AMPP™

Cathodic Protection Specialist Level 4

Theory and Case-Based Exams

Exam Preparation Guide
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- Appendix D – Table / Scale Preparation and Study Materials
- Appendix E – Certification Requirements
- Appendix F – Sample Exam Questions
- Appendix G – Exam Calculator
Target Audience

AMPP Cathodic Protection Specialist certification is targeted toward individuals who have considerable experience and knowledge in the understanding of theory, design, recommendation, and analysis of cathodic protection (CP) and the installation, and maintenance of CP systems. This certification is currently the highest-level credential for Cathodic Protection.

How do I know that I have the knowledge and skills needed for this level of Certification?

Introduction

The Cathodic Protection Specialist Exam (CP 4) is designed to assess the necessary knowledge and skills of candidates who desire to be granted industry recognition as an AMPP certified - Cathodic Protection Specialist.

1. Candidates for this exam should have a thorough understanding of the entire cathodic protection knowledge base that includes, but is not limited to:
   a. Knowledge and understanding of theoretical CP concepts,
   b. Knowledge and skills to direct and perform CP design across multiple electrolytes and structure types,
   c. Knowledge and skills to direct and perform all necessary levels of field testing,
   d. Knowledge and skills to direct and perform the interpretation of CP data, and
   e. Knowledge and skills to direct and provide recommendation and conclusion.
To help clarify intended roles and responsibilities, the following table provides guidance of the technical oversight (supervision\(^1\)) for a Cathodic Protection Specialist:

<table>
<thead>
<tr>
<th>Task</th>
<th>Cathodic Protection Specialist (CP4)</th>
</tr>
</thead>
</table>
| **Testing**           | • Develop comprehensive testing plans  
                        | • Can use specialized test equipment to perform and lead all levels of testing jobs  
                        | • Can perform or oversee complex or unique field testing and troubleshooting for all types of structures |
| **Data Analysis**     | • Comprehensive understanding of data, reactions, and results  
                        | • Skills to troubleshoot all situations and provide recommendations  
                        | • Can both recognize and address complex or unique situations |
| **Installation Support** | • Can provide installation support and recommendation for all situations |
| **Design**            | • Can lead and / or review all levels of design, including complex or unique situations (e.g., multiple structure systems, stray current interference) |
| **Supervision Authority** | • As required by the owner /agency and or AMPP guidelines for direct / indirect supervision of CP1, CP2, and CP3 certified individuals. |

This table is for guideline and reference purposes only. See the AMPP website for more information.

A. Knowledge and Skills Assessment Guidance

Candidates can review the information attached to this exam preparation guide (EPG) to perform a self-assessment and / or as a study guide for this level of certification – Cathodic Protection Specialist (CP4).

Because this certification is currently the highest-level credential for Cathodic Protection, there are knowledge and skills which are unique to this level. A part of this body of knowledge and skill may need to have been obtained at lower CP certification levels.

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\(^1\) The term “supervision” refers to technical oversight and not general supervision of employment.
The following critical areas of this exam preparation guide (EPG) can help you prepare for this certification exam:

- See Appendix A of this exam preparation guide (EPG) for exam blueprint information related to knowledge and skills. (CP4_0003_13_06_2024_blueprint_VerA0)

- See Appendix B of this exam preparation guide (EPG) for preparation training and study materials. (CP4_0005_13_06_2024_prepreft_VerA0)

- See Appendix C of this exam preparation guide (EPG) for equation preparation and study materials. (CP4_0007_13_06_2024_equatref_VerA0)

- See Appendix D of this exam preparation guide (EPG) for table / scale preparation and study materials. (CP4_0007b_13_06_2024_eqtableref_VerA0)
How do I become Certified at this level?

Certification Requirements

There are requirements that a Candidate must meet in order to be granted industry credentialed as an AMPP Cathodic Protection Specialist (CP4). These requirements are:

1. Meet work experience and education requirements
2. Meet prerequisite requirements
3. Take and successfully complete all required exam(s)
4. Complete and apply for certification.

A. Certification Progression Note

The Cathodic Protection Specialist (CP 4) is not intended as a direct progression from Cathodic Protection Technologist (CP 3). The Candidate needs significant industry experience and more knowledge:

- Substantial experience beyond that of a CP 3 is critical to a candidate’s success on this exam. This experience relates to all aspects of CP including:
  - practical testing and design experience across all types of facilities and electrolytes, and
  - formal or equivalent CP educational experience and knowledge studies related to such areas as: math, geology, chemistry, and / or engineering

- Prior to scheduling the Cathodic Protection Specialist exam (CP 4) it is strongly recommended that candidates successfully complete or have an equivalent level of training to:
  - Cathodic Protection Technologist Course (CP 3)

- Prior to scheduling the Cathodic Protection Specialist exam (CP 4) it is strongly recommended that candidates successfully complete or have an equivalent level of training to:
  - Cathodic Protection Specialist Refresher Course (CP 4)
What will the Certification Exam be like?

Certification Exam Information

There are certification exam requirements that a Candidate must meet in order to be an AMPP Cathodic Protection Specialist (CP4). The Cathodic Protection Specialist Exam includes exam questions related to Theory and to Case-based or scenario studies. More information is provided below:

A. Exam Elements – Theory and Cased-Based

1. **Theory Exam** - in summary consists of 60 multiple-choice questions that requires the candidate to demonstrate their “application of knowledge” based on the entire Cathodic Protection (CP) body of knowledge.

<table>
<thead>
<tr>
<th>Exam Name</th>
<th>AMPP -Cathodic Protection Specialist Theory Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam Code</td>
<td>NACE-CP4-Theory¹</td>
</tr>
<tr>
<td>Time</td>
<td>4 hours³</td>
</tr>
<tr>
<td>Number of Questions</td>
<td>60</td>
</tr>
<tr>
<td>Format</td>
<td>Computer Based Testing- CBT</td>
</tr>
</tbody>
</table>

2. **Case-Based Exam** – in summary consists of 30 multiple-choice questions related to a case study, scenario, or problem that requires the application of candidate knowledge based on the entire Cathodic Protection (CP) body of knowledge.

<table>
<thead>
<tr>
<th>Exam Name</th>
<th>AMPP -Cathodic Protection Specialist Case-Based Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam Code</td>
<td>NACE-CP4- Cased-Based²</td>
</tr>
<tr>
<td>Time</td>
<td>4 hours³</td>
</tr>
<tr>
<td>Number of Questions</td>
<td>Each Candidate will receive:</td>
</tr>
<tr>
<td></td>
<td>25 exam questions that are scored</td>
</tr>
<tr>
<td></td>
<td>5 exam questions that are unscored⁴</td>
</tr>
<tr>
<td>Format</td>
<td>Computer Based Testing- CBT</td>
</tr>
</tbody>
</table>

² The exam system will grade the Theory and Case-Based exams scores separately. The exam system will show a pass/fail grade on completion of each exam. Candidates must pass both exams.  
³ Exam time includes 4 minutes for the non-disclosure agreement and 6 minutes for the system tutorial.  
⁴ Unscored exam questions are being evaluated for future exams.
B. Exam Elements – Sample Exam Questions

This closed-book exam consists of multiple-choice questions. The questions are based on the exam blueprint which reflects the knowledge and skills needed in the CP industry for a Cathodic Protection Specialist.

C. Exam Elements – Use of Calculators

Candidates will have access to either a digital TI-108 Standard and/or TI-30XS Scientific calculator for use during the Certification Exam. During the exam, you may have to switch or select one of these calculators for use. Candidates will not be able to use their own calculator for this exam.

D. Exam Elements – Provided Exam Resources

Candidates will have access to the necessary reference material needed during the exam. This reference material could include such items as:

- industry standards (where indicated in Appendix B)
- equations (where indicated in Appendix C)
- conversion charts (where indicated in Appendix D)
- other where considered appropriate

Note: AMPP course manuals are not available as part of the resources provided for this exam.
Appendix A
Exam Blueprint Information related to Knowledge and Skills
Exam Blueprint (CP4)

Basics (1% - 2%)¹
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. Be able to identify different forms of corrosion.
J. Understand the effect of polarization on the environment.

Periodic Surveys (1% - 2%)
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.
H. Utilize a current interrupter to determine IR Free readings during close interval or annual surveys.
I. Understand how IR Free readings can be used to determine the true level of polarization on your pipeline.
J. Conduct polarization decay test.

¹ This value reflects the proportion of the exam covered (domain weight) by the section indicated.
Reference Cells (1%-2%)

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 SDS 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.

Field Tests (8% - 10%)

A. Perform current requirement test.
B. Perform soil pH test.
C. Perform IR Drop test.
D. Run "shorted casing test" on casings that are suspected of being shorted and interpret the results of the test.
E. Perform coating examinations on sections of pipeline that have been excavated.
F. Perform soil resistivity test to evaluate the area for a conventional ground bed site.
G. Conduct Pearson surveys to evaluate the coating condition of a section of pipeline.
H. Conduct computerized close interval surveys where needed and evaluate the graphs produced from the data.
I. Locate breaks in header cables with an "audio type" pipe and cable locator.
J. Investigate shorts on a pipeline or other structure.
K. Verify the results of shorted casing test.
L. Understand the factors that affect cathodic protection system performance at the anode, at the structure performance, in the electrolyte, in the metallic path, at the power supply, because of anode arrangement, and interference.
M. Perform advanced cathodic protection testing using correct measurement techniques to monitor CP system performance and accurately interpret the data collected to ensure optimum cp system performance.
N. Based on data collected, determine if correction/modifications to system components are necessary. Identify errors in data collection/CP measurements including contact resistance errors, voltage drop errors, and reference electrode errors.
O. Utilize the instruments required to accomplish advanced cathodic protection testing and collection of cathodic protection systems measurements.
P. Conduct cathodic protection surveys, including close interval surveys and DCVG, where needed or required and evaluate the graphs produced from the data collected during the surveys.
Q. Troubleshoot rectifiers and make corrections/repair as necessary.
R. Perform efficiency test on rectifiers.
S. Install new rectifiers.
T. Understand the use of external CP coupons and be able to identify if the use of external coupons is needed for a CP system.
U. Understand in-line and direct inspection (understand and be able to implement ECDA).

**DC Stray Current Interference (5% - 7%)**
A. Conduct and document interference tests where stray currents are suspected.
B. Once interference tests have been run, suggest method of control that will mitigate the effects of the stray current.
C. Understand how IR Drop test stations can be used to evaluate stray current.
D. Understand how Coupon Test stations can be used to determine the presence of and the mitigation of stray current.
E. Calculate the resistance required to provide the amount of current drain desired at a resistance bond installation.
F. Understand the causes (sources) and the effects of interference.
G. Understand the methods available to mitigate interference.

**AC Mitigation (1% - 2%)**
A. Understand the safety requirements when installing test stations under high voltage power lines.
B. Take appropriate steps to mitigate the effects of excessive AC voltage induced on underground structures.

**Corrosion Theory (7% - 8%)**
A. Understand the composition of a basic galvanic cell and the electrochemical reactions that allow corrosion to occur at the anode rather than the cathode.
B. Describe the characteristics of anodic and cathodic reactions.
C. Understand and apply the principles of electricity and electrical circuits (series, parallel, and series-parallel circuits) (including the application of Ohm’s and Kirchhoff’s Laws to electrical circuits.)

**Polarization (7% - 8%)**
A. Understand the cause and effect of polarization in a galvanic cell.
B. Understand activation, concentration, and resistance polarization and the mathematical expressions of these concepts.
C. Understand the factors that affect polarization (area, temperature, relative movement, ion concentration, oxygen concentration).
D. Perform calculations using Ohm’s Law and calculations related to series and parallel circuits.

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

F. Understand Faraday’s Law and perform calculations using Faraday’s law to determine required anode weight for cathodic protection.

Cathodic Protection (33% - 35%)

A. Understand the concept cathodic protection and be knowledgeable of the components required for both galvanic and impressed current systems.

B. Be able to design and install simplistic forms of galvanic and impressed current cathodic protection facilities.

C. Understand the relationship between cathodic protection and other methods of corrosion mitigation.

D. Understand the factors that affect the amount of current required for a cathodic protection system.

E. Understand the NACE criteria for Cathodic Protection and be able to apply the criteria and adjust as necessary to CP systems in order to comply with the criteria defined by the company where the specialist is employed.

F. Understand IR drop and be able to determine the IR drop and apply correction techniques as needed.

G. Understand and apply E Log I criteria and construct polarization curves.

H. Understand the concept of current distribution and be able to determine ideal current distribution for a CP system considering the factors affecting current distribution (anode-to-cathode separation distance, electrolyte and structure resistivity variation, current attenuation).

I. Understand the effects of current path geometry, protective coatings, and polarization on current distribution.

Codes and Compliance (1% - 2%)

A. Should have a good working knowledge of appropriate regulations that apply to the products, transportation or storage means being utilized by your company.

B. Should know the reports and other documentation that is required by the agencies that inspect your facilities.

C. Should have a good understanding of the National Electrical Code as it relates to cathodic protection facilities in all divisions and classes.

D. Should have a good working knowledge of grounding practices and lightning protection and how it can affect a CP system.
Design (22% - 33%)

A. Utilize field data to accomplish the calculations required to design cathodic protection current sources.

B. Select site locations and implement the design of cathodic protection current sources for distribution or transmission pipeline systems.

C. Design cathodic protection systems for the inside of water tanks.

D. Design cathodic protection for the tank bottoms of aboveground storage tanks.

E. Design cathodic protection for underground storage tanks.

F. Work with engineering in the proper use of insulation for newly designed facilities.

G. Provide information on underground coating performance for those selecting coatings for new facilities.
Appendix B
Exam Preparation Training and Study Materials
Suggested Preparation Training (CP4)

1. AMPP Cathodic Protection Specialist - Course CP 4 (Refresher)
2. AMPP Cathodic Protection Technologist - Course CP 3
3. AMPP Cathodic Protection Technician - Course CP 2
4. AMPP Cathodic Protection Tester - Course CP 1

Suggested Preparation Training (CP4)

1. AMPP Cathodic Protection Specialist Exam Preparation Guide (EPG)
2. AMPP Cathodic Protection Technologist Exam Preparation Guide (EPG)
3. AMPP Cathodic Protection Technician Exam Preparation Guide (EPG)
4. AMPP Cathodic Protection Tester Exam Preparation Guide (EPG)

Suggested Cathodic Protection Specialist Study Material (CP4)

Books


### Standards


### Other Resources

1. NACE SP 0207 (2007). “Performing Close Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines.”


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1 Candidate will have access to this necessary reference material as part of the exam
Appendix C
Equation Preparation and Study Materials
**Calculation Resource**

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

### RESISTANCE TO EARTH OF SINGLE VERTICAL ANODE

\[ R_v = \left[ \frac{0.00521 \rho}{L} \right] \left[ \ln \left( \frac{8L}{d} \right) - 1 \right] \]

Where:
- \( R_v \) = resistance (Ω)
- \( \rho \) = resistivity (Ω·cm)
- \( L \) = anode length (ft)
- \( d \) = anode diameter (ft)

**OR**

\[ R_v = \left[ \frac{\rho}{2\pi L} \right] \left[ \ln \left( \frac{8L}{d} \right) - 1 \right] \]

Where:
- \( R_v \) = resistance (Ω)
- \( \rho \) = resistivity (Ω·m)
- \( L \) = anode length (m)
- \( d \) = anode diameter (m)

### RESISTANCE TO EARTH OF MULTIPLE VERTICAL ANODES

\[ R_v = \left[ \frac{0.00521 \rho}{NL} \right] \left[ \ln \left( \frac{8L}{d} \right) - 1 + \left( \frac{2L}{S} \right) \ln(0.66N) \right] \]

Where:
- \( R_v \) = resistance (Ω)
- \( \rho \) = resistivity (Ω·cm)
- \( L \) = anode length (ft)
- \( N \) = number of anodes
- \( S \) = anode spacing center-to-center (ft)
- \( d \) = anode diameter (ft)

**OR**

\[ R_v = \left[ \frac{\rho}{2\pi NL} \right] \left[ \ln \left( \frac{8L}{d} \right) - 1 + \left( \frac{2L}{S} \right) \ln(0.66N) \right] \]

Where:
- \( R_v \) = resistance (Ω)
- \( \rho \) = resistivity (Ω·m)
- \( L \) = anode length (m)
- \( N \) = number of anodes
- \( S \) = anode spacing center-to-center (m)
- \( d \) = anode diameter (m)

**NOTE:** Use the units specified.

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1 Candidate will have access to this necessary reference material as part of the exam.
RESISTANCE TO EARTH OF SINGLE HORIZONTAL ANODE

\[ R_H = \left[ \frac{0.00521\rho}{L} \right] \left[ \ln \left( \frac{4L^2 + 4L\sqrt{S^2 + L^2}}{dS} \right) + \frac{S}{L} - \frac{\sqrt{S^2 + L^2}}{L} \right] - 1 \]

Where:
- \( R_H \) = resistance (\( \Omega \))
- \( \rho \) = resistivity (\( \Omega \)-cm)
- \( L \) = anode length (ft)
- \( S \) = twice the anode depth (ft)
- \( d \) = anode diameter (ft)

OR

\[ R_H = \left[ \frac{\rho}{2\pi L} \right] \left[ \ln \left( \frac{4L^2 + 4L\sqrt{S^2 + L^2}}{dS} \right) + \frac{S}{L} - \frac{\sqrt{S^2 + L^2}}{L} \right] - 1 \]

Where:
- \( R_H \) = resistance (\( \Omega \))
- \( \rho \) = resistivity (\( \Omega \)-m)
- \( L \) = anode length (m)
- \( S \) = twice the anode depth (m)
- \( d \) = anode diameter (m)

RESISTANCE TO EARTH OF MULTIPLE HORIZONTAL ANODES

\[ R_T = \frac{R_H}{N} F \]

Where:
- \( R_T \) = resistance of multiple horizontal anodes (\( \Omega \))
- \( F \) = Anode Interference or Crowding Factor
- \( R_H \) = resistance of single horizontal anode (\( \Omega \))
- \( N \) = number of anodes

COUPLING FACTOR

\[ R = \frac{\Delta V}{\Delta I} \]

Where:
- \( R \) = coupling factor in mV / A
- \( \Delta V \) = pipe-to-soil potential shift in mV
- \( \Delta I \) = applied current A

ANODE INTERFERENCE BETWEEN ANODES (Crowding Factor)

\[ F = 1 + \frac{\rho}{\frac{\pi S R_H}{\ln[0.66 N]}} \]

Where:
- \( F \) = Anode Interference or Crowding Factor
- \( \rho \) = resistivity in (\( \Omega \)-m)
- \( R_H \) = resistance of single horizontal anode (\( \Omega \))
- \( N \) = number of anodes
- \( S \) = distance between anodes (m)
PIPE OR CABLE RESISTANCE FROM RESISTIVITY
(Pouillet’s Law)

\[ R = \frac{\rho L}{A} \]

Where:
- \( R \) = resistance (\( \Omega \))
- \( \rho \) = resistivity in ohm-cm
- \( A \) = cross-sectional area in cm\(^2\)
- \( L \) = length in cm

LENGTH OF BARE STRUCTURE RECEIVING PROTECTION

\[ L = 2d \tan 60^\circ \]

Where:
- \( d \) = perpendicular distance between anode and structure
- \( L \) = length of structure receiving protection

PIPE RESISTANCE TO REMOTE EARTH

\[ R_{p, re} = \frac{V_{on} - V_{off}}{I_t} \]

Where:
- \( R_{p, re} \) = Resistance at remote earth (\( \Omega \))
- \( V_{on} \) = \( V_{DC} \) with test current ON
- \( V_{off} \) = \( V_{DC} \) with test current OFF
- \( I_t \) = Test current

\[ R_{p, re} = \frac{r'_c}{I_t} \]

Where:
- \( R_{p, re} \) = Resistance at remote earth (\( \Omega \))
- \( r'_c \) = \( V_{DC} \) with test current ON
- \( I_t \) = Test current

TEMPERATURE CONVERSION

\[ ^\circ C = \frac{5}{9} (^\circ F - 32^\circ) \]

\[ ^\circ F = \frac{9}{5} (^\circ C + 32^\circ) \]
**WENNER SOIL RESISTIVITY**

\[ \rho = 2\pi AR \]

Where:
- \( \rho \) = soil resistivity in \( \Omega \)
- \( A \) = distance between probes in cm
- \( R \) = soil resistance \( \Omega \) \{instrument reading\}

**OR**

\[ \rho = 191.5 AR \]

Where:
- \( \rho \) = soil resistivity in ohm-cm
- \( A \) = distance between probes in feet
- \( R \) = soil resistance \( \Omega \) \{instrument reading\}

**TRUE POTENTIAL**

\[ E_{true} = \frac{V_h (1 - K)}{1 - \left| K \left( \frac{V_h}{V_l} \right) \right|} \]

Where:
- \( E_{true} \) = true potential (V)
- \( K \) = input resistance ratio \( R_t/R_h \)
- \( R_t \) = lowest input resistance (\( \Omega \))
- \( R_h \) = highest input resistance (\( \Omega \))
- \( V_l \) = voltage measured with lowest input resistance (V)
- \( V_h \) = voltage measured with lowest input resistance (V)

**TOTAL CIRCUIT RESISTANCE**

\[ R_t = \frac{R_m \cdot E_{true}}{V_m} \]

\( R_t \) = total circuit resistance

**PIPE RESISTANCE**

\[ R_{pipe} = \frac{1}{g(A_p)} \]

Where:
- \( g \) = specific coating conductance
- \( A_p \) = surface area of the pipeline

**VOLTAGE (\( E_0 \))**

\[ E_0 = I_{cp} (R_{pipe} + R_{gb,h}) + E_b \]

Where:
- \( I_{cp} \) = current output
- \( R_{pipe} \) = pipe resistance
- \( R_{gb,h} \) = calculated multiple horizontal anode resistance
- \( E_b \) = assumed back voltage
ATTENUATION

Where:
- $I_s =$ current (A) at sending end
- $E_s =$ potential (mV) at sending end
- $y =$ number of unit lengths from sending end
- $x =$ number of unit lengths from receiving end
- $I_r =$ current (A) at receiving end
- $E_r =$ potential (mV) at receiving end

\[
E = E_r \cosh(\alpha x) + R_G I_r \sinh(\alpha x)
\]

\[
E = E_s \cosh(\alpha y) - R_G I_s \sinh(\alpha y)
\]

\[
I = I_r \cosh(\alpha x) + \frac{E_r}{R_G} \sinh(\alpha x)
\]

\[
I = I_s \cosh(\alpha y) - \frac{E_s}{R_G} \sinh(\alpha y)
\]

\[
\alpha = \sqrt{rg}
\]

Where:
- $\alpha =$ attenuation constant
- $r =$ longitudinal resistance of structure (Ω)
- $g =$ conductance to earth in S

\[
r' = R_L A_S
\]

Where:
- $r' =$ specific leakage resistance (Ω·m² (Ω·ft²))
- $R_L =$ average total leakage resistance (Ω)
- $A_S =$ total surface area (m² (ft²))

\[
R_G = \sqrt{\frac{r}{g}}
\]

Where:
- $R_G =$ characteristic resistance
- $r =$ longitudinal resistance (Ω) of structure
- $g =$ conductance to earth in S

\[
R_{SO} = R_G \coth(\alpha x)
\]

Where:
- $R_{SO} =$ resistance (Ω) looking into open line

\[
R_G = \sqrt{R_{SO} R_{SS}}
\]

Where:
- $R_{SS} =$ resistance (Ω) looking into open line
AC CURRENT DENSITY

\[ i_{AC} = \frac{8V_{AC}}{\rho \pi d} \]

Where:
- \( i_{AC} \) = AC current density (A / m²)
- \( V_{AC} \) = AC volts (V)
- \( \rho \) = soil resistivity (Ω-m)
- \( d \) = holiday diameter (m)

REFERENCE ELECTRODE TEMPERATURE CONVERSION

\[ E = E_{25^\circ C/SHE}^0 + k_t (T - 25^\circ C) \]

Where:
- \( K_t \) = temperature coefficient in \( \frac{mV}{^\circ C} \)
- \( E_t \) = reference potential at temperature \( T \) in °C (SHE)
- \( E_{25^\circ C/SHE}^0 \) = reference potential at 25°C

KIRCHHOFF’S LAW

\[ V_m = \frac{R_m}{R_t} E_t \]

Where:
- \( V_m \) = voltage drop across the voltmeter
- \( R_m \) = voltmeter input resistance
- \( R_t \) = total resistance
- \( E_t \) = true potential

FARADAY’S LAW

\[ \Delta m = \frac{MQ}{zF} \]

Where:
- \( \Delta m \) = mass of dissolved metal
- \( M \) = atomic weight
- \( Q \) = transferred electric charge
- \( z \) = valance of the metal ions
- \( F \) = Faraday’s constant

MINIMUM WEIGHT OF ANY ANODE MATERIAL

\[ W = \frac{I_{cp} L C_r}{UE} \text{ or } W = \frac{I_{cp} L}{C_a UE} \]

Where:
- \( W \) = minimum weight of anode material (kg (lb))
- \( I_{cp} \) = cathodic protection (A)
- \( L \) = life of anode in years
- \( C_r \) = theoretical consumption rate of anode material in \( \frac{kg}{Amp-yr} \)
- \( C_a \) = theoretical capacity of anode material in \( \frac{Amp-yr}{kg \text{ (lb)}} \)
- \( U \) = utilization factor
- \( E \) = electrochemical efficiency
BARNES LAYER

\[ R_{L2} = \frac{R_1 R_2}{R_1 - R_2} \]

Where:
- \( R_{L2} \) = resistance (\( \Omega \)) of layer 2
- \( R_1 \) = resistance (\( \Omega \)) measured to depth \( S_1 \)
- \( R_2 \) = resistance (\( \Omega \)) measured to depth \( S_2 \)
- \( L_2 = S_2 - S_1 \)

NERNST EQUATIONS

\[ E_M = E_M^0 + \frac{RT}{nF} \ln \frac{\alpha_M^{n+}}{\alpha_M^0} \]

Where:
- \( E_M \) = metal potential
- \( E_M^0 \) = metal potential at standard conditions
- \( R \) = universal gas constant (\( J/mol-^\circ K \))
- \( T \) = absolute temperature (\(^\circ K \))
- \( F \) = Faraday’s Constant (96,500 coulombs)
- \( \alpha_M^{n+} \) = metal ion activity
- \( \alpha_M^0 \) = metal activity
- \( n \) = number of electrons transferred

CYLINDRICAL ANODES IN CIRCULAR LIQUID (WATER) TANKS

\[ R = \frac{\rho x}{2\pi L} \ln \left( \frac{d_r}{d_a} \right) \]

Where:
- \( R \) = anode to tank resistance (\( \Omega \))
- \( \rho \) = liquid (water) resistivity (\( \Omega \cdot \text{cm} \))
- \( d_r \) = tank diameter (m)
- \( d_a \) = anode diameter (m)
- \( L \) = length of single anode (cm)

SINGLE HORIZONTAL ANODE RESISTANCE (WATER) TANKS

\[ R = \frac{\rho}{2\pi l} \ln \left( \frac{l^2}{td} \right) \]

Where:
- \( d < l \) and \( t < l \)
- \( \rho \) = resistivity
- \( l \) = length of anode
- \( d \) = anode diameter
- \( t \) = anode depth below surface
Estimated Leakage Conductance of a Pipeline

\[ g = GA_{surface} \]

\[ R' = \frac{1}{g} \]

\[ R = \frac{R' \times (\text{SR average})}{1000} \]

Where:
- \( g \) = estimated leakage conductance of the pipeline in 1000 \( \Omega \)-cm soils
- \( G \) = Specific coating conductance
- \( A_{surface} \) = Surface area of the pipeline
- \( R' \) = Resistance to remote earth
- \( R \) = Resistance to remote earth in SR average soil

Input Impedance Measurement Correction

\[ E_{true} = \frac{V_h (1 - K)}{1 - K \frac{V_h}{V_l}} \]

Where:
- \( E_{true} \) = true potential in V
- \( K \) = input resistance ratio \( \frac{R_l}{R_h} \)
- \( R_l \) = lowest input resistance in ohms
- \( R_h \) = highest input resistance in ohms
- \( V_l \) = voltage measured with lowest input resistance in V
- \( V_h \) = voltage measured with highest input resistance in V
Appendix D
Table / Scale Preparation and Study Materials
**Table / Scale References**¹

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

### METRIC PREFIXES

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Factor</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>tera</td>
<td>T</td>
<td>1 000 000 000 000</td>
<td>10¹²</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>1 000 000 000</td>
<td>10⁹</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>1 000 000</td>
<td>10⁶</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>1 000</td>
<td>10³</td>
</tr>
<tr>
<td>hекто</td>
<td>h</td>
<td>100</td>
<td>10²</td>
</tr>
<tr>
<td>deca</td>
<td>da</td>
<td>10</td>
<td>10¹</td>
</tr>
<tr>
<td>(none)</td>
<td>(none)</td>
<td>1</td>
<td>10⁰</td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>0.1</td>
<td>10⁻¹</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>0.01</td>
<td>10⁻²</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>0.001</td>
<td>10⁻³</td>
</tr>
<tr>
<td>micro</td>
<td>μ</td>
<td>0.000 001</td>
<td>10⁻⁶</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>0.000 000 001</td>
<td>10⁻⁹</td>
</tr>
<tr>
<td>pico</td>
<td>p</td>
<td>0.000 000 000 001</td>
<td>10⁻¹²</td>
</tr>
</tbody>
</table>

### CONVERSIONS

<table>
<thead>
<tr>
<th>EMF</th>
<th>electromotive force – any voltage unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>E or e</td>
<td>any voltage unit</td>
</tr>
<tr>
<td>V</td>
<td>volts</td>
</tr>
<tr>
<td>mV</td>
<td>millivolts</td>
</tr>
<tr>
<td>µV</td>
<td>microvolts</td>
</tr>
<tr>
<td>I</td>
<td>any amperage unit</td>
</tr>
<tr>
<td>mA</td>
<td>milliamperes or milliamps</td>
</tr>
<tr>
<td>µA</td>
<td>microamps or microamps</td>
</tr>
</tbody>
</table>

**Resistance**

<table>
<thead>
<tr>
<th>Value</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000 volts</td>
<td>= 1 megavolt</td>
</tr>
<tr>
<td>1,000 volts</td>
<td>= 1 kilovolt</td>
</tr>
<tr>
<td>1.0 volt</td>
<td>= 1000 millivolts</td>
</tr>
<tr>
<td>0.100 volt</td>
<td>= 100 millivolts</td>
</tr>
<tr>
<td>0.010 volt</td>
<td>= 10 millivolts</td>
</tr>
<tr>
<td>0.001 volt</td>
<td>= 1 millivolt</td>
</tr>
<tr>
<td>0.000001 volt</td>
<td>= 1 microvolt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000 amperes</td>
<td>= 1 mega-ampere</td>
</tr>
<tr>
<td>1,000 amperes</td>
<td>= 1 kiloampere</td>
</tr>
<tr>
<td></td>
<td>= 1000 milliampere</td>
</tr>
<tr>
<td>0.100 ampere</td>
<td>= 100 milliampere</td>
</tr>
<tr>
<td>0.010 ampere</td>
<td>= 10 milliampere</td>
</tr>
<tr>
<td>0.001 ampere</td>
<td>= 1 milliampere</td>
</tr>
<tr>
<td>0.000001 ampere</td>
<td>= 1 microampere</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000 ohms</td>
<td>= 1 mega-ohm</td>
</tr>
<tr>
<td>1,000 ohms</td>
<td>= 1 kilo-ohm</td>
</tr>
<tr>
<td>1.0 ohms</td>
<td>= 1000 milliohms</td>
</tr>
<tr>
<td>0.100 ohm</td>
<td>= 100 milliohms</td>
</tr>
<tr>
<td>0.010 ohm</td>
<td>= 10 milliohms</td>
</tr>
<tr>
<td>0.001 ohm</td>
<td>= 1 milliohm</td>
</tr>
<tr>
<td>0.000001 ohm</td>
<td>= 1 micro-ohm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 meter</td>
<td>= 100 cm</td>
</tr>
<tr>
<td>1 meter</td>
<td>= 1000 mm</td>
</tr>
<tr>
<td>1 inch</td>
<td>= 2.54 cm</td>
</tr>
<tr>
<td>1 foot</td>
<td>= 30.48 cm</td>
</tr>
</tbody>
</table>

¹ Candidate will have access to this necessary reference material as part of the exam.
### U.S. Customary/Metric Conversion for Units of Measure
Commonly Used in Corrosion-Related Publications

| 1 A/ft² | = 10.76 A/m² |
| 1 acre | = 4,047 m² = 0.4047 ha |
| 1 Ah/lb | = 2.0149 Ah/kg |
| 1 bbl (oil, U.S.) | = 159 L = 0.159 m³ |
| 1 bpd (oil) | = 159 L/d = 0.159 m³/d |
| 1 Btu | = 1,055 J |
| 1 Btu/ft² | = 11,360 J/m² |
| 1 Btu/h | = 0.2931 W |
| 1 Btu/h·ft² | = 3.155 W/m² (K-factor) |
| 1 Btu/h·ft²·°F | = 5.678 W/m²·K |
| 1 Btuin/h·ft²·°F | = 0.1442 W/m²·K |
| 1 cfm | = 28.32 L/min = 0.02832 m³/min |
| = 40.78 m³/d |

| 1 cup | = 236.6 mL = 0.2366 L |
| 1 cycle/s | = 1 Hz |
| 1 ft | = 0.3048 m |
| 1 ft² | = 0.0929 m² = 929 cm² |
| 1 ft³ | = 0.02832 m³ = 28.32 L |
| 1 ft·lb (energy) | = 1.356 J |
| 1 ft·lb (torque) | = 1.356 Nm |
| 1 ft/s | = 0.3048 m/s |
| 1 gal (Imp.) | = 4.546 L = 0.004546 m³ |
| 1 gal (U.S.) | = 3.785 L = 0.003785 m³ |
| 1 gal (U.S.)/min (gpm) | = 3.785 L/min = 0.2721 m³/h |
| 1 gal/bag (U.S.) | = 89 mL/kg (water/cement ratio) |
| 1 grain | = 0.06480 g = 64.80 mg |
| 1 grain/ft³ | = 2.288 g/m³ |
| 1 grain/100 ft³ | = 22.88 mg/m³ |
| 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 in² | = 6.452 cm² = 645.2 mm² |
| 1 in³ | = 16.387 cm³ = 0.01639 L |
| 1 in·lbf (torque) | = 0.113 Nm |
| 1 inHg | = 3.386 kPa |

| 1 inH₂O | = 249.1 Pa |
| 1 knot | = 0.5144 m/s |
| 1 ksi | = 6,895 MPa |
| 1 lb | = 453.6 g = 0.4536 kg |
| 1 lbf/ft² | = 47.88 Pa |
| 1 lb/ft³ | = 16.02 kg/m³ |
| 1 lb/100 gal (U.S.) | = 1.198 g/L |
| 1 lb/1,000 bbl | = 2.853 mg/L |
| 1 mA/in² | = 0.155 mA/cm² |
| 1 m³/h | = 1.076 m³/min |
| 1 Mbpd (oil) | = 159 kl/d = 159 m³/d |
| 1 mile | = 1.609 km |

| 1 square mile | = 2.590 km² |
| 1 mile (nautical) | = 1.852 km |
| 1 mil | = 0.0254 mm = 25.4 μm |
| 1 MMcf/d | = 2.832 x 10⁴ m³/d |
| 1 mph | = 1.609 km/h |
| 1 mps | = 0.0254 mm/s = 25.4 μm/s |
| 1 oz | = 28.35 g |
| 1 oz fluid (Imp.) | = 28.41 mL |
| 1 oz fluid (U.S.) | = 29.57 mL |
| 1 oz/t | = 29.93 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 yd² | = 0.8361 m² |
| 1 yd³ | = 0.7646 m³ |
## Common Reference Electrodes and Their Potentials at Temperature Coefficients

<table>
<thead>
<tr>
<th>Reference Electrode</th>
<th>Electrolyte Solution</th>
<th>Potential @ 25°C (V/SHE)</th>
<th>Temperature Co-efficient (mV/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu / CuSO₄ (CSE)</td>
<td>Sat. CuSO₄</td>
<td>+0.316</td>
<td>0.9</td>
</tr>
<tr>
<td>Ag / AgCl (SJ) (SSC)</td>
<td>0.6M NaCl (3½%)</td>
<td>+0.256</td>
<td>−0.33</td>
</tr>
<tr>
<td>Ag / AgCl (LJ) (SSC)</td>
<td>Sat. KCl</td>
<td>+0.222</td>
<td>−0.70</td>
</tr>
<tr>
<td>Ag / AgCl (LJ) (SSC)</td>
<td>0.1N KCl</td>
<td>+0.288</td>
<td>−0.43</td>
</tr>
<tr>
<td>Sat. Calomel (SCE)</td>
<td>Sat KCl</td>
<td>+0.244</td>
<td>−0.70</td>
</tr>
<tr>
<td>Zn (ZRE)</td>
<td>Saline Solution</td>
<td>−0.79</td>
<td>---</td>
</tr>
<tr>
<td>Zn (ZRE)</td>
<td>Soil</td>
<td>−0.80</td>
<td>---</td>
</tr>
</tbody>
</table>

SJ – solid junction    LJ – liquid junction
Typical Consumption Rate and Capacities of Different Anode Materials in Soils or Fresh Waters

<table>
<thead>
<tr>
<th>Galvanic Anode Material</th>
<th>Theoretical Consumption Rate</th>
<th>Theoretical Capacity</th>
<th>Typical Efficiency (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg / A-yr</td>
<td>lb. / A-yr</td>
<td>A-yr / kg</td>
</tr>
<tr>
<td>Magnesium</td>
<td>3.98</td>
<td>8.76</td>
<td>0.250</td>
</tr>
<tr>
<td>Zinc</td>
<td>10.76</td>
<td>23.50</td>
<td>0.093</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.94</td>
<td>6.49</td>
<td>0.340</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impressed Current Anode</th>
<th>Theoretical Consumption Rate</th>
<th>Theoretical Capacity</th>
<th>Typical Efficiency (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-yr / kg</td>
<td>A-yr / lb.</td>
<td>%</td>
</tr>
<tr>
<td>Graphite / Carbon</td>
<td>0.1 to 1.0</td>
<td>0.22 to 2.2</td>
<td>10.1 to 1.0</td>
</tr>
<tr>
<td>High Silicon Iron</td>
<td>0.25 to 1.0</td>
<td>0.55 to 2.2</td>
<td>4.0 to 1.0</td>
</tr>
<tr>
<td>Steel</td>
<td>9.1</td>
<td>20</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Note: Platinum-clad and mixed metal oxide coated anodes are quantified by thickness of the surface film rather than by weight.

(1) Efficiency of galvanic anodes is dependent on the anode current density.
Typical Potential-pH (Pourbaix) Diagram Iron in Water at 25°C
Reference Electrode Conversion Scale

(SJ) = only solid silver chloride (AgCl) over the silver wire.

(LJ) = a silver wire surrounded by a concentrated solution of KCl.
Appendix E
Certification Requirements
Certification Requirements

Cathodic Protection Specialist (CP4) certification requirements are as follows:

1. Meet work experience and education requirements:

<table>
<thead>
<tr>
<th>Option one</th>
<th>Option two</th>
<th>Option three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor’s degree in either physical science or engineering and an advanced degree in physical sciences of engineering that required an exam, or</td>
<td>Bachelor’s degree in physical sciences or engineering and</td>
<td>2-years post high school training from math or science / trade school and</td>
</tr>
<tr>
<td>Engineering-in-Training registration or equivalent, or</td>
<td>6-years of verifiable work experience in advanced cathodic protection, including 4-years in responsible charge.</td>
<td>12-years of verifiable work experience in advanced cathodic protection, including 4-years in responsible charge.</td>
</tr>
<tr>
<td>Professional Engineer’s License.</td>
<td>And</td>
<td>And</td>
</tr>
<tr>
<td>4-years of verifiable work experience in advanced cathodic protection, including 4-years in responsible charge.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Meet prerequisite requirements:

<table>
<thead>
<tr>
<th>Prerequisite</th>
<th>Successful completion of the Ethics for the Corrosion Professional Course or an accepted training equivalent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
3. Take and successfully complete required exam(s):

| ✓ | Certification Exam | Cathodic Protection Specialist Theory Exam |
|   |                     |                                           |
| ✓ | Certification Exam | Cathodic Protection Case-Based Exam       |

4. Complete and Apply for the Certification:

| ✓ | Submit an Application | Candidates must apply for this certification by submitting an on-line application. |
|   |                      |                                                                                   |

- The application is subject to review and approval.
  - Upon successful completion of all requirements, AMPP credentialing and certification will grant the candidate industry recognition as an AMPP certified - Cathodic Protection Specialist.
  - Applications to AMPP credentialing and certification must be within 3-years of successful completion of the certification exam.
  - Successful completion of the certification exam(s) does not grant the candidate any use of the certification title.
  - Completion of Cathodic Protection Specialist Refresher Course does not grant the candidate any use of the certification title.
Appendix F

Sample Exam Questions
Examples of the Type of Exam Questions

Description of Questions

This closed-book exam consists of multiple-choice questions. The questions are based on the exam blueprint knowledge and skills needed in the CP industry for a Cathodic Protection Specialist.

Sample Theory Questions

The following provides sample questions to illustrate the formats and types of questions that will be on the exam. You should not consider your performance on the sample questions as a predictor of your performance on the actual exam. The sample questions are for illustrative purposes only.

Theory Type Questions

1. Which of the following statements describe the size (magnitude) of short-term geomagnetically induced voltage on a pipeline?

A. Unrelated to pipelines’ coating resistance
B. Dependent on the pipeline’s location relative to the geomagnetic poles
C. Inversely proportional to the length of the pipeline length
D. Remains stable regardless of the time of day

2. Which of the following electrical interference situations will have the greatest adverse effect on the structure?

A. Stray DC current pick-up of 3 mV on a bare low carbon steel pipe
B. Stray AC current density of <2 mA / cm² on steel
C. Stray current discharge from a cast iron pipe
D. Polarized potential on steel shifted from -1080 mVCSE to -880 mVCSE
3. Which of the following conditions will increase galvanic anode polarization?

**SELECT ALL THAT APPLY**

A. Increased agitation
B. Decreased Mn\(^+\) ions
C. Decreased temperature
D. Decreased surface area
Sample Case-Based Questions

The following provides sample questions to illustrate the formats and types of questions that will be on the exam. You should not consider your performance on the sample questions as a predictor of your performance on the actual exam. These sample question examples are for illustrative purposes only.

Pipeline Interference Case

Two gas pipelines come from separate processing plants, found near the seashore. They cross each other with a separation of 3.2 ft (1 m) at a location 656.2 ft (200 m) away from one of the plants. Each pipeline has an impressed current cathodic protection (CP) system. The soil surrounding both structures has:

- High chloride content
- Low resistivity (500-1000 ohm-cm)
- An ambient temperature of 77° F (25° C)

Pipeline A has a:
- Diameter of 18-in (45.7 cm)
- FBE coating
- Cathodic protection system that consists of a transformer / rectifier unit connected to a 295.3 ft (90 m) deep anode groundbed
- 25-year operating history

Pipeline B has a:
- Diameter of 20-in (50.8 cm)
- 3-layer LPE coating
- Cathodically protection system that consists of a shallow vertical anode groundbed connected to a thermo-generator.
- 30-year operating history
Stray current interference is occurring between the two structures.

- Pipeline A is picking up current from the groundbed that protects Pipeline B; and
- Pipeline A is discharging the current back to Pipeline B at the crossing point.
  - This is causing blisters (disbondment) on the coating of Pipeline A.

**Representative Drawing (not to scale)**
Case-Based Type Questions

1. What of the following mitigation measures is correct for this situation?
   A. Ensure minimal separation exists between Pipeline A and Pipeline B.
   B. Magnesium anodes connected to Pipeline B at the crossing.
   C. Zinc anodes connected to Pipeline A at the crossing.
   D. Re-application of the coating at the disbanded areas of Pipeline A.

2. What testing will confirm the interference condition fully mitigated?
   A. DCVG
   B. Coating conductance test
   C. CIS involving all current sources
   D. Soil analysis
After testing, the interference condition continues to be present. A resistance bond between the two pipeline systems is installed at the crossing. Both CP systems are being simultaneously interrupted for the data below:

### Table 1 – Resistance Bond Data

<table>
<thead>
<tr>
<th></th>
<th>Without Resistance</th>
<th>With Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ON (mV&lt;sub&gt;DC&lt;/sub&gt;&lt;sub&gt;CSE&lt;/sub&gt;)</td>
<td>OFF (mV&lt;sub&gt;DC&lt;/sub&gt;&lt;sub&gt;CSE&lt;/sub&gt;)</td>
</tr>
<tr>
<td>Pipeline A</td>
<td>-1121</td>
<td>-1202</td>
</tr>
<tr>
<td>Pipeline B</td>
<td>-1520</td>
<td>-1180</td>
</tr>
</tbody>
</table>

3. Based on the data provided in Table 1, the installed resistance bond is?

   A. reducing electrolytic current flow from Pipeline A to Pipeline B and mitigating the interference
   
   B. limiting CP current for Pipeline B and leaving it unprotected.
   
   C. is ineffective as mitigation as the potentials measured are too high after connection.
   
   D. is mitigating the interference and preventing electrolytic current discharge from Pipeline A.
Answer Key - Sample Theory Questions

1. B
2. C
3. C and D

Answer Key - Sample Case-Based Questions

1. A
2. C
3. D
Appendix G
Exam Calculator
Exam Calculator

Candidates will have access to either a digital TI-108 Standard and / or TI-30XS Scientific calculator for use during the Certification Exam. During the exam, you may have to switch or select one of these calculators for use. Candidates will not be able to use their own calculator for this exam.

Prior to attending your exam session:

✓ It is highly recommended that you review how this calculator operates and how you will use it. Other suggestions:
  
  o You may be able to find this calculator (TI-30XS) in the Google Store for Android phones to practice on.
    ▪  https://play.google.com/store/apps/details?id=calc991.calculator.scientific.xs30.t34.free&pcampaignid=web_share
    ▪  A similar version may be available for Apple IOS
  
  o You may wish to purchase a TI-30XS (approximate cost $ 20.00 US dollars)

✓ The candidate can use the exam calculator for trigonometric hyperbolic functions like:

- $\sinh x = \frac{e^x - e^{-x}}{2}$
  
  Key stroke example for $\sinh x$ is $2^{nd}$, hyperbolic (hyp), sin, enter number, ), enter.

- $\cosh x = \frac{e^x + e^{-x}}{2}$

- $\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$

- $\coth x = \frac{\cosh x}{\sinh x} = \frac{e^x + e^{-x}}{e^x - e^{-x}}$

- $\text{sech} x = \frac{1}{\cosh x} = \frac{2}{e^x + e^{-x}}$

- $\text{csch} x = \frac{1}{\sinh x} = \frac{2}{e^x - e^{-x}}$
### Standard Calculator

#### Standard Mode Functions
- Add (+)
- Subtract (−)
- Multiply (×)
- Divide (÷)
- Negative (−)
- Percentage (%)
- Square Root (√)
- Reciprocal (Inverse) (1/x)
- Store value to variable (M±)
- Access variable (MR, MC)
- Clear variable (MR, MC)

#### Scientific Calculator

#### Scientific Mode Functions
- Add (+)
- Subtract (−)
- Multiply (×)
- Divide (÷)
- Negative (−)
- Percentage (%)
- Square Root (√)
- Reciprocal (Inverse) (1/x)
- Store value to variable (M±)
- Access variable (MR, MC)
- Clear variable (MR, MC)

### Numeric Notation

#### Standard (Floating Decimal)
- Notation (digits to the left and right of decimal)
- *Example:* 123.45678
- Mode menu options: NORM, SCI, ENG

#### Scientific Notation
- (1 digit to the left of decimal and appropriate power of 10)
- *Example:* 1.234567 × 10^5
- Mode menu options: NORM, SCI, ENG

#### Engineering Notation
- (number from 1 to 999 times 10 to an integer power that is a multiple of 3)
- *Example:* 1.2345678 × 10^3
- Mode menu options: NORM, SCI, ENG
The scientific calculator might show the results of certain calculations as a fraction – 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.

Note: This following option may or may not be available based on testing center.

- 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. The Test Administrator may be able to provide you with either the scientific or non-scientific calculator model as referenced above.

As a reminder, candidates will not be able to use their own calculator for this exam.