Role	Responsibilities
Mechanical Designer	The Mechanical Designer is responsible for ensuring: • completion of the mechanical design • accommodation for the required support types • the piping layout and adequate bracing • all drawings are reviewed to ensure that the edge of the support is a minimum of one diameter (1d) away from any pipe girth weld and that the other requirements of this specification are met • provision of adequate space for the pipe support on the ISO sketches • provision of adequate clearances between supports and weld joints in the spool drawings.
Checker, Mechanical Designer	The Checker is responsible for ensuring that the Mechanical Designer has: • completed the mechanical design • accommodated for the required support types • verified the piping layout and ensured adequate bracing • ensured all drawings are reviewed to confirm that the edge of the support is a minimum of one diameter (1d) away from any pipe girth weld, and that the other requirements of this specification are met • provided adequate space for the pipe support on the ISO sketches • provided adequate clearances between supports and weld joints in the spool drawings
Pipe Stress Analyst	The Pipe Stress Analyst is responsible for ensuring: • integration between the mechanical and civil design/function gap • completion of the stress analysis • long-term operation through the range of operating conditions • reduction of mechanical and civil complexity, pipe stress (membrane) and nozzle loads • augmentation of piping system flexibility • compliance with all applicable codes, specifications and any manufacturer's requirements • errors, issues, concerns, bugs or other software problems used for conducting the stress analysis are addressed and actions have been taken to ensure code compliance • validation of the all software used for the piping stress analysis

Role	Responsibilities
Checker, Pipe Stress Analyst	The Checker is responsible for ensuring that the Pipe Stress Analyst has: • bridged the gap between the mechanical and civil design/function • completed the stress analysis • ensured long-term operation through the range of operating conditions • reduced mechanical and civil complexity, pipe stress (membrane) and nozzle loads • augmented piping system flexibility • complied with all applicable codes, specifications and any manufacturer's requirements • addressed errors, issues, concerns, bugs or other problems encountered with the software used for conducting the stress analysis and taken the necessary action to ensure code compliance • validated all software used for the piping stress analysis
Project Engineer (PE)	The Project Engineer (PE) is responsible for ensuring: • adherence to this specification • competency of the analyst has been demonstrated in the experience section of the stress analysis report • any and all considerations have been documented • documentation of any areas where the Project Engineer (PE) has assumed responsibility • documentation and inclusion of competency in project records
Project Manager (PM)	The Project Manager (PM) is responsible for ensuring: • adherence to this specification • competency of the analyst has been demonstrated in the experience section of the stress analysis report • any and all considerations have been documented • documentation of any areas where the Project Manager (PM) has assumed responsible • documentation and inclusion of competency in the project records

10 REFERENCES

This document relies on a number of references to regulation, industry codes and standards, general industry guidance as well as internal references. These documents are detailed below in Table 10-1, Table 10-2, and Table 10-3. Use the latest document revision, unless otherwise approved by TransCanada.

Table 10-1: Regulatory References

Organization/Document No.	Title
NEB OPR SOR/99-294	*National Energy Board Onshore Pipeline Regulations (NEB OPR)*
CFR Title 49 Part 192	*Transportation of Natural And Other Gas By Pipeline: Minimum Federal Safety Standards*
NORMA Oficial Mexicana NOM-007-SECRE-2010	*Transporte de gas natural and any amendment or errata issued by CRE*

Table 10-2: External Industry References

Organization/Document No.	Title
ALA	*ALA (2002) Guideline for the Design of Buried Steel Pipe – July 2001, American Lifelines Alliance.*
API 650	*American Petroleum Institute - Welded Tanks for Oil Storage*
API 1102	*American Petroleum Institute - Steel Pipelines Crossing Railroads and Highways*
ASME/ANSI B1.1	*American National Standards Institute - Screw Thread Standards*
ASME B31.8	*American Society of Mechanical Engineers - Gas Transmission and Distribution Piping Systems*
ASME BPVC-VIII	*American Society of Mechanical Engineers - Boiler and Pressure Vessel Code, Section VIII, Division 1, Rules for Construction of Pressure Vessels*
CEPA	*Canadian Energy Pipeline Association - Surface Loading Calculator*
CSA Z662	*Construction Safety Association - Oil and Gas Pipeline Systems*
DNV	*Structural Analysis of Piping Systems*, DNV–RP-D101, DNV October 2008.
Energy Institute Publication	*Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework*, January 2008.
Kormann, P. and Zhou, J.	*Support Spacing of Buried and Above-Ground Piping, Second International Conference, Advances in Underground Pipeline Engineering.* American Society of Civil Engineers, Bellevue, Washington, June 25-28, 1995.
Young, W.C.	*Roark's Formulas for Stress and Strain*, 6th ed., McGraw-Hill Book Co., New York, 1989.

Table 10-3: Internal References

Document No.	Title
EDMS No. 000006566	*TES-DV26-2906 Tubing and Fittings*
EDMS No. 000006457	*TES-DV31-2333 Excavating, Backfilling, and Grading*
EDMS No. 004430969	*TES-DV31-2333-US Excavating, Backfilling and Grading*
EDMS No. 007913244	*TES-ME-STRHO-GL Pipe Stress Engineering Analysis and Design of Hot Tap Branch Connections (CDN-US-MEX)*

11 DOCUMENT HISTORY

Rev.		
02	**Description**	**Effective Date**
	3.11 was updated to ensure the supports spacing for aboveground piping includes all pipe diameters	2017-Dec-01
	Rationale Statement	**Responsible Engineer**
	n/a	Michael Martens
	Impact Assessment Summary	**Document Owner**
	n/a	Michael Martens
Rev.		
01	**Description**	**Effective Date**
	New document.	2017-Apr-10
	Rationale Statement	**Responsible Engineer**
	This document was developed in order to address the following requirements: • Consolidation of specifications. The following specifications/documents have been combined into this document: – *TES-STRS-METER, Pipe Stress Analysis for Meter Stations (CDN-US-MEX)* – *TES-STRS-GBRANCH, Gas Pipelines Small Diameter Piping, Branch Connections and Attachments (CDN-US-MEX)* (TES-STRS-GBRANCH was in draft at the time of the consolidation)	Michael Martens
	Impact Assessment Summary	**Document Owner**
		Michael Martens

12 APPROVALS

APPROVALS		
Originator: Michael Martens, M.Sc., P. Eng. Mechanical & Civil Engineering	Michael G. Martens Signature	Nov. 14. 2017 Date
Reviewer: Les Tan, P. Eng. Pipeline Engineering	 Signature	Nov. 16, 2017 Date
Reviewer: Steven Foo, P. Eng. Measurement Engineering	 Signature	Nov. 14, 2017 Date
Responsible Engineer: Michael Martens, M. Sc., P. Eng. Mechanical & Civil Engineering	Michael G. Martens Signature Nov. 22. 2017 Date	PROFESSIONAL ENGINEER ALBERTA MICHAEL G. MARTENS APEGA Permit to Practice P7100
Management Endorsement: Seema Makwana, Manager Mechanical & Civil Engineering	 Signature	Nov 23 2017 Date

APPROVALS

Originator and Document Contact: Ryan M°Kay, P. Eng. Corrosion Engineer Pipe Integrity, Corrosion Prevention	Signature	Date: Feb 19, 2014
Reviewer: John Chin US Pipeline Operations Regulatory Compliance	Signature	Date
Reviewer: Charles Bucy Corrosion Specialist Pipe Integrity, Corrosion Prevention	Signature	Date: Feb. 19, 2014
Reviewer: Matt Cetiner, P. Eng Senior Engineer Pipe Integrity, Program Strategy	Signature	Date: Feb 19, 2014
Design Discipline Checker / Responsible Engineer / Approver / Engineer-in-Charge: Chad Khattar, P. Eng. Senior Engineer Pipe Integrity, Corrosion Prevention	Signature Date: April 7, 2014	APEGA Permit to Practice P7100
Management Endorsement: James Card, BSEE Manager Pipe Integrity, Corrosion Prevention	Signature	Date: Feb 19, 2014

SUMMARY

This specification outlines the criteria for cathodic protection on the Company's natural gas and hazardous liquid buried pipelines in Canada, Mexico, and the US.

TES-CP-CR Cathodic Protection Criteria Specification (CDN-MEX-US)

APPROVALS

Originator and Document Contact: Ryan M°Kay, P. Eng. Corrosion Engineer Pipe Integrity, Corrosion Prevention	Signature	Date
Reviewer: John Chin US Pipeline Operations Regulatory Compliance	John S Chin Signature	3/7/14 Date
Reviewer: Charles Bucy Corrosion Specialist Pipe Integrity, Corrosion Prevention	Signature	Date
Reviewer: Matt Cetiner, P. Eng Senior Engineer Pipe Integrity, Program Strategy	Signature	Date
Design Discipline Checker / Responsible Engineer / Approver / Engineer-in-Charge: Chad Khattar, P. Eng. Senior Engineer Pipe Integrity, Corrosion Prevention	Signature Date	APEGA Permit to Practice P7100
Management Endorsement: James Card, BSEE Manager Pipe Integrity, Corrosion Prevention	Signature	Date

SUMMARY

This specification outlines the criteria for cathodic protection on the Company's natural gas and hazardous liquid buried pipelines in Canada, Mexico, and the US.

DOCUMENT HISTORY

Rev. No.		
05	**Description**	**Effective Date**
	Addition of criteria for aboveground storage tanks bottoms. Addition of criteria for pipelines in Mexico.	2014-Feb-12
	Rationale Statement	**Responsible Engineer**
	Compliance to industry and regulatory standards. Compliance to regulatory standards in Mexico.	Chad Khattar
	Impact Assessment Summary	**Team Owner**
	Impact assessment is covered in the associated TOPs.	Pipe Integrity, Corrosion Prevention
04	**Description**	**Effective Date**
	Editorial and format changes throughout the document Addition of US piping	2012-Dec-21
	Rationale Statement	**Responsible Engineer**
		Brad Woloschuk
	Impact Assessment Summary	**Team Owner**
	This specification applies to all the Company's natural gas and hazardous liquid pipeline systems in Canada and the US	Pipe Integrity, Corrosion Prevention
03	**Description**	**Effective Date**
	Revision to criteria for pipe in MLVs 2-43, the 400 Line, & Foothills Pipelines. Clarification of criteria for all lines.	2004-Mar-25
	Rationale Statement	**Responsible Engineer**
		Garry Norton
	Impact Assessment Summary	**Team Owner**
		Engineering and Operation Services (E & OS)
02	**Description**	**Effective Date**
	Revision to criteria for pipe in MLVs 2-43, the 400 Line, & Foothills Pipelines. Clarification of criteria for all lines.	2003-Apr-01
	Rationale Statement	**Responsible Engineer**
		Wayne Corcoran
	Impact Assessment Summary	**Team Owner**
		Engineering and Operation Services (E & OS)
01	**Description**	**Effective Date**
	Revisions to criteria and editorial changes mostly associated with reference drawing updates.	2001-Dec-15
	Rationale Statement	**Responsible Engineer**
		Corey Goulet
	Impact Assessment Summary	**Team Owner**
		Engineering and Operation Services (E & OS)

00	Description	Effective Date
	New document.	2000-Sep-01
	Rationale Statement	**Responsible Engineer**
	This document was developed in order to address the following requirements: • To meet regulatory criteria	Larry Saisho
	Impact Assessment Summary	**Team Owner**
		Engineering and Operation Services (E & OS)-Engineering Analysis, Standards & Technology

BRIEF DESCRIPTION OF CHANGE

REGULATORY	
Section	**Description of Change**
	N/A
INDUSTRY STANDARDS	
Section	**Description of Change**
	N/A
GENERAL	
Section	**Description of Change**
	Editorial and format changes throughout the document
	Addition of Mexico piping

Table of Contents

List of Tables

DEFINITIONS

Term	Definition
AC	alternating current
cathodic protection (CP)	A technique used to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
CFR	Code of Federal Regulations
CGA	Canadian Gas Association
Company	TransCanada
corrosion potential	The mixed potential of a freely corroding metal surface for a reference cell in contact with the same electrolyte (also referred to as native, static or initial potential).
CP	cathodic protection
CSA	Canadian Standards Association
DC	direct current
electrolyte	A chemical substance containing ions that migrate in an electric field. Water or soils are common electrolytes for pipelines.
environment	The conditions that the structure and/or cathodic protection system operates, which might include atmospheric and/or underground conditions, stress, temperature, soil, liquids and solids.
Foothills Pipelines (FHPL)	Foothills Pipelines and facilities are located within British Columbia, Alberta and Saskatchewan.
HVAC	high-voltage AC power line
instant-off potential	The measured pipe-to-electrolyte potential taken immediately after all influencing cathodic protection systems have been de-energized. This is also referred to as the polarized potential.
IR drop	The voltage across a resistance in accordance with Ohm's Law.
mA	milliampere (10-3 amperes)
MIC	microbially-influenced corrosion
mV	millivolt (10-3 volts)
NACE	NACE International (formerly National Association of Corrosion Engineers)
NOM	Norma Oficial Mexicana
off potential	See *instant-off potential*.
on potential	The measured pipe-to-electrolyte potential with cathodic protection current applied. The components of an on potential include the native potential, polarization and IR drop.
permanent reference electrode	A half-cell, usually Cu-$CuSO_4$ that is designed to last many years in a permanently buried position.
pipe-to-electrolyte (pipe-to-soil or pipe-to-seawater) potential	The potential difference between the pipe metallic surface and the electrolyte (soil) that is measured to a reference electrode in contact with the electrolyte (soil).
polarization	The deviation from the corrosion potential of an electrode resulting from the flow of current between the electrode and the electrolyte.

Term	Definition
polarized potential	The potential across the structure or electrolyte interface to a reference electrode that is the sum of the corrosion potential and the cathodic polarization. See also *instant-off potential*.
reference electrode	A portable or permanently installed half-cell, usually Cu-$CuSO_4$, that is used to take coupon or pipe-to-electrolyte potentials from grade, inside the coupon test station's reference tube or from a permanently installed buried location.
voltage	An electromotive force or a difference in electrode potentials (volts).

1 PURPOSE

This specification outlines the criteria for cathodic protection on buried pipelines, and is intended for use by knowledgeable, trained, experienced and operator qualified (US requirement) personnel. These criteria have been developed through research, laboratory and field-testing, and an analysis of empirical data.

2 SCOPE

This specification applies to all the Company's natural gas and hazardous liquid pipeline systems in Canada, Mexico and the US.

3 REFERENCES

3.1 Regulations Codes and Standards

The jurisdictional regulations and legal requirements that apply to this specification are:

- 49 Code of Federal Regulations (CFR):
  - 192, Subpart I, Appendix D
  - 195, Subpart H
- Canadian Standards Association (CSA) Z662 (2011) *Oil and Gas Pipeline Systems*
- Norma Oficial Mexicana (NOM) NOM-007-SECRE-2010 *Natural Gas Transportation – Appendix I*

3.2 Industry Publications and References

The industry publications and references that apply to this specification are:

- Canadian Gas Association (CGA) OCC-1-2005 – Recommended Practice – Control of External Corrosion on Buried or Submerged Metallic Piping System
- CSA Standard 22.3 No. 6, Principles and Practices of Electrical Coordination Between Pipeline and Electric Supply Lines
- NACE International:
  - SP0169-2007 – *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*
  - TM0497-2002 – *Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems*

3.3 Internal References

The Company procedures, guidelines, reports and documents that apply to this specification are:

- *Memo – Justification for 900 mV Criterion and Discontinuation of the Interrupted Surveys* (EDMS No. 007759192)
- *Operations and Maintenance (O&M) Manual U.S. Hazardous Liquids Pipelines* (EDMS No. 005713585)
- *Operations and Maintenance (O&M) Manual U.S. Natural Gas Pipelines* (EDMS No. 005404490)

- *Operator Qualification Program* (EDMS No. 004504739)
- Report – *Optimization of Survey Frequency – Statistical Analysis of On-Potential Criterion* (EDMS No. 007759183)
- Report – *Pulse Generator/Wave Form Analyzer Study of Cathodic Protection Pipe to Soil Potentials of Below Ground Steel Pipelines in Alberta* (EDMS No. 007759215)
- TES-CP-IV *Mitigation of Induced AC Voltage Effects (CDN-US)* (EDMS No. 003671383)
- TOP *Cathodic Protection Single Point Survey Inspection* (EDMS No. 003671419)

4 CRITERIA APPLICATION BY REGION AND PIPELINE

4.1 General

The Company adheres to:

- Canadian Standards Association (CSA) Z662 (2011) *Oil and Gas Pipeline Systems*
- recommended practice CGA OCC-1-2005 Appendix B.2.1
- 49 CFR 192, Subpart I,
- 49 CFR 195, Subpart H criteria
- NOM-007-SECRE-2010 Appendix I

The cathodic protection criteria for steel structures are as follows:

- A negative polarized (instant-off) potential of at least 850 mV.
- A negative polarized (on) potential of at least 850 mV accounting for the voltage (IR) drops.
- A minimum of 100 mV of cathodic polarization between the structure and a reference electrode contacting the electrolyte, as measured by the formation or decay of polarization.

Unless otherwise specified, all structure-to-electrolyte potentials are measured for a saturated copper–copper sulphate reference electrode placed in contact with the soil directly above the buried pipe or, when applicable, adjacent to a pipe riser.

4.1.1 Special Considerations

Sometimes conditions exist where cathodic protection is ineffective, or only partially effective. These conditions might include such things as elevated temperatures, under disbonded coating, shielding and soil conditions. Deviation from the specification might be warranted, providing an engineering analysis demonstrates that the objectives inherent in this specification have been achieved.

Where regulations permit, other CP criteria may be used in site-specific locations where corrosion control can be demonstrated through an engineering analysis and supported by Pipe Integrity.

Microbially Influenced Corrosion

The criteria for areas with microbially influenced corrosion (MIC) shall be to achieve a more negative polarized (instant-off) potential of -950 mV relative to a saturated copper–copper sulphate electrode. If this criterion is not met, tests must be done to determine if at least 150 mV polarization is achieved. Note: For Mexico the 150 mV polarization criterion does not apply.

Aboveground Storage Tanks

The 100 mv "shift" criteria listed in Section 4.1 may be more suitable for aboveground storage tank bottoms. Achieving -850 mV "OFF" may be impractical and could cause electro-osmotic drying under the tank resulting in irreversible damage to the CP system and CP environment.

4.2 Alberta

This section applies to the pipelines in Alberta, including Foothills Pipelines.

The criterion for the operation and maintenance of cathodic protection shall be to achieve an "on" potential more negative than -950 mV, as per the Report – *Pulse Generator/Wave Form Analyzer Study of Cathodic Protection Pipe to Soil Potentials of Below Ground Steel Pipelines in Alberta*, except as noted in the following clauses.

Where an on potential of -950 mV cannot be met, the criteria outlined in Section 4.1 applies.

4.2.1 Single Non-Looped Extruded Polyethylene Coated Pipelines

The criterion shall be to achieve an on potential more negative than -1000 mV, relative to a saturated copper–copper sulphate electrode on the test lead furthest from the groundbed. The test lead furthest from the groundbed shall be monitored annually. The remaining test leads shall be monitored at least every five years, and shall achieve an on potential more negative than -950 mV. For more information, refer to TOP *Cathodic Protection Single Point Survey Inspection*.

4.2.2 Peace River Mainline

Due to known areas of MIC on a tape-coated pipeline in this area, the criteria shall be to achieve an on potential more negative than -1000 mV. Where instant-off potentials are practical, a more negative polarized (instant-off) potential of -950 mV relative to a saturated copper–copper sulphate electrode shall be the criterion. If this criterion is not met, tests must be done to determine if at least 150 mV polarization is achieved in MIC areas.

4.2.3 Western Alberta System

For the Western Alberta System (WAS) extension north of Valve 1024, the criteria shall be to achieve an on potential between -1000 mV and -1200 mV with reference to a saturated copper–copper sulphate electrode, if an instant-off potential or depolarization test result cannot be obtained.

4.3 Mainline

4.3.1 Saskatchewan and Manitoba

The criterion applies to the Mainline pipeline from Mainline Valve 1 (MLV 1) to Mainline Valve 43 (MLV 43) inclusive, and the 400 lines.

The criterion for the operation and maintenance of cathodic protection shall be to achieve an on potential more negative than -900 mV, as per the Memo – *Justification for 900 mV Criterion and Discontinuation of the Interrupted Surveys* and theReport – *Optimization of Survey Frequency – Statistical Analysis of On-Potential Criterion.*

Where an on potential of -900 mV cannot be met, the criteria outlined in Section 4.1 applies.

4.3.2 Foothills Saskatchewan

Zone 9 Mainline and Loops

The criterion for the operation and maintenance of cathodic protection shall be to achieve an on potential more negative than -950 mV.

Where an on potential of -950 mV cannot be met, the criteria outlined in Section 4.1 applies.

Zone 9 Compressor Stations, Sales Meter and Foreign Crossings

The criterion for the operation and maintenance of cathodic protection shall be to achieve an instant-off potential more negative than -850 mV, relative to a saturated copper–copper sulphate electrode.

4.4 Mexico

This section applies to the pipelines in Mexico. In addition to the criteria set forth in Section 4.1, the maximum voltage should not exceed -2.5 volts in powered conditions in relation to a reference electrode, or -1.1 volts in a condition of instant shutdown.

4.5 Off-shore Facilities

The cathodic protection criteria for off-shore facilities are as follows:

- A negative polarized (instant-off) potential of at least 800 mV referenced to a silver-silver chloride reference cell.
- A negative polarized (on) potential of at least 800 mV accounting for the voltage (IR) drops referenced to a silver-silver chloride reference cell..

4.6 A minimum of 100 mV of cathodic polarization between the structure and a reference electrode contacting the electrolyte, as measured by the formation or decay of polarization.Alternating Current Voltages

For pipelines near an high-voltage alternating current (HVAC) powerline where personnel might be in contact with the pipeline and associated facilities, the maximum safe voltage, for steady-state conditions on a pipeline is 15 volts AC (see CSA 22.3 No.6, and CFR 192 and CFR 195). Refer to TES-CP-IV *Mitigation of Induced AC Voltage Effects (CDN-US)* for further information.

4.7 Summary

The above criteria for all regions of the Company's natural gas and hazardous liquid pipeline systems in Canada, Mexico and the US are summarized in Table 4-1. Note: all of the general criteria detailed in Section 4.1 apply, but are not detailed in the table below.

Table 4-1: Summary of the Company's Cathodic Protection Criteria

Location	Criterion	Survey Requirement
British Columbia (BC), Canadian Montana Lateral, and WAS from Burton Creek Lateral to Alberta–BC Border (including FHPL)		
All lines, stations.	Minimum -850 mV "off"	Perform "on/off" survey.

Location	Criterion	Survey Requirement
Alberta		
Peace River mainline and areas of known MIC.	Minimum –1000 mV "on"	Perform "on" survey.
WAS Extension North of Valve 1024.	Between –1000 mV and –1200 mV "on"	Perform "on" survey.
In Wildrose Alberta, small diameter non-looped extruded polyethylene lines.	Minimum –1000 mV "on" (annual) Minimum -950 mV "on" (5 year full survey)	Perform "on" survey. Refer to Section 4.2.1 (single-point survey required).
All other lines (including FHPL), stations.	Minimum –950 mV "on"	Perform "on" survey.
Aboveground storage tanks	Minimum –850 mV "off"	Perform "on/off" survey.
Mainline: MLV 1 to MLV 43 and the 400 Lines		
All lines and sales meter stations (SMSs), except MLV 16.	Minimum –900 mV "on"	Perform "on" survey. At foreign crossings, interrupt closest upstream and downstream rectifiers.
Foothills Saskatchewan mainline and loops.	Minimum -950 mV "on"	Perform "on" survey. At foreign crossings, interrupt closest upstream and downstream rectifiers.
MLV 16 (including SMSs).	Minimum –900 mV "on"	Perform "on/off" survey.
Stations and foreign crossings (including Foothills).	Minimum –850 mV "off"	Perform partial "on/off" survey. Only interrupt rectifiers within the station yard.
Mainline: MLV 43 & Eastward		
All lines, MLVs, SMSs and stations.	Minimum –850 mV "off"	Perform "on/off" survey.
United States: ANR, North Baja, Bison, Great Lakes, GTN, Keystone, Northern Border, and Tuscarora		
All lines, MLVs, SMSs, aboveground storage tanks and stations.	Minimum –850 mV "off"	Perform "on/off" survey.
Mexico: Guadalajara and Tamazunchale		
All lines, MLVs, SMSs, aboveground storage tanks and stations.	Minimum –850 mV "off"	Perform "on/off" survey.

5 QUALITY MANAGEMENT

5.1 Specification Deviations

When there is a request to vary from the specification as documented, an approved Management of Change is required. All deviations are to be reviewed and approved by the specification owner before the variance can proceed on the deliverable, data or report. In no case will a variance be granted that causes an applicable regulatory requirement to be violated.

5.2 Noncomformance Management

All nonconformances to this specification will be reviewed by the Company and dispositioned by the vendor.

TES-CP-MS Cathodic Protection Material Specification (Cdn-US)

Item ID: 003670944 Rev.: 05 Status: Issued Effective Date: 2013-JAN-21

APPROVALS

Originator: Ryan McKay, P. Eng Corrosion Engineer Pipe Integrity, Corrosion Prevention	Signature	Jan 22, 2013 Date
Reviewer: Chad Khattar, P. Eng Senior Engineer Pipe Integrity, Corrosion Prevention	Signature	Jan 23 2013 Date
Reviewer: Brent McKinnon Program Management U.S. Pipeline Maintenance Projects	Signature	Jan 24 2013 Date
Responsible Engineer/Approver/ Engineer-in-charge/Document Contact: Brad Woloschuk, P. Eng Senior Engineer Pipe Integrity, Corrosion Prevention	Signature FEBRUARY 01, 2013 Date	PROFESSIONAL ENGINEER 2013-02-01 APEGA Permit to Practice P7100
Accountable Manager: James Card, BSEE Manager Pipe Integrity, Corrosion Prevention	Signature	1/28/13 Date

SUMMARY

This specification establishes the requirements for cathodic protection materials for the installation of cathodic protection facilities for Company gas and hazardous liquid pipeline systems in Canada and the United States.

BRIEF DESCRIPTION OF CHANGE

REGULATORY

- N/A

GENERAL

- Editorial and format changes throughout the document.

TABLE OF CONTENTS

List of Tables

DEFINITIONS

Terms	
ACSR	aluminum conductor steel-reinforced cable
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
CEC	Canadian Electrical Code
CSA	Canadian Standards Association
ECTFE	ethylene chlorotrifluoroethylene
HMW-MDPE	high molecular weight high density polyethylene
HMWPE	high molecular weight polyethylene
IEC	International Electrotechnical Commission
NACE	NACE International
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
RMU	remote monitoring unit
The Company	TransCanada PipeLines
XLPE	cross-linked polyethylene

Tools and Applications	
Incident and Issue Tracking (IIT)	An electronic database tool used to report incidents and issues involving employees, contractors and third parties.
FileNet-EDMS	The Company's web-based electronic document management system.

1 PURPOSE

This specification establishes the requirements for cathodic protection materials for the installation of cathodic protection facilities for the Company's buried pipeline systems in Canada and the United States.

This specification shall be used:

- By Company employees and all prime and Subcontractors employed by the Company
- In all activities related to cathodic protection, including design, construction, operations and maintenance

Materials supplied shall meet all requirements of this specification and any additional requirements on the applicable request for quotation, purchase order and applicable Company standard drawings.

Before a material is added to the Approved Material List, it shall be reviewed and approved by the Company's Cathodic Protection Engineering personnel.

2 SCOPE

This specification applies to materials for cathodic protection for the Company's gas and hazardous liquid pipeline systems in Canada and the United States.

3 REFERENCES

3.1 Regulations, Codes and Standards

The jurisdictional regulations and legal requirements that apply to this procedure are:

- 49 Code of Federal Regulations (CFR):
  - 192, Subpart I
  - 195, Subpart H
- Canadian Standards Association (CSA):
  - Z662-11 *Oil and Gas Pipeline Systems*
  - C22.1 Canadian Electrical Code (CEC), *Part I, Safety Standard for Electrical Installations (Section 80)*
  - C22.2 No. 107.1, *General Use of Power Supplies*
  - C22.2 No. 131, *Type TECK 90 Cable*
  - C22.2 No. 75, *Thermoplastic-Insulated Wires and Cables (Tri-National standard, with UL 83 and NMX-J-010-ANCE*, 2008
  - Special Publication SPE-1000-94, *Model Code for the Field Evaluation of Electrical Equipment*
- National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)

3.2 Industry Publications and References

The industry publications and references that apply to this procedure are:

- NACE International:
  - SP0169-2007, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*
  - SP0572-2007, *Design, Installation, Operations, and Maintenance of Impressed Current Deep Anode Beds*
- American Society for Testing and Materials (ASTM) International:
  - G97, *Standard Test Method for the Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications*
  - B265, *Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate*
  - B418, *Standard Specification for Cast and Wrought Galvanic Zinc Anodes*
  - B843, *Standard Specification for Magnesium Alloy Anodes for Cathodic Protection*
  - A518, *Standard Specification for Corrosion-Resistant High-Silicon Iron Castings*
  - D1248, *Standard Specification for Polyethylene Plastics Molding and Extrusion Materials For Wire and Cable*
  - D2000, *Standard Classification System for Rubber Products in Automotive Applications*
  - B3, *Standard Specification for Soft or Annealed Copper Wire*
  - B8, *Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*
  - D293, *Standard Test Method for the Sieve Analysis of Coke*
  - D709, *Standard Specification for Laminated Thermosetting Materials*
  - D3172, *Standard Practice for Proximate Analysis of Coal and Coke*
  - D3173, *Standard Test Method for Moisture in the Analysis Sample of Coal and Coke*
  - D3174, *Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal*
  - D3178, *Standard Test Method for Ultimate Analysis for Hydrogen Content*
  - D5142, *Standard Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures*
  - D4239, *Standard Test Methods for Sulphur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods*
  - D4749, *Standard Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size*
- American Society of Mechanical Engineers (ASME) B16.21, *Nonmetallic Flat Gaskets for Pipe Flanges*
- International Electrotechnical Commission (IEC):
  - 60060-1, *High-voltage test techniques, Part 1: General definitions and test requirements*
  - 60060-2, *High voltage test techniques, Part 2: Measuring systems*
  - 60228, *Conductors of Insulated Cables*

- National Electrical Manufacturers Association (NEMA):
  - WC70/ICEA S-96-658, *Thermoplastic Insulated Wire & Cable for Transmission & Distribution*
  - Standard Publication No. MR 20-1958 (reaffirmed by NEMA 1971) – *Semiconductors, Rectifiers, Cathodic Protection Units*
  - Standard Publication No. MR 250-1979 (including Rev No. 1 December 1980), *Enclosures for Electrical Equipment (1000 Volts Maximum)*

3.3 Internal References

The Company procedures, guidelines, reports and documents that apply to this specification are:

- *Operations and Maintenance (O&M) Manual U.S. Natural Gas Pipelines* (EDMS No. 005404490)
- *Operations and Maintenance (O&M) Manual U.S. Hazardous Liquids Pipelines* (EDMS No. 005713585)
- *Operator Qualification Program* (EDMS No. 004504739)
- TEP-INT-MOC *Pipe Integrity Management of Change Procedure* (EDMS No. 006425143)

4 ROLES, RESPONSIBILITIES AND QUALIFICATIONS

4.1 Manufacturer's Responsibilities

4.1.1 Requirements for All Materials

Following are material requirements:

- The manufacturer shall be on the Company's cathodic protection Approved Materials List (see APPENDIX A) for the production of cathodic protection materials.
- At the request of the Company Representative, cathodic protection material may be retained by the Company for evaluation to ensure the material conforms to this specification.
- The Company shall have the right to review the manufacturer's work at any time.
- The manufacturer shall supply to the Company at the time of quotation any exceptions or alternatives to this specification.

4.1.2 Preproduction Provisions

For isolation sets, the manufacturer shall submit to the Company the following:

- For each sleeve size, the inside diameter (ID), outside diameter (OD), thickness and length (all in millimetres or inches), material type, and the dielectric strength (volts per 1 mm or inch).
- For each washer type and size, the ID, OD and thickness (all in millimetres or inches), material type, and if applicable, dielectric strength (volts per 1 mm or 1 inch).

For rectifiers, the manufacturer shall submit to the Company:

- A certification that the rectifier meets the requirements of this specification
- A nationally recognized testing laboratories (NRTL) approval certification
- A circuit diagram and dimensions of the enclosure

For:

- Thermoelectric generators (TEG), the manufacturer shall certify that the TEG(s) meet the requirements of this specification, and provide a diagram showing the components of the TEG(s) and dimensions of the enclosure(s).
- Calcined coke, the manufacturer shall submit a datasheet detailing the chemistry and other requirements in Section 5.3.
- Cables, the manufacturer shall certify that the cable meets the requirements of the CEC or the NEC (as applicable), ASTM D 1248 or NACE Standard SP0572 and this specification.
- Each monolithic isolator, the manufacturer shall submit to the Company the fabrication drawing and the production schedule.
- Remote monitoring equipment and rectifiers, the manufacturer shall supply laminated electrical schematic drawings with each rectifier, and copies shall be submitted to the Company.

4.2 Company Responsibilities

The Company representative shall obtain all QA/QC documents for materials to be installed, in accordance with the project description.

5 CATHODIC PROTECTION MATERIALS – REQUIREMENTS

5.1 Anodes

5.1.1 High-Potential Magnesium Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The anode shall conform to ASTM B843, Grade M1C.
- The anode shall have a minimum efficiency of 43%, when tested in accordance with ASTM G97.
- The mass of the anode, anode dimensions and package dimensions shall be as specified on the purchase order.
- A galvanized steel core shall be cast at least 75% of the full anode length.

Lead Wire

See Section 5.2.2, Magnesium Anodes or Zinc Anodes.

Backfill

See Section 5.3.5.

Markings

The anode type, mass (kg/lbs) and Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., High Potential Magnesium, 15 lbs, TES-CP-MS [Cdn-US], 2012/10/01).

Shipping

Shipping specifications are as follows:

- The backfill package shall consist of a cotton bag or wettable (e.g., no wax or plastic coated) cardboard tube with the dimensions as specified on the purchase order.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.2 Zinc Ribbon

Chemical Composition, Mass and Dimensions

Chemical composition, mass and dimension specifications are as follows:

- The chemical composition of zinc ribbon shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.
- The anode shall be manufactured by extrusion with a continuous centered 1/8" galvanized steel core.

Lead Wire

Not applicable.

Backfill

Not Applicable.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the reel (or other device anode is wrapped around):

- manufacturer
- anode model
- ribbon type
- cross section (X millimetres [inches] x Y millimetres [inches])
- length (metres or feet)
- Company specification and revision date

For example, "manufacturer", aaa, zinc ribbon, 12 mm x 15 mm, 500m, TES-CP-MS (Cdn-US), 2012/10/01.

Shipping

Shipping specifications are as follows:

- The ribbon shall be packaged in a manner to allow for ease of shipping.
- The zinc ribbon shall be prepared for shipment and storage in such a manner that it will not be exposed to weather or water, as directed by the supplier.

5.1.3 Zinc Grounding Cells

Chemical Composition, Mass and Dimensions

The chemical composition for the zinc shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.

Lead Wire

See Section 5.2.2, Magnesium Anodes or Zinc Anodes.

Backfill

See Section 5.3.5.

Markings

The anode type, mass (kilograms or pounds) and the Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., Zinc Grounding cell, 7.7 kg, TES-CP-MS [Cdn-US], 2012/10/01).

5.1.4 Silicon-Chromium Cast Iron Anodes

Chemical Composition, Mass and Dimensions

The following clauses shall apply to both tubular and stick anodes castings:

- The anode shall be chill cast or equal, from an alloy conforming to ASTM A518 GR3.
- Each anode shall be supplied free from casting defects, porosity, voids and fissures. The anode surface shall be free from adhering foundry sand or mould release agents.
- The anode mass and anode dimensions shall be as specified on the purchase order or Company standard drawings.
- All anode manufacturers shall be approved by the Company.

Lead Wire

See Section 5.2.2, Tubular Anodes.

Backfill

See Sections 5.3.1 to 5.3.4.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- anode type
- anode mass (kilograms or pounds)
- anode OD (millimetres or inches)
- length (millimetres or inches)
- Company specification
- revision date

For example, "manufacturer", aaa, stick, 20 kg, 50 mm, 1520 mm, TES-CP-MS (Cdn-US), 2012/10/01.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.5 Continuous Polymer Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical compositions, mass and dimensions are as follows:

- Continuous polymer anodes shall be constructed as stranded American Wire Gauge (AWG) 6 annealed copper conductors with a conductive polymer jacket (rather than an insulating polymer jacket).
- The conductive polymer jacket shall provide a moisture-proof barrier to protect the copper cable.
- The conductive polymer jacket shall be capable of continuously discharging a current of 50 mA per linear metre (15 mA per linear foot) of anode material for a minimum of twenty years.

Lead Wire

See Section 5.2.3.

Backfill

See Section 5.3.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- polymer type
- length (metres or feet)
- Company specification
- revision date

For example, "manufacturer", aaa, carbon impregnated polyethylene, 500m, TES-CP-MS (Cdn-US), 2012/10/01).

Shipping

Shipping specifications are as follows:

- As specified on the purchase order or Company standard drawings, continuous polymer anodes may be supplied bare (by itself) or prepackaged in a 38 mm (1½ inch) diameter flexible mesh tube.
- Prepackaged conductive polymer anodes shall contain a high-grade coke backfill conforming to Section 5.3. The conductive polymer anode shall be centered within the flexible mesh tube.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.6 Canister Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- Only tubular anodes shall be placed in canisters. Anodes shall meet the requirements of Section 5.1.4 before assembly.
- The canisters shall be manufactured as follows:
  - spiral corrugated perforated galvanized steel – 28 gauge minimum
  - diameter – 225 to 235 mm (8 inches) minimum
  - length – anode length + 600 mm (2 feet)
  - plywood end caps – 16 mm (¾ inch) minimum thickness

Assembly

High silicon chromium anode assemblies shall be canistered as follows:

- With the bottom end cap in place, the anode shall be centered in the can and filled with coke, such that the anode has 200 mm (8 inches) of coke beyond each anode end.
- Calcined petroleum coke, as per Section 5.3, shall be mechanically compacted around the anode.
- An inner plywood cap shall be secured to the can immediately above the compacted calcined petroleum coke.
- A steel bolted eyelet shall be attached to the top inner plywood cap, and the lead wire shall exit through a close fitting hole to the side of center.
- The wire shall be coiled and placed on the inner cap.
- A top end cap, with access to the coiled wire, shall be attached to protect the coiled wire during shipping.

Refer to Company standard drawings.

Shipping

Shipping specifications are as follows:

- All canned anodes shall be securely attached to a pallet in such a manner to avoid damage to the anodes or canisters.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.7 Graphite Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The chemical composition for the graphite shall be GR060CP grade or equal.
- The graphite shall be treated with wax or resin, as specified on the purchase order.
- Center connections shall be tested to verify the connection falls below 0.004 ohms (4 milliohms).

Lead wire

See Section 5.2.2.

Backfill

See Section 5.3.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.8 Mixed Metal Oxide Anodes – MMO Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass, and dimensions are as follows:

- The chemical composition of titanium shall conform to ASTM B265.
- The anode rating per foot and length is as specified on the purchase order.

Lead wire

See Section 5.2.2.

Backfill

See Section 5.3.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid damage during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.2 Cable

5.2.1 General

General specifications for cable are as follows:

- All cable shall be rated for use from -40°C to 60°C, or -40°F to 140°F.
- Cables shall have an underground rating.
- All cables shall conform to ASTM B3 and ASTM B8 or IEC 60228.
- All cables shall be rated to handle 600 V direct current.
- Unless specified, the cable size, cable length and cable colour shall be as indicated on the purchase order or Company standard drawings.
- The outer insulation layer shall be marked to include the manufacturer, conductor size and number of strands (e.g., "manufacturer," AWG 4, 7/S).

5.2.2 Anode Lead Wire

Magnesium Anodes or Zinc Anodes

Specifications for magnesium anodes or zinc anodes are as follows:

- The anode lead wire shall be a continuous seven stranded, AWG 10 or larger (unless specified on the purchase order) annealed copper conductor, minimum 3 metres (10 feet) long. The insulation shall be blue for magnesium anodes and white for zinc, unless specified on the purchase order, to be consistent with site specific installations. The insulation shall be RWU90 cross-linked polyethylene (XLPE), or direct burial high molecular weight polyethylene (HMWPE).
- Lead wires shall be attached to the galvanized steel core by silver solder, and the connection shall be made moisture-proof by encapsulating the connection with an electrical sealing compound. The lead wire connection shall withstand a steady load pull of 200 kg (440 lbs) without separation from the anode.
- For zinc grounding cells, the lead wire shall be a continuous seven stranded, AWG 2 or larger annealed copper conductor, minimum 3 metres (10 feet) long. The insulation shall be white for zinc anodes. The insulation shall be RWU90 XLPE, or direct burial HMWPE. The wire shall be compression connected to the anode core and sealed with an electrical sealing compound.
- If magnesium anodes are to be used with solar panels, the cables shall meet the requirements of an impressed current system.

Tubular Anodes

Specifications for tubular anodes are as follows:

- For deep-well anode leads, see Deep Anode Lead Cable in Section 5.2.3.
- Unless otherwise specified, anode leads shall be AWG 8.
- The anode lead wire shall be a continuous conductor of AWG 8 with a seven-stranded copper conductor. The insulation shall be black, and shall consist of at least 2.78 mm (0.1 inch) of high molecular weight, medium density polyethylene that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9.
- The use of lead (Pb) anchors for cable connections is not permissible.
- Attachment of the lead wire to the anode shall be made by a permanent compression connection. The lead wire connection shall be centered inside the anode.
- The anode lead wire shall be visually inspected before attaching the anchoring assembly, to ensure that none of the copper strands have been scored or scratched. Before applying the compression crimp connector, the copper strands of the lead wire shall be manually twisted into a compact spiral to facilitate even distribution of stress to each of the strands.
- The lead wire MDPE or HMWPE jacket surface shall be roughened for 50 mm (2 inches) anode end to improve adhesion to the sealant.

- The lead wire center connection to the anode shall be sealed using ArmorThane STS-200 Side A and Side B cured polyurethane, or approved equivalent. The sealant thicknesses shall be a minimum of 150 mm (6 inches) both above and below the center connection. The depths (millimetre or inches) of top and bottom epoxy seals shall be measured by probing and recorded directly on the outside of all anodes with a permanent marker. In addition, date and distributor name shall be marked with a permanent marker on the anode.
- The seller to the Company shall perform non-destructive random checks of sealant levels, as quality assurance that sealant levels marked on the outside of the anodes are correct. Records of quality assurance checks completed shall be sent to the Company before shipping. If any non-conformances are indicated, all other anodes having the same assembly date and manufacturer shall be inspected and repaired as necessary to meet this specification.
- The lead wire connection to the anchoring assembly shall be destructively tested before and at the end of each production day, to ensure compression equipment is operating satisfactorily. In addition, each anode shall be manually (i.e., by hand) pull tested by the technician after the mechanical connection to the anode is completed. Pull tests shall not be performed after sealant application.
- All anode leads shall be tested to ensure electrical continuity to the anode after sealant has cured and before shipping.
- Anode leads shall be attached in accordance with anode manufacturer's recommended mechanical procedures. The anode manufacturer shall provide a lead wire installation procedure to the anode supplier and Company. In case of conflict between this specification and manufacturer's recommended procedures, this specification shall apply.
- Attachment of the anode lead wire shall only be performed by previously approved distributors.

5.2.3 Other Cable

Negative Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class D, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

Positive Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class C, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, and shall be high molecular weight, medium density polyethylene that conforms to:

- ASTM D 1248 Type II, Class D, Category 4, Grade D6
- ASTM D 1248, Type I, Class C, Category 5, Grade E5
- J1 or ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The cable shall be tested for cold bend at -30°C (-22°F) and impact at -40°C (-40°F). Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2. The minimum thickness of the HMWPE shall be 4 mm (0.16 inch).

Note: Cable colour should be consistent with specific installation practices.

Alternatively, an additional 1.52 mm (0.06 mm) thick red PVC outer jacket shall be extruded over the 2.78 mm (0.1 inch) HMWPE black cable.

Armoured Cable

Single conductor armoured cable shall have stranded annealed copper wire. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene (HMW-MDPE) that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9. Minimum thickness of the HMW-MDPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and 19 strands for cable sizes larger than AWG 2. The middle layer shall consist of aluminum armour.

Multiconductor armoured cable shall be Teck 90, conforming to CSA C22.2 No. 131, or an ASTM equivalent. The middle layer shall consist of aluminum armour.

Single Jacket Cable – Test Leads and Sacrificial Anodes

Single-jacket cable shall be stranded copper conductor in sizes not larger than AWG 6. Insulation shall be RWU-90 XLPE (-40°C/-40°F), with a thickness of 1.83 mm (5/64") and conform to CSA C22.2 No. 38, or an ASTM equivalent.

Deep Anode Lead Cable

To resist chemical attack, cable for deep anode bed applications shall be ethylene chlorotrifluoroethylene (ECTFE) fluoropolymer (HALAR or equivalent) jacketed.

Dual-extrusion HALAR cable shall have stranded annealed copper wires. Insulation shall be a homogenous wall of natural ECTFE fluoropolymer (HALAR or equivalent) extruded over the conductor. Insulation shall conform to NEMA WC70/ICEA S-96-658 and the outer insulation shall be high molecular weight polyethylene conforming to ASTM D 1248, Type 1, Class C, Category 5, Grades E5 and J1. Average thickness of the HALAR insulation shall be 0.5 mm (0.02 inches). Minimum thickness at any point shall be not less than 90% of the specified average thickness. Average outer jacket insulation thickness shall be 1.6 mm (0.06 inches). The minimum thickness shall be not less than 80% of the specified average thickness. The completed cable shall be tested in accordance with the requirements of NEMA WC70/ICEA S-96-658.

5.2.4 Summary

Table 5-1 provides a summary of the cable specifications.

Table 5-1: Summary Cable Specifications

Description	Insulation Description	Insulation Thickness (min mm)	Insulation Thickness (min inch)	Colours Specified
Armoured cable, AWG 2, 4	Inner: HMW-MDPE	2.78	7/64	N/A
	Middle: Aluminum armour	Standard	Standard	N/A
	Outer: Colored PVC	1.52	1/16	Per site specific construction drawings
AWG 2, 4 mainline positive cable (Option 1)	Inner: HMW-MDPE	2.78	7/64	Black
	Outer: Coloured PVC	1.52	1/16	Red
AWG 2, 4 mainline positive cable (Option 2)	HMW-MDPE	4.00	5/32	Red
AWG 2, 4 Alberta positive cable	HMW-MDPE	2.78	7/64	Black
AWG 4 negative cable	HMW-MDPE	2.78	7/64	White
Single jacket cable AWG 6	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings
Single jacket cable AWG 8	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings

Table 5-1: Summary Cable Specifications (Cont'd)

Description	Insulation Description	Insulation Thickness (min mm)	Insulation Thickness (min inch)	Colours Specified
Single jacket cable AWG 10, 12	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings
Dual extrusion (HALAR or approved equivalent)	Inner: ECTFE fluoropolymer	0.5	2/100	Per site specific construction drawings
	Outer: ASTM D 1248 (colored)	1.6	1/16	Per site specific construction drawings
No. 2 ACSR	N/A	N/A	N/A	Per site specific construction drawings

For shipping, all cables (i.e., anode lead wires, cable spools and test station wires) shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.2.5 Splice Kits

Splice kit specifications are as follows:

- Epoxy splice kits shall contain a plastic mold, which completely surrounds the crimped cable connection and seals the cables such that the epoxy does not leak out during the cure time. Kits shall contain tape to seal the points at which the cables enter the plastic mold. Epoxy mixture shall cure in 30 minutes at temperatures of 15°C (60°F) and above. Kits shall also be rated up to 1000 volts.
- Heat shrink splice kits shall contain, as a minimum, an adhesive coated polyethylene sleeve, mastic filler and black cloth tape, or a Company approved equivalent. The sleeve shall extend 50 mm (2 inches) beyond each end of the connection. Refer to Company standard drawings.
- For splicing and sealing of continuous polymer anodes, only end caps, splice kits and tees that are approved by the conductive polymer anode manufacturer shall be used.

5.2.6 DC Poleline and Cables

DC poleline and cable specifications are as follows:

- The poles shall be minimum 12.2 metres (40 feet) long, Class 5, with Penta #8 retention, or CCA-peg treatment.
- The conductor shall be No. 2 ACSR cable, unless specified otherwise.
- Rock anchors for the poles shall be Tri-Anchor Line Pole Rock Anchor type 8-18-28.
- All pole line hardware shall be galvanized according to Ontario Hydro Electrical Safety Code, Section 75, or equivalent.

- Guy wires shall be stranded steel. The wires shall be galvanized and have a diameter of 9 mm minimum. Guy guards are required at all installed locations. Guy guards are to be made of plastic, and provide visual identification for public safety. The guards shall be secure to the guy wire using the manufacturer's supplied hardware.
- Insulators shall be selected in accordance with Ontario Hydro Specifications 31, 32, 33, or Table 100 or equivalent.

5.3 Coke and Other Backfill

5.3.1 General

All coke supplied shall be calcined, and all coke tests shall be conducted as per the referenced test methods.

5.3.2 Chemistry

The composition and tests methods are based on dry weight, and are outlined in Table 5-2.

Table 5-2: Test Methods and Coke Composition

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Carbon (fixed)	ASTM D3172 or D5142	98.7% minimum	99.2% minimum	99.2% minimum
Ash	ASTM D3174 or D5142	0.60% maximum	0.60% maximum	0.60% maximum
Sulfur	ASTM D4239	6% maximum	6% maximum	6% maximum
Moisture	ASTM D3173 or D5142	0.20% maximum	0.20% maximum	0.20% maximum
Hydrogen	ASTM D5373 (ultimate analysis for hydrogen content)	0.10% maximum	0.10% maximum	0.10% maximum

5.3.3 Other Requirements

Coke for deep anodes and continuous polymer anodes shall be dust-free. No de-dusting oils shall be used in the manufacture of the calcined coke.

Coke shall meet or exceed the requirements outlined in Table 5-3.

Table 5-3: Other Requirements for Coke

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Bulk density	Modified ASTM D4292	≥975 kg/m3	≥1,100 kg/m3	≥1,100 kg/m3
Resistivity	carbon industry test C12A @ 150 psi (dry basis)	<0.2 Ωcm	<0.2 Ωcm	<0.2 Ωcm
Particle size	ASTM D293 or ASTM D4749	#4 Mesh - 95% #200 Mesh - 5%	#12 mesh -100% #200 mesh - 5%	#12 mesh - 100% #200 mesh - 5%

Note: Particle size is listed as a percentage of coke passing through the screen.

For deep and continuous anode installations, Loresco SC-3 Coke Breeze, TC-Alcoke/Z0637 Coke Breeze and Asbury 251-P Coke Breeze, or a Company-approved equivalent are acceptable.

For shallow anode installations, Loresco DW-1 Coke Breeze, TC-Alcoke/Z0637, or a Company approved equivalent are acceptable.

The coke breeze supplier shall provide the Company with a "Certificate of Analysis" for each batch or lot (as specified by manufacturer) of coke breeze indicating that the coke breeze meets Company specifications.

5.3.4 Conductive Carbon Grout

Conductive carbon grout specifications follow:

- In areas where the current discharge zone could lead to the interchange flow between water-bearing formations, conductive carbon grout shall be used in the annular to form a conductive seal.
- The mixture of grout and round-grain calcined petroleum coke particles shall have additional additives to minimize the apparent viscosity of the slurry.
- The coke particles shall meet the minimum coke requirements listed above.

5.3.5 Other Backfill

The anode shall be centered in the backfill.

Backfill surrounding magnesium anodes shall have the following composition and properties:

- Gypsum – 75 to 80%
- Bentonite – 15 to 20%
- Sodium sulphate – 0 to 5%

Backfill surrounding the zinc grounding cells shall have the following composition and properties:

- Gypsum – 80 to 85%
- Bentonite – 15 to 20%
- Sodium sulphate – 0 to 5%

5.3.6 Shipping

All backfill shall be wrapped in weather and water tight UV-resistant plastic. All backfill packaging shall be clearly labelled with material designations, as specified in Sections 5.3.3, 5.3.4, and 5.3.5.

5.4 Deep Anode Venting

Deep-anode venting specifications are as follows:

- Shall allow for venting of gases a full 360-degree of the vent pipe without a loss of pipe strength.
- Vertical slits are preferred, and shall be 3.8 cm (1½ inches) in length, or greater, and shall be 0.015 cm (1/64 inch) in width.
- The diameter of piping shall be 25.4 mm (1 inch) inside diameter and 32.3 mm (1¼ inches) outside diameter.
- Material shall be non-conducting and resistant to chlorine attack, if chlorine is a possibility.
- Lengths of pipe joints shall be in either 3 metres (10 feet) or 6 metres (20 feet) lengths.
- If plowing is used, vent piping from a deep well to a vent termination point shall be 1 inch non-perforated coiled HDPE pipe. The minimum outside diameter of HDPE pipe shall be 33.4 mm (1.3 inches) and the minimum wall thickness shall be 3.02 mm (0.1 inches).

5.5 Isolation Sets

5.5.1 Flange Isolating Kit

Flange isolating kit specifications are as follows:

- These devices shall be pressure rated for the intended use, as shown on the Company standard drawing.
- Component dimensions shall conform to ANSI B16.21, Type F.
- Washers shall be zinc-plated steel.
- Retainers and double washers shall be glass reinforced epoxy (G10).
- Viton or Teflon shall be used as the sealing element.
- Minlon or Mylar insulation sleeves shall be used with insulation sets.

5.5.2 Monolithic Isolators

Monolithic isolator specifications are as follows:

- Metal components (excluding pipe-end pups) shall be forged steel.
- Pipe-end pups shall conform to the requirements for each installation, as specified on the purchase order or Company standard drawings.
- "Stiff" electrical isolating components shall consist of glass-reinforced epoxy composite conforming to ASTM D709, Type IV, Group G.10 requirements (G.11 is an acceptable alternative).
- Elastomeric sealing elements shall consist of nitrile butadiene rubber, conforming to ASTM D2000.
- Insulating filler materials shall consist of solventless epoxy resin.

- Adhesive sealant elastomeric materials shall be silicon.
- Each device shall be tested as follows:
  - Electrical test – each monolithic isolator shall be tested according to the requirements of the IEC 60-1 and 60-2
  - DC resistance test – each isolator shall maintain a resistance of at least 5 MΩ for one minute at an applied stress of 1000 VDC
  - AC resistance test – each isolator shall maintain a resistance of at least 1 MΩ for one minute at an applied stress of 5000 VAC (50-60Hz)

5.5.3 Isolating Unions

Isolating union specifications are as follows:

- Metal components shall be forged steel.
- Insulated against galvanic corrosion.
- Tailpiece coated with a tough baked industrial thermo-setting epoxy, bonded directly to the metal.
- Teflon shoulder gasket for extra wear resistance
- Insulating properties – exceeds 500 volts dielectric resistance

5.6 Rectifiers

5.6.1 General Information

General specifications for rectifiers are as follows:

- Rectifiers shall be designed to operate continuously at temperatures between -40°C and 50°C (-40°F and 122°F).
- The DC voltage output shall be fully isolated from the line voltage.
- Rectifiers shall have a primary and secondary arrestor designed to protect against electrical transients caused by lightning, induction and switching surges.
- Output ratings shall be as specified on the purchase order and Company standard drawings.
- The AC input of all rectifiers shall be single phase, 60 Hz, AC 230V, or as specified on the purchase order and Company standard drawings.
- The AC input lugs are to be sized to accommodate an AWG 2 and to provide a "dead front" for connection to the AC line.
- All rectifiers are to be equipped with an AC 115V, 15A, 3-pin ground fault interrupt (GFI) service receptacle. This receptacle is to be connected between the hot and the neutral through a fully magnetic circuit breaker from the line side of the rectifier's main circuit breaker. This receptacle is to be mounted on the front of the panel for easy access.
- Rectifying elements shall be silicon solid state and derated to 50% of the manufacturer's current rating at 100°C (212°F). Silicon diodes shall be constructed into a single-phase full wave bridge configuration. Heat sinks shall be sized to keep diode junction and core temperatures from exceeding 100°C (212°F) in 45°C (113°F) ambient conditions. Diodes shall have a minimum peak inverse voltage (PIV) of 800 V. Where applicable, clear chromate finish aluminum heat sinks (per MIL-C-5541) are acceptable. NOTE: ROHS (Restrictions of Hazardous Substances) disallows anodizing due to use of sulphuric and chromic acids.

- All cables, including jacket materials, shall be suitable for handling, and shall be rated to operate continuously over a temperature range -40°C to +105°C (-40°F to 220°F) ambient air temperature. Alternatively, all cables shall have the insulated jacket coatings de-rated according to applicable electrical codes or standards (Canadian and US) to satisfy the ambient air-temperature operating range.

5.6.2 Enclosure

Enclosure specifications are as follows:

- Enclosures for air-cooled cathodic protection rectifiers shall be constructed to CSA Enclosure 3R Classification, as required by CSA C22.2, No. 107.1 or NEMA MR 20 and NEMA MR 250. The rectifier case shall be NEMA 3R, and completely weatherproof for outdoor use.
- Minimum sheet metal thickness shall be 12 gauge wiped coat mill galvanized steel, as per ASTM 123 and, when practical, the cabinet shall be equipped with a slide-out chassis. Enclosures shall be vented for natural air convection and screened against insects. Screens shall be reinforced to provide structural integrity to the rectifier cabinet. Screens over openings shall meet the requirements set forth by CSA C22. No. 107.1. Hinges and enclosure assembly bolts shall be of stainless steel.
- Enclosures shall be painted white (or as otherwise specified), with the Company rectifier number or identifier in 50 mm to 75 mm (2 inches to 3 inches) black lettering on the outside of the front cabinet door and equipped with a pad lockable draw latch, consisting of a heavy-duty, single-hasp draw latch.
- Either a pole-mounting bracket or legs on the bottom (minimum length 600 mm [24 inches]) so it can be platform mounted, shall be provided and will be specified on the purchase order.
- Electrical panels shall be minimum thickness of 4.7 mm of (0.2 inches) NEMA Grade 'XX' phenolic. For panels greater than 100A, NEMA Grade 'UTR' type shall be used.
- All electrical hardware shall be copper, or brass finished in electroless nickel plate. All connections shall be made secure with lockwashers and nuts torqued in accordance with manufacturer's recommendations.
- For all rectifiers, a flush-mount outdoor wall plate (Leviton part #4925-2) is to be installed and if possible it is to be located on the bottom of the rectifier cabinet adjacent the closest side, or back wall, of the rectifier cabinet nearest the low voltage interruption plug and adjacent to the 200 mm x 250 mm x 150 mm (10 inches x 10 inches x 6 inches) equipment bay. The access port shall have a hinged and environmentally sealed cover. The cover hinge shall also be spring loaded for closure.
- The enclosure shall have the appropriate dimensions to accommodate an empty space for other equipment. The equipment bay is to be located on the bottom of the rectifier, adjacent to the access port described in the previous bullet. The free and clear dimensions of the equipment bay are to be 250 mm x 250 mm x 150 mm (10 inches x 10 inches x 6 inches). The equipment bay dimensions do not include the volume taken by the access port.

5.6.3 Transformer and Efficiency Filter Construction

Transformer and efficiency filter construction specifications are as follows:

- The transformer is to be designed as full isolation with separate and isolated primary and secondary windings, with a minimum efficiency of 95% at the maximum-rated voltage output.
- Transformer magnet wire and insulation materials are to be rated for CEC Class H (180°C) or NEC Class F (355°F), as applicable. Insulating materials shall be dipped in a thermosetting varnish and baked. Varnish shall meet or exceed the CSA requirements for Class H or NEC requirements for Class F operations, as applicable. Transformer voltage regulation shall not exceed 3% from full-rated load to no load.
- Dielectric strength of all insulating materials shall not be less than 2000 V RMS, as tested for one minute when applied between windings and the transformer core.
- The transformer shall be equipped with a minimum of 25 tap bar steps of secondary voltage adjustment (five coarse and five fine).
- Rectifier input overload and short-circuit protection shall be accomplished by magnetic circuit breakers; one pole per input line of AC power. Circuit breakers must trip at 140% of the rated AC input capacity of the rectifier. The input shall be labelled.
- Rectifier output over-load and short circuit protection shall be achieved by rectifier fuses in the transformer secondary of the rectifier. Rectifier fuses shall be sized for 120% rated transformer secondary RMS current. The output shall be labelled. (When the secondary fusing requirement exceeds 90 amps AC, the electronic Fuse Replacement Module will be considered as an acceptable alternative).
- Where specified, an efficiency filter (choke) shall be provided in the negative output of the rectifier. In the case of a multi-circuit rectifier, each circuit shall be provided with a choke, as mentioned. The choke shall be connected between the stack negative and the negative bus.

5.6.4 Instrumentation

Instrumentation specifications are as follows:

- The rectifier shall be equipped with multi-position switch(s) to connect a digital ammeter and voltmeter into each rectifier circuit, or pipeline negative lead. In addition, the multi-position switch shall have an "off" position that leaves the meter disconnected. The multi-position switch will also have a "lines" position, which activates a second switch that will connect each pipeline into the digital ammeter. In other words, two eight position rotary switches with the following settings:
  - Primary rotary switch – "Off, Circuit 1, Circuit 2, Circuit 3, Circuit 4, Circuit 5, Circuit 6 and Line" labels
  - Secondary line rotary switch – "Line 1, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7, Bond" labels

  This represents a case for a six-circuit rectifier connected to seven pipelines and one bond. Switch types and configurations may be varied according to the number of rectifier circuits, pipelines or bonds that must be metered. The off position for the primary switch shall isolate the ammeter and the voltmeter from any internal and external signal sources.

- The ammeter and voltmeter panel displays shall be high-intensity light emitting diode (LED) displays, with a minimum 13.2 mm (0.52 inch) digit height. All metered readings shall maintain a displayed measurement accuracy to one decimal place (i.e., 0.1 Volts or 0.1 A). The ammeter shall have a minimum 3.5 digit display, and the voltmeter shall have a minimum 4 digit or 4.5 digit display. Both metres shall be auto zeroing and auto calibrating, during the manufacturer's initial setup. The required nominal voltage measurement range for the ammeter is ±199.9 mV (with the display scaled to the shunt ratings), and for the voltmeter it is ±199.9 volts (displayed as measured).
- Both the ammeter and voltmeter shall have an accuracy of ±0.10% (or two counts) at 25°C (77°F). The drift in measurement accuracy shall not exceed ±0.50% at a temperature of -40°C (40°F). Test data documenting the accuracy of both the ammeter and the voltmeter over a -40 to +80 °C (40°F to175°F) temperature range shall be provided to verify the accuracy criteria outlined above. The Company shall approve the digital ammeters and voltmeters before purchase.
- The power supply for the high-intensity LED ammeter and voltmeter shall have a dedicated on/off switch, and a protective fuse installed downstream of the AC input surge arrestor for the rectifier.
- The 50A/50 mV metering shunts shall be the panel-mounted Holloway type 'SW' style, with an accuracy of ±0.25%, where output currents are less than or equal to 50 A DC on any structure or rectifier circuit being measured. The Mobiltex or manufacturer of other existing remote monitoring units (RMUs) can measure shunt voltages ± 158 mV. Where currents to be measured exceed 50 A DC, the provisions two bullet points below shall be used. For the digital ammeter, the following shunt sizes are compatible with the ammeter: 50 A/50 mV, 100 A/100 mV and 200 A/200 mV.
- Where line return currents or individual rectifier circuit outputs are less than, or equal to, 50 A DC, the shunts shall be 50 mV and sized for the maximum rectifier output current for negative drains, and shall be installed in each "line" negative output of the rectifier, including bonds. A separate 50 mV shunt, also sized for the maximum rectifier (single circuit) or circuit output (multi-circuit units) current shall be placed to provide metering for each different circuit's output. The shunt voltage shall be a negative common mode voltage for compatibility with the RMU.
- Where line return currents or individual rectifier circuit output currents exceed 50 A DC, two shunts shall be installed in series on each rectifier circuit or line return exceeding the 50 A DC limit. The first shunt installed shall be a 50 mV shunt, sized as previously outlined in this section, and shall be dedicated to the sense leads for the RMU pre-wire. A second shunt shall be installed downstream of the first, with a rating such that a minimum of 1 mV of voltage drop occurs across the shunt for each 1 A of current (i.e., 100 mV – 100 A shunt) to be measured by the high intensity LED digital ammeter.

5.6.5 Terminals

Negative Output Terminals

When specified, all rectifier negatives, including those for multi-rectifier units, shall be bused together using removable shorting bars. The bars shall be placed after the choke (where applicable) on the negative side of the negative meter shunts on each circuit, and fed to one set of output terminals (lugs). The output terminals are to be labeled "Line 1", "Line 2", etc. Output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

Positive Output Terminals

Separate positive output terminals are to be provided with each circuit, and are to be labelled. The output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

Bond Terminals

Terminals labeled "bonds" shall always be provided as specified on the purchase order or Company standard drawings. Bond terminals are to be directly connected to the negative bus. Shunts for bond connections shall also be provided, if indicated on the purchase order or Company standard drawings. Bond terminal lugs are to be sized to accommodate an AWG 1/0, unless otherwise specified.

Remote Monitoring Unit (RMU) Pre-Wire

RMU pre-wire specifications are as follows:

- Optional, based upon site-specific requirements.
- All rectifiers requiring remote monitoring shall be pre-wired with sense cabling connected to a termination block
- Current measurement shunts (50 mV) for each rectifier circuit shall be located on the return side of each rectifier circuit to provide a negative common-mode voltage with the drain terminals. Sense cables shall be installed across each 50 mV shunt installed on the negative return for each rectifier circuit and negative line drains. These sense cables shall be labelled and terminated.
- As specified by the Company, voltage dividers shall be provided on sense cabling for each rectifier circuit to meet the specifications in Table 5-4.

Table 5-4: Voltage Divider Specifications

Rectifier Circuit Rating	Scaling Factor	RMU Metered Voltage into Pre-Wired Terminal Block
>150 Volts	10 : 1	0 – 20 Volts
0 – 150 Volts	1 : 1	0 – 150 Volts

- These dividers shall be installed in conjunction with the standard RMU pre-wire, as specified by Company. If no voltage dividers are called for, then the sense cables are to carry rectifier circuit line voltages, and are to be terminated.

- Sense cables shall be provided for all bonds to foreign structures, to measure both the bond current and the pipe-to-soil voltage on the foreign structure. In addition, the bond measurement facilities must ensure compatibility with the RMU. The channels allocated for measurement of bond currents and voltages shall have an option provided for full electrical isolation.
- This option is to be provided, as specified by the Company. If no electrical isolation devices are specified, then an empty terminal is to be left for the foreign structure sense lead (non-current carrying) and leave a blank terminal for a fixed reference cell lead. The 50 mV foreign structure current measurement shunt(s) shall be installed in series with the current carrying bond lead, and shall have sense leads terminated.
- Sense cables allocated to fixed reference cells must also ensure compatibility with the RMU.
- All sense cables shall be AWG 12 in size and have jacket materials compatible with the operation within the environment inside the rectifier cabinet. The sense cables, including jacket materials, shall be suitable for handling over a temperature range -40°C to 105°C (-40°F to 220°F) ambient air temperature. A control transformer shall be installed in each rectifier unit for future power for the RMU5 remote monitoring device.

Low-Voltage Interruption Terminal

Low-voltage interruption terminal specifications are as follows:

- All rectifiers shall be wired with a CONXALL 4282-5SG-300 (including 4295 dust cap) 5-pin female connector. The wiring associated with the plug shall be AWG 20 TEW stranded copper cable rated to operate up to 105°C (220°F) temperature. Wire terminations for the connector are to be made as per Section 5.6.9.
- The CONXALL 4282-5SG-300 5-pin female connector shall be installed on the rectifier's front phenolic panel to allow the 4295 dust cap to have a minimum clearance of 51 mm (2") from the rectifier cabinet door.
- The AC interruption relays shown in Table 5-5 shall be installed in parallel with the high-voltage twist-lock hubble connector across the interruption switch located on the L1 leg of the AC power supply wiring downstream of the AC surge suppressor (See Section 5.6.9).

Table 5-5: AC Interruption Relays

Rectifier AC Power Input Rating	AC Relays Types	AC Relay Model Numbers
0 – 50 A	Crydom Series 1	Model D2450-10
>50 A	Crydom Series 1	Model D24110-10

- All AC relays shall be installed with heat sinks appropriately sized to facilitate continuous operation of the AC relay under interruption.
- A Hammond BD2E 12 volt power supply transformer is to be installed to power terminals four and five on the CONXALL 4282-5SG-300 5-pin female connector. The input leads on the transformer are to be wired into the L1 AC supply lead, downstream of the AC surge suppressor, and the second lead is to be wired into the AC neutral (see Section 5.6.9).

- The wiring for the CONXALL 4282-5SG-300 5-pin female connector and the Crydom relays, as outlined previously in this section, shall be compatible with the Mobiltex CorrTalk Portable Interrupter Model SPI-1A, SESCO GPS timing device model TCMAD1-100, or SESCO GPS current interrupter model TCFAD1-100 in synchronously actuating the relays with respect to pre-set GPS time-based interruption intervals.

5.6.6 Lightning Protection

Lighting protection specifications are as follows:

- Unless otherwise specified, metal oxide varistor arrestors shall be installed on both the AC input and the DC output of the rectifier.
- An arrestor shall be placed between the chassis and DC positive of each circuit, DC negative of each circuit and the chassis ground.
- Where semi-conductor or valve type arrestors are used, they are to be in an accessible location and enclosed in a small metal enclosure. The enclosure is to prevent fire in the event of a fault or surge.
- Arrestors are not to be mounted on the front control panel.

5.6.7 Inspection and Testing

Testing

All units shall be subjected to tests that verify that specifications are met. Documentation of these tests shall be provided.

Dielectric Strength Tests

Dielectric strength-test specifications are as follows:

- Every transformer shall be subjected to dielectric strength tests, conducted as per CSA C22.2 No. 107.1, or UL 60950, or NFPA 70 as applicable.
- Dielectric strength tests shall be conducted on the transformer before varnish dipping and baking, and after baking. The after baking test can be included as part of the final rectifier dielectric test.
- All assembled rectifiers shall be subjected to dielectric strength tests, as outlined in CSA C22.2 No. 107.1, or UL 60950, or NFPA 70 as applicable.

Inspection

After assembly, the rectifier shall be subjected to inspection of all wiring and mechanical components and their connections. Inspection shall also include over-all workmanship.

Operation

Rectifiers shall be subjected to testing and recording of all rectifier electrical parameters as follows:

- AC input voltage, current, apparent power and true power
- DC output voltage, current and power
- AC power factor
- AC to DC conversion efficiency

If a filter is required, the ripple at full output voltage shall be measured and documented.

Rectifier metres shall be tested to meet the requirements specified in Section 5.7.4.

5.6.8 Shipping

A rectifier identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- Manufacturer's name and code number
- AC volts and amperes
- line frequency
- number of phases
- DC voltage and ampere ratings
- ambient temperature rating
- serial number
- CSA file number (as applicable)

The following items are to be in a waterproof enclosure with documentation in the rectifier door, or if specified, label using lamacoid plates, or an equivalent approved by Company cathodic protection engineering personnel. Labels are to have a black background and white lettering.

- AC rectifier input terminals
- transformer tap positions (coarse & fine)
- negative and positive output lugs
- all metres
- Switch positions
- main breaker
- DC and AC arrestors
- all fuses (size and type)
- interrupter mode switch
- interrupter receptacle
- utility receptacle
- high voltage (if applicable)

A circuit diagram and parts list shall be included with each rectifier. The rectifier drawing shall be laminated and mounted on the inside of the front door of the rectifier. In addition, a paper copy of the rectifier electrical schematic and a parts list for each rectifier detailing all of the components shall be provided to Company Cathodic Protection Engineering personnel.

Each rectifier shall be individually packaged for shipment, and shall have the rectifier name or rectifier number clearly labelled on the exterior of the shipping box.

5.6.9 Rectifier Circuit Diagram

Refer to the Company standard drawings, or as per the Company's instruction.

5.7 Thermoelectric Generators

5.7.1 General Information

General specifications for thermoelectric generators are as follows:

- TEGs shall be designed to operate at temperatures between -45°C and 65°C.(-50°F and 150°F).
- TEGs shall be designed to operate in unlimited rain or snowfall, provided that the unit is not flooded.
- TEGs shall operate in 100% relative humidity.
- TEGs shall operate in wind gusts of up to 140 km/hr (85 mph).
- TEGs shall come complete with automatic re-ignition.
- All components shall be manufactured in modules, or assemblies for easy field maintenance.
- As necessary, the units shall be furnished with over-temperature protection circuitry.

5.7.2 Enclosure

Enclosure specifications are as follows:

- Enclosures shall be designed for outdoor installation, and be of stainless steel and aluminum construction.
- Enclosures shall be equipped with pad-lockable latches.
- All electrical hardware shall be copper, or brass finished in electrolysis nickel plate. All connections shall be made secure with lockwashers and nuts, or with compression-type terminals.
- Enclosures shall be identified with the Company's rectifier number, or identifier in 50.8 mm to 76.2 mm (2 inch to 3 inch) black lettering on the outside of the front cabinet.

5.7.3 Mechanical Construction

Mechanical construction specifications are as follows:

- Units shall have a lead telluride solid-state, hermetically sealed power unit.
- Units shall have a nickel-alloy construction, meeker-type burner design that is stable in normal operating conditions.
- The individual TEG(s) shall be ordered to operate on butane, propane or natural gas, depending on the available fuel supply.

5.7.4 Metering and Instrumentation

Metering and instrumentation specifications are as follows:

- A separate suitably scaled voltmeter and ammeter as well as a current measuring shunt shall be provided to measure the DC output.
- Metres shall be a minimum 90 mm (3½ inches) size, with a minimum scale length of 73 mm (2⅞ inches).
- Metering accuracy shall be ±2% of full-scale deflection at 25°C (77°F). Temperature compensation shall be no more than 0.85% per 10°C (50°F), for temperatures other than 25°C (77°F).
- The package shall contain a terminal block capable of accepting 2/0 AWG (9 mm or ⅜ inch) cable.
- The package shall contain a variable resistor designed to control current output.
- Electrical output isolation from the chassis shall be achieved such that the leakage current does not exceed 100 mA.

5.7.5 Inspection and Testing during Manufacture

Inspection and testing specifications during manufacturing are as follows:

- All units shall be subjected to testing at 100% of rating.
- All units shall be subjected to tests as outlined in SPE-1000-94 for dielectric strength, bonding continuity, leakage current, stability and temperature.
- All units shall be subjected to testing and recording of all performance parameters as follows:
  - DC output voltage, current and power
  - DC input voltage, current and power
  - fuel pressure for rated power
  - set up voltage for rated power
  - leak test of fuel system
  - verification of ignition system operation

5.7.6 Shipping

An identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- Manufacturer's name and code number
- serial number
- fuel usage
- fuel pressure setting

5.8 Solar-Power Units

5.8.1 General Information

General specifications for solar-power units are as follows:

- Solar-power units shall be as specified on the purchase order.
- The number of solar panels to deliver the requirements as specified in the purchase order, or Company standard drawings, shall be determined by the manufacturer or distributor.
- The size of the units (typically 12V DC or 24V DC) shall be specified on the purchase order or Company standard drawings.
- All solar-power units shall have a main disconnect switch between the solar panels and the controller.
- All solar-power units are to be supplied with a silicon oxide varistor lightning arrestor with:
  - clamp voltage 100 V
  - maximum operating voltage 48V DC
  - maximum current 50 kA
  - maximum energy 750 Joules (0.7 BTU)
  - unlimited number of surges
  - 10 nanosecond response time

  They are also to be supplied with a system electrical groundlug.

5.8.2 Panels

Panel specifications are as follows:

- Solar panels shall be mounted on 12 metres (40 feet) of Class 6 wooden utility poles.
- The diameter of the pole at the panel-mounting location is to be approximately 200 mm (8 inches).
- Mounting brackets to secure the solar panels shall be sized to accommodate attachment to the highest point on the utility pole.

5.8.3 Controllers

Controller specifications are as follows:

- Controllers shall be sized to accommodate the voltage and the current requirements as specified on the purchase order or Company standard drawings.
- Controllers shall have a continuous voltage and current display.
- Controllers shall be housed in a watertight enclosure with securable locking latches or handle.

5.8.4 Batteries

Battery specifications are as follows:

- All units shall be supplied with either absorbed glass mat (AGM) or gel-sealed batteries, as specified on the purchase order. The self-discharge rate of the battery must be less than 2% per month, and must have a 12-month warranty.
- Battery quantities and sizes shall be to provide a minimum of 72 hours autonomy, with no more than 50% depth of discharge.
- Batteries shall be housed in a separate insulated and vented battery box.
- The battery box is to have securable locking latches or handles. The battery box is to have mounting lugs to secure the box to a wooden platform, or platform approved by Company Cathodic Protection Engineering personnel.

5.8.5 Enclosure

Enclosed specifications are as follows:

- Power center enclosures must be rated as NEMA Type 3, 3R or 4, and are to be rain and sleet proof.
- The enclosures must have a drip shield over the door.
- The hinged door is to be sealed with seamless poured urethane gasket, and come complete with a lockable latching mechanism that maintain constant pressure on the gasket.
- The battery box shall be insulated with 50 mm (2 inch) high-density foam and sized to allow a 10 mm (½ inch) battery separation and be complete with a hinged lid with a lockable latch.

5.8.6 Shipping

The location to which the units are to be shipped shall be clearly marked.

5.9 Test Stations

The test lead assembly shall be as per Company standard drawings.

5.10 Remote Monitoring Equipment

5.10.1 General Information

General specifications for remote monitoring equipment are as follows:

- All RMUs shall be CSA certified, or UL approved.
- All units shall have flash program memory.
- Internal components shall operate in the temperature range -40°C to +80°C (-40°F to +175°F).

5.10.2 Enclosures

Enclosure specifications are as follows:

- Enclosures for RMUs shall be NEMA 4X rated fiberglass or polycarbonate.
- Enclosures shall be equipped with a pad-lockable draw latch.

- All units to be fitted with a CSA or UL approved (as applicable) 10 watt heater and control thermostat to maintain the enclosure internal temperature within the radio's operating temperature range.
- Insulation shall be a "K" value suitable to allow a 10 watt heater to provide the required minimum temperature.
- Insulation to be rigid, foil backed non-hygroscopic and non-flammable to provide for a maintenance-free interior.
- Enclosure to have a mounting plate supported over the insulation, for mounting components.
- GPS antenna is to be mounted on the top of the enclosure and to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.
- The external electronic temperature sensor shall be mounted off-centre on the bottom of the enclosure, and is to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.

5.10.3 Channels

Channel specifications are as follows:

- All units to be equipped with 10 analog inputs and one interrupt drive output.
- All units shall have four isolated digital input points.
- All units shall have one internal (mounted on a PCB), and one external electronic temperature sensor.

5.10.4 Interruption

Interruption:

- Shall be a solid state AC interrupt relay, 25 A @ 280 VAC maximum
- Is to occur via GPS time receiver

5.10.5 Communication

IMARSAT communication is to be via Easy Track Communication/ GPS unit, with an operating temperature range of -30°C to +50°C (-22°F to 122°F).

5.10.6 Command Options

All units shall be able to indicate:

- AC "power fail" alarm. (Debounce timer set to 1 hour.)
- AC power restored. (Debounce timer set to 1 hour)
- DC power fail (DC current goes to zero, e.g. fuse fails, rectifier fails). (Debounce timer set to 1 hour.)
- Low battery (no time delay in sending this alarm)

5.10.7 Power Supply

Power shall consist of 120 VAC to 12 VDC supply for transceiver and electronics. (TEG version will be 24 VDC to 12 VDC.)

All units shall have a battery backup with charger and a low-voltage disconnect.

5.11 Junction Boxes and Terminal Boxes

5.11.1 Junction Boxes

Junction-box specifications are as follows:

- Junction box size and location shall be as per the purchase order or Company standard drawings.
- Junction box enclosures shall be cast aluminum, as per Wright Aluminum Ltd. specifications (Model# WAL-56 or Model# WAL-102).
- All junction-box enclosures shall have a high-voltage shield, and be mounted on 76 mm (3 inches) OD conduit(s), as per Company standard drawings.
- All junction boxes shall be constructed to CSA Enclosure 3R Classification, or equivalent.

5.11.2 Terminal Boxes

Terminal box specifications are as follows:

- Terminal box size and locations shall be as per the purchase order and Company standard drawings.
- Terminal boxes shall meet Hammond (Model 1418N4M8) or Bel (Model R363008) specifications.
- Terminal-box enclosures shall have a minimum sheet-metal thickness of 14 gauge.
- All steel terminal box enclosures shall be CEMA/NEMA 4 rated, and shall be powder coated (ASA61 grade polyester or ANSI/ASA61 grey baked recoatable enamel).
- Hinges and enclosure assembly bolts shall be stainless steel or aluminum. The enclosure shall be equipped with a latching device.
- All terminal box enclosures shall have a high-voltage shield, and be mounted on two 76 mm (3 inches) OD conduits as per Company standard drawings.

5.11.3 Panels

Junction box panels shall be a minimum thickness of 4.7 mm (0.2 inches) of NEMA grade 'XX' phenolic.

All electrical hardware shall be copper or brass, finished in electrolysis deposited nickel plate. All connections shall be made secure with lockwashers and nuts tightened to the manufacturer's recommended torque.

5.12 Copper–Copper Sulphate Reference Electrodes

Unless otherwise specified, all copper–copper sulphate reference electrodes shall be EDI Model UL - 30 Year LongLifeTM reference electrodes. Element type shall be a saturated gelled Cu/CuSO4. The lead wire shall be AWG 14 or larger, 15 metres (45 feet) or greater in length, insulated in high molecular weight polyethylene, and rated for underground service.

Where specified, the CSCL copper–copper sulphate reference electrode shall be CPMP-2-50. The length of the cable shall be as per the site-specific construction drawings.

5.13 NovaProbes

NovaProbe specifications are as follows:

- Permanent NovaProbes are patented and only available from licensed manufacturers.
- Permanent NovaProbes shall measure the following parameters:
  - local soil resistivity
  - local soil pH
  - local oxidation reduction potential
  - "on" pipe-to-soil potential

5.14 Coupons

Coupons shall be either 9 cm^2 or 50 cm^2 (1.4 in^2 or 9 in^2). Coupon test stations shall comply with Company standard drawings.

5.15 Exothermic Welds and Bonds

5.15.1 Thermite Welds

Thermite weld specifications are as follows:

- Thermite welds shall be a #15 gram charge (green cap) maximum with F-33 powder, or approved equivalent.
- A copper sleeve shall be used for wire sizes smaller than AWG 8. The sleeve size shall correspond to cable size.

5.16 Silver Soldering

Silver soldering specifications are as follows:

- Use only 2% silver/98% tin soldier material with the appropriate flux.
- "Tin" the pipe and the conductor to be soldered.
- Heat the pipe and melt a solder puddle sufficient in size to attach the conductor.
- Test for adequate bond and neutralize the acid flux with base solution.

5.17 Mechanical Bonds

Mechanical bond specifications are as follows:

- Circumferential clamp(s) is to maintain residual tension after the tensioning device is withdrawn. The cable connection to a circumferential clamp must be achieved by welding, or bolting to the clamping device.
- Any connection to structures, other than a pipe, must be achieved using materials required in the CEC or the NEC (as applicable) for grounding connections.
- Specially designed alteration to an electrical LB (elbow, back opens) fitting and connected to a flange bolt may be used. The apparatus shall be constructed of rigid conduit from a point 450 mm below grade and up to the LB. The cable shall pass through the conduit and connect to a lug inside the LB fitting. The conduit must be equipped with an EYS sealed fitting at the point of emergence from the ground.
- An alternate to the rigid conduit and EYS fitting is to use a single conductor Teck cable connected to the LB fitting with a "liquid tight" transition fitting.

5.18 Controlled Interference Bonds

Control device in an interference bond circuit shall consist of an appropriately sized resistor, or rheostat, and a meter or shunt.

5.19 AC Mitigation, Surge Protection and DC Decoupling

5.19.1 General Information

General specifications for AC mitigation, surge protection and DC decoupling are as follows:

- Isolation surge protectors shall be designed to simultaneously provide DC isolation and AC continuity at cathodic protection isolator locations, plus meet environmental ratings outlined in NEMA 4X and hazardous classifications for NEC, CSA: Class 1, Division 1 & 2, Groups A,B,C, D.
- Typical applications include installation where the facilities are subject to AC coupling, AC faults, or lightning, or electrical switching transients. Under AC faults or lightning (short term transients) it is allowable for the device to temporarily conduct DC current.
- The device shall be designed to allow an unlimited number of switching operations (associated with occasional AC faults or lightning events) without failure.
- The ultimate failure mode of the device shall be in the closed-circuit position.
- The device shall be equipped with two hole (⅜ inch diameter) terminal pads for cable connection.
- Isolation surge protectors shall be solid-state devices capable of normal operation at ambient temperatures between -45°C and +45°C (-50°F and 113°F).

5.19.2 Polarization Cell Replacements – Electronic Device Performance Characteristics

The performance characteristics shall be specified by the following product ratings.

- lightning surge current
- voltage threshold
- 60 Hz fault current
- 60 Hz steady-state current
- enclosure
- instrument test feature
- special requirements

If not specified on the purchase order, the following parameters shall apply:

- Lightning surge current – 50 kA: This parameter specifies the maximum current that the device must be capable of passing while holding the voltage across the terminals below 700 volts. The test waveform shall be 8 X 20uS.
- DC blocking voltage – 4.5 volts: This parameter specifies the upper DC voltage level, which will be blocked by the device while continuously conducting 60 Hz AC current.
- AC fault current at 60Hz – 50 kA for 1 cycle: This parameter specifies the minimum AC fault current that the device must be capable of passing without failure.

- Steady-state AC current at 60 Hz – 50 A RMS: This parameter specifies the maximum allowable steady state AC current that can be passed through the device while maintaining DC isolation.
- AC voltage drop under fault at 60 Hz – 35 volts AC: This parameter specifies the maximum AC voltage drop through the device under full rated fault current.

5.19.3 Enclosure

Enclosure specifications are as follows:

- Unless otherwise specified, the device shall be furnished with a NEXA 4X metallic enclosure suitable for all or channel mount, complete with a padlockable access cover.
- The device shall be marked with the manufacturer's name, the device model number and the device serial number.

5.19.4 Instrumentation

The device shall contain a sufficient number and type of test terminals to allow AC and DC voltage and current measurements while in operation. All test terminals shall incorporate a dead-front design to prevent personnel shock, and shall be clearly labelled.

5.19.5 Shipping

The device shall be packaged for shipping in order to prevent damage.

6 QUALITY MANAGEMENT

6.1 Quality Checks and Documentation

The Company requires the following reviews before and during work:

- Review that the manufacturer is approved within the Company's approved vendor list
- Review the materials adhere to the guidelines set forth in this specification

The Company requires the following documentation before work starts:

- Verification of equipment calibration, as per equipment specifications

6.2 Performance Measures

The manufacturer will be evaluated on the following measures:

- Adherence to the schedule – the ability to achieve milestones set forth by the Company.
- Delivery of materials – the materials are delivered to the Company in the timelines provided.
- Quality of materials – the materials adhere to the guidelines set forth in this specification.
- Adherence to safety – the ability to complete work safely with no lost time incidents.

6.3 Specification Deviations

Any deviations from this specification shall be identified and addressed as per the TEP-INT-MOC *Pipe Integrity Management of Change Procedure*. Deviations are to be reviewed and accepted by the Company's representative before acceptance of the deliverables, data or report.

6.4 Nonconformance Management

All nonconformances to the specification will be identified by the vendor, and reviewed and dispositioned by the Company.

APPENDIX

APPENDIX A APPROVED MATERIAL LIST

Table A-1: Approved Material List

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
Anodes	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660	Length: 1524 mm Diameter: 66 mm Mass: 23 kg (nominal)	Length: 60 in Diameter: 2.6 in Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684	Length: 2134 mm Diameter: 66 mm Mass: 31 kg (nominal)	Length: 84 in Diameter: 2.6 in Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884	Length: 2134 mm Diameter: 97 mm Mass: 31 kg (nominal)	Length: 84 in Diameter: 3.8 in Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660Z	Length: 1524 mm Diameter: 69 mm Mass: 23 kg (nominal)	Length: 60 in Diameter: 2.7 in Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684Z	Length: 2134 mm Diameter: 69 mm Mass: 32 kg (nominal)	Length: 84 in Diameter: 2.7 in Mass: 70 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884Z	Length: 2134 mm Diameter: 76 mm Mass: 41 kg (nominal)	Length: 84 in Diameter: 3.0 in Mass: 90 lb (nominal)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 1016 mm Diameter: 102 mm Mass: 16 kg (nominal)	Length 40 inch. Diameter 4 inch Mass: 35 lb. (nominal)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 1524 mm Diameter: 76 mm Mass: 12 kg (nominal)	Length 60 inch. Diameter 3 inch Mass: 27 lb. (nominal)

Table A-1: Approved Material List (Cont'd)

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 2032 mm Diameter: 102 mm Mass: 29 kg (nominal)	Length 80 inch. Diameter 4 inch 64 lb.
		Mixed Metal Oxide Anode	Varies depending on supplier	As specified on the purchase order.	As specified on the purchase order.

TES-CP-MS Cathodic Protection Material Specification (Cdn-US)

APPROVALS

Originator: Ryan M°Kay, P. Eng Corrosion Engineer Pipe Integrity, Corrosion Prevention	Signature	Jan 22, 2013 Date
Reviewer: Chad Khattar, P. Eng Senior Engineer Pipe Integrity, Corrosion Prevention	Signature	Jan 23 2013 Date
Reviewer: Brent McKinnon Program Management U.S. Pipeline Maintenance Projects	Signature	Jan 24 2013 Date
Responsible Engineer/Approver/ Engineer-in-charge/Document Contact: Brad Woloschuk, P. Eng Senior Engineer Pipe Integrity, Corrosion Prevention	Signature FEBRUARY 01, 2013 Date	PROFESSIONAL ENGINEER BRADLEY J. WOLOSCHUK 2013-02-01 APEGA Permit to Practice P7100
Accountable Manager: James Card, BSEE Manager Pipe Integrity, Corrosion Prevention	Signature	1/28/13 Date

SUMMARY

This specification establishes the requirements for cathodic protection materials for the installation of cathodic protection facilities for Company gas and hazardous liquid pipeline systems in Canada and the United States.

BRIEF DESCRIPTION OF CHANGE

REGULATORY

- N/A

GENERAL

- Editorial and format changes throughout the document.

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DEFINITIONS

Terms	
ACSR	aluminum conductor steel-reinforced cable
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
CEC	Canadian Electrical Code
CSA	Canadian Standards Association
ECTFE	ethylene chlorotrifluoroethylene
HMW-MDPE	high molecular weight high density polyethylene
HMWPE	high molecular weight polyethylene
IEC	International Electrotechnical Commission
NACE	NACE International
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
RMU	remote monitoring unit
The Company	TransCanada PipeLines
XLPE	cross-linked polyethylene

Tools and Applications	
Incident and Issue Tracking (IIT)	An electronic database tool used to report incidents and issues involving employees, contractors and third parties.
FileNet-EDMS	The Company's web-based electronic document management system.

1 PURPOSE

This specification establishes the requirements for cathodic protection materials for the installation of cathodic protection facilities for the Company's buried pipeline systems in Canada and the United States.

This specification shall be used:

- By Company employees and all prime and Subcontractors employed by the Company
- In all activities related to cathodic protection, including design, construction, operations and maintenance

Materials supplied shall meet all requirements of this specification and any additional requirements on the applicable request for quotation, purchase order and applicable Company standard drawings.

Before a material is added to the Approved Material List, it shall be reviewed and approved by the Company's Cathodic Protection Engineering personnel.

2 SCOPE

This specification applies to materials for cathodic protection for the Company's gas and hazardous liquid pipeline systems in Canada and the United States.

3 REFERENCES

3.1 Regulations, Codes and Standards

The jurisdictional regulations and legal requirements that apply to this procedure are:

- 49 Code of Federal Regulations (CFR):
  - 192, Subpart I
  - 195, Subpart H
- Canadian Standards Association (CSA):
  - Z662-11 *Oil and Gas Pipeline Systems*
  - C22.1 Canadian Electrical Code (CEC), *Part I, Safety Standard for Electrical Installations (Section 80)*
  - C22.2 No. 107.1, *General Use of Power Supplies*
  - C22.2 No. 131, *Type TECK 90 Cable*
  - C22.2 No. 75, *Thermoplastic-Insulated Wires and Cables (Tri-National standard, with UL 83 and NMX-J-010-ANCE*, 2008
  - Special Publication SPE-1000-94, *Model Code for the Field Evaluation of Electrical Equipment*
- National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)

3.2 Industry Publications and References

The industry publications and references that apply to this procedure are:

- NACE International:
  - SP0169-2007, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*
  - SP0572-2007, *Design, Installation, Operations, and Maintenance of Impressed Current Deep Anode Beds*
- American Society for Testing and Materials (ASTM) International:
  - G97, *Standard Test Method for the Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications*
  - B265, *Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate*
  - B418, *Standard Specification for Cast and Wrought Galvanic Zinc Anodes*
  - B843, *Standard Specification for Magnesium Alloy Anodes for Cathodic Protection*
  - A518, *Standard Specification for Corrosion-Resistant High-Silicon Iron Castings*
  - D1248, *Standard Specification for Polyethylene Plastics Molding and Extrusion Materials For Wire and Cable*
  - D2000, *Standard Classification System for Rubber Products in Automotive Applications*
  - B3, *Standard Specification for Soft or Annealed Copper Wire*
  - B8, *Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*
  - D293, *Standard Test Method for the Sieve Analysis of Coke*
  - D709, *Standard Specification for Laminated Thermosetting Materials*
  - D3172, *Standard Practice for Proximate Analysis of Coal and Coke*
  - D3173, *Standard Test Method for Moisture in the Analysis Sample of Coal and Coke*
  - D3174, *Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal*
  - D3178, *Standard Test Method for Ultimate Analysis for Hydrogen Content*
  - D5142, *Standard Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures*
  - D4239, *Standard Test Methods for Sulphur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods*
  - D4749, *Standard Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size*
- American Society of Mechanical Engineers (ASME) B16.21, *Nonmetallic Flat Gaskets for Pipe Flanges*
- International Electrotechnical Commission (IEC):
  - 60060-1, *High-voltage test techniques, Part 1: General definitions and test requirements*
  - 60060-2, *High voltage test techniques, Part 2: Measuring systems*
  - 60228, *Conductors of Insulated Cables*

- National Electrical Manufacturers Association (NEMA):
  - WC70/ICEA S-96-658, *Thermoplastic Insulated Wire & Cable for Transmission & Distribution*
  - Standard Publication No. MR 20-1958 (reaffirmed by NEMA 1971) – *Semiconductors, Rectifiers, Cathodic Protection Units*
  - Standard Publication No. MR 250-1979 (including Rev No. 1 December 1980), *Enclosures for Electrical Equipment (1000 Volts Maximum)*

3.3 Internal References

The Company procedures, guidelines, reports and documents that apply to this specification are:

- *Operations and Maintenance (O&M) Manual U.S. Natural Gas Pipelines* (EDMS No. 005404490)
- *Operations and Maintenance (O&M) Manual U.S. Hazardous Liquids Pipelines* (EDMS No. 005713585)
- *Operator Qualification Program* (EDMS No. 004504739)
- TEP-INT-MOC *Pipe Integrity Management of Change Procedure* (EDMS No. 006425143)

4 ROLES, RESPONSIBILITIES AND QUALIFICATIONS

4.1 Manufacturer's Responsibilities

4.1.1 Requirements for All Materials

Following are material requirements:

- The manufacturer shall be on the Company's cathodic protection Approved Materials List (see APPENDIX A) for the production of cathodic protection materials.
- At the request of the Company Representative, cathodic protection material may be retained by the Company for evaluation to ensure the material conforms to this specification.
- The Company shall have the right to review the manufacturer's work at any time.
- The manufacturer shall supply to the Company at the time of quotation any exceptions or alternatives to this specification.

4.1.2 Preproduction Provisions

For isolation sets, the manufacturer shall submit to the Company the following:

- For each sleeve size, the inside diameter (ID), outside diameter (OD), thickness and length (all in millimetres or inches), material type, and the dielectric strength (volts per 1 mm or inch).
- For each washer type and size, the ID, OD and thickness (all in millimetres or inches), material type, and if applicable, dielectric strength (volts per 1 mm or 1 inch).

For rectifiers, the manufacturer shall submit to the Company:

- A certification that the rectifier meets the requirements of this specification
- A nationally recognized testing laboratories (NRTL) approval certification
- A circuit diagram and dimensions of the enclosure

For:

- Thermoelectric generators (TEG), the manufacturer shall certify that the TEG(s) meet the requirements of this specification, and provide a diagram showing the components of the TEG(s) and dimensions of the enclosure(s).
- Calcined coke, the manufacturer shall submit a datasheet detailing the chemistry and other requirements in Section 5.3.
- Cables, the manufacturer shall certify that the cable meets the requirements of the CEC or the NEC (as applicable), ASTM D 1248 or NACE Standard SP0572 and this specification.
- Each monolithic isolator, the manufacturer shall submit to the Company the fabrication drawing and the production schedule.
- Remote monitoring equipment and rectifiers, the manufacturer shall supply laminated electrical schematic drawings with each rectifier, and copies shall be submitted to the Company.

4.2 Company Responsibilities

The Company representative shall obtain all QA/QC documents for materials to be installed, in accordance with the project description.

5 CATHODIC PROTECTION MATERIALS – REQUIREMENTS

5.1 Anodes

5.1.1 High-Potential Magnesium Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The anode shall conform to ASTM B843, Grade M1C.
- The anode shall have a minimum efficiency of 43%, when tested in accordance with ASTM G97.
- The mass of the anode, anode dimensions and package dimensions shall be as specified on the purchase order.
- A galvanized steel core shall be cast at least 75% of the full anode length.

Lead Wire

See Section 5.2.2, Magnesium Anodes or Zinc Anodes.

Backfill

See Section 5.3.5.

Markings

The anode type, mass (kg/lbs) and Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., High Potential Magnesium, 15 lbs, TES-CP-MS [Cdn-US], 2012/10/01).

Shipping

Shipping specifications are as follows:

- The backfill package shall consist of a cotton bag or wettable (e.g., no wax or plastic coated) cardboard tube with the dimensions as specified on the purchase order.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.2 Zinc Ribbon

Chemical Composition, Mass and Dimensions

Chemical composition, mass and dimension specifications are as follows:

- The chemical composition of zinc ribbon shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.
- The anode shall be manufactured by extrusion with a continuous centered 1/8" galvanized steel core.

Lead Wire

Not applicable.

Backfill

Not Applicable.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the reel (or other device anode is wrapped around):

- manufacturer
- anode model
- ribbon type
- cross section (X millimetres [inches] x Y millimetres [inches])
- length (metres or feet)
- Company specification and revision date

For example, "manufacturer", aaa, zinc ribbon, 12 mm x 15 mm, 500m, TES-CP-MS (Cdn-US), 2012/10/01.

Shipping

Shipping specifications are as follows:

- The ribbon shall be packaged in a manner to allow for ease of shipping.
- The zinc ribbon shall be prepared for shipment and storage in such a manner that it will not be exposed to weather or water, as directed by the supplier.

5.1.3 Zinc Grounding Cells

Chemical Composition, Mass and Dimensions

The chemical composition for the zinc shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.

Lead Wire

See Section 5.2.2, Magnesium Anodes or Zinc Anodes.

Backfill

See Section 5.3.5.

Markings

The anode type, mass (kilograms or pounds) and the Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., Zinc Grounding cell, 7.7 kg, TES-CP-MS [Cdn-US], 2012/10/01).

5.1.4 Silicon-Chromium Cast Iron Anodes

Chemical Composition, Mass and Dimensions

The following clauses shall apply to both tubular and stick anodes castings:

- The anode shall be chill cast or equal, from an alloy conforming to ASTM A518 GR3.
- Each anode shall be supplied free from casting defects, porosity, voids and fissures. The anode surface shall be free from adhering foundry sand or mould release agents.
- The anode mass and anode dimensions shall be as specified on the purchase order or Company standard drawings.
- All anode manufacturers shall be approved by the Company.

Lead Wire

See Section 5.2.2, Tubular Anodes.

Backfill

See Sections 5.3.1 to 5.3.4.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- anode type
- anode mass (kilograms or pounds)
- anode OD (millimetres or inches)
- length (millimetres or inches)
- Company specification
- revision date

For example, "manufacturer", aaa, stick, 20 kg, 50 mm, 1520 mm, TES-CP-MS (Cdn-US), 2012/10/01.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.5 Continuous Polymer Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical compositions, mass and dimensions are as follows:

- Continuous polymer anodes shall be constructed as stranded American Wire Gauge (AWG) 6 annealed copper conductors with a conductive polymer jacket (rather than an insulating polymer jacket).
- The conductive polymer jacket shall provide a moisture-proof barrier to protect the copper cable.
- The conductive polymer jacket shall be capable of continuously discharging a current of 50 mA per linear metre (15 mA per linear foot) of anode material for a minimum of twenty years.

Lead Wire

See Section 5.2.3.

Backfill

See Section 5.3.

Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- polymer type
- length (metres or feet)
- Company specification
- revision date

For example, "manufacturer", aaa, carbon impregnated polyethylene, 500m, TES-CP-MS (Cdn-US), 2012/10/01).

Shipping

Shipping specifications are as follows:

- As specified on the purchase order or Company standard drawings, continuous polymer anodes may be supplied bare (by itself) or prepackaged in a 38 mm (1½ inch) diameter flexible mesh tube.
- Prepackaged conductive polymer anodes shall contain a high-grade coke backfill conforming to Section 5.3. The conductive polymer anode shall be centered within the flexible mesh tube.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.6 Canister Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- Only tubular anodes shall be placed in canisters. Anodes shall meet the requirements of Section 5.1.4 before assembly.
- The canisters shall be manufactured as follows:
  - spiral corrugated perforated galvanized steel – 28 gauge minimum
  - diameter – 225 to 235 mm (8 inches) minimum
  - length – anode length + 600 mm (2 feet)
  - plywood end caps – 16 mm (¾ inch) minimum thickness

Assembly

High silicon chromium anode assemblies shall be canistered as follows:

- With the bottom end cap in place, the anode shall be centered in the can and filled with coke, such that the anode has 200 mm (8 inches) of coke beyond each anode end.
- Calcined petroleum coke, as per Section 5.3, shall be mechanically compacted around the anode.
- An inner plywood cap shall be secured to the can immediately above the compacted calcined petroleum coke.
- A steel bolted eyelet shall be attached to the top inner plywood cap, and the lead wire shall exit through a close fitting hole to the side of center.
- The wire shall be coiled and placed on the inner cap.
- A top end cap, with access to the coiled wire, shall be attached to protect the coiled wire during shipping.

Refer to Company standard drawings.

Shipping

Shipping specifications are as follows:

- All canned anodes shall be securely attached to a pallet in such a manner to avoid damage to the anodes or canisters.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.7 Graphite Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The chemical composition for the graphite shall be GR060CP grade or equal.
- The graphite shall be treated with wax or resin, as specified on the purchase order.
- Center connections shall be tested to verify the connection falls below 0.004 ohms (4 milliohms).

Lead wire

See Section 5.2.2.

Backfill

See Section 5.3.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.1.8 Mixed Metal Oxide Anodes – MMO Anodes

Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass, and dimensions are as follows:

- The chemical composition of titanium shall conform to ASTM B265.
- The anode rating per foot and length is as specified on the purchase order.

Lead wire

See Section 5.2.2.

Backfill

See Section 5.3.

Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid damage during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.2 Cable

5.2.1 General

General specifications for cable are as follows:

- All cable shall be rated for use from -40°C to 60°C, or -40°F to 140°F.
- Cables shall have an underground rating.
- All cables shall conform to ASTM B3 and ASTM B8 or IEC 60228.
- All cables shall be rated to handle 600 V direct current.
- Unless specified, the cable size, cable length and cable colour shall be as indicated on the purchase order or Company standard drawings.
- The outer insulation layer shall be marked to include the manufacturer, conductor size and number of strands (e.g., "manufacturer," AWG 4, 7/S).

5.2.2 Anode Lead Wire

Magnesium Anodes or Zinc Anodes

Specifications for magnesium anodes or zinc anodes are as follows:

- The anode lead wire shall be a continuous seven stranded, AWG 10 or larger (unless specified on the purchase order) annealed copper conductor, minimum 3 metres (10 feet) long. The insulation shall be blue for magnesium anodes and white for zinc, unless specified on the purchase order, to be consistent with site specific installations. The insulation shall be RWU90 cross-linked polyethylene (XLPE), or direct burial high molecular weight polyethylene (HMWPE).
- Lead wires shall be attached to the galvanized steel core by silver solder, and the connection shall be made moisture-proof by encapsulating the connection with an electrical sealing compound. The lead wire connection shall withstand a steady load pull of 200 kg (440 lbs) without separation from the anode.
- For zinc grounding cells, the lead wire shall be a continuous seven stranded, AWG 2 or larger annealed copper conductor, minimum 3 metres (10 feet) long. The insulation shall be white for zinc anodes. The insulation shall be RWU90 XLPE, or direct burial HMWPE. The wire shall be compression connected to the anode core and sealed with an electrical sealing compound.
- If magnesium anodes are to be used with solar panels, the cables shall meet the requirements of an impressed current system.

Tubular Anodes

Specifications for tubular anodes are as follows:

- For deep-well anode leads, see Deep Anode Lead Cable in Section 5.2.3.
- Unless otherwise specified, anode leads shall be AWG 8.
- The anode lead wire shall be a continuous conductor of AWG 8 with a seven-stranded copper conductor. The insulation shall be black, and shall consist of at least 2.78 mm (0.1 inch) of high molecular weight, medium density polyethylene that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9.
- The use of lead (Pb) anchors for cable connections is not permissible.
- Attachment of the lead wire to the anode shall be made by a permanent compression connection. The lead wire connection shall be centered inside the anode.
- The anode lead wire shall be visually inspected before attaching the anchoring assembly, to ensure that none of the copper strands have been scored or scratched. Before applying the compression crimp connector, the copper strands of the lead wire shall be manually twisted into a compact spiral to facilitate even distribution of stress to each of the strands.
- The lead wire MDPE or HMWPE jacket surface shall be roughened for 50 mm (2 inches) anode end to improve adhesion to the sealant.

- The lead wire center connection to the anode shall be sealed using ArmorThane STS-200 Side A and Side B cured polyurethane, or approved equivalent. The sealant thicknesses shall be a minimum of 150 mm (6 inches) both above and below the center connection. The depths (millimetre or inches) of top and bottom epoxy seals shall be measured by probing and recorded directly on the outside of all anodes with a permanent marker. In addition, date and distributor name shall be marked with a permanent marker on the anode.
- The seller to the Company shall perform non-destructive random checks of sealant levels, as quality assurance that sealant levels marked on the outside of the anodes are correct. Records of quality assurance checks completed shall be sent to the Company before shipping. If any non-conformances are indicated, all other anodes having the same assembly date and manufacturer shall be inspected and repaired as necessary to meet this specification.
- The lead wire connection to the anchoring assembly shall be destructively tested before and at the end of each production day, to ensure compression equipment is operating satisfactorily. In addition, each anode shall be manually (i.e., by hand) pull tested by the technician after the mechanical connection to the anode is completed. Pull tests shall not be performed after sealant application.
- All anode leads shall be tested to ensure electrical continuity to the anode after sealant has cured and before shipping.
- Anode leads shall be attached in accordance with anode manufacturer's recommended mechanical procedures. The anode manufacturer shall provide a lead wire installation procedure to the anode supplier and Company. In case of conflict between this specification and manufacturer's recommended procedures, this specification shall apply.
- Attachment of the anode lead wire shall only be performed by previously approved distributors.

5.2.3 Other Cable

Negative Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class D, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

Positive Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class C, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, and shall be high molecular weight, medium density polyethylene that conforms to:

- ASTM D 1248 Type II, Class D, Category 4, Grade D6
- ASTM D 1248, Type I, Class C, Category 5, Grade E5
- J1 or ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The cable shall be tested for cold bend at -30°C (-22°F) and impact at -40°C (-40°F). Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2. The minimum thickness of the HMWPE shall be 4 mm (0.16 inch).

Note: Cable colour should be consistent with specific installation practices.

Alternatively, an additional 1.52 mm (0.06 mm) thick red PVC outer jacket shall be extruded over the 2.78 mm (0.1 inch) HMWPE black cable.

Armoured Cable

Single conductor armoured cable shall have stranded annealed copper wire. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 inch) and shall be high molecular weight, medium density polyethylene (HMW-MDPE) that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9. Minimum thickness of the HMW-MDPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and 19 strands for cable sizes larger than AWG 2. The middle layer shall consist of aluminum armour.

Multiconductor armoured cable shall be Teck 90, conforming to CSA C22.2 No. 131, or an ASTM equivalent. The middle layer shall consist of aluminum armour.

Single Jacket Cable – Test Leads and Sacrificial Anodes

Single-jacket cable shall be stranded copper conductor in sizes not larger than AWG 6. Insulation shall be RWU-90 XLPE (-40°C/-40°F), with a thickness of 1.83 mm (5/64") and conform to CSA C22.2 No. 38, or an ASTM equivalent.

Deep Anode Lead Cable

To resist chemical attack, cable for deep anode bed applications shall be ethylene chlorotrifluoroethylene (ECTFE) fluoropolymer (HALAR or equivalent) jacketed.

Dual-extrusion HALAR cable shall have stranded annealed copper wires. Insulation shall be a homogenous wall of natural ECTFE fluoropolymer (HALAR or equivalent) extruded over the conductor. Insulation shall conform to NEMA WC70/ICEA S-96-658 and the outer insulation shall be high molecular weight polyethylene conforming to ASTM D 1248, Type 1, Class C, Category 5, Grades E5 and J1. Average thickness of the HALAR insulation shall be 0.5 mm (0.02 inches). Minimum thickness at any point shall be not less than 90% of the specified average thickness. Average outer jacket insulation thickness shall be 1.6 mm (0.06 inches). The minimum thickness shall be not less than 80% of the specified average thickness. The completed cable shall be tested in accordance with the requirements of NEMA WC70/ICEA S-96-658.

5.2.4 Summary

Table 5-1 provides a summary of the cable specifications.

Table 5-1: Summary Cable Specifications

Description	Insulation Description	Insulation Thickness (min mm)	Insulation Thickness (min inch)	Colours Specified
Armoured cable, AWG 2, 4	Inner: HMW-MDPE	2.78	7/64	N/A
	Middle: Aluminum armour	Standard	Standard	N/A
	Outer: Colored PVC	1.52	1/16	Per site specific construction drawings
AWG 2, 4 mainline positive cable (Option 1)	Inner: HMW-MDPE	2.78	7/64	Black
	Outer: Coloured PVC	1.52	1/16	Red
AWG 2, 4 mainline positive cable (Option 2)	HMW-MDPE	4.00	5/32	Red
AWG 2, 4 Alberta positive cable	HMW-MDPE	2.78	7/64	Black
AWG 4 negative cable	HMW-MDPE	2.78	7/64	White
Single jacket cable AWG 6	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings
Single jacket cable AWG 8	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings

Table 5-1: Summary Cable Specifications (Cont'd)

Description	Insulation Description	Insulation Thickness (min mm)	Insulation Thickness (min inch)	Colours Specified
Single jacket cable AWG 10, 12	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site specific construction drawings
Dual extrusion (HALAR or approved equivalent)	Inner: ECTFE fluoropolymer	0.5	2/100	Per site specific construction drawings
	Outer: ASTM D 1248 (colored)	1.6	1/16	Per site specific construction drawings
No. 2 ACSR	N/A	N/A	N/A	Per site specific construction drawings

For shipping, all cables (i.e., anode lead wires, cable spools and test station wires) shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.2.5 Splice Kits

Splice kit specifications are as follows:

- Epoxy splice kits shall contain a plastic mold, which completely surrounds the crimped cable connection and seals the cables such that the epoxy does not leak out during the cure time. Kits shall contain tape to seal the points at which the cables enter the plastic mold. Epoxy mixture shall cure in 30 minutes at temperatures of 15°C (60°F) and above. Kits shall also be rated up to 1000 volts.
- Heat shrink splice kits shall contain, as a minimum, an adhesive coated polyethylene sleeve, mastic filler and black cloth tape, or a Company approved equivalent. The sleeve shall extend 50 mm (2 inches) beyond each end of the connection. Refer to Company standard drawings.
- For splicing and sealing of continuous polymer anodes, only end caps, splice kits and tees that are approved by the conductive polymer anode manufacturer shall be used.

5.2.6 DC Poleline and Cables

DC poleline and cable specifications are as follows:

- The poles shall be minimum 12.2 metres (40 feet) long, Class 5, with Penta #8 retention, or CCA-peg treatment.
- The conductor shall be No. 2 ACSR cable, unless specified otherwise.
- Rock anchors for the poles shall be Tri-Anchor Line Pole Rock Anchor type 8-18-28.
- All pole line hardware shall be galvanized according to Ontario Hydro Electrical Safety Code, Section 75, or equivalent.

- Guy wires shall be stranded steel. The wires shall be galvanized and have a diameter of 9 mm minimum. Guy guards are required at all installed locations. Guy guards are to be made of plastic, and provide visual identification for public safety. The guards shall be secure to the guy wire using the manufacturer's supplied hardware.
- Insulators shall be selected in accordance with Ontario Hydro Specifications 31, 32, 33, or Table 100 or equivalent.

5.3 Coke and Other Backfill

5.3.1 General

All coke supplied shall be calcined, and all coke tests shall be conducted as per the referenced test methods.

5.3.2 Chemistry

The composition and tests methods are based on dry weight, and are outlined in Table 5-2.

Table 5-2: Test Methods and Coke Composition

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Carbon (fixed)	ASTM D3172 or D5142	98.7% minimum	99.2% minimum	99.2% minimum
Ash	ASTM D3174 or D5142	0.60% maximum	0.60% maximum	0.60% maximum
Sulfur	ASTM D4239	6% maximum	6% maximum	6% maximum
Moisture	ASTM D3173 or D5142	0.20% maximum	0.20% maximum	0.20% maximum
Hydrogen	ASTM D5373 (ultimate analysis for hydrogen content)	0.10% maximum	0.10% maximum	0.10% maximum

5.3.3 Other Requirements

Coke for deep anodes and continuous polymer anodes shall be dust-free. No de-dusting oils shall be used in the manufacture of the calcined coke.

Coke shall meet or exceed the requirements outlined in Table 5-3.

Table 5-3: Other Requirements for Coke

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Bulk density	Modified ASTM D4292	≥975 kg/m3	≥1,100 kg/m3	≥1,100 kg/m3
Resistivity	carbon industry test C12A @ 150 psi (dry basis)	<0.2 Ωcm	<0.2 Ωcm	<0.2 Ωcm
Particle size	ASTM D293 or ASTM D4749	#4 Mesh - 95% #200 Mesh - 5%	#12 mesh -100% #200 mesh - 5%	#12 mesh - 100% #200 mesh - 5%

Note: Particle size is listed as a percentage of coke passing through the screen.

For deep and continuous anode installations, Loresco SC-3 Coke Breeze, TC-Alcoke/Z0637 Coke Breeze and Asbury 251-P Coke Breeze, or a Company-approved equivalent are acceptable.

For shallow anode installations, Loresco DW-1 Coke Breeze, TC-Alcoke/Z0637, or a Company approved equivalent are acceptable.

The coke breeze supplier shall provide the Company with a "Certificate of Analysis" for each batch or lot (as specified by manufacturer) of coke breeze indicating that the coke breeze meets Company specifications.

5.3.4 Conductive Carbon Grout

Conductive carbon grout specifications follow:

- In areas where the current discharge zone could lead to the interchange flow between water-bearing formations, conductive carbon grout shall be used in the annular to form a conductive seal.
- The mixture of grout and round-grain calcined petroleum coke particles shall have additional additives to minimize the apparent viscosity of the slurry.
- The coke particles shall meet the minimum coke requirements listed above.

5.3.5 Other Backfill

The anode shall be centered in the backfill.

Backfill surrounding magnesium anodes shall have the following composition and properties:

- Gypsum – 75 to 80%
- Bentonite – 15 to 20%
- Sodium sulphate – 0 to 5%

Backfill surrounding the zinc grounding cells shall have the following composition and properties:

- Gypsum – 80 to 85%
- Bentonite – 15 to 20%
- Sodium sulphate – 0 to 5%

5.3.6 Shipping

All backfill shall be wrapped in weather and water tight UV-resistant plastic. All backfill packaging shall be clearly labelled with material designations, as specified in Sections 5.3.3, 5.3.4, and 5.3.5.

5.4 Deep Anode Venting

Deep-anode venting specifications are as follows:

- Shall allow for venting of gases a full 360-degree of the vent pipe without a loss of pipe strength.
- Vertical slits are preferred, and shall be 3.8 cm (1½ inches) in length, or greater, and shall be 0.015 cm (1/64 inch) in width.
- The diameter of piping shall be 25.4 mm (1 inch) inside diameter and 32.3 mm (1¼ inches) outside diameter.
- Material shall be non-conducting and resistant to chlorine attack, if chlorine is a possibility.
- Lengths of pipe joints shall be in either 3 metres (10 feet) or 6 metres (20 feet) lengths.
- If plowing is used, vent piping from a deep well to a vent termination point shall be 1 inch non-perforated coiled HDPE pipe. The minimum outside diameter of HDPE pipe shall be 33.4 mm (1.3 inches) and the minimum wall thickness shall be 3.02 mm (0.1 inches).

5.5 Isolation Sets

5.5.1 Flange Isolating Kit

Flange isolating kit specifications are as follows:

- These devices shall be pressure rated for the intended use, as shown on the Company standard drawing.
- Component dimensions shall conform to ANSI B16.21, Type F.
- Washers shall be zinc-plated steel.
- Retainers and double washers shall be glass reinforced epoxy (G10).
- Viton or Teflon shall be used as the sealing element.
- Minlon or Mylar insulation sleeves shall be used with insulation sets.

5.5.2 Monolithic Isolators

Monolithic isolator specifications are as follows:

- Metal components (excluding pipe-end pups) shall be forged steel.
- Pipe-end pups shall conform to the requirements for each installation, as specified on the purchase order or Company standard drawings.
- "Stiff" electrical isolating components shall consist of glass-reinforced epoxy composite conforming to ASTM D709, Type IV, Group G.10 requirements (G.11 is an acceptable alternative).
- Elastomeric sealing elements shall consist of nitrile butadiene rubber, conforming to ASTM D2000.
- Insulating filler materials shall consist of solventless epoxy resin.

- Adhesive sealant elastomeric materials shall be silicon.
- Each device shall be tested as follows:
  - Electrical test – each monolithic isolator shall be tested according to the requirements of the IEC 60-1 and 60-2
  - DC resistance test – each isolator shall maintain a resistance of at least 5 MΩ for one minute at an applied stress of 1000 VDC
  - AC resistance test – each isolator shall maintain a resistance of at least 1 MΩ for one minute at an applied stress of 5000 VAC (50-60Hz)

5.5.3 Isolating Unions

Isolating union specifications are as follows:

- Metal components shall be forged steel.
- Insulated against galvanic corrosion.
- Tailpiece coated with a tough baked industrial thermo-setting epoxy, bonded directly to the metal.
- Teflon shoulder gasket for extra wear resistance
- Insulating properties – exceeds 500 volts dielectric resistance

5.6 Rectifiers

5.6.1 General Information

General specifications for rectifiers are as follows:

- Rectifiers shall be designed to operate continuously at temperatures between -40°C and 50°C (-40°F and 122°F).
- The DC voltage output shall be fully isolated from the line voltage.
- Rectifiers shall have a primary and secondary arrestor designed to protect against electrical transients caused by lightning, induction and switching surges.
- Output ratings shall be as specified on the purchase order and Company standard drawings.
- The AC input of all rectifiers shall be single phase, 60 Hz, AC 230V, or as specified on the purchase order and Company standard drawings.
- The AC input lugs are to be sized to accommodate an AWG 2 and to provide a "dead front" for connection to the AC line.
- All rectifiers are to be equipped with an AC 115V, 15A, 3-pin ground fault interrupt (GFI) service receptacle. This receptacle is to be connected between the hot and the neutral through a fully magnetic circuit breaker from the line side of the rectifier's main circuit breaker. This receptacle is to be mounted on the front of the panel for easy access.
- Rectifying elements shall be silicon solid state and derated to 50% of the manufacturer's current rating at 100°C (212°F). Silicon diodes shall be constructed into a single-phase full wave bridge configuration. Heat sinks shall be sized to keep diode junction and core temperatures from exceeding 100°C (212°F) in 45°C (113°F) ambient conditions. Diodes shall have a minimum peak inverse voltage (PIV) of 800 V. Where applicable, clear chromate finish aluminum heat sinks (per MIL-C-5541) are acceptable. NOTE: ROHS (Restrictions of Hazardous Substances) disallows anodizing due to use of sulphuric and chromic acids.

- All cables, including jacket materials, shall be suitable for handling, and shall be rated to operate continuously over a temperature range -40°C to +105°C (-40°F to 220°F) ambient air temperature. Alternatively, all cables shall have the insulated jacket coatings de-rated according to applicable electrical codes or standards (Canadian and US) to satisfy the ambient air-temperature operating range.

5.6.2 Enclosure

Enclosure specifications are as follows:

- Enclosures for air-cooled cathodic protection rectifiers shall be constructed to CSA Enclosure 3R Classification, as required by CSA C22.2, No. 107.1 or NEMA MR 20 and NEMA MR 250. The rectifier case shall be NEMA 3R, and completely weatherproof for outdoor use.
- Minimum sheet metal thickness shall be 12 gauge wiped coat mill galvanized steel, as per ASTM 123 and, when practical, the cabinet shall be equipped with a slide-out chassis. Enclosures shall be vented for natural air convection and screened against insects. Screens shall be reinforced to provide structural integrity to the rectifier cabinet. Screens over openings shall meet the requirements set forth by CSA C22. No. 107.1. Hinges and enclosure assembly bolts shall be of stainless steel.
- Enclosures shall be painted white (or as otherwise specified), with the Company rectifier number or identifier in 50 mm to 75 mm (2 inches to 3 inches) black lettering on the outside of the front cabinet door and equipped with a pad lockable draw latch, consisting of a heavy-duty, single-hasp draw latch.
- Either a pole-mounting bracket or legs on the bottom (minimum length 600 mm [24 inches]) so it can be platform mounted, shall be provided and will be specified on the purchase order.
- Electrical panels shall be minimum thickness of 4.7 mm of (0.2 inches) NEMA Grade 'XX' phenolic. For panels greater than 100A, NEMA Grade 'UTR' type shall be used.
- All electrical hardware shall be copper, or brass finished in electroless nickel plate. All connections shall be made secure with lockwashers and nuts torqued in accordance with manufacturer's recommendations.
- For all rectifiers, a flush-mount outdoor wall plate (Leviton part #4925-2) is to be installed and if possible it is to be located on the bottom of the rectifier cabinet adjacent the closest side, or back wall, of the rectifier cabinet nearest the low voltage interruption plug and adjacent to the 200 mm x 250 mm x 150 mm (10 inches x 10 inches x 6 inches) equipment bay. The access port shall have a hinged and environmentally sealed cover. The cover hinge shall also be spring loaded for closure.
- The enclosure shall have the appropriate dimensions to accommodate an empty space for other equipment. The equipment bay is to be located on the bottom of the rectifier, adjacent to the access port described in the previous bullet. The free and clear dimensions of the equipment bay are to be 250 mm x 250 mm x 150 mm (10 inches x 10 inches x 6 inches). The equipment bay dimensions do not include the volume taken by the access port.

5.6.3 Transformer and Efficiency Filter Construction

Transformer and efficiency filter construction specifications are as follows:

- The transformer is to be designed as full isolation with separate and isolated primary and secondary windings, with a minimum efficiency of 95% at the maximum-rated voltage output.
- Transformer magnet wire and insulation materials are to be rated for CEC Class H (180°C) or NEC Class F (355°F), as applicable. Insulating materials shall be dipped in a thermosetting varnish and baked. Varnish shall meet or exceed the CSA requirements for Class H or NEC requirements for Class F operations, as applicable. Transformer voltage regulation shall not exceed 3% from full-rated load to no load.
- Dielectric strength of all insulating materials shall not be less than 2000 V RMS, as tested for one minute when applied between windings and the transformer core.
- The transformer shall be equipped with a minimum of 25 tap bar steps of secondary voltage adjustment (five coarse and five fine).
- Rectifier input overload and short-circuit protection shall be accomplished by magnetic circuit breakers; one pole per input line of AC power. Circuit breakers must trip at 140% of the rated AC input capacity of the rectifier. The input shall be labelled.
- Rectifier output over-load and short circuit protection shall be achieved by rectifier fuses in the transformer secondary of the rectifier. Rectifier fuses shall be sized for 120% rated transformer secondary RMS current. The output shall be labelled. (When the secondary fusing requirement exceeds 90 amps AC, the electronic Fuse Replacement Module will be considered as an acceptable alternative).
- Where specified, an efficiency filter (choke) shall be provided in the negative output of the rectifier. In the case of a multi-circuit rectifier, each circuit shall be provided with a choke, as mentioned. The choke shall be connected between the stack negative and the negative bus.

5.6.4 Instrumentation

Instrumentation specifications are as follows:

- The rectifier shall be equipped with multi-position switch(s) to connect a digital ammeter and voltmeter into each rectifier circuit, or pipeline negative lead. In addition, the multi-position switch shall have an "off" position that leaves the meter disconnected. The multi-position switch will also have a "lines" position, which activates a second switch that will connect each pipeline into the digital ammeter. In other words, two eight position rotary switches with the following settings:
  - Primary rotary switch – "Off, Circuit 1, Circuit 2, Circuit 3, Circuit 4, Circuit 5, Circuit 6 and Line" labels
  - Secondary line rotary switch – "Line 1, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7, Bond" labels

  This represents a case for a six-circuit rectifier connected to seven pipelines and one bond. Switch types and configurations may be varied according to the number of rectifier circuits, pipelines or bonds that must be metered. The off position for the primary switch shall isolate the ammeter and the voltmeter from any internal and external signal sources.

- The ammeter and voltmeter panel displays shall be high-intensity light emitting diode (LED) displays, with a minimum 13.2 mm (0.52 inch) digit height. All metered readings shall maintain a displayed measurement accuracy to one decimal place (i.e., 0.1 Volts or 0.1 A). The ammeter shall have a minimum 3.5 digit display, and the voltmeter shall have a minimum 4 digit or 4.5 digit display. Both metres shall be auto zeroing and auto calibrating, during the manufacturer's initial setup. The required nominal voltage measurement range for the ammeter is ±199.9 mV (with the display scaled to the shunt ratings), and for the voltmeter it is ±199.9 volts (displayed as measured).
- Both the ammeter and voltmeter shall have an accuracy of ±0.10% (or two counts) at 25°C (77°F). The drift in measurement accuracy shall not exceed ±0.50% at a temperature of -40°C (40°F). Test data documenting the accuracy of both the ammeter and the voltmeter over a -40 to +80 °C (40°F to175°F) temperature range shall be provided to verify the accuracy criteria outlined above. The Company shall approve the digital ammeters and voltmeters before purchase.
- The power supply for the high-intensity LED ammeter and voltmeter shall have a dedicated on/off switch, and a protective fuse installed downstream of the AC input surge arrestor for the rectifier.
- The 50A/50 mV metering shunts shall be the panel-mounted Holloway type 'SW' style, with an accuracy of ±0.25%, where output currents are less than or equal to 50 A DC on any structure or rectifier circuit being measured. The Mobiltex or manufacturer of other existing remote monitoring units (RMUs) can measure shunt voltages ± 158 mV. Where currents to be measured exceed 50 A DC, the provisions two bullet points below shall be used. For the digital ammeter, the following shunt sizes are compatible with the ammeter: 50 A/50 mV, 100 A/100 mV and 200 A/200 mV.
- Where line return currents or individual rectifier circuit outputs are less than, or equal to, 50 A DC, the shunts shall be 50 mV and sized for the maximum rectifier output current for negative drains, and shall be installed in each "line" negative output of the rectifier, including bonds. A separate 50 mV shunt, also sized for the maximum rectifier (single circuit) or circuit output (multi-circuit units) current shall be placed to provide metering for each different circuit's output. The shunt voltage shall be a negative common mode voltage for compatibility with the RMU.
- Where line return currents or individual rectifier circuit output currents exceed 50 A DC, two shunts shall be installed in series on each rectifier circuit or line return exceeding the 50 A DC limit. The first shunt installed shall be a 50 mV shunt, sized as previously outlined in this section, and shall be dedicated to the sense leads for the RMU pre-wire. A second shunt shall be installed downstream of the first, with a rating such that a minimum of 1 mV of voltage drop occurs across the shunt for each 1 A of current (i.e., 100 mV – 100 A shunt) to be measured by the high intensity LED digital ammeter.

5.6.5 Terminals

Negative Output Terminals

When specified, all rectifier negatives, including those for multi-rectifier units, shall be bused together using removable shorting bars. The bars shall be placed after the choke (where applicable) on the negative side of the negative meter shunts on each circuit, and fed to one set of output terminals (lugs). The output terminals are to be labeled "Line 1", "Line 2", etc. Output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

Positive Output Terminals

Separate positive output terminals are to be provided with each circuit, and are to be labelled. The output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

Bond Terminals

Terminals labeled "bonds" shall always be provided as specified on the purchase order or Company standard drawings. Bond terminals are to be directly connected to the negative bus. Shunts for bond connections shall also be provided, if indicated on the purchase order or Company standard drawings. Bond terminal lugs are to be sized to accommodate an AWG 1/0, unless otherwise specified.

Remote Monitoring Unit (RMU) Pre-Wire

RMU pre-wire specifications are as follows:

- Optional, based upon site-specific requirements.
- All rectifiers requiring remote monitoring shall be pre-wired with sense cabling connected to a termination block
- Current measurement shunts (50 mV) for each rectifier circuit shall be located on the return side of each rectifier circuit to provide a negative common-mode voltage with the drain terminals. Sense cables shall be installed across each 50 mV shunt installed on the negative return for each rectifier circuit and negative line drains. These sense cables shall be labelled and terminated.
- As specified by the Company, voltage dividers shall be provided on sense cabling for each rectifier circuit to meet the specifications in Table 5-4.

Table 5-4: Voltage Divider Specifications

Rectifier Circuit Rating	Scaling Factor	RMU Metered Voltage into Pre-Wired Terminal Block
>150 Volts	10 : 1	0 – 20 Volts
0 – 150 Volts	1 : 1	0 – 150 Volts

- These dividers shall be installed in conjunction with the standard RMU pre-wire, as specified by Company. If no voltage dividers are called for, then the sense cables are to carry rectifier circuit line voltages, and are to be terminated.

- Sense cables shall be provided for all bonds to foreign structures, to measure both the bond current and the pipe-to-soil voltage on the foreign structure. In addition, the bond measurement facilities must ensure compatibility with the RMU. The channels allocated for measurement of bond currents and voltages shall have an option provided for full electrical isolation.
- This option is to be provided, as specified by the Company. If no electrical isolation devices are specified, then an empty terminal is to be left for the foreign structure sense lead (non-current carrying) and leave a blank terminal for a fixed reference cell lead. The 50 mV foreign structure current measurement shunt(s) shall be installed in series with the current carrying bond lead, and shall have sense leads terminated.
- Sense cables allocated to fixed reference cells must also ensure compatibility with the RMU.
- All sense cables shall be AWG 12 in size and have jacket materials compatible with the operation within the environment inside the rectifier cabinet. The sense cables, including jacket materials, shall be suitable for handling over a temperature range -40°C to 105°C (-40°F to 220°F) ambient air temperature. A control transformer shall be installed in each rectifier unit for future power for the RMU5 remote monitoring device.

Low-Voltage Interruption Terminal

Low-voltage interruption terminal specifications are as follows:

- All rectifiers shall be wired with a CONXALL 4282-5SG-300 (including 4295 dust cap) 5-pin female connector. The wiring associated with the plug shall be AWG 20 TEW stranded copper cable rated to operate up to 105°C (220°F) temperature. Wire terminations for the connector are to be made as per Section 5.6.9.
- The CONXALL 4282-5SG-300 5-pin female connector shall be installed on the rectifier's front phenolic panel to allow the 4295 dust cap to have a minimum clearance of 51 mm (2") from the rectifier cabinet door.
- The AC interruption relays shown in Table 5-5 shall be installed in parallel with the high-voltage twist-lock hubble connector across the interruption switch located on the L1 leg of the AC power supply wiring downstream of the AC surge suppressor (See Section 5.6.9).

Table 5-5: AC Interruption Relays

Rectifier AC Power Input Rating	AC Relays Types	AC Relay Model Numbers
0 – 50 A	Crydom Series 1	Model D2450-10
>50 A	Crydom Series 1	Model D24110-10

- All AC relays shall be installed with heat sinks appropriately sized to facilitate continuous operation of the AC relay under interruption.
- A Hammond BD2E 12 volt power supply transformer is to be installed to power terminals four and five on the CONXALL 4282-5SG-300 5-pin female connector. The input leads on the transformer are to be wired into the L1 AC supply lead, downstream of the AC surge suppressor, and the second lead is to be wired into the AC neutral (see Section 5.6.9).

- The wiring for the CONXALL 4282-5SG-300 5-pin female connector and the Crydom relays, as outlined previously in this section, shall be compatible with the Mobiltex CorrTalk Portable Interrupter Model SPI-1A, SESCO GPS timing device model TCMAD1-100, or SESCO GPS current interrupter model TCFAD1-100 in synchronously actuating the relays with respect to pre-set GPS time-based interruption intervals.

5.6.6 Lightning Protection

Lighting protection specifications are as follows:

- Unless otherwise specified, metal oxide varistor arrestors shall be installed on both the AC input and the DC output of the rectifier.
- An arrestor shall be placed between the chassis and DC positive of each circuit, DC negative of each circuit and the chassis ground.
- Where semi-conductor or valve type arrestors are used, they are to be in an accessible location and enclosed in a small metal enclosure. The enclosure is to prevent fire in the event of a fault or surge.
- Arrestors are not to be mounted on the front control panel.

5.6.7 Inspection and Testing

Testing

All units shall be subjected to tests that verify that specifications are met. Documentation of these tests shall be provided.

Dielectric Strength Tests

Dielectric strength-test specifications are as follows:

- Every transformer shall be subjected to dielectric strength tests, conducted as per CSA C22.2 No. 107.1, or UL 60950, or NFPA 70 as applicable.
- Dielectric strength tests shall be conducted on the transformer before varnish dipping and baking, and after baking. The after baking test can be included as part of the final rectifier dielectric test.
- All assembled rectifiers shall be subjected to dielectric strength tests, as outlined in CSA C22.2 No. 107.1, or UL 60950, or NFPA 70 as applicable.

Inspection

After assembly, the rectifier shall be subjected to inspection of all wiring and mechanical components and their connections. Inspection shall also include over-all workmanship.

Operation

Rectifiers shall be subjected to testing and recording of all rectifier electrical parameters as follows:

- AC input voltage, current, apparent power and true power
- DC output voltage, current and power
- AC power factor
- AC to DC conversion efficiency

If a filter is required, the ripple at full output voltage shall be measured and documented.

Rectifier metres shall be tested to meet the requirements specified in Section 5.7.4.

5.6.8 Shipping

A rectifier identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- Manufacturer's name and code number
- AC volts and amperes
- line frequency
- number of phases
- DC voltage and ampere ratings
- ambient temperature rating
- serial number
- CSA file number (as applicable)

The following items are to be in a waterproof enclosure with documentation in the rectifier door, or if specified, label using lamacoid plates, or an equivalent approved by Company cathodic protection engineering personnel. Labels are to have a black background and white lettering.

- AC rectifier input terminals
- transformer tap positions (coarse & fine)
- negative and positive output lugs
- all metres
- Switch positions
- main breaker
- DC and AC arrestors
- all fuses (size and type)
- interrupter mode switch
- interrupter receptacle
- utility receptacle
- high voltage (if applicable)

A circuit diagram and parts list shall be included with each rectifier. The rectifier drawing shall be laminated and mounted on the inside of the front door of the rectifier. In addition, a paper copy of the rectifier electrical schematic and a parts list for each rectifier detailing all of the components shall be provided to Company Cathodic Protection Engineering personnel.

Each rectifier shall be individually packaged for shipment, and shall have the rectifier name or rectifier number clearly labelled on the exterior of the shipping box.

5.6.9 Rectifier Circuit Diagram

Refer to the Company standard drawings, or as per the Company's instruction.

5.7 Thermoelectric Generators

5.7.1 General Information

General specifications for thermoelectric generators are as follows:

- TEGs shall be designed to operate at temperatures between -45°C and 65°C (-50°F and 150°F).
- TEGs shall be designed to operate in unlimited rain or snowfall, provided that the unit is not flooded.
- TEGs shall operate in 100% relative humidity.
- TEGs shall operate in wind gusts of up to 140 km/hr (85 mph).
- TEGs shall come complete with automatic re-ignition.
- All components shall be manufactured in modules, or assemblies for easy field maintenance.
- As necessary, the units shall be furnished with over-temperature protection circuitry.

5.7.2 Enclosure

Enclosure specifications are as follows:

- Enclosures shall be designed for outdoor installation, and be of stainless steel and aluminum construction.
- Enclosures shall be equipped with pad-lockable latches.
- All electrical hardware shall be copper, or brass finished in electrolysis nickel plate. All connections shall be made secure with lockwashers and nuts, or with compression-type terminals.
- Enclosures shall be identified with the Company's rectifier number, or identifier in 50.8 mm to 76.2 mm (2 inch to 3 inch) black lettering on the outside of the front cabinet.

5.7.3 Mechanical Construction

Mechanical construction specifications are as follows:

- Units shall have a lead telluride solid-state, hermetically sealed power unit.
- Units shall have a nickel-alloy construction, meeker-type burner design that is stable in normal operating conditions.
- The individual TEG(s) shall be ordered to operate on butane, propane or natural gas, depending on the available fuel supply.

5.7.4 Metering and Instrumentation

Metering and instrumentation specifications are as follows:

- A separate suitably scaled voltmeter and ammeter as well as a current measuring shunt shall be provided to measure the DC output.
- Metres shall be a minimum 90 mm (3½ inches) size, with a minimum scale length of 73 mm (2⅞ inches).
- Metering accuracy shall be ±2% of full-scale deflection at 25°C (77°F). Temperature compensation shall be no more than 0.85% per 10°C (50°F), for temperatures other than 25°C (77°F).
- The package shall contain a terminal block capable of accepting 2/0 AWG (9 mm or ⅜ inch) cable.
- The package shall contain a variable resistor designed to control current output.
- Electrical output isolation from the chassis shall be achieved such that the leakage current does not exceed 100 mA.

5.7.5 Inspection and Testing during Manufacture

Inspection and testing specifications during manufacturing are as follows:

- All units shall be subjected to testing at 100% of rating.
- All units shall be subjected to tests as outlined in SPE-1000-94 for dielectric strength, bonding continuity, leakage current, stability and temperature.
- All units shall be subjected to testing and recording of all performance parameters as follows:
  - DC output voltage, current and power
  - DC input voltage, current and power
  - fuel pressure for rated power
  - set up voltage for rated power
  - leak test of fuel system
  - verification of ignition system operation

5.7.6 Shipping

An identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- Manufacturer's name and code number
- serial number
- fuel usage
- fuel pressure setting

5.8 Solar-Power Units

5.8.1 General Information

General specifications for solar-power units are as follows:

- Solar-power units shall be as specified on the purchase order.
- The number of solar panels to deliver the requirements as specified in the purchase order, or Company standard drawings, shall be determined by the manufacturer or distributor.
- The size of the units (typically 12V DC or 24V DC) shall be specified on the purchase order or Company standard drawings.
- All solar-power units shall have a main disconnect switch between the solar panels and the controller.
- All solar-power units are to be supplied with a silicon oxide varistor lightning arrestor with:
  - clamp voltage 100 V
  - maximum operating voltage 48V DC
  - maximum current 50 kA
  - maximum energy 750 Joules (0.7 BTU)
  - unlimited number of surges
  - 10 nanosecond response time

  They are also to be supplied with a system electrical groundlug.

5.8.2 Panels

Panel specifications are as follows:

- Solar panels shall be mounted on 12 metres (40 feet) of Class 6 wooden utility poles.
- The diameter of the pole at the panel-mounting location is to be approximately 200 mm (8 inches).
- Mounting brackets to secure the solar panels shall be sized to accommodate attachment to the highest point on the utility pole.

5.8.3 Controllers

Controller specifications are as follows:

- Controllers shall be sized to accommodate the voltage and the current requirements as specified on the purchase order or Company standard drawings.
- Controllers shall have a continuous voltage and current display.
- Controllers shall be housed in a watertight enclosure with securable locking latches or handle.

5.8.4 Batteries

Battery specifications are as follows:

- All units shall be supplied with either absorbed glass mat (AGM) or gel-sealed batteries, as specified on the purchase order. The self-discharge rate of the battery must be less than 2% per month, and must have a 12-month warranty.
- Battery quantities and sizes shall be to provide a minimum of 72 hours autonomy, with no more than 50% depth of discharge.
- Batteries shall be housed in a separate insulated and vented battery box.
- The battery box is to have securable locking latches or handles. The battery box is to have mounting lugs to secure the box to a wooden platform, or platform approved by Company Cathodic Protection Engineering personnel.

5.8.5 Enclosure

Enclosed specifications are as follows:

- Power center enclosures must be rated as NEMA Type 3, 3R or 4, and are to be rain and sleet proof.
- The enclosures must have a drip shield over the door.
- The hinged door is to be sealed with seamless poured urethane gasket, and come complete with a lockable latching mechanism that maintain constant pressure on the gasket.
- The battery box shall be insulated with 50 mm (2 inch) high-density foam and sized to allow a 10 mm (½ inch) battery separation and be complete with a hinged lid with a lockable latch.

5.8.6 Shipping

The location to which the units are to be shipped shall be clearly marked.

5.9 Test Stations

The test lead assembly shall be as per Company standard drawings.

5.10 Remote Monitoring Equipment

5.10.1 General Information

General specifications for remote monitoring equipment are as follows:

- All RMUs shall be CSA certified, or UL approved.
- All units shall have flash program memory.
- Internal components shall operate in the temperature range -40°C to +80°C (-40°F to +175°F).

5.10.2 Enclosures

Enclosure specifications are as follows:

- Enclosures for RMUs shall be NEMA 4X rated fiberglass or polycarbonate.
- Enclosures shall be equipped with a pad-lockable draw latch.

- All units to be fitted with a CSA or UL approved (as applicable) 10 watt heater and control thermostat to maintain the enclosure internal temperature within the radio's operating temperature range.
- Insulation shall be a "K" value suitable to allow a 10 watt heater to provide the required minimum temperature.
- Insulation to be rigid, foil backed non-hygroscopic and non-flammable to provide for a maintenance-free interior.
- Enclosure to have a mounting plate supported over the insulation, for mounting components.
- GPS antenna is to be mounted on the top of the enclosure and to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.
- The external electronic temperature sensor shall be mounted off-centre on the bottom of the enclosure, and is to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.

5.10.3 Channels

Channel specifications are as follows:

- All units to be equipped with 10 analog inputs and one interrupt drive output.
- All units shall have four isolated digital input points.
- All units shall have one internal (mounted on a PCB), and one external electronic temperature sensor.

5.10.4 Interruption

Interruption:

- Shall be a solid state AC interrupt relay, 25 A @ 280 VAC maximum
- Is to occur via GPS time receiver

5.10.5 Communication

IMARSAT communication is to be via Easy Track Communication/ GPS unit, with an operating temperature range of -30°C to +50°C (-22°F to 122°F).

5.10.6 Command Options

All units shall be able to indicate:

- AC "power fail" alarm. (Debounce timer set to 1 hour.)
- AC power restored. (Debounce timer set to 1 hour)
- DC power fail (DC current goes to zero, e.g. fuse fails, rectifier fails). (Debounce timer set to 1 hour.)
- Low battery (no time delay in sending this alarm)

5.10.7 Power Supply

Power shall consist of 120 VAC to 12 VDC supply for transceiver and electronics. (TEG version will be 24 VDC to 12 VDC.)

All units shall have a battery backup with charger and a low-voltage disconnect.

5.11 Junction Boxes and Terminal Boxes

5.11.1 Junction Boxes

Junction-box specifications are as follows:

- Junction box size and location shall be as per the purchase order or Company standard drawings.
- Junction box enclosures shall be cast aluminum, as per Wright Aluminum Ltd. specifications (Model# WAL-56 or Model# WAL-102).
- All junction-box enclosures shall have a high-voltage shield, and be mounted on 76 mm (3 inches) OD conduit(s), as per Company standard drawings.
- All junction boxes shall be constructed to CSA Enclosure 3R Classification, or equivalent.

5.11.2 Terminal Boxes

Terminal box specifications are as follows:

- Terminal box size and locations shall be as per the purchase order and Company standard drawings.
- Terminal boxes shall meet Hammond (Model 1418N4M8) or Bel (Model R363008) specifications.
- Terminal-box enclosures shall have a minimum sheet-metal thickness of 14 gauge.
- All steel terminal box enclosures shall be CEMA/NEMA 4 rated, and shall be powder coated (ASA61 grade polyester or ANSI/ASA61 grey baked recoatable enamel).
- Hinges and enclosure assembly bolts shall be stainless steel or aluminum. The enclosure shall be equipped with a latching device.
- All terminal box enclosures shall have a high-voltage shield, and be mounted on two 76 mm (3 inches) OD conduits as per Company standard drawings.

5.11.3 Panels

Junction box panels shall be a minimum thickness of 4.7 mm (0.2 inches) of NEMA grade 'XX' phenolic.

All electrical hardware shall be copper or brass, finished in electrolysis deposited nickel plate. All connections shall be made secure with lockwashers and nuts tightened to the manufacturer's recommended torque.

5.12 Copper–Copper Sulphate Reference Electrodes

Unless otherwise specified, all copper–copper sulphate reference electrodes shall be EDI Model UL - 30 Year LongLifeTM reference electrodes. Element type shall be a saturated gelled Cu/CuSO4. The lead wire shall be AWG 14 or larger, 15 metres (45 feet) or greater in length, insulated in high molecular weight polyethylene, and rated for underground service.

Where specified, the CSCL copper–copper sulphate reference electrode shall be CPMP-2-50. The length of the cable shall be as per the site-specific construction drawings.

5.13 NovaProbes

NovaProbe specifications are as follows:

- Permanent NovaProbes are patented and only available from licensed manufacturers.
- Permanent NovaProbes shall measure the following parameters:
  - local soil resistivity
  - local soil pH
  - local oxidation reduction potential
  - "on" pipe-to-soil potential

5.14 Coupons

Coupons shall be either 9 cm^2 or 50 cm^2 (1.4 in^2 or 9 in^2). Coupon test stations shall comply with Company standard drawings.

5.15 Exothermic Welds and Bonds

5.15.1 Thermite Welds

Thermite weld specifications are as follows:

- Thermite welds shall be a #15 gram charge (green cap) maximum with F-33 powder, or approved equivalent.
- A copper sleeve shall be used for wire sizes smaller than AWG 8. The sleeve size shall correspond to cable size.

5.16 Silver Soldering

Silver soldering specifications are as follows:

- Use only 2% silver/98% tin soldier material with the appropriate flux.
- "Tin" the pipe and the conductor to be soldered.
- Heat the pipe and melt a solder puddle sufficient in size to attach the conductor.
- Test for adequate bond and neutralize the acid flux with base solution.

5.17 Mechanical Bonds

Mechanical bond specifications are as follows:

- Circumferential clamp(s) is to maintain residual tension after the tensioning device is withdrawn. The cable connection to a circumferential clamp must be achieved by welding, or bolting to the clamping device.
- Any connection to structures, other than a pipe, must be achieved using materials required in the CEC or the NEC (as applicable) for grounding connections.
- Specially designed alteration to an electrical LB (elbow, back opens) fitting and connected to a flange bolt may be used. The apparatus shall be constructed of rigid conduit from a point 450 mm below grade and up to the LB. The cable shall pass through the conduit and connect to a lug inside the LB fitting. The conduit must be equipped with an EYS sealed fitting at the point of emergence from the ground.
- An alternate to the rigid conduit and EYS fitting is to use a single conductor Teck cable connected to the LB fitting with a "liquid tight" transition fitting.

5.18 Controlled Interference Bonds

Control device in an interference bond circuit shall consist of an appropriately sized resistor, or rheostat, and a meter or shunt.

5.19 AC Mitigation, Surge Protection and DC Decoupling

5.19.1 General Information

General specifications for AC mitigation, surge protection and DC decoupling are as follows:

- Isolation surge protectors shall be designed to simultaneously provide DC isolation and AC continuity at cathodic protection isolator locations, plus meet environmental ratings outlined in NEMA 4X and hazardous classifications for NEC, CSA: Class 1, Division 1 & 2, Groups A,B,C, D.
- Typical applications include installation where the facilities are subject to AC coupling, AC faults, or lightning, or electrical switching transients. Under AC faults or lightning (short term transients) it is allowable for the device to temporarily conduct DC current.
- The device shall be designed to allow an unlimited number of switching operations (associated with occasional AC faults or lightning events) without failure.
- The ultimate failure mode of the device shall be in the closed-circuit position.
- The device shall be equipped with two hole (⅜ inch diameter) terminal pads for cable connection.
- Isolation surge protectors shall be solid-state devices capable of normal operation at ambient temperatures between -45°C and +45°C (-50°F and 113°F).

5.19.2 Polarization Cell Replacements – Electronic Device Performance Characteristics

The performance characteristics shall be specified by the following product ratings.

- lightning surge current
- voltage threshold
- 60 Hz fault current
- 60 Hz steady-state current
- enclosure
- instrument test feature
- special requirements

If not specified on the purchase order, the following parameters shall apply:

- Lightning surge current – 50 kA: This parameter specifies the maximum current that the device must be capable of passing while holding the voltage across the terminals below 700 volts. The test waveform shall be 8 X 20uS.
- DC blocking voltage – 4.5 volts: This parameter specifies the upper DC voltage level, which will be blocked by the device while continuously conducting 60 Hz AC current.
- AC fault current at 60Hz – 50 kA for 1 cycle: This parameter specifies the minimum AC fault current that the device must be capable of passing without failure.

- Steady-state AC current at 60 Hz – 50 A RMS: This parameter specifies the maximum allowable steady state AC current that can be passed through the device while maintaining DC isolation.
- AC voltage drop under fault at 60 Hz – 35 volts AC: This parameter specifies the maximum AC voltage drop through the device under full rated fault current.

5.19.3 Enclosure

Enclosure specifications are as follows:

- Unless otherwise specified, the device shall be furnished with a NEXA 4X metallic enclosure suitable for all or channel mount, complete with a padlockable access cover.
- The device shall be marked with the manufacturer's name, the device model number and the device serial number.

5.19.4 Instrumentation

The device shall contain a sufficient number and type of test terminals to allow AC and DC voltage and current measurements while in operation. All test terminals shall incorporate a dead-front design to prevent personnel shock, and shall be clearly labelled.

5.19.5 Shipping

The device shall be packaged for shipping in order to prevent damage.

6 QUALITY MANAGEMENT

6.1 Quality Checks and Documentation

The Company requires the following reviews before and during work:

- Review that the manufacturer is approved within the Company's approved vendor list
- Review the materials adhere to the guidelines set forth in this specification

The Company requires the following documentation before work starts:

- Verification of equipment calibration, as per equipment specifications

6.2 Performance Measures

The manufacturer will be evaluated on the following measures:

- Adherence to the schedule – the ability to achieve milestones set forth by the Company.
- Delivery of materials – the materials are delivered to the Company in the timelines provided.
- Quality of materials – the materials adhere to the guidelines set forth in this specification.
- Adherence to safety – the ability to complete work safely with no lost time incidents.

6.3 Specification Deviations

Any deviations from this specification shall be identified and addressed as per the TEP-INT-MOC *Pipe Integrity Management of Change Procedure*. Deviations are to be reviewed and accepted by the Company's representative before acceptance of the deliverables, data or report.

6.4 Nonconformance Management

All nonconformances to the specification will be identified by the vendor, and reviewed and dispositioned by the Company.

APPENDIX

APPENDIX A APPROVED MATERIAL LIST

Table A-1: Approved Material List

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
Anodes	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660	Length: 1524 mm Diameter: 66 mm Mass: 23 kg (nominal)	Length: 60 in Diameter: 2.6 in Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684	Length: 2134 mm Diameter: 66 mm Mass: 31 kg (nominal)	Length: 84 in Diameter: 2.6 in Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884	Length: 2134 mm Diameter: 97 mm Mass: 31 kg (nominal)	Length: 84 in Diameter: 3.8 in Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660Z	Length: 1524 mm Diameter: 69 mm Mass: 23 kg (nominal)	Length: 60 in Diameter: 2.7 in Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684Z	Length: 2134 mm Diameter: 69 mm Mass: 32 kg (nominal)	Length: 84 in Diameter: 2.7 in Mass: 70 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884Z	Length: 2134 mm Diameter: 76 mm Mass: 41 kg (nominal)	Length: 84 in Diameter: 3.0 in Mass: 90 lb (nominal)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 1016 mm Diameter: 102 mm Mass: 16 kg (nominal)	Length 40 inch. Diameter 4 inch Mass: 35 lb. (nominal)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 1524 mm Diameter: 76 mm Mass: 12 kg (nominal)	Length 60 inch. Diameter 3 inch Mass: 27 lb. (nominal)

Table A-1: Approved Material List (Cont'd)

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
		Graphite Center Tap Anode	Varies depending on supplier	Length: 2032 mm Diameter: 102 mm Mass: 29 kg (nominal)	Length 80 inch. Diameter 4 inch 64 lb.
		Mixed Metal Oxide Anode	Varies depending on supplier	As specified on the purchase order.	As specified on the purchase order.

APPROVALS

Originator/Document Contact: Mark Whittington Corrosion Specialist Pipe Integrity, Corrosion Prevention	Mark Whittington Signature	4/8/14 Date
Reviewer: Tim Leitao, P. Eng. Senior Engineer Pipe Integrity, Corrosion Prevention	Signature	April 8, 2014 Date
Reviewer: Brent McKinnon Program Management Canadian Pipeline Maintenance Projects	Signature	Apr. 18, 2014 Date
Reviewer: David Gulen Program Management U.S. Pipeline Maintenance Projects	Signature	4/9/14 Date
Design Discipline Checker/ Responsible Engineer/Approver/ Engineer-In-Charge/Document Contact: Chad Khattar, P. Eng Senior Engineer Pipe Integrity, Corrosion Prevention	Signature Apr 14/2014 Date	APEGA Permit to Practice P7100
Management Endorsement: James Card, BSEE Manager Pipe Integrity, Corrosion Prevention	Signature	4/14/14 Date

SUMMARY

This specification establishes the requirements for cathodic protection materials to install cathodic protection facilities for Company gas and hazardous liquid pipeline systems in Canada and the United States.

DOCUMENT HISTORY

Rev. No.		
06	**Description**	**Effective Date**
	Revised Section 9.8 and referenced Appendix A Table A-2 and Figures A-1, A-2, A-3 and A-4. This gives better direction in which insulators should be used below and above ground. In Section 20 added Pin Brazing as an acceptable application in the US only to install test leads. In Section 24.8 additional information was added about the equipment.	2014-Apr-08
	Rationale Statement	**Responsible Engineer**
	Annual Review of document.	Chad Khattar
	Impact Assessment Summary	**Team Owner**
	The additions to this document will not impact operations and will not require additional training.	Corrosion Prevention, Pipe Integrity
05	**Description**	**Effective Date**
	Editorial and format changes throughout the document.	2013-Jan-21
	Rationale Statement	**Responsible Engineer**
		Brad Woloschuk
	Impact Assessment Summary	**Team Owner**
	This specification establishes the requirements for cathodic protection materials for the installation of cathodic protection facilities for Company gas and hazardous liquid pipeline systems in Canada and the United States.	Pipe Integrity, Corrosion Prevention
04	**Description**	**Effective Date**
	Specification revised to apply in the United States. Code and references revised.	2009-Oct-15
	Rationale Statement	**Responsible Engineer**
	This Specification shall be used in all activities related to cathodic protection, including design, construction, operations and maintenance of Company facilities in Canada and in the United States.	Brad Woloschuk
	Impact Assessment Summary	**Team Owner**
		Engineering and Asset Reliability
03	**Description**	**Effective Date**
	Updated cable specs, anode specs, coke specs, vent piping specs, rectifier specs, test station reference drawings, junction & terminal box specs, and reference electrode specs. Updated anode lead attachment quality requirements Updated anode manufacturing approval.	2008-Aug-11
	Rationale Statement	**Responsible Engineer**
		Matt Cetiner
	Impact Assessment Summary	**Team Owner**
		Engineering

02	**Description**	**Effective Date**
	Coke breeze requirements updated and a materials summary list was added to the Appendix. Alberta drain lead cable colors (AWG #4 cable) were changed to black and white and the mainline uses red and white.	2005-Jul-13
	Rationale Statement	**Responsible Engineer**
		Garry Norton
	Impact Assessment Summary	**Team Owner**
		Pipe Engineering
01	**Description**	**Effective Date**
	Major revisions to the content.	2001-Dec-15
	Rationale Statement	**Responsible Engineer**
	This specification establishes the requirements for cathodic protection materials.	Wayne Corcoran Corey Goulet
	Impact Assessment Summary	**Team Owner**
	Drawing revisions and the addition of AC Mitigation Devices and general editing.	Engineering and Operation Services (E&OS)
00	**Description**	**Effective Date**
	New document.	1999-Jul-01
	Rationale Statement	**Responsible Engineer**
	This specification establishes the requirements for cathodic protection materials.	Burke Delanty Robert Basaraba
	Impact Assessment Summary	**Team Owner**
	This specification replaces Nova Gas Transmission Ltd. Cathodic Protection (CP) Materials Specification, Revision 1998-04-06. This specification replaces TransCanada PipeLines Rectifier Specification, Revision 1997-03-23.	Quality, Standards and Technology

BRIEF DESCRIPTION OF CHANGE

REGULATORY	
Section	**Description of Change**
	N/A
INDUSTRY STANDARDS	
Section	**Description of Change**
	N/A
GENERAL	
Section	**Description of Change**
	Editorial and format changes throughout.
	Revised Section 9.8 and referenced Appendix A Table A-2 and Figures A-1, A-2, A-3 and A-4. This gives better direction in which insulators should be used below and above ground. In Section 20 added Pin Brazing as an acceptable application in the US only to install test leads. In Section 24.8 additional information was added about the equipment.

DEVIATION FROM THIS SPECIFICATION

TransCanada Engineering Standards and Specifications must be followed by internal and external users to ensure a safe, reliable and technically correct design.

Deviations to this standard may be acceptable if a technical assessment approved by TransCanada Engineering Specification Owner shows that the deviation meets the intent of this specification, does not compromise safety and also complies with applicable industry standards, regulatory requirements and is consistent with good engineering judgment.

Any deviation must follow the appropriate TransCanada management of change variance procedure.

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DEFINITIONS

Term	Definition
AC	alternating current
ACSR	aluminum conductor steel-reinforced cable
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
CEC	Canadian Electrical Code
Company	TransCanada Corporation
CSA	Canadian Standards Association
DC	direct current
ECTFE	ethylene chlorotrifluoroethylene
HMW-MDPE	high molecular weight high density polyethylene
HMWPE	high molecular weight polyethylene
ID	inside diameter
IEC	International Electrotechnical Commission
LED	light emitting diode
NACE	NACE International
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
OD	outside diameter
PCR	polarization cell replacement
RMU	remote monitoring unit
TEG	thermoelectric generator
UV	ultra violet
XLPE	cross-linked polyethylene

Tools and Applications	
Incident and Issue Tracking (IIT)	An electronic database tool used to report incidents and issues involving employees, contractors and third parties.
FileNet-EDMS	The Company's web-based electronic document management system.

1 PURPOSE

This specification establishes the requirements for cathodic protection materials to install cathodic protection facilities for the Company's buried pipeline systems in Canada and the United States.

This specification shall be used:

- By Company employees and all prime and subcontractors employed by the Company
- In all activities related to cathodic protection, including design, construction, operations and maintenance

Materials supplied shall meet all requirements of this specification and any additional requirements on the applicable request for quotation, purchase order and applicable Company standard drawings.

Before a material is added to the approved material list, it shall be reviewed and approved by the Company's cathodic protection engineering personnel.

2 SCOPE

This specification applies to materials for cathodic protection for the Company's gas and hazardous liquid pipeline systems in Canada and the United States.

3 REFERENCES

3.1 Regulations Codes and Standards

The jurisdictional regulations and legal requirements that apply to this specification are:

- 49 Code of Federal Regulations (CFR):
  - 192, Subpart I
  - 195, Subpart H
- Canadian Standards Association (CSA):
  - Z662-11 Oil and Gas Pipeline Systems, Section 9
  - C22.1 Canadian Electrical Code (CEC), Part I, Safety Standard for Electrical Installations (Section 80)
  - C22.2 No. 107.1, General Use of Power Supplies
  - C22.2 No. 131, Type TECK 90 Cable
  - C22.2 No. 75, Thermoplastic-Insulated Wires and Cables (Tri-National standard, with UL 83 and NMX-J-010-ANCE, 2008)
  - Special Publication SPE-1000-94, Model Code for the Field Evaluation of Electrical Equipment
  - Ontario Hydro Electrical Safety Code, Section 7
  - Ontario Hydro Specifications 31, 32, 33, or Table 100
- National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)

3.2 Industry Publications and References

The industry publications and references that apply to this specification are:

- NACE International:
  - SP0169-2007, Control of External Corrosion on Underground or Submerged Metallic Piping Systems
  - SP0572-2007, Design, Installation, Operations, and Maintenance of Impressed Current Deep Anode Beds
- American Society for Testing and Materials (ASTM) International:
  - G97, Standard Test Method for the Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications
  - B265, Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
  - B418, Standard Specification for Cast and Wrought Galvanic Zinc Anodes
  - B843, Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
  - A518, Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
  - D1248, Standard Specification for Polyethylene Plastics Molding and Extrusion Materials For Wire and Cable
  - D2000, Standard Classification System for Rubber Products in Automotive Applications
  - B3, Standard Specification for Soft or Annealed Copper Wire
  - B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
  - D293, Standard Test Method for the Sieve Analysis of Coke
  - D709, Standard Specification for Laminated Thermosetting Materials
  - D3172, Standard Practice for Proximate Analysis of Coal and Coke
  - D3173, Standard Test Method for Moisture in the Analysis Sample of Coal and Coke
  - D3174, Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal
  - D3178, Standard Test Method for Ultimate Analysis for Hydrogen Content
  - D5142, Standard Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures
  - D4239, Standard Test Methods for Sulphur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods
  - D4749, Standard Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size
- American Society of Mechanical Engineers (ASME) B16.21, *Nonmetallic Flat Gaskets for Pipe Flanges*

- International Electrotechnical Commission (IEC):
  - 60060-1, High-voltage test techniques, Part 1: General definitions and test requirements
  - 60060-2, High voltage test techniques, Part 2: Measuring systems
  - 60228, Conductors of Insulated Cables
- National Electrical Manufacturers Association (NEMA):
  - WC70/ICEA S-96-658, Thermoplastic Insulated Wire & Cable for Transmission & Distribution
  - Standard Publication Number MR 20-1958 (reaffirmed by NEMA 1971) – *Semiconductors, Rectifiers, Cathodic Protection Units*
  - Standard Publication No. MR 250-1979 (including Rev No. 1 December 1980), *Enclosures for Electrical Equipment (1000 Volts Maximum)*

3.3 Internal References

The Company procedures, guidelines, reports and documents that apply to this specification are:

- TED-CP-DD *Cathodic Protection Design Directive (CDN-US)* (EDMS No. 003746511)
- TEP-INT-MOC *Pipe Integrity Management of Change Procedure* (EDMS No. 006425143)
- *Operations and Maintenance (O&M) Manual – U.S. Natural Gas Pipelines* (EDMS No. 005404490)
- *TransCanada O&M Manual – U.S. Hazardous Liquids Pipelines* (EDMS No. 005713585)
- *Operator Qualification Program (US)* (EDMS No. 004504739)
- *Operator Qualification Program for Construction of Pipelines covered by 49 CFR §192.620 & under Special Permit of 49 CFR §195* (EDMS No. 005713585)

4 ROLES, RESPONSIBILITIES AND QUALIFICATIONS

4.1 Vendor Responsibilities and Qualifications

4.1.1 Requirements for All Materials

Following are material requirements:

- The manufacturer shall be on the Company's cathodic protection Approved Materials List (see Appendix A) for the production of cathodic protection materials.
- The manufacturer shall supply to the Company, at the time of quotation, any exceptions or alternatives to this specification.

4.1.2 Preproduction Provisions

For isolation sets, the manufacturer shall submit to the Company the following:

- For each sleeve size, the inside diameter (ID), outside diameter (OD), thickness and length (all in millimetres or inches), material type and the dielectric strength (volts per 1 mm or in.).

- For each washer type and size, the ID, OD and thickness (all in millimetres or inches), material type, and if applicable, dielectric strength (volts per 1 mm or 1 in.).

For rectifiers, the manufacturer shall submit to the Company:

- A certification that the rectifier meets the requirements of this specification
- A nationally recognized testing laboratories (NRTL) approval certification
- A circuit diagram and dimensions of the enclosure

For:

- Thermoelectric generators (TEG), the manufacturer shall certify that the TEG(s) meet the requirements of this specification, and provide a diagram showing the components of the TEG(s) and dimensions of the enclosure(s).
- Calcined coke, the manufacturer shall submit a datasheet detailing the chemistry and other requirements in Section 7.
- Cables, the manufacturer shall certify that the cable meets the requirements of the Canadian Electric Code (CEC) or the NEC (as applicable), ASTM D 1248 or NACE Standard SP0572 and this specification.
- Each monolithic isolator, the manufacturer shall submit to the Company the fabrication drawing and the production schedule.
- Remote monitoring equipment and rectifiers, the manufacturer shall supply laminated electrical schematic drawings with each rectifier, and copies shall be submitted to the Company.

4.2 Company Responsibilities

The Company representative shall obtain all QA/QC documents for materials to be installed, in accordance with the project description. At the request of a Company Representative, cathodic protection material may be retained by the Company for evaluation to ensure the material conforms to this specification.

The Company shall have the right to review the manufacturer's work at any time.

5 ANODES

5.1 High-Potential Magnesium Anodes

5.1.1 Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The anode shall conform to ASTM B843, Grade M1C.
- The anode shall have a minimum efficiency of 43%, when tested in accordance with ASTM G97.
- The mass of the anode, anode dimensions and package dimensions shall be as specified on the purchase order.
- A galvanized steel core shall be cast at least 75% of the full anode length.

5.1.2 Lead Wire

See Section 6, magnesium anodes or zinc anodes.

5.1.3 Backfill

See Section 7

5.1.4 Markings

The anode type, mass (kg/lb) and Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., High potential magnesium, 15 lb, TES-CP-MS [Cdn-US], 2012/10/01).

5.1.5 Shipping

Shipping specifications are as follows:

- The backfill package shall consist of a cotton bag or wettable (e.g., no wax or plastic coated) cardboard tube with the dimensions as specified on the purchase order.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to ultra violet (UV) rays, or as directed by the supplier.

5.2 Zinc Ribbon

5.2.1 Chemical Composition, Mass and Dimensions

Chemical composition, mass and dimension specifications are as follows:

- The chemical composition of zinc ribbon shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.
- The anode shall be manufactured by extrusion with a continuous centered 1/8 in. galvanized steel core.

5.2.2 Lead Wire

Not applicable.

5.2.3 Backfill

Not Applicable.

5.2.4 Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the reel (or another device that the anode is wrapped around):

- manufacturer
- anode model
- ribbon type
- cross section (X millimetres [inches] x Y millimetres [inches])
- length (metres or feet)
- Company specification and revision date

For example, "manufacturer", aaa, zinc ribbon, 12 mm x 15 mm, 500 m, TES-CP-MS (Cdn-US), 2012/10/01.

5.2.5 Shipping

Shipping specifications are as follows:

- The ribbon shall be packaged in a manner to allow for ease of shipping.
- The zinc ribbon shall be prepared for shipment and storage in such a manner that it will not be exposed to weather or water, as directed by the supplier.

5.3 Zinc Grounding Cells

5.3.1 Chemical Composition, Mass and Dimensions

The chemical composition for the zinc shall conform to ASTM B418, Type II. The anode dimensions shall be as specified on the purchase order or Company standard drawings.

5.3.2 Lead Wire

See Section 6, magnesium anodes or zinc anodes.

5.3.3 Backfill

See Section 7

5.3.4 Markings

The anode type, mass (kilograms or pounds) and the Company specification and revision date shall be legibly marked on each anode package with a weather-resistant marker or a label (e.g., Zinc grounding cell, 7.7 kg, TES-CP-MS [Cdn-US], 2012/10/01).

5.4 Silicon-Chromium Cast Iron Anodes

5.4.1 Chemical Composition, Mass and Dimensions

The following clauses shall apply to both tubular and stick anode castings:

- The anode shall be chill cast or equal, from an alloy conforming to ASTM A518 GR3.
- Each anode shall be supplied free from casting defects, porosity, voids and fissures. The anode surface shall be free from adhering foundry sand or mould release agents.

- The anode mass and anode dimensions shall be as specified on the purchase order, or Company standard drawings.
- All anode manufacturers shall be approved by the Company.

5.4.2 Lead Wire

See Section 6

5.4.3 Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- anode type
- anode mass (kilograms or pounds)
- anode OD (millimetres or inches)
- length (millimetres or inches)
- Company specification
- revision date

For example, "manufacturer", aaa, stick, 20 kg, 50 mm, 1520 mm, TES-CP-MS (Cdn-US), 2012/10/01.

5.4.4 Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.5 Continuous Polymer Anodes

5.5.1 Chemical Composition, Mass and Dimensions

Specifications for chemical compositions, mass and dimensions are as follows:

- Continuous polymer anodes shall be constructed as stranded American Wire Gauge (AWG) 6 annealed copper conductors with a conductive polymer jacket (rather than an insulating polymer jacket).
- The conductive polymer jacket shall provide a moisture-proof barrier to protect the copper cable.
- The conductive polymer jacket shall be capable of continuously discharging a current of 50 mA per linear metre (15 mA per linear foot) of anode material for a minimum of twenty years.

5.5.2 Lead Wire

See Section 6

5.5.3 Backfill

See Section 7

5.5.4 Markings

The following shall be legibly marked with a weather-resistant marker on a tag attached to the anode:

- manufacturer
- anode model
- polymer type
- length (metres or feet)
- Company specification
- revision date

For example, "manufacturer", aaa, carbon impregnated polyethylene, 500 m, TES-CP-MS (Cdn-US), 2012/10/01).

5.5.5 Shipping

Shipping specifications are as follows:

- As specified on the purchase order or Company standard drawings, continuous polymer anodes may be supplied bare (by itself) or prepackaged in a 38 mm (1½ in.) diameter flexible mesh tube.
- Prepackaged conductive polymer anodes shall contain a high-grade coke backfill conforming to Section 7. The conductive polymer anode shall be centered within the flexible mesh tube.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.6 Canister Anodes

5.6.1 Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- Only tubular anodes shall be placed in canisters. Anodes shall meet the requirements of Section 5.6.2 before assembly.
- The canisters shall be manufactured as follows:
  - spiral corrugated perforated galvanized steel – 28 gauge minimum
  - diameter – 225 mm to 235 mm (8 in.) minimum
  - length – anode length + 600 mm (2 ft)
  - plywood end caps – 16 mm (¾ in.) minimum thickness

5.6.2 Assembly

High silicon-chromium anode assemblies shall be canistered as follows:

- With the bottom end cap in place, the anode shall be centered in the can and filled with coke, such that the anode has 200 mm (8 in.) of coke beyond each anode end.
- Calcined petroleum coke, as per Section 7 shall be mechanically compacted around the anode.
- An inner plywood cap shall be secured to the can immediately above the compacted calcined petroleum coke.
- A steel bolted eyelet shall be attached to the top inner plywood cap, and the lead wire shall exit through a close fitting hole to the side of centre.
- The wire shall be coiled and placed on the inner cap.
- A top end cap, with access to the coiled wire, shall be attached to protect the coiled wire during shipping.

Refer to Company standard drawings.

5.6.3 Shipping

Shipping specifications are as follows:

- All canned anodes shall be securely attached to a pallet in such a manner to avoid damage to the anodes or canisters.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water, as directed by the supplier.
- All anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.7 Graphite Anodes

5.7.1 Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The chemical composition for the graphite shall be GR060CP grade or equal.
- The graphite shall be treated with wax or resin, as specified on the purchase order.
- Centre connections shall be tested to verify that the connection falls below 0.004 ohms (4 milliohms).

5.7.2 Lead wire

See Section 6

5.7.3 Backfill

See Section 7

5.7.4 Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid breaking during shipment.

- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode lead wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

5.8 Mixed Metal Oxide Anodes

5.8.1 Chemical Composition, Mass and Dimensions

Specifications for chemical composition, mass and dimensions are as follows:

- The chemical composition of titanium shall conform to ASTM B265.
- The anode rating per foot and length is as specified on the purchase order.

5.8.2 Lead wire

See Section 6

5.8.3 Backfill

See Section 7

5.8.3 Shipping

Shipping specifications are as follows:

- Anodes shall be packaged in a manner to avoid damage during shipment.
- The packaged anodes shall be prepared for shipment and storage in such a manner that the anodes will not be exposed to weather or water.
- The anode wires shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

6 CABLE

6.1 General

General specifications for cable are as follows:

- All cable shall be rated for use from -40°C to 60°C, or -40°F to 140°F.
- Cables shall have an underground rating.
- All cables shall conform to ASTM B3 and ASTM B8 or IEC 60228.
- All cables shall be rated to handle 600 V direct current.
- Unless specified, the cable size, cable length and cable colour shall be as indicated on the purchase order or Company standard drawings.
- The outer insulation layer shall be marked to include the manufacturer, conductor size and number of strands (e.g., "manufacturer," AWG 4, 7/S).

6.2 Anode Lead Wire

6.2.1 Magnesium Anodes or Zinc Anodes

Specifications for magnesium anodes or zinc anodes are as follows:

- The anode lead wire shall be a continuous seven stranded, AWG 10 or larger (unless specified on the purchase order) annealed copper conductor, minimum 3 m (10 ft) long. The

insulation shall be blue for magnesium anodes and white for zinc, unless specified on the purchase order, to be consistent with site-specific installations. The insulation shall be RWU90 cross-linked polyethylene (XLPE), or direct-burial high molecular weight polyethylene (HMWPE).

- Lead wires shall be attached to the galvanized steel core by silver solder, and the connection shall be made moisture-proof by encapsulating the connection with an electrical sealing compound. The lead wire connection shall withstand a steady load pull of 200 kg (440 lb) without separation from the anode.
- For zinc grounding cells, the lead wire shall be a continuous seven stranded, AWG 2, or larger, annealed copper conductor, minimum 3 m (10 ft) long. The insulation shall be white for zinc anodes. The insulation shall be RWU90 XLPE, or direct burial HMWPE. The wire shall be compression connected to the anode core and sealed with an electrical sealing compound.
- If magnesium anodes are to be used with solar panels, the cables shall meet the requirements of an impressed current system.

6.2.2 Tubular Anodes

Specifications for tubular anodes are as follows:

For deep-well anode leads, see Deep Anode Lead Cable below.

- Unless otherwise specified, anode leads shall be AWG 8.
- The anode lead wire shall be a continuous conductor of AWG 8 with a seven-stranded copper conductor. The insulation shall be black, and shall consist of at least 2.78 mm (0.1 in.) of high molecular weight, medium density polyethylene that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9.
- The use of lead (Pb) anchors for cable connections is not permissible.
- Attachment of the lead wire to the anode shall be made by a permanent compression connection. The lead wire connection shall be centered inside the anode.
- The anode lead wire shall be visually inspected before attaching the anchoring assembly, to ensure that none of the copper strands have been scored or scratched. Before applying the compression crimp connector, the copper strands of the lead wire shall be manually twisted into a compact spiral to facilitate even distribution of stress to each of the strands.
- The lead wire MDPE or HMWPE jacket surface shall be roughened for 50 mm (2 in.) anode end to improve adhesion to the sealant.
- The lead-wire centre connection to the anode shall be sealed using ArmorThane STS-200 Side A and Side B cured polyurethane, or approved equivalent. The sealant thicknesses shall be a minimum of 150 mm (6 in.) both above and below the centre connection. The depths (millimetre or inches) of top and bottom epoxy seals shall be measured by probing and recorded directly on the outside of all anodes with a permanent marker. In addition, the date and distributor name shall be marked with a permanent marker on the anode.
- The seller to the Company shall perform non-destructive random checks of sealant levels, as quality assurance that sealant levels marked on the outside of the anodes are correct. Records of quality assurance checks completed shall be sent to the Company before shipping. If any

nonconformances are indicated, all other anodes having the same assembly date and manufacturer shall be inspected and repaired as necessary to meet this specification.

- The lead wire connection to the anchoring assembly shall be destructively tested before and at the end of each production day, to ensure compression equipment is operating satisfactorily. In addition, each anode shall be manually (i.e., by hand) pull tested by the technician after the mechanical connection to the anode is completed. Pull tests shall not be performed after sealant application.
- All anode leads shall be tested to ensure electrical continuity to the anode after a sealant has cured and before shipping.
- Anode leads shall be attached in accordance with the anode manufacturer's recommended mechanical procedures. The anode manufacturer shall provide a lead-wire installation procedure to the anode supplier and Company. In case of conflict between this specification and manufacturer's recommended procedures, this specification shall apply.
- Attachment of the anode lead wire shall only be performed by previously approved distributors.

6.3 Other Cable

6.3.1 Negative Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 in.) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class D, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

6.3.2 Positive Cable

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 in.) and shall be high molecular weight, medium density polyethylene that conforms to either:

- ASTM D 1248, Type II, Class C, Category 4, Grade J4E9,
- ASTM D 1248, Type I, Class C, Category 5, Grade E5 and J1, or
- ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2.

Cables shall have stranded annealed copper wires. Insulation shall conform to NEMA WC70/ICEA S-96-658, and shall be high molecular weight, medium density polyethylene that conforms to:

- ASTM D 1248 Type II, Class D, Category 4, Grade D6
- ASTM D 1248, Type I, Class C, Category 5, Grade E5
- J1 or ASTM D 1248, Type I, Class A, Category 5, Grade E4 and E5

The cable shall be tested for cold bend at -30°C (-22°F) and impact at -40°C (-40°F). Minimum thickness of the HMWPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and a minimum of 18 strands for cable sizes larger than AWG 2. The minimum thickness of the HMWPE shall be 4 mm (0.16 in.).

Note: Cable colour should be consistent with specific installation practices.

Alternatively, an additional 1.52 mm (0.06 mm) thick red PVC outer jacket shall be extruded over the 2.78 mm (0.1 in.) HMWPE black cable.

6.3.3 Armored Cable

Single conductor armored cable shall have stranded annealed copper wire. Insulation shall conform to NEMA WC70/ICEA S-96-658, have a minimum thickness of 2.78 mm (0.1 in.) and shall be high molecular weight, medium density polyethylene (HMW-MDPE) that conforms to ASTM D 1248, Type II, Class C, Category 4, Grade J4E9. Minimum thickness of the HMW-MDPE at any point shall be not less than 90% of the specified average thickness. Cable shall be intended for cathodic protection applications. The cables shall have seven strands for sizes up to, and including, AWG 2 and 19 strands for cable sizes larger than AWG 2. The middle layer shall consist of aluminum armour.

Multi-conductor armored cable shall be Teck 90, conforming to CSA C22.2 No. 131, or an ASTM equivalent. The middle layer shall consist of aluminum armor.

6.3.4 Single Jacket Cable – Test Leads and Sacrificial Anodes

Single-jacket cable shall be stranded copper conductor in sizes not larger than AWG 6 or less. Insulation shall be RWU-90 XLPE (-40°C/-40°F), with a thickness of 1.83 mm (5/64 in.) and conform to CSA C22.2 No. 38, or an ASTM equivalent.

6.3.5 Deep Anode Lead Cable

To resist chemical attack, cable for deep anode bed applications shall be ethylene chlorotrifluoroethylene (ECTFE) fluoropolymer (HALAR or equivalent) jacketed.

Dual-extrusion HALAR cable shall have stranded annealed copper wires. Insulation shall be a homogenous wall of natural ECTFE fluoropolymer (HALAR or equivalent) extruded over the conductor. Insulation shall conform to NEMA WC70/ICEA S-96-658 and the outer insulation shall be high molecular weight polyethylene conforming to ASTM D 1248, Type 1, Class C, Category 5, Grades E5 and J1. Average thickness of the HALAR insulation shall be 0.5 mm (0.02 in.). Minimum thickness at any point shall be not less than 90% of the specified average thickness. Average outer jacket insulation thickness shall be 1.6 mm (0.06 in.). The minimum thickness shall be not less than 80% of the specified average thickness. The completed cable shall be tested in accordance with the requirements of NEMA WC70/ICEA S-96-658.

6.4 Summary

Table 6-1 provides a summary of the cable specifications.

Table 6-1: Summary Cable Specifications

Description	Insulation Description	Insulation Thickness (min mm)	Insulation Thickness (min inch)	Colours Specified
Armoured cable, AWG 2, 4	Inner: HMW-MDPE	2.78	7/64	N/A
	Middle: Aluminum armour	Standard	Standard	N/A
	Outer: Coloured PVC	1.52	1/16	Per site-specific construction drawings
AWG 2, 4 mainline positive cable (Option 1)	Inner: HMW-MDPE	2.78	7/64	Black
	Outer: Coloured PVC	1.52	1/16	Red
AWG 2, 4 mainline positive cable (Option 2)	HMW-MDPE	4.00	5/32	Red
AWG 2, 4 Alberta positive cable	HMW-MDPE	2.78	7/64	Black
AWG 4 negative cable	HMW-MDPE	2.78	7/64	White
Single jacket cable AWG 6	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site-specific construction drawings
Single jacket cable AWG 8	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site-specific construction drawings
Single jacket cable AWG 10, 12	RWU-90 XLPE (-40°C/-40°F)	1.83	5/64	Per site-specific construction drawings
Dual extrusion (HALAR or approved equivalent)	Inner: ECTFE fluoropolymer	0.5	2/100	Per site-specific construction drawings
	Outer: ASTM D 1248 (colored)	1.6	1/16	Per site-specific construction drawings
No. 2 ACSR	N/A	N/A	N/A	Per site-specific construction drawings

For shipping, all cables (i.e., anode lead wires, cable spools and test station wires) shall be wrapped in weather-tight plastic opaque to UV rays, or as directed by the supplier.

6.5 Splice Kits

Splice kit specifications are as follows:

- Epoxy splice kits shall contain a plastic mold, which completely surrounds the crimped cable connection and seals the cables such that the epoxy does not leak out during the cure time. Kits shall contain tape to seal the points at which the cables enter the plastic mold. Epoxy mixture shall cure in 30 minutes at temperatures of 15°C (60°F) and above. Kits shall also be rated up to 1000 V.
- Heat-shrink splice kits shall contain, as a minimum, an adhesive coated polyethylene sleeve, mastic filler and black cloth tape, or a Company approved equivalent. The sleeve shall extend 50 mm (2 in.) beyond each end of the connection. Refer to Company standard drawings.
- For splicing and sealing of continuous polymer anodes, only end caps, splice kits and tees that are approved by the conductive polymer anode manufacturer shall be used.
- Rubberized 3M slicing tape and the 3M Scotchkote Electrical Coating may be used on above ground splices in junction boxes.

6.6 Direct Current Pole line and Cables

Direct current (DC) pole line and cable specifications are as follows:

- The poles shall be minimum 12.2 m (40 ft) long, Class 5, with Penta #8 retention, or CCA-peg treatment.
- The conductor shall be No. 2 ACSR cable, unless specified otherwise.
- Rock anchors for the poles shall be Tri-Anchor Line Pole Rock Anchor type 8-18-28.
- All pole line hardware shall be galvanized according to Ontario Hydro Electrical Safety Code, Section 75, or equivalent.
- Guy wires shall be stranded steel. The wires shall be galvanized and have a diameter of 9 mm (3/8 in.) minimum. Guy guards are required at all installed locations. Guy guards are to be made of plastic, and provide visual identification for public safety. The guards shall be secured to the guy wire using the manufacturer's supplied hardware.
- Insulators shall be selected in accordance with Ontario Hydro Specifications 31, 32, 33, or Table 100 or equivalent.

7 COKE AND OTHER BACKFILL

7.1 General

All coke supplied shall be calcined, and all coke tests shall be conducted as per the referenced test methods.

7.2 Chemistry

The composition and tests methods are based on dry weight, and are outlined in Table 7-1.

Table 7-1: Test Methods and Coke Composition

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Carbon (fixed)	ASTM D3172 or D5142	98.7% minimum	99.2% minimum	99.2% minimum
Ash	ASTM D3174 or D5142	0.60% maximum	0.60% maximum	0.60% maximum
Sulfur	ASTM D4239	6% maximum	6% maximum	6% maximum
Moisture	ASTM D3173 or D5142	0.20% maximum	0.20% maximum	0.20% maximum
Hydrogen	ASTM D5373 (ultimate analysis for hydrogen content)	0.10% maximum	0.10% maximum	0.10% maximum

7.3 Other Requirements

Coke for deep anodes and continuous polymer anodes shall be dust-free. No de-dusting oils shall be used in the manufacture of the calcined coke.

Coke shall meet or exceed the requirements outlined in Table 7-2.

Table 7-2: Other Requirements for Coke

Category	Test Method	Shallow Anodes	Deep Anodes	Continuous Polymer Anodes
Bulk density	Modified ASTM D4292	≥975 kg/m^3	≥1,100 kg/m^3	≥1,100 kg/m^3
Resistivity	Carbon industry test C12A @ 150 psi (dry basis)	<0.2 Ωcm	<0.2 Ωcm	<0.2 Ωcm
Particle size	ASTM D293 or ASTM D4749	#4 Mesh - 95% #200 Mesh - 5%	#12 mesh -100% #200 mesh - 5%	#12 mesh - 100% #200 mesh - 5%

Note: Particle size is listed as a percentage of coke passing through the screen.

For deep and continuous anode installations, Loresco SC-3 Coke Breeze, TC-Alcoke/Z0637 Coke Breeze and Asbury 251-P Coke Breeze, or a Company-approved equivalent are acceptable.

For shallow anode installations, Loresco DW-1 Coke Breeze, TC-Alcoke/Z0637, or a Company approved equivalent is acceptable.

The coke breeze supplier shall provide the Company with a Certificate of Analysis for each batch or lot (as specified by manufacturer) of coke breeze indicating that the coke breeze meets Company specifications.

7.4 Conductive Carbon Grout

Conductive carbon grout specifications follow:

- In areas where the current discharge zone could lead to the interchange flow between water-bearing formations, conductive carbon grout shall be used in the annular to form a conductive seal.
- The mixture of grout and round-grain calcined petroleum coke particles shall have additional additives to minimize the apparent viscosity of the slurry.
- The coke particles shall meet the minimum coke requirements listed above.

7.5 Other Backfill

The anode shall be centered in the backfill.

Backfill surrounding magnesium anodes shall have the following composition and properties:

- gypsum – 75% to 80%
- bentonite – 15% to 20%
- sodium sulphate – 0% to 5%

Backfill surrounding the zinc grounding cells shall have the following composition and properties:

- gypsum – 80% to 85%
- bentonite – 15% to 20%
- sodium sulphate – 0% to 5%

7.6 Shipping

All backfill shall be wrapped in weather and water-tight UV-resistant plastic. All backfill packaging shall be clearly labeled with material designations, as specified in Sections 7.10 and 7.11.

8 DEEP ANODE VENTING

Deep-anode venting specifications are as follows:

- Venting of gases shall be allowed for a full 360 degrees of the vent pipe without a loss of pipe strength.
- Vertical slits are preferred, and shall be 3.8 cm (1½ in.) in length, or greater, and shall be 0.015 cm (1/64 in.) in width.
- The diameter of piping shall be 25.4 mm (1 in.) inside diameter and 32.3 mm (1¼ in.) outside diameter.
- Material shall be non-conducting and resistant to chlorine attack, if chlorine is a possibility.
- Lengths of pipe joints shall be in either 3 m (10 ft) or 6 m (20 ft) lengths.
- If plowing is used, vent piping from a deep well to a vent termination point shall be 1 in. non-perforated coiled HDPE pipe. The minimum outside diameter of HDPE pipe shall be 33.4 mm (1.3 in.) and the minimum wall thickness shall be 3.02 mm (0.1 in.).

9 ISOLATION SETS

9.1 Flange Isolating Kit

Flange isolating kit specifications are as follows:

- These devices shall be pressure rated for the intended use, as shown on the Company standard drawing.
- Washers shall be zinc-plated steel.
- G10 retainer or gasket face shall be a Type F glass reinforced epoxy.
- Viton or Teflon shall be used as the sealing element.
- G10 insulation sleeves shall be used with insulation sets.
- Double washer set is required for aboveground applications, which will include two steel washers and two G10 isolating washers for each stud or bolt.
- G10 one piece sleeve and washer sets, or full length sleeves and single washer set configuration is required for below-ground installations to allow the cathodic protection current to protect the nuts and bolts of the buried flange.
- See Appendix A, Table A-1, Table A-2 for the approved material list. Figures A-1, A-2, A-3 and A-4 for examples of sleeve and washer configurations

9.2 Monolithic Isolators

Monolithic isolator specifications are as follows:

- Metal components (excluding pipe-end pups) shall be forged steel.
- Pipe-end pups shall conform to the requirements for each installation, as specified on the purchase order or Company standard drawings.
- "Stiff" electrical isolating components shall consist of glass-reinforced epoxy composite conforming to ASTM D709, Type IV, Group G.10 requirements (G.11 is an acceptable alternative).

- Elastomeric sealing elements shall consist of nitrile butadiene rubber, conforming to ASTM D2000.
- Insulating filler materials shall consist of epoxy resin without solvents.
- Adhesive sealant elastomeric materials shall be silicon.
- Each device shall be tested as follows:
  - Electrical test – each monolithic isolator shall be tested according to the requirements of the IEC 60-1 and 60-2
  - DC resistance test – each isolator shall maintain a resistance of at least 5 MΩ for one minute at an applied stress of 1000 VDC
  - Alternating current (AC) resistance test – each isolator shall maintain a resistance of at least 1 MΩ for one minute at an applied stress of 5000 VAC (50-60 Hz)

9.3 Isolating Unions

Isolating union specifications are as follows:

- Metal components shall be forged steel.
- Isolating union shall be insulated against galvanic corrosion.
- The tailpiece shall be coated with a tough-baked industrial thermo-setting epoxy, bonded directly to the metal.
- A Teflon shoulder gasket shall be provided for extra-wear resistance.
- Insulating properties – exceeds 500 V dielectric resistance.

10 RECTIFIERS

10.1 General Information

General specifications for rectifiers are as follows:

- Rectifiers shall be designed to operate continuously at temperatures between -40°C and 50°C (-40°F and 122°F).
- The DC voltage output shall be fully isolated from the line voltage.
- Rectifiers shall have a primary and secondary arrestor designed to protect against electrical transients caused by lightning, induction and switching surges.
- Output ratings shall be as specified on the purchase order and Company standard drawings.
- The AC input of all rectifiers shall be single phase, 60 Hz, AC 230 V, or as specified on the purchase order and Company standard drawings.
- The AC input lugs are to be sized to accommodate an AWG 2 and to provide a "dead front" for connection to the AC line.
- All rectifiers are to be equipped with an AC 115V, 15A, 3-pin ground fault interrupt- (GFI) service receptacle. This receptacle is to be connected between the hot and the neutral through a fully magnetic circuit breaker from the line side of the rectifier's main circuit breaker. This receptacle is to be mounted on the front of the panel for easy access.
- Rectifying elements shall be silicon solid state and de-rated to 50% of the manufacturer's current rating at 100°C (212°F). Silicon diodes shall be constructed into a single-phase full

wave bridge configuration. Heat sinks shall be sized to keep diode junction and core temperatures from exceeding 100°C (212°F) in 45°C (113°F) ambient conditions. Diodes shall have a minimum peak inverse voltage (PIV) of 800 V. Where applicable, clear chromate finish aluminum heat sinks (per MIL-C-5541) are acceptable. NOTE: ROHS (restrictions of hazardous substances) disallows anodizing due to use of sulphuric and chromic acids.

- All cables, including jacket materials, shall be suitable for handling, and shall be rated to operate continuously over a temperature range -40°C to +105°C (-40°F to 220°F) ambient air temperature. Alternatively, all cables shall have the insulated jacket coatings de-rated according to applicable electrical codes or standards (Canadian and US) to satisfy the ambient air-temperature operating range.

10.2 Enclosure

Enclosure specifications are as follows:

- Enclosures for air-cooled cathodic protection rectifiers shall be constructed to CSA Enclosure 3R Classification, as required by CSA C22.2, No. 107.1 or NEMA MR 20 and NEMA MR 250. The rectifier case shall be NEMA 3R, and completely weatherproof for outdoor use.
- Minimum sheet metal thickness shall be 12 gauge, wiped coat mill-galvanized steel, as per ASTM 123 and, when practical, the cabinet shall be equipped with a slide-out chassis. Enclosures shall be vented for natural air convection and screened against insects. Screens shall be reinforced to provide structural integrity to the rectifier cabinet. Screens over openings shall meet the requirements set forth by CSA C22. No. 107.1. Hinges and enclosure assembly bolts shall be of stainless steel.
- Enclosures shall be painted white (or as otherwise specified), with the Company rectifier number or identifier in 50 mm to 75 mm (2 in. to 3 in.) black lettering on the outside of the front cabinet door and equipped with a pad lockable draw latch, consisting of a heavy-duty, single-hasp draw latch.
- Either a pole-mounting bracket, or legs on the bottom (minimum length 600 mm [24 in.]) so it can be platform mounted, shall be provided and will be specified on the purchase order.
- Electrical panels shall be minimum thickness of 4.7 mm of (0.2 in.) NEMA Grade 'XX' phenolic. For panels greater than 100A, NEMA Grade UTR type shall be used.
- All electrical hardware shall be copper, or brass finished in electroless nickel plate. All connections shall be made secure with lock washers and nuts torqued in accordance with manufacturer's recommendations.

For all rectifiers, a flush-mount outdoor wall plate (Leviton part #4925-2) is to be installed. If possible, it is to be located on the bottom of the rectifier cabinet adjacent the closest side, or back wall, of the rectifier cabinet nearest the low-voltage interruption plug and adjacent to the 200 mm x 250 mm x 150 mm (10 in. x 10 in. x 6 in.) equipment bay. The access port shall have a hinged and environmentally sealed cover. The cover hinge shall also be spring loaded for closure.

The enclosure shall have the appropriate dimensions to accommodate an empty space for other equipment. The equipment bay is to be located on the bottom of the rectifier, adjacent to the access port described in the previous bullet. The free and clear dimensions of the equipment bay are to be 250 mm x 250 mm x 150 mm (10 in. x 10 in. x 6 in.). The equipment bay dimensions do not include the volume taken by the access port.

10.3 Transformer and Efficiency Filter Construction

Transformer and efficiency filter construction specifications are as follows:

- The transformer is to be designed as full isolation with separate and isolated primary and secondary windings, with a minimum efficiency of 95% at the maximum-rated voltage output.
- Transformer magnet wire and insulation materials are to be rated for CEC Class H (180°C) or NEC Class F (355°F), as applicable. Insulating materials shall be dipped in a thermosetting varnish and baked. Varnish shall meet or exceed the CSA requirements for Class H or NEC requirements for Class F operations, as applicable. Transformer voltage regulation shall not exceed 3% from full-rated load to no load.
- Dielectric strength of all insulating materials shall not be less than 2000 V RMS, as tested for one minute when applied between windings and the transformer core.
- The transformer shall be equipped with a minimum of 25 tap bar steps of secondary voltage adjustment (five coarse and five fine).
- Rectifier input overload and short-circuit protection shall be accomplished by magnetic circuit breakers; one pole per input line of AC power. Circuit breakers must trip at 140% of the rated AC input capacity of the rectifier. The input shall be labelled.
- Rectifier output overload and short-circuit protection shall be achieved by rectifier fuses in the transformer secondary of the rectifier. Rectifier fuses shall be sized for 120% rated transformer secondary RMS current. The output shall be labeled. (When the secondary fusing requirement exceeds 90 amps AC, the electronic Fuse Replacement Module will be considered as an acceptable alternative).
- Where specified, an efficiency filter (choke) shall be provided in the negative output of the rectifier. In the case of a multi-circuit rectifier, each circuit shall be provided with a choke, as mentioned. The choke shall be connected between the stack negative and the negative bus.

10.4 Instrumentation

Instrumentation specifications are as follows:

- The rectifier shall be equipped with multi-position switch(s) to connect a digital ammeter and voltmeter into each rectifier circuit, or pipeline negative lead. In addition, the multi-position switch shall have an "off" position that leaves the meter disconnected. The multi-position switch will also have a "lines" position, which activates a second switch that will connect each pipeline into the digital ammeter. In other words, two eight position rotary switches with the following settings:
  - Primary rotary switch – "Off, Circuit 1, Circuit 2, Circuit 3, Circuit 4, Circuit 5, Circuit 6 and Line" labels
  - Secondary line rotary switch – "Line 1, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7, Bond" labels
- This configuration represents a case for a six-circuit rectifier connected to seven pipelines and one bond. Switch types and configurations may be varied according to the number of rectifier circuits, pipelines or bonds that must be metered. The off position for the primary switch shall isolate the ammeter and the voltmeter from any internal and external signal sources.
- The ammeter and voltmeter panel displays shall be high-intensity light emitting diode (LED) displays, with a minimum 13.2 mm (0.52 in.) digit height. All metered readings shall

maintain a displayed measurement accuracy to one decimal place (i.e., 0.1 V or 0.1 A). The ammeter shall have a minimum 3.5 digit display, and the voltmeter shall have a minimum four digit or 4.5 digit display. Both meters shall be auto-zeroing and auto-calibrating, during the manufacturer's initial setup. The required nominal voltage measurement range for the ammeter is ±199.9 mV (with the display scaled to the shunt ratings), and for the voltmeter it is ±199.9 V (displayed as measured).

- Both the ammeter and voltmeter shall have an accuracy of ±0.10% (or two counts) at 25°C (77°F). The drift in measurement accuracy shall not exceed ±0.50% at a temperature of -40°C (40°F). Test data documenting the accuracy of both the ammeter and the voltmeter over a -40 to +80 °C (40°F to175°F) temperature range shall be provided to verify the accuracy criteria outlined above. The Company shall approve the digital ammeters and voltmeters before purchase.
- The power supply for the high-intensity LED ammeter and voltmeter shall have a dedicated on/off switch, and a protective fuse installed downstream of the AC input surge arrestor for the rectifier.
- The 50A/50 mV metering shunts shall be the panel-mounted Holloway type SW style, with an accuracy of ±0.25%, where output currents are less than or equal to 50 A DC on any structure or rectifier circuit being measured. The Mobiltex, or manufacturer of other existing remote monitoring units (RMUs), can measure shunt voltages ± 158 mV. Where currents to be measured exceed 50 A DC, the provisions two bullet points below shall be used. For the digital ammeter, the following shunt sizes are compatible with the ammeter: 50 A/50 mV, 100 A/100 mV and 200 A/200 mV.
- Where line return currents or individual rectifier circuit outputs are less than, or equal to, 50 A DC, the shunts shall be 50 mV and sized for the maximum rectifier output current for negative drains, and shall be installed in each "line" negative output of the rectifier, including bonds. A separate 50 mV shunt, also sized for the maximum rectifier (single circuit) or circuit output (multi-circuit units) current shall be placed to provide metering for each different circuit's output. The shunt voltage shall be a negative common mode voltage for compatibility with the RMU.
- Where line return currents or individual rectifier circuit output currents exceed 50 A DC, two shunts shall be installed in series on each rectifier circuit or line return exceeding the 50 A DC limit. The first shunt installed shall be a 50 mV shunt, sized as previously outlined in this section, and shall be dedicated to the sense leads for the RMU pre-wire. A second shunt shall be installed downstream of the first, with a rating such that a minimum of 1 mV of voltage drop occurs across the shunt for each 1 A of current (i.e., 100 mV – 100 A shunt) to be measured by the high-intensity LED digital ammeter.

10.5 Terminals

10.5.1 Negative Output Terminals

When specified, all rectifier negatives, including those for multi-rectifier units, shall be bused together using removable shorting bars. The bars shall be placed after the choke (where applicable) on the negative side of the negative meter shunts on each circuit, and fed to one set of output terminals (lugs). The output terminals are to be labeled "Line 1," "Line 2." Output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

10.5.2 Positive Output Terminals

Separate positive output terminals are to be provided with each circuit, and are to be labelled. The output terminal lugs are to be sized to accommodate up to an AWG 1/0, unless otherwise specified.

10.5.3 Bond Terminals

Terminals labelled "bonds" shall always be provided as specified on the purchase order, or Company standard drawings. Bond terminals are to be directly connected to the negative bus. Shunts for bond connections shall also be provided, if indicated on the purchase order, or Company standard drawings. Bond terminal lugs are to be sized to accommodate an AWG 1/0, unless otherwise specified.

10.5.4 Remote Monitoring Unit Pre-Wire

RMU pre-wire specifications are as follows:

- Optional, based upon site-specific requirements.
- All rectifiers requiring remote monitoring shall be pre-wired with sense cabling connected to a termination block
- Current measurement shunts (50 mV) for each rectifier circuit shall be located on the return side of each rectifier circuit to provide a negative common-mode voltage with the drain terminals. Sense cables shall be installed across each 50 mV shunt installed on the negative return for each rectifier circuit and negative line drains. These sense cables shall be labelled and terminated.
- As specified by the Company, voltage dividers shall be provided on sense cabling for each rectifier circuit to meet the specifications in Table 10-1.

Table 10-1: Voltage Divider Specifications

Rectifier Circuit Rating	Scaling Factor	RMU Metered Voltage into Pre-Wired Terminal Block
>150 V	10 : 1	0 – 20 V
0 – 150 V	1 : 1	0 – 150 V

- These dividers shall be installed in conjunction with the standard RMU pre-wire, as specified by the Company. If no voltage dividers are called for, then the sense cables are to carry rectifier circuit-line voltages, and are to be terminated.
- Sense cables shall be provided for all bonds to foreign structures, to measure both the bond current and the pipe-to-soil voltage on the foreign structure. In addition, the bond measurement facilities must ensure compatibility with the RMU. The channels allocated for measurement of bond currents and voltages shall have an option provided for full electrical isolation.
- If no electrical isolation devices are specified, then an empty terminal is to be left for the foreign structure sense lead (non-current carrying) and leave a blank terminal for a fixed reference cell lead. The 50 mV foreign structure current measurement shunt(s) shall be installed in series with the current carrying bond lead, and shall have sense leads terminated.
- Sense cables allocated to fixed reference cells must also ensure compatibility with the RMU.

- All sense cables shall be AWG 12 in size and have jacket materials compatible with the operation within the environment inside the rectifier cabinet. The sense cables, including jacket materials, shall be suitable for handling over a temperature range of -40°C to 105°C (-40°F to 220°F) ambient air temperature. A control transformer shall be installed in each rectifier unit for future power for the RMU5 remote monitoring device.

10.5.5 Low-Voltage Interruption Terminal

Low-voltage interruption terminal specifications are as follows:

- All rectifiers shall be wired with a CONXALL 4282-5SG-300 (including 4295 dust cap) 5-pin female connector. The wiring associated with the plug shall be AWG 20 TEW stranded copper cable rated to operate up to 105°C (220°F) temperature. Wire terminations for the connector are to be made as per Section 10.16.
- The CONXALL 4282-5SG-300 5-pin female connector shall be installed on the rectifier's front phenolic panel to allow the 4295 dust cap to have a minimum clearance of 51 mm (2 in.) from the rectifier cabinet door.
- The AC interruption relays shown in Table 10-2 shall be installed in parallel with the high-voltage twist-lock hubble connector across the interruption switch located on the L1 leg of the AC power supply wiring downstream of the AC surge suppressor (see Section 10.16).

Table 10-2: AC Interruption Relays

Rectifier AC Power Input Rating	AC Relays Types	AC Relay Model Numbers
0 – 50 A	Crydom Series 1	Model D2450-10
>50 A	Crydom Series 1	Model D24110-10

- All AC relays shall be installed with heat sinks appropriately sized to facilitate continuous operation of the AC relay under interruption.
- A Hammond BD2E 12 V power-supply transformer is to be installed to power terminals four and five on the CONXALL 4282-5SG-300 5-pin female connector. The input leads on the transformer are to be wired into the L1 AC supply lead, downstream of the AC surge suppressor, and the second lead is to be wired into the AC neutral (see Section 10.16).
- The wiring for the CONXALL 4282-5SG-300 5-pin female connector and the Crydom relays, as outlined previously in this section, shall be compatible with the Mobiltex CorrTalk Portable Interrupter Model SPI-1A, SESCO GPS timing device model TCMAD1-100, or SESCO GPS current interrupter model TCFAD1-100 in synchronously actuating the relays for pre-set GPS time-based interruption intervals.

10.6 Lightning Protection

Lighting protection specifications are as follows:

- Unless otherwise specified, metal oxide varistor arrestors shall be installed on both the AC input and the DC output of the rectifier.
- An arrestor shall be placed between the chassis and DC positive of each circuit, DC negative of each circuit and the chassis ground.

- Where semi-conductor or valve type arrestors are used, they are to be in an accessible location and enclosed in a small metal enclosure. The enclosure is to prevent fire in the event of a fault or surge.
- Arrestors are not to be mounted on the front control panel.

10.7 Inspection and Testing

10.7.1 Testing

All units shall be subjected to tests that verify that specifications are met. Documentation of these tests shall be provided.

10.7.2 Dielectric Strength Tests

Dielectric strength-test specifications are as follows:

- Every transformer shall be subjected to dielectric strength tests, conducted as per CSA C22.2 No. 107.1, or UL 60950, or NFPA 70, as applicable.
- Dielectric strength tests shall be conducted on the transformer before varnish dipping and baking, and after baking. The after baking test can be included as part of the final rectifier dielectric test.
- All assembled rectifiers shall be subjected to dielectric strength tests, as outlined in CSA C22.2 No. 107.1, or UL 60950, or NFPA 70, as applicable.

10.7.3 Inspection

After assembly, the rectifier shall be subjected to inspection of all wiring and mechanical components and their connections. Inspection shall also include over-all workmanship.

10.7.4 Operation

Rectifiers shall be subjected to testing and recording of all rectifier electrical parameters as follows:

- AC input voltage, current, apparent power and true power
- DC output voltage, current and power
- AC power factor
- AC to DC conversion efficiency

If a filter is required, the ripple at full output voltage shall be measured and documented.

Rectifier meters shall be tested to meet the requirements specified in Section 11.11.

10.8 Shipping

A rectifier identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- manufacturer's name and code number
- AC volts and amperes
- line frequency
- number of phases
- DC voltage and ampere ratings

- ambient temperature rating
- serial number
- CSA file number (as applicable)

The following items are to be in a waterproof enclosure with documentation in the rectifier door, or if specified, labelled using lamacoid plates, or an equivalent approved by Company cathodic protection engineering personnel. Labels are to have a black background and white lettering.

- AC rectifier input terminals
- transformer tap positions (coarse and fine)
- negative and positive output lugs
- all meters
- switch positions
- main breaker
- DC and AC arrestors
- all fuses (size and type)
- interrupter mode switch
- interrupter receptacle
- utility receptacle
- high voltage (if applicable)

A circuit diagram and parts list shall be included with each rectifier. The rectifier drawing shall be laminated and mounted on the inside of the front door of the rectifier. In addition, a paper copy of the rectifier electrical schematic and a parts list for each rectifier detailing all of the components shall be provided to Company cathodic protection engineering personnel.

Each rectifier shall be individually packaged for shipment, and shall have the rectifier name or rectifier number clearly labeled on the exterior of the shipping box.

10.9 Rectifier Circuit Diagram

Refer to the Company standard drawings, or as per the Company's instruction.

11 THERMOELECTRIC GENERATORS

11.1 General Information

General specifications for thermoelectric generators are as follows:

- TEGs shall be designed to operate at temperatures between -45°C and 65°C (-50°F and 150°F).
- TEGs shall be designed to operate in unlimited rain or snowfall, provided that the unit is not flooded.
- TEGs shall operate in 100% relative humidity.
- TEGs shall operate in wind gusts of up to 140 km/h (85 mph).
- TEGs shall come complete with automatic re-ignition.

- All components shall be manufactured in modules, or assemblies for easy field maintenance.
- As necessary, the units shall be furnished with over-temperature protection circuitry.

11.2 Enclosure

Enclosure specifications are as follows:

- Enclosures shall be designed for outdoor installation, and be of stainless steel and aluminum construction.
- Enclosures shall be equipped with pad-lockable latches.
- All electrical hardware shall be copper, or brass finished in electrolysis nickel plate. All connections shall be made secure with lock washers and nuts, or with compression-type terminals.
- Enclosures shall be identified with the Company's rectifier number, or identifier in 50.8 mm to 76.2 mm (2 in. to 3 in.) black lettering on the outside of the front cabinet.

11.3 Mechanical Construction

Mechanical construction specifications are as follows:

- Units shall have a lead telluride solid-state, hermetically sealed power unit.
- Units shall have a nickel-alloy construction, meeker-type burner design that is stable in normal operating conditions.
- The individual TEG(s) shall be ordered to operate on butane, propane or natural gas, depending on the available fuel supply.

11.4 Metering and Instrumentation

Metering and instrumentation specifications are as follows:

- A separate suitably scaled voltmeter and ammeter as well as a current measuring shunt shall be provided to measure the DC output.
- Meters shall be a minimum 90 mm (3½ in.) size, with a minimum scale length of 73 mm (2⅞ in.).
- Metering accuracy shall be ±2% of full-scale deflection at 25°C (77°F). Temperature compensation shall be no more than 0.85% per 10°C (50°F), for temperatures other than 25°C (77°F).
- The package shall contain a terminal block capable of accepting 2/0 AWG (9 mm or ⅜ in.) cable.
- The package shall contain a variable resistor designed to control current output.
- Electrical output isolation from the chassis shall be achieved such that the leakage current does not exceed 100 mA.

11.5 Inspection and Testing during Manufacture

Inspection and testing specifications during manufacturing are as follows:

- All units shall be subjected to testing at 100% of rating.
- All units shall be subjected to tests as outlined in SPE-1000-94 for dielectric strength, bonding continuity, leakage current, stability and temperature.

- All units shall be subjected to testing and recording of all performance parameters as follows:
  - DC output voltage, current and power
  - DC input voltage, current and power
  - fuel pressure for rated power
  - set up voltage for rated power
  - leak test of fuel system
  - verification of ignition system operation

11.6 Shipping

An identification plate shall be firmly attached on the inside of the cabinet door, and shall contain the following:

- manufacturer's name and code number
- serial number
- fuel usage
- fuel pressure setting

12 SOLAR-POWER UNITS

12.1 General Information

General specifications for solar-power units are as follows:

- Solar-power units shall be as specified on the purchase order.
- The number of solar panels to deliver the requirements as specified in the purchase order, or Company standard drawings, shall be determined by the manufacturer or distributor.
- The size of the units (typically 12V DC or 24V DC) shall be specified on the purchase order, or Company standard drawings.
- All solar-power units shall have a main disconnect switch between the solar panels and the controller.
- All solar-power units are to be supplied with a silicon oxide varistor lightning arrestor with:
  - clamp voltage 100 V
  - maximum operating voltage 48V DC
  - maximum current 50 kA
  - maximum energy 750 Joules (0.7 BTU)
  - unlimited number of surges
  - 10 nanosecond response time

Solar-power units are also to be supplied with a system electrical ground lug.

12.2 Panels

Panel specifications are as follows:

- Solar panels shall be mounted on 12 m (40 ft) of Class 6 wooden utility poles.
- The diameter of the pole at the panel-mounting location is to be approximately 200 mm (8 in.).

- Mounting brackets to secure the solar panels shall be sized to accommodate attachment to the highest point on the utility pole.

12.3 Controllers

Controller specifications are as follows:

- Controllers shall be sized to accommodate the voltage and the current requirements as specified on the purchase order, or Company standard drawings.
- Controllers shall have a continuous voltage and current display.
- Controllers shall be housed in a water-tight enclosure with securable locking latches or handle.

12.4 Batteries

Battery specifications are as follows:

- All units shall be supplied with either absorbed glass mat (AGM) or gel-sealed batteries, as specified on the purchase order. The self-discharge rate of the battery must be less than 2% per month, and must have a 12-month warranty.
- Battery quantities and sizes shall be to provide a minimum of 72 hours autonomy, with no more than 50% depth of discharge.
- Batteries shall be housed in a separate insulated and vented battery box.
- The battery box is to have securable locking latches or handles. The battery box is to have mounting lugs to secure the box to a wooden platform, or platform approved by Company cathodic protection engineering personnel.

12.5 Enclosure

Enclosed specifications are as follows:

- Power centre enclosures must be rated as NEMA Type 3, 3R or 4, and are to be rain and sleet proof.
- The enclosures must have a drip shield over the door.
- The hinged door is to be sealed with seamless poured urethane gasket, and come complete with a lockable latching mechanism that maintain constant pressure on the gasket.
- The battery box shall be insulated with 50 mm (2 in.) high-density foam and sized to allow a 10 mm (½ in.) battery separation and be complete with a hinged lid with a lockable latch.

12.6 Shipping

The location to which the units are to be shipped shall be clearly marked.

13 TEST STATIONS

The test lead assembly shall be as per Company standard drawings.

14 REMOTE MONITORING EQUIPMENT

14.1 General Information

General specifications for remote monitoring equipment are as follows:

- All RMUs shall be CSA certified, or UL approved.
- All units shall have flash program memory.
- Internal components shall operate in the temperature range -40°C to +80°C (-40°F to +175°F).

14.2 Enclosures

Enclosure specifications are as follows:

- Enclosures for RMUs shall be NEMA 4X rated fibreglass or polycarbonate.
- Enclosures shall be equipped with a pad-lockable draw latch.
- All units are to be fitted with a CSA or UL approved (as applicable) 10 W heater and control thermostat to maintain the enclosure internal temperature within the radio's operating temperature range.
- Insulation shall be a "K" value suitable to allow a 10 W heater to provide the required minimum temperature.
- Insulation is to be rigid, foil backed non-hygroscopic and non-flammable to provide for a maintenance-free interior.
- The enclosure is to have a mounting plate supported over the insulation, for mounting components.
- A GPS antenna is to be mounted on the top of the enclosure and to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.
- The external electronic temperature sensor shall be mounted off-centre on the bottom of the enclosure, and is to be suitably sealed to prevent both the ingress of moisture and unnecessary heat loss.

14.3 Channels

Channel specifications are as follows:

- All units to be equipped with 10 analog inputs and one interrupt drive output.
- All units shall have four isolated digital input points.
- All units shall have one internal (mounted on a PCB), and one external electronic temperature sensor.

14.4 Interruption

Interruption:

- shall be a solid state AC interrupt relay, 25 A at 280 VAC maximum
- is to occur via GPS time receiver

14.5 Communication

IMARSAT communication is to be via Easy Track Communication/GPS unit, with an operating temperature range of -30°C to +50°C (-22°F to 122°F).

14.6 Command Options

All units shall be able to indicate:

- AC power fail alarm. (Debounce timer set to 1 hour.)
- AC power restored. (Debounce timer set to 1 hour)
- DC power fail (DC current goes to zero, e.g. fuse fails or rectifier fails). (Debounce timer set to 1-hour.)
- Low battery (no time delay in sending this alarm).

14.7 Power Supply

Power shall consist of 120 VAC to 12 VDC supply for transceiver and electronics. (TEG version will be 24 VDC to 12 VDC.)

All units shall have a battery backup with charger and a low-voltage disconnect.

15 JUNCTION BOXES AND TERMINAL BOXES

15.1 Junction Boxes

Junction-box specifications are as follows:

- Junction box size and location shall be as per the purchase order or Company standard drawings.
- Junction box enclosures shall be cast aluminum, as per Wright Aluminum Ltd. specifications (Model# WAL-56 or Model# WAL-102).
- All junction-box enclosures shall have a high-voltage shield, and be mounted on 76 mm (3 in.) OD conduit(s), as per Company standard drawings.
- All junction boxes shall be constructed to CSA Enclosure 3R Classification, or equivalent.

15.2 Terminal Boxes

Terminal box specifications are as follows:

- Terminal box size and locations shall be as per the purchase order and Company standard drawings.
- Terminal boxes shall meet Hammond (Model 1418N4M8) or Bel (Model R363008) specifications.
- Terminal-box enclosures shall have a minimum sheet-metal thickness of 14 gauge.
- All steel terminal box enclosures shall be CEMA/NEMA 4 rated, and shall be powder coated (ASA61 grade polyester or ANSI/ASA61 grey baked recoatable enamel).
- Hinges and enclosure assembly bolts shall be stainless steel or aluminum. The enclosure shall be equipped with a latching device.
- All terminal box enclosures shall have a high-voltage shield, and be mounted on two 76 mm (3 in.) OD conduits as per Company standard drawings.

15.3 Panels

Junction box panels shall be a minimum thickness of 4.7 mm (0.2 in.) of NEMA Grade 'XX' phenolic.

All electrical hardware shall be copper or brass, finished in electrolysis deposited nickel plate. All connections shall be made secure with lock washers and nuts tightened to the manufacturer's recommended torque.

16 COPPER–COPPER SULPHATE REFERENCE ELECTRODES

Unless otherwise specified, all copper–copper sulphate reference electrodes shall be EDI Model UL - 30 Year LongLifeTM reference electrodes. Element type shall be a saturated gelled Cu/CuSO4. The lead wire shall be AWG 14 or larger, 15 m (45 ft) or greater in length, insulated in high molecular weight polyethylene, and rated for underground service.

Where specified, the CSCL copper–copper sulphate reference electrode shall be CPMP-2-50. The length of the cable shall be as per the site-specific construction drawings.

17 NOVAPROBES

NovaProbe specifications are as follows:

- Permanent NovaProbes are patented and only available from licensed manufacturers.
- Permanent NovaProbes shall measure the following parameters:
  - local soil resistivity
  - local soil pH
  - local oxidation reduction potential
  - "on" pipe-to-soil potential

18 COUPONS

Coupons shall be either 9 cm^2 or 50 cm^2 (1.4 in^2 or 9 in^2). Coupon test stations shall comply with Company standard drawings.

19 EXOTHERMIC WELDS AND BONDS

19.1 Thermite Welds

Thermite weld specifications are as follows:

- Thermite welds shall be a #15 gram charge (green cap) maximum with F-33 powder, or approved equivalent.
- A copper sleeve shall be used for wire sizes smaller than AWG 8. The sleeve size shall correspond to cable size.

20 PIN BRAZING

Pin brazing specifications are as follows:

- Pin brazing is acceptable application to attach test leads and bond wires (United States only).

- Reference the pin brazing equipment manual for the pin brazing techniques and surface preparation.
- Test for adequate bond and coat connection with approved coating.

21 SILVER SOLDERING

Silver soldering specifications are as follows:

- Use only 2% silver/98% tin soldier material with the appropriate flux.
- "Tin" the pipe and the conductor to be soldered.
- Heat the pipe and melt a solder puddle sufficient in size to attach the conductor.
- Test for adequate bond, and neutralize the acid flux with base solution.

22 MECHANICAL BONDS

Mechanical bond specifications are as follows:

- Circumferential clamp(s) is to maintain residual tension after the tensioning device is withdrawn. The cable connection to a circumferential clamp must be achieved by welding, or bolting to the clamping device.
- Any connection to structures, other than a pipe, must be achieved using materials required in the CEC or the NEC (as applicable) for grounding connections.
- Specially designed alteration to an electrical LB (elbow, back opens) fitting and connected to a flange bolt may be used. The apparatus shall be constructed of rigid conduit from a point 450 mm below grade and up to the LB. The cable shall pass through the conduit and connect to a lug inside the LB fitting. The conduit must be equipped with an EYS sealed fitting at the point of emergence from the ground.
- An alternative to the rigid conduit and EYS fitting is to use a single conductor Teck cable connected to the LB fitting with a "liquid tight" transition fitting.

23 CONTROLLED INTERFERENCE BONDS

A control device in an interference bond circuit shall consist of an appropriately sized resistor, or rheostat, and a meter or shunt.

24 AC MITIGATION, SURGE PROTECTION AND DC DECOUPLING

24.1 General Information

General specifications for AC mitigation, surge protection and DC decoupling are as follows:

- Isolation surge protectors shall be designed to simultaneously provide DC isolation and AC continuity at cathodic protection isolator locations, plus meet environmental ratings outlined in NEMA 4X and hazardous classifications for NEC, CSA: Class 1, Division 1 and 2, Groups A,B,C, D.
- Typical applications include installation where the facilities are subject to AC coupling, AC faults, or lightning, or electrical switching transients. Under AC faults or lightning (short-term transients) it is allowable for the device to temporarily conduct DC current.

- The device shall be designed to allow an unlimited number of switching operations (associated with occasional AC faults or lightning events) without failure.
- The ultimate failure mode of the device shall be in the closed-circuit position.
- The device shall be equipped with two-hole terminal pads for cable connection. The polarization cell replacement (PCR) device shall be equipped with two-hole (to accommodate ½ in. stainless steel bolts) terminal pads for cable connection. The solid-state decoupler (SSD) device shall be equipped with a single-hole (to accommodate 5/16 in. stainless steel bolts) terminal pads for cable connection.
- Isolation surge protectors shall be solid-state devices capable of normal operation at ambient temperatures between -45°C and +45°C (-50°F and 113°F).
- Ensure the PCR device meets the criteria for "an effective grounding path," as defined in Section 250.2 and 250.4(A)(5) of NFPA 70, and Section 10-500, 10-806 of CSA C22.1-12 (2012), and CSA C22.2 No. 0.4-04M1982 (R2009),and CSA C22.2-No. 213-M1987 (R2008).
- All DC decouplers shall be CSA certified, or UL approved.

24.2 DC Decouplers– Electronic Device Performance Characteristics

The performance characteristics of the DC decouplers (PCRs and SSDs) shall be specified by the following product ratings.

- lightning surge current
- voltage threshold
- 60 Hz fault current
- 60 Hz steady-state current
- enclosure
- instrument test feature
- special requirements

If not specified on the purchase order, the following parameters shall apply:

- Lightning surge current – 50 kA: This parameter specifies the minimum current that the device must be capable of passing while holding the voltage across the terminals below 700 V. The test waveform shall be 8 X 20uS.
- DC blocking voltage – -3/+1 V: This parameter specifies the upper DC voltage level, which will be blocked by the device while continuously conducting 60 Hz AC current.
- AC fault current: The magnitude and duration of fault current during a fault condition. The selected DC decoupler specification must meet or exceed maximum probable current and duration.
- Steady-state AC current at 60 Hz –45A RMS: This parameter specifies the maximum allowable steady state AC current that can be passed through the device while maintaining DC isolation.
- AC voltage drop under fault at 60 Hz ,<10 V ACrms: This parameter specifies the maximum AC voltage drop through the device under full rated fault current.

24.3 Enclosure

Enclosure specifications are as follows:

- Unless otherwise specified, the device shall be furnished with a NEMA 4X fibreglass-reinforced polyester enclosure suitable for outdoor non-submersible applications.
- The device shall be marked with the manufacturer's name, the device model number, the device serial number, and the month and year of manufacturer.
- UL or CSA certification shall be evident on the enclosure.

24.4 Instrumentation

The device shall contain a sufficient number and type of test terminals to allow AC and DC voltage and current measurements while in operation. All test terminals shall incorporate a dead-front design to prevent personnel from shocks, and shall be clearly labelled. Note: Separate test terminals are not provided. All tests can be conducted using the existing external bushing terminals. Even under the worst case, fault current rating for any decoupler model, the maximum voltage across the device terminals will be <10 VAC, well below the NACE maximum allowable voltage of 15 VAC. Consider adding DC decoupling devices that must be readily tested using standard field equipment, such as multi-meters and ammeters, and that manufacturers shall provide such testing instructions.

24.5 Shipping

The device shall be packaged for shipping to prevent damage.

- Refer to TED-CP-DD *Cathodic Protection Design Directive (CDN-US)* for application of the devices.

25 DELIVERABLES

- Material Safety Data Sheets
- Design Documents

26 QUALITY MANAGEMENT

26.1 Quality Checks and Documentation

The Company requires the following reviews before and during work:

- Review that the manufacturer is approved within the Company's approved vendor list.
- Review the materials adhere to the guidelines set forth in this specification.

The Company requires the following documentation before work starts:

- Verification of equipment calibration, as per equipment specifications.

26.2 Performance Measures

The manufacturer will be evaluated on the following measures:

- Adherence to the schedule – the ability to achieve milestones set forth by the Company.
- Delivery of materials – the materials are delivered to the Company in the timelines provided.
- Quality of materials – the materials adhere to the guidelines set forth in this specification.

26.3 Specification Deviations

When there is a request not to follow the specification as documented, an approved Management of Change is required. All deviations are to be reviewed and approved by the specification owner before the variance can proceed on the deliverable, data or report.

26.4 Noncomformance Management

All nonconformances to this specification will be reviewed by the Company and dispositioned by the vendor or manufacturer.

APPENDIX

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APPENDIX A APPROVED MATERIAL LIST

Table A-1: Approved Material List

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
Anodes	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660	Length: 1524 mm Diameter: 66 mm Mass: 23 kg (nominal)	Length: 60 in. Diameter: 2.6 in. Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684	Length: 2134 mm Diameter: 66 mm Mass: 31 kg (nominal)	Length: 84 in. Diameter: 2.6 in. Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884	Length: 2134 mm Diameter: 97 mm Mass: 31 kg (nominal)	Length: 84 in. Diameter: 3.8 in. Mass: 68 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2660Z	Length: 1524 mm Diameter: 69 mm Mass: 23 kg (nominal)	Length: 60 in. Diameter: 2.7 in. Mass: 50 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	2684Z	Length: 2134 mm Diameter: 69 mm Mass: 32 kg (nominal)	Length: 84 in. Diameter: 2.7 in. Mass: 70 lb (nominal)
	Anotec	High Silicon Chromium Chill Cast Iron Tubular Anodes c/w individual stranded AWG 8 stranded SPCP cable	3884Z	Length: 2134 mm Diameter: 76 mm Mass: 41 kg (nominal)	Length: 84 in. Diameter: 3.0 in. Mass: 90 lb (nominal)
		Graphite Centre Tap Anode	Varies depending on supplier	Length: 1016 mm Diameter: 102 mm Mass: 16 kg (nominal)	Length 40 in. Diameter 4 in. Mass: 35 lb (nominal)
		Graphite Centre Tap Anode	Varies depending on supplier	Length: 1524 mm Diameter: 76 mm Mass: 12 kg (nominal)	Length 60 in. Diameter 3 in. Mass: 27 lb (nominal)

Table A-1: Approved Material List (Cont'd)

Material Type	Manufacturer	Description	Model	Size (Metric)	Size (Imp)
		Graphite Centre Tap Anode	Varies depending on supplier	Length: 2032 mm Diameter: 102 mm Mass: 29 kg (nominal)	Length 80 in. Diameter 4 inch 64 lb
		Mixed Metal Oxide Anode	Varies depending on supplier	As specified on the purchase order.	As specified on the purchase order.

Table A-2: Approved MANUFACTURERS List

Material Type	Manufacturer	Model	Description – Above Ground Insulating Set	Description – Below Ground Insulating Set	Notes
Insulating flange gasket kit	GPT (www.gptindustries.com)	Pikotek VCS	• Type F gasket • G10 isolating retainer • Teflon or Viton seal • G10 isolating sleeve • Double Washer Set G10/ZPS washers	• Type F gasket • G10 isolating retainer • Teflon or Viton seal • G10 one piece isolating sleeves and washer sets or the G10 full length sleeves and single washer set configuration is required for below ground installations to allow the cathodic protection current to protect the nuts and bolts of the buried flange.	• Specify nominal pipe size, ANSI pressure class , temperature rating and media when ordering • ZPS - Zinc-Plated Steel Washers • When using the single washer configuration the isolating washer is placed against the flange, then the steel washer is placed next to the nut. Ensure the isolating washer is installed on the opposite side of the flange from TransCanada's CP system so the bolts can receive our CP current.
	GPT (www.gptindustries.com)	PSI Linebacker	• Type F gasket • G10 isolating retainer • Teflon or Viton seal • G10 isolating sleeve • Double Washer Set G10/ZPS washers	• Type F gasket • G10 isolating retainer • Teflon or Viton seal • G10 one piece isolating sleeves and washer sets or the G10 full length sleeves and single washer set configuration is required for below ground installations to allow the cathodic protection current to protect the nuts and bolts of the buried flange.	• Specify nominal pipe size, ANSI pressure class, temperature rating and media when ordering • ZPS - Zinc-Plated Steel Washers • When using the single washer configuration the isolating washer is placed against the flange, then the steel washer is placed next to the nut. Ensure the isolating washer is installed on the opposite side of the flange from TransCanada's CP system so the bolts can receive our CP current.

Figure A-1: Sleeve and Washer Configurations

Figure A-2: Single Washer Set for Below Ground Applications

Note: Double Washer Set for Above Ground Applications

Figure A-3: Double Washer Set for Aboveground Applications

Note: One isolation sleeve, two steel washers and two insulating washers for each stud/bolt.

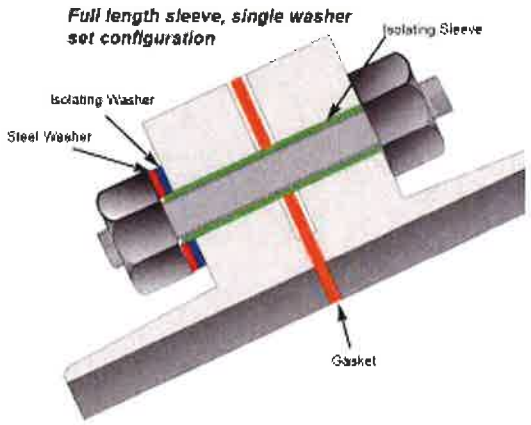

Figure A-4: One Piece Sleeve and Washer Sets for Below Ground Applications

APPROVALS

Originator: Swarandeep Sandhawalia Measurement Specialist EAR Measurement Engineering	Signature	May 15/2014 Date
Reviewer: Giles Brown, P.L.(Eng), C.E.T. EAR Measurement Engineering	Signature	June 30/2014 Date
Reviewer: Nathan Burgess, P. Eng. EAR Design Engineering Support	Signature	June 5, 2014 Date
Reviewer: Derek Chen, P. Eng. EAR Materials Engineering	Signature	May 29, 2014 Date
Reviewer: Jeff Cheong, P. Eng. EAR Electrical Engineering	Signature	MAY 22 / 2014 Date
Responsible Engineer: Chris Dennison, P. Eng. EAR Measurement Engineering	Signature 2014-July-7 Date	PROFESSIONAL ENGINEER CHRISTOPHER J. DENNISON ALBERTA APEGA Permit to Practice P7100
Management Endorsement: Troy Pipella, Manager EAR Measurement Engineering	Signature	July 7, 2014 Date

SUMMARY

This Specification defines the Company's minimum requirements for the design, manufacture, testing, documentation, shipping preparation and supply of a natural gas Coriolis flow meter used for natural gas Custody Transfer applications in TransCanada. The Specification applies to all Company owned or operated natural gas custody transfer facilities in Canada, the United States, and Mexico.

DOCUMENT HISTORY

Rev. No.		
00	**Description**	**Effective Date**
	This is a new document.	2014-May-15
	Rationale Statement	**Responsible Engineer**
	This document defines the Company requirements for the use of Coriolis meters in Custody Transfer gas measurement.	Chris Dennison
	Impact Assessment Summary	**Team Owner**
	Training on document content for engineering service providers and current USTD drawings will require updating for complete alignment at the next release (when Rev 2 is released).	Measurement Engineering

BRIEF DESCRIPTION OF CHANGE

REGULATORY	
Section	**Description of Change**
	N/A
INDUSTRY STANDARDS	
Section	**Description of Change**
	N/A.
GENERAL	
Section	**Description of Change**
	This Specification is a new document.

DEVIATION FROM THIS SPECIFICATION

TransCanada Engineering Standards and Specifications must be followed by internal and external users to ensure a safe, reliable and technically correct design.

Deviations to this standard may be acceptable if a technical assessment approved by TransCanada Engineering & Asset Reliability shows that the deviation meets the intent of this specification, does not compromise safety and also complies with applicable industry standards, regulatory requirements and is consistent with sound engineering judgment.

Any deviation must follow the appropriate TransCanada management of change variance procedure.

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List of Tables

DEFINITIONS

Term	Definition
AGA	American Gas Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
Company	TransCanada
CSA	Canadian Standards Association
IP	Ingress protection
ISA	Instrument Society of America
Manufacturer	A company responsible for the development and production of equipment
MPMS	Manual of Petroleum Measurement Standards
NFPA	National Fire Protection Association
NPS	Nominal Pipe Size
Q_T	The flow rate above which the meter is functioning within its optimal range
Q_{MAX}	The maximum allowable flow rate through the meter
Q_{MIN}	The minimum allowable flow rate through the meter
SI	International System of Units
UPS	Uninterruptible power supply
UL	Underwriters Laboratories testing agency
VDC	Volts Direct Current
Vendor	Any outside source hired by the Company to complete work or supply material

1 PURPOSE

This Specification defines the Company's minimum requirements for the design, manufacture, testing, documentation, shipping preparation and installation of natural gas Coriolis flow meters used for Custody Transfer gas applications.

This Specification defines the Company's requirements to the equipment Manufacturer, Vendor or Engineer performing detailed engineering design.

2 SCOPE

This Specification applies to all natural gas custody transfer measurement facilities owned or operated by TransCanada in Canada, the United States, and Mexico.

3 REFERENCES

This Specification references documents listed in Section 3.1, 3.2 and 3.3; these documents shall be deemed part of this Specification and are mandatory requirements. This Specification only states the "highest level" relevant references. However, if any of the references cite other applicable documents, those documents shall be deemed part of this Specification. For example, CSA C22.2 is a mandatory requirement of CSA C22.1. However, this Specification only references CSA C22.1.

3.1 Regulatory Codes

- Canadian Standards Association (CSA) C22.1 *Canadian Electrical Code, Part 1*
- Industry Canada LMB-EG-08 *Specifications for approval of Type of Gas Meters and Auxiliary Devices*
- Measurement Canada, AG-0480 *Notice of Approval- Micro Motion Elite series*
- Canadian Standards Association (CSA) Z245.12 *Steel flanges*
- The American Society of Mechanical Engineers (ASME) B16.5 *Pipe Flanges and Flanged Fittings*
- National Fire Protection Association (NFPA) 70 *National Electrical Code*

3.2 Industry Codes and Standards

- American Gas Association Report No.11 *Measurement of Natural Gas by Coriolis Meter*
- American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS) Chapter 14.9 *Measurement of Natural Gas by Coriolis Meter*
- American National Standards Institute/Instrument Society of America (ANSI/ISA) 12.27.01 *Requirements for Process Sealing Between Electrical Systems and Flammable or Combustible Process Fluids*

3.3 Internal References

- TEP-QUAL-ESM-VAR *TransCanada Engineering Standards Variance Request Procedure (CDN-US-MEX)* (EDMS No. 006491847)
- TES-MATL-MD1 *Piping System Materials for Pipeline, Compression, and Metering Facilities* (EDMS No. 003764909)
- TES-MATL-MD1-US *Piping System Materials for Pipeline, Compression, and Metering Facilities Design to -50°F* (EDMS No. 004471280)
- TES-MATL-COMP Specification for the *Materials Requirements of Pressure Containing Equipment Components (CDN-US-MEX)* (EDMS No. 008071725)
- TES-PIPE-P8 *Specification for Meter Tube Pipe* (EDMS No. 003695410)

4 REQUIREMENTS

The meter shall be the industry standard product of a Manufacturer regularly engaged in the production of this type of equipment, and Measurement Engineering approved.

In addition:

- If the Vendor has any exceptions to the provisions of this Specification, the Vendor shall submit the exceptions in writing to the Company for approval.
- If the Vendor encounters conflicts between this Specification and other referenced documents, the Vendor shall inform the Company in writing and request clarification.
- If the Vendor does not understand requirements in this Specification, the Vendor shall request clarification in writing from the Company.
- Compliance with the requirements of this Specification does not relieve the Vendor of the responsibility to supply a suitably designed and manufactured meter for the intended service.

The Vendor shall have a certified quality program encompassing all aspects of design, fabrication, installation, commissioning and service provided to the Company.

The Vendor should be aware that manufacturing requirements may vary depending on the location where the meter is to be installed. These requirement variations may depend not only on country of installation but also jurisdiction within that country. This Specification will state different country requirements where applicable

4.1 Units of Measure

4.1.1 Measuring units and engineering information shall be stated in accordance with local custom and engineering practice;

- In Canada and Mexico, units shall be SI with the exception of those requirements stipulated by the codes and standards listed in this specification, and those stated in Section 4.1.2.
- In the United States units may be US Customary where applicable and shall comply with those stated in Section 4.1.2

4.1.2 All pipe and fitting sizes shall be nominal sizes (e.g. NPS 2, etc.) and tubing shall be outside diameter in fractional imperial units (e.g. ¾", etc.).

5 CIVIL AND STRUCTURAL

5.1 Design and Installation Requirements

5.1.1 The Meter location shall be chosen to provide easy access to the meter and transmitter.

5.1.2 The Coriolis meter installation shall be in an environment isolated from vibration.

5.1.3 The meter run piping on either side of the meter shall be supported in accordance with the manufacturer's recommendations.

5.1.4 Support members shall not be connected directly to the Coriolis meter unless explicitly permitted by the manufacturer.

6 MECHANICAL, MATERIALS, WELDING, AND COATING

6.1 Materials Requirements

6.1.1 The Vendor shall supply meter material suitable for the fluid and service conditions as specified in the equipment data sheet.

6.1.2 Meter run piping shall be designed according to TES-PIPE-P8.

6.1.3 Meter run materials shall be designed according to TES-MATL-MD1 for installations in Canada, and TES-MATL-MD1-US for installations in the US and Mexico.

6.1.4 Additional requirements are defined in TES-MATL-COMP.

6.1.5 Coriolis flow meter shall operate properly over a minimum ambient range of -40 to 60°C.

6.1.6 The vendor shall supply Material Inspection and Hydrotest certificate with the meter in accordance with TES-MATL-COMP.

6.2 Mechanical Design and Installation Requirements

6.2.1 Meter station piping shall be aligned before the meter is installed so that there is no torsion force or bending moment applied to the meter or meter run assembly by the station piping.

6.2.2 The Coriolis meter run shall be assembled together as one unit before connecting to the field piping section.

6.2.3 A minimum of 5 nominal diameters of straight pipe shall be installed upstream and downstream of the meter

6.2.4 No process connections are permitted within 3 nominal diameters upstream or downstream of the meter.

6.2.5 If reducers are required to match the internal diameter of the meter run piping to the meter, they shall be placed directly adjacent to the meter flanges.

6.2.6 The Coriolis meter shall be mounted with the measuring tubes above the plane of the meter run piping so that, liquids will not be allowed to gather in the oscillating tubes.

6.2.7 The station piping shall be designed using a minimum of NPS 2 pipe.

6.2.8 The Coriolis meter run shall be located between upstream and downstream isolation valves.

6.2.9 The meter run shall incorporate a downstream normally closed ball valve to depressurize the meter, referred to as the blown down valve.

- The blow down valve shall be closed with a plug if mounted outdoors or vented externally if mounted indoors.

6.2.10 The facility design shall facilitate the removal of the meter run for maintenance.

6.2.11 If the customer cannot tolerate a flow outage for routine maintenance then the design shall incorporate a bypass path around the meter.

- The bypass path shall be equipped with a block valve, which shall be locked in the closed position during normal operation.

6.2.12 If a filter/strainer is required, it shall be located upstream of the Coriolis meter and between the upstream and downstream meter run isolation valves to facilitate maintenance.

6.2.13 If required, pressure or flow limiting devices shall be installed downstream of the meter run.

6.2.14 The flowing velocity inside the Coriolis meter body tubing shall not exceed the manufacturer's stated limits.

6.2.15 Meter run piping velocity shall not exceed 21 m/s except within the meter body and adjacent reducers during normal operations.

7 TELECOMMUNICATIONS

7.1 Local Communication Links

7.1.1 The Coriolis meter or its associated transmitter shall accommodate local communication links via Ethernet or Serial MODBUS communications.

7.1.2 The meter shall provide a local operator means of communication for maintenance purposes that does not disrupt the functionality described in 7.1.1.

8 INSTRUMENTATION AND CONTROL

8.1 Process Connections

8.1.1 All Coriolis meter runs shall include threadolets for the following:

- Upstream Pressure Sensor – NPS ½
- Upstream Temperature Sensor – NPS ¾ on NPS 2, NPS 1 on larger piping.
- Spare – NPS ¾ on NPS 2, NPS 1 on larger piping.
- Composite Sample port for Composite sampler or Analyzer – NPS ¾
- Downstream Analyzer Sample / Spare – NPS 1
- Downstream Blow down – NPS 1

8.1.2 Pressure monitoring process connections and thermowells shall be installed upstream of the primary flowing direction of the meter and minimum of 3 pipe diameters upstream of the meter.

8.1.3 Fuel gas take-off connections shall be located outside of the meter run to ensure that the facility is supplied with fuel gas while maintaining the meter run.

8.1.4 For Canadian projects gas quality and composition monitoring sample probes and fuel gas take-offs shall be located on the pipeline side of the meter and not on the customer side of the meter.

8.1.5 For the US and Mexico projects gas quality and composition monitoring sample probes and utility gas take-offs shall be located as defined in the Project Design Basis.

8.2 Measurement Signal

8.2.1 All Coriolis meter installations shall interface with a Company standard flow computer capable of mass measurement calculations as defined in AGA Report No. 11.

8.2.2 All outputs should be isolated from ground and be protected against over-voltage events.

8.2.3 The Coriolis meter transmitter shall provide an uncompensated mass flow rate signal to the flow computer.

8.2.4 For custody transfer applications the Coriolis transmitter shall be configured to provide an open collector or equivalent pulse train to flow computer.

8.2.5 Where regulations permit and as defined in the project design basis, a serial or Ethernet signal incorporating mass flow rate may be used in lieu of the signal defined in 8.2.4.

8.2.6 The Coriolis meter transmitter may be configured with analog output representing uncompensated mass flow rate indication however this analog signal shall not be used for the purpose of custody transfer measurement.

8.2.7 If the measurement facility is designed for bi-directional flow, two separate frequency outputs or two separate registers in the transmitter shall be used, one for each flowing direction.

- Each frequency output shall only indicate in its designated flowing direction and shall be inactive in the opposite direction.

8.2.8 A no-flow cut-off value equal to 0.05% of sensor maximum flow rate shall be used that sets the flow rate output to zero when the indicated flow rate is below the set value..

9 ELECTRICAL

9.1 Electrical Supply

9.1.1 For Installation in Canada, the meter and transmitter shall meet CSA or equivalent testing requirements and approval shall be clear and permanently indicated on the equipment.

9.1.2 For installation in U.S. and Mexico, the meter and transmitter shall meet UL or equivalent testing requirements and approval shall be clearly and permanently indicated on the equipment.

9.1.3 The meter and transmitter enclosure shall be rated IP 65 or greater.

9.1.4 All Coriolis meters shall be powered by a UPS backed 24 VDC power supply.

9.1.5 The meter and transmitter electronics shall be isolated from ground such that they operate on a floating power supply without causing a ground fault.

9.1.6 The meter and transmitter shall be suitable for installation in Class 1 Zone 1 Group IIA hazardous location.

9.2 Wiring Methods

9.2.1 The meter interconnection wiring shall comply with the electrical area classification in which the meter is installed.

10 CORIOLIS METER AND TRANSMITTER REQUIREMENTS

10.1 Meter Requirements

10.1.1 The Vendor shall supply a meter meeting the requirements stated in Table 10-1.

Table 10-1: Meter Performance Requirements

PARAMETER	DESCRIPTION
Meter Principle	Coriolis
Mass Flow Rate Accuracy	±0.35% of flow rate between Q_T and Q_{MAX}
Turndown	Vendor shall define meter turndown within +/-0.5% uncertainty limit.
Mass Flow Repeatability	±0.20% of flow rate between Q_T and Q_{MAX}

10.1.2 The meter's minimum flow rate Q_{MIN} is defined by the maximum permitted uncertainty of ±0.5% over the expected flow range of the meter.

10.1.3 The meter's maximum flow rate, Q_{MAX} is defined by the manufacturer recommended maximum allowable gas velocity of 120m/s through the meter.

10.1.4 Coriolis meters shall be sized using the manufacturer's recommended sizing tool.

10.1.5 The Coriolis meter shall be calibrated by an approved calibration facility at Q_{MIN} , 2.5%, 10%, 25%, 50%, 75% and 100% of Q_{MAX}.

10.1.6 Fixed value for pressure compensation shall be used if the calibration pressure is different from operating pressure.

10.1.7 All openings on the meter shall be securely plugged and the meter and transmitter shall be packaged prior to shipping to mitigate handling damage.

10.1.8 The maximum rate factor (scaling factor) for each size of Coriolis meter is based on the Maximum Operating pressure, Minimum Operating temperature and maximum allowable velocity of 120m/s through the meter.

Note 1: The maximum scaling factor values applicable to Canada are as per Measurement Canada Notice of Approval **AG-0480**

10.2 Transmitter Requirements

10.2.1 The Transmitter shall be supplied with Measurement Canada approved Firmware/Software.

10.2.2 The Vendor shall supply transmitters with Weights and Measures features enabled.

10.2.3 In Canada, Custody transfer installations at high intervention sites shall be sealed by a Measurement Canada Representative.

10.2.4 Installations at Low intervention sites in Canada and all sites in US and Mexico do not require sealing.

10.2.5 All configurable parameters shall be stored in non-volatile memory.

11 DOCUMENTATION REQUIREMENTS

11.1 Documentation Required with Quote

11.1.1 The Vendor shall submit documentation to the Company for approval prior to manufacturing of meter. As a minimum, the Vendor shall submit the following information with the quote:

- list of any exceptions to this Specification
- meter outline and bore dimensions
- pressure drop calculations across the meter at maximum operating viscosity, minimum operating temperature and maximum flowrate
- sizing calculation
- proposed production schedule

11.2 Documentation Required Post-Award

11.2.1 After testing, the Vendor shall update drawings with any changes required by testing and submit to Company.

11.2.2 As a minimum, the Vendor shall submit the following documentation post-award:

- Factory Calibration report
- Completed data sheets
- Documents stated in TES-MATL-COMP
- Equipment installation, operating and maintenance manuals
- Vendor Drawings

12 CONFLICTS, SUBSTITUTIONS, EXCEPTIONS OR DEVIATIONS

The Vendor is responsible to ensure that all materials comply with the requirements of this Specification and shall not make any substitutions without the prior written approval of the Company. However, any such approval will in no way relieve the Vendor of full responsibility of the adequacy of all materials provided.

PURPOSE

This Specification provides the design and material requirements for selecting control valves, and also addresses the installation requirements of control valves for use in natural gas and liquid hydrocarbon services .This specification applies to all control valves used in Canada, the United States, and Mexico.

SCOPE / APPLICABILITY

Within this Specification, TransCanada is referred to as the Company.

This Specification applies to:

- Control valves used in the Company's liquid pipelines and related facilities.
- Control valves used in the Company's natural gas pipelines and related facilities.

Within this Specification, the following terms and definitions apply for requirements:

- Shall—expresses a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard. Shall is not a recommendation but a requirement.
- Should—expresses a strong preference, recommendation or that which is advised, but not required.
- Must—denotes a requirement of the Company, for which no deviation or variance would be granted.
- May—expresses an option or that which is permissible within the limits of the standard.
- Consider—assumes that a competent person will evaluate options to fulfill the intent of the requirement and make a documented decision supported by evidence to ensure protection of people, equipment and the environment by achieving the appropriate level of functional integrity.

Wherein the Manufacturer's literature, governmental or regulatory requirements conflict with this Specification, the more stringent requirement shall govern.

Table of Contents

List of Tables

1 GLOSSARY

Actuator

A pneumatic, hydraulic, or electro-hydraulic device that supplies force and motion to open or close a valve

API

American Pipeline Institute

ASME

American Society of Mechanical Engineers

ASTM

American Society for Testing and Materials

Ball Valve

A valve with a spherical disc to control flow; the sphere has a hole or port, which, depending on the alignment, allows flow.

CFR

Code of Federal Regulations

CSA

Canadian Standards Association

Cavitation

Cavitation is very similar to flashing, but with one exception; the fluid pressure recovers to a pressure that is above its vapour pressure. This causes the previously formed vapour cavities to implode, producing impinging jets that have the potential to cause severe erosive damage. This type of damage is marked by rough gouges in material. (Definition from Fisher Controls)

Control valve

A valve used to control conditions such as flow and pressure by fully or partially opening or closing in response to signals. The signals are received from controllers that compare a *set point* to a *process variable*; this value is provided by sensors that monitor changes in such conditions.

dBA

A-weighted decibels are an expression of the relative loudness of sound, in air, as perceived by the human ear.

FCI

Fluid Controls Institute

Flashing

Occurs when the pressure of a fluid falls below its vapour pressure, changing from a liquid to a vapour. During this process, small vapour cavities form that grind away at the outlet of the control valve and its trim components. Flashing damage is marked by shiny, smooth gouges in material. (Definition from Fisher Controls.)

Flow coefficient (Cv)

A constant related to a valve's geometry for a given travel and can be used to establish flow capacity. Cv=1 is the amount of water at 60°F (15.6°C) in US gallons that flows through a valve per minute with a 1 psi (6.9 kPa) pressure drop.

Globe valve

A valve with a linear motion closure member, one or more ports, and a body distinguished by a globular cavity around the port region.

ISA

International Society of Automation

Jam-Nut

A nut used to jam and lock another nut securely in place; the second and locking nut on a stud bolt. After the first nut is threaded and tightened on a stud, a second nut is tightened down on the first nut to prevent it from working loose.

Positioner

Positioners typically move a control valve to a specified position so a process meets specific parameters (flow, pressure and temperature).

Trim

Trim refers to all internal process wetted components. Trim includes the valve plug, the valve plug stem, the cage and the seat ring.

ANSI/ISA 75.05.01-2000 defines trim as "*the internal components of a valve that modulates the flow of the controlled fluid*."

2 DESIGN REQUIREMENTS

2.1 Required Process Conditions

The following process conditions shall be collected before the control valve selection process begins.

2.1.1 Gas Service

- Gas properties, e.g., specific gravity, composition, and water content
- The control valve shall pass the minimum design flow at no less than 10% of valve travel, or as recommended by the Vendor. The maximum design flow shall be no greater than 80% of valve travel (for throttling conditions) and 100% for full flow, or as recommended by the Vendor.

2.1.2 Liquid Service

- Fluid properties, e.g., liquid density, viscosity, critical pressure and vapour pressure (at selected conditions);
- The control valve shall pass the minimum design flow at no less than 20% of valve travel, or as recommended by the Vendor. The maximum design flow shall be no greater than 80% of valve travel, or as recommended by the Vendor, and 100% for full flow, or as recommended by the Vendor.

2.1.3 Common for Liquid and Gas Services

- Temperature of the fluid (minimum, and maximum); (T_{min}, T_{max})
- Flow rate (minimum, normal and maximum); (Q_{max}, Q, Q_{min})
- Inlet pressure at the valve (minimum, normal and maximum); (P_{1min}, P_1, P_{1max})
- Outlet pressure at the valve (minimum, normal and maximum); (P_{2min}, P_2, P_{2max})
- Class shutoff (leakage classification Class IV or better)
- Inlet and outlet pipeline size and wall thickness; (D_i, D_o, t)
- Preferred valve type, if known, ball or globe
- For certain process flow conditions, axial flow control valve may be used
- Maximum permissible noise level (dBA)

2.2 Control Valve Applications

- If the required range of process conditions is too large for one control valve, two or more control valve regulation runs might be required to operate in a split-range mode or parallel mode. In some applications, a monitoring control valve can be installed in conjunction with a working control valve in a single regulation run also known as a working/monitoring installation.

- Typically ball valves are selected for high capacity volumes whereas globe valves are selected for high pressure cut applications.

2.3 Determine Process Conditions for Sizing

2.3.1 The following process conditions shall be assumed:

- Q_{max}: P_{1min} and minimum pressure drop, conditions for the largest flow coefficient (C_v)
- Q_{min}: P_{1max} and maximum pressure drop, condition for the smallest C_v
- Q_{max}: P_{1max} and maximum pressure drop, condition for loudest noise
- Q_{max}: P_{1min} and minimum pressure drop at 100% open (if different C_v than condition No. 1)
- Normal operations, the condition the valve operates in most of the time.

2.3.2 Future design conditions shall be known and considered. This allows for the consideration of increased flow, when sizing the control valve. For example, if a globe control valve is selected, then a reduced trim may be appropriate, with the possibility of changing to a larger trim in the future. If a different style of valve is suitable for the required service conditions, the Vendor may offer it as an option. Conversely, an alternative way to size a control valve is to use an iterative process where preliminary C_v is calculated. Noise and cavitation calculations are then carried out to verify that the C_v provides acceptable noise and cavitation as specified by the project data sheet.

2.3.3 If the existing design has significantly changed from the original design and has caused noticeable changes in vibration, noise level, or wall thickness reduction due to erosion, then a design review shall be required.

2.3.4 The control valve shall be designed to operate within the range of operating fluid temperatures outlined on the data sheet, confirming that the ambient temperature of where the valve is installed falls within that range. Typically, control valves are ordered for -45°C or -29°C (-49°F or -20°F) ambient temperature; the temperature dictates the type of material from which the control valve body should be made.

2.4 Sizing Calculations

2.4.1 Common for Liquid and Gas Services

- Designers shall perform sizing calculations and verify the Vendor's calculations, as required.
- The Vendor shall identify the method of valve size calculation.
- The Vendor shall perform and provide sizing calculations at various operating conditions, as indicated on the data sheet supplied by the Company, as per section 2.1.

- The Vendor shall supply computer-generated sizing data sheets, based on *ISA S75.01.01* or the Vendor's sizing program.

2.4.2 Liquid Service

- The valve shall not cavitate or flash throughout its required process conditions.
- The Vendor shall recommend any special materials, valve construction, or special trim required to prevent cavitation or flashing.

2.5 Noise Calculations

- The Vendor shall ensure the maximum sound level does not exceed 85 dBA, and 90 dBA for unmanned facilities at a distance of 1 m (3 ft.) downstream/upstream and 1 m (3 ft.) above the pipe from the valve. Any exceptions shall require the written approval of the Company.

  Note:
  NOM-081-SEMARNAT-1994 requires that Mexican facilities maintain a noise level below 65 dBA at the facility's fence limit during normal operating conditions. The Designer shall indicate in the data sheet the valve's maximum noise level at 1 m (3 ft.) distance from the valve to comply with the requirements of *NOM-081-SEMARNAT-1994*, based on noise calculations and the fencing location relative to the control valve.

- The lower noise levels shall be maintained in locations where a minimum noise level is required at a nearby property line. Other means of attenuation may be required, such as thicker pipe, larger pipe, or acoustic insulation.
- The Vendor shall provide noise design calculations for the process conditions provided on the datasheet for review and approval.

2.6 Valve Type Selection

2.6.1 The sections below outline the characteristics of control valve options. The following ball valve characteristics shall be considered:

- good for flow control
- less useful for large pressure drops
- less pressure drops across the valve at 100% open, therefore it is useful for free-flow (no restriction) applications
- greater capacity for a given valve size
- available with noise and cavitation trim for **Liquid Service**
- available with noise attenuation trim for **Gas Service**
- produce greater noise at a higher pressure drop (compared to globe valves)

2.6.2 The following globe valve characteristics shall be considered:

- lower capacity for the same nominal size compared to the same size ball valve
- mainly used for continuous throttling applications
- good for large pressure drops over long durations
- available with noise and cavitation trims for **Liquid Service**
- available with noise attenuation trim for **Gas Service**
- greater noise reduction capability than ball valves

2.6.3 The following axial flow valve characteristics shall be considered

- good for flow control
- less useful for large pressure drops
- At 100% open, pressure drop will be greater than a ball valve
- At less than 20% open, control stability issues and high noise may be encountered
- greater capacity for a given valve size
- available with noise and cavitation trim for **Liquid Service**
- available with noise attenuation trim for **Gas Service**
- produce greater noise at a higher pressure drop (compared to globe valves)

2.7 Trim Type and Material Selection

2.7.1 The required process conditions shall be considered (see sections 2.1, 2.2 and 2.3) when selecting trim materials to ensure that the trim will function properly and withstand its operational requirements. Normally, Vendors are consulted for recommendations regarding the trim material.

2.8 Leakage Requirements

2.8.1 The seat leakage classification shall be for control valves is Class IV or better, as defined in *ANSI/FCI 70-2*.

2.8.2 A seat leak test is required as per *FCI 70-2,* unless specified on the datasheet supplied by the Company.

2.9 Hydrostatic Testing Requirements

2.9.1 All control valves shall be subjected to shell hydrostatic pressure test in accordance with the TES-MATL-COMP (EDMS No. 8071725) except in Canada due to the required longer test duration.

2.9.2 All control valves in Canada shall be hydrostatically tested to a minimum of one-hour shell test, either within the manufacturing facility (preferred) or a fabrication facility.

2.9.3 The minimum shell test pressure shall be 1.5 times the rated cold working pressure.

2.9.4 There shall be no leakage for the duration of the pressure test and no permanent distortion as a result of the pressure test.

3 ACTUATOR AND ACCESSORIES

3.1 Actuators

3.1.1 Liquid Service

- The control valves shall be equipped with electro-hydraulic actuators, for most of the applications. The designer, in consultation with Electrical Engineering, shall define the electric requirements for the electro-hydraulic actuator (available AC voltage level, frequency, available DC voltage level, etc.). This shall be incorporated in the data sheet issued by Company. The Vendor shall complete the data sheet (required power etc.) and return it to company.
- The time required to actuate the valve shall be determined and noted on the datasheet.

  Note:
  In previous liquid pipeline systems, the time required to actuate the valve fully has been limited to a maximum of 10 seconds. However, this is only a guideline from previous projects. The stroking time should be determined in consultation with System Design in conjunction with a transient hydraulic analysis, and will be indicated on data sheet.
- Electro-hydraulic actuators shall be used for fine and rapid positioning requirements involving the control of pipeline pressure and flow rates, as well as situations where a certain valve fail position is required.
- Electro hydraulic actuators shall be designed to provide its rated torque within +/-10% of nominal voltage
- The following additional requirements shall apply:
  - Neutral position shall be clearly indicated. The actuator shall be capable of stroking the valve in increments of 15% of full stroke.
  - The hydraulic circuit shall be totally self-contained and require minimum maintenance.
- The Vendor shall ensure the tag number, the manufacturer, and the model number is provided on the datasheet. The Company specifies the tag number.

3.1.2 Gas Service

- The actuator shall be air or gas operated, as specified in the data sheet.
- The pneumatic actuators shall be used for fine and rapid positioning requirements involving the control of pipeline pressure and flow rates, as well as

situations where a certain valve fail position is required. The pneumatic actuator shall be either spring opposed diaphragm or double acting piston.

- The Vendor shall size the actuator with consideration of flow, gas properties and operating conditions, as described in Section 2.1.
- Actuators shall be designed to fail close, or fail open, or last position on loss of pneumatic supply and open or close on loss of signal. Actuators may be reverse or direct acting. Required Failure position on loss of supply or signal shall be indicated on the data sheet.
- The Vendor shall ensure the tag number, the manufacturer, and the model number is provided on the datasheet. The Company specifies the tag number.

3.1.3 Common for Liquid and Gas Services

- All necessary components and hardware to adapt and mount the actuator to a bare stem shall be supplied by the Vendor.
- Actuators on ball valves shall be mounted on the left or right-hand side of the control valve when looking downstream. Actuators on globe valves shall be vertically mounted. The Designer shall confirm the position with Field Operations and indicate it on the datasheet, to be issued by the Company.
- The valve actuators shall be sized for 1.2 times the maximum valve torque requirements, and be approved by the Company. The additional torque requirements will ensure that the valve can be actuated quickly without risk of damage to the actuator.
- The Vendor shall ensure that actuators are designed to fail in the position as specified on the data sheet.
- The Vendor shall consider stroking time, if indicated in the data sheets for actuator selection.
- The control valve shall be supplied with the actuator already mounted.

3.2 Control Valve Accessories

3.2.1 Signal Transducer (I/P)

- The signal transducer, when selected, shall provide an output of 4 mA to 20 mA to indicate a range from fully closed to fully open (or vice versa).
- The manufacturer, model, type, supply pressure, signal action (direct or reverse), and valve position at outputs of 4 mA and 20 mA shall be recorded on the datasheet.

3.2.2 Positioner and Controllers

- Valve positioners (if requested) shall be provided on control valves, as specified in the data sheet issued by the Company.

- The tag number, manufacturer, model, type and signal action of the positioner shall be recorded on the completed data sheet.
- The indicator pointer shall be directly connected to the stem or shaft. The valve position shall be indicated on reversible scale with clearly graduating marking at 25% valve opening position intervals and labelled with the words Open and Closed at the valve's travel limits.
- Pneumatic valve positioners shall be provided with gauges to indicate supply pressure, control signal and positioner output pressure.
- Electro-pneumatic valve positioners and pneumatic valve positioners with integral electro-pneumatic transducers shall not be used in potentially vibrated service if they are mounted on the control valve. The I/P transducer shall be mounted separately from valve and actuator assembly. Where possible, digital valve controller positioners (e.g., DVC, DNGP, PMV Controllers) should be used, as they offer stable control and diagnostic capabilities.
- The total maximum inaccuracy of the signal conversion in I/P, due to any limitations, shall be less than 2%.
- Natural gas operated control valve actuators / positioners / controllers shall be equipped with quarter inch NPT connections (minimum) that would allow gas bleeds to be piped outside of classified buildings.
- Low bleed natural gas operated positioners / controllers shall be given preference over high bleed pneumatic positioners / controllers.

3.2.3 Position Transmitter

- The position transmitter shall be provided, if requested on the data sheet. The position transmitter shall provide position indications from 0% to 100% of valve travel, or 0 to 90 degrees of ball valves openings.
- The Indication shall be a linear 4 mA to 20 mA from the valve fully closed to fully open position, or vice versa.
- The manufacturer, model, type, mechanical link (rotation, direction, cable or magnetic) and valve position at outputs of 4 mA and 20 mA shall be recorded on the data sheet.

3.2.4 Solenoid Valve

- If a solenoid valve is required, the Designer, in consultation with Automation Engineering, shall determine the following solenoid valve features:
    - power supply
    - de-energized state (valve open, valve closed)
    - energized state

3.2.5 Limit Switches

- When required, limit switches are double pole, double throw proximity type and hermetically sealed as specified in the data sheet. Two single-pole, double-throw switches can be substituted for each double pole, double throw switch.
- Limit switches, at a minimum, shall be rated for 2 Amps at 24 Voltage Direct Current (VDC).
- Limit switches shall be actuated by a mechanical switch or proximity sensor.

3.2.6 Travel Stop

- When travel stops are required, the adjustment shall be lockable or be equipped with a jam-nut arrangement. Travel stops are rarely required.

4 VALVE-SPECIFIC REQUIREMENTS

4.1 Ball Valve

4.1.1 The Vendor shall ensure that ball valves meet the following criteria:

- Ball valves shall be of raised face flanged end or flangeless raised face design.
- The seat ring and seal joint area of the ball, or segmented ball, shall be designed for continuous throttling control of the process service.
- Stem seals shall be resistant to vibration
- Ball valves shall have trunnion-mounted balls and blowout proof stems.
- Ball valves shall be supplied with noise attenuation trims or cavitation trims **(Liquid Service)**, if required.
- In some applications, bi-directional flow may be required. In these situations, the valves shall be equipped with dual seats that will preclude leakage in either direction.

4.2 Globe Valve

4.2.1 The Vendor shall ensure that globe valves meet following criteria:

- Globe valves shall be flanged-end, unless otherwise specified on the data sheet
- Stem seals shall be resistant to vibration.

If a noise trim is required, the size of the openings in the trim should be greater than 6 mm (1/4 in.), to allow passage of debris (e.g., welding slag) without getting caught in the holes and causing damage to the cage. Larger trim openings have not been shown to significantly increase valve noise

5 MATERIAL REQUIREMENTS

5.1 Material

5.1.1 The following material requirements shall be considered:

- The valve materials, including body and bonnet, shall be in compliance with TES-MATL-COMP (EDMS No. 8071725) requirements and compatible with the conditions specified in the data sheet.
- Trim materials shall be selected to withstand corrosion, erosion and wear under severe service conditions. Material combination shall be selected for maximum galling resistance.

  Note:

  Typically, valve bodies are made of carbon steel such as *ASTM A350 LF2* or *ASTM A352 LCB/LCC*. For 50 mm (2”) and smaller control valves, *ASTM A216 WCB* or *WCC* is acceptable.

5.1.2 The Vendor shall supply a stainless-steel nameplate and permanently fasten it to each valve body, as per the requirements of TES-MATL-COMP (EDMS No. 8071725).

5.1.3 The Vendor shall ensure that all control valves have flanged-end connections, unless otherwise specified in the data sheets.

5.2 Flow Direction

5.2.1 The primary flow direction shall be indicated on the valve body, or alternatively, a stainless-steel arrow shall be permanently fixed to the body.

5.3 Packing

5.3.1 Packing shall meet the requirements of the process conditions, and should be based on Vendor’s recommendations.

5.4 Bolting

5.4.1 The Vendor shall recommend bolting materials for the particular conditions. Typically, studs are made to *ASTM A320 L7* and nuts to *ASTM A194 Gr. 4 or 7*.

5.4.2 The Vendor shall ensure that, if special bolting is required for the control valves, they are supplied. Rolled thread bolts shall be supplied for flange insert control valves.

6 INSTALLATION REQUIREMENTS

6.1.1 Control valves accessories, at a minimum, shall be designed for Class 1, Division 2 areas.

6.1.2 If the control valve is being installed outdoors, site-specific consideration shall be given to ensure that it is weather proof and properly covered/protected. Typically, some type of enclosure should be installed to protect the control valve.

6.1.3 Control Valves in Liquid Service

- Control valves in liquid service shall not be installed below ground.

6.1.4 Control Valves in Gas Service

- Control valves in gas service may be installed below ground; however, they can be flanged or welded connections. The Company preference is flanged connections in below ground applications.

7 DOCUMENTATION

7.1.1 Upon receipt of the order, the Vendor shall supply an authenticated copy of the sizing calculations and completed data sheets for the Company's review and approval.

7.1.2 The Vendor shall provide certified drawings for review and mill reports or mill test reports to the Company upon delivery of the valve.

7.1.3 As a minimum, documentation submitted by Vendor shall include:

- Capacity (C_v) as function of travel; confirmation by the Vendor that the required range-ability can meet with proposed control valve.
- Noise calculations, including the calculation basis and results for each specified flow condition.
- Vendor should also specify body and trim exit fluid velocity expressed in m/s (ft/s) and sonic (Mach).

7.1.4 Additional items required at the time of delivery:

- Actuator load calculations for the control valve
- Hydrostatic test report
- Seat leakage test report, if performed
- Stroke performance test report

8 VARIANCES

Any deviation shall follow the TransCanada Management of Change (MOC) Variance Procedure (EDMS No. 7728702). External Vendors shall contact the TransCanada Project Engineer for variance approval.

9 ROLES AND RESPONSIBILITIES

Table 9-1 below outlines the roles and responsibilities required for the use of this Specification.

Table 9-1: Roles and Responsibilities

Role	Responsibilities
Design Engineer/Designer	The Design Engineer is responsible for the design of the control valve and for ensuring the control valve is design in accordance with applicable codes, standards, and regulations. Design Engineers may be from the Company or from an external engineering company.
Vendor	Control valve manufacturer or provider of the control valve – also those who have been contracted to supply valves, which also include their manufacturing facilities and sub-vendors.
The Company	TransCanada, its corporate affiliates or its agents.

10 REFERENCES

This document relies on a number of references to regulation, industry codes and standards, general industry guidance as well as internal references. These documents are detailed below in Table 10-1. Use the latest document revision, unless otherwise approved by TransCanada.

Table 10-1: External and Internal References

Document No.	Title
Regulatory Codes	
SOR/99-294	National Energy Board Onshore Pipeline Regulations
CFR Title 49 Part 192	Transportation of Natural and Other Gas by Pipeline
CFR Title 49 Part 195	Transportation of Hazardous Liquids by Pipeline
SOR/86-304	Canada Occupational Health and Safety Regulations
NOM-007-SECRE-2010	Transporte de Gas Natural
NOM-081-SEMARNAT-1994	Que establece los límites máximos permisibles de emisión de ruido de las fuentes fijas y su método de medición.
Industry Codes and Standards	
National Fire Protection Association	National Fire Protection Association
CSA Group (CSA) – Concrete materials and methods of concrete	CSA Group (CSA) – Concrete materials and methods of concrete
American Pipeline Institute (API) Spec 6D	Specification for Pipeline and Piping Valves

Document No.	Title
American Society of Mechanical Engineers (ASME) B16.47	Large Diameter Steel Flanges: NPS 26 Through NPS 60 Metric/Inch Standard
ASME B16.5	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
ASME B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
ASME B31.8	Gas Transmission and Distribution Piping Systems
American Society for Testing and Materials (ASTM) A216	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service • WCB or WCC (-29°C or -20°F)
ASTM A352	Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service • LCB or LCC (-46°C or -50°F)
ASTM A350	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components • LF2 and LF3 (-45°C or -49°F)
Canadian Standards Association (CSA) Z245.12	Steel Flanges
CSA Z662	Oil and Gas Pipeline Systems
FCI 70-2	Control Valve Seat Leakage
ISA RP75.23	Considerations for Evaluating Control Valve Cavitation
ISA 75.01.01	Industrial-Process Control Valves – Part 2-1: Flow Capacity - Sizing Equations for Fluid Flow Under Installed Conditions
ISA 75.02	Control Valve Capacity Test Procedure
ISA 75.05	Control Valve Terminology
ISA 75.08.01	Face-to-Face Dimensions for Integral Flanged Globe-Style Control Valve Bodies (ANSI Classes 125, 150, 250, 300, and 600)
ISA 75.08.02	Face-to-Face Dimensions for Flangeless Control Valves (ANSI Classes 150, 300, 600)
ISA 75.08.06	Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (ANSI Classes 900, 1500, and 2500)
ISA 75.17	Control Valve Aerodynamic Noise Prediction

Document No.	Title
ISA 75.19.01	Hydrostatic Testing of Control Valves
ISA 75.25.01	Test Procedure for Control Valve Response Measurement from Step Inputs
Internal References – Documents Referenced by this Specification	
EDMS No. 3677475	TEF-MECH-LIQ-CV Liquid Control Valve Data Sheet Form (CDN-US-MEX)
EDMS No. 3677384	TEF-MECH-GAS-CV Gas Control Valve Data Sheet Form (CDN-US-MEX)
EDMS No. 8071725	TES-MATL-COMP Materials Requirements of Pressure Containing Equipment Components Specification (CDN-US-MEX)
EDMS No. 1001891682	TES-VALV- G Steel Valves for Gas Service Specification (CDN-US-MEX)
EDMS No. 1001895584	TES-VALV-L Steel Valves for Liquid Service Specification (CDN-US-MEX)
DS-4002 (CPG)	Pressure Regulation, Overpressure Protection & Flow Control Design
EDMS No. 3671710	TES-COAT-EPU Field-Applied External Liquid Coating Systems for Steel Pipes Specification (CDN-US-MEX)
EDMS No. 3694704	TES-COAT-P1 Paint Systems for Above Ground Facilities (Coastal and Non-Coastal) Specification (CDN-US-MEX)

11 DOCUMENT HISTORY

Rev.		
00	**Description**	**Effective Date**
	New document.	2016-Dec-01
	Rationale Statement	**Responsible Engineer**
	This document was developed / revised in order to address the following requirements: • Consolidation of specifications. The following specifications/documents have been combined into this document: – TES-MECH-CV-LIQ Control Valve Design Specification for Liquid Service (CDN-US-MEX) – TES-MECH-CV-GAS Control Valve Design Specification for Gas Service (CDN-US-MEX)	Dawood Habib
	Impact Assessment Summary	**Document Owner**
	Identify and address the potential impacts to operations, training, competency, safety and the environment, lines of business, based on the impact analysis done prior to the creation of the document.	Dawood Habib

12 DESCRIPTION OF CHANGE

Section	Description of Change
Regulatory	
N/A	N/A
Industry Standards	
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General	
N/A	This Specification is a new document.

13 APPROVALS

APPROVALS		
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PURPOSE

This Standard defines requirements for the selection and design of filtration units for natural gas transmission systems and associated facilities.

SCOPE/APPLICABILITY

This Standard applies to slug catchers, harp type slug catchers, centrifugal/cyclonic separators, vane type separators, suction scrubbers, filter separators, coalescing filters and cone strainers.

This Standard does not apply to separation or filtration systems that are part of fuel gas systems except where the drain systems are connected.

This Standard applies to all divisions of the Company and its wholly-owned subsidiaries, and all operated entities/facilities in Canada, the United States (U.S.) and Mexico.

This Standard does not apply to liquids facilities except where natural gas utilities are present.

Within this Standard, TransCanada is referred to as the Company.

Within this Standard, the following terms and definitions apply for requirements:

- Shall—expresses a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard. Shall is not a recommendation but a requirement.
- Should—expresses a strong preference, recommendation or that which is advised, but not required.
- Must—denotes a requirement of the Company, for which no deviation or variance would be granted.
- May—expresses an option or that which is permissible within the limits of the standard.
- Consider—assumes that a competent person will evaluate options to fulfill the intent of the requirement and make a documented decision supported by evidence to ensure protection of people, equipment and the environment by achieving the appropriate level of functional integrity.

Wherein governmental or regulatory requirements conflict with this Standard, the more stringent requirement shall govern.

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1 GLOSSARY

Bridle

Also known as an instrument bottle. A small external vessel with top and bottom inlets mounted at the anticipated liquid level, allowing external mounting of level indicators, switches, etc.

Components

Any valves, flanges, flange accessories, standard fittings, taps, components fabricated by welding, welded branch connections, and extruded outlets.

dPIT

Differential Pressure Indicating Transmitter

ESD

Emergency Shutdown

Liquid accumulator barrel

Also known as a blowflask.

Piping

The inlet and outlet points of gas entry and fluid holding areas of the system.

2 GLOBAL CONSIDERATIONS AND DESIGN REQUIREMENTS

2.1 Global Considerations

2.1.1 Slug catchers, separators and filters are designed to remove particulates, liquids and mists from gas before it is processed through other operations (such as compression or measurement).

2.1.2 Slug catchers should be used to collect large volumes of liquids (slugs) that come through the pipeline.

2.1.3 Separators and filters should be used to catch lower concentrations of liquids as well as particulates and mists.

2.1.4 Filters or coalescing filters should be used where high separation efficiencies are required to protect downstream equipment.

2.1.5 The separation/filtration system should consist of the following components:

- separation/filtration device (slug catcher, separator, or filter as applicable)
- sump, which may be integral to the vessel
- drain system
- low pressure drain line cyclone separator, if required
- storage drain tank, with flame arrestor if required

2.1.6 Due to the wide variation in gas flow conditions and variation of characteristics of the equipment, the specifying engineer may need to select more than one piece of equipment to provide proper gas conditioning.

2.1.7 See the flow chart in Appendix A for further filtration selection guidance.

2.1.8 Designers shall consider the requirements in the following specifications, regulations and standards, as applicable:

- *TED-MATL-FRAC Materials Fracture Control Plan (CAN-US-MEX)* (EDMS No. 007076183)
- Canada: CSA Z662 *Oil and Gas Pipeline Systems*
- U.S.: 49 CFR 192 *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*
- Mexico: NOM-007-SECRE-2010 *Transporte de gas natural*

2.2 Global Considerations for Compressor Stations

2.2.1 Each compressor unit shall be protected against the introduction of liquids, entrained vapors and other contaminants in quantities.

2.2.2 A natural gas separation or filtration system should be installed in the high-pressure gas piping downstream of the station suction isolation valve (ESD valve). Where mainline filtration is desired during station by-pass operation, consider installing the system upstream of the station suction isolation valve (ESD valve).

2.2.3 If appropriately sized, a single system may be used for the protection of multiple compressor units.

2.2.4 For stations operating centrifugal compressors, the system shall be capable of removing 99.8% of all particles and liquids 10 microns and larger over the expected range of gas flows.

2.2.5 For stations operating reciprocating compressors, the system shall be capable of removing 99.8% of all particles and liquids 1 micron and larger over the expected range of gas flows.

2.2.6 The low pressure drain line cyclone separator, if required, shall provide separation of the collected liquids and other contaminants from any entrained natural gas, allowing mist-free natural gas to dissipate and the liquids and other contaminants to gravity drain into the drain tank.

2.3 Global Considerations for Measurement and Regulating Stations

2.3.1 Measurement equipment should be protected against the introduction of liquids, entrained vapors and other contaminants in quantities that could cause equipment damage or measurement error.

2.3.2 If appropriately sized, a single system may be used for the protection of multiple meter runs.

2.3.3 For measurement and regulating stations, the system shall be capable of removing 99.8% of all particles and liquids over the expected range of gas flows as follows:

- Canada and Mexico: 10 microns and larger
- U.S.: 3 microns and larger

2.4 Global Considerations for Mainline Separation or Filtration

2.4.1 Where specified, launcher/receiver sites or mainline piping may be equipped with a natural gas separation or filtration system to extract liquids, entrained vapors and other contaminants in quantities that could cause damage. If installed at launcher/receiver sites, the system should be on the kicker line.

2.4.2 For launcher/receiver sites or mainline filtration sites, the filtration system shall be capable of removing 99.8% of all particles and liquids 10 microns and larger over the expected range of gas flows.

2.5 Global Design Requirements

2.5.1 The equipment shall be designed to this Standard, and site-specific and operating requirements.

2.5.2 The separation or filtration system pressure vessels shall be manufactured as specified in *TES-ME-PV1-GLE Pressure Vessels Specification (CAN-US-MEX)* (EDMS No. 000006406).

2.5.3 The bridles (instrument bottles) shall be fabricated by the separation/filtration device manufacturer.

2.5.4 The system pressure vessels shall be designed to a maximum allowable working pressure equal to or greater than the facility design pressure or pipeline design pressure as applicable. Typically, this will be 10% greater than the design pressure to account for pressure-relieving devices.

2.5.5 Vessels shall have supports, anchors or attachment points designed for any reaction forces due to process conditions, and wind or snow loading and/or earthquake zone conditions.

2.5.6 The system shall be provided with overpressure protection by a relieving device or with overpressure protection by system design.

2.5.7 A fire-sized relief valve shall be considered if pressure vessels could be isolated from the system's overpressure relieving device or overpressure protection system.

2.5.8 The system shall be designed to a minimum design metal temperature (MDMT) of -45°C (-50°F) or -29°C (-20°F) in accordance with *TED-MATL-FRAC Materials Fracture Control Plan (CAN-US-MEX)* (EDMS No. 007076183), and a maximum temperature of 75°C (167°F) unless a higher design temperature is required due to process conditions.

2.5.9 Separation systems shall be specified to have a maximum pressure drop of 14 kPad (2.0 psid) at maximum design flow and minimum pressure.

2.5.10 Filtration systems shall have a maximum design pressure drop at rated capacity in new condition of 14.0 kPad (2.0 psid) and shall alarm at 70 kPad (10 psid) with shutdown at 95 kPad (14 psid) or as recommended by the Vendor.

2.5.11 If no drain system and sump are installed, the pressure vessel shall be equipped with a grounding lug or static bonding and grounding reel.

2.6 Sump Requirements

2.6.1 There shall be an appropriate area or volume for catching and retaining the liquids and other contaminants.

2.6.2 Liquid storage shall be designed to have sufficient retention time before dumping to allow entrained gas to dissipate from the liquid.

2.7 Drain System Requirements

2.7.1 There shall be a method of removing the liquids and other contaminants from the equipment.

2.7.2 At compressor stations, automatic liquid dumps are required unless otherwise specified by the Company and shall be designed to remove at least two times the rate of any anticipated rate of liquid or material influx.

2.7.3 At meter stations and launcher/receiver sites, either manual or automatic dumps should be installed as specified by the Company.

2.8 Instrumentation Requirements

2.8.1 Adequate instrumentation shall be installed to permit safe monitoring, operation and control of the separation/filtration system.

2.9 Insulation or Freeze Protection Requirements

2.9.1 Where insulation is required, sump areas of the vessel shall be heated and/or insulated in accordance with *TES-ME-INSUL-GLE Piping and Equipment Insulation Specification (CAN-US-MEX)* (EDMS No. 1003873027).

2.9.2 Condition monitoring location (CML) ports on the shell, heads and boots shall be considered for inspection in accordance with *TES-ME-INSUL-GLE Piping and Equipment Insulation Specification (CAN-US-MEX)* (EDMS No. 1003873027).

2.9.3 Internal piping/tubing coil for anti-freeze circulation in the liquid collection area may also be considered.

2.9.4 A fabricated sump enclosure that contains catalytic heaters may also be considered.

2.9.5 If a fabricated sump enclosure is used, the enclosure shall be designed to allow access for maintenance and inspection. See Figure 2-1 and Figure 2-2 for interior and exterior photos of a typical installation.

Figure 2-1: Enclosure Interior Detail

Figure 2-2: Enclosure Exterior

3 SLUG CATCHER

3.1 Slug Catcher General Requirements

3.1.1 The vessel shall be designed for shock loading due to the arrival of liquid slugs.

3.1.2 Any internals shall be designed to resist damage due to liquid slugs.

3.1.3 The slug catcher shall meet the following efficiencies:

- 100% of free liquids including slugs
- 99.0% of droplets 10 microns and larger

3.1.4 Consider a mist eliminator near the outlet portion of the vessel to capture fine liquids carried by the gas flow. If required, specify on the datasheet.

3.2 Harp Type Slug Catcher Design Requirements

3.2.1 The reaction forces generated by inlet flow rate and velocity shall be listed on the datasheet.

3.2.2 Harp type slug catcher assemblies shall include the following major equipment components (see Figure 3-1):

- storage “harps”
- dry gas risers
- dry gas outlet
- separation chambers

- liquid and storage manifold
- distribution manifold
- two-phase (wet) gas inlet
- vent gas piping with supports
- structural storage tube anchors
- structural sliding supports

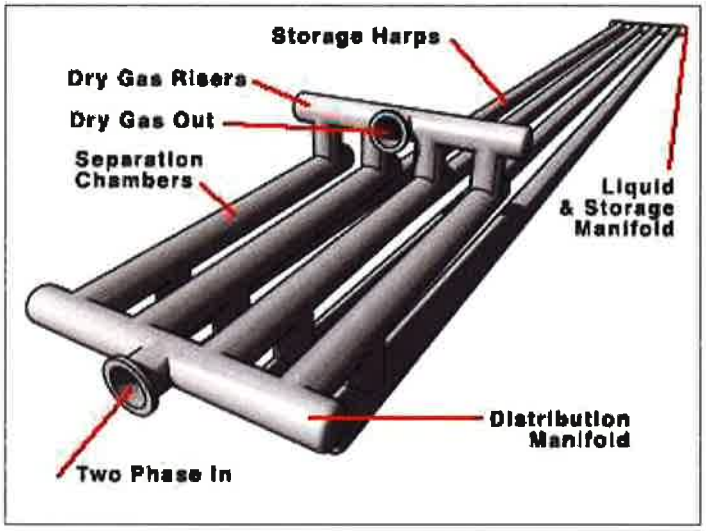


Figure 3-1: Harp Type Slug Catcher

3.3 Horizontal Vessel Type Slug Catcher Requirements

3.3.1 Consider a bottom sump. If required, specify on the datasheet.

3.3.2 If bottom sumps are specified, they shall include full opening blind flanges on each end to facilitate inspection and cleaning.

3.3.3 The quantity of expected free liquids shall be stated on the datasheet.

Note:

Figure 3-2 shows a typical horizontal vessel type slug catcher.

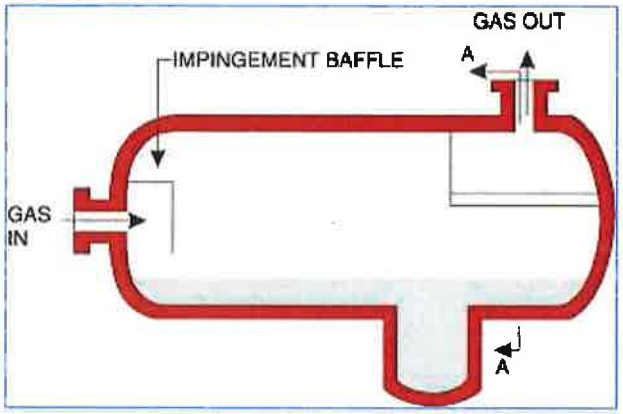


Figure 3-2: Horizontal Vessel Type Slug Catcher

3.4 Vertical Vessel Type Slug Catcher Requirements

3.4.1 Vertical slug catchers shall have a minimum sump capacity of 3,800 L (1,000 gal.) and the ability to handle a 1,900 L (500 gal.) slug, unless the designer notes otherwise on the datasheet.

3.5 Dump System Requirements

3.5.1 A manual dump system shall be installed for each section of the slug catcher.

3.5.2 Consider an automatic dump system in parallel with a manual dump system.

3.6 Instrumentation Requirements

3.6.1 As applicable, the instrumentation should generally follow the arrangement shown in Appendix B.

3.6.2 Level gauges and level switches shall be installed on each section of the slug catcher.

3.6.3 For horizontal vessels with sumps, a bridle (instrument bottle) shall be installed on each sump to permit the installation of devices for remote monitoring and controlling the liquid level in the sump.

3.6.4 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- liquid-filled pressure gauge with isolation valve
- temperature gauge
- relief valve connection, if specified
- dump valve connection with siphon off the side
- bottom drain connection

- adequate venting for purging the system
- upper and lower level gauge/switch connections with level gauge or switches for each vessel section
- level gauges, if specified, shall be supplied with valves to permit isolation and cleaning while vessel is in-service

4 SEPARATION SYSTEMS

4.1 Horizontal Suction Separator/Scrubber Design Requirements

4.1.1 The separator/scrubber elevation from scrubber centreline to bottom of support steel should be adequate to ensure the scrubber sumps, instrumentation and drainage systems can be installed below the scrubber shell.

4.1.2 Separators/scrubbers and bridles (instrument bottles) shall follow the arrangements shown on *STDS-01-CS-03-088 Typ. Scrubber Arrangement Centrifugal Station* and *STDS-01-CS-03-090 Suction Scrubber Instrument Bottles* as applicable.

4.2 Suction Separator/Scrubber Sump Design Requirements

4.2.1 Vertical sumps should be provided directly below the horizontal separator/scrubber barrel to collect and hold the liquids and solids knocked out of the gas for periodic disposal.

4.2.2 Two sumps, minimum NPS 16, are preferred. Each vertical sump should have an active liquid holding capacity of 40 L (10 gal.) as minimum.

4.2.3 At stations with a history of high liquid levels, consider increasing the sump size or including a larger horizontal liquid accumulator barrel, as shown in Figure 5-1.

4.2.4 Two NPS 2 connections shall be provided on each of the vertical sumps; one for the top bridle connection, the second for the combined bottom bridle, auto-dump and manual dump connection, as shown on the left side of Figure 4-1; except in cases where the alternate arrangement described in 4.2.5 is used.

4.2.5 Where high concentrations of solids are expected, a separate lower connection for the bridle and auto-dump with a siphon and a bottom connection for the manual dump connection may be utilized, as shown on the right side of Figure 4-1.

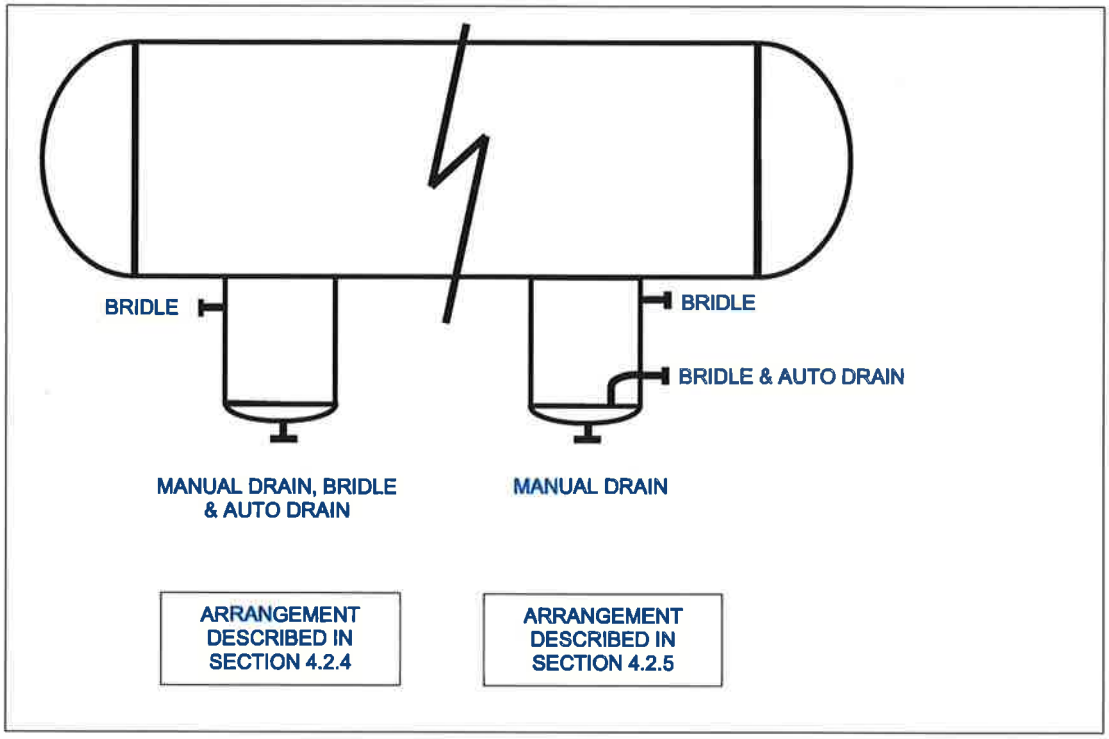


Figure 4-1: Sump Design Requirements

4.2.6 One NPS 6 port shall be provided on each of the vertical sumps to provide an inspection or cleanout access.

4.3 Centrifugal/Cyclonic Separator Design Requirements

4.3.1 Centrifugal/cyclonic separator assemblies (see Figure 4-2), shall include the following major equipment components:

- separator pressure vessel
- mist pad or vane assembly
- provisions for inducing gas swirl
- access manway and inspection ports for inspection and cleaning
- dump system

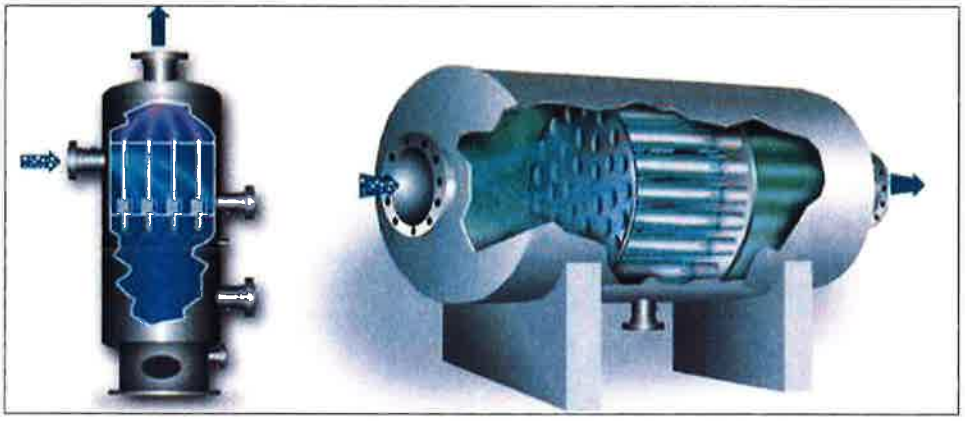


Figure 4-2: Centrifugal/ Cyclonic/ Type Gas Cleaner Pressure Vessel

4.3.2 To improve the performance of the system, the following deviations may be used:

- mechanism for inducing swirl (inlet baffle, cyclone tubes, etc.)
- mist pad, vane assembly or other means of trapping small liquid particles
- modification of the sump size/typical retention time

4.4 Vane Type Separator Design Requirements

4.4.1 Vane type separator assemblies shall include the following major equipment components:

- separator pressure vessel
- mist pad and vane assembly
- access manway and inspection ports for inspection and cleaning
- dump system

4.4.2 To improve the performance of the system, the following deviations may be included:

- mist pad or other means of trapping small liquid particles
- modification of the sump size/typical retention time
- method and actuation of level control

5 FILTRATION

5.1 Filter-Separator General Considerations

5.1.1 Filter-separators (see Figure 5-1) shall be designed to remove entrained liquid and solid particles, including dust, rust, compressor oils, liquid hydrocarbons, glycol and water from the natural gas stream.

5.1.2 There shall be adequate clearance below the filter-separator shell to install the sumps, instrumentation and drainage system.

5.1.3 Filter-separators shall be furnished complete with a horizontal liquid accumulator barrel and liquid dump systems serving both ends of the filter-separator/accumulator.

5.1.4 The accumulator shall have 150 L (40 gal.) minimum capacity and quick-opening (i.e., non-threaded) closures on both ends.

5.1.5 Filter-separators and bridles shall follow the arrangements shown on *STDS-01-CS-03-089 Typ. Scrubber Arrangement Reciprocating Station* and *STDS-01-CS-03-090 Suction Scrubber Instrument Bottles* as applicable.

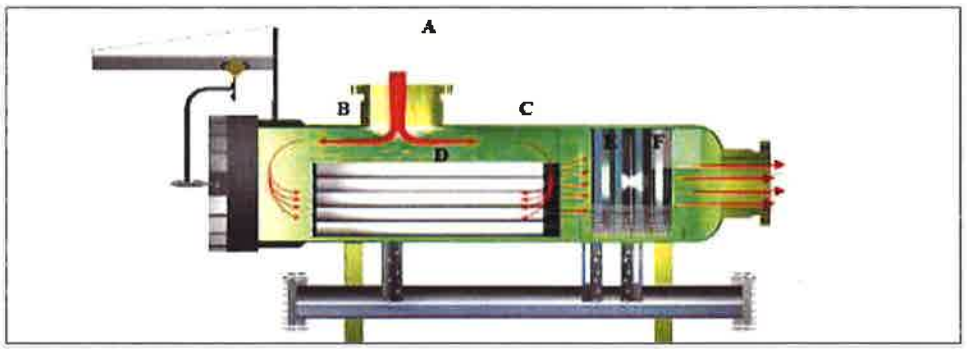


Figure 5-1: Filter-Separator Schematic

5.2 Filter-Separator Design Requirements

5.2.1 The vessel shall be capable of handling flows from zero to full design capacity with no reduction in efficiencies at the lower flows.

5.2.2 The design for horizontal and vertical type filters shall incorporate a "full end" end closure (i.e., the end closure shall match the vessel diameter), designed for optimal safety and ease of access for routine maintenance (cleaning and filter element replacements). Quick opening closures (i.e., non-threaded) are preferred.

5.2.3 The enclosures shall be meet *TES-FITG-EC1 End Closures Specification* (EDMS No. 003779256).

5.2.4 Mist extractors shall be of stainless steel construction.

5.2.5 If a mist extractor is specified, an inspection opening shall be provided to allow visual inspection and cleaning of the mist extractor.

5.2.6 Two connections shall be provided, one at each end of cyclone tube type separators, to be used to flush the interior.

5.3 Coalescing Filter-Separator Design Requirements

5.3.1 Unless otherwise specified, coalescing filter separators should be of the forward flow type.

5.3.2 Coalescing filter-separators (see Figure 5-2) shall include the following major equipment components:

- separator pressure vessel
- filter elements
- filter element supports
- filter access with access door supported either by hinges or a davit assembly (for vertical vessels, clam shell type vessels are preferred)
- separate sump and dump controls for the filter section and for separator sections, if separator section is specified
- mist eliminator

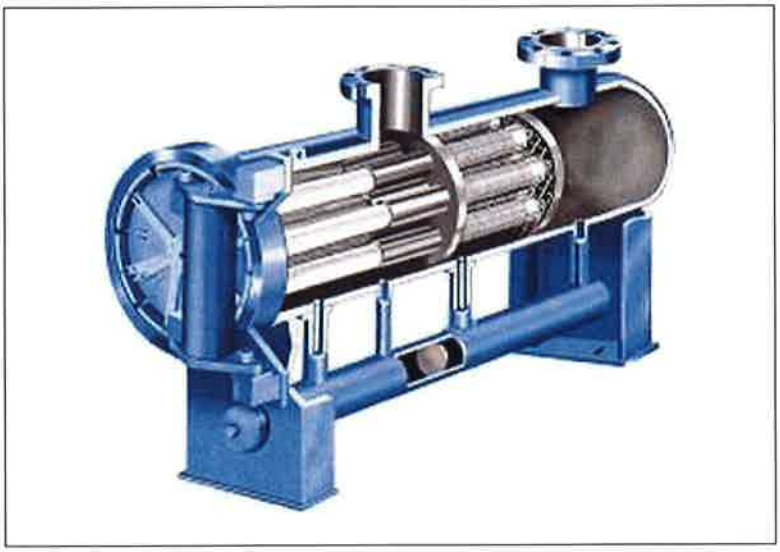


Figure 5-2: Coalescing Filter-Separator Pressure Vessel

6 INSTRUMENTATION AND DUMP DESIGN REQUIREMENTS FOR VESSELS WITH VERTICAL SUMPS

6.1 Design Requirements for Compressor Stations

6.1.1 Instrumentation should generally follow the arrangement shown in Appendix D.

6.1.2 The differential pressure across the filtration system shall be measured using a differential pressure gauge.

6.1.3 A differential pressure transmitter should be installed to alarm and/or shut down the downstream equipment when predetermined values are reached.

6.1.4 Where a differential pressure transmitter is installed, consider using a combined differential pressure transmitter (dPIT).

6.1.5 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral five-way manifold valve
- differential pressure transmitter, if specified
- liquid filled pressure gauge with isolation valve
- temperature gauge
- relief valve connection
- automatic dump valves, if specified
- manual dump valves
- adequate venting for purging the system
- liquid level control bridles (instrument bottles) to include:
  - top vent connection
  - bottom drain plug
  - three level gauge connections
  - liquid reservoir low level alarm switches
  - liquid reservoir high-level alarm switches
  - liquid reservoir high-high level alarm switches

Note:

Where external power is not available, consider replacing level switches with liquid level controllers with externally caged floats.

6.1.6 NPS 2 ball valves shall be installed between the scrubber sump and bridles connections for isolation purposes.

6.1.7 NPS 1 ball valves shall be installed in the vent and drain connections of each bridle.

6.1.8 Bridles shall be fabricated by the separator/scrubber manufacturer.

6.2 Design Requirements for Measurement and Regulating Stations

6.2.1 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral 5-way manifold valve
- differential pressure transmitter, when required

- instrument that provides visual verification of liquid level, such as a sight-glass, with valves to provide the capability to isolate and clean the instrument
- high point vent
- port for high level switch

6.2.2 Consider measuring the differential pressure across the filtration system using a differential pressure gauge and transmitter.

6.2.3 Consider a differential pressure transmitter to alarm and/or shut down the downstream equipment when predetermined values are reached.

6.2.4 Where a differential pressure transmitter is installed, consider using a combined differential pressure transmitter (dPIT).

6.3 Manual Dump Line Design Requirements

6.3.1 Two NPS 2 ball valves shall be installed between each separator/scrubber sump and manual dump line.

6.3.2 The ball valve immediately downstream of the sump shall be normally opened and the other ball valve shall be normally closed.

6.3.3 An NPS 2 line shall take off from each set of manual dump valves and join to form a common drain line header.

6.3.4 An NPS 1 line shall take off from each bridle and join the common drain header.

6.3.5 The common drain header shall be sloped at a minimum of 1% toward the storage drain tank (or cyclone separator if installed).

6.3.6 The drain line shall be designed to the same design pressure as upstream pressure equipment.

6.4 Automatic Dump Line Design Requirements

6.4.1 The automatic dump line shall be connected immediately downstream of the normally opened NPS 2 ball valve described in 6.3.1.

6.4.2 An automatic dump valve shall be installed in the automatic dump line downstream of each NPS 2 ball valve in parallel with the manual dump valve.

6.4.3 The automatic dump valves shall be specified to fail closed on loss of control signal or ESD condition.

6.4.4 A restriction orifice should be installed in the vertical section of the automatic dump piping immediately downstream of each automatic dump downstream isolation valve to provide pressure reduction downstream of the control valve to prevent freeze off and/or excessive seat wear.

6.4.5 The automatic and manual dump lines shall be connected together in the vicinity of the suction scrubber, and the common drain header shall be sloped at a minimum of 1% toward the storage drain tank (or cyclone separator) if installed.

7 INSTRUMENTATION AND DUMP DESIGN REQUIREMENTS FOR VESSELS WITH A HORIZONTAL LIQUID ACCUMULATOR BARREL

7.1 Design Requirements for Compressor Stations

7.1.1 Instrumentation should generally follow the arrangement shown in Appendix C.

7.1.2 The differential pressure across the filtration system shall be measured using a differential pressure gauge.

7.1.3 A differential pressure transmitter should be installed to alarm and/or shut down the downstream equipment when predetermined values are reached.

7.1.4 Where a differential pressure transmitter is installed, consider using a combined differential pressure transmitter (dPIT).

7.1.5 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral five-way manifold valve
- differential pressure transmitter, if specified
- liquid filled pressure gauge with isolation valve
- temperature gauge
- relief valve connection
- automatic dump valves, if specified
- manual dump valves
- adequate venting for purging the system
- liquid level control bridles (instrument bottles) to include:
  - top vent connection
  - bottom drain plug
  - three level gauge connections
  - liquid reservoir low level alarm switches
  - liquid reservoir high-level alarm switches
  - liquid reservoir high-high level alarm switches

Note:

Where external power is not available, consider replacing level switches with liquid level controllers with externally caged floats.

7.1.6 NPS 2 ball valves shall be installed between the liquid accumulator barrel and bridle connections for isolation purposes.

7.1.7 NPS 1 ball valves shall be installed in the vent and drain connections of each bridle.

7.2 Design Requirements for Measurement and Regulating Stations

7.2.1 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral five-way manifold valve
- differential pressure transmitter, if specified
- instrument that provides visual verification of liquid level, such as sight-glass, with valves to provide the capability to isolate and clean the instrument
- high point vent
- port for high level switch

7.2.2 Consider measuring the differential pressure across the filtration system using a differential pressure gauge.

7.2.3 A differential pressure transmitter should be installed to alarm and/or shut down the downstream equipment when predetermined values are reached.

7.2.4 Where a differential pressure transmitter is installed, consider using a combined dPIT.

7.3 Manual Dump Line Design Requirements

7.3.1 An NPS 2 ball valve shall be installed between each side of the liquid accumulator barrel and the manual dump line.

7.3.2 The ball valve shall be normally closed.

7.3.3 An NPS 2 line shall take off from each set of manual dump valves. Each line shall join an automatic dump line then pass through a check valve and restriction orifice before combining to form a single line to the storage dump tank.

7.3.4 The drain line shall be designed to the same design pressure of upstream pressure equipment.

7.4 Automatic Dump Line Design Requirements

7.4.1 An automatic dump valve shall be connected between two normally open NPS 2 ball valves on each side of the liquid accumulator barrel.

7.4.2 The automatic dump valves shall be specified to fail closed on loss of control signal or in an ESD condition.

7.4.3 Each NPS 2 automatic dump line shall join the manual dump line for each side of the liquid accumulator barrel.

7.4.4 The dump lines from each side of the liquid accumulator barrel shall be connected together in the vicinity of the suction scrubber and this common drain head shall be routed to the storage drain tank (or cyclone separator if installed), at a 1% slope.

8 INSTRUMENTATION AND DUMP DESIGN REQUIREMENTS FOR VERTICAL VESSELS

8.1 Design Requirements for Compressor Stations

8.1.1 Instrumentation should generally follow the arrangement shown in Appendix B.

8.1.2 The differential pressure across the filtration system shall be measured using a differential pressure gauge.

8.1.3 A differential pressure transmitter should be installed to alarm and/or shut down the downstream equipment when predetermined values are reached.

8.1.4 Where a differential pressure transmitter is installed, consider using a combined differential pressure transmitter (dPIT).

8.1.5 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral five-way manifold valve
- differential pressure transmitter, if specified
- liquid filled pressure gauge with isolation valve
- temperature gauge
- relief valve connection
- automatic dump valves, if specified
- manual dump valves
- top vent connection
- bottom drain plug
- three level gauge connections
- liquid reservoir low level alarm switches
- liquid reservoir high-level alarm switches
- liquid reservoir high-high level alarm switches

Note:

Where external power is not available, consider replacing level switches with liquid level controllers with externally caged floats.

8.2 Design Requirements for Measurement and Regulating Stations

8.2.1 Instrumentation should generally follow the arrangement shown in Appendix E.

8.2.2 The scope of work and datasheet shall specify that the Vendor shall provide, at a minimum, the connections and provisions for the following equipment and instrumentation:

- differential pressure gauge with integral five-way manifold valve
- differential pressure transmitter, if specified
- instrument that provides visual verification of liquid level, such as sight-glass, with valves to provide the capability to isolate and clean the instrument
- high point vent
- port for high level switch

8.2.3 Consider measuring the differential pressure across the filtration system using a differential pressure gauge.

8.2.4 A differential pressure transmitter should be installed to alarm and/or shut down the downstream equipment when predetermined values are reached.

8.2.5 Where a differential pressure transmitter is installed, consider using a combined differential pressure transmitter.

8.3 Manual Dump Line Design Requirements

8.3.1 An NPS 2 ball valve shall be installed between each section of the vessel and the manual dump line.

8.3.2 The ball valve shall be normally closed.

8.3.3 An NPS 2 line shall take off from each manual dump valve and shall connect together in the vicinity of the vessel; this common drain header shall be routed to the storage drain tank.

8.3.4 The drain line shall be designed to the same design pressure as upstream pressure equipment.

8.4 Automatic Dump Line Design Requirements

Note:

The clauses in this section apply only if an automatic dump valve is specified.

8.4.1 The automatic dump valve shall be connected in parallel with the manual dump valve between two normally open NPS 2 ball valves.

8.4.2 The automatic dump valve shall be specified to fail closed on loss of control signal or in an ESD condition.

8.4.3 The dump lines from each section of the vessel shall be connected together in the vicinity of the vessel, and this common drain head shall be routed to the storage drain tank (or cyclone separator if installed), at a 1% slope.

9 LOW PRESSURE DRAIN LINE CYCLONE SEPARATOR

9.1 General Requirements

9.1.1 Consider a cyclone separator to separate liquid and gas in the compressor station scrubber drain and fuel gas drain system.

9.1.2 Where low volumes of liquids and other contaminants are expected, the cyclone separator may be omitted.

9.1.3 If the cyclone separator is omitted from the design, the drain line and drain tank design shall ensure there is no risk of over-pressuring the drain tank during automatic or manual dumping, and that mist carryover from the drain tank during automatic or manual dumping is minimized.

9.2 Design Requirements

9.2.1 A vertical cyclone separator should normally be selected for gas/liquid separation.

9.2.2 The cyclone separator shall have a design pressure of 103 kPa (15 psig), with blowdown vents to atmosphere.

9.2.3 The cyclone separator liquid drain shall be located at the bottom of the separator. An NPS 4 (preferred size) pipe shall be connected between the liquid drain and the drain tank.

9.2.4 The line between the cyclone separator and drain tank shall be sloped a minimum 1% grade towards the drain tank, to ensure gravity drainage of liquids to the drain tank.

9.2.5 Detailed design of the cyclone separator shall be in accordance with *STDS-01-CS-03-091 Typical Scrubber Arrangement – Centrifugal Station*.

10 GAS PROCESS STORAGE DRAIN TANK

10.1 Storage Drain Tank General Requirements

10.1.1 A double-walled steel tank shall be installed in the compressor/meter station yard in the vicinity of the cyclone separator to provide temporary storage of liquid waste drained from the filtration system and fuel gas drain.

10.1.2 The storage drain tank shall be fabricated in accordance with *TES-MECH-ASFT Aboveground Shop Fabricated Tanks Specification (CAN-US-MEX)* (EDMS No. 009214522).

10.1.3 Above ground field-erected tanks shall be in accordance with *TES-ME-AST-GLE Field-Erected Aboveground Storage Tanks Atmospheric Specification* (CAN-US-MEX) (EDMS No. 008042207).

10.1.4 Underground tanks, if applicable, shall be in accordance with *TES-ME-UST-GLE Underground Tank Specification (CAN-US-MEX)* (EDMS No. 008113769).

10.1.5 If required by local codes or regulations, or the result of a Process Hazard Assessment, a flame arrestor shall be installed on the drain tank vent.

10.1.6 If the storage drain tank vent height is mandated by local codes or regulations, ensure the height meets minimum requirements based on tank volume, liquid type and class.

10.1.7 Consider adding a static bonding and grounding reel to the storage drain tank in lieu of a grounding lug.

10.2 Storage Drain Tank Design Requirements

10.2.1 The storage drain tank capacity should not be less than 5,000 L (1,320 gal.).

10.2.2 The storage drain tank shall be equipped with a high-level alarm to alert operators to dispose of tank contents as soon as possible.

10.2.3 Sufficient volume above the high-level alarm should be provided for collecting solids and liquids from the suction scrubber.

10.2.4 The storage drain tank shall be equipped with a high-high level station shutdown lockout to eliminate the possibility of liquids overfilling the drain tank and to ensure that liquids collected in the scrubber sumps are not vented to atmosphere through the cyclone separator.

10.2.5 For facilities with multiple storage drain tanks, the high-high level alarm shall shut off the drain to the associated drain tank, allowing the facility to continue to operate until all tanks reach high-high level.

10.2.6 If required due to regular freezing conditions at the facility site, the drain tank should be insulated and heated, and the enclosure should include temperature instruments and a pump out connection.

10.2.7 The storage drain tank should be prefabricated, skid mounted, and shipped to the site as a complete system.

11 CONE STRAINER

11.1 Cone Strainer General Considerations

11.1.1 The units (see Figure 11-1) shall be installed at locations in process systems where particulate matter may adversely affect the operation of equipment or systems.

11.2 Cone Strainer Design Requirements

11.2.1 Strainers may be provided in diameter and bolt-hole patterns to match ANSI classes 150, 300, 600, 900, 1500 or 2500, as indicated by the service location.

11.2.2 The certifying engineer shall develop a project-specific datasheet, specifying the intended service for cone installation (e.g., pipe diameter and ANSI flange class).

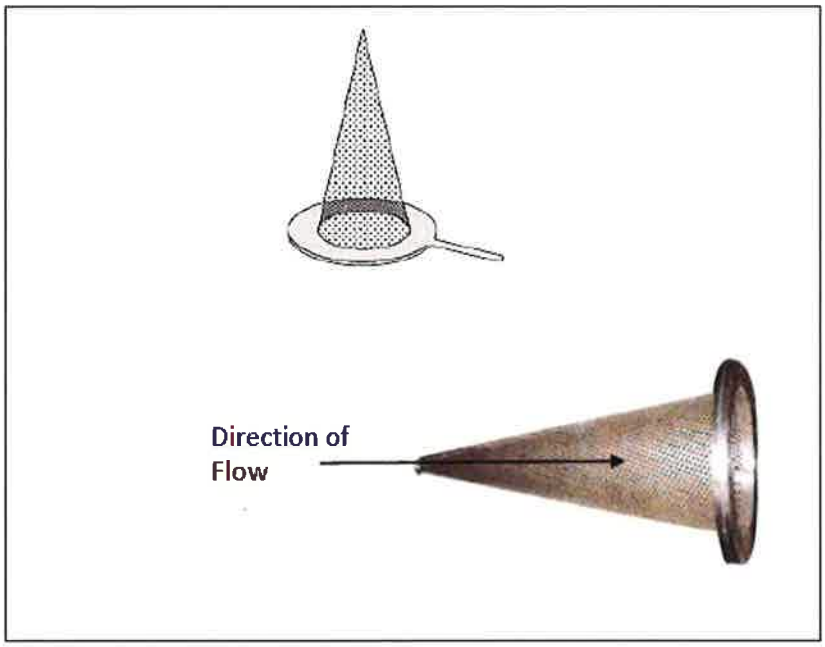


Figure 11-1: In-Line (Cone Type) Strainers

11.2.3 The strainer (without the fabric) shall have a minimum of 200% flow area with 3 mm (1/8 in.) holes at 13 mm (3/16 in.) spacing and shall have not less than 100% flow area with the wire mesh installed.

11.2.4 Wire fabric shall be on the upstream side of the cone and of square mesh construction having a maximum 30-mesh opening.

11.2.5 To improve the performance of the system, one or more of the following deviations may be used:

- reduced diameter to fit inside an ANSI flange bolt circle; however, this deviation is not permitted where flat-faced flanges are used
- support structure for the perforated cone

11.2.6 For start-up cone strainers, a matching spacer ring shall be provided by the Vendor, allowing removal of the cone strainer without impacting the piping or equipment alignment.

12 VENDOR CONSIDERATIONS

12.1 Technical Proposal Information Requirements

The designer shall ensure the request for proposal includes the Vendor requirements in this section.

12.1.1 The Vendor shall provide the following information:

- slug, solid and droplet removal capabilities
- capacity curves (pressure versus flow rate), and actual pressure drop (clean & dry and clean & wet for filter-separators) at design condition
- guaranteed removal efficiency based on total vessel configuration, including vessel internal separation device and filter elements if included
- sump capacity to meet or exceed the capacity specified on the datasheet
- the maximum (clean & dry and clean & wet) operating pressure drops across tube sheet or any gas deflection device internally placed in the vessel
- separate pricing for accessories, itemizing the description and prices for relief valve, bridle (instrument bottle) assembly, level control valves, level alarms, differential pressure transmitter and manual drain/vent valves
- outline drawing of proposed equipment noting the size, weight, support locations, nozzles and equipment layout

12.1.2 The system, including foundation mountings, shall be designed to absorb and transmit to the foundation the reaction forces generated by the inlet flow rate and velocity specified in the datasheet.

12.1.3 Inlet nozzles shall be designed, oriented, or shall have internal baffling so that inlet gas flow does not directly impinge on any internal surface of the vessel.

12.1.4 Vessel sizing and sump sizing shall take into account the amount of gas flow required and the expected quantity of free liquid slugs.

12.1.5 The base of the vessel shall be designed and constructed to support the weight of the vessel and the maximum amount of liquids.

12.1.6 The base of vertical vessels shall have an opening for pipe and vessel inspection purposes, which shall have an area equivalent to a 508 mm (20 in.) diameter opening.

12.2 Additional Filter-Separator Technical Proposal Information Requirements

The designer shall ensure the request for proposal includes the following Vendor requirements:

- number, type and cost of filter elements to meet rated efficiency
- the filter's rated collapse pressure
- the cost of full-size flanges with davits or hinges as an alternative

13 VARIANCES

Any deviation shall follow the Company's *Controlled Document Variance Procedure (Cdn-US-Mex)* (EDMS No. 007728702). External Vendors shall contact the Company Project Engineer or another authorized Company representative for variance approval.

14 REFERENCES

This document relies on a number of references to regulation, industry codes and standards, general industry guidance as well as internal references. These documents are listed in Table 14-1, Table 14-2 and Table 14-3. Use the latest document revision, unless otherwise approved by TransCanada.

Table 14-1: Regulatory References

Organization/Document No.	Title
Canadian Standards Association (CSA)	CSA Z662 *Oil and Gas Pipeline Systems*
Code of Federal Regulations (CFR)	49 CFR 192 *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*
Norma Oficial Mexicana (NOM)	NOM-007-SECRE-2010 *Transporte de gas natural*

Table 14-2: External Industry References

Organization/Document No.	Title
For this Specification, there are no specific external industry references.	

Table 14-3: Internal References

Document No.	Title
EDMS No. 007728702	*Controlled Document Variance Procedure (Cdn-US-Mex)*
EDMS No. N/A	STDS-01-CS-03-088 *Typ. Scrubber Arrangement Centrifugal Station*
EDMS No. N/A	STDS-01-CS-03-089 *Typ. Scrubber Arrangement Reciprocating Station*
EDMS No. N/A	STDS-01-CS-03-090 *Suction Scrubber Instrument Bottles*
EDMS No. N/A	STDS-01-CS-03-091*Cyclone Separator Details*
EMDS No. 007076183	*TED-MATL-FRAC Materials Fracture Control Plan (CAN-US-MEX)*
EDMS No. 003677428	*TEF-ME-FIL-GE Separator and Filter Data Sheet*

Document No.	Title
EDMS No. 003779256	*TES-FITG-EC1 End Closures Specification (CDN-US-MEX)*
EDMS No. 008042207	*TES-ME-AST-GLE Field-Erected Aboveground Storage Tanks Atmospheric Specification (CAN-US-MEX)*
EDMS No. 009214522	*TES-MECH-ASFT Aboveground Shop Fabricated Tanks Specification (CAN-US-MEX)*
EDMS No. 1003873027	*TES-ME-INSUL-GLE Piping and Equipment Insulation Specification (CAN-US-MEX)*
EDMS No. 000006406	*TES-ME-PV1-GLE Pressure Vessels Specification (CAN-US-MEX)*
EDMS No. 008113769	*TES-ME-UST-GLE Underground Tank Specification (CAN-US-MEX)*

15 DOCUMENTATION AND RECORDKEEPING

Designers shall ensure that all technical document submittal requirements are provided in the Vendor Technical Document Requirements List (VDRL) included with the proposal request or purchase order.

16 DOCUMENT HISTORY

Rev.		
00	**Description**	**Effective Date**
	New document.	2018-Jan-01
	Rationale Statement	**Responsible Engineer**
	This document was developed in order to address the following requirements: • Consolidation of the following specifications/documents: ▪ *Coalescer Filter Specification Material/Equipment Spec. No.: EQ.40.004 - CPG* ▪ *Cone Strainer Specification Material/Equipment Spec. No.: EQ.40.006* ▪ *Cyclonic Separator Specification Material/Equipment Spec. No.: EQ.40.003* ▪ *Filter Separator Specification Material/Equipment Spec. No.: EQ.40.008* ▪ *Gas Cleaner and Slug Catcher Standard DESIGN STANDARD NO.: DS.40.003* ▪ *Harp Separator Specification Material/Equipment Spec. No.: EQ.40.002* ▪ *Slug Catcher Specification Material/Equipment Spec. No.: EQ.40.015* ▪ *Vane Separator Specification Material/Equipment Spec. No.: EQ.40.005* ▪ *TES-Gas Scrubber Separator Specification EDMS No. 9092437* ▪ *TEN-ME-HPG-G Compressor Station High Pressure Gas Piping Design* (sections of this Specification)	Greg Szuch, P. Eng.
	Impact Assessment Summary	**Document Owner**
	This Standard is an amalgamation of existing requirements. There is no impact to operations, training, competency, safety or the environment. Standard developed as part of the ESS project.	Greg Szuch, P. Eng.

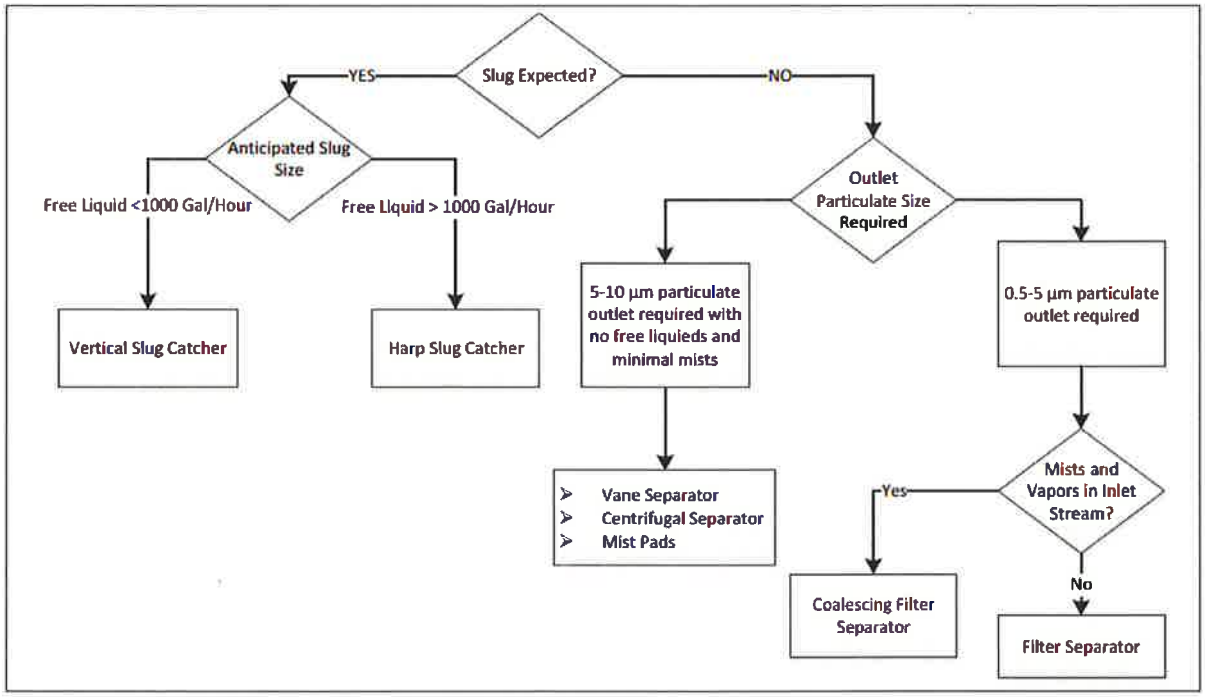
17 DESCRIPTION OF CHANGE

Section	Description of Change
Regulatory	
N/A	N/A
Industry Standards	
N/A	N/A
General	
N/A	This Standard is a new document.

18 APPROVALS

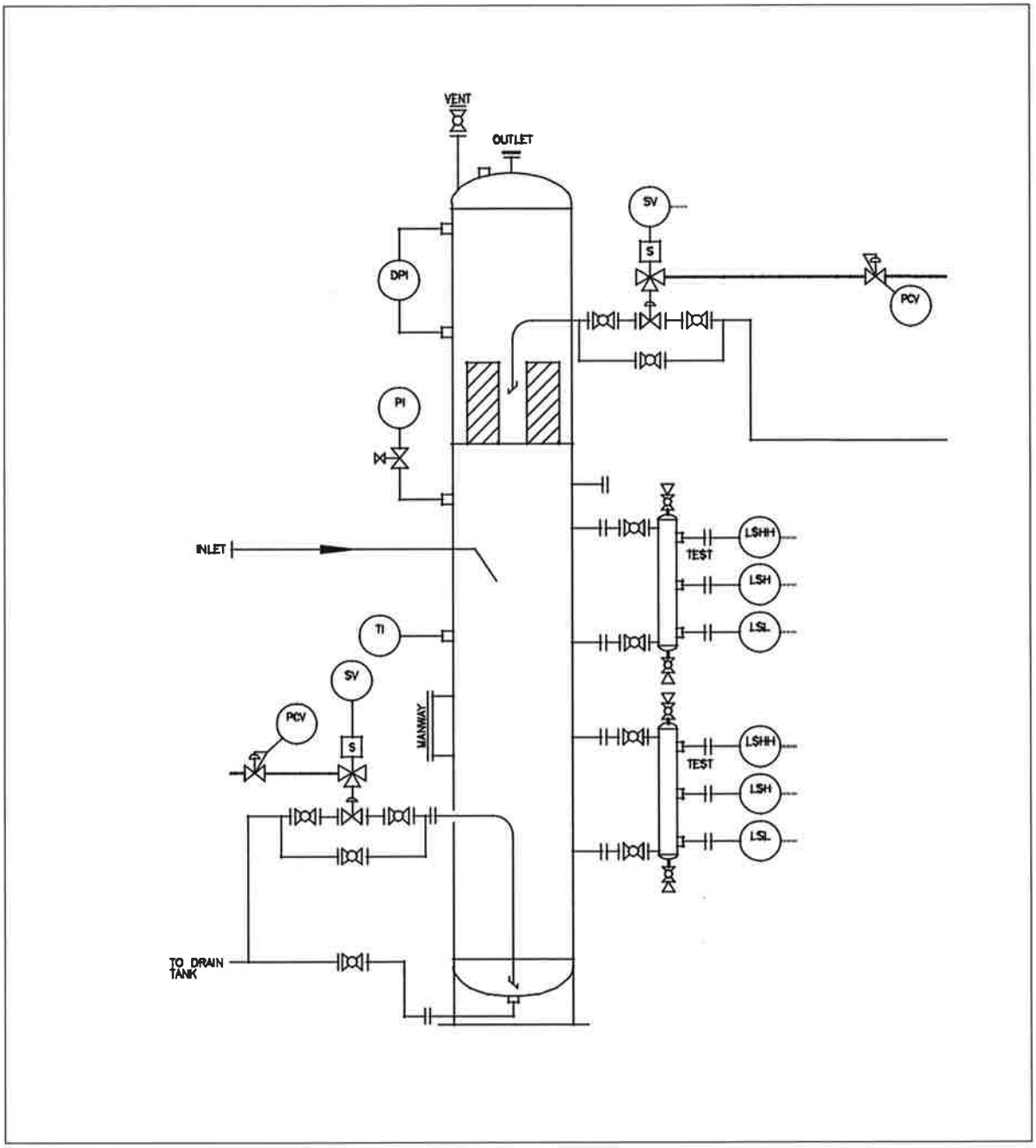
APPROVALS		
Originator: Greg Szuch, P. Eng. Facility Integrity Engineering	Signature	Nov 28, 2017 Date
Reviewer: David Thom, P. Eng. MX - Engineering	Signature	Dec 7, 2017 Date
Reviewer: Molly Beckel, P. Eng. CGO TS – Engineering Support	Signature	Nov 29, 2017 Date
Reviewer: Robert Rushman, P. E. USTS Compression West	Signature	11/28/2017 Date
Reviewer: Jose Jairzinho Cervantes Herrera MGO Asset Reliability & Performance	Signature	06 Dec 2017 Date
Reviewer: Steven Foo, P. Eng. CGO Compression Engineering	Signature	Dec. 6, 2017 Date
Responsible Engineer: Greg Szuch, P. Eng. Facility Integrity Engineering	Signature Dec 11, 2017 Date	PROFESSIONAL ENGINEER ALBERTA APEGA Permit to Practice P7100
Management Endorsement: Muhammad Riaz, P. Eng., Manager Engineering Standards Governance	Li Wei on behalf of Riaz Signature	Dec 14, 2017 Date

APPENDIX A FLOW CHART FOR FILTRATION SELECTION GUIDANCE



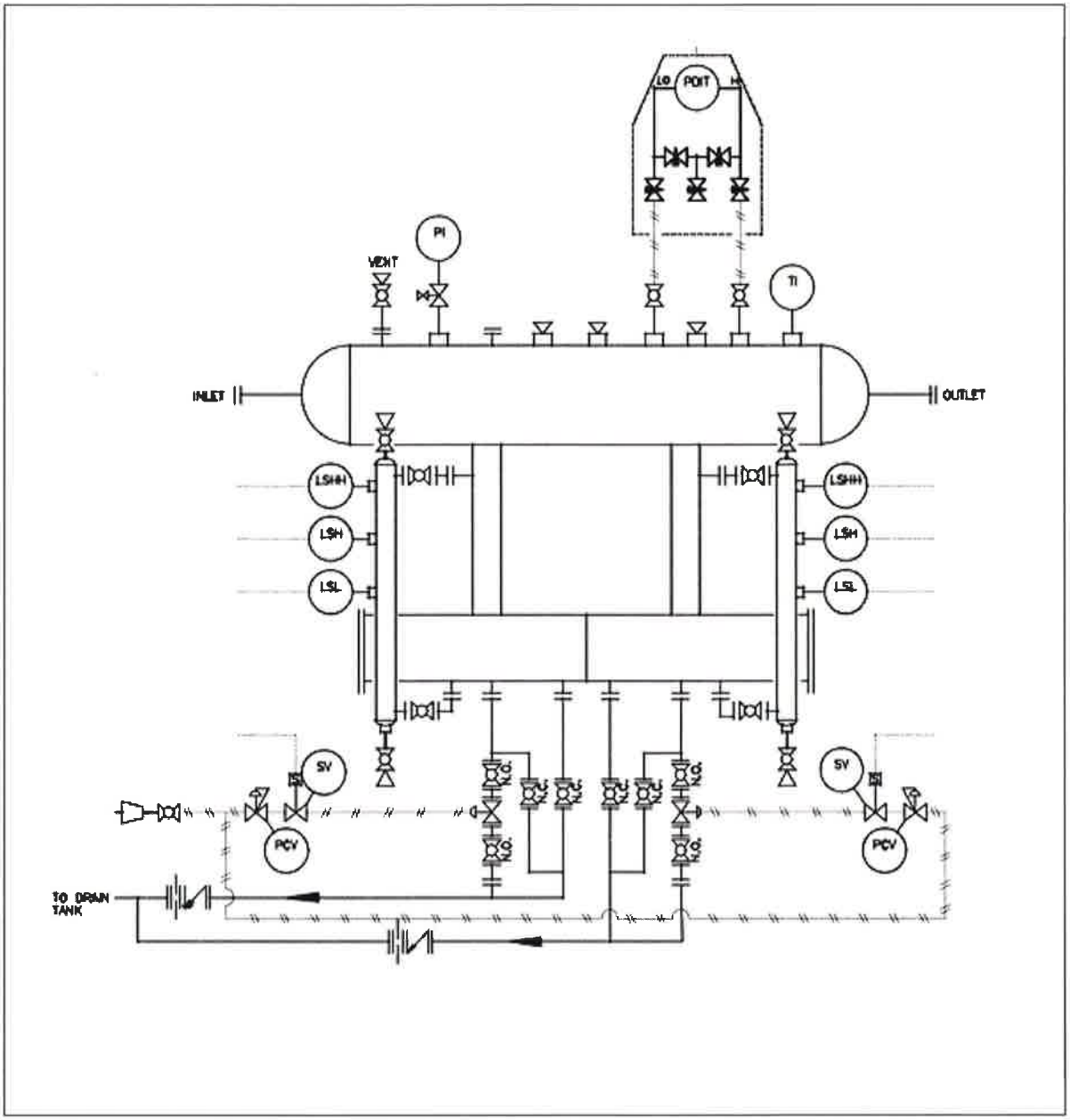
Appendix Figure A-1: Flow Chart for Filtration Selection Guidance

APPENDIX B SLUG CATCHER



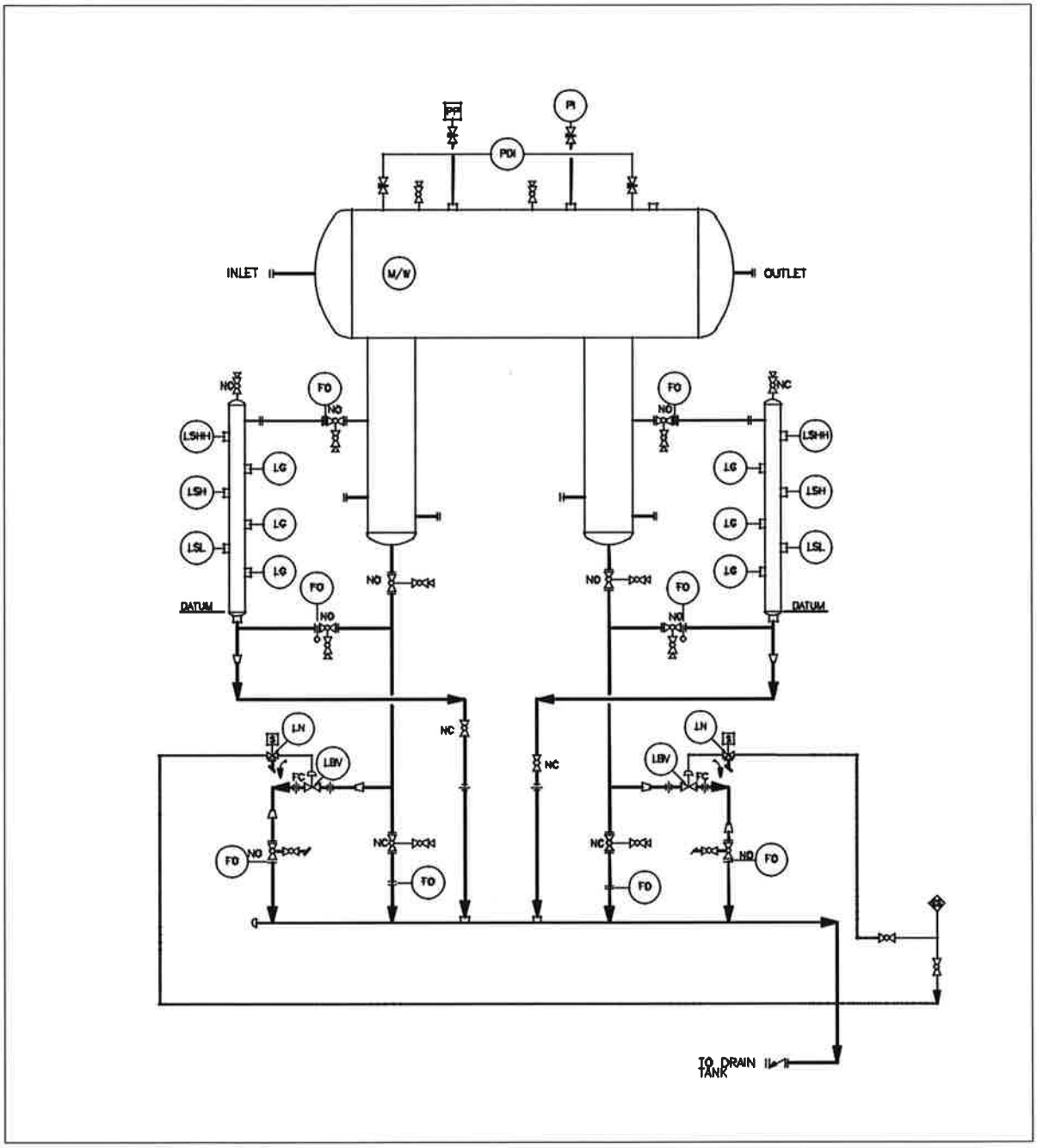
Appendix Figure B-1: Slug Catcher

APPENDIX C HORIZONTAL FILTER/SEPARATOR



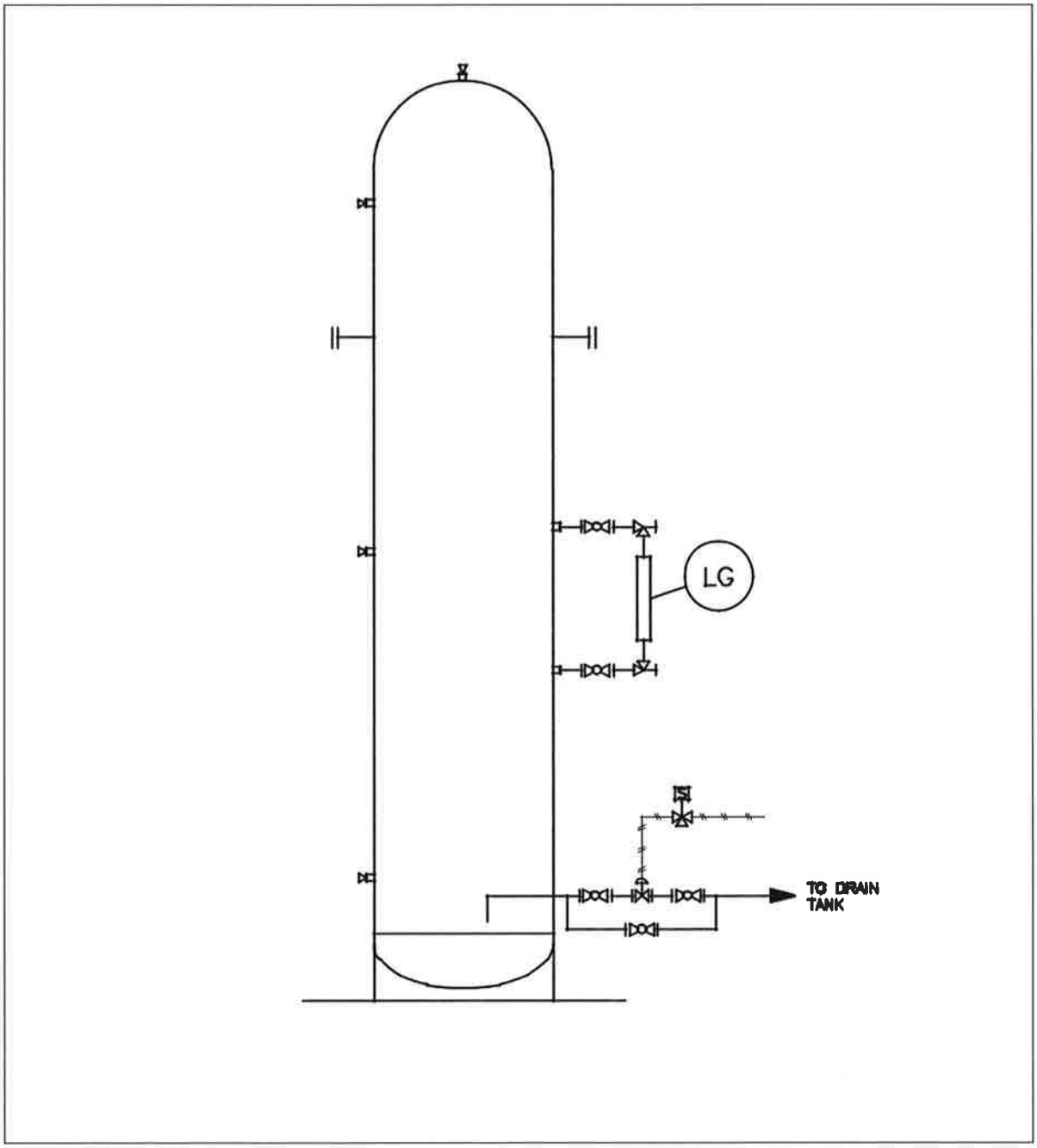
Appendix Figure C-1: Horizontal Filter/Separator

APPENDIX D SCRUBBER/SEPARATOR



Appendix Figure D-1: Scrubber/Separator

APPENDIX E VERTICAL SEPARATOR



Appendix Figure E-1: Vertical Separator

PURPOSE

The purpose of this Specification is to provide Company requirements for welding pipelines and facilities.

SCOPE/APPLICABILITY

This Specification describes the technical requirements for qualification of welding procedures, welders, production welding, visual and nondestructive examination, and repair welding for welds in hazardous liquids and gas pipeline systems in the United States (U.S.) and Mexico. The requirements in this Specification apply to both Company employee welders and welders employed by contractors or sub-contractors.

This Specification shall be read in conjunction with American Petroleum Institute (API) 1104 and covers additional requirements of 49 Code of Federal Regulations (CFR) 192 for natural and other gas pipelines and 49 CFR 195 for hazardous liquids pipelines.

This Specification applies to pipelines and facilities (i.e., compression, meter and pump facilities), and to welds made using welding procedures qualified in accordance with the requirements of API 1104 and American Society of Mechanical Engineers (ASME), Section IX, as appropriate.

This Specification does not apply to welds for:

- in-service piping that are covered by Company Specification *TES-WL-APIIS-GL Welding on In-Service Pipelines Specification (US-MEX)* (EDMS no. 6717380)
- pressure vessel or storage tank fabrication covered by ASME, Section IX
- structural welds that fall under the jurisdiction of AWS D1.1

Contact the Responsible Engineer for clarification if needed.

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1 GLOSSARY

API

American Petroleum Institute

ASME

American Society of Mechanical Engineers

ASTM

American Society for Testing and Materials

AUT

Automated Ultrasonic Testing

AWS

American Welding Society

CFR

Code of Federal Regulations

Company

TransCanada, as well as all partially owned entities and/or joint ventures where TransCanada has operational control.

CSA

Canadian Standards Association

CVN

Charpy V-notch

FCAW

Flux-cored Arc Welding

GMAW

Gas Metal Arc Welding

GTAW

Gas Tungsten Arc Welding

HAZ

Heat-affected Zone

MCAW

Metal Cored Arc Welding

MTR

Material Test Report

NDE

Nondestructive Examination

NDT

Nondestructive Testing

PQR

Procedure Qualification Record

PWHT

Post-weld Heat Treatment

SAW

Submerged Arc Welding

Shall

A mandatory requirement.

Should, May

A recommended or suggested practice.

SMAW

Shielded Metal Arc Welding

SMYS

Specified Minimum Yield Strength

WPDS

Welding Procedure Data Sheet

WPS

Welding Procedure Specification

2 REQUIREMENTS

2.1 General Requirements

2.1.1 Wherein the Manufacturer's literature, governmental or regulatory requirements conflict with this Specification, the more stringent requirement shall govern.

2.1.2 Unless specified, all statements in this Specification are requirements.

2.1.3 Unless specified, the Contractor and/or internal welding departments are the subject for all requirements included in this Specification.

2.2 Weld Design—General

2.2.1 Perform all welding, including tack welds, temporary welds and utility piping welds, using qualified welding procedures as provided in the Project Welding Plan and approved for use by Engineering.

2.2.2 Use welders who are qualified to use the specific welding procedure.

2.2.3 For projects overseen by Construction Management Services, a Welding Inspector will be assigned to witness all welding of process, gas transmission, hazardous liquid, or other types of pressurized piping including temporary welds.

2.2.4 For projects completed by Operations and Maintenance, welding inspection will be performed as per *TES-WL-INSPQ-G Welding Inspector Qualification for Operations and Maintenance Related Work Specification (US)* (EDMS no. 1004847508).

2.2.5 The Welding Inspector checks certification records for each welder working on Company projects to assure that proper and current qualification data is on file and is appropriate for the welding to be performed. Welder documentation is to be placed into the project file.

2.2.6 For pipeline and pump station applications, the Welding Inspector ensures that no welder welds piping unless the welder has both:

- successfully completed a qualification weld in accordance with either API 1104 or ASME BPV, Section IX (as appropriate for the work to be performed)
- had a weld tested either:
  - destructively, in accordance with API 1104 or ASME IX, as appropriate
  - nondestructively, in accordance with API 1104, with prior written Engineering approval

2.2.7 For facility (i.e., compression, metering) applications, the Welding Inspector ensures that no welder makes any weld unless the following conditions have been met:

- The welder has made a weld in accordance with either API 1104 or ASME BPV, Section IX (as appropriate for the work to be performed).
- The welder has had it destructively tested either to the requirements of API 1104 or ASME IX, as applicable.

2.3 Weld Design—Design Temperature

2.3.1 Qualify welding procedures at or below the pipeline/facility minimum design temperature. Unless otherwise specified, minimum design temperatures are:

- 32°F (0°C) for welds in buried pipelines (depth of cover two feet or greater)
- either -20°F (-29°C) or -49°F (-45°C) for above-grade facilities and facilities with less than two feet of cover, depending on location

Refer to *TED-MATL-FRAC Materials Fracture Control Plan* (CDN-US-MEX) (EDMS no. 7076183) for the design temperature zone map.

2.3.2 Minimum design temperature shall be shown on the appropriate Welding Procedure Specification (WPS).

2.4 Welding Procedures—General

2.4.1 Use the following processes, or combinations thereof, for welding procedures:

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Pulsed Gas Metal Arc Welding (GMAW-P)
- Gas Tungsten Arc Welding (GTAW)
- Flux-Cored Arc Welding (FCAW)
- Metal-Cored Arc Welding (MCAW)
- Submerged Arc Welding (SAW)

2.4.2 Other welding processes may be used if approved by the Company.

2.4.3 If inconsistencies between this Specification and a WPS are found, the WPS shall govern unless specifically noted in the text of this Specification.

2.4.4 Welding Engineering shall be alerted to any conflicts other than those where an authorized Company representative is given the authority to make this type of decision.

2.5 Welding Procedures—Application Method

2.5.1 Weld deposition can be manual, mechanized or semi-automatic.

2.6 Welding Procedures—Recommended Combinations

2.6.1 Welding process selection and acceptable combinations of processes for pipe with a specified minimum yield strength (SMYS) greater than or equal to API 5L X60 are listed in Appendix B.

2.7 Welding Procedures—Additional Requirements

2.7.1 Make fillet welds using low-hydrogen welding consumables. The first pass may be applied with cellulosic consumables.

2.7.2 For material grades of 60,000 psi SMYS and below:

- Where design temperature is -49°F (-45°C) and/or nominal wall thickness is greater than 0.750 in. (19.1 mm), complete fill and cap passes with low hydrogen consumables in accordance with the appropriate WPS.
- Except where the piping is internally cleaned after welding, complete the root pass of butt welds in lube oil piping using GTAW and bare consumables.
- Cellulosic electrodes may be used for the root pass of through-wall repairs; complete all remaining passes on repair welds using low-hydrogen consumables.
- Make all back welds, including repairs, using low hydrogen consumables.

2.7.3 For material grades of 65,000 and 70,000 psi SMYS:

- Where design temperature is -49°F (-45°C) and/or nominal wall thickness is greater than 0.750 in. (19.1 mm), complete fill and cap passes using low-hydrogen consumables in accordance with the appropriate WPS.
- Girth welds involving a component where design temperature is 32°F (0°C) or -20°F (-29°C) may be welded using cellulosic consumables provided that all of the following conditions are met:
  - the CE value, defined in CSA Z245.1, of the component is less than 0.43%

    Note:

    If the CE value of the component is unknown, cellulosic electrodes may be used for the root/hot passes and low hydrogen consumables shall be used for fill and cap passes.
  - the nominal pipe wall thickness is less than 0.750 in. (19.1mm)
  - the ambient temperature at the time of welding is greater than the design temperature
- Cellulosic electrodes may be used for the root pass of through-wall repairs; complete the remaining passes on repair welds using low-hydrogen consumables.
- Make back welds, including repairs, with low-hydrogen consumables.

2.8 Welding Procedures—Joint Design

2.8.1 Butt Welds

- Ensure bevel angles are 30° -0/+5°, unless otherwise specified, and all field cuts are 90° to the pipe axis.
- Between pipes of unequal nominal wall thickness, make butt welds using a transition designed in accordance with the requirements of Company Procedure *TEP-MECH-TRAN-US Selection of Transition Pieces and Joining Methods* (EDMS No. 5695478).

- Make mechanized GMAW butt welds using a narrow gap bevel configuration. Mechanized welding systems can use either an automated internal welding system and clamp, or an internal clamp with a copper backing ring with an external mechanized welding system to make the root weld.
- Miter joints are prohibited. A deflection up to 3° caused by misalignment is not considered a miter joint. Multiple deflections each less than 3° cannot be combined to produce a bend.
- The use of backing rings and/or backing welds is prohibited.

2.8.2 Fillet Welds

- Except where specified by the design, do not use socket coupling fillet welds to join piping larger than NPS 2 (60.3 mm OD).

2.8.3 Tack Welds in Fabrication

- A qualified welder or welding operator makes tack welds (using an appropriate, approved welding procedure) within the weld bevel area. Place a minimum of four tack welds equidistant around the pipe circumference. The Contractor/Fabricator assesses weight and size of the fabricated assembly to determine the appropriate length of tacks required to safely move and support it.
- Make tack welds at the root using filler metal with equivalent mechanical properties to that of the root pass, and then either fuse it to the root pass weld or remove it ahead of welding the root.
- Remove bridge tacks (above the root) ahead of welding the root pass.
- Tack welds follow the preheat requirements outlined in the applicable WPS.

2.9 Welding Procedures—Materials

2.9.1 Pipe and Components

- Weld materials according to their P-Number and Group Number, as given in ASME Section IX, or the base material groupings as given in API 1104. Materials that do not conform to the P-Number and Group Numbers specified by ASME Section IX are considered to be unassigned. Do not use unassigned base metals, as described in ASME BPVC Section IX, Clause QW-424.
- Weld materials listed in API 1104 according to their SMYS in one of the following groupings:
  - SMYS less than or equal to 42,000 psi
  - SMYS greater than 42,000 psi and less than 65,000 psi
  - Each material with SMYS greater than or equal to 65,000 psi requires a separate qualification
- Clearly identify all materials to be welded and ensure the Manufacturer's material test reports (MTR) are included in the project record.

2.9.2 Filler Metals

- Select or combine filler metals that have yield and tensile properties on the completed/combined deposit weld to match or exceed yield and tensile strengths for the materials being welded. All FCAW consumables require Company approval prior to use. Random destructive testing may be implemented for FCAW and MCAW wire consumables on a batch number basis.
- Store and handle filler metals and fluxes to avoid damage to them and to their shipping containers. Protect consumables in opened containers from deterioration and protect coated filler metals from excessive moisture changes. Discard filler metals and fluxes that show signs of damage or deterioration.
- Keep low-hydrogen type covered electrodes in hermetically sealed, moisture-proof containers until ready for use. After opening, store low-hydrogen electrodes in appropriate holding ovens. AWS A-5.1 suggests holding oven temperatures should be in the range of 50°F to 250°F (30°C to 120°C) above ambient temperature, or per the Manufacturer's recommended holding temperature.
- Contractors and the Company's Construction department shall have a welding consumable handling and storage plan in place. If no such plan is in place, follow the requirements of *TEP-WELD-SC Storage and Control of Welding Consumables* (EDMS no. 8816242).
- Holding ovens are for low hydrogen electrodes only. Do not store other types of electrodes (e.g., cellulosic) in holding ovens.

2.10 Welding Procedures—Shielding Gases

2.10.1 Ensure components of shielding gases have a purity of at least 99.5% and a dew point of -30°F (-35°C) or lower. Make certificates of conformance of the shielding gases available to the Company upon request.

2.11 Welding Procedure Qualifications—General

2.11.1 Qualify WPS, other than those previously qualified and provided by the Company, in accordance with the requirements of API 1104 or ASME Section IX, along with the additional requirements of this Specification.

2.11.2 For qualification welds, record welding parameters on each pass. Record details of the welding procedure qualification tests required by API 1104 or ASME IX (as appropriate), and this Specification. Make the WPS and copies of the procedure qualification records (PQRs) available for review by the Company.

2.11.3 Welding procedures are reviewed and approved by Engineering prior to the start of welding.

2.11.4 The Company requires separate repair welding procedures when procedure qualification is to API 1104. See section 2.54 of this Specification.

Note:

In accordance with ASME BPV Code Section IX, WPS and welding procedure qualifications are the sole ownership of the company or entity that develops the procedures and employs the welders. This weld documentation is non-transferable between unaffiliated companies. Therefore, Company ASME IX WPS are only be used by internal Company-employed welders. Contractor welders cannot use Company ASME IX Welding procedures.

2.12 Welding Procedure Qualifications—Additional Essential Variables

2.12.1 WPS are limited by the following additional essential variables:

- changes to pulse parameters or pulsed software version from those used on qualification weld (i.e., modified wave form GMAW, such as controlled-dip and pulsed)
- change to a minimum design temperature lower than impact toughness testing temperature during procedure qualification

2.13 Welding Procedure Qualifications—Test Weld Acceptability for Destructive Testing

2.13.1 Ensure test welds meet the visual inspection requirements given in section 2.51 of this Specification.

2.13.2 Only subject procedure qualification welds to nondestructive examination (NDE) to determine if the weld is acceptable to API 1104 criteria. Do not use NDE to determine locations of destructive test coupons.

2.13.3 If test welds fail to meet visual inspection requirements, stop procedure qualification, do not proceed with destructive testing, and initiate new test welds for qualification.

2.14 Welding Procedure Qualifications—Impact Toughness Testing

2.14.1 Test one set of three Charpy V-notch specimens from each of the weld metal and heat-affected zones (HAZ) in accordance with the requirements of ASTM E 23.

- Perform testing at a temperature at or below the minimum design temperature.
- When the weld joins different material types or grades, take one set of Charpy specimens from each HAZ of the parent metals.

2.14.2 When post-weld heat treatment (PWHT) is used in the welding procedure, test additional specimens of parent metals in the PWHT condition.

2.14.3 The minimum average absorbed energy value of the Charpy V-notch testing for three full size (10 mm x 10 mm) specimens is 20 ft.-lbs. (27 J). Only one absorbed energy value may be below the minimum of 20 ft.-lbs. (27 J) and the minimum absorbed energy value is 15 ft.-lbs. (20 J). Proportional reduction of this minimum absorbed energy requirement for sub-sized specimens is permissible. Do not lower the minimum absorbed energy requirement based upon reduced test temperature.

2.14.4 Record test values, including percent shear and lateral expansion (for information only).

2.15 Welding Procedure Qualifications—Tensile Testing

2.15.1 Follow the requirements in API 1104, Section 5.6: Testing of Welded Joints – Butt Welds.

2.15.2 All-weld metal tensile testing may be required for welding consumables used on materials with SMYS greater than or equal to 70,000 psi (API 5L PSL 2 X70).

2.15.3 Record test values and failure locations on the procedure qualification record.

2.16 Welding Procedure Qualifications—Hardness Testing

2.16.1 For carbon steel welds, ensure the welding procedure qualification records include macroindentation hardness traverses across the weld, HAZ, and parent metal, as shown in Figure 2-1.

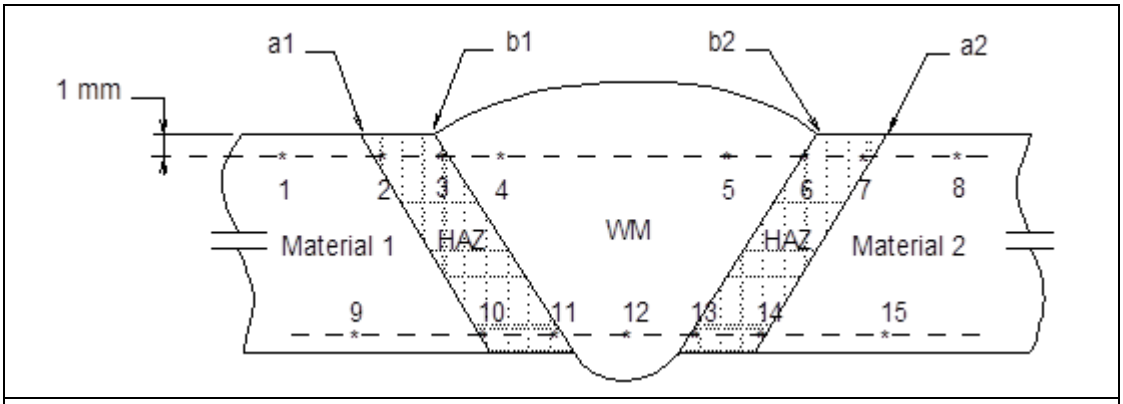
- Hardness impressions 3, 6, 11 and 13 should be entirely within the HAZ, as close as possible to the fusion boundary.
- Impressions 2 and 7 should also be within the HAZ.

2.16.2 Perform macroindentation hardness tests in accordance with ASTM E384 for Vickers testing (maximum 10 kg load) or ASTM E18 for superficial Rockwell testing. Ensure the maximum HAZ hardness is 350 HV10, 77 HR 15-N, or 55 HR30-N (see ASTM E18, Table A5.3 for approximate conversions).

2.16.3 Do not convert hardness readings from one hardness scale to another.

2.16.4 Report hardness measurements without converting lab results.

2.16.5 Record the measured hardness values of the base metals, HAZ, and weld metal on the procedure qualification record.



Lines a1 and a2 illustrate the boundary visible after etching between HAZ and unaffected parent metal.
Lines b1 and b2 illustrate the boundary visible after etching between weld metal and HAZ.

Figure 2-1: Vickers Hardness Traverse Locations

2.17 Welding Procedure Qualifications—Additional Testing for Alternate Acceptance Criteria

2.17.1 Where an alternate acceptance criterion is specified for NDE of production welds, conduct additional mechanical testing at a temperature not higher than minimum design temperature in accordance with API 1104, Appendix/Annex A.

2.17.2 The average value of the Charpy V-notch absorbed energy reading is a minimum of 30 ft.-lbs. (40 J). Ensure the minimum energy value for any one specimen is not less than 20 ft.-lbs. (27 J).

2.17.3 The Company reviews and accepts crack tip opening displacement (CTOD) testing. Perform CTOD testing at a facility approved by the Company. Ensure the minimum CTOD value of all six specimens is greater than 0.002 in. (0.05 mm).

2.18 Welding Procedure Qualifications—Mechanized Welding

2.18.1 Qualify mechanized GMAW welding procedures in accordance with API 1104 and Company Engineering Procedure *TEP-WELD-QUAL-MECH Qualification Procedure for Mechanized Welding Procedure Specifications (CDN-US-MEX)* (EDMS no. 7169231).

2.19 Welder Qualifications—General

2.19.1 Ensure each welder producing welds is entitled to work in the jurisdiction where the work is performed. For example, the State of Oklahoma requires welders to be licensed by the state to weld pressure piping. Similar requirements could be in effect in other states.

2.19.2 Do not use a welder's first production weld for welder qualification. Qualify welders on a test coupon prior to commencement of production welding.

2.19.3 Assign welders a unique symbol for the purpose of identification on all welds. Once a symbol is assigned to a welder, do not reassign it to another welder during the Project. It is recommended to use the welder's initials combined with the last four digits of their Social Security Number (e.g., JJ-1234).

2.19.4 Conduct qualification of welders in the presence of a Company representative.

2.19.5 Repair welder qualifications are determined according the applicable code of construction.

2.19.6 API 1104 Welder qualifications performed for companies other than TransCanada will not be considered. ASME Section IX welder qualifications may be considered (see section 2.22 of this Specification).

2.20 Welder Qualifications—Mechanized GMAW

2.20.1 Ensure welding operators complete a Contractor-developed training program accepted by the Company to ensure a suitable level of competence with the welding process, equipment and technique. The training program should be agreed upon and established with the supplier of the automatic welding equipment.

2.20.2 Use single qualification for mechanized GMAW when the NDE method for the project is AUT. Use both AUT and RT for welds meeting the requirements of API 1104, Section 9.

2.20.3 For mechanized GMAW, qualify welding operators in accordance with API 1104, Section 12.6.

2.20.4 Welding operators may be qualified for all passes (except the root pass) using mechanized welding equipment to produce a half-circumference test weld (with the root pass being made by other welders).

2.20.5 Qualify welding operators on the maximum wall thickness they will encounter on the Project.

2.21 Welder Qualifications—API 1104 SMAW

2.21.1 Qualify welders in accordance with the requirements of the API 1104, Section 6, Multiple Qualification Test. Appendix A of this Specification provides guidance on conducting qualification welds.

2.21.2 Welders who can produce proof of appropriate, current qualification by the Company in accordance with the requirements of API 1104 for a given process may be exempted from re-qualification, provided that within the preceding six calendar months they have engaged in welding with that process and had one weld tested and found acceptable under API 1104, Section 9.

- Document such tests using *TEF-WELD-QUA-US Welder Qualification Form – API 1104* (EDMS no. 4470567).
- Ensure radiographic inspection reports clearly identify the welder, date of welding and disposition to API 1104.

2.21.3 Single qualification of welders may be considered on a per project basis with prior written approval from Engineering.

2.22 Welder Qualifications—ASME Section IX

2.22.1 If welders employed by the Company are required to fabricate welds to the ASME IX Code using a qualified WPS, Engineering will provide guidance on performing the qualification welds.

2.22.2 Contractors using their own ASME IX qualified WPS are accountable to qualify their welder and maintain welder qualifications as part of their quality program. Such welder qualifications shall be current and appropriate for the welding to be performed.

2.23 Welder Qualifications—Records of Qualified Welders and Welding Operators

2.23.1 A Construction Management Services representative or their designee (i.e., Sr. Welding Inspector, Chief Inspector) will review all welder/welder operator qualification reports prior to the start of production welding.

2.23.2 Develop and maintain a list of qualified welders for the Project.

2.23.3 Make welder/welder operator qualification records available to the Company, and submit them as part of Project documentation. The Company reserves the right to request a requalification if there is any reason to question welder/welder operator ability.

2.24 Weld Execution—General

2.24.1 During construction, ensure copies of the welding specifications are available for reference at the local work site where the welding is performed.

2.25 Weld Execution—Compliance with Specifications

2.25.1 Maintain records of welding parameters (e.g., amps, volts, travel speed) used for production welding to demonstrate compliance with requirements of this Specification and the WPS. Ensure such records are available to the Company upon request.

2.25.2 The Company reserves the right to measure welding parameters on any production weld. When parameters measured on a weld do not comply with the specified values, the Company reserves the right to reject such welds and any weld made after the last compliant record, unless the party responsible for the work can demonstrate that such welds are in full compliance with the WPS.

2.25.3 Non-compliance with the requirements of API 1104 or ASME IX (as appropriate), this Specification, or the WPS is cause for weld rejection.

2.25.4 If the Company identifies an unacceptable weld repair rate, the welding contractor will submit a remedial plan that includes quality checks such as welder retraining, root cause analysis of weld defects, and welding process improvement.

2.26 Weld Preparations—Cleaning of Pipe Ends

2.26.1 Clean areas to be welded (including the weld bevel and both internal and external pipe surface in the vicinity of the weld) to a minimum distance of 1 in. (25.4 mm) from the ends of the pipe, so they are free of oxides or other extraneous matter.

2.26.2 Grind flame-cut bevels prior to welding. Ensure bevel surfaces are smooth and free of irregularities that could adversely affect the welder’s ability to produce high quality welds.

2.27 Weld Preparations—Pipe Identification

2.27.1 Where a pipe is cut, transfer pipe identification (such as pipe number, grade, heat number, Company purchase order and Manufacturer) to both ends of the pipe. It is recommended that this identification also be placed on the pipe ID surface, where possible.

2.27.2 Do not die stamp the pipe or weld for pipe identification or any other purpose.

2.28 Weld Preparations—Base Metal Examination

2.28.1 When tie-in welds are made to existing pipe or facilities, the pipe shall be examined for lamination and/or other injurious conditions that could affect welding (internal corrosion, inclusions, etc.). This examination shall be performed over the entire 360° circumference for a 12 in. (305 mm) width, centered at the proposed weld location, using visual testing and straight beam ultrasonic testing. An ultrasonic thickness gauge is acceptable for base metal examination, with preference given to an ultrasonic flaw detector with an “A” scan display. Determine the weld location before cutting the pipe.

2.28.2 Once the straight beam ultrasonic examination has been completed, examine the prepared weld bevel using magnetic particle inspection. Lamination or other mid-wall conditions (at or near the bevel that could affect the completed weld) having a circumferential length greater than 0.250 in. (6 mm) are classified as defects. Cut back the piping until no deleterious condition is present at the weld bevel area.

2.28.3 Features determined to be internal corrosion greater than 10 percent of nominal pipe thickness shall be directed to a Corrosion Specialist for disposition.

2.29 Weld Preparations—Grinding of Seam Welds

2.29.1 For welds subject to NDE using radiography, grind the pipe seam welds flush (-0, +1/32 in.) for a minimum distance of 1 in. (25.4 mm) from the bevel edge (internally and externally), with a gradual transition to the weld reinforcement.

2.29.2 For welds subject to NDE using ultrasonic examination, grind the pipe seam welds flush (-0, +1/32 in.) for a minimum distance of 4 in. (100 mm) from the bevel edge (internally and externally), with a gradual transition to the weld reinforcement.

2.30 Weld Preparations—Alignment and Fit-Up

2.30.1 Do not use miter joints. (Deflections up to 3° caused by misalignment are not considered miter joints.)

2.30.2 Minimize external forces required to align pipes. If pipes to be joined are in place:

- Below grade, expose a sufficient length of each end of the pipes so each can be moved without imposing detrimental external stresses at the joint. If the Company welding representative determines that external stress has been put on the weld, a 24-hour delay prior to NDE will be enforced.
- When there is not sufficient length to allow free movement, consultation with the onsite Company representative to determine the appropriate course of action is required. This may include having to cut and reinstall the pipe to bring the misalignment within tolerance. See section 2.30.11 for guidance.

2.30.3 For buried piping, except in the case of bends, stagger longitudinal seam welds on adjacent pipe at approximately the 10 o'clock and 2 o'clock positions.

2.30.4 On longitudinal seam welded pipe, place the seam at right angles ±10° to the plane of bending. On combination bends, this may not be achievable and the Project or Design Engineer shall be contacted for guidance.

2.30.5 For above grade piping, locate the seam weld as to not interfere with possible branch connections at the 12, 3, 6 or 9 o'clock positions.

2.30.6 Where two seam welds on adjacent pipes meet at a common girth weld, offset the two seams by a minimum distance of 2 in. (50 mm) from each weld toe. Aligned seams on either side of a girth are acceptable only when a fabricated assembly has been cut for transportation purposes and will be reassembled on site.

2.30.7 Any branch attachment shall be located a minimum of 2 in. (50mm) (toe-of-weld to toe-of-weld) from any girth weld or pipe seam weld.

2.30.8 Do not locate pipe seam welds on top of any pipe support (i.e., beam or concrete support).

2.30.9 Do not hammer pipe. (Use of a small hard plastic or steel hammer to signal release of internal clamps is acceptable as long as there is no damage to the pipe surface or adjacent coating). Where external line-up clamps are used, correct minor out-of-roundness and misalignment using wedges.

2.30.10 Line-up clamps are to have approximately equally spaced pressure points around the surface of the pipe.

2.30.11 Line-up clamps selected for the job must be of the size and type capable of holding and maintaining the proper line up of the joint to be welded. They shall be capable of removing out-of-roundness permitted in pipe manufacture to within the tolerance permitted in section 2.30.12. For shop fabrication, other acceptable line-up devices/techniques may be substituted, if acceptable to the Company representative.

- On new mainline construction, the use of internal line-up clamps is preferred for mainline pipe-to-pipe welds. Approval for use of external clamps shall be obtained from the Project Construction Manager.
- For tie-ins, maintenance projects and facility construction, external clamps may be used.

2.30.12 For pipe-to-pipe welds of the same nominal wall thickness, do not exceed the maximum offset or misalignment of the abutting pipe ends, as follows:

- $\leq$ 0.250 in. (6.4 mm) do not exceed 1/16 in. (1.6 mm)
- > 0.250 in. (6.4 mm) to 0.500in. (12.7 mm) do not exceed 3/32 in. (2.5 mm)
- > 0.500 in. (12.7 mm) do not exceed 1/8 in. (3.2 mm)

2.30.13 For pipe-to-component joints of equal nominal wall thickness, do not exceed 1/8 in. (3.2 mm) external offset. Ensure internal offsets exceeding 3/32 in. (2.4 mm) conform to the conditions specified in section 2.43 of this Specification.

2.30.14 Fully insert pipe into Sockolet fittings, ensuring a gap of 1/16 in. (1.2 mm) between the pipe and the bottom of the Sockolet. Gapolets are an acceptable means of maintaining the gap requirements.

2.30.15 Segmentable fittings must have a minimum arc length measured along the crotch, as per Table 2-1.

Table 2-1: Minimum Arc Length for Segmentable Fittings

NPS (in.)	Min. Allow. Angle (Deg) Std. Rad.	Min. Allow. Angle (Deg) Short Rad.	NPS (in.)	Min. Allow. Angle (Deg) Std. Rad.	Min. Allow. Angle (Deg) Short. Rad.
2	31	70	12	5	10
3	20	45	14	4	8

NPS (in.)	Min. Allow. Angle (Deg) Std. Rad.	Min. Allow. Angle (Deg) Short Rad.	NPS (in.)	Min. Allow. Angle (Deg) Std. Rad.	Min. Allow. Angle (Deg) Short. Rad.
4	16	32	16	3	7
6	10	21	18	3	6
8	7	15	20	3	5.5
10	6	12	≥24	3	5

2.31 Special Pipeline Applications

2.31.1 For all welding on coupled pipelines, a technical welding support person shall be consulted prior to any production welding.

2.31.2 For all welding on well casing pipelines, the Company has established WPS ASME-GW-01. However, casing materials are significantly more variable than standard pipe material and caution must be used when applying this procedure. Contact a technical welding support person for additional guidance.

2.32 Weld Preparations—Pipe Support

2.32.1 Do not weld supports, bracing bars or counter balance weights to pressure piping and components.

2.32.2 Ensure pipe is supported in accordance with standard industry practice. Report any occurrence of a section of line falling from its support to the Company, together with any tests, inspections and remedial work performed as a result of the fall. The Company determines whether the piping is acceptable for use.

2.33 Weld Preparations—Weather Conditions

2.33.1 Protect welds during welding from weather conditions considered detrimental to weld quality. Portable enclosures may be used to make conditions satisfactory for welding.

2.33.2 Wrap the completed weld in a clean, dry welding blanket when ambient temperature at the time of welding is below 50°F (10°C). Remove the blanket once the weld area reaches ambient temperature.

2.34 Weld Preparations—Grounding and Cables

2.34.1 Securely attach grounding devices in a manner to prevent arc burns. Do not weld grounding devices to pipe, or place on the pipe body. Preferably, make contact within the weld groove and ensure the grounding device is large enough to prevent local overheating or arcing (i.e., minimum 0.5 in. (12.7 mm) wide and 1/8 in. (3.2 mm) thick). Ensure devices grounding in the bevel area are made of steel. Do not use copper or bronze tips for such purpose.

2.34.2 The use of magnetic ground clamps is prohibited.

2.34.3 Ensure welding cables, ground clamps and connections are insulated to prevent arcing to the pipe surface. Avoid ground paths through valves.

2.35 Weld Preparations—Protection of Coatings

2.35.1 Protect existing coatings on piping to minimize damage that may result from the welding operations. Following the root pass, the top third of the pipe is to be protected from welding spatter any time the welder is working in that section.

2.36 Weld Preparations—Preheating and Controlled Cooling

2.36.1 Unless otherwise specified on the welding procedure, use the preheat temperatures given in Table 2-2.

2.36.2 Preheating of material should be done by one of the following methods:

- Electrical Resistance or Induction Heating.
- Gas Torch, where two torches are required for NPS 16 and larger piping. Care shall be exercised to raise the temperature evenly around the entire circumference of the joint.

2.36.3 Apply preheat for a minimum distance of:

- 3 in. (76.2 mm) to each side of the weld for the full circumference, in the case of girth welds
- 5 in. (127 mm) from any point of the area to be repaired, in the case of repairs

2.36.4 Maintain minimum preheat temperatures until the completion of all welding, except as allowed in section 2.41 of this Specification. Welds must be at the minimum preheat temperature (or higher) prior to welding each pass.

2.36.5 Welders, or welder's helpers, shall check preheat and interpass temperatures at the top, bottom and both sides of the pipe using temperature-indicating crayons or contact thermocouple probes. Ensure temperatures are within the specified limits prior to the start of welding. Infrared pyrometers may be used by inspection staff for quality control checks, but shall not be used as the final determination of preheat and interpass temperatures prior to welding.

2.36.6 Do not cool passes of a weld at a rate greater than that provided by natural air cooling.

Table 2-2: Preheating Temperatures

Application - Process - Grade	Wall Thickness (inches)	Carbon (weight %)	Minimum Preheat	Maximum Interpass
Grade X60 and lower, all processes	< 1 (25.4 mm)	≤ 0.30	125°F 50°C	450°F 235°C
		> 0.30	200°F 95°C	450°F 235°C
	≥ 1 (25.4 mm)	All	200°F 95°C	450°F 235°C

Application - Process - Grade	Wall Thickness (inches)	Carbon (weight %)	Minimum Preheat	Maximum Interpass
Grade X65 and higher, all processes	All	All	200°F 95°C	450°F 235°C
Repairs, all processes and grades	All	All	250°F 120°C	450°F 235°C
Legacy CPG Well Casing Pipe	All	All	350°F 177°C	475°F 246°C

2.37 Weld Preparations—Number of Welders

2.37.1 For pre-fabricated welds on piping greater than NPS 14 (356 mm), a minimum of two welders shall be required for the root, hot pass and first fill (if required), then one welder may complete the weld as long as pre-heat is maintained on the entire weld.

2.37.2 Tie-in welds on piping greater than or equal to NPS 14 shall be completed with two welders for the entire weld.

2.37.3 One welder is acceptable for position welds on piping less than NPS 14 and roll welds of any diameter.

2.38 Weld Preparations—Start of Welding

2.38.1 Do not commence welding until all parts to be joined are secured against movement.

2.39 Weld Preparations—Release of Line-Up Clamp

2.39.1 When using internal line-up clamps, complete the root pass for 100% of the circumference prior to release.

2.39.2 For external line-up clamps, ensure the root pass is at least 50% complete before removal of the clamp, unless stated otherwise on the welding procedure. Ensure there is no pipe movement until the root pass is 100% complete.

Note:

To minimize the risk of cracking of mainline manual welds (i.e., manual welds completed with an internal line-up clamp), it may be necessary to weld the hot pass for an approximate length of 1 ft. (305 mm) in the area of highest anticipated stresses, prior to moving the pipe. This area would typically be on the bottom of the pipe, but could be on the top of the pipe in an overbend situation, or on the sides of the pipe in a side bend situation.

2.40 Weld Preparations—Cleaning between Passes

2.40.1 Remove clusters of surface porosity, weld bead starts, high points and slag by grinding prior to depositing weld metal in subsequent passes. Clean between passes as necessary for all welding processes to ensure weld quality.

2.41 Weld Preparations—Interruptions in Welding

2.41.1 When welding less than 0.500 in. (12.7 mm) nominal wall thickness, a minimum of three passes is required prior to any interruption.

2.41.2 When welding 0.500 in. (12.7 mm) nominal and greater wall thickness, the filler passes shall be applied one after another without interruption until at least one- half the wall thickness of the welding groove is filled. An exception to this rule is allowed for standard breaks or lunch, provided the pipe is securely supported. In no case is the groove to be less than one-half-filled overnight or longer.

2.41.3 Mainline welds in a pipe laying operation shall be completed as stated on the approved WPS with a maximum to completion of 72 hours.

2.41.4 Tie-in welds shall be completed the day they are started, continuously without delay.

2.42 Weld Preparations—Bead Sequence, Width, and Capping

2.42.1 For semi-automatic/automatic processes, ensure the maximum width of any weld bead within the weld groove is 0.75 in. (19.1 mm).

2.42.2 For SMAW, ensure the maximum bead width is no more than three times the electrode diameter being used.

2.42.3 Overlap the circumferential start locations of consecutive beads by at least 1 in. (25.4 mm).

2.42.4 Ensure the toe of the completed weld is no more than 1/8 in. (3.2 mm) beyond the edge of the original groove.

2.42.5 For split weld caps and multi-pass weld caps, avoid having the edge of any bead along the weld centerline.

2.43 Weld Preparations—Back Welding

2.43.1 Backwelding using low-hydrogen consumables is permitted in any area where the internal misalignment exceeds 3/32 in. (2.4 mm).

2.43.2 Ensure welding produces a gradual transition in material thickness.

2.43.3 Remove root pass metal reinforcement in areas to be backwelded by grinding before welding.

2.43.4 The Contractor/Fabricator must have a qualified backweld procedure or request a procedure from the Company.

2.44 Weld Preparations—In-Process Repairs

2.44.1 In-process repairs may be made with Company approval using an appropriate WPS qualified for groove welds.

2.44.2 Flaws must be mechanically removed and re-welded before the weld is presented for final visual inspection.

2.44.3 In-process repairs do not count as a repair attempt for any grinding or welding on a completed weld to correct an individual defect or accumulation of defects in the weld

after it has been rejected by visual examination in accordance with acceptance criteria of the appropriate standard.

2.45 Weld Preparations—Transition Welds

2.45.1 Make transition welds using a transition designed in accordance with *TEP-MECH-TRAN-US Selection of Transition Pieces and Joining Methods* (EDMS no. 5695478).

2.46 Weld Preparations—Identification of Welds and Welders

2.46.1 Mark welds with a unique identification on the top quadrant of the pipe, adjacent to each weld.

2.46.2 Welders are responsible for marking their unique welder number/letter on the top quadrant of the pipe adjacent to each weld they have worked on using a permanent marker (the use of low stress stamps is not acceptable for pressure piping).

2.46.3 Ensure welder markings are at least 3 in. (75 mm) from the edge of the coating cutback (approximately 8 in. (200 mm) from the weld centerline).

2.46.4 Record the welder identification number/letter on the weld log, NDE inspection record and relevant drawing/spool sheets.

2.47 Weld Preparations—Closure Welds

2.47.1 Submit welds that are not hydrostatically tested to in-process examination as outlined in *TEF-WELD-TIE-IN Tie-in Weld In-Process Examination Form (CDN-US-MEX)* (EDMS no. 8275922).

2.48 Weld Preparations—Weld Cleanup

2.48.1 Completely remove weld spatter, coating or loose debris from the surface of the joint for a minimum distance of 4 in. (100 mm) on each side of the weld, as required for NDE inspection.

2.49 Inspection and Nondestructive Examination of Welds—General

2.49.1 Except as noted in 2.49.2, inspect completed welds for 100% of their lengths and assess any imperfection using the applicable standard of acceptability given in section 2.53 of this Specification, as well as API 1104, Section 9. Fully document all inspections.

2.49.2 Small diameter, low pressure lines (i.e., lines that operate at a low percent SMYS) may have different inspection requirements. Refer to *TES-WL-INSP-G Minimum Weld Inspection Requirements for Small Diameter, Low Percent SMYS Piping Specification (US)* (EDMS no. 1004847597)).

2.49.3 Perform visual inspection in accordance with *TEP-NDT-VT Visual Examination (CDN-US-MEX)* (EDMS no. 7381161). Ensure the completed weld is free from cracks, inadequate penetration and burn-through, and presents a neat workman-like appearance. Ensure any undercut meets the requirements of API 1104, Table 4.

2.49.4 Document the visual inspection of each weld on the appropriate form, along with the acceptance to API 1104.

2.49.5 Welds that do not pass visual inspection in accordance with API 1104 shall not be submitted to NDE until the discrepancy has been rectified to the satisfaction of the welding inspector.

2.49.6 Use radiographic inspection (*TES-RT-API Radiographic Examination of Welds Specification (US-MEX)* (EDMS no. 4472888)) or ultrasonic inspection (*TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)* (EDMS no. 1001828660)) methods, or a combination of such methods, for butt weld NDE. For welds completed using a back bevel, consider the difference in wall thickness (WT) across the weld when selecting the NDE method/technique.

2.49.7 Do not use manual ultrasonic inspection as the primary inspection method for girth welds. When used, perform manual ultrasonic inspection in accordance with the requirements of *TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)* (EDMS no. 1001828660).

2.49.8 For buried service, unequal wall thickness pipe-to-pipe field welds (NPS 12 and greater) with one side having a back bevel transition, a shear wave or time-of-flight diffraction (TOFD), ultrasonic inspection shall be performed when cellulosic consumables are used and other hydrogen mitigation actions have not been implemented. This shall be a secondary inspection to screen for lack of fusion in the root or cracking. Refer to Appendix C of this specification for additional guidance regarding this secondary UT inspection. This ultrasonic inspection should be performed at least 24 hours after the weld has been completed. Alternatively, AUT can be utilized as both the primary and secondary inspection as specified in the project documents issued to the Contractor.

2.49.9 Use magnetic particle inspection for fillet weld NDE on ferromagnetic materials in accordance with API 1104 Clauses 9.4 and 11.2, as well as ASME BPVC Section V, Article 7.

2.49.10 Use liquid penetrant inspection for fillet weld NDE on non-ferromagnetic materials in accordance with API 1104, Clauses 9.5 and 11.3, and ASME BPVC Section V, Article 6.

2.49.11 Phased-array ultrasonics using an approved procedure and operators may be implemented for pipe-to-pipe butt welds, but only with prior written permission from Engineering.

2.49.12 The Company may require additional inspection with other NDE methods.

2.49.13 Inspect repair welds with the same NDE method used to identify the original defect.

2.49.14 Evaluate welds to the acceptance criteria for each relevant NDE method shown in Section 9 of API 1104.

2.50 Inspection and Nondestructive Examination of Welds—Delayed Hydrogen Cracking

2.50.1 Three main factors contribute to delayed hydrogen-induced cracking of girth welds:

- residual stresses

- hydrogen trapped in the weld
- hard, brittle microstructure in the HAZ

2.50.2 For pipeline maintenance and facility construction, Engineering evaluates the scope of work and the material being welded on the Project, and provides guidance on mitigating risks of having delayed hydrogen crack issues when welding procedures are selected. This may include delaying NDE up to 24 hours.

2.50.3 For new mainline construction (SMAW or Mechanized GMAW), Engineering works in conjunction with the Project to determine a 24-hour delayed inspection plan for both mainline and tie-in welds. This may include a specified number of welds subject to a 24-hour delayed NDE at the start of the project to verify the Contractor has an acceptable construction process in place. Ensure these requirements are included in the project documents issued to the Contractor.

2.50.4 For welds with no subsequent pressure test (i.e. tie-in welds), temperature maintenance may be required to decrease the likelihood of hydrogen cracking, and/or there may be a delay prior to inspection so the inspection can detect delayed hydrogen cracking. An inspection delay is required when a weld procedure other than API-08-GW-FTI is used and any of the following conditions exist:

- nominal wall thickness is greater than 0.375 in. (9.5 mm)
- pipe is pre-1980 vintage or unknown seam weld
- carbon equivalent is known to be greater than 0.45%
- ambient temperature is at or below 15°F (-10°C)

The inspection delay may be avoided if the requirements in WPS API-08-GW-FTI are followed and the weld area is maintained at a minimum of 250°F (120°C) for at least 15 minutes after welding is completed and before the weld has cooled.

2.51 Inspection and Nondestructive Examination of Welds—Disposition of Defective Welds

2.51.1 Remove or repair welds that are found to be unacceptable, as specified in section 2.54 of this Specification.

2.52 Inspection and Nondestructive Examination of Welds—NDE Records

2.52.1 Prepare inspection records showing milepost, the number of girth welds made, the number non-destructively tested, the number rejected, and the disposition of the welds. Provide the inspection records to the Company. Keep these records for the life of the pipeline.

2.53 Standards of Acceptability

2.53.1 Refer to the following Company-applicable NDE procedures, and API 1104, Section 9 for acceptability for production welding:

- *TES-RT-API Radiographic Examination of Welds Specification (US-MEX)* (EDMS no. 4472888)

- *TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)* (EDMS no. 1001828660)
- *TEP-NDT-VT Visual Examination (CDN-US-MEX)* (EDMS no. 7381161)

2.54 Repair of Welds Containing Defects—General

2.54.1 Qualify separate welding procedures for repair welding in accordance with API 1104. ASME Section IX states that the original WPS may be used for repair welds.

2.54.2 Ensure repair welding of defects in production welds meets the following requirements:

- Approval obtained from the Company Welding Inspector.
- Qualified welders approved by the Company perform welding using an applicable WPS that has been approved by the Company.
- Repair welding recorded on the inspection reports.

2.55 Repair of Welds Containing Defects—Cracks

2.55.1 Crater cracks may be repaired. Do not repair other cracks of any type or size. Remove indications of cracking by cutting out the weld as a pipe cylinder.

2.55.2 For pipeline applications, remove a cylinder containing the crack and install a replacement pup, if required. Ensure the pup is the greater of 3 ft. (914 mm) or one pipe diameter in length.

2.55.3 For fabrication and facility applications involving pipe-to-pipe or pipe-to-component welds, remove the weld and clean the bevels, and then inspect with MT to ensure the defect has been removed. Alternatively, the cut may be a minimum of 1 in. (25.4 mm) from the edge of the weld. The joint may then be re-welded.

2.56 Repair of Welds Containing Defects—Removal of Defects Other Than Cracks

2.56.1 Except as permitted below, remove defects in welds by grinding.

2.56.2 Defects in welds may be removed by air carbon arc gouging when all of the following requirements are met:

- Ensure wall thickness exceeds 0.375 in. (9.5 mm).
- Preheat a 1 ft. (305 mm) wide area centered around the defective weld metal to a minimum of 125°F (50°C) and a maximum 300°F (150°C) before the gouging process begins.
- After gouging and prior to commencement of welding, make gouged surfaces smooth and free of irregularities by grinding a minimum of 1/16 in. (1.6 mm) of material from the bottom and edges of the groove.
- Ensure the cavity complies with bevel requirements indicated in the repair procedure.

- Visually examine the groove preparation to ensure all traces of carburized metal, copper deposits or other extraneous matter have been removed from the groove.
- Obtain approval from the Company prior to commencing repair welding.

2.56.3 Arc burns shall be reported to the Welding Engineering for disposition. Cut out and replace any section of pipe containing arc burns that cannot be repaired in accordance with Company Specification *TEP-WELD-ABR-US Removal of Arc Burns (New and Existing Piping Facilities) (US-MEX)* (EDMS no. 4472941).

2.56.4 For replacement pups, if required, follow the guidelines in section 2.55.2 of this Specification.

2.56.5 Evaluate pinholes as spherical porosity. Steel punching or peening of pinholes are not acceptable repair methods.

2.56.6 Ensure the maximum individual through-wall repair length is no greater than 10% of the circumference of the pipe. Once this area has been repaired, the process may be repeated. If there is any deviation from this, contact Engineering for approval before proceeding.

2.56.7 Completely remove welds when they contain defects with a total length greater than 1/3 the pipe circumference.

2.57 Repair of Welds Containing Defects—Welding Processes and Consumables

2.57.1 Appendix B of this Specification includes the acceptability of welding processes and consumables, and inspection methods for repairing mainline, tie-in and crossing welds in line pipe with SMYS of 60,000 to 70,000 psi. It does not include line pipe with SMYS greater than or equal to 80,000 psi, or branch connection welds.

2.58 Repair of Welds Containing Defects—Preheat for Repair Welding

2.58.1 Preheat the repair area in accordance with the requirements given in Table 2-2 of this Specification, as well as the appropriate approved repair welding procedure.

2.59 Repair of Welds Containing Defects—Start and Stop of Repair Welds

2.59.1 Grind start/stop of repair welds to conform to the contour of the original weld. Stagger start/stop areas for multi-pass welds by at least 0.5 in. (12.7 mm).

2.60 Repair of Welds Containing Defects—Minimum Length of Repair

2.60.1 The minimum length of a repair is 2 in. (50 mm).

2.61 Repair of Welds Containing Defects—Inspection of Repairs

2.61.1 Confirm removal of defects and repair welding using the same inspection method(s) and procedures used to find the original defects.

2.61.2 Assess any imperfection using the applicable standard of in API 1104 Section 9 and applicable Company Specifications.

2.62 Repair of Welds Containing Defects—Further Repair Attempts

2.62.1 Further repair attempts (double repair) are allowed only after the Inspector has reviewed the weld history, has determined why the first repair attempt was not successful, and has discussed this with the repair welder. If the second repair attempt is not successful, the weld shall be cut out.

2.62.2 Document the action to be taken for any further repairs and submit the plan for approval by Welding Engineering.

2.62.3 To complete further repair attempts, use qualified welding procedures that include multiple repairs and a qualified welder.

2.63 Records and Documentation

2.63.1 Submit a Contractor Turnover Package to the Company at completion of the Project that includes, but is not limited to, the following:

- Purchase order number, Project number
- MTRs
- Weld Map and Weld Log, including NDE log
- List of welding procedures, welding consumable documentation, welding parameter reports, and welder identification used for field installation
- NDE reports (i.e., visual inspection records, radiographic inspection reports, and ultrasonic testing records) that identify the procedure method and technique used for the inspection

3 VARIANCES

Any deviation shall follow the TransCanada Management of Change (MOC) Variance Procedure (EDMS no. 7728702). External vendors must contact the TransCanada Project Engineer for variance approval, who in turn will submit the request to the Responsible Engineer.

4 ROLES AND RESPONSIBILITIES

Table 4-1 below outlines the roles and responsibilities required for the use of this Specification.

Table 4-1: Roles and Responsibilities

Role	Responsibilities
Project Manager	The Project Manager is responsible for ensuring: • all required documentation is submitted and approved • all directives from the Welding Engineer and/or Technologist are understood and followed

Role	Responsibilities
Welding Engineer/Technologist	The Welding Engineer/Technologist is responsible for ensuring: • all required information is reviewed, approved and recorded, and documentation is completed • welding memorandum are issued to the project, outlining the required WPSs and engineering specifications • any requests to deviate from the standards and/or specifications are thoroughly reviewed • changes to Specifications are justified
Welding Inspector (internal and external)	The Welding Inspector is responsible for ensuring: • welders have valid certification • welding parameters are within the weld procedure and documented • NDE inspections are carried out • NDE inspection information is recorded and documentation is submitted • all directives from the Welding Engineer and/or Technologist are understood and followed
Welder (internal and external)	The Welder is responsible for ensuring • all reference documentation is up-to-date • welding specifications are understood and followed • all directives from the Welding Engineer and/or Technologist are understood and followed

5 REFERENCES

This document relies on a number of references to regulation, industry codes and standards, general industry guidance as well as internal references. These documents are detailed below in Table 5-1. Use the latest document revision, unless otherwise approved by TransCanada.

Table 5-1: External and Internal References

Document No.	Title
Legal Requirements	
49 CFR Part 192	Code of Federal Regulations, Title 49 Part 192, Transportation of Natural Gas and Other Gas by Pipeline: Minimum Federal Safety Standard
49 CFR Part 195	Code of Federal Regulations, Title 49 Part 195, Transportation of Hazardous Liquids by Pipeline: Minimum Federal Safety Standard
NOM-007-SECRE-2010	Transport of Natural Gas

Document No.	Title
Industry Codes and Standards	
API 1104	American Petroleum Institute (API) Welding of Pipelines and Related Facilities
ASME Section IX	American Society of Mechanical Engineers (ASME) BPVC Section IX - Welding, Brazing, and Fusing Qualifications
ASME B31.4	ASME Pipeline Transportation Systems for Liquids and Slurries
ASME B31.8	ASME Gas Transmission and Distribution Piping Systems
ASTM A370	American Society for Testing and Materials (ASTM) Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM E18	Standard Test Methods for Rockwell Hardness of Metallic Materials
ASTM E23	Test Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E384	Standard Test Method for Knoop and Vickers Hardness of Materials
AWS A5.1	American Welding Society (AWS) Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
AWS A5.4	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
AWS A5.5	Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding
AWS A5.18	Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding
CSA 245.1	Steel Pipe
Internal References – Documents Referenced by this Specification	
EDMS No. 7076183	TED-MATL-FRAC Materials Fracture Control Plan (CDN-US-MEX)
EDMS No. 4470567	TEF-WELD-QUAL-US Welder Qualification Form - API 1104
EDMS No. 8275922	TEF-WELD-TIE-IN Tie-in Weld In-Process Examination Form (CDN-US-MEX)
EDMS No. 5695478	TEP-MECH-TRAN-US Selection of Transition Pieces and Joining Methods
EDMS No. 7381161	TEP-NDT-VT Visual Examination (CDN-US-MEX)
EDMS No. 4472941	TEP-WELD-ABR-US Removal of Arc Burns (New and Existing Piping Facilities) (US-MEX)
EDMS No. 7169231	TEP-WELD-QUAL-MECH Qualification Procedure for Mechanized Welding Procedure Specifications (CDN-US-MEX)
EDMS No. 8816242	TEP-WELD-SC Storage and Control of Welding Consumables
EDMS No. 6717380	*TES-WL-APIIS-GL Welding on In-Service Pipelines Specification (US-MEX)*

Document No.	Title
EDMS No. 4472888	TES-RT-API (TES-NDT-RT-US) Radiographic Examination of Welds Specification (US-MEX)
EDMS No. 1001828660	TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)
EDMS No. 1001828218	TES-WELD-API Welding of Pipelines and Facilities Specification (US-MEX)
EDMS No. 1004847597	TES-WL-INSP-G Minimum Weld Inspection Requirements for Small Diameter, Low Percent SMYS Piping Specification (US)
EDMS No. 1004847508	TES-WL-INSPQ-G Welding Inspector Qualification for Operations and Maintenance Related Work Specification (US)

6 DOCUMENTATION AND RECORDKEEPING

Due to the broad range of data types that may be required in support of this Specification, there are a number of repositories that may need to be utilized for documentation purposes. A summary of key data repositories appears in Table 6-1.

Table 6-1: Documentation Requirements

Documentation Description	Repository / Link
Bid Documents Package: • All required specifications, drawings, timelines, materials, etc. for Contractor to bid on project and complete work.	
Turnover Package: • Welder qualifications, weld combustibles, pipe information, test reports etc. All information gathered and recorded by the Contractor during the duration of the project.	

7 DOCUMENT HISTORY

Rev.		
01	**Description**	**Effective Date**
	Revised document to integrate CPG welding program.	2017-May-17
	Rationale Statement	**Responsible Engineer**
	This document was revised to address the following requirements:	Simon Hsu, P.E

Rev.		

	• integration of CPG and TransCanada welding programs
	  • CPG Welding Manual - 290.01.05
	  • CPG Welding Procedure Index - 290.001.004
	  • Default In-Service Welding Plan - Standard (non-STOPPLE) Application - 290.01.02
	  • Default In-Service Welding Plan - STOPPLE or Pressure Tee Fitting - 290.01.01
	  • In-Service Welding - 290.01.06	

	Impact Assessment Summary	**Document Owner**
	This Specification was revised to combine the best practices of both legacy organizations during the integration of CPG and TransCanada.	Simon Hsu, P.E
00	**Description**	**Effective Date**
	Revised document developed as part of the Centre Of Excellence project.	2016-Nov-01
	Rationale Statement	**Responsible Engineer**
	This document was revised in order to address the following requirements: • Alignment with new document definitions, structure, and templates.	Simon Hsu, P.E
	Impact Assessment Summary	**Document Owner**
	This Specification was revised to streamline the documentation for the Engineering group and clarify the language for readers.	Simon Hsu, P.E

8 DESCRIPTION OF CHANGE

Section	Description of Change
Regulatory	
N/A	N/A
Industry Standards	
N/A	N/A
General	
N/A	

9 APPROVALS

APPROVALS		
Originator: Trent Bertholet, Sr. Welding Technologist Welding and Materials Engineering	Signature	Date: May 17, 2017
Reviewer: Salvatore Delisi, Sr. Welding Technologist Welding and Materials Engineering	Signature	Date: 2017-May-17
Reviewer: David Adler, Welding Engineer USGO Engineer	Signature	Date: 5-17-2017
Responsible Engineer: Simon Hsu, P.E. Welding and Materials Engineering	Signature Date: May 17, 2017	
Management Endorsement: James Ferguson, Manager Welding and Materials Engineering	Signature	Date: May 17, 2017

APPENDIX A API 1104 MULTIPLE QUALIFICATIONS OF WELDERS

A-1 PURPOSE

This describes the steps used to multiple qualify welders in accordance with API 1104 for Company projects.

TransCanada does not accept either AWS D1.1 or ASME IX welder certifications for welding with procedures qualified under API 1104 Code.

A-2 GENERAL REQUIREMENTS

Perform welder qualification in accordance with the applicable requirements of:

- 49 CFR 192, Subpart E for gas pipelines
- 49 CFR 195 Subpart D for liquid pipelines
- API 1104
- any amendment, supplement or errata issued by the United States Department of Transportation (DOT) and the American Petroleum Institute

Each welder that successfully completes the four welds described below (Test 1a, 1b, 2a and 2b) is considered a fully multiple-qualified welder for Company projects.

A-2-1 WELDING INSPECTION PERSONNEL

All testing is witnessed, visually accepted and documented by a Certified Welding Inspector (CWI) with a current certification issued through the American Welding Society (AWS) or a Company employee deemed qualified through documented experience (i.e., resume, training records) by Construction Management Services or Technical Training.

Welding inspection personnel are qualified by experience and training for the specified inspection task they perform. Their qualifications are acceptable to and retained by the Company. Documentation includes, but is not limited to the following:

- education and experience, a resume is preferred
- training records
- results of any qualification examinations

A-3 DOCUMENTATION

Take parameters during testing and document the parameters on *TEF-WELD-QUAL-US Welder Qualification Form - API 1104* (EDMS no. 4470567).

A-3-1 WELDING PRE-TEST REVIEW WITH WELDER

- On the Cellulosic (6010/8010) Tests #1 & #1a, 1/8 in. (32 mm) consumables are not permitted on the Hot, Fill or Cap passes.
- Prior to the test commencing, the inspector will check the fit up (clean bevel, proper land, spacing and tacks).

- Cap pass on both butt welds shall be a single puddle cap. The branch welds shall have a two-pass strip cap.

A-3-2 TEST #1

- Cellulose (E6010/E8010) Multiple Qualification Test
- Pipe is NPS 12 (12.750 in. OD) with a wall thickness of 0.250 in. or 0.375 in.
- Pipe grade is not an essential variable for welder testing

Test 1a—The welder first makes a butt weld in the fixed 6G position with the axis of the pipe inclined from the horizontal plane at an angle not exceeding 45°.

- Complete butt weld using WPS API-0-GW-01.
- Validate qualification by:
  - visual examination in accordance with API 1104, Section 6.4
  - destructive testing in accordance with API 1104, Section 6.5
- Two root bends and four nick breaks.

Test 1b—The welder lays out, cuts, fits and welds a full-size, branch-on-pipe connection in the fixed overhead position. Cut a full-size hole in the run. Make the weld with the run pipe axis in the horizontal position, and the branch pipe axis extending vertically downward from the run.

- Complete branch weld using WPS API-0-MQ-11.
- Validate qualification by:
  - visual examination in accordance with API 1104, Section 6.4
  - destructive testing in accordance with API 1104, Section 6.5
- Four nick breaks.

A-3-3 TEST #2

- Cellulose/low-hydrogen (E6010/E8010/E8018) Multiple Qualification Test.
- Pipe is NPS 12 (12.750 in. OD) with a wall thickness of 0.250 in. or 0.375 in.
- Pipe grade is not an essential variable for welder testing.

Test 2a—The welder first makes a butt weld in the fixed 6G position with the axis of the pipe inclined from the horizontal plane at an angle not exceeding 45°.

- Complete butt weld using WPS API-08-GW-02.
- Qualification is validated by:
  - visual Examination in accordance with API 1104, Section 6.4
  - destructive testing in accordance with API 1104, Section 6.5

- Two root bends and four nick breaks.

Test 2b—The welder lays out, cuts, fits and welds a full-size, branch-on-pipe connection in the fixed overhead position. Cut a full-size hole in the run. Make the weld with the run pipe axis in the horizontal position, and the branch pipe axis extending vertically downward from the run.

- Complete branch weld using WPS API-08-MQ-12.
- Validate qualification by:
  - visual examination in accordance with API 1104, Section 6.4
  - destructive testing in accordance with API 1104, Section 6.5
- Four nick breaks.

A-4 NOTES

Test pipe remains fully fixed during welder qualification. Do not move, rotate or otherwise manipulate test pipe from its original position during welder qualification.

All qualification welds (butt and branch) shall be complete (groove and/or fillet entirely filled). Partially completed welds presented for visual or destructive testing are cause to cease further testing.

For the butt weld tests, nick breaks should be substituted for the requisite number of tensile specimens.

Refer to API 1104, Figure 11 for location to remove branch weld destructive test specimens.

Refer to API 1104, Figure 12 for location to remove butt weld destructive test specimens.

A welder who has successfully completed all above weld qualification tests is qualified to weld in all positions, on all wall thicknesses, joint designs, and pipe diameters using all cellulosic or combination-cellulosic and low-hydrogen electrodes, as appropriate.

A-5 WELDER SIX-MONTH RENEWAL TEST

Requalify welders at intervals not to exceed six calendar months.

Perform renewal via radiography by completing a butt weld on NPS 2 or greater piping using either WPS API-0-GW-01 or API-08-GW-02.

Clearly indicate the welder's first name, last name and welder ID on the radiographic inspection report. Submit the report and renewal form *TEF-WELD-QUAL-US Welder Qualification Form - API 1104* (EDMS no. 4470567).

Radiographic inspection reports that do not identify the welder are not be accepted.

Ensure renewal tests are witnessed and documented by an AWS Certified Welding Inspector or a Company employee deemed qualified by Construction Management Services or a representative from the Technical Training group.

Welders who fail to maintain active certifications at maximum six-month intervals are deemed unqualified and must qualify as a new welder taking both API 1104 multiple qualification tests.

APPENDIX B MAINLINE CONSTRUCTION WELDING PROCESSES—SELECTION OF WELDING PROCEDURES FOR PIPE WITH SMYS OF 60,000 TO 70,000 PSI

B-1 PURPOSE

The purpose of this Appendix is to communicate the acceptability and availability of various welding process combinations for welding large diameter pipe with a SMYS of 60,000 to 70,000 psi. This Appendix is provided to Contractors bidding for the construction of large diameter pipelines to help them prepare the welding plan.

B-2 SCOPE

This Appendix includes the acceptability of welding processes and consumables, and inspection methods for making and repairing mainline, tie-in, and crossing welds in line pipe with a SMYS of 60,000 to 70,000 psi. It does not include line pipe with a SMYS greater than or equal to 80,000 psi, or branch connection welds.

B-3 PROCEDURE

The welding plan shall be prepared using a limited number of options of acceptable process combinations for each application as given in section B-4 of this Appendix. Section B-4 also indicates which procedures shall be qualified using project material to develop alternate acceptance criteria in accordance with the requirements of API 1104 Appendix A or an acceptable alternative standard.

Process details for each option, such as joint detail and consumables, and inspection methods shall meet the requirements given in B-5.

Acceptable and qualified options for repair welding are listed in B-6.

B-4 PROCESS COMBINATIONS AND ACCEPTABILITY

Appendix Table B-4-1: Process Combinations and Acceptability for Pipe with SMYS of 60,000 to 70,000 psi

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Root Pass	Internal Mechanized GMAW	External Mechanized GMAW			External Cellulosic SMAW (5)		
Hot Pass	External Mechanized GMAW	External Mechanized GMAW	External Mechanized GMAW or FCAW	External Mechanized GMAW or External LHVD SMAW	External LHVD SMAW or External Cellulosic SMAW (2)	External FCAW or External Cellulosic SMAW (2)	External Cellulosic SMAW
Remaining Passes	External Mechanized GMAW	External Mechanized GMAW	External FCAW	External LHVD SMAW	External LHVD SMAW	External FCAW	External Cellulosic SMAW
Mainline Welding	ACCEPTABLE (1)		ACCEPTABLE (4)		ACCEPTABLE (3)		
Crossings (see Contract Document)	ACCEPTABLE (1)		ACCEPTABLE (4)		ACCEPTABLE (3)		
Tie-ins	N/A				ACCEPTABLE (3)		

Notes:

(1) Requires procedure qualification for each project. To develop alternate acceptance criteria, ensure procedure qualification in accordance with the requirements of API 1104, Appendix A for each wall thickness and consumable combination.

(2) Optional cellulosic hot pass.

(3) Qualified procedures may be available from the Company.

(4) Requires procedure development and qualification. Inspection remains to workmanship criteria.

(5) Optional semi-automatic GMAW (controlled-dip transfer) when using FCAW with external gas shielding for remainder of weld.

B-5 WELDING PROCESS DETAILS

Appendix Table B-5-1: Welding Process Details for Pipe with SMYS of 60,000 to 70,000 psi

	Option 1	Option 2	Option 3	Option 4	Option 5
Joint Design	Narrow Gap Bevel	Narrow Gap Bevel with copper back-up	Standard Bevel		
Root Pass Filler Metal & (Shielding Gas)	K Nova or Lincoln SupraMIG ULTRA with 75Ar-25 CO_2 or 85Ar-15 CO_2	K Nova or Lincoln SupraMIG ULTRA with 100 CO_2, 75Ar-25 CO_2 or 85Ar-15 CO_2	E6010 or ER70S-G (4)		
Hot Pass Filler Metal & (Shielding Gas)	K Nova or Lincoln SupraMIG ULTRA with 100 CO_2	K Nova or Lincoln SupraMIG ULTRA With 100 CO_2 or 75Ar-25 CO_2	Bohler BVD 90 or E8010-G/P1 (2)	NR-208H or E8010-G/P1 (2) or E11T1-K3MJ-H4 with 75Ar-25 CO_2	E8010-G/P1
Remaining Passes Filler Metal & (Shielding Gas)	K Nova or Lincoln SupraMIG ULTRA with 100 CO_2, 75Ar-25CO_2 or 85Ar-15CO_2	K Nova or Lincoln SupraMIG ULTRA with 100 CO_2, 75Ar-25 CO_2 or 85Ar-15 CO_2	Bohler BVD 90	NR-208H None Or E11T1-K3MJ-H4 with 75Ar-25 CO_2	E8010-G/P1
Inspection Method	Mechanized Ultrasonic Testing		Radiographic Testing or Mechanized Ultrasonic Testing to workmanship criteria (3)		

Notes:

(1) Optional FCAW hot pass using NR-208H pending qualification.

(2) Optional cellulosic hot pass.

(3) Check Mechanized Ultrasonic Inspection Procedure status with the Company project manager. Ultrasonic Inspection for semi-auto GMAW.

(4) Optional semi-automatic GMAW (controlled-dip transfer) when using FCAW with external gas shielding for remainder of weld.

B-6 REPAIR WELDING PROCEDURES

Appendix Table B-6-1: Repair Welding Procedures for Pipe with SMYS of 60,000 to 70,000 psi

Process	Filler Metal	Preheat / Interpass	Position and Direction	Inspection Method	Qualifications
I General Repair Procedure					
SMAW, SMAW/FCAW or GMAW/FCAW(1)	Root (through-wall repair): E6010 Remaining: E8018-C1/E8018-C3 or Bohler BVD 90* Internal backweld, where applicable: E8018-C1/E8018-C3, or Bohler BVD 90*	250°F Min 450°F Max	Root: Vertical-down Remainder: Vertical-up	• Ultrasonic testing for weld repairs originally called by ultrasonic inspection • Radiographic inspection for weld repairs originally called by radiographic inspection	Qualified procedures may be available from the Company.
II Internal Bead Misfire Rerun (For Option 1)					
Semi-automatic GMAW. Manual SMAW	K Nova or Lincoln SupraMIG ULTRA, Shielding gas: 75Ar-25CO_2 E8018-C1/E8018-C3	250°F Minimum 450°F Maximum	• Vertical-down welding, GMAW • Vertical-up welding, SMAW	Ultrasonic testing, included in mainline inspection	Requires qualification using project pipe and consumables.

Notes:

(1) When using GMAW/Mech. FCAW: Semi-Auto controlled-dip transfer GMAW (ER70S-G) – root (though-wall repair). Semi-Auto FCAW, E111T1-K3MJ-H4, Lincoln NR-208H remaining.

*Bohler BVD 100 subject to prior approval.

APPENDIX C GUIDANCE FOR THE ULTRASONIC TESTING OF WELDS COMPLETED WITH CELLULOSIC CONSUMABLES (ROOT AND HOT PASS) BETWEEN PIPES OF UNEQUAL WALL THICKNESS WITH ONE SIDE HAVING A BACK BEVEL TRANSITION FOR CRACKS

C-1 PURPOSE

This Appendix describes the requirements for the ultrasonic testing of Shielded Metal Arc Welding back bevel transition girth welds for the detection of cracking.

C-2 SCOPE

This Appendix applies only to welds made using the Shielded Metal Arc Welding (SMAW) process. Further, this Appendix applies only to back bevel transition welds completed with cellulosic consumables (root and hot pass) between pipes having an unequal wall thickness. The examination shall be limited to the inspection of cracking only. Other workmanship imperfections are not to be evaluated.

C-3 NDE TECHNICIAN QUALIFICATION REQUIREMENTS

The qualification of NDE Technicians shall be in accordance with Appendix C of *TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)* (EDMS no. 1001828660).

C-4 ULTRASONIC PROCEDURE

An Ultrasonic Testing procedure shall be established using guidance shown in API 1104 Section 11.4.2.2.

C-5 EQUIPMENT REQUIREMENTS

The equipment used as required by this Appendix shall be in accordance with Appendix C of *TES-UT-API Ultrasonic Examination of Girth Welds Specification (US-MEX)* (EDMS no. 1001828660).

An IIW or similar block is recommended for equipment calibration. Specified reflectors (e.g., drilled holes, flat bottom holes, notches) shall be used to establish primary reference responses of the equipment. Alternative reflector(s) may be used provided that the alternative reflector(s) produces a sensitivity equal to or greater than the specified reflector(s) (e.g., drilled holes in lieu of notches).

C-6 EXAMINATION OF WELDS

C-6-1 BASE METAL EXAMINATION

A compression wave test of the parent material on both sides of the weld (minimum distance of 1.25 times the longest surface skip distance) shall be performed. All interfering partial and full beam reflectors shall be noted (datum location and distance from the weld edge) and recorded on the examination record.

Using a longitudinal wave transducer, adjust the second back-wall echo in the base material to at least 80 % of FSH and examine for laminar or stringer imperfections which may interfere with the transverse wave examination. All significant imperfections shall be recorded and, where practical, the transverse wave

examination shall be modified to compensate for their presence. The area to be examined shall cover 100 % of the base metal though which the transverse wave will pass.

C-6-2 MANUAL ULTRASONIC TESTING

Manual ultrasonic weld testing shall be performed at a scanning sensitivity of DAC/TCG reference sensitivity plus 6 dB minimum. All indications that exceed 50% of DAC/TCG screen height shall be evaluated. Evaluation sensitivity for manual ultrasonic weld testing should be DAC/TCG reference sensitivity plus 6 dB with an evaluation level for all indications at 50% of DAC/TCG screen height.

C-6-3 AUTOMATED ULTRASONIC WELD TESTING

Automated ultrasonic weld testing should be performed at a scanning sensitivity of 80% screen height reference sensitivity plus 4 dB when using the pulse-echo technique. Evaluation should be the same as scanning sensitivity. Evaluation level screen height (recording threshold) should be 40% of full screen height using the automated pulse-echo technique. Other automated techniques, reference reflectors, reference, scanning sensitivities, evaluation sensitivities and evaluation levels may be used if demonstrated to be equivalent to the pulse-echo technique for the detection and evaluation of weld imperfections.

C-7 EVALUATION

Indications evaluated as a crack of any size, in any pass, are deemed unacceptable and shall be reported to the Company. The inspection report shall note the crack length and location.

Welder's Name (print)	Welder's ID Stamp (Initials – last 4 digits of SSN)	Project Name

Initial Multiple Qualification	☐	Multiple Qual. Renewal by NDE	☐	Project Number

TEST CONDITIONS

Weld Type	Butt	Branch
Pipe Specification & Grade		
Diameter of Test Pipe		
Wall Thickness		
Fixed Pipe Position		
API Filler Metal Groups (1 - E6010 / 2 - E8010 / 3 - E8018)		
Welding Procedure Specification		

VISUAL ACCEPTABLE ("X")	YES	☐	NO	☐	YES	☐	NO	☐

		Butt QTY	Butt Pass	Butt Fail	Branch QTY	Branch Pass	Branch Fail
Number of Tests Completed Per Weld	Nick						
	Face						
	Root						
	Tensile						
	Side						

6 MONTH EXTENSION OF MULTIPLE QUALIFICATION BASED ON NDE OF BUTT WELD

(NDE Report Must Be Attached to this Form and Identify the Welder)

NDE VENDOR	LEVEL II TECH	WELD ID	NDE REPORT NO.

NDE ACCEPTABLE TO API 1104	☐	YES	☐	NO

Comments

Welding Inspector's Name (Please Print)	Welding Inspector's Signature & CWI Stamp	Date of Test
		Date of Qualification Expiry (Valid 6 Months)

WELD PARAMETER DETAILS						
Welder Name and ID Stamp:						
Welding Procedure:	☐ **API-0-GW-01**			☐ **API-08-GW-02**		
Welding Position:	**FIXED - 5G**			**Preheat:**		
Weld Pass #:	**ROOT**	**HOT**	**FILL**	**CAP**		
Electrode Diameter:						
Electrode Type:						
Measured Weld Current Range:						
Measured Weld Voltage Range:						
Measured Travel Speed Range:						
Direction of Travel:						
Welding Procedure:	☐ **API-0-MQ-11**			☐ **API-08-MQ-12**		
Welding Position:	**FIXED – BRANCH FACING DOWN**			**Preheat:**		
Weld Pass #:	**ROOT**	**HOT**	**FILL**	**CAP**		
Electrode Diameter:						
Electrode Type:						
Measured Weld Current Range:						
Measured Weld Voltage Range:						
Measured Travel Speed Range:						
Direction of Travel:						

PURPOSE

This Specification outlines the engineering and design requirements for the successful completion of a pressure test on new construction and system additions.

SCOPE / APPLICABILITY

This Specification applies to the following pipelines and facilities constructed for and/or operated by the Company in the United States (U.S.):

- new construction and additions to existing systems of both natural gas and natural gas liquid pipelines and hazardous liquid pipelines
- meter, regulator, compressor, pump, and delivery station piping
- terminal piping and service lines

This Specification applies to the following pipelines and facilities constructed for and/or operated by the Company in Mexico:

- new construction and additions to existing natural gas pipelines
- meter, regulator, compressor station piping, and service lines

This Specification does not apply to:

- pressure testing of high vapor pressure (HVP) pipelines (except natural gas liquid), and CO2 pipelines
- energy facilities (power plants)
- integrity testing of existing pipelines; refer to *TES-HYDRO-INT-US Hydrostatic Test Specification for Integrity Testing of Existing Pipelines (US)* (EDMS No. 6058463)
- LNG process piping testing; refer to *CPG: Pressure Test LNG Process Piping Plan (US) Plan 310.34.02*
- tank pressure testing; refer to *TES-TANK-HYDRO Tank Hydrotest Specification (CDN-US-MEX) (EDMS No. 8040864)*

For pressure testing requirements of pipelines and piping systems that are not within the scope of this Specification, refer to the applicable sections of *CFR 49 Part 192,195 and 193, NOM-007-SECRE-2010,* other company standards, specifications and applicable industry codes or consult with the Responsible Engineer.

Within this Specification, TransCanada is referred to as the Company.

Within this Specification, the following terms and definitions apply for requirements:

- Shall—expresses a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard. Shall is not a recommendation but a requirement.

- Should—expresses a strong preference, recommendation or that which is advised, but not required.
- Must—denotes a requirement of the Company, for which no deviation or variance would be granted.
- May—expresses an option or that which is permissible within the limits of the standard.
- Consider—assumes that a competent person will evaluate options to fulfill the intent of the requirement and make a documented decision supported by evidence to ensure protection of people, equipment and the environment by achieving the appropriate level of functional integrity.

This document shall be reviewed once per calendar year, not to exceed 15 months.

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1 GLOSSARY

ANSI

American National Standards Institute

API

American Petroleum Institute

ASME

American Society of Mechanical Engineers

Certificate of Compliance/Certificate of Conformance (CofC)

A quality assurance document generally received from valve manufacturers (for material items 2" in diameter or smaller) certifying the item was produced in compliance with international standards organization standards (ANSI, ASME, etc.).

CFR

Code of Federal Regulations

Design pressure (internal design pressure)

The maximum internal pressure limit based on the material of the pipeline segment. Design pressure is greater than or equal to the maximum allowable operating pressure (MAOP) of natural and other gas pipelines, or the maximum operating pressure (MOP) in the case of hazardous liquids pipelines.

Double deviation (0.2% deviation)

The pressure at which the number of pump strokes (measured volume) per increment of pressure rise becomes twice the number of pump strokes (measured volume) per increment of pressure rise that was required during the straight-line part of the pressure-volume plot before any deviation occurs.

Gas

Natural gas, flammable gas, or gas which is toxic or corrosive.

Hazardous liquid

Petroleum, petroleum products or anhydrous ammonia

HDD

Horizontal Directional Drill

High consequence area (HCA)

Refer to 49 *CFR* part 192.903, 192.905 and part 195.450 for the definition of High Consequence Areas.

High vapor pressure (HVP)

A pipeline system conveying hydrocarbons or hydrocarbon mixtures in the liquid or quasi-liquid state with a vapour pressure greater than 110 kPa absolute at 38°C, as determined using the Reid method (see *ASTM D323*).

Leak test

A procedure used in conjunction with testing to detect the existence or evidence of leaks in the pipeline by means of visual or analytical processes.

For piping that is entirely visible during the test, the leak test will consist of observation of the piping while under pressure to check for visible or audible evidence of a leak. For piping below ground or otherwise not visible, the leak test will consist of an approved procedure whereby pressure variations during Strength Testing are accounted for, taking into account the effects of temperature and pressure on the test medium and pipe. Pressure loss that cannot be satisfactorily attributed to these factors, measurement error or other factors peculiar to the situation will be considered evidence of a leak.

Maximum allowable operating pressure (MAOP)

The maximum pressure at which a pipeline or segment of a pipeline may be operated under *49 CFR Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*. Maximum Permissible Operating Pressure (MPOP) may be applied in Mexico when used in according to NOM-007-SECRE-2010.

Maximum operating pressure (MOP)

The maximum pressure at which a pipeline or segment of a pipeline may be normally operated under *49 CFR Part 195 Transportation of Hazardous Liquids by Pipeline.*

Maximum test pressure (MTP)

The maximum internal fluid pressure permitted for testing, for the materials and for Part 192 and 195 facilities, class location involved. The Company's limit is 110 percent SMYS of the weakest segment of pipe or pipe-type component or the pressure that produces double deviation, or pressure rating of non-pipe components, whichever is lower.

MTR

A Mill Test Report, Material Test Report, Mill Test Certificate or equivalent is a quality assurance document used in the metals industry that certifies a material's chemical and physical properties. It also confirms that the material was produced in compliance with international standards organization (e.g., ANSI, ASME, etc.)

NGL

Natural Gas Liquids

Regulatory Commission of Energy

Mexican regulating authority

P-V plot

A pressure vs. volume plot. Also known as a yield plot.

PHMSA

Pipeline and Hazardous Materials Safety Administration of US Department of Transportation (DOT)

Post-test tie-ins (non-pressure tested field welds)

Welds completed after the pressure test is conducted. The welds required to install the tested item/assembly in its final location.

Prefabricated / fabricated assembly

An arrangement of piping that is joined together prior to installation in the pipeline system. Fabricated assemblies are defined as the joining of fittings, valves, flanges and other components.

Pressure test failure

A pipeline rupture or leak that occurs during a pressure test.

Service line

A distribution line that transports gas from a common source of supply to an individual customer, to two adjacent or adjoining residential or small commercial customers, or to multiple residential or small commercial customers served through a meter header or manifold. A service line ends at the outlet of the customer meter or at the connection to a customer's piping, whichever is further downstream, or at the connection to customer piping if there is no meter.

Short section

Pipeline assemblies, piping spools, fabricated assemblies, and lengths of pipe (typically less than 120 ft) which are 100 percent visible.

SMYS

Specified Minimum Yield Strength of a material. Minimum Resistance Transfer (MRT) is equivalent to the SMYS term and may be used in Mexico in according to NOM-007-SECRE-2010.

Start pressure (strength test)

The minimum strength test pressure.

Strength test

The test designed to establish a pipeline's operating pressure limit as required by code or regulation. It involves the pressurization of piping to a minimum

predetermined stress level or pressure and maintaining this stress level or pressure for a predetermined time interval or hold period.

Test head assembly

The assembly of valves, pipe, cradle grating (if applicable), fittings, etc. that together form the temporary facility used for the pressure testing piping. Test head assemblies are used on longer pipeline sections. A test head assembly is normally provided with a separate (NPS 4 to NPS8) fill valve along with throttling valves (NPS 2). The distance between the fill valves and throttling valves shall be sufficient for at least two pigs to fit in the assembly. The pig length is generally less than 1.5 times the test head nominal pipe diameter.

Test cap assembly

The assembly of valves, pipe, fittings, etc. that together form the temporary facility used for the pressure testing piping. Test cap assemblies are used on short section of pipelines and facility piping. A test cap assembly is provided with throttling valves (NPS 2) that are also used for filling the test sections. The distance between the fill/throttling valves shall be sufficient for one pig to fit in the assembly. The pig length is generally less than 1.5 times the test head nominal pipe diameter.

Test end cap

An end cap fitting that can only be used once for pressure testing

2 GENERAL

2.1 General Requirement

2.1.1 A pipeline is generally pressure-tested above its operating pressure in place, after installation, but before it is put into service. The pressure testing must comply with the following, as well as with any additional requirements indicated within project specific special permits if applicable:

- U.S.: *49 CFR Part 192 Transportation of Natural and Other Gas by Pipeline, Minimum Federal Safety Standards*, including:
  - Subpart G – General Construction Requirements for Transmission Lines and Mains
  - Subpart J –Test Requirements
  - Subpart L – Operations
- U.S.: *49 CFR Part 195 Transportation of Hazardous Liquids by Pipeline*, including:
  - Subpart D – Construction
  - Subpart E – Pressure Testing
- Mexico: *NOM-007-SECRE-2010: Transport of Natural Gas*

3 SAFETY REQUIREMENTS

3.1 General

3.1.1 All field work shall conform to the site-specific safety plan.

3.1.2 The site-specific safety plan shall address the following:

- location of test sections relative to HCA in the case of uncontrolled depressurization, including property, operating facilities, public spaces, and testing personnel
- test failure modes
- pressure level
- safe access, egress, and escape from test head and pressure recording equipment locations

3.1.3 All work shall conform to relevant Occupational Safety and Health regulations.

4 ENVIRONMENTAL CONSIDERATIONS

4.1.1 Project personnel shall contact the appropriate Company's environmental group for environmental requirements:

- For natural gas pipelines and facilities, the project team shall engage the Environmental Planning and Permitting team to develop site-specific plans for water discharge (and withdrawal if required).
- For hazardous liquid pipelines, the project team shall engage the Liquids Environmental Services team to develop site-specific plans for water discharge (and withdrawal if required).

4.1.2 Project personnel shall contact the Company's Environmental Advisor for considerations and/or requirements.

5 BURIED PIPELINE PRESSURE TEST REQUIREMENTS

5.1 General

5.1.1 Test pressures and durations shall be provided on the drawings, test plan and/or in the project-specific documents.

5.1.2 Relocated, replaced and/or otherwise changed pipe and assemblies must be pressure tested to substantiate the MAOP/MOP in accordance with CFR 192.503 and 195.302 before returning to service.

5.1.3 The test pressure shall not exceed the specified maximum test pressure (MTP) and shall not drop below the prescribed minimum test pressure.

5.1.4 A pressure test conducted between the maximum and minimum test pressure limits and for the correct test duration but without consideration of the pressure versus temperature (i.e. ambient, test medium and/or ground temperatures) data is not automatically an acceptable test.

5.2 Test Medium

The following requirements apply to natural gas pipelines:

5.2.1 Water is the preferred pressure test medium for steel pipe. See 5.2.2 through 5.2.8 for conditions for use of other mediums.

5.2.2 Site-specific approval shall be acquired from the Company's Design Engineer for natural gas as a test medium.

5.2.3 Site-specific approval shall be acquired from the Company's Design Engineer for air or inert gas as a test medium for pipelines operating at a hoop stress of 30 percent or more of SMYS.

5.2.4 Site-specific approval shall be acquired from the Company's Design Engineer to test with air or inert gas as a test medium for pipe sizes NPS 10 and larger.

5.2.5 Air is the preferred medium for testing polyethylene plastic pipelines. Inert gas or natural gas may also be used. The use of water for testing polyethylene pipe is discouraged.

5.2.6 Typical conditions for the use of air, inert or natural gas as a test mediums are as follows:

- The ambient temperature is expected to be less than 32°F.
- Water of appropriate quality is not available in sufficient quantity.
- The piping configuration will make liquid removal difficult or impractical.
- The pipeline has large elevation differences needing excessive number of test sections for hydrostatic test.

5.2.7 CO2, HVP liquids, or fluids containing H2S shall not be used as pressure test medium.

5.2.8 For **hazardous liquid service pipelines**, air or inert gas may be used as the test medium in low-stress (≤ 20 percent of SMYS) hazardous liquid pipelines, in accordance with *49 CFR Part 195.306 (d)*.

5.3 Pre-Installation One-Hour Leak Test

5.3.1 All HDD pipe, concrete-coated pipe, and other pipe specified in the contract shall be pre-tested.

5.3.2 The pre-test pressure shall be equal to or greater than the test pressure required for the Mainline test that will be conducted for the intended MAOP/MOP for a minimum of one hour or until the piping is determined to be leak free, whichever is longer, before the installation of HDD pipe, concrete-coated pipe, or other pipe specified in the contract. Once in place, the pre-tested carrier pipe shall be tested as part of the post installation mainline test.

5.3.3 Non-HDD bores for high pressure gas and hazardous liquid pipeline crossings which include, but are not limited to, road, railroad, river, stream, or creek crossings may be pre-tested, as specified in the contract, permit and/or the crossing agreement. Once in place, the pre-tested pipe shall be tested as part of the post-installation mainline test.

5.4 Natural and Other Gas Pipeline Test Pressure and Duration

5.4.1 Operation at a Hoop Stress of 30 percent or More of SMYS

5.4.1.1 Test Pressure Limits

1. The pressure test should be performed at the highest possible test pressure commensurate with the design pressure to qualify for operation in the highest-class location area possible.
2. At any point in the test section, pressure shall not produce hoop stress that exceeds the lesser of 0.2 percent deviation on a P-V plot

or 110 percent of the pipe's SMYS. Concurrently, the maximum working pressure of the test heads used shall not be exceeded.

3. The strength test shall start at a pressure between the minimum and maximum limits. Refer to Table 5-1 below for minimum and maximum pressure test pressure limits based on requirements in 49 CFR 192.503 and 192.619, and the Company requirements for natural gas pipelines.

Table 5-1: Pressure Test Pressure Limits

Application	Minimum Test Pressure Limit Using Water	Maximum Test Pressure Limit for Using Water	Maximum Hoop Stress Limitation for Using Air or Inert Gas	Maximum Hoop Stress Limitation for Using Natural Gas
Pipeline in Class 1 Location	1.25 × MAOP	Lesser of 0.2% deviation on a PV-plot or 110% SMYS	80% SMYS[1]	80% SMYS
Pipeline in Class 2 Location	1.25 × MAOP		75% SMYS[1]	30% SMYS
Pipeline in Class 3 Location[2]	1.50 × MAOP		50% SMYS	30% SMYS
Pipeline in Class 4 Location[2]	1.50 × MAOP		40% SMYS	30% SMYS
Meter and Regulator Station	1.50 × MAOP		See Class Location for Limit	See Class Location for Limit
Compressor Station	1.50 × MAOP		See Class Location for Limit	See Class Location for Limit

[1] See *49 CFR Part 192.505 (a)* for additional provisions.

[2] For Mexico; pipeline must be hydrostatically tested in accordance with *NOM-007-SECRE-2010.*

4. Refer to Table 5-2 for minimum and maximum pressure test pressure limits based on requirements of *49 CFR 192.620, Alternative Maximum Allowable Operating Pressure (MAOP).*

Table 5-2: Pressure Test Pressure Limits – Alternative MAOP

Application	Alternative Design Factor	Minimum Test Pressure Limit for Using Water	Maximum Test Pressure Limit for Using Water
Pipeline in Class 1 Location	0.8	1.25 × MAOP	Lesser of 0.2% deviation on a P-V plot and 110% SMYS
Pipeline in Class 2 Location	0.67	1.50 × MAOP	
Pipeline in Class 3 Location	0.56	1.50 × MAOP	

5.4.1.2 Pressure Test Duration

1. The duration of the strength test shall not be less than eight continuous hours above the minimum test pressure. For short-section and prefabricated assemblies, refer to section 6.3.

5.4.1.3 Leak Test

1. For tests of pipelines operating over 30 percent SMYS, 49 CFR Part 192 does not require a separate leak test; therefore, it may be conducted concurrently with the strength test.
2. For pneumatic tests carried out in Mexico, test duration shall be 24 hours in accordance with NOM-007-SECRE-2010.

5.4.2 Operation at a Hoop Stress Less Than 30% of SMYS and at or Above 100 psig (689 kPa)

5.4.2.1 Except for service lines and plastic pipelines, each segment of a pipeline that is to be operated at a hoop stress less than 30 percent of SMYS and at or above 100 psig (689 kPa) must be tested in accordance with 49 CFR Part 192.507:

1. The Company must use a test procedure that will ensure discovery of all potentially hazardous leaks in the segment being tested.
2. If, during the test, the segment is to be stressed to 20 percent or more of SMYS and natural gas, inert gas, or air is the test medium.
   - A leak test must be made at a pressure between 100 psig (689 kPa) gauge and the pressure required to produce a hoop stress of 20 percent of SMYS.
   - The line must be walked to check for leaks while the hoop stress is held at approximately 20 percent of SMYS.
3. The pressure must be maintained at or above the test pressure for at least one hour.

5.4.3 Operation at Pressure Less than 100 psig (689 kPa) for Steel Pipelines

5.4.3.1 Except for service lines and plastic pipelines, each segment of a pipeline that is to be operated below 100 psig (689 kPa) must be leak tested in accordance with 49 CFR Part 192.509:

1. The Company must use a test procedure that will ensure discovery of all potentially hazardous leaks in the segment being tested.
2. Each main that is to be operated at less than 1 psig (6.9 kPa) must be tested to at least 10 psig (69 kPa) and each main to be operated at or above 1 psig (6.9 kPa) must be tested to at least 90 psig (621 kPa).

5.4.3.2 In addition, pipelines intended for operation below 100 psig (689 kPa) shall be successfully leak tested to at least 150 percent MAOP or 90 psig (621 kPa), whichever is greater, for a minimum duration of one hour using water, air, or inert gas as a test medium.

5.4.4 Steel Service Pipelines

5.4.4.1 Steel service pipelines shall be successfully tested in accordance with 49 CFR Part 192.511 Test Requirements for Services Lines as follows:

1. Each segment of a service line (other than plastic) must be leak tested in accordance with this section before being placed in service. If feasible, the service line connection to the main must be included in the test; if not feasible, it must be given a leakage test at the operating pressure when placed in service.
2. Each segment of a service line (other than plastic) intended to be operated at a pressure of at least 1 psig (6.9 kPa) but not more than 40 psig (276 kPa) must be given a leak test at a pressure of not less than 50 psig (345 kPa).
3. Each segment of a service line (other than plastic) intended to be operated at pressures of more than 40 psig (276 kPa) must be tested to at least 90 psig. (621 kPa), except that each segment of a steel service line stressed to 20 percent or more of SMYS must be tested in accordance with 49 CFR Part 192.507.

5.4.4.2 Test shall be conducted for a minimum of one hour.

5.4.5 Polyethylene Plastic Pipelines

5.4.5.1 Polyethylene plastic pipelines shall be successfully tested in accordance with 49 CFR Part 192.513 at a minimum:

1. Each segment of a plastic pipeline must be tested in accordance with this section.
2. The test procedure must insure discovery of all potentially hazardous leaks in the segment being tested. See section 5.4.5.3 for the Company's required minimum duration.
3. See section 5.4.5.2 for Company required minimum test pressures. These exceed the requirements of 49 CFR 192.513 which reads as follows:

   The test pressure must be at least 150 percent of the maximum operating pressure or 50 psig (345 kPa), whichever is greater. However, the maximum test pressure may not be more than three times the pressure determined under 49 CFR Part 192.121, at a temperature not less than the pipe temperature during the test.
4. During the test, the temperature of thermoplastic material may not be more than 100°F (38°C), or the temperature at which the material's long-term hydrostatic strength has been determined under the listed specification, whichever is greater.

5.4.5.2 In addition, the test pressure must be at least 150 percent of the MAOP or 90 psig (620 kPa), whichever is greater. However, the MTP shall not be more than three times the pressure determined under 49 CFR Part

192.121, at a temperature not less than the pipe temperature during the test.

5.4.5.3 Test shall be conducted for a minimum of one hour.

5.5 Hazardous Liquid Pipeline Test Pressure and Duration

5.5.1 A hazardous liquid pipeline pressure test shall consist of a strength test and a leak test in accordance with *49 CFR Part 195.304*.

5.5.2 In accordance with *49 CFR Part 195.304*: "The test pressure must be maintained at a pressure equal to or greater than 125 percent of the MOP for four continuous hours. A concurrent leak test shall be conducted if the pipeline is visible. In the case of a pipeline that is not visually inspected for leakage during the test, the test pressure shall be maintained for at least an additional four continuous hours at a pressure equal to or greater than 110 percent of the MOP."

5.5.3 The MTP for a section shall be the lesser of 0.2 percent deviation on a P-V plot or 110 percent of the pipe's SMYS.

5.6 P-V Plotting

5.6.1 P-V plotting shall be required for hydrotesting at a pressure which will produce a hoop stress equal to or greater than 100 percent SMYS of the pipe.

5.6.2 If P-V plots cannot be produced accurately for short test sections, the pipe used for the test section shall be designed such that the MTP will produce a hoop stress less than 100 percent SMYS of the pipe.

5.7 Testing of Tie-Ins

The following requirements apply to non-pressure tested tie-in welds for natural and other gas pipelines:

5.7.1 The regulations and codes of construction for pipelines and pipeline facilities in the U.S. and Mexico recognize that not all welds can be pressure tested. Appendix A is non-mandatory and provides examples for guidance only. Selection and justification of locations for non-pressure tested welds is project specific and subject to project specific conditions and risks.

5.7.2 The rationale used to determine the location and number of non-pressure tested welds left in a pipeline system shall be documented.

5.7.3 Also refer to the following sections for scenarios in which post-test tie-in welds (non-pressure tested field welds) may be acceptable in an installed pressure piping system. Prior written approval is needed from the Company Integrity and/or Reliability Engineering Manager.

5.7.3.1 Tie-ins to existing facilities – Non-pressure tested welds required to make tie-ins of short lengths of pipe or new piping assemblies to existing facilities are acceptable. Re-testing of previously in-service components in the test section shall be avoided. Refer to Appendix A for examples of tie-ins to

existing facilities to assist the Company's Design Engineer in minimizing the number of non-pressure-tested welds.

5.7.3.2 Tie-ins to previously pressure tested pipelines – This section does not preclude the cutting in of pipeline assemblies following a pressure test of a new pipeline. Refer to Appendix A for examples of tie-ins to previously tested facilities to assist the Company's Design Engineer in minimizing the number of non-pressure tested welds.

5.7.3.3 Positioning of test caps or test heads – Where field pressure testing is performed, space is required to accommodate the required test heads or test caps. Following the test, the head or cap is removed and may be replaced with pre-tested pipe or a pre-tested spool piece to make the final connections to existing infrastructure or other parts of the new facility, resulting in non-pressure tested field welds.

5.7.3.4 Stress free tie-ins and weld alignment – Alignment of piping to meet the requirements of the design code to produce stress free welds can result in the need for non-pressure-tested welds to allow sufficient adjustability to achieve compliant alignment. Where the specified welding alignment cannot be achieved without placing excessive external forces on the pipe, additional non-pressure tested welds are permitted. Refer to the Company's Welding specification TES-WELD-API Welding of Pipelines and Facilities Specification (US-MEX) *(EDMS No.* 1001828218) or guidance on alignment prior to welding (i.e. clause 2.30.2: "External forces to align pipe shall be kept to a minimum").

Note:

This justification shall be used with care and discretion to account for unknown or unknowable factors that cannot be mitigated by careful planning in the design phase. For documentation of justification for non-pressure tested welds, refer to Appendix B.

5.7.3.5 Non-pressure tested welds are acceptable when testing to eliminate such a weld would create an unsafe condition that cannot be mitigated by other means.

5.7.4 For **hazardous liquid pipelines**, pipe associated with tie-ins must be pressure tested, either with the section to be tied in or separately.

5.7.5 Each non-welded joint (i.e., flanges and threaded joints) must be leak tested at not less than its operating pressure.

6 SHORT SECTION PRESSURE TEST REQUIREMENTS

6.1 General

6.1.1 All pipe and fabricated units installed directly into or connected to an existing pipeline or facility shall be pressure tested before installation.

6.1.2 If a component other than pipe is the only item being replaced or added to a pipeline, a strength test after installation is not required, if the manufacturer of the component certifies that it is tested during manufacturing at the pressure required for the system to which it is being added in accordance with *49 CFR Part 192.503 (e) (1), (2), (3)* and *49 CFR Part 195.305 (b)*

6.1.3 If an ASME pressure vessel (e.g., strainer, filter, heat exchanger, etc.) is the only item being replaced or added to a pipeline; and if it is tested during manufacturing at the pressure and duration required for the system to which it is being added; and the manufacturer provides the documentation; it does not require pressure-testing again.

6.1.4 Equipment or vessels may be tested with the rest of the system if the system test pressure is less than the equipment or vessel Manufacturer's MTP. To test a piece of equipment or vessel above the MTP used by the Manufacturer requires verification from the Manufacturer that the item is capable of holding the proposed pressure with no damage.

6.1.5 For fabricated units and short sections of pipe, for which a post-installation test is impractical, a pre-installation strength test must be conducted by maintaining the pressure at or above the test pressure for at least four hours.

6.1.6 Pipe with a counter bore and taper transition must be shop or field pressure tested, counter bore and taper cannot be done after pressure testing.

6.2 Test Medium

6.2.1 Refer to section 5.2, test medium.

6.3 Natural and Other Gas Pipeline Test Pressure and Duration

6.3.1 Operation at a Hoop Stress of 30% or More of SMYS

6.3.1.1 The short section pressure test shall include a strength test, in accordance with 49 CFR, Part 192, subpart J and the Company requirements.

6.3.1.2 The minimum and maximum test pressure limits listed in Table 5-1 shall be used for short section strength tests. Where applicable, Table 5-2 shall be used for alternative maximum and minimum pressure limits.

6.3.1.3 The duration of the strength test shall not be less than eight continuous hours at or above the minimum test pressure, unless a post-installation test is impractical. In this case, a four-hour pre-installation strength test may be acceptable (see section 5.7 for justification of non-pressure tested tie-in welds).

6.3.1.4 For fully visible piping and assemblies, the leak test may be conducted concurrent with the strength test provided enough time is taken to adequately inspect the short section.

6.3.2 For operation at a hoop stress less than 30 percent of SMYS and at or above 100 psig (689 kPa), refer to section 5.4.2.

6.3.3 For operation at pressure less than 100 psig (689 kPag), refer to section 5.4.3.

6.3.4 For steel service pipelines, refer to section 5.4.4.

6.3.5 For polyethylene plastic pipelines, refer to section 5.4.5.

6.4 Hazardous Liquid Pipeline Test Pressure and Duration

6.4.1 Refer to section 5.5, hazardous liquid pipeline test pressure and duration.

7 PRESSURE TEST REQUIREMENTS FOR AUXILIARY PIPING & TUBING

7.1 Test Pressure and Duration

7.1.1 Auxiliary piping is piping required for direct operation of a station/facility, other than main gas or fuel gas piping (upstream of the first cut DOT regulator). Examples of auxiliary piping may include:

- air systems (B31.1 and B31.3)
- ESD pneumatic air systems (B31.1 and B31.3)
- lube oil system (B31.3)
- cooling water/jacket water systems (B31.1)
- hydraulic oil systems (B31.3)
- glycol systems (B31.1)
- fuel gas piping downstream of first cut DOT regulator (B31.3)
- vent piping (e.g. inlet pipe for silencers or mist eliminators, outlet piping for relief valves, etc.) (code used depends on the service)

7.1.2 Pressure test requirements for various piping systems are outlined in Table 7-1 below:

Table 7-1: Pressure Test Requirements for Auxiliary Piping Systems

Applicable Systems	Test Medium	Pressure Testing Requirements	Test Pressure(s)	Duration
• High Pressure Fire Suppression Piping • Cooling Water Piping • Potable and Fresh Water Lines[1] • Compressed Air Piping (design pressure up to 150 psig (1035 kPa) • Heating System (Water/Glycol Piping)	Service Fluid	All piping at every point within the system shall be subject to an in-service leak test. The test supervisor must be satisfied that any changes in pressure are not the result of leaks before the leak test is concluded.	MAOP/MOP	Not less than 10 minutes and additional time as necessary to conduct an examination for leakage.

Applicable Systems	Test Medium	Pressure Testing Requirements	Test Pressure(s)	Duration
• High Pressure Seal and Hydraulic Oil Piping • Compressed Air Piping (design pressure over 150 psig (1035 kPa) • Low Pressure Lubricating Oil Piping • ESD Air System • Fuel gas piping downstream of first cut DOT regulator	Water	The test pressure shall not exceed the MTP of any component in the system.	150% of Design Pressure and shall not exceed 100% SMYS.	Not less than one hour and additional time as necessary to conduct an examination for leakage.
• High Pressure Seal and Hydraulic Oil Piping • Compressed Air Piping (design pressure over 150 psig (1035 kPa) • Low Pressure Lubricating Oil Piping • ESD Air System • Fuel gas piping downstream of first cut DOT regulator	Inert Gas	The test pressure shall not exceed the MTP of any component in the system.	110% of Design Pressure or min. test pressure plus 50 psig and shall not exceed 90% SMYS.	Not less than one hour, and additional time as necessary to conduct an examination for leakage.
• Seal Oil Piping (External to skid only) • Lube Oil Piping (External to skid only)	Lube Oil	The test pressure shall not exceed the MTP of any component in the system.	150% of Design Pressure and shall not exceed 100% SMYS.	One hour
• Plumbing Vents and Drains[1]	Water		Minimum Test Pressure 2 psig (14 kPag), Maximum Test Pressure 5 psig (35 kPag)	One hour
[1] Refer to applicable plumbing codes for additional testing requirements.				

7.1.3 Most vent piping (e.g., ESD vents, relief valve stacks, etc.) does not require a test. The exception to this is vent piping that could become obstructed (e.g. ice, etc.) such that would retain pressure. If this is anticipated, the piping shall be tested according to this Specification.

7.2 Test Requirements for Tubing

7.2.1 Tubing shall be subjected to a leak test, in accordance with the requirements outlined in Table 7-2, after it has been bent, assembled, and installed in place. All fittings shall be examined visually to ensure the integrity and confirm that proper compression has occurred in the fitting.

7.2.2 Pressure rated tubing NPS 1/2 and smaller does not need to be tested; however, a soap bubble leak test must be done at all connections once the tubing has been installed and put into service.

Table 7-2: Leak Test Requirements for Tubing

Topic	Requirements
Test conditions	• Instrument tubing supplied and installed by Vendors on control valves and all other instruments shall be leak tested on-site by the Contractor. • Where practical, the tubing shall be isolated from the rest of system. • All fittings shall be checked for leaks using gas and "Snoop" fluid or soap solution and brushes.
Leak test pressure	• The leak test pressure shall be the maximum system pressure available at the time of the test. • The pressure shall be increased gradually in steps providing sufficient time to allow the tubing to equalize strains during test and to check for leaks.
Leak test duration	• The duration of the leak test shall be maintained for a sufficient time, not less than ten (10) minutes.
Results	• The test supervisor must be satisfied that any changes in pressure are not the result of leaks before the leak test is concluded. • If there is evidence of leakage, the pressure shall be lowered to 50 psig (350 kPa) before any attempts are made to tighten the fittings. • Testing shall be repeated until leakage is completely eliminated.

8 TEST HEAD ASSEMBLIES AND TEST CAPS

8.1 General Requirements

8.1.1 All temporary and re-usable test-head and test cap assemblies shall meet the minimum design and construction requirements of *49 CFR, Part 192 Subpart D* and *Subpart G* as well as *Part 195 Subpart C* and *Subpart D*.

8.1.2 Welding specifications and procedures used for fabrication, or modification of all temporary and re-usable test head and test cap assemblies shall meet the requirements of *TES-WELD-API Welding of Pipelines and Facilities Specification (US-MEX) (EDMS No. 1001828218)*.

8.1.3 Any transition piece, if required, connected to a test head or test cap assembly shall not be considered a part of the assembly.

8.1.4 For test head and test cap assemblies to be constructed by the Contractor, the Contractor shall use the requirements listed in section 8.2 and/or 8.3 and supply the Company with applicable documentation.

8.1.5 Test (end) cap and test assembly usage:

Table 8-1: Test Cap and Test Assembly Usage

Type	Re-usable	Temporary – One Time Use
Test Head Assembly	Yes	Yes
Test Cap Assembly	Yes	Yes
Test (End) Cap	No	Yes

Refer to 17Appendix C SAMPLE TEST HEAD DRAWINGS.

8.2 Re-usable Test Head and Test Cap Assemblies Requirements

8.2.1 Re-usable test head and test cap assemblies shall also be designed in accordance with *TES-PRES-TH-US Design of Pipeline Test Head Assemblies (EDMS No. 7911901)*.

8.2.2 Maximum working pressure shall be marked on each assembly.

8.2.3 When used for pressure testing, the maximum working pressure of re-useable assemblies shall not:

- produce hoop stresses greater than 80 percent SMYS of any pipe or fitting in the assembly
- be higher than the maximum cold working pressure of any flange or valve in the assembly plus 25 psig (172 kPag)

8.2.4 Re-useable assemblies shall be visually inspected and defects repaired before use and in accordance with *TEF-PRES-TH Test Head Inspection Checklist (EDMS No. 4986590)*.

8.2.5 Re-usable assemblies, to be used at a hoop stress of greater than or equal to 30 percent SMYS of the limiting item of the assembly, shall be pressure tested fully exposed for a minimum of four hours between:

- the minimum pressure of 125 percent of the intended maximum working pressure of the assembly
- the maximum working pressure that will produce a hoop stress not exceeding 100 percent of the SMYS of any pipe or fitting in the assembly, or 150 percent of the cold working pressure rating of any flange or valve in the assembly, whichever is less

8.2.6 Material and pressure testing records shall be maintained for each re-useable assembly for its lifetime. Documentation will be kept in the project file for assembly(s) used.

8.2.7 Re-useable assemblies shall be painted.

8.2.8 Test head assemblies that have been damaged, have incomplete or missing records, or do not meet the requirements outlined above shall be rendered unusable and scrapped.

8.3 Temporary Test (End) Cap and Test Assembly Requirements

8.3.1 Test (end) caps shall only be used once.

8.3.2 Temporary test assemblies shall be designed such that the hoop stress does not exceed 80 percent SMYS at the upper limit of the test pressure range.

8.3.3 Pipe wall thickness, flange rating, and grade of a test assembly shall be determined on a per project basis.

8.3.4 All material documents, including MTRs, and design drawings and test assembly pressure test documentation shall be submitted, as a part of project pre-hydrotest documentation, to the Company's Design Engineer for review.

8.3.5 All piping components of a test assembly shall have a visible heat number.

8.3.6 Lifting stand and/or cradle requirements shall be determined based on project specific needs.

8.3.7 Flanged connections are preferred for NPS 2 or smaller size valves; however, threaded connections are also acceptable.

8.3.8 All pipes must have a joint efficiency factor of 1.0.

8.3.9 Temporary test assemblies may be painted.

8.3.10 Each weld in a temporary test assembly shall be non-destructively inspected.

9 TEST DOCUMENTS

9.1 General Requirements

9.1.1 Pressure test form, pressure test schematic and profile drawings, MTRs, certificates of compliance, certificates of calibration, drawings of the installation location and pressure test plan shall be created and submitted, at least 14 business days before the pressure test is conducted, to the Company's Design Engineer for review and/or approval.

9.1.2 In the event of an emergency pressure test, the pressure test must be approved in advance by the Company Design Engineer.

10 TRAINING AND QUALIFICATION REQUIREMENTS

10.1.1 All individuals who will be responsible for the execution and/or inspection of a Company pressure test in the US shall be qualified to perform pressure testing related covered tasks in accordance with the *Company Operator Qualification Program (EDMS No. 4504739)*.

10.1.2 For Company training requirements refer to *TEN-ME-PRES-GL Pressure Testing Standard (US-MEX) (EDMS No. 1003107276)* and is only applicable to Company individuals.

11 VARIANCES

Any deviation shall follow the Company Management of Change (MOC) Variance Procedure in Table 11-1 below. The Contractor shall contact the Company's Project Engineer for variance approval.

Table 11-1: Variance Procedure & Preferred Role Assignment

	Scope	Procedure	Originator	Owner / Approver	SME	Processor / Implementer
Controlled Document Variance Procedure	Deviations from how work is required to be done by a controlled document (e.g., processes, procedures, standards, work instructions)	EDMS No. 7728702	Project or Operation Eng. / Project Manager	Company's Design Eng. / Responsible Eng.	Responsible Eng.	Company's Design Eng. / Responsible Eng.

12 ROLES AND RESPONSIBILITIES

12.1 Roles

Table 12-1: Examples of Common Role and Responsibilities outlines the typical roles and responsibilities assigned for the use of this Standard. Of the typical roles listed in this section, the Company shall appoint individuals to the applicable pressure testing roles as needed.

Table 12-1: Examples of Common Role and Responsibilities

Role	Responsibilities
Company's Construction Manager	The Construction Manager is responsible for oversight of the field pipeline construction. The Construction Manager manages the commencement of the pressure testing and supervises the Contractors and Inspectors. The Construction Manager is responsible for the handling and use of test heads. The Construction Manager supervises the Pipeline Contractor.
Company's Design Engineer	The Design Engineer is responsible for the final design of the pipeline and for ensuring the pressure test is designed in accordance with this specification, applicable codes, standards and regulations. The Design Engineer can include Integrity and Reliability engineers.
Company's Project Manager	The Project Manager is accountable for all phases of the pressure testing, pressure test calculations, designs and test plans. The Project Manager is accountable for coordinating the inspection and repair of all identified test head damages resulting from field use.

Role	Responsibilities
Company's Test Inspector (CTI)	Company trained and certified to oversee all pressure test activities start to finish.
Company's Test Head Coordinator	Accountable for managing test head inventory and advising project personnel of test head availability. Responsible for maintaining the test head technical information database and the Test Head Central File. This individual/group responsible for the coordination of fabrication, repair and testing of reusable test heads in accordance with industry standards and Company specifications.
Contractor	The third party responsible for conducting the pressure test and for the purpose of this document, it includes the Company Construction Crew.
Company's Test Supervisor	The Test Supervisor is responsible for reviewing technical documentation and contractual requirements, coordinating the activities of the pressure test contractors, and ensuring safe execution of all testing.

12.2 High-Level Responsibilities

12.2.1 The Company shall be accountable for ensuring all pressure test activities conform to this Specification and all pressure test requirements as described in *49 CFR Part 192 and 195*. Pressure testing shall be performed under the direct supervision of the Company's Test Inspector.

12.2.2 Company Specific Roles (Company's Construction Manager, Company's Design Engineer, Company's Project Manager, Company's Test Inspector, Company's Test Supervisor) are personnel designated by the Company to witness, certify or perform pressure testing tasks. A Company Specific Role can be a Company's employee, a Contractor's employee, or a third party Company's employee.

12.2.3 The Contractor and the Company shall provide for the safety of all pipeline construction personnel and the public during pressure test operations.

12.2.4 The Contractor is responsible for all documentation relating to pressure testing, monitoring the testing operations, and checking all data for quality and completeness. The Company is responsible for verifying the documentation listed above, performing quality control and the submission of pressure testing documentation to regulatory authorities, when required. Any questions relating to procedures and documentation should be directed to the Company's Test Inspector for resolution.

12.2.5 The Company's Design Engineer is responsible for the mechanical designs relating to pressure testing and ensures the Pressure Test designs conform to the requirements of this Specification and *49 CFR Part 192* and *195*.

12.2.6 The Company is responsible for securing water permits from the governing authorities for the use and disposal of test water.

12.3 Responsibility Matrix for Engineering and Quality Activities - US

Table 12-2: US – Responsibility Matrix

		Project Manager	Engineer[1,4]		Pressure Test Contractor	Company's Test Inspector	Compliance
			Project / Operations Engineer	Design Engineer[2]			
Pre-Test	Create Calculations and Drawings	A	I/R	R	N/A	N/A	N/A
	Review and Approval Calculations and Drawings	A	R	R	I	N/A	C
	Create Test Plan	A	C	C	R	N/A	C
	Accept Test Plan	A	R	C	I	R	I/C
During Test	Perform Test	A	I	N/A	R	I	N/A
	Monitor and Accept Test	A	C	C	I	R	C
	Adjust Test[3]	A	R*	C	R**	R	C
	Create Test Document Package	A	C	N/A	R	R	N/A
Post Test	Review and Sign-off Test Document Package	A	R	R***	I	R	I
	File Test Document Package	A	R	N/A	N/A	N/A	I

Notes:

[1] For small projects, one individual may take on three roles such as Project/Operations Engineer, Design Engineer, and Project Manager. An independent design discipline check by a degreed engineer shall be conducted for Pressure Test calculations, designs, and test plans.

[2] Design Engineers may be from the Company, or from an external engineering company.

[3] Adjustments include test schedule, equipment failure, conflicts between the Contractor and the Company.

[4] As per TES-ENG-POE Practice of Engineering within TransCanada.

Legend:

A – Accountable; Individual who is ultimately accountable for the activity

R – Responsible; Individual(s) who performs the task/role for the activity

R* – Responsible; Individual(s) who approves the adjusted test plan

R** – Responsible; Individual(s) who shall notify any potential deviations/modifications to the original test plan to the Company for approval and ensures the Pressure Test is performed in accordance with the new approved adjusted test plan

R*** – Responsible; Individual(s) who review the test document package

C – Consult; Individual(s) who is consulted for the activity

I – Inform; Individual(s) who is informed for the activity

N/A – Not Applicable

12.4 Responsibility Matrix for Engineering and Quality Activities - Mexico

Table 12-3: Mexico – Responsibility Matrix

		Project Manager	Engineer[1,5]		Pressure Test Contractor	Company's Test Inspector	Compliance [4]
			Project / Operations Engineer	Design Engineer[2]			
Pre-Test	Create Calculations and Drawings	A	C	C	R	N/A	N/A
	Review and Approval Calculations and Drawings	A	R	R	I	N/A	N/A
	Create Test Plan	A	C	C	R	N/A	N/A
	Accept Test Plan	A	R	R	I	R	N/A
During Test	Perform Test	A	I	I	R	C	N/A
	Monitor and Accept Test	A	C	C	I	R	N/A
	Adjust Test[3]	A	N/A	R*	R**	C	N/A
	Create Test Document Package	A	I	I	R	I	N/A
Post Test	Review and Sign-off Test Document Package	A	I	I	R***	R	N/A
	File Test Document Package	A	I	I	R	N/A	I

Notes:

[1] For small projects, one individual may take on three roles such as Project/Operations Engineer, Design Engineer, and Project Manager. An independent design discipline check by a degreed engineer shall be conducted for Pressure Test calculations, designs, and test plans.

[2] Design Engineers may be from the Company, or from an external engineering company.

[3] Adjustments include test schedule, equipment failure, conflicts between the Contractor and the Company.

[4] Compliance department in Mexico is the connection of the project with customer and governmental agencies. They inform to them when the test has passed successfully.

[5] As per TES-ENG-POE Practice of Engineering within TransCanada.

Legend:

A – Accountable; Individual who is ultimately accountable for the activity

R – Responsible; Individual(s) who performs the task/role for the activity

R* – Responsible; Individual(s) who approves the adjusted test plan

R** – Responsible; Individual(s) who shall notify any potential deviations/modifications to the original test plan to the Company for approval and ensures the Pressure Test is performed in accordance with the new approved adjusted test plan

R*** – Responsible; Individual(s) who review the test document package

C – Consult; Individual(s) who is consulted for the activity

I – Inform; Individual(s) who is informed for the activity

N/A – Not Applicable

13 REFERENCES

This document relies on a number of references to regulation, industry codes and standards, general industry guidance as well as internal references. These documents are detailed below in Table 13-1, Table 13-2 and Table 13-3. For Regulatory and External Industry References, use the latest approved edition referenced in CFR Title 49 Part 192 and 195. For Internal References, use the latest document revision, unless otherwise approved by the Company.

Table 13-1: Regulatory References

Organization/Document No.	Title
CFR Title 49 Part 192	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
CFR Title 49 Part 195	Transportation of Hazardous Liquids by Pipeline
NOM-007-SECRE-2010	Transport of Natural Gas

Table 13-2: External Industry References

Organization/Document No.	Title
ANSI/ASME B31.3	Process Piping
ANSI/ASME B31.4	Liquid Transportation System for Hydrocarbons
ANSI/ASME B31.8	Gas Transmission Distribution and Piping Systems
ANSI/GPTC Z380.1	Guide for Gas Transmission and Distribution Piping Systems
API RP 1110	Pressure Testing of Steel Pipelines for the Transportation of Gas, Petroleum Gas, Hazardous Liquids, Highly Volatile Liquids or Carbon Dioxide

Table 13-3: Internal References

Document No.	Title
EDMS No. 7911901	TES-PRES-TH-US Design of Pipeline Test Head Assemblies
EDMS No. 4986590	TEF-PRES-TH Test Head Inspection Checklist
EDMS No. 1001828218	TES-WELD-API Welding of Pipelines and Facilities Specification (US-MEX)
EDMS No. 1003107361	TEP-ME-PRES-GL Pressure Testing Procedure (US-MEX)
EDMS NO. 1003430939	TEF-ME-PRES-GL Pressure Test Form (US-MEX)

14 DOCUMENTATION AND RECORDKEEPING

Due to the broad range of data types that may be required in support of this Specification, there are a number of repositories that may need to be utilized for documentation purposes. A summary of key data repositories appears in Table 14-1.

Table 14-1: Documentation Requirements

Documentation Description	Repository / Link
TEF-ME-PRES -GL Pressure Test Form	Project Specific Binder

15 DOCUMENT HISTORY

Rev.		
00	**Description**	**Effective Date**
	This Specification contains pressure testing engineering design requirements. The content has been derived from previous pressure testing specification *TES-HYDRO-HTS-US*.	2018-Jan-01
	Rationale Statement	**Responsible Engineer**
	This Specification is a new document. It has been simplified and all procedural content has been moved to *TEP-ME-PRES-GL*. This document was developed as part of Engineering Standards Streamlining Process. This document was developed / revised in order to address the following requirements: • Consolidation of TransCanada specifications. The following specifications/documents have been combined into this document: – *TES-HYDRO-HTS-US* • Consolidation of CPG specifications. The following specifications/documents have been combined into this document: – Piping Testing Requirements Plan – Auxiliary Piping Design, Inspection and Testing Plan – Hydrostatic Test Water – Liquid Piping Testing Requirements Plan • Improved clarity • Mexican requirements in accordance with *NOM-007-SECRE-2010*.	Vivian Liu
	Impact Assessment Summary	**Document Owner**