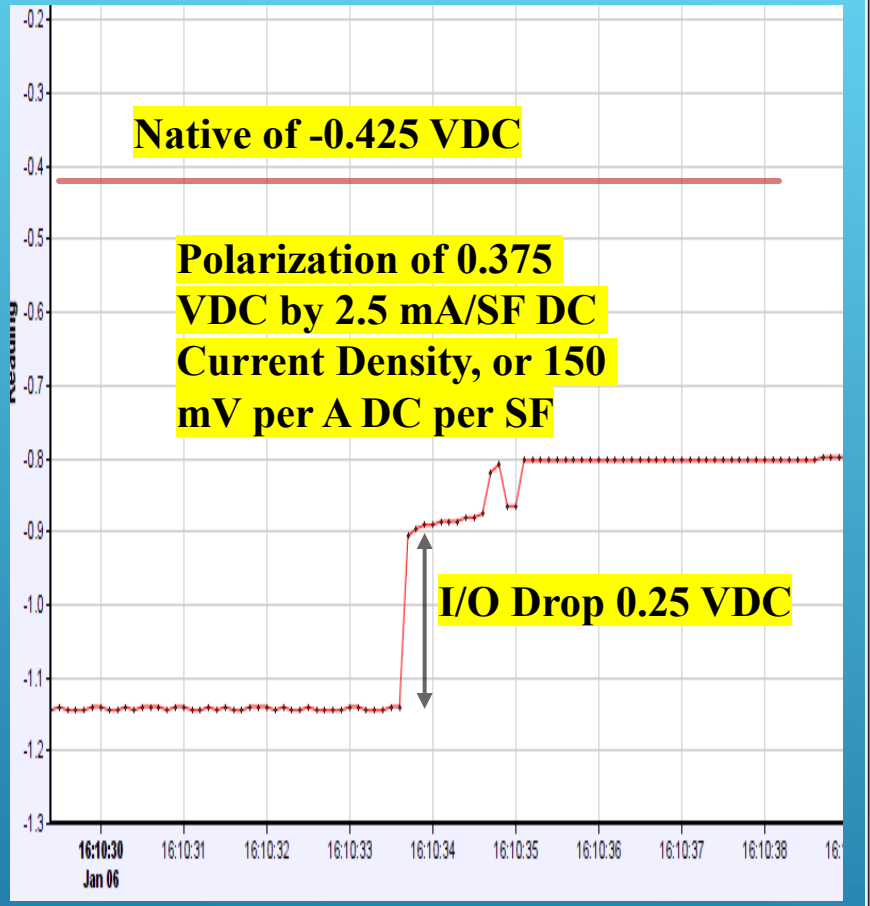
# WHAT IS GROUNDING, EARTHING? BONDING?

- **Grounding or Earthing** – Every electrical device is supposed to be grounded (as well as towers and many other structures). If an electrical fault (or lightning strike) occurs, the current flows to "ground mass" (Earth), and then goes "home" to point of origin. **Let's avoid using a person or high-value asset to flow current;**
- RISK MATRIX FOR FAULT CURRENT AND LIGHTNING EVENTS– LOW FREQUENCY, CATASTROPHIC CONSEQUENCES.
- **Electrical Bonding** – used to join all structures and grounding devices on a site/block together. No voltage builds up and causes static-electric spark or other shock. Reduces total resistance for every ground . . . All is electrically common/EQUI-POTENTIAL.

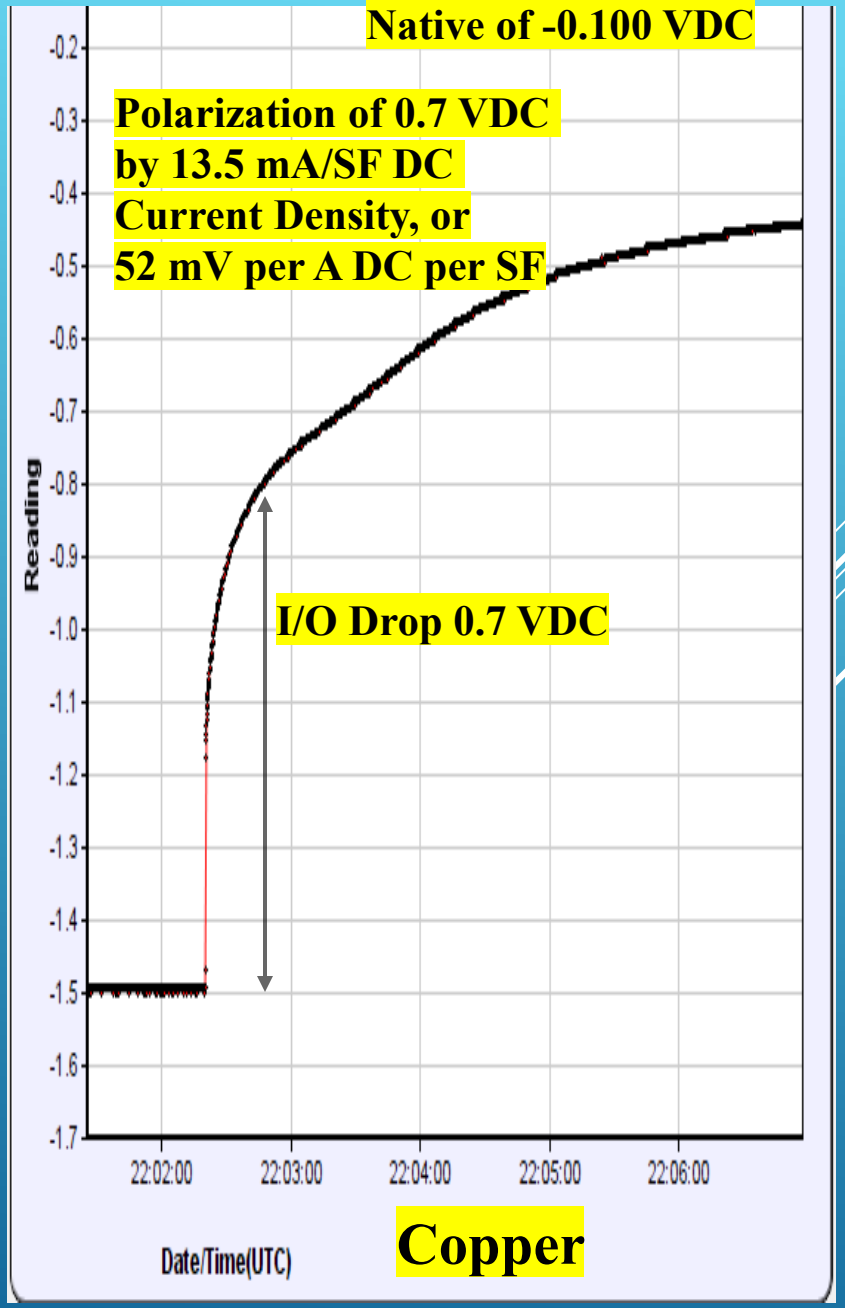
# COMPARING METALS WITH CP, AND WITH DEPOLARIZING




**Carbon Steel**
**(all to $Cu/CuSO_4$ CSE)**

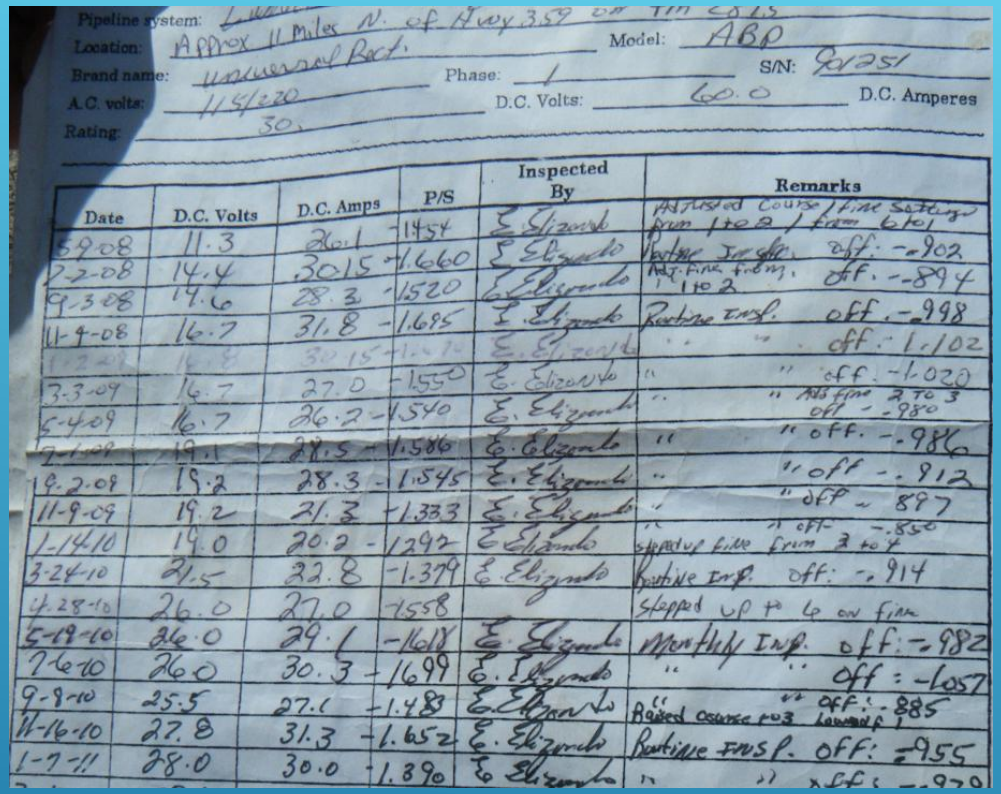



**316 Stainless Steel**
**(Avoid CP over-protection)**




**Copper**

# CP BEHAVIORS NEAR LAREDO, TX, USA, 2013



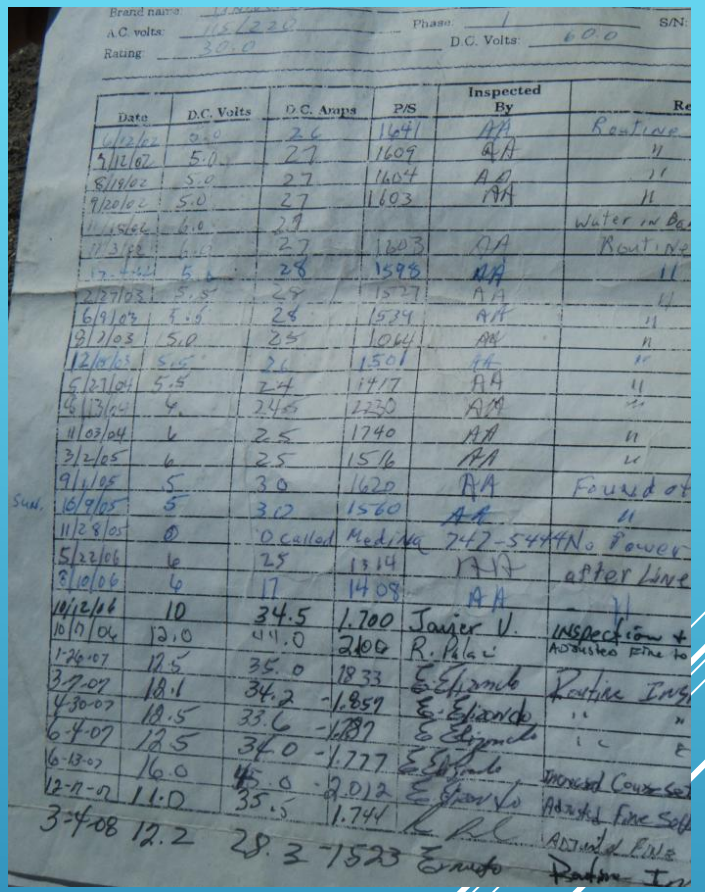
Pipeline system: [illegible] Location: Approx 11 Miles N. of Hwy 359 on FM 2813
Brand name: Universal Rect. Model: ABP
A.C. volts: 115/220 Phase: 1 S/N: 90251
Rating: 30 D.C. Volts: 60.0 D.C. Amperes

| Date | D.C. Volts | D.C. Amps | P/S | Inspected By | Remarks |
|---|---|---|---|---|---|
| 5-9-08 | 11.3 | 26.1 | -1454 | E. Elizondo | Adjusted course / fine setting from 1 to 2 / from 6 to 1 |
| 7-2-08 | 14.4 | 30.15 | -1.660 | E. Elizondo | Routine Insp. off: -.902 |
| 9-3-08 | 14.6 | 28.3 | -1520 | E. Elizondo | Adj. fine from 1 to 2 off. -.894 |
| 11-4-08 | 16.7 | 31.8 | -1.685 | E. Elizondo | Routine Insp. off. -.998 |
| [illegible] | [illegible] | 30.15 | -1.[illegible] | E. Elizondo | " " off. -1.102 |
| 3-3-09 | 16.7 | 27.0 | -1.550 | E. Elizondo | " " off. -1.020 |
| 5-4-09 | 16.7 | 26.2 | -1.540 | E. Elizondo | " " Adj fine 2 to 3 off -.980 |
| 7-[illegible]-09 | 19.1 | 28.5 | -1.586 | E. Elizondo | " " off. -.986 |
| 9-2-09 | 19.2 | 28.3 | -1.545 | E. Elizondo | " " off -.912 |
| 11-9-09 | 19.2 | 21.3 | -1.333 | E. Elizondo | " " off -.897 |
| 1-14-10 | 19.0 | 20.2 | -1292 | E. Elizondo | " " off -.850 Adjusted fine from 3 to 4 |
| 3-24-10 | 21.5 | 22.8 | -1.379 | E. Elizondo | Routine Insp. off: -.914 |
| 4-28-10 | 26.0 | 27.0 | -1558 | | Stepped up to 6 on fine |
| 5-19-10 | 26.0 | 29.1 | -1618 | E. Elizondo | Monthly Insp. off: -.982 |
| 7-6-10 | 26.0 | 30.3 | -1.699 | E. Elizondo | " " off: -1.057 |
| 9-9-10 | 25.5 | 27.1 | -1.483 | E. Elizondo | " " off: -.885 |
| 11-16-10 | 27.8 | 31.3 | -1.652 | E. Elizondo | Added course to 3 lowered 1 |
| 1-7-11 | 28.0 | 30.0 | -1.890 | E. Elizondo | Routine Insp. off: -.955 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | " " off: -.970 |

**Sys 1, 0.5 to 0.89 Ω in 2.5 yrs**

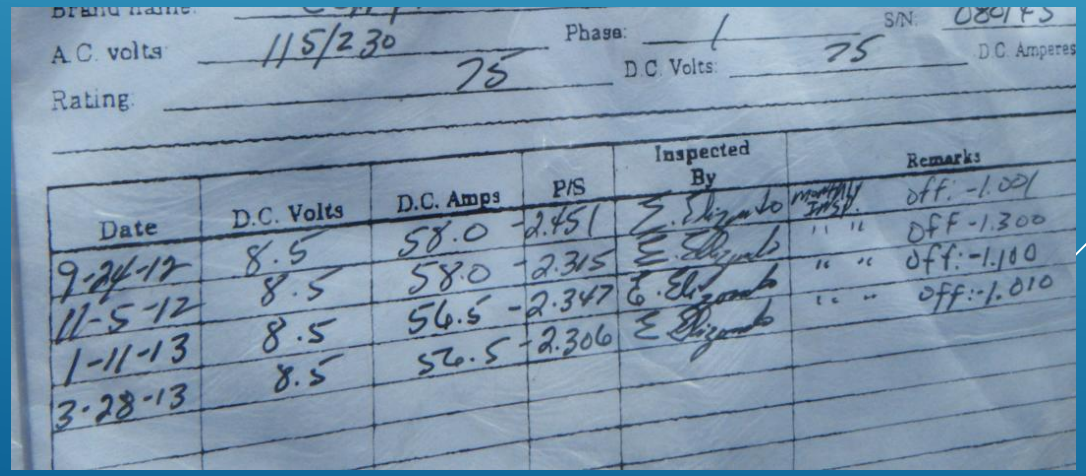
**12-INCH TRUNK GAS PIPELINE RUNNING 115 MILES (186 km). ISOLATED FROM GATHERING? NO!!**

**Sys 2, 0.25 Ω, stable over 5 years**



Brand name: [illegible] A.C. volts: 115/220 Phase: 1 S/N:
Rating: 30.0 D.C. Volts: 60.0

| Date | D.C. Volts | D.C. Amps | P/S | Inspected By | Remarks |
|---|---|---|---|---|---|
| 6/2/02 | 5.0 | 26 | 1641 | AA | Routine |
| 9/11/02 | 5.0 | 27 | 1609 | AA | " |
| 8/19/02 | 5.0 | 27 | 1604 | AA | " |
| 9/20/02 | 5.0 | 27 | 1603 | AA | " |
| 11/15/06 | 6.0 | 29 | | | Water in Box |
| 1/3/03 | 6.0 | 27 | 1603 | AA | Routine |
| 12-[illegible] | 5.5 | 28 | 1598 | AA | " |
| 2/27/03 | 5.5 | 29 | 1577 | AA | " |
| 6/9/03 | 5.5 | 28 | 1584 | AA | " |
| 8/21/03 | 5.0 | 25 | 1644 | AA | " |
| 12/16/03 | 5.5 | 26 | 1501 | AA | " |
| 5/21/04 | 5.5 | 24 | 1417 | AA | " |
| 8/13/04 | 4 | 24.5 | 1230 | AA | " |
| 11/03/04 | 6 | 25 | 1740 | AA | " |
| 3/2/05 | 6 | 25 | 1516 | AA | " |
| 9/1/05 | 5 | 30 | 1620 | AA | Found at |
| 11/28/05 | 0 | 0 called | Medina | 742-5444 | No Power after Line |
| 5/22/06 | 6 | 25 | 1314 | AA | |
| 8/10/06 | 6 | 17 | 1408 | AA | |
| 10/2/06 | 10 | 34.5 | 1.700 | Javier V. | Inspection + |
| 10/1/04 | 12.0 | 41.0 | 2100 | R. Plaia | Adjusted fine to |
| 1-26-07 | 12.5 | 35.0 | 1833 | E. Elizondo | Routine Insp |
| 3-7-07 | 18.1 | 34.2 | -1.859 | E. Elizondo | " |
| 4-30-07 | 18.5 | 33.6 | -1.887 | E. Elizondo | " |
| 6-4-07 | 12.5 | 34.0 | -1.777 | E. Elizondo | " |
| 6-13-07 | 16.0 | 45.0 | -2.012 | E. Elizondo | Increased Course Set |
| 12-11-07 | 11.0 | 35.5 | 1.744 | E. Elizondo | Adjusted fine Set |
| 3-4-08 | 12.2 | 28.3 | -1523 | Ernesto | Adjusted FINE Routine Insp |



Brand name: [illegible] A.C. volts: 115/230 Phase: 1 S/N: 08145
Rating: 75 D.C. Volts: 75 D.C. Amperes

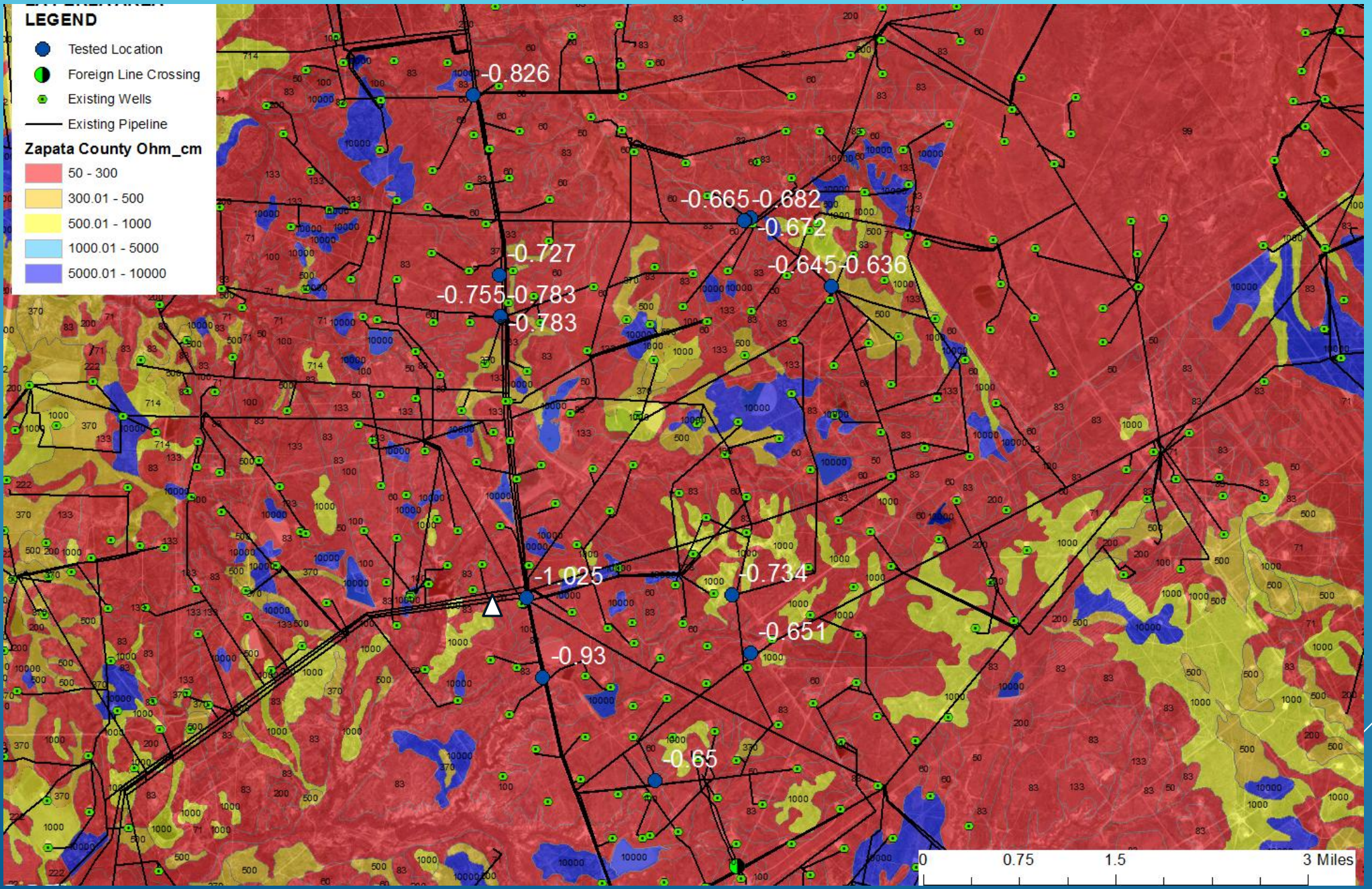
| Date | D.C. Volts | D.C. Amps | P/S | Inspected By | Remarks |
|---|---|---|---|---|---|
| 9-24-12 | 8.5 | 58.0 | -2.451 | E. Elizondo | Monthly Insp. off. -1.001 |
| 11-5-12 | 8.5 | 58.0 | -2.315 | E. Elizondo | " " off -1.300 |
| 1-11-13 | 8.5 | 56.5 | -2.347 | E. Elizondo | " " off:-1.100 |
| 3-28-13 | 8.5 | 56.5 | -2.306 | E. Elizondo | " " off:-1.010 |

**Sys 3, new; 0.15 Ω. Why? Also tied to AC neutral!**

0.25 MILE (0.4 KM) FROM RECTIFIER 3, SOUTHEAST OF LAREDO, TX. **WE HAVE -1.0 V "ON" AT VALVE. RECTIFIER BOND AT -2.3 V "SYSTEM ON."**

WHERE IS THE PROTECTION?

# BANGING OUT 58 AMPS, SYSTEM #3. NO PROTECTION?




Track P/S Voltage reads in pipe network, to locate the strong accidental tie(s) to AC neutral system!

**Suspect meter runs, instrument power, ONE RECTIFIER.**

# WHAT'S THE PATTERN? WHAT'S THE CP & ELECTRICAL CIRCUIT?!

- Copper AC neutral wires should always be near zero VDC to copper/copper sulfate reference cell (native copper about -0.1 V, typically);
- Neutrals and grounds should NEVER touch in a breaker panel, or in a facility, EXCEPT ONCE AT MAIN POWER SERVICE – TIED TOGETHER THERE BY CODE FOR FAULT CURRENT FLOWS – and this automatically affects CP;
- Remember that every AC power drop neutral wire has to tie back to regional neutral. WHAT ABOUT TELECOM GROUNDS? INSTRUMENT GROUNDS? CONTROL AND SCADA CIRCUITS WITH OFFSITE TIES/GROUNDS?
- If someone ever ties a green ground to a white neutral, or to the neutral bus in breaker panel, then DC current will more strongly join to and travel on that facility grounding, all metal on site, the AC neutral system, and then other facilities across the area.
- **Large copper masses and surface areas act as huge cathodes, making all exposed steel become strong anode across wide areas when these metals are joined.**

# AC WIRING – NEUTRALS AND GROUNDS

**Power Pole Butt Grounds – What Are They?**

**Copper grounding sheets, with wire attachments tying to Neutral wire up above**

# NACE/SSPC/AMPP CONFERENCE 2024
# C2024-21340, BY CHAPMAN

- Reach of AC neutral interaction with West Texas pipeline CP systems was more than 50 miles in all directions, with very high density of pipelines and facilities;
- Take 50-mile-reach of road network and power runs (on section lines, at least). For 2,500 miles of electrical distribution, services, substations, etc., butt grounds and other copper represent at least 16,700 square feet of bare metal in soil contact. If copper takes 5 mA/sf, that is 83 A DC of CP current taken;
- **Pipeline CP in this case totaled 170 amps from six CP systems in 53-mile pipeline system. More than half the anode bed life and power bill was going to copper protection – AND how under-protected is pipeline? A mixed-metal structure should meet -0.850-VDC current-interrupted NACE criterion. (See SP0169, part 6.3.4 and other references. What is open-circuit, native V for isolated carbon steel? Get 100 mV DC more negative than that.)**

# AC NEUTRAL BUTT GROUNDS AS PART OF CP CIRCUIT

- Copper conducts about 11 times better than carbon steel, just for electrical conductivity and same wire sizing/stranding;
- In electrical distribution, about 17 power poles per mile of run, all with neutral butt grounds and bare copper wire (aluminum wires overhead);
- Take 10-mile-reach of road network and power runs (on section lines, at least). At least 1,700 neutral butt grounds, all as parallel CP current pickups. How can one pipeline compete with this low-resistance circuit?
- **This circuit now has a three-ohm pipeline (as example) competing with a 0.01-ohm or lower-R copper neutral network in soils. CP goes to the copper, not to pipe coating holidays. You will measure moderate to very negative P/S "On," terrible "instant off" voltages on that pipeline.**

# 2004, TRUCKING FACILITY, EAST SAN ANTONIO, TX, USA

| Step 3 | Rectifier Output | | Sys On | Immed Off | Sys Off | Polariz'n |
|---|---|---|---|---|---|---|
| Taps A 4 | Volts DC | Amps DC | V DC | V DC | V DC | V DC |
| | 10.74 | 6.00 | | | | |
| Tank 1 | | | -0.950 | -0.580 | -0.540 | |
| Tank 2 | | | -0.950 | -0.580 | -0.540 | |
| Tank 3 | | | -0.950 | -0.580 | -0.540 | |
| Tank 4 | | | -0.950 | -0.580 | -0.540 | |
| Tank 5 | | | -0.950 | -0.580 | -0.540 | |
| Tank 6 | | | -0.950 | -0.580 | -0.540 | |
| Tank 7 | | | -0.960 | -0.580 | -0.540 | |


**Seven diesel USTs had CP applied. We cycled rectifier, found copper ground & AC butt ground metal shifting to north, east, southeast. Copper instant-off? Same -0.540 VDC in 1,000-foot reach. Tanks were mixed-metal system.**

# COPPER AND CARBON STEEL IN LARGER FACILITIES


CP survey performed in 2021 at this petroleum terminal, Four Corners area, New Mexico, USA (former refinery).

235 ADC delivered by six different IC CP systems to bulk tank bottoms and on-site buried pipelines. Large copper grounding grid also present at site, and all structures commingled with this grounding.

Surface area comparisons of bulk tank carbon steel to copper are much different in facility, compared to pipelines. Copper may take only 10 to 40 percent of the total CP involved, but the only de-coupling opportunity is at the AC neutral tie-back to regional copper grid (and other services).

Common grounding ALSO to south side structures.

# AT THIS TERMINAL, BULK AST CP NEEDS ARE SIGNIFICANT

Figure 2.0 ma/sf for tank bottoms

| # Tanks | Diam (ft) | Surf Area per Tank | Surf Area (sf) | CP Need (A DC) |
|---|---|---|---|---|
| 1 | 140 | 15394 | 15394 | 30.8 |
| 1 | 110 | 9503 | 9503 | 19.0 |
| 3 | 101 | 8012 | 24036 | 48.1 |
| 2 | 95 | 7088 | 14176 | 28.4 |
| 1 | 92 | 6648 | 6648 | 13.3 |
| 3 | 86 | 5809 | 17426 | 34.9 |
| 5 | 65 | 3318 | 16592 | 33.2 |
| 2 | 44 | 1521 | 3041 | 6.1 |
| 3 | 36 | 1018 | 3054 | 6.1 |
| Total current need | | | 109869 | 219.7 |
| Other assets? | | | | |

At 1.0 ma/sf for tank bottoms

| # Tanks | Diam (ft) | Surf Area per Tank | Surf Area (sf) | CP Need (A DC) |
|---|---|---|---|---|
| 1 | 140 | 15394 | 15394 | 15.4 |
| 1 | 110 | 9503 | 9503 | 9.5 |
| 3 | 101 | 8012 | 24036 | 24.0 |
| 2 | 95 | 7088 | 14176 | 14.2 |
| 1 | 92 | 6648 | 6648 | 6.6 |
| 3 | 86 | 5809 | 17426 | 17.4 |
| 5 | 65 | 3318 | 16592 | 16.6 |
| 2 | 44 | 1521 | 3041 | 3.0 |
| 3 | 36 | 1018 | 3054 | 3.1 |
| Total current need | | | 109869 | 109.9 |

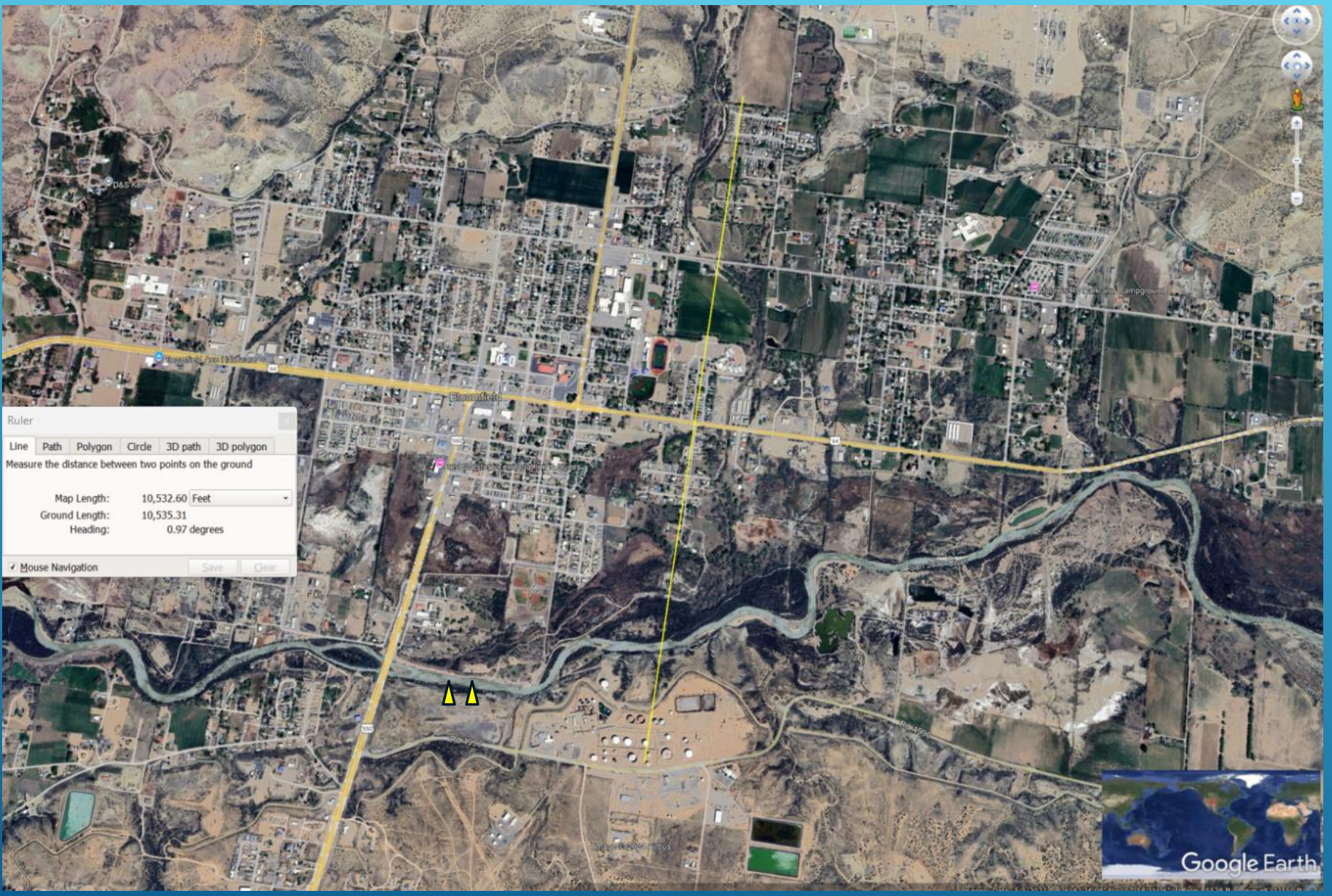
If one mA is good for dry soils, dry containments and tank bottom areas, then copper is taking huge portion of current produced.

**Total of 235 A DC being supplied by six CP systems in 2021. Tank bottoms might be taking 220 A, at 2 mA/sq ft (21/5 mA/sq m).**

**But current demand may be smaller, with tanks only needing 110 A DC (at 1 mA/sf). Very dry region.**

**On-site assets, including copper grounding, and off-site copper AC neutral grid are likely taking the rest.**

# COPPER IN AC NEUTRAL GRID NETWORK?




**Tank bottom metal needs 110 A DC, possibly more. Is it under-protected as mixed metal system?**

**Look at electrical grid density within two miles (3.2 km), mainly to east, north and west. Is on-site and regional copper combination taking a third of available CP? Even half?**

**How to better estimate those copper CP losses? And then, how might we de-couple? Dollars involved?**

# COPPER IN AC NEUTRAL GRID NETWORK?



**Left photo is 2,250 ft (685 m) to west of nearest bulk tank in petroleum terminal.**

**Lower right photo is 1,950 ft (595 m) to west of nearest bulk tank. As one moves closer to on-site assets, the copper structure-to-soil voltage goes more negative. The petroleum terminal is the source of this CP on copper neutral grid in area.**

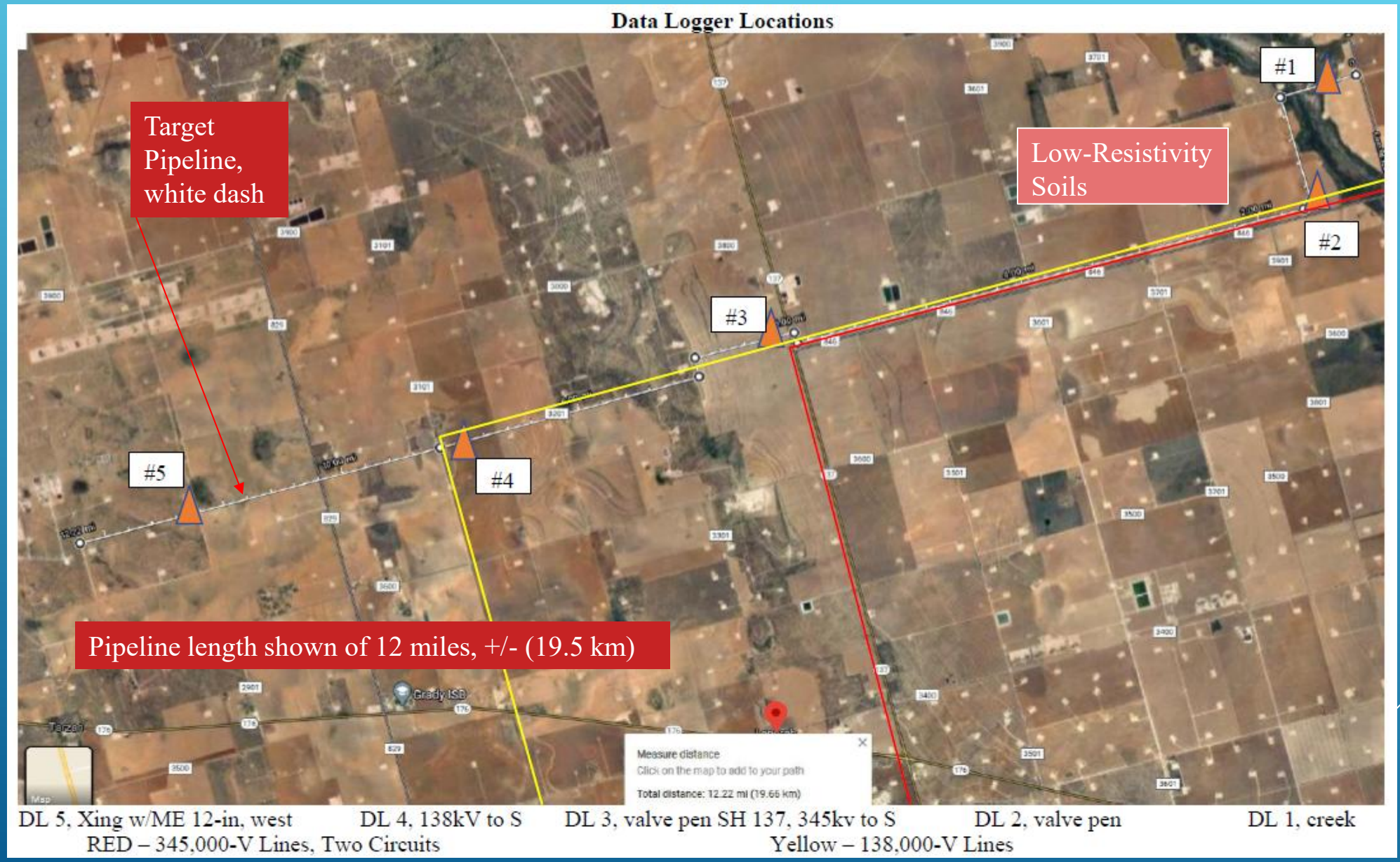
**We had techs there in December 2024 for these measurements.**

# ANOTHER MAJOR CAUTION:

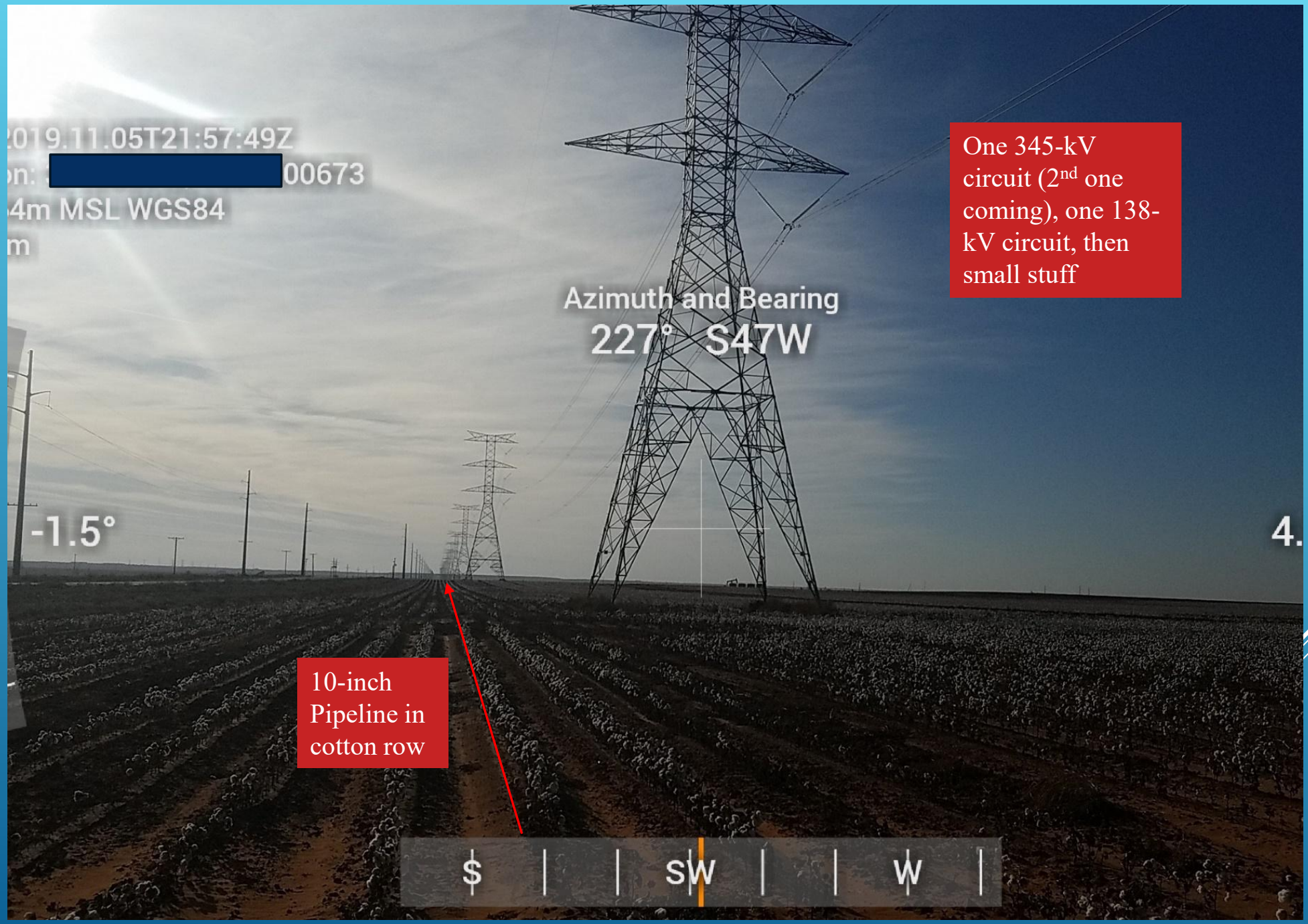
- **What other tie-backs to AC neutral might be present at this terminal? Look for telecommunications coming in – fiber optic and copper phone bundles have electrical grounding tied back to regional AC neutral.**
- **So do radio communications networks, SCADA setups, and other control applications that take data onsite/offsite.**
- **Do you have an external security platform, with cameras, sensors, etc.? That will likely tie to an outside service center, data management location, and is yet another bypass from local grounding to regional neutral grid.**
- **De-couple once? If it works, great! If not, find other ties, and add de-coupling as needed. (Not always easy to track down . . .)**

# WE LOVE DATA LOGGERS AND COUPON SETS.

## FROM CHAPMAN C2021-16611, SALT LAKE CITY NACE:




**New 10-inch (25.4-cm)-diameter pipeline heavily affected by HVAC power lines.**




One 345-kV circuit (2nd one coming), one 138-kV circuit, then small stuff

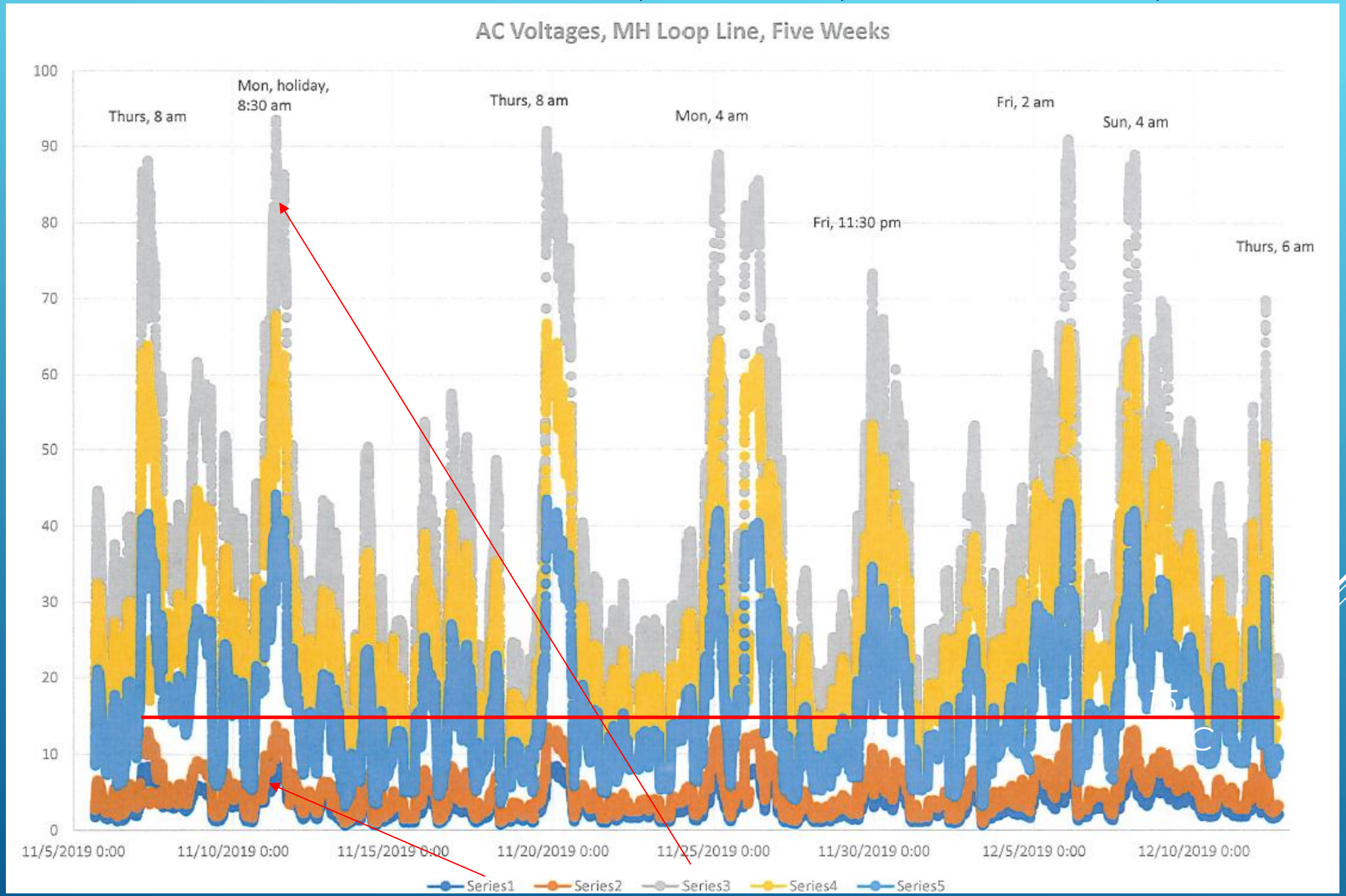
10-inch Pipeline in cotton row

345-kV lines, 138-kV lines and a new 10-inch crude oil pipeline interacting with geography, soils/moisture, geology and chemistry


**Data logger set up to read coupon metal for DC P/S V, AC P/S V, 1x/minute for five weeks.**

**70.8 Volts AC displayed at data-logger.**

# INDUCED AC LINKAGE, CASE #1, WEST TEXAS, USA



# AC NEUTRAL SYSTEM INTERACTIONS

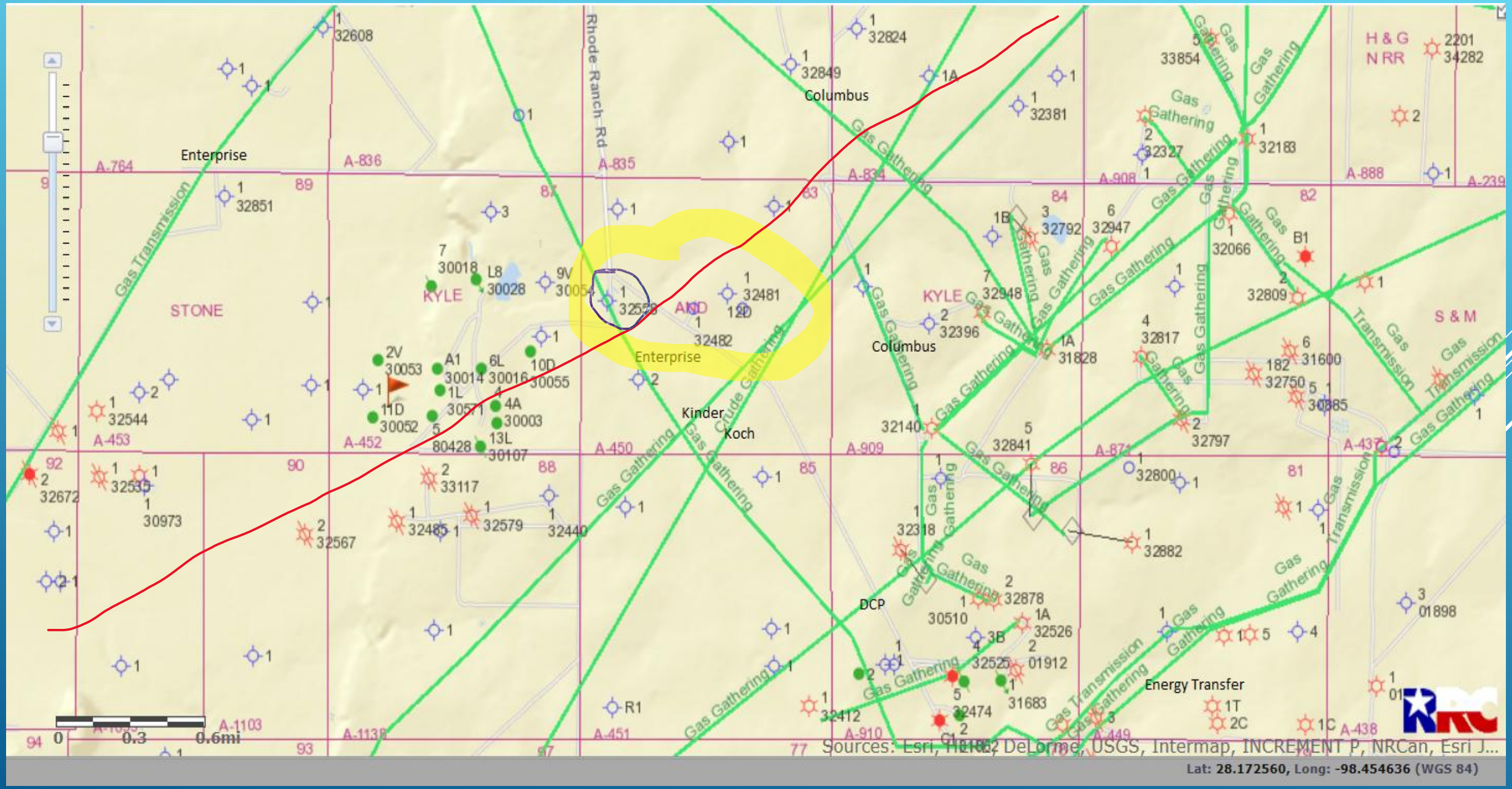
## COPPER GETS PUT ON THE ANODE SIDE OF ICCP SYSTEM!

## THE CHICKEN FARMER'S HUNTING RANCH:

**(Everything about this is BAD!)**

- Winter 2006-2007 – got a call. Gonzales, TX, USA-based chicken farmer bought a hunting ranch in McMullen County, south of Tilden, Texas.
- Buried copper line from propane tank to hunting lodge/small house for kitchen use and heat – he was "smelling propane."
- Water well had gone out, twice in SIX DAYS! This over Christmas Break.
- Pump technician found corrosion pin-holes in stainless steel submersible motor/pump body, both times.

# 300-ACRE (121-HECTARE) RANCH AND A FEW PIPELINES



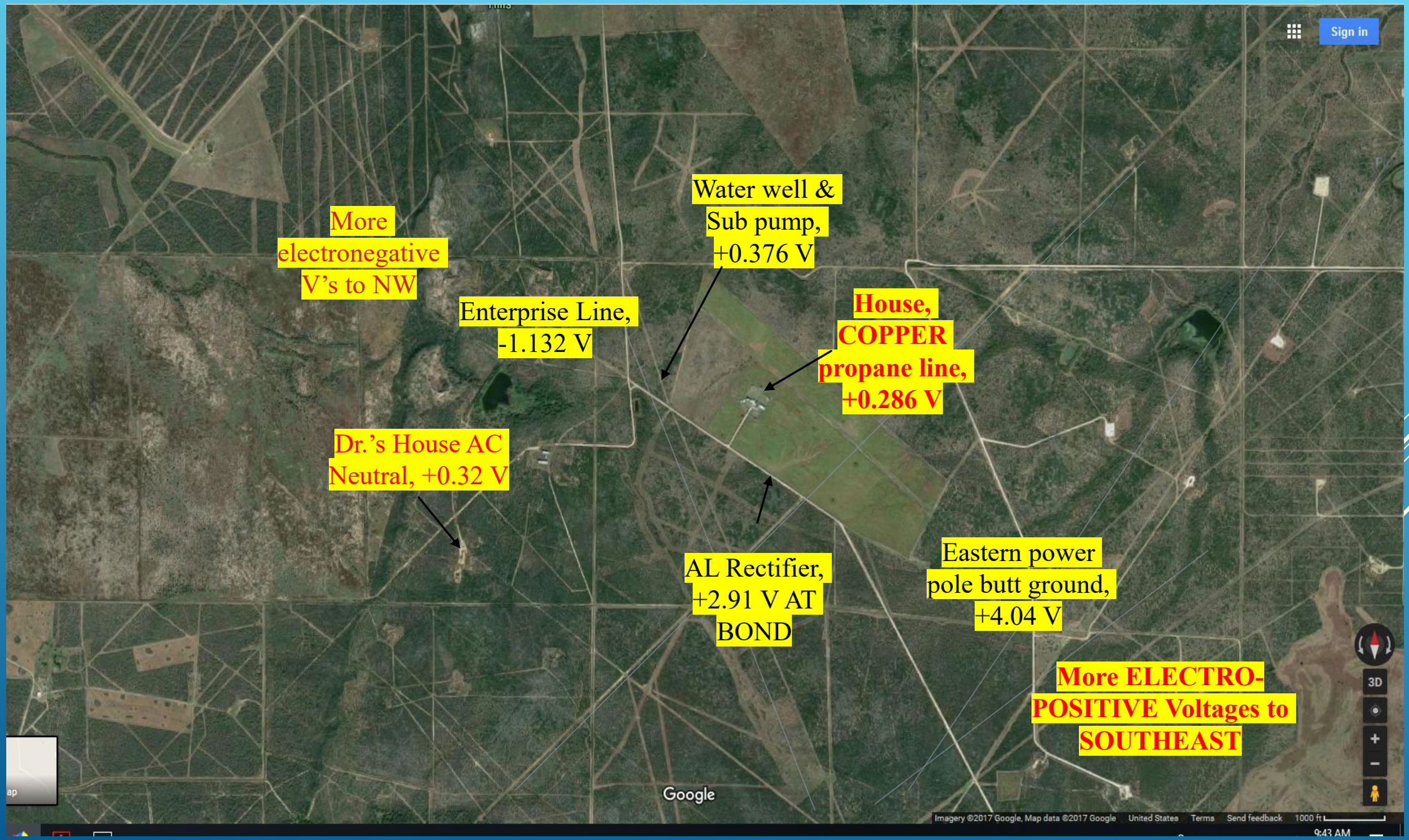
# WATER WELL, ALONG PIPELINE ROW, FEB 2007 VISIT

# "STRAY-CURRENT DC INTERFERENCE"

**February 2007, measurements obtained:**

| | |
|---|---|
| •Main water well casing | -0.581 V structure-to-soil **(grounded effectively)** |
| •Main water well ground wire | **+0.376 V to Cu/$CuSO_4$ ref cell** |
| •Electrical service box neutral wire | **+0.387 V** (at his lodge building) |
| •Utility Pole Guy Anchor (galv steel) near main well | -0.405 V |
| •Steel T-Post 100 feet west of main well | -0.442 V (True native carbon steel?) |
| •Pipeline measurement, Enterprise Products Line | -1.132 V |
| •"Pens" water well casing | -0.599 V (grounded effectively) |
| •"Pens" power pole guy anchor | **-0.260 V** |
| •**"Pens" power pole neutral wire** | **+1.255 V** |
| • **Air Liquide Rectifier Utility Pole neutral wire** | **+2.91 V (this rectifier found "on")** |
| •Eastern-most ranch power pole neutral wire | **+4.04 V** |
| •Eastern-most power pole guy anchor | -0.349 V |
| •House **copper water line** in soil contact | **+0.288** V |
| •House electric service neutral wire at ground rod | +0.290 V |
| •**House copper line for propane buried in soil** | **+0.286 V** |
| •House power pole guy anchor (to west) | -0.320 V |
| •Dr. Bridges property power pole neutral wire (to W) | +0.320 V |
| •Dr. Bridges house service pole guy anchor (to W) | +0.120 V |

# 300-ACRE RANCH AND "INTERFERENCE PATTERN"



# WHAT'S THE PATTERN?
# WHAT'S THE CIRCUIT?!

- AC neutral wire butt ground runs are almost all very positive to half-cell (native copper should be -0.1 V);
- Going west and northwest, less positive;
- Going south and southeast, more positive. So we got three pipeline techs, Electric Coop rep, all started driving pipeline rights-of-way, opening locks and gates, and measuring;
- Got about four miles (6.5 km) to southeast. Found rectifier we could access.

# WHAT DID WE FIND?

# WHAT'S THE PATTERN?

- **+4.8 VDC on rectifier case!**
- Found the unlocked power cut-off box. Killed the switch. Case went to 0 VDC, immediately.
- All local copper butt grounds INSTANTLY went to -0.1 VDC to reference cell.
- Called the company contact phone number. Pipeline Corrosion Tech said, "I'll be out in a couple days."
- We made an appointment. Two days later, trampled grass, rectifier POWER OFF inside cabinet (0 volts DC still on case!), but no tech showed up for us!
- And no further communication ever had . . .

# HOW MUCH DC CURRENT WILL COPPER TAKE, COMPARED TO CARBON STEEL?

- In 2019 study, Midland, Texas area, CP data on carbon steel pipeline network versus copper AC neutral butt grounds suggested copper was taking half the available CP amperage, if not more.
- In test bed built by our company, bare copper cable took 13.5 mA per square foot of CP current, compared to 1.0 mA per sf for carbon steel. Copper polarized one-seventh as effectively as the carbon steel, even though massive current density delivered to it!
- Copper is taking more than 90 percent of available CP current in this small set of test bed circuits.

# LAST DISSIMILAR-METAL STORY

416 Stainless Steel Pipe String showed aggressive external corrosion after three years in use. Artesian water flow, no pumping. Through-wall holes in multiple locations.

# No outside DC or AC power sources identified.

**Copper Grounding Conductors on Enclosure Racks Tied to Dedicated Copper Ground Ring Around Wellhead.**

**416 SS was not rated for water-submerged service, depassivated and suffered aggressive attack.**

| Test | Current Flow from Pipe to Cu thru Electrolyte (A DC) | Potential Changes at Well Piping (V DC) | Remarks |
|---|---|---|---|
| 1 | **1.70** | **-0.167** | Southern Ground then Disconnected; **Mixed-metal V seen** |
| 2 | 0.91 | -0.237 | South Central Ground Disconnected |
| 3 | 0.46 | -0.335 | North Central Ground Disconnected |
| 4 | 0.04 | -0.670 | Northern Ground Disconnected; **V now resembles native steel** |

**Copper system bonded to exposed steel. (How extensive a copper system? On-site grounds, regional AC neutral all involved.)**

**Electrochemical battery of approximately 0.2 volt DC. Current flow of 1.7 A DC. Resistance of about 0.11 ohm. This dissimilar-metal corrosion would continue for how long?**

KEEPING PRODUCT ON THE INSIDE AND FLOWING TO CUSTOMERS. THAT'S A GOOD THING.

***To TAKE CARE OF YOUR ASSETS calls for Continuous Improvement.***

***Get good data! Study it.***

***APPLY LESSONS LEARNED.***

Thanks.

800 - 375 - 7747
www.chapman.engineering