COPPER GROUNDING CORROSION OF STEEL PIPE IN POWER PLANTS

Typical Gas Fired Power Plant

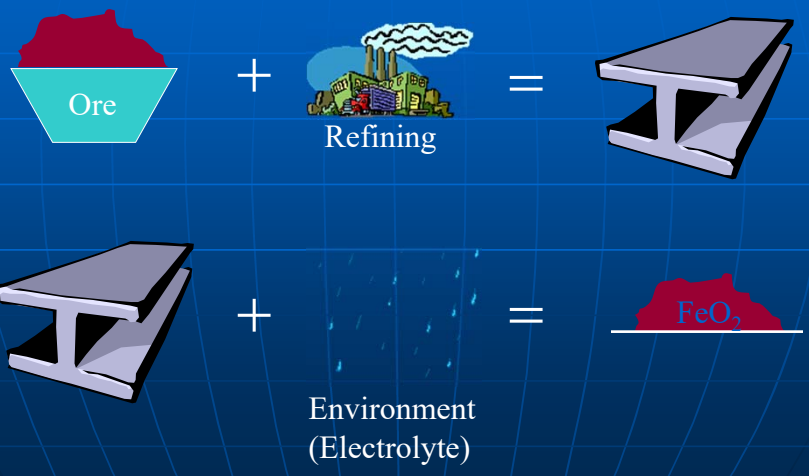
Piping Systems, Ground Wires, Rebar and Conduits Going Everywhere

Piping, Cables and Conduits

POWER PLANT COPPER GROUND GRID CORROSION QUESTIONS TO DISCUSS

- 1. Are Copper Ground Grids Installed for Personnel Safety Purposes? Older plants do not have ground grids.
- 2. Do copper ground grids cause bi-metallic corrosion on steel piping and tanks?
- 3. Which is better, grounded or isolated cathodic protection designs
- 4. How do we verify that full cathodic protection levels have been achieved?
- 5. Do most people really understand how copper affects cathodic protection of steel?

What is Corrosion?
Basic Common Corrosion

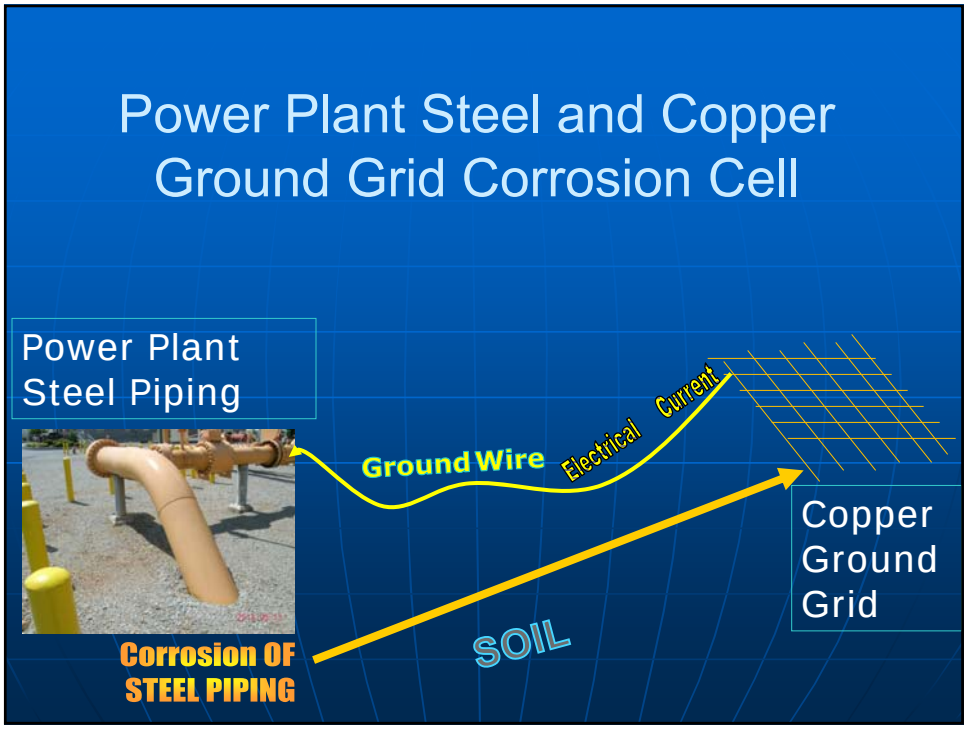


Challenge #1
External Underground Bimetallic Corrosion

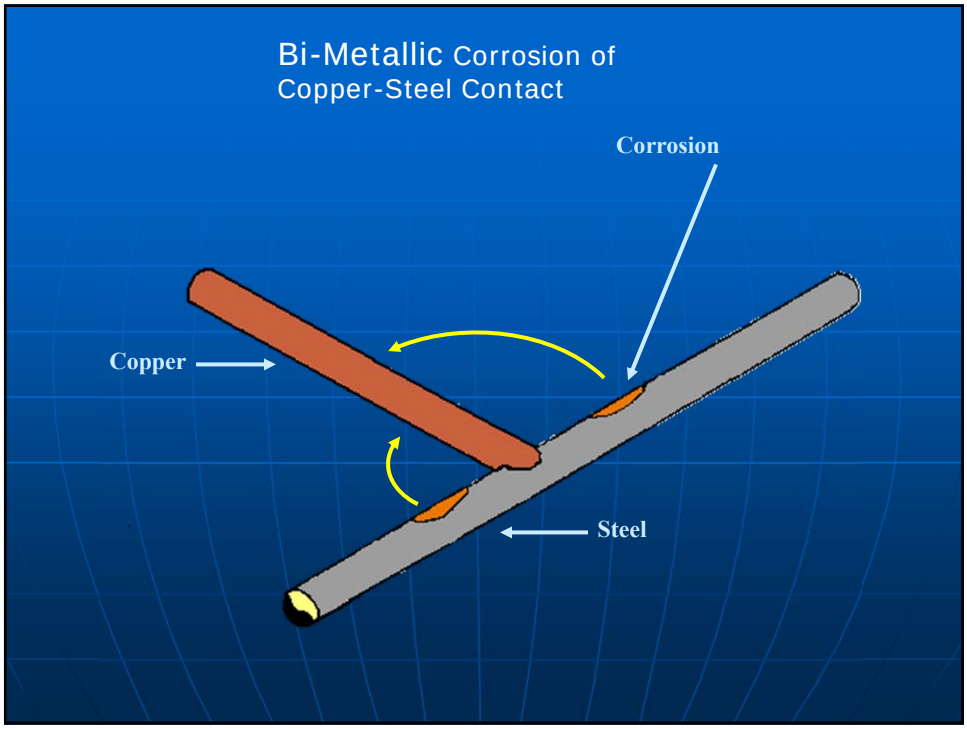
- Three necessary components bimetallic corrosion are:
  - Metal Steel Pipe Surface
  - Copper Grounding Grids
  - Metal Copper Ground Wires or Contact between Copper and Steel
  - Soil or Water Environment

  (where ions can exchange with the environment)

Power Plant Steel and Copper Ground Grid Corrosion Cell



Bi-Metallic Corrosion of Copper-Steel Contact



Electrochemical Series

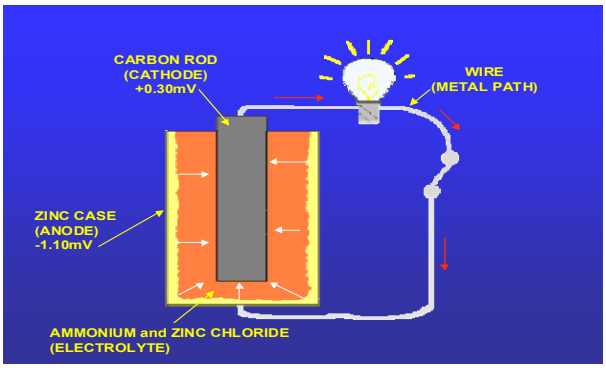
Material	Voltage	
•Magnesium	-1.6	More Active
•Zinc	-1.1	
•Steel	-.5	
•Copper	0	
•Cast iron	+.1	
•Steel in concrete	+.1	
•Silver	+.2	
•Gold	+.2	
•Carbon	+.4	More Noble

•Flashlight Battery – Zinc (-1.1V) to Carbon (+.4V)=1.5 Volts Corrosion Power

•Power Plant – Steel pipe (-.5V) to Copper (0 V)= .5 Volts Corrosion Power

Battery Corrosion cell

Dry Cell Battery



Criteria Questions for Copper-Steel Couplings

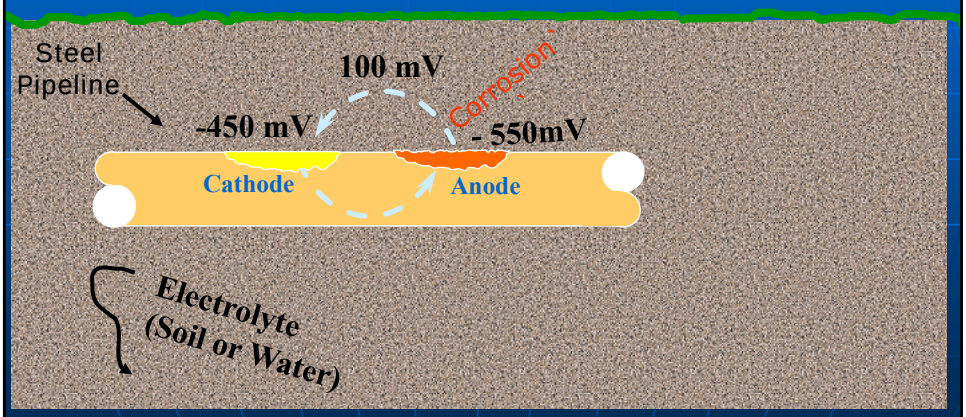
Are corrosion protection criteria for steel also good for copper pipe?

When you have a bimetallic copper-steel coupling which metal do you test?

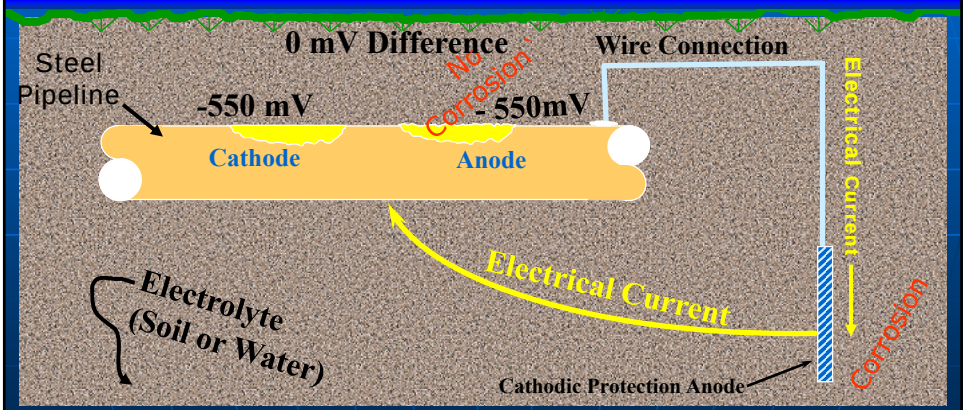
Where did criteria come from?

Holy Book? Clay tablets from a cave? Top secret Russian testing? Laboratory Testing? Field experience?

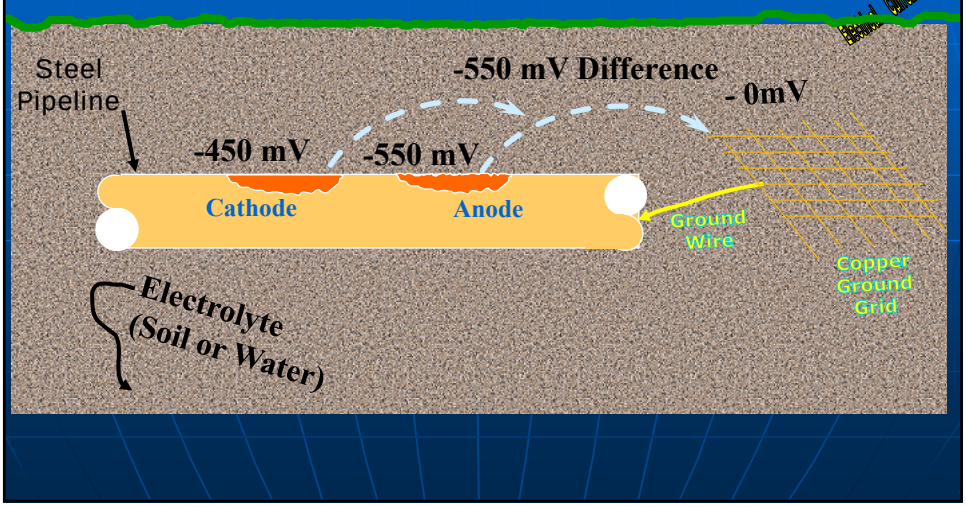
Basis for NACE-AMPP 100 mV Shift Criteria
Corrosion activity is started by voltage differences on the surface of the metal caused by changes in moisture, temperature, soil type, heat, etc. Maximum difference is assumed to be no more than 100 mV for steel.



Cathodic Protection – All Natural Corrosion of the Metal Will Cease Once the Applied Cathodic Protection Current Equals the Corrosion Current



Copper Ground Grid Will Increase the Original 100 mv Shift to 550 mV Required to Stop Corrosion and a Lot More Anode Current



NACE INTERNATIONAL

NACE SP0169-2007
(formerly RP0169-2002)
Item No. 21001

Standard Practice

Control of External Corrosion on Underground or Submerged Metallic Piping Systems

6.2.2 Steel and Cast Iron Piping

6.2.2.1 External corrosion control can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of specific data that demonstrate that adequate CP has been achieved, one or more of the following shall apply:

6.2.2.1.1 A negative (cathodic) potential of at least 850 mV with the CP applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement.

6.2.2.1.3 A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.

Add Copper to the Steel

6.2.4 Copper Piping

6.2.4.1 The following criterion shall apply: a minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of this polarization can be used in this criterion.

6.2.5 Dissimilar Metal Piping

6.2.5.1 A negative voltage between all pipe surfaces and a stable reference electrode contacting the electrolyte equal to that required for the protection of the most anodic metal should be maintained.

My Personal Test- Steel Pipe, Copper Pipe, Magnesium Anodes. All Sanded and Shiny for Maximum output

Test Area Water is 13,000 ohm-cm resistivity. Melted snow water from Sierra Nevada irrigation canal

Test Area

Magnesium Anoode Cathodic Protection Test of Copper and Steel Grounded Piping System

No Anode Current - Bond Copper to Steel							
	Native (-mV)	Off (-mV)	On (-mV)	Off/On Shift (mV)	Off/Native Shift (mV)	Current in Wire Bond (A)	Direction
Copper	84	122	280	158	38	0.004	From Copper
Steel	551	534	480	-54	-17	0.004	To Steel
Conclusion: When bonded together, steel becomes the anode to the copper and steel pipe is corroding more rapidly than if it was electrically isolated and not bonded to copper							

Magnesium Anode Cathodic Protection Test of Copper and Steel Grounded Piping System

Small amount of current applied with magnesium anodes								
	Native (-mV)	Off (-mV)	On (-mV)	Off/On Shift (mV)	Off/Native Shift (mV)	Current in Wire Bond (A)	Direction	% current
Copper	84	420	635	215	336	0.020	From Copper	83
Steel	551	570	828	258	19	0.004	From Steel	17
Magnesium	1703					0.024	To Mag Anodes	100

Conclusion: Most - 83% of the cathodic protection current is going to the copper because it is a lower resistance metal (20 x as conductive) and has a greater driving difference in potential from the anode. 1703-551=1152 mV for Steel and 1703-84=1609 mV for copper

Impressed Current Cathodic Protection Test of Copper and Steel Grounded Piping System

Larger amount of current applied with battery and magnesium anodes	Native (-mV)	Off (-mV)	On (-mV)	Off/On Shift (mV)	Off/Native Shift (mV)	Current in Wire Bond (A)	Direction	% current
Copper	84	908	3439	2531	824	0.124	From Copper	58
Steel	551	943	3400	2457	392	0.091	From Steel	42
Magnesium	1703					0.215	To Mag Anodes	100

Conclusions:

1. Steel and copper are becoming polarized and copper is taking a less current (58% now vs 83% before) of cathodic protection current as the polarized potential of steel and copper become more equal.
2. The "off" potential of the copper must be brought up to the same level as the steel for full cathodic protection based the logic of NACE/AMP Standard RP0169. That would be a 500 mV shift from off to native. The results are 824 mV shift for copper or almost 500 mv. 392 shift mV of the steel is close to full protection for the steel but still not 500 mV if that criteria is used.
3. If 850 is used as the criteria then both metals make it both "Off and "On"

Power Plant Corrosion Grounded Structure Congestion - What is ratio of concrete coated steel and copper to gas steel pipe? 1000:1 ratio?

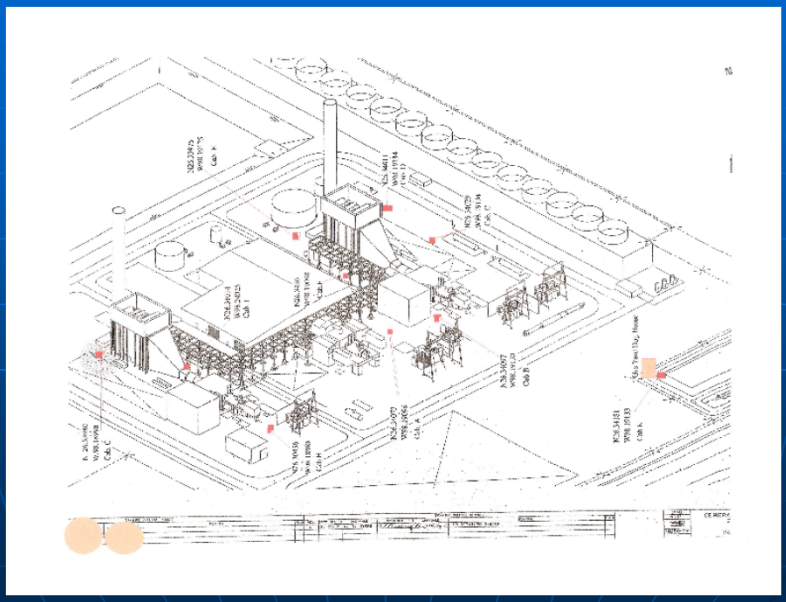
Electrochemical Series

•Material	Voltage	
•Steel	-.5	More Active
•Copper	0	
•Steel in concrete	+.1	More Noble

•Basic Corrosion Mechanism is that all voltage/potential differences must be eliminated.

•Copper must be brought up to the voltage potential of steel which would be a .5 volt (500 mV) shift for copper and volt .6 (600 mV for steel in concrete.

10 each 40 Amp Rectifiers in this Power Plant



Corrosion on the Incoming Pipelines from Copper Grounding

Gas Transmission Pipeline
Copper Grounding Bi-Metallic Corrosion

- Two years of bi-metallic external corrosion with CP. 16” .344 wall pipe, .047 loss = 14%

Power Plant Corrosion
Plant Outage and Gas Leak

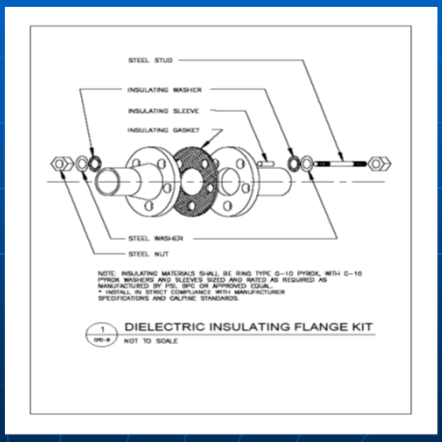
- 8 years of bi-metallic corrosion – Power plant fuel gas piping. - 12” .408” wall pipe

Short Gas Pipelines Across Driveways May Be Overlooked among Other grounded Piping, Conduits and Structures

Power Plant Corrosion
Gas Leak And Plant Outage

- 10 years of bi-metallic external corrosion – power plant fuel gas piping. – 4" .237 wall pipe

Insulating Flange Kit at all Cathodically Protected Pipe Risers



Electrical Isolation of Buried Piping from Copper Grounding May Reduce Corrosion Rate by 90% Even without Cathodic Protection

Thoughts about Copper Grounding

- Irony of Design: A copper ground grid installed for personal safety from electrical hazards becomes a battery powered corrosion cell that increases possibility of leaks of hazardous materials like natural gas, ammonia, hydrogen and fuel oil.
- In a vast maze of pipes, conduits, copper cables and rebar with high amp output from multiple rectifiers, where do you measure the potential?
- Some people recommend using coupons for verification but where do you put them with current fields going in many directions?
- To verify a 100 mV criteria, the current has to be interrupted and then it reverses during interruption. How do you measure instant "off" during a current reversal? Native values in a bimetallic coupling are not valid.
- In my Opinion, Cathodic protection of non-isolated steel piping in power plants is not verifiable and may not be possible. Steel piping must be electrically isolated for to stop all corrosion.

Piping Systems To Receive Corrosion Protection By Priority - Cannot Protect Everything

- **Safety: Fuel Gas, Ammonia, Hydrogen – Protect at any cost**
- **Reliability: Cooling water, Instrument air – Cost effectiveness**
- **Environmental Liability: Aboveground Diesel storage tanks, Underground Storage STP-3 Tanks, Diesel piping.**
- **Other Systems: Raw water and demin tanks, water top off piping, gravity drains, boiler blow down.**

Conclusions from Experience

- The dominant corrosion mechanism on grounded steel piping in power plants is corrosion accelerated by copper ground grid bi-metallic coupling.
- Copper is 20 X more electrically conductive than steel and will conduct more cathodic protection current.
- The ratio of concrete coating and copper to steel pipe is very high in the power plant and will greatly increase corrosion on the steel piping.
- Coating defects can focus the corrosion on a small area of the coated steel pipe surface and cause leaks in a short period of time. Ratio of copper to Steel is even greater if steel pipes are coated.

The End

- Questions?