NACE Cathodic Protection Tester Level 1 Theory Exam

Exam Preparation Guide

November 2019

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Introduction

The Cathodic Protection Tester (CP 1) Theory exam is designed to assess whether a candidate has the requisite knowledge and skills that a minimally qualified Cathodic Protection Tester must possess. The exam consists of 85 multiple-choice questions that are based on the entry-level Cathodic Protection Body of Knowledge (BOK), which is common in the CP industry.

Test Name	NACE CP1 – Cathodic Protection Tester – Theory Exam
Test Code	NACE-CP1-001
Time	2 ½ hours*
Number of Questions	85
Format	Computer Based Testing (CBT)

NOTE: A pass/fail grade is provided at the end of the exam.

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

NOTE: The course manual is **NOT** provided in 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 Tester (CP 1) should ideally have entry-level knowledge of corrosion theory, CP concepts, the types of CP systems in common use, and basic field measurement techniques and equipment. However, CP Tester candidates can range from persons new to the CP industry, with little or no CP field experience, to experienced testers, technicians, or engineers with some level of CP skill. Typically, CP Testers are responsible for testing and recording the effectiveness of operating CP systems and/or assisting in the installation of new CP systems or components under the direction of experienced CP personnel.

Requirements

Cathodic Protection Tester (CP 1)

- Work Experience + 2 Core Exams

Work Experience Requirements
6 months of CP-related work experience
Core Exam Requirements
The following 2 core exams are required:
Cathodic Protection Tester (CP 1) Practical Exam (hands-on) Cathodic Protection Tester (CP 1) Theory Exam (multiple choice, closed-book, with relevant references)

Note: Completion of course does not entitle the candidate to the certification.

Note: The Cathodic Protection Tester (CP 1) Practical Exam is given at the conclusion of the NACE Cathodic Protection Tester (CP 1) course.

Upon successful completion of requirements, the candidate will be awarded a Cathodic Protection Tester (CP 1) Certification.

Next Level of Certification:

Cathodic Protection Technician (CP 2)

CP1 – 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. **BASICS**

   A. Understand the relationship between voltage, current, and resistance as expressed by Ohm's Law.

   B. Understand basic AC and DC circuits, to include series, parallel, and series-parallel.

   C. Understand the composition of a basic galvanic cell and the electro-chemical reactions that allow corrosion to occur at the anode rather than the cathode.

   D. Understand the cause and effect of polarization in a galvanic cell.

   E. Understand the concept cathodic protection and the two primary methods of applying it to metal objects underground or otherwise immersed in an electrolyte.

   F. Understand how corrosion cells are formed on metal objects that are underground or otherwise immersed in an electrolyte.

   G. Understand the concept of shielding and how it can affect metallic objects that are cathodically protected.

   H. Understand the principles of magnetism and how it applies to transformers.

   I. Understand the application of Kirchhoff's electrical circuit laws.

   J. Understand the physical and chemical characteristics of metal and electrolytes that affect corrosion rates.

   K. Understand the characteristics and application methods of common pipeline coatings.

   L. Understand the use of Faraday's first law in relation to cathodic protection and corrosion of metals.

   M. Understand the causes and types of AC interference (or interactions) with pipelines and related safety standards and safe work practices.

   N. Understand safety considerations and methods for dealing with spark hazards and current in piping.

2. **ATMOSPHERIC**

   A. Perform periodic atmospheric corrosion inspections and document your findings according to company procedures.

3. **INSULATORS AND SHORTS**

A. Understand the need for insulation or isolation between facilities.
B. Understand the effect a metallic short can have on your CP system.
C. Test to see if an insulator is shorted using pipe-to-soil readings.
D. Test an insulator with an electronic insulator checking instrument.
E. Locate and clear shorts on an underground pipeline system.
F. Understand the use of protective devices for isolations devices.

4. **INSTRUMENTS**

A. Understand the operation of a volt-ohm meter (Multimeter) as to how it is used to measure current, voltage, and resistance.
B. Use a volt-ohm meter (Multimeter) to determine the voltage and current output of a rectifier.
C. Understand the operation of a soil resistivity meter.
D. Use a volt-ohm meter to determine the current output of sacrificial anodes installed on your system.
E. Conduct a soil resistivity test with a Vibroground, Nilsson, or equivalent instrument.
F. Conduct soil resistivity measurements by using a Soil Box.
G. Conduct single-point soil resistivity readings with a Collins Rod.
H. Install interrupters in rectifiers or bonds for the purpose of taking ON / OFF readings.
I. Understand the various types of pipe locating instruments and be able to utilize them to locate pipelines or cables in all underground environments.
J. Understand the methods and equipment for testing pipeline coatings for holidays (damage) before burial.

5. **CP CURRENT SOURCES**

A. Install galvanic anodes, document the installation, and test to ensure proper operation.
B. Obtain periodic rectifier readings.
C. Troubleshoot a rectifier installation by using a volt-ohm meter (Multimeter) to follow the input AC voltage through the transformer to the stack and the DC from the stack to the load.
D. Understand the different types of impressed current and galvanic anodes and how they are installed in soil and water environments.
E. Understand a simple transformer-rectifier circuit and be able to follow the input AC voltage through the transformer to the rectification stack and the DC from the stack to the load.
F. Understand the causes of common abnormal CP circuit conditions and their resulting effects on rectifier DC output.

6. **CP TEST LEADS**

   A. Install test leads for a potential test station according to company specifications.
   B. Install jumper test leads across an insulated flange according to company specifications.
   C. Install test leads for a critical bond according to company specifications.
   D. Install test leads for a mV drop configuration in order to measure current flow in a pipeline.
   E. Install test leads for a foreign line crossing.
   F. Make attachments to a pipe or tank by silver soldering the connection.
   G. Make attachments to a pipeline or tank by using an exothermic weld kit.
   H. Make repairs and / or splices to bond leads, header cables, and test leads.

7. **SHUNTS**

   A. Understand how to determine the amount of current flowing through various size shunts by reading the mV drop across it with a volt-ohm meter and applying the correct conversion factor.
   B. Understand how to determine the direction of current flow through a shunt by observing the polarity of the mV reading.
   C. Read shunts in rectifiers to determine the output current.
   D. Read shunts in bonds with foreign structures.
   E. Read shunts for individual anodes associated with deep well ground beds.
   F. Utilize an external shunt to determine the output current of a rectifier with a broken amp meter.
   G. Read shunts that are installed in galvanic anodes to determine the amount of current they are putting out.

8. **PERIODIC SURVEYS**

   A. Conduct annual pipe to soil surveys on all facilities.
   B. Conduct rectifier readings.
   C. Conduct surveys of bonds.
   D. Conduct surveys of diodes or current reversing switches.
   E. Conduct soil resistivity surveys.
   F. Collect data on external coupon test stations.
   G. Conduct offshore platform and riser surveys.

9. **REFERENCE CELLS**

A. Understand the construction and operation of reference cells and maintain them in a manner that will provide comparative readings.

B. Install permanent reference cells and check them periodically to ensure that are in good working order.

C. Abide by the recommendations in the MSDS sheet pertaining to the handling and disposal of copper sulfate.

D. Use an antimony half-cell in comparison to a copper / copper sulfate half-cell for determining the pH of soils.

10. **RECORDKEEPING AND ADMINISTRATIVE**

A. Record readings from periodic surveys according to the methods provided by your company.

B. Keep all records required by the DOT for the life of the facility involved.

C. Use computer word processing or spread sheets to prepare reports, letters, and other necessary correspondence.

D. Understand how to read your alignment sheets and other system maps and be able to provide accurate locations where work was done or new facilities installed.

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 Tester. While the NACE 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. Which of the following results from polarization of a metal?

   A. Corrosion
   B. Reduced corrosion rate
   C. Increased corrosion rate
   D. Increased amount of current

2. Which of the following are advantages of impressed current systems?

   A. No external power is required.
   B. Voltage and current outputs are flexible.
   C. They are less susceptible to damage from lightning.
   D. No routine inspections are required.

3. Which of the following data are used to determine when adequate cathodic protection is achieved?

   A. Rectifier output voltage
   B. Resistance of impresses current anode groundbeds
   C. Current output of galvanic anodes
   D. Structure-to-electrolyte potentials

4. The primary source of information about chemical hazards can be obtained from which of the following?

   A. Product data sheet
   B. Code of federal regulations
   C. Material Safety Data Sheet
   D. Equipment schematics

Answer Key

1. **B**
2. **B**
3. **D**
4. **C**

Preparation

Training—None Required

NACE 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 International.

NACE Cathodic Protection Tester—CP 1 course material

Standards

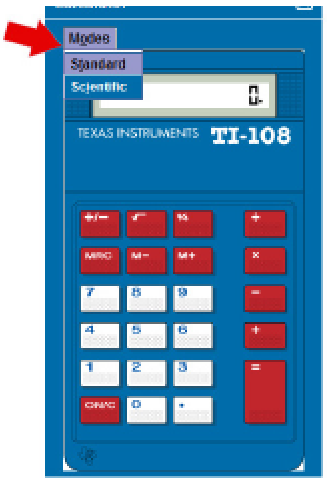
Latest editions should be used for all standards. Certain content from these standards is incorporated in the NACE Cathodic Protection Tester (CP 1) course materials and some of them are included in the course manual.

- NACE International SP 0169 (2013). "Control of External Corrosion on Underground of Submerged Metallic Piping Systems." NACE International.
- NACE International SP 0176 (2007) SG. "Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production." NACE International.
- NACE International SP 0177 (2014). "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems." NACE International.
- NACE International SP 0200 (2014). "Steel-Cased Pipeline Practices." NACE International.

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

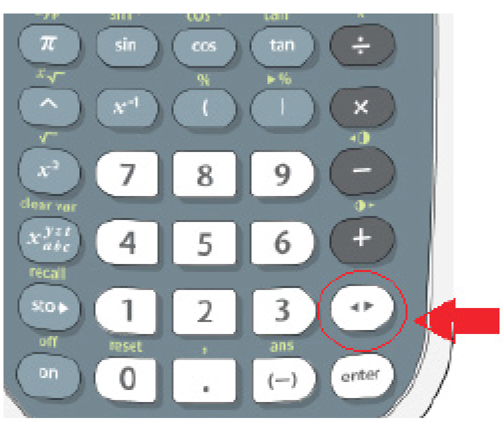
Square a value	[x^2]	
Cube a value	[^]	
Raise value to specified power	[^]	Example (2^4) 2 [^] 4
Square root	[2nd] [√]	Example (√16): [2nd] [√] 16
Reciprocal	[x^{-1}]	Example (n^{th} root): 5^{th} root of 8: 5 [2nd] [ˣ√] 8

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)

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

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

$$\pi = r^2$$

Where

π = approximately 3.14
r = radius of circle

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

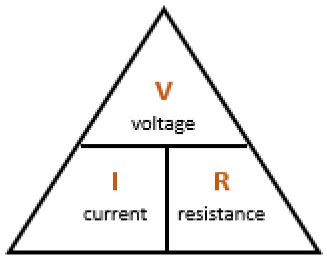
$$\rho = 191.5\, AR$$

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

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

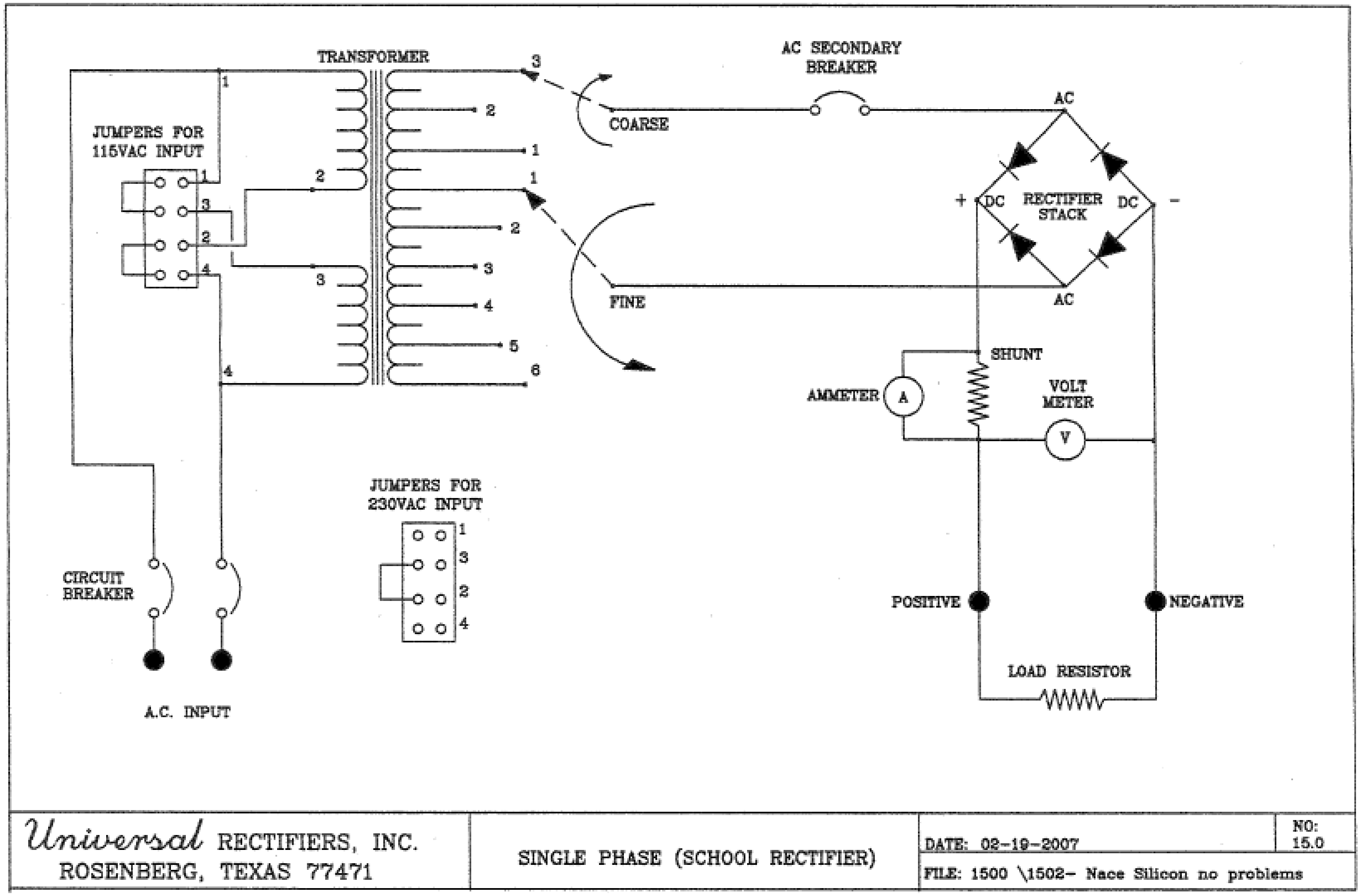
Electrode (Half-Cell)	Potential (Volt)
Copper–Copper Sulfate (Saturated) (CSE)	0.000
Silver–Silver Chloride (3.5%) (SSC)	-0.060
Saturated Calomel (SCE)	-0.072
Hydrogen (SHE)	-0.316
Pure Zinc (ZN)	-1.100

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

$$I = KV$$

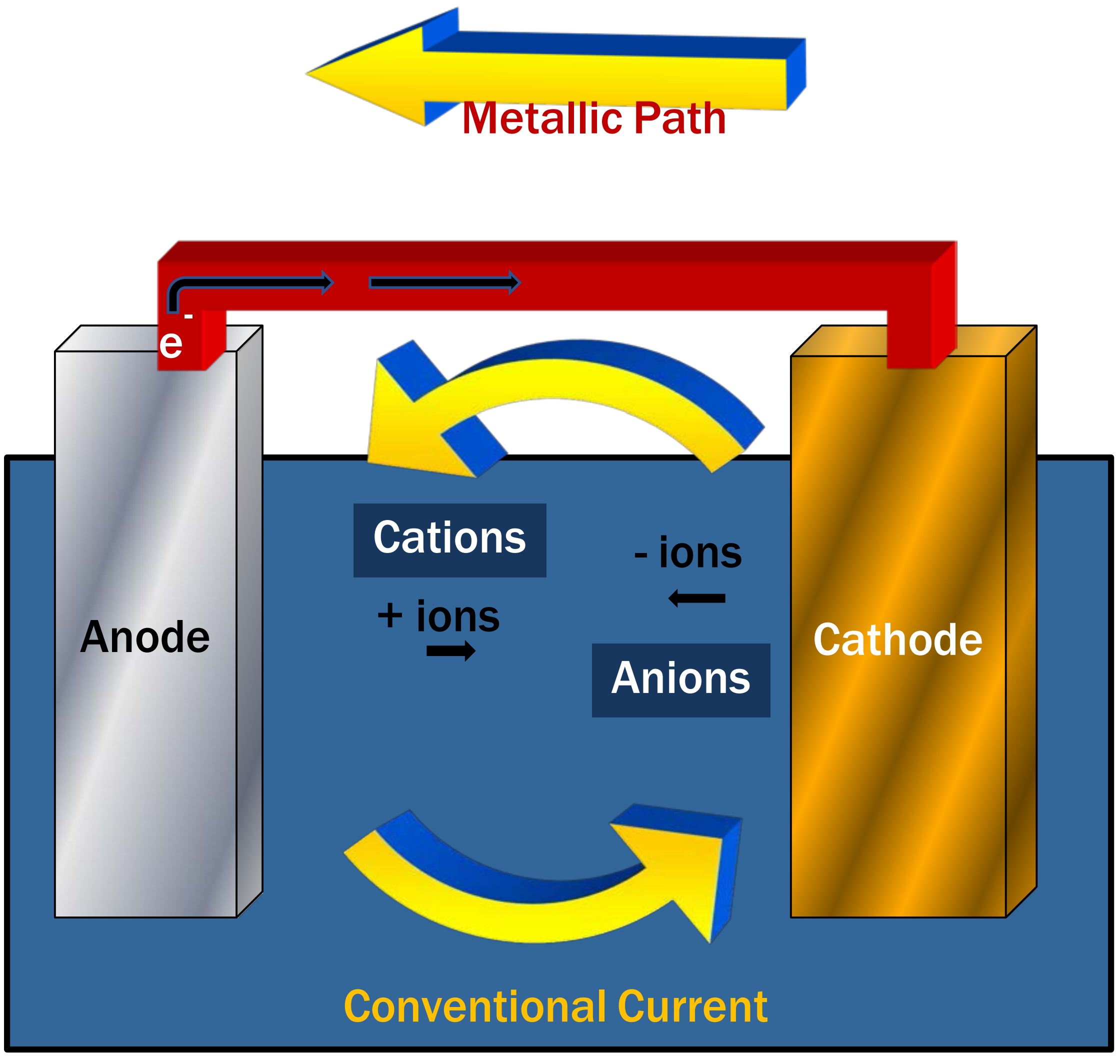
Where

I = pipeline current in amps

K = calibration factor in amps / mV

V = voltage drop in pipeline section in mV

ELECTROCHEMICAL CIRCUITS



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

REFERENCES & STANDARDS USED TO DEVELOP THE REFERENCE MATERIAL

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

NACE Corrosion Engineers Reference Handbook, Baboian, 3rd Edition (2002).

Electrical Engineering Principles and Applications—5th Edition. Hambley, A. (2005). Prentice-Hall Publishing.

Core Engineering Concepts for Students and Professionals—1st Edition. Lindeburg, M. (2010). Professional Publications, Inc.

"American National Standard for Use of the International System of Units (SI): The Modern Metric System" ASTM SI 10. (2002). ASTM.

Universal Rectifiers Website. www.universalrectifiers.com

NACE International SP 0169 (2013). "Control of External Corrosion on Underground of Submerged Metallic Piping Systems." NACE International.

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