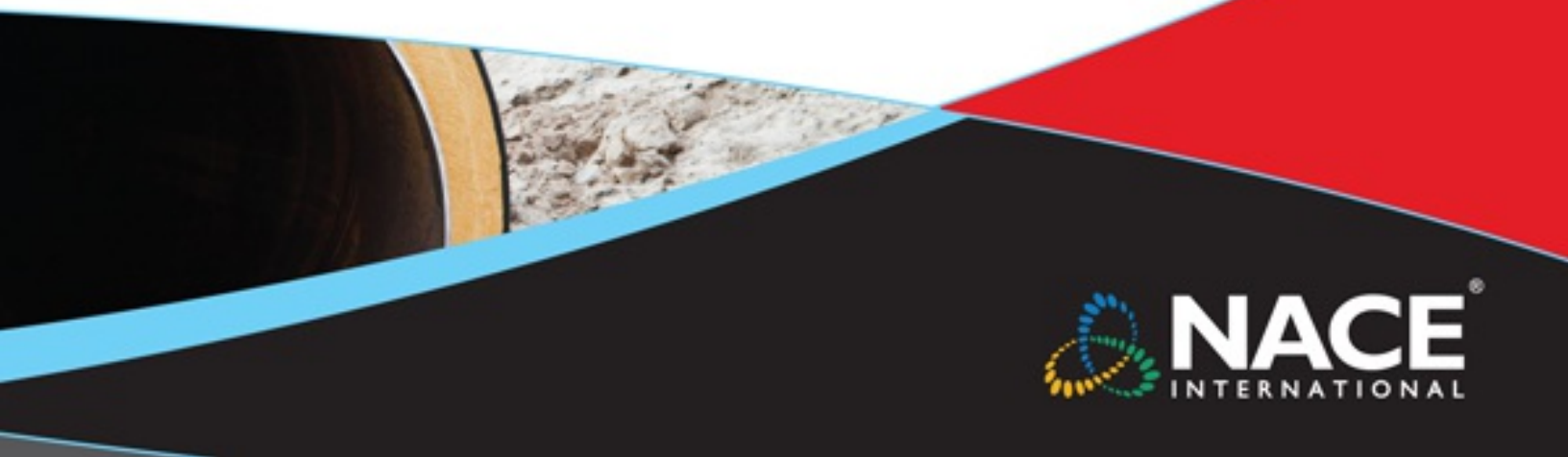




Cathodic Protection Survey Procedures Third Edition

W. Brian Holtsbaum



Cathodic Protection Survey Procedures

Third Edition

W. Brian Holtsbaum



NACE International
The Worldwide Corrosion Authority

©2016 by NACE International
All Rights Reserved
Printed in the United States of America

ISBN: 978-1-57590-332-3

Reproduction of the contents in whole or part or transfer into electronic or photographic storage without permission of the copyright owner is strictly forbidden.

Neither NACE International, its officers, directors, nor members thereof accept any responsibility for the use of the methods and materials discussed herein. No authorization is implied concerning the use of patented or copyrighted material. The information is advisory only and the use of the materials and methods is solely at the risk of the user.

NACE International
The Worldwide Corrosion Authority
15835 Park Ten Place
Houston, TX 77084
nace.org

Table of Contents

Preface

1. Rectifier Adjustment, Inspection, and Basic Troubleshooting

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Rectifier Components
- 6.0 Measurement Procedure
- 7.0 Inspection Procedure
- 8.0 Troubleshooting Procedure
- 9.0 References

2. Structure-to-Electrolyte Potential Measurement

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

Appendix A: Reference Electrode Maintenance

- 1.0 Copper-Copper Sulfate Reference Electrode (CSE)
- 2.0 Silver-Silver Chloride Reference Electrode for Use in Seawater
- 3.0 Closed Silver-Silver Chloride Reference Electrode

3. Direct Current Measurements

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

4. Diagnostic Testing (Current Requirement)

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

5. Adjustive Survey

- 1.0 Purpose
- 2.0 Tools and Equipment
- 3.0 Safety Equipment

- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

6. Commissioning Survey

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

7. Close Interval Potential Survey

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

8. Direct Current Stray Current Interference

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

9. Electrical Isolation

- 1.0 Purpose
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

Appendix A: Decision Tree for Isolation Tests

10. Road and Railroad Cased Crossings (Basic)

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

Appendix A: Decision Tree for Testing Isolation

11. Alternating Current Voltage Testing

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

12. Soil Resistivity Measurement

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

13. Well Casing

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

14. Aboveground Storage Tanks

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

15. Underground Storage Tanks

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Procedure
- 6.0 Analysis
- 7.0 References

16. Thermoelectric Generators

- 1.0 Introduction
- 2.0 Tools and Equipment
- 3.0 Safety Equipment
- 4.0 Precautions
- 5.0 Design Considerations
- 6.0 Startup and Operating Procedure for TEG
- 7.0 Startup Procedure for TEG Options
- 8.0 Troubleshooting

9.0 Maintenance
10.0 Reference

Index

Preface

When I began working in cathodic protection (CP) in 1957, there was very limited information on CP testing and design, but I had the good fortune to have Marshall Parker, author of *“Pipeline Corrosion and Cathodic Protection – A Field Manual”* as my mentor. I still have his original book that I have referenced over the years. Admittedly one had to be experienced to understand the implications of several statements in the book; but having received instruction from the author, this book was very useful. A.W. Peabody published the next very helpful text, and the second revision of this book is still widely used along with several other publications. Even with this information, many procedures had to be developed to complete field tests and to design, commission, and troubleshoot various CP systems.

Later, when training new CP recruits, I often wished that there were a book covering detailed step-by-step testing procedures for them to study and have as a reference. Persons delegated to training often have many other pressing duties, so the trainees have to supplement their knowledge from other sources. NACE is a huge resource for our industry and, hopefully, this text will be a useful addition to these resources.

Several texts and many papers that describe the theory and application of CP are referenced in this book. This document does not revisit these areas because it is assumed that the field person will have this background knowledge and is accustomed to the safe use of instruments. Instead, this manual is intended to provide a step-by-step survey procedure for certain tests related to CP. The book is divided into “stand-alone” procedures, and, as a result, some repetition does exist between these procedures. Even so, some cross-referencing between procedures is necessary.

Training as a NACE cathodic protection tester, a NACE CP technician, or equivalent is recommended as a minimum to complete these field procedures. The analysis of this work should be completed by persons having the equivalent of a NACE CP technologist or NACE CP specialists with appropriate recognition of the local jurisdiction.

The first edition of this book was focused on pipelines, although the same procedures can be adapted to many other structures. The second edition included the first set of procedures but added the different testing requirements for well casings, above-ground storage tanks, and underground storage tanks. This edition adds testing of thermoelectric generators as these power sources are very different in their operation and testing from transformer rectifiers. In addition, some updating of standards and clarification of the original text has been included in this edition on the analysis of cased road crossings.

I want to extend my gratitude to Mr. Kevin Garrity, P.E., who not only completed a technical review of the original book, but the second edition and now the third edition. Mr. Garrity is a highly

recognized expert in CP and corrosion for whom I have a great deal of respect. I am very grateful that he took time out of his busy schedule to complete this task.

Finally, I offer my encouragement to the CP testers, technicians, technologists, and specialists of the world to continue to study and work safely to gather and accept only accurate, legible, and well-documented data so as to ensure the preservation of our future infrastructure and the safety of the public.

W. Brian Holtsbaum, P.Eng.
NACE Corrosion Specialist

1

Rectifier Adjustment, Inspection, and Basic Troubleshooting

1.0 INTRODUCTION

The purpose of this procedure is to outline a plan to adjust, inspect, and perform basic troubleshooting tasks on a cathodic protection rectifier. A person must be trained and qualified to perform each specific task safely.

The basic components of a cathodic protection rectifier normally consist of the following:

- A rectifier case and panel
- Alternating current (AC) voltage input terminals (and taps if a dual-voltage input)
- AC circuit breaker mounted on the panel
- Transformer (and taps if a constant voltage rectifier)
- Rectifying elements
- Panel voltmeter and ammeter c/w shunt*
- Direct current (DC) output terminals
- AC/DC fuses*
- AC and DC surge protection*

Rectifiers for cathodic protection service can be categorized as constant voltage, constant current, and constant potential. The majority of the rectifiers in use are a constant voltage type and, as a result, most of the discussion is related to this type of rectifier. The differences between constant voltage rectifiers and the other types of rectifiers are discussed.

Table 1.1 Suggested NACE Qualifications for Specific Activities

Qualifications for Activity

CP Procedure No. 1	CP Tester or Equivalent	CP Technician, Corrosion Technician with CP, or Equivalent	CP Technologist, Corrosion Technologist with CP, or Equivalent	CP Specialist, Corrosion Specialist with CP, or Equivalent
Section 1.0	X	X	X	X
Section 2.0	X	X	X	X
Section 3.0	X	X	X	X
Section 4.0	X	X	X	X
Section 5.0	X	X	X	X
Section 6.0				
6.1.1-6.1.6	X	X	X	X
6.1.7, 6.1.8		X	X	X
6.1.9-6.1.16	X	X	X	X
6.1.17, 6.1.18		X	X	X
6.1.19			X	X
6.2	X	X	X	X
6.3.1	X	X	X	X
6.3.2		X	X	X
6.3.3	X	X	X	X
6.4	X	X	X	X
6.5	X	X	X	X
Section 7.0				
7.1	X	X	X	X
7.2	X	X	X	X
7.3.1-7.3.5	X	X	X	X
7.3.6-7.3.9		X	X	X
7.3.10	X	X	X	X
Section 8.0				
8.1		X	X	X
8.2		X	X	X
8.3	X	X	X	X
8.4		X	X	X
8.5	X	X	X	X
8.6		X	X	X
8.7.1	X	X	X	X
8.7.2		X	X	X
8.7.3-8.7.5	X	X	X	X
8.8	X	X	X	X
8.9	X	X	X	X
8.10		X	X	X
8.11	X	X	X	X
8.12	X	X	X	X

The analysis of data recorded is given in each section, as appropriate. Rectifier readings, adjustment, inspection, and troubleshooting rectifiers are often completed while working alone, and safety is paramount. A company's working alone policy must be met in these circumstances.

Although possible hazards are covered in the following sections, they cannot be expected to cover all of the hazards that one might encounter. Most companies have a process to identify hazards, determine the level of risk, and develop preventive measures for each task or project. Such a process should be followed before starting work. If the hazards change during the work, a new assessment should be completed and appropriate changes made. An example of a change in hazard is for a person to expand testing on the panel to testing behind the panel with the AC power still energized. Testing of components under live loads by qualified persons may be needed for troubleshooting. Measures that may be required could include the following:

- An increase in the qualification of the person doing the work
- A change in the work permit, as necessary
- If applicable, readdressing your working alone procedure for the job and perhaps making more frequent contact with the safety contact when the risk increases

Table 1.1 relates the suggested NACE certification for a person assigned to an activity, as described within this procedure. Certainly, those with other applicable training, such as electricians, may also be qualified.

Be alert and safe and, if hazards are encountered that are not highlighted in this procedure, formally alert others to the hazard and take steps to reduce the hazard.

2.0 TOOLS AND EQUIPMENT

Select tools and equipment that are appropriate for work on electrical components and offer the level of personal protection for the hazard involved. The following tools are the minimum that will be required:

- Multimeter capable of measuring 1 mV_{DC} to 100 V_{DC} and 250 V_{AC} (or exceeding the AC input voltage), complete with leads with insulated probes; a higher AC voltage may be necessary, depending on the AC supply voltage
- Optional clamp-on AC/DC ammeter sized for AC and DC current rating of the rectifier
- Tools, including:
 - Wrench/socket drive to fit the adjustment taps, if applicable
 - Screwdriver of the type and size for terminal strip type of tap
 - Small screwdriver sized to adjust circuit board potentiometers, if applicable
- Temporary resistance load sized for the rated current and wattage of the rectifier, if the rectifier is to be run on a temporary load
- Wrench to fit DC terminals

3.0 SAFETY EQUIPMENT

- Standard safety equipment and clothing, as required by the company's safety manual and regulations
- Electrical lock-out/tag-out equipment
- Electrically insulated clips and probe handles for meter leads
- External electrical disconnect to the rectifier
- An instrument that alerts one to high voltage without touching

4.0 PRECAUTIONS

- 4.1 *Caution!* Exposed bare terminals may be at a high voltage. See reference 9.6 for a safer rectifier design. Wherever possible, select the test that can be performed with the rectifier turned off and locked out/tagged out.
- 4.2 The person working on a rectifier must be qualified and/or hold proper certification in accordance with local regulations and company policy to conduct tests on and adjustments to the rectifiers.
- 4.3 Prior to touching a rectifier case, take a case to ground AC voltage measurement to confirm that it is safe. Alternatively, an instrument is available that, when held near the rectifier, will turn on a light if a hazardous voltage exists. Never grab a case latch or lock with your hand because a dangerous voltage will cause the fingers to contract, preventing you from letting go. Touching the case with the back of the hand has been recommended in the past because a contraction in the fingers will not lock your hand onto the case. This still allows a shock and is no longer considered a safe practice.
- 4.4 The rectifier must be turned off for all rectifier adjustments. Turn off the external AC disconnect prior to working inside the rectifier. Lock-out/tag-out equipment must be in place before working on rectifier components.
- 4.5 An inoperative rectifier is to be initially energized at a low tap setting.
- 4.6 Open the rectifier case very carefully as it may have become a residence for dangerous insects (bees, wasps, or hornets), snakes, or rodents. Entry holes should be blocked in this event.
- 4.7 For air-cooled rectifiers, ensure that all screened areas are clean and that there is proper air circulation throughout the rectifier components. Any holes in the screens should be repaired or the screen replaced.
- 4.8 For oil-cooled rectifiers, ensure that the oil is clear and to the correct level before energizing. If an older oil-cooled rectifier, confirm that the oil does not contain polychlorinated biphenyls (PCBs). If it does, do not touch the oil and wear protective clothing.
- 4.9 Review the monitoring data to determine the rectifier operating history.
- 4.10 Before adjusting a rectifier with an abnormal DC voltage or DC current output, complete an inspection of the rectifier or conduct a diagnostic investigation of the structure network, including bonds, to determine the cause.

4.11 Adjusting a rectifier without knowing the cause of the change in output may result in more damage to the structure. For example, if a structure bond is broken, increasing the current may increase stray current interference in that area.

5.0 RECTIFIER COMPONENTS

5.1 General

A general understanding of the components and their function in a cathodic protection rectifier must be known.^{9.1} Although all options may not be installed in each rectifier, the order of the components for a constant voltage rectifier is as follows:

1. AC supply
2. Primary transformer taps (if a dual-AC-voltage input)
3. AC surge protection
4. AC circuit breaker
5. Transformer
6. Secondary taps
7. AC fuse
8. Rectifying elements
9. DC fuse
10. Shunt/ammeter and voltmeter
11. DC surge protection
12. DC output terminals
13. Noise/efficiency filters (optional)

5.2 Alternating Current Supply and Primary Alternating Current Transformer Taps

- 5.2.1 The AC supply is normally brought into terminal blocks that are located at the back or bottom of the rectifier.
- 5.2.2 If the rectifier is a dual-AC-voltage input, the primary of the transformer is divided into two parts, which can either be placed in series for the higher voltage input or in parallel for the lower voltage output. Link bars or wires are located near the AC supply with directions for their position for either the lower or higher AC voltage input. Note that the rectifier can operate when set for the higher AC voltage but supplied with a lower AC voltage, except that only one-half the rated DC voltage output can be obtained. Damage to the transformer can be expected if set for the lower AC voltage input and supplied with the higher AC voltage.

5.3 Alternating Current Surge Protection and Alternating Current Breaker