Cathodic Protection Technician Level 2 Theory Exam

Exam Preparation Guide

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Introduction

The Cathodic Protection Technician (CP 2) Theory Exam is designed to assess whether a candidate has the requisite knowledge and skills that a minimally qualified Cathodic Protection Technician must possess. The exam consists of 89 multiple-choice questions covering intermediate and basic areas of the Cathodic Protection Body of Knowledge (BOK). A candidate should have intermediate-level knowledge of corrosion theory, CP concepts, types of CP systems, and advanced field measurement techniques.

Test Name	AMPP CP 2 – Cathodic Protection Technician – Theory Exam
Test Code	NACE-CP2-001
Time	2 ½ hours*
Number of Questions	89
Format	Computer Based Testing (CBT)

*Exam time includes 4 minutes for the non-disclosure agreement and 6 minutes for the system tutorial.

Note:

- A pass/fail grade is provided at the end of the exam.
- The course manual is NOT provided during the exam.
- Reference material is provided as a PDF for questions that require an equation, conversion chart, or other reference.

Target Audience

Candidates for Cathodic Protection Technician (CP 2) should ideally have several years of CP field experience and possess intermediate-level knowledge of corrosion theory, CP concepts, the types of CP systems in common use, and be competent with basic rectifier diagnostics, as well as intermediate field measurement techniques and equipment. CP Technician candidates could also be practicing technicians or engineers with a more modest level of CP experience, but with more significant relevant technical education.

Typically, Cathodic Protection Technicians are responsible for testing and maintaining the effectiveness of operating CP systems and supervising or assisting with the installation of CP systems. This includes troubleshooting, identifying interference conditions, performing over-the-line surveys, and evaluating the results obtained.

Requirements

Cathodic Protection Technician (CP 2)

- Prerequisite + Work Experience + 2 Core Exams + Application

The following prerequisite is required:
Successful completion of Cathodic Protection Tester (CP 1), or equivalent training
Work Experience
Choose one of the following work experience options:
3 years verifiable CP work experience
2 years verifiable CP work experience **AND** 2 years post high school training from approved math / science or technical / trade school
1 year verifiable CP work experience **AND** 4-year physical science or engineering degree
Core Exam Requirements:
The following exams are required: (2 core exams required)
Cathodic Protection Technician (CP 2) Practical Exam (hands-on) Cathodic Protection Technician (CP 2) Theory Exam (multiple choice, closed-book, with relevant references)
Application Requirement:
Approved Cathodic Protection Technician (CP 2) application

Upon successful completion of requirements, the candidate will be awarded a Cathodic Protection Technician (CP 2) Certification.

Note:

- Completion of the course does not entitle the candidate to the certification.
- The Cathodic Protection Technician (CP 2) Practical Exam is given at the conclusion of the Cathodic Protection Technician (CP 2) course.

Next Level of Certification:

Cathodic Protection Technologist (CP 3)

CP 2 – Knowledge and Skill Areas Tested

NOTE: At the end of the CBT exam, the candidate will receive a bar chart of strengths and weaknesses that correspond to these domains.

1. **Corrosion Theory**

    1.1 Theory of Electrochemistry

    - 1.1.1 Identify the parts of the corrosion cell and electrochemical reactions
    - 1.1.2 Understand the electrochemical reaction leading to corrosion and the primary reactions at the anode surface
    - 1.1.3 Understand Evans' diagram
    - 1.1.4 Understand different forms of corrosion
    - 1.1.5 Understand electrolyte resistivity and pH, and how they affect the corrosivity of an electrolyte
    - 1.1.6 Understand the Nernst equation
    - 1.1.7 Understand Faraday's Law and how it predicts corrosion weight loss
    - 1.1.8 Understand the polarizing and depolarizing effects
    - 1.1.9 Understand activation and concentration polarization
    - 1.1.10 Understand polarization curves in aerated and deaerated solutions
    - 1.1.11 Understand E log I relationship
    - 1.1.12 Understand the effect of electrolyte/electrode movement on polarization
    - 1.1.13 Understand the electrolyte concentration effect
    - 1.1.14 Understand the effect of changing the concentration of cathodic reactants
    - 1.1.15 Understand the difference between passive-acting and nonpassive-acting

    1.2 CP Theory & Application

    - 1.2.1 Understand how to use reference electrodes to measure the potential of a metal surface
    - 1.2.2 Understand the economic benefits of CP
    - 1.2.3 Understand the usage of portable and stationary reference electrodes
    - 1.2.4 Apply cathodic protection current to reduce the potential difference between anodic and cathodic sites
    - 1.2.5 Understand series, parallel, and series-parallel electrical circuits
    - 1.2.6 Restate the definition of structure-to-electrolyte potential

1.2.7 Calculate reference cell conversions

1.2.8 Understand the relationship between CP current and corrosion rate

1.2.9 Understand the relationship between environmental polarization and cathodic protection

1.2.10 Understand the environmental issues and concerns related to deep-anode CP systems

1.2.11 Explain the components of galvanic cathodic protection

1.2.12 Recognize the effect of CP on amphoteric metals

1.2.13 Explain the components of impressed current cathodic protection

1.2.14 Explain the application of impressed current cathodic protection

1.2.15 Calculate corrosion rate using Faraday's Law

1.2.16 Explain different types of impressed current cathodic protection systems

1.2.17 Understand applications of different types of galvanic anodes

1.2.18 Understand the importance of anode configurations for cathodic protection

1.2.19 Understand the effect of cathodic protection on reinforced concrete structures

1.3 Influencing Factors

1.3.1 Recognize examples of depolarizers

1.3.2 Understand the effect of temperature on current required for cathodic protection

1.3.3 Understand the effect of oxygen on current required for cathodic protection

1.3.4 Understand the effect of relative movement on current required for cathodic protection

1.3.5 Understand the effect of electrolyte resistivity

1.3.6 Describe stray current interference

1.3.7 Understand how stray current enters the pipe or other structure through the soil

1.3.8 Understand static and dynamic interference current

1.3.9 Understand inductive, conductive, and capacitive coupling

1.3.10 Compare and contrast AC voltage-to-ground with a DC structure-to-electrolyte potential

1.3.11 Recognize the effect of shielding and how it affects cathodically protected structures

2. **Equipment and Equipment Management**

2.1 Equipment and Equipment Management

2.1.1 Perform basic equipment maintenance and repair

2.1.2 Recognize meter impedance requirements and select the appropriate meter

2.1.3 Understand how to use an ammeter, a clamp-on ammeter, and a current shunt in the field

2.1.4 Confirm proper operation and calibration of equipment, and troubleshoot if necessary

2.1.5 Maintain portable reference electrodes

2.1.6 Understand the importance of equipment preparation, storage, consumables, and equipment spares

2.1.7 Know how to use a digital multimeter (DMM) to measure voltage, current, and resistance

2.1.8 Determine the appropriate tools and equipment for the project

2.1.9 Identify and correct IR drop errors in the measurement circuit

2.1.10 Consult with equipment and material manufacturers and/or representatives on applications and technical issues

2.1.11 Select the appropriate reference cell for work conditions

2.1.12 Identify issues with polarity sensitive current interrupters

2.1.13 Assist in the evaluation of new equipment, products, and procedures

3. **Field Measurements of CP Systems**

3.1 Survey Methods

3.1.1 Understand the use of survey methods to measure the effectiveness of cathodic protection

3.1.2 Measure current using an ammeter

3.1.3 Perform measurement of CP coupons and use ER probes

3.1.4 Understand how to minimize reference electrode contact resistance in different types of electrolytes

3.1.5 Understand what causes a voltage drop in an electrically long structure

3.1.6 Understand reference electrode placement relative to cathodic protection current, and its effect on the potential measurement

3.1.7 Describe typical test methods to measure structure-to-electrolyte potentials

3.1.8 Understand the purpose, limitations, and procedures of "on" and "on-off" potential surveys.

3.1.9 Understand the purpose and limitations of a close-interval potential survey (CIPS), and perform the technique

3.1.10 Understand the purpose and limitations of a direct-current voltage gradient (DCVG) survey, and perform the technique

3.1.11 Understand the purpose and limitations of an alternating-current voltage gradient (ACVG) survey, and perform the technique

3.1.12 Understand the purpose and limitations of an alternating-current-current attenuation (ACCA) survey, and perform the technique

3.1.13 Understand the procedures used in offshore close-interval potential surveys (CIPS) using contact measurements

3.1.14 Perform current requirement tests for cathodic protection

3.1.15 Understand the purpose and limitations of using the current response test

3.1.16 Understand the purpose and limitations of the voltage-drop method

3.1.17 Understand the purpose and limitations of the current span test

3.1.18 Understand the purpose and limitations of coating conductance test

3.1.19 Perform multiple tests of soil resistivity such as the Wenner method

3.1.20 Recognize the methods used to locate an electrical isolating device and test to determine if it is functioning properly

3.1.21 List different ways of measuring electrolyte pH

3.2 Casings

3.2.1 Understand the purposes of casings

3.2.2 Understand structure-to-electrolyte potentials at casings

3.2.3 Understand what isolated and shorted casings are as well as their pros and cons

3.2.4 Understand the different environments that exist in the annular space between the casing and the pipe

3.2.5 Demonstrate the protection methods to protect the pipe inside the casing.

3.3 Interference

3.3.1 Detect static interference current by using a combination of multiple test methods

3.3.2 Understand how to detect dynamic stray currents by measuring potential differences

3.3.3 Understand the difficulties related to finding the source of a stray current

3.3.4 List specific techniques to resolve interference problems

3.3.5 Understand how to control the direction of stray currents through the bond

3.3.6 Understand how to control stray current through cathodic protection

3.3.7 Understand methods to detect AC currents and voltage that appear on metallic structures near AC power lines

3.3.8 Understand AC mitigation methods

4. **ICCP Power Sources**

4.1 ICCP Power Sources

4.1.1 Understand different types of DC power sources and rectifiers

4.1.2 Understand proper safety procedures for rectifiers

4.1.3 Understand how to read the schematic of DC power sources

4.1.4 Understand three common rectifier operation modes

4.1.5 Understand the purpose of transformers

4.1.6 Understand how the rectifier can convert AC to DC voltage

4.1.7 Identify different types of rectifying elements

4.1.8 Understand how different types of circuit breakers are used

4.1.9 Understand the different components of operational rectifiers, such as surge/transient protection

4.1.10 Understand the basic structure of solar-power supply systems and how to maintain them

4.1.11 Compute rectifier efficiency

4.1.12 Perform troubleshooting operations of internal components of transformer rectifiers

5. **Field Data Interpretation and Documentation**

5.1 Field Data Interpretation and Documentation

5.1.1 List information needed to be compiled before a field survey

5.1.2 Interpret alignment sheets, facility maps, and other system maps to identify accurate testing locations

5.1.3 Evaluate different data collection methods for documentation

5.1.4 Demonstrate the importance of documentation, communication, and procedures regarding equipment and troubleshooting.

5.1.5 Understand the importance of various monitoring requirements and data components that need to be recorded regularly

5.1.6 Prepare adequate documentation/illustration depicting CP components and completed fieldwork

5.1.7 Understand the importance of an appropriate inspection plan

5.1.8 Document name, model, and serial numbers of exact instruments used for readings

5.1.9 Document site information (such as date, time, weather, sketch of site, photos, location information) and conditions (such as ground moisture, vegetation, hazards)

5.1.10 Demonstrate accurate representation of polarity, magnitude, significant figures, and unit of measure on field data

5.1.11 Document key activities and findings in logbook, diary, and notes

5.1.12 Document and justify technical deviations from the procedures

5.1.13 Document non-standard test stations, and any other abnormal conditions/factors that could affect CP systems

5.1.14 Understand the importance of indirect inspection documentation in relation to the external-corrosion direct assessment (ECDA) process

5.1.15 Certify the accuracy of all data collected and recorded

5.1.16 Analyze ON/OFF potential measurements and polarity, and identify reverse shifts

5.1.17 Calculate and analyze layer resistivity

6. **Field Supervision and Installation**

6.1 Field Supervision and Installation

6.1.1 Provide CP-related support for scheduling, work plan/progress, and production

6.1.2 Provide CP-related expertise during the installation and field operations

6.1.3 Coordinate with senior CP staff to ensure quality and resolve the on-site deficiencies

6.1.4 Provide technical supervision during CP-related installation and field operations

6.1.5 Support company personnel and non-company personnel in aspects of corrosion control

6.1.6 Inspect and verify received CP-related materials according to the Bill of Materials

6.1.7 Maintain and manage stock of consumables and spares

6.1.8 Identify, evaluate, and select relevant components and installation materials

6.1.9 Perform installation of test stations, bonds, anodes, and CP components according to the correct procedures

7. **Industry Practices/Requirements**

7.1 Industry Practices/Requirements

7.1.1 Identify and apply relevant company, local, domestic, and international standard practices related to CP

7.1.2 Identify and apply relevant local, domestic, and international rules, codes, and regulations related to CP

7.1.3 Understand cathodic protection criteria for different materials, such as aluminum, copper, and concrete structures

7.1.4 Understand the technical importance of accurate and precision recordkeeping

7.1.5 Understand the purpose and which records shall be maintained for technical, historical, and legal requirements

7.1.6 Understand the legal implication of accurate and ethical recordkeeping

8. **Safety**

8.1 Safety

8.1.1 Demonstrate and enforce safe working practices

8.1.2 Perform job safety analysis (JSA)

8.1.3 Comply with the company's/client's safety procedures

8.1.4 Understand the role of the safety officer

8.1.5 Identify and mitigate hazards that can be encountered in cathodic protection testing and inspection

8.1.6 Understand safety issues related to the CP field surveys

8.1.7 Recognize the importance of stop-work and apply protective measures against severe weather and environmental hazards

8.1.8 Understand the importance of communicating personal medical conditions (e.g., pacemaker)

8.1.9 Utilize appropriate PPE and site-specific safety equipment

8.1.10 Understand the importance of tasks per site-specific safety training (e.g., coal plants, H2S environments, gas production facilities, explosive environments, radioactive environments, confined spaces/trenches, heights/fall protection)

8.1.11 Acquire the permit and authorization to work

8.1.12 Identify hazardous materials

8.1.13 Follow SDS recommendations for handling disposals

8.1.14 Understand how lockout/tagout (LOTO) is used to ensure safety

8.1.15 Identify and mitigate workplace hazards encountered while working on electrical equipment

8.1.16 Interpret pipe/soil for indications of high AC voltage which may lead to corrosion or safety issues

8.1.17 Identify the risk associated with high voltage gradient with respect to step and touch potential

8.1.18 Apply all safety guidelines when traveling in a vehicle (e.g., wearing a seat belt in a car, wearing a seat belt and ear protection in a helicopter)

8.1.19 Understand the purpose of proper certification/training for all equipment (e.g., ATV/UTV/winch, loading/unloading)

8.1.20 Recognize special equipment for protection from wildlife (e.g., signal device, pepper spray), hazardous plants, and insects, and take appropriate preventative measures

Types of Questions

Description of Questions

This closed-book exam consists of multiple-choice questions where some questions may have multiple answers that require more than one answer choice, as well as matching items. The questions are based on the knowledge and skills required in the CP industry for a Cathodic Protection Technician. While the training course is an excellent method of preparation, it is not the only reference used in the development of the questions. Additional references can be found in the Reference section.

Sample Questions

The sample questions are included to illustrate the formats and types of questions that will be on the exam. Your performance on the sample questions should not be viewed as a predictor of your performance on the actual test.

1. What is the current in a 91 m (300 ft) span of 762 mm (30 in) pipe weighing 176.65 kg/m (118.7 lb/ft), if the voltage drop across that span is 0.62 mV?

   A. 0.850 A

   B. 1.176 A

   C. 2.802 A

   D. 2.585 A

2. What is the pipe-to-earth resistance of a 3 km (1.86 mi) section of 32 cm (12.75 in) diameter pipe that has a 4-wire current span at each end with the following data?

Eon TS1 = -1320 mV	Eon TS2 = -1240 mV
Eoff TS1 = -1000 mV	Eoff TS2 = -1080 mV
Ion TS1 = 3.0 A	Ion TS2 = 2.6 A
Ioff TS1 = 1.0 A	Ioff TS2 = 1.0 A

   A. 0.052 Ω

   B. 0.076 Ω

   C. 0.15 Ω

   D. 0.60Ω

3. When an ammeter with an internal resistance of 0.15 Ω is inserted into a circuit that is normally operating at 5 V and 20 A, what will the ammeter current read?

   A. 0.08 A

   B. 10 A

   C. 12.5 A

   D. 50 A

Answer Key

1. **A**
2. **D**
3. **C**

Preparation

Training—None Required

AMPP Cathodic Protection Technician – CP 2 Course (Available)

AMPP Cathodic Protection Tester – CP 1 Course (Available)

Recommended Study Material

Books

Peabody, A. W. (2001). *Peabody's Control of Pipeline Corrosion* (No. Ed. 2). NACE.

AMPP Cathodic Protection Technician – CP 2 course material

Standards

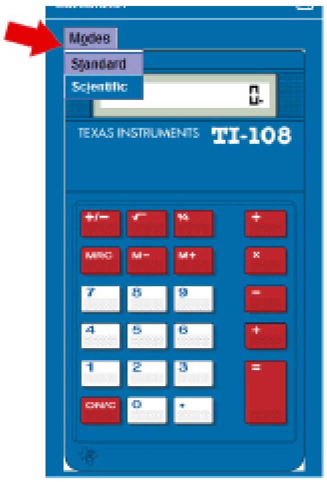
Latest editions should be used for all standards. Certain content from these standards is incorporated in the AMPP Cathodic Protection Tester (CP 1) course materials and some of them are included in the course manual.

- NACE SP 0169 (2013). "Control of External Corrosion on Underground of Submerged Metallic Piping Systems."
- NACE SP 0176 (2007) SG. "Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production."
- NACE SP 0177 (2019). "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems."
- NACE SP 0200 (2014). "Steel-Cased Pipeline Practices."
- NACE SP 0207 (2007). "Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines."
- NACE SP 21424 (2018). "Alternating Current Corrosion on Cathodically Protected Pipelines: Risk Assessment, Mitigation, and Monitoring."

Calculators

Students will have access to either a TI Standard or TI Scientific calculator for use during the CBT Exam.

Standard Calculator



Standard Mode Functions

Add	[+]	
Subtract	[-]	
Multiply	[X]	
Divide	[÷]	
Negative	[(-)]	
Percentage	[%]	
Square Root	[√]	Example: 4 [√]
Reciprocal (Inverse)	X	Example: 1 [÷] 2 [=]
Store value to variable	[M+]	Example: 3 [*] 5 [=] [M+]
Access variable	[MRC]	Example: 7 [+] [MRC] [=]
Clear variable	[M-] [MRC]	

Scientific Calculator

Scientific Mode Functions

Add	[+]	
Subtract	[-]	
Multiply	[X]	
Divide	[÷]	
Negative	[(-)]	
Percentage	[2nd] [%]	
Square Root	[√]	Example: [2nd] [√] 4 [enter]
Reciprocal (Inverse)	[X^{-1}]	Example: 2 [X^{-1}] [enter]
Store value to variable	[sto▶] [X^{yzt}]	Example: 3 [*] 5 [enter] [sto▶] [X^{yzt}] [enter]
Access variable	[X^{yzt}] or [2nd] [recall]	Example: 7 [+] [2nd] [recall] [enter] [enter]

Numeric Notation

Standard (Floating Decimal) Notation (digits to the left and right of decimal	mode menu options **NORM** SCI ENG e.g. 123456.78 FLOAT 0 1 2 3 **4** 5 … e.g. 123456.7800
Scientific Notation (1 digit to the left of decimal and appropriate power of 10)	mode menu options NORM **SCI** ENG e.g. 1.2345678*105
Engineering Notation (numer from 1 to 999 times 10 to an integer power that is a multiple of 3)	mode menu options NORM **SCI** ENG e.g. 123.45678*103

Fractions

Simple fractions	n/d
Mixed numbers	2nd [Un/d]
Conversion b/w simple fraction and mixed number	2nd [n/d ◀ ▶ Un/d]
Conversion b/w fraction and decimal	2nd [f ◀ ▶ d]

Powers, roots, and inverses

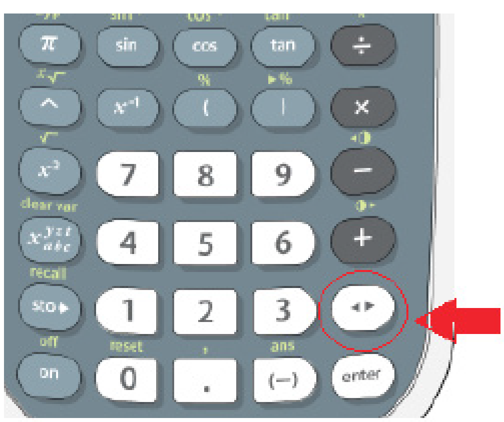
Square a value	x^2	
Cube a value	^	
Raise value to specified power	^	Example (2^4) 2 ^ 4
Square root	2nd [√]	Example (√16): 2nd [√] 16
Reciprocal	x^{-1}	Example (n^{th} root): 5^{th} root of 8: 5 2nd [^{x}√] 8

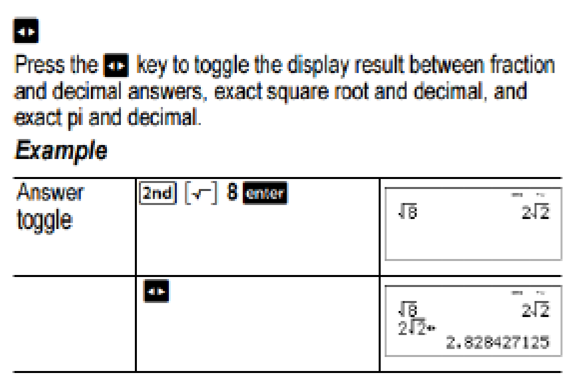
Pi

PI (π)	π

Toggle

The scientific calculator might show the results of certain calculations as a fraction - possibly involving pi or a square root. To convert this kind of result to a single number with a decimal point, you will need to use the "toggle answer" button circled in the picture below. Pressing this button will change the display from a fractional to a decimal format.




Answer Toggle

Press the ◀▶ key to toggle the display result between fraction and decimal answers, exact square root and decimal, and exact pi and decimal.

Example

Answer toggle	2nd [√‾] 8 enter	√8 2√2
	◀▶	√8 2√2 2√2 2.828427125

Note: If you find this onscreen calculator difficult to use, raise your hand and ask the Test Administrator to provide you with a hand-held calculator. **If available,** you will be provided with a scientific or non-scientific calculator. Candidates are not permitted to bring their own calculator into the testing room.

NOTE: All references, including equations, were taken from original sources and may differ from those used in course manuals and presentations.

EQUATIONS

RESISTIVITY (POUILLET'S LAW)

$$\rho = \frac{RA}{L} \qquad \textbf{OR} \qquad R = \frac{\rho A}{L}$$

Where

ρ = resistivity in ohm-cm*
R = resistance in ohms
A = cross-sectional area in cm^2*
L = length in cm*

*length and area can be in any unit, as long as they are consistent

AREA OF A CIRCLE

$$A = \pi r^2$$

Where

π = approximately 3.14
r = radius of circle
A = area

WENNER SOIL RESISTIVITY

$$\rho = 2\pi AR$$

Where

ρ = soil resistivity in ohm-cm*
A = distance between probes in cm*
R = soil resistance in ohms {instrument reading}

*pin spacing can be in any unit, as long as it is consistent with resistivity

OR

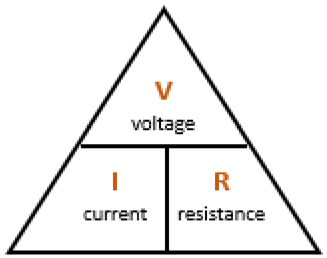
$$\rho = 191.5\, AR$$

Where

ρ = soil resistivity in ohm-cm
A = distance between probes in feet
R = soil resistance in ohms {instrument reading}

OHM'S LAW

$$V = IR \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$



POWER

$$P = EI$$
$$P = I^2R$$

Where:

- P = power in watts
- R = resistance in ohms
- E = voltage in volts
- I = current in amps

SERIES CIRCUIT

$$V_T = V_1 + V_2 + V_3$$

$$I_T = I_1 = I_2 = I_3$$

$$R_T = R_1 + R_2 + R_3$$

PARALLEL CIRCUIT

$$V_T = V_1 = V_2 = V_3$$

$$I_T = I_1 + I_2 + I_3$$

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

FARADAY'S LAW

$$W_t = KIT$$

Where:

- W_t = weight loss in kg*
- K = electrochemical equivalent in kg / A-yr
- I = current in amps
- T = time in years

*weight can be in any unit, as long as they are consistent

TRANSFORMER WINDING

$$\frac{Primary\ Turns}{Secondary\ Turns} = \frac{Primary\ Volts}{Secondary\ Volts}$$

IMPRESSED CURRENT RECTIFIER OPERATING EFFICIENCY

$$\%\ Efficiency = \left(\frac{D.C.\ Volts * D.C.Amps}{\text{A.C.Watts}}\right) * 100$$

Where:

$$A.C.Watts = \frac{K * N * 3600}{T}$$

K = meter constant (found on face of meter)
N = number of revolutions of the meter disc
T = time of measurement in seconds

CONSUMPTION RATE (K) FOR VARIOUS METALS

Metal	kg / A-yr	lb / A-yr
Carbon	1.3	2.86
Aluminum	3.0	6.5
Magnesium	4.0	8.8
Iron / Steel	9.1	20.1
High Silicon / Chromium Iron	0.5	1.0
Nickel	9.6	21.2
Copper (Monovalent)	20.8	45.8
Zinc	10.7	23.6
Tin	19.4	42.8
Lead	33.9	74.7

RELATIVE VALUES OF TYPICAL REFERENCE ELECTRODES TO COPPER–COPPER SULFATE REFERENCE ELECTRODE

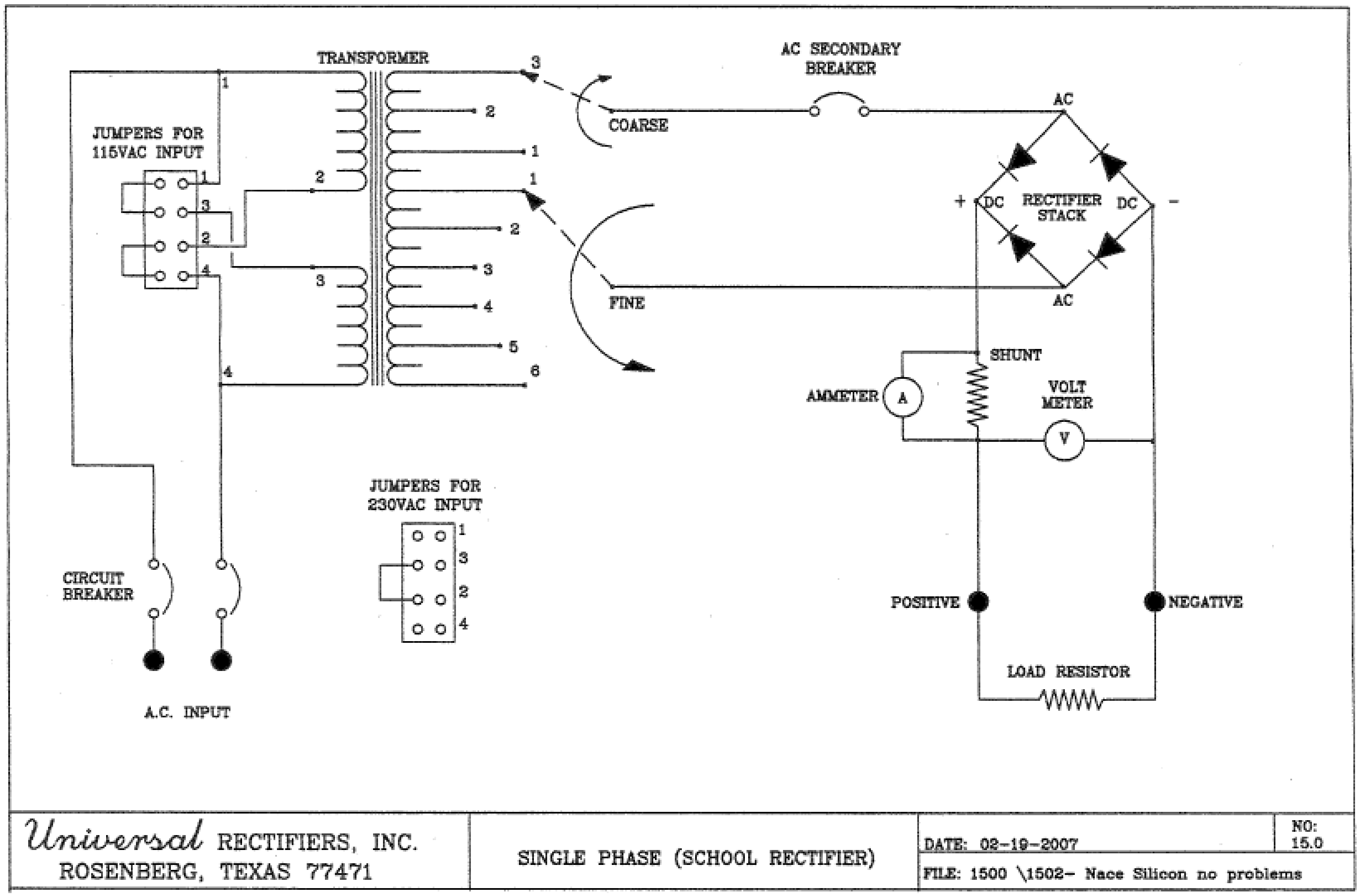
Electrode (Half-Cell)	Potential (Volt)
Copper–Copper Sulfate (Saturated) (CSE)	0.000
Silver–Silver Chloride (3.5%) (SSC)	-0.060
Saturated Calomel (SCE)	-0.072
Hydrogen (SHE)	-0.316
Pure Zinc (ZN)	-1.100

Based on seawater resistivity of 20 ohm-cm

SHUNT TYPES AND VALUES

	Shunt Rating		Shunt	Shunt
	Amps	mV	ohms	A / mV
Holloway Type				
RS	5	50	0.01	0.1
SS	25	25	0.001	1
SO	50	50	0.001	1
SW or CP	1	50	0.05	0.02
SW or CP	2	50	0.025	0.04
SW or CP	3	50	0.017	0.06
SW or CP	4	50	0.0125	0.08
SW or CP	5	50	0.01	0.1
SW or CP	10	50	0.005	0.2
SW	15	50	0.0033	0.3
SW	20	50	0.0025	0.4
SW	25	50	0.002	0.5
SW	30	50	0.0017	0.6
SW	50	50	0.001	1
SW	60	50	0.0008	1.2
SW	75	50	0.00067	1.5
SW	100	50	0.0005	2
J.B. Type				
Agra-Mesa	5	50	0.01	0.1
Cott or MCM				
Red	2	200	0.1	0.01
Yellow	8	80	0.01	0.1
Orange	25	25	0.001	1

RECTIFIER CIRCUIT



PRACTICAL GALVANIC SERIES

Material	Potential (V)*
High Potential Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.10
Aluminum Alloy	-1.05
Clean Carbon Steel	-0.50 to -0.80
Rusted Carbon Steel	-0.20 to -0.50
Cast / Ductile Iron	-0.50
Lead	-0.50
Steel in Concrete	-0.20
Copper	-0.20
High Silicon Iron	-0.20
Carbon, Graphite	+0.30

*Potentials with respect to saturated Cu–$CuSO_4$ electrode

4-WIRE LINE CURRENT TEST CALIBRATION

$$K = \frac{I_{test}}{\Delta V_{test}}$$

Where

K = calibration factor in amps / mV

I_{test} = test current applied to pipe section in amps

$\Delta V_{test} = V_{test,current\ applied} - V_{test,\ no\ current\ applied}$ in mV

CURRENT IN PIPE

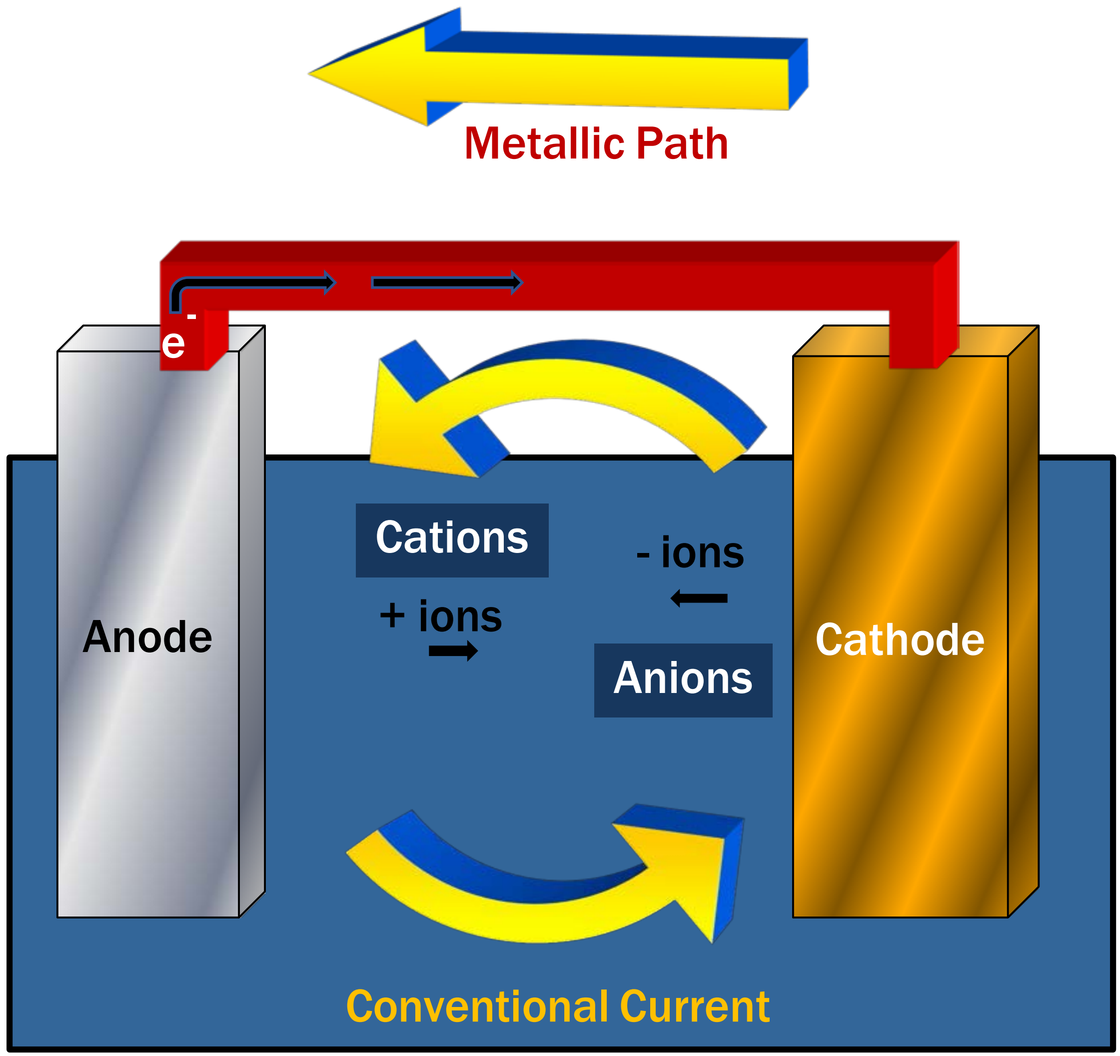
$$I = KV$$

Where

I = pipeline current in amps

K = calibration factor in amps / mV

V = voltage drop in pipeline section in mV


Metallic Path
e-
Cations
+ ions
- ions
Anions
Anode
Cathode
Conventional Current

CONVERSIONS

EMF	electromotive force – any voltage unit
E or e	any voltage unit
V	volts
mV	millivolts
μV	microvolts
I	any amperage unit
mA	milliamperes or milliamps
μA	microamperes or microamps
R or Ω	Resistance

1,000,000 volts	= 1 megavolt
1,000 volts	= 1 kilovolt
1.0 volt	= 1000 millivolts
0.100 volt	= 100 millivolts
0.010 volt	= 10 millivolts
0.001 volt	= 1 millivolt
0.000001 volt	= 1 microvolt

1,000,000 amperes	= 1 mega-ampere
1,000 amperes	= 1 kiloampere
1.0 ampere	= 1000 milliamperes
0.100 ampere	= 100 milliamperes
0.010 ampere	= 10 milliamperes
0.001 ampere	= 1 milliampere
0.000001 ampere	= 1 microampere

1,000,000 ohms	= 1 mega-ohm
1,000 ohms	= 1 kilo-ohm
1.0 ohms	= 1000 milliohms
0.100 ohm	= 100 milliohms
0.010 ohm	= 10 milliohms
0.001 ohm	= 1 milliohm
0.000001 ohm	= 1 micro-ohm

1 meter	= 100 cm
1 meter	= 1000 mm
1 inch	= 2.54 cm
1 foot	= 30.48 cm

U.S. Customary/Metric Conversion for Units of Measure Commonly Used in Corrosion-Related Publications

1 A/ft^2	= 10.76 A/m^2
1 acre	= 4,047 m^2 = 0.4047 ha
1 A·h/lb	= 2.205 A·h/kg
1 bbl (oil, U.S.)	= 159 L = 0.159 m^3
1 bpd (oil)	= 159 L/d = 0.159 m^3/d
1 Btu	= 1,055 J
1 Btu/ft^2	= 11,360 J/m^2
1 Btu/h	= 0.2931 W
1 Btu/h·ft^2	= 3.155 W/m^2 (K-factor)
1 Btu/h·ft^2·°F	= 5.678 W/m^2·K
1 Btu·in/h·ft^2·°F	= 0.1442 W/m·K
1 cfm	= 28.32 L/min = 0.02832 m^3/min = 40.78 m^3/d
1 cup	= 236.6 mL = 0.2366 L
1 cycle/s	= 1 Hz
1 ft	= 0.3048 m
1 ft^2	= 0.0929 m^2 = 929 cm^2
1 ft^3	= 0.02832 m^3 = 28.32 L
1 ft·lbf (energy)	= 1.356 J
1 ft·lbf (torque)	= 1.356 N·m
1 ft/s	= 0.3048 m/s
1 gal (Imp.)	= 4.546 L = 0.004546 m^3
1 gal (U.S.)	= 3.785 L = 0.003785 m^3
1 gal (U.S.)/min (gpm)	= 3.785 L/min = 0.2271 m^3/h
1 gal/bag (U.S.)	= 89 mL/kg (water/cement ratio)
1 grain	= 0.06480 g = 64.80 mg
1 grain/ft^3	= 2.288 g/m^3
1 grain/100 ft^3	= 22.88 mg/m^3
1 hp	= 0.7457 kW
1 microinch (µin)	= 0.0254 µm = 25.4 nm
1 in	= 0.0254 m = 2.54 cm = 25.4 mm
1 in^2	= 6.452 cm^2 = 645.2 mm^2
1 in^3	= 16.387 cm^3 = 0.01639 L
1 in·lbf (torque)	= 0.113 N·m
1 inHg	= 3.386 kPa
1 inH_2O	= 249.1 Pa
1 knot	= 0.5144 m/s
1 ksi	= 6.895 MPa
1 lb	= 453.6 g = 0.4536 kg
1 lbf/ft^2	= 47.88 Pa
1 lb/ft^3	= 16.02 kg/m^3
1 lb/100 gal (U.S.)	= 1.198 g/L
1 lb/1,000 bbl	= 2.853 mg/L
1 mA/in^2	= 0.155 mA/cm^2
1 mA/ft^2	= 10.76 mA/m^2
1 Mbpd (oil)	= 159 kL/d = 159 m^3/d
1 mile	= 1.609 km
1 square mile	= 2.590 km^2
1 mile (nautical)	= 1.852 km
1 mil	= 0.0254 mm = 25.4 µm
1 MMcfd	= 2.832 x 10^4 m^3/d
1 mph	= 1.609 km/h
1 mpy	= 0.0254 mm/y = 25.4 µm/y
1 oz	= 28.35 g
1 oz fluid (Imp.)	= 28.41 mL
1 oz fluid (U.S.)	= 29.57 mL
1 oz/ft^2	= 2.993 Pa
1 oz/gal (U.S.)	= 7.49 g/L
1 psi	= 0.006895 MPa = 6.895 kPa
1 qt (Imp.)	= 1.1365 L
1 qt (U.S.)	= 0.9464 L
1 tablespoon (tbs)	= 14.79 mL
1 teaspoon (tsp)	= 4.929 mL
1 ton (short)	= 907.2 kg
1 U.S. bag cement	= 42.63 kg (94 lb)
1 yd	= 0.9144 m
1 yd^2	= 0.8361 m^2
1 yd^3	= 0.7646 m^3

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