ภาคผนวก ข-5

การตรวจสอบ Cathodic Protection

Cathodic Protection
for
Test Inspection

Chevron Songkhla JO Terminal Underground Pipeline Project

Submitted to
New Star International Co., Ltd.
July 18, 2022

Prepared by
CPE Engineering and Service Company Limited

Doc. No. : CPED-2022/040

TABLE OF CONTENT

- **CATHODIC PROTECTION TEST PROCEDURE**

TABLE OF CONTENT

1. INTRODUCTION

1.1. Scope of Work

This proposal is specifically written for **Chevron Songkhla JO Terminal Underground Pipeline Project** in addressing Cathodic Protection System for the corrosion protection of coated buried steel pipeline.

Scope of Work

On Shore Rack (Depot)

-Pipe to Soil Potentiall Measurement and Insulation Flange Kit Check

Middle Line Island

-Pipe to Soil Potential Measurement

Loading Jetty

-Pipe to Sea Water Potential Measurement and Insulation Flange Kit Check

2. CATHODIC PROTECTION CRITERIA

The NACE standard SP0169-2007 section 6 provided lists criteria and other consideration for Cathodic Protection that will indicate, when used either separately or in combination, whether adequate Cathodic Protection of a metallic pipeline system has been achieved Section 6.2 lists a criteria for steel and cast iron pipeline as the following below : -

6.2.2.1.1. A negative potential of at least 850 mV with the Cathodic Protection applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte . Voltage drop other than those across the structure-to-electrolyte boundry must be considered for valid interpretation of this voltage measurement.

6.2.2.1.2. A negative polarized potential of at least 850 mV relative at saturated copper/ copper sulfate reference electrode.

6.2.2.1.3. A minimum of 100 mV Cathodic Protection polarization between the structure surface and stable reference electrode contacting the electrolyte. The formation of decay of polarization can be measured of satisfy this criteria.

Altrenative Reference Electrode

Other standard reference electrode may be substituted for the saturated copper/copper sulfate reference electrode. Can be commonly used reference electrode with their voltage equivalent to -850 mV refered to saturated copper/copper sulfate reference electrode. So, saturated silver/silver chloride reference electrode used in 25 ohm-cm sea water is -800 mV.

3. CATHODIC PROTECTION TEST PROCEDURE

3.1. Pipe to Soil and Sea Water Potential Measurement

Pipe to soil and sea water potential measurement is made most frequently in pipeline corrosion test work and carried out confirm the protective condition of the pipeline. Pipe to soil potential is measured with respect to a saturated copper/copper sulfate reference electrode (Cu/CuSO4) and silver/silver chloride reference electrode (Ag/AgCl) is used for pipe to sea water potential measurement with a digital multimeter at all test boxes.

3.1.1. Natural Potential Measurement

1). Before the energization or turn up of any anode groundbed, natural pipe to soil potentials should be measured at all test boxes.

2). The measurement method is shown in Figure 1.

3). The direction for using a saturated copper/copper sulfate reference electrode as following :

-Put the reference electrode on the ground surface just above the pipeline, to decrease effect of IR drop when pipe to soil potential be measured.

-The reference electrode should be inserted approximately 2 centimetre into the soil to be good contact with the soil.

3.1.2. Energized Potential Measurement

1). The anode groundbed should be energized and make pipe to soil potential more negative than -0.850 volt (vs. $Cu/CuSO_4$) or -0.80 volt (vs. Ag/AgCl) at all test boxes.

2). Energized potentials should be recorded at all location where the natural potential were recorded.

3.2. Insulation Flange Check

The purpose of this test is to prove that propose pipeline is electrically seperated from piping and other metallic system.

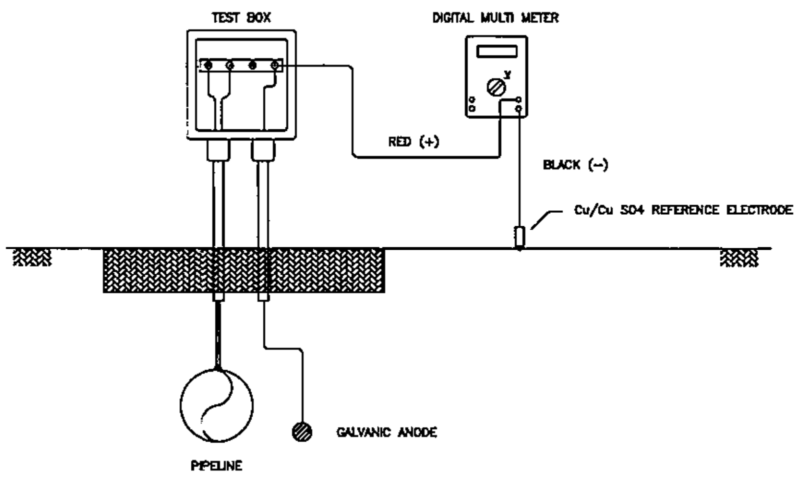
3.2.1. Equipment

- Insulation checker gas electronic model 601

3.2.2. Test Procedure

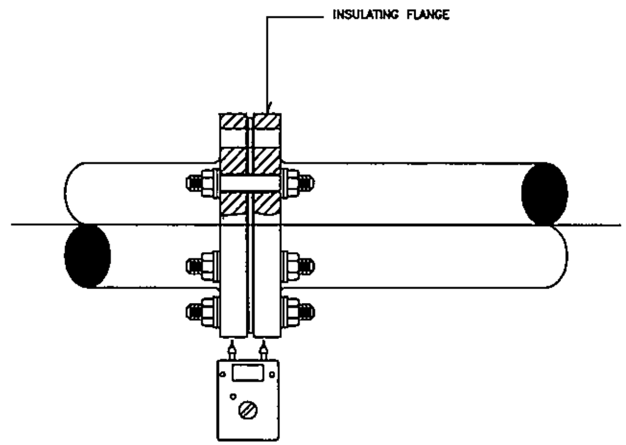
- Turn instrument "on" with the left hand toggle switch.
- Flip the right hand toggle switch to the "zero" position.
- Adjust potentiometer knob pointer is at "zero"
- Flip the right hand toggle switch to the "test" position (pointer will strong swing to the right pointer stop)
- Checking may be done by shorting across the probes with a screwdriver, knife, etc. this should show a direct short deflecting the pointer "zero" of below
- Make contact with each probe across the insulator in question the following results will be obtained;

If an insulator is shorted, the meter pointer will be deflected to or near to "zero" on the meter scale



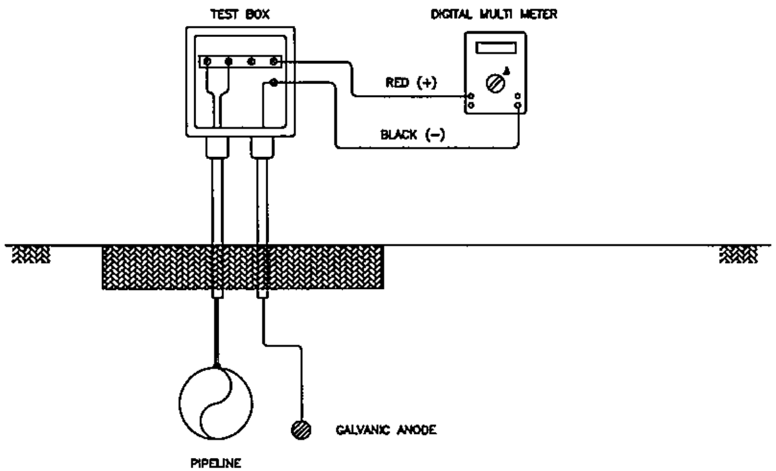
PIPE TO SOIL POTENTIAL MEASUREMENT

FIG.1



INSULATING FLANGE MEASUREMENT

FIG.2



DC CURRENT MEASUREMENT

FIG.3

REFERENCE DRAWINGS	MK	DATE	BY	APPROVED	REVISIONS

CPE Engineering and Service
CPE Engineering and Service Co.,Ltd.
154/980 Moo 1 Bangkruy-trinet Rd.
Pimolraj Bangbuathong Nonthaburi
PHONE / FAX : 0-8984-3084

FIGURE FOR TEST COMMISSIONING

DRAWN BY	CHECKED BY	ENGINEER	CERTIFIED
PPS	CCW	CCW	KCH
DATE	DATE	DATE	APPROVED
20/01/02	21/01/02	21/01/02	22/01/

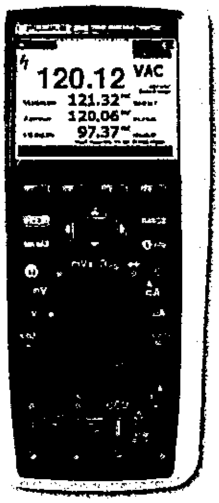
SCALE	PROJECT NO.	PAGE NO.	DRAWING NO.	REV.
NONE				0

FILES..\FIGURE MEASUREMENT

4. TEST INSTRUMENT AND CATALOGUE

4.1. Digital Multimeter Fluke 289
4.2. Cu/$CuSO_4$ and Ag/AgCl Reference Electrode
4.3. Insulation Checker Model 601

164/620 Moo 1, Soi Jamjuree 4, Bangkruy-Trinoy Rd., Pimolraj, Bangbuathong, Nondhaburi 11110
T. 0-2924-3024, 0-2924-9553-4 F. 0-2924-1744 / www.cpe-eng.co.th / e-mail : cpe@cpe-eng.co.th



Fluke 289 and 287 True-rms Logging Multimeters

Find little problems before they become big ones

The Fluke 289 and 287 are high performance industrial logging multimeters. The large 50,000 count, 1/4 VGA dot matrix display and multiple on screen displays give you sharp, clear readings. Use the logging function with expanded memory for unattended monitoring of signals over time. With on-board TrendCapture, you can graphically review up 10,000 recorded events and logged readings. Then, zoom on trend provides an unprecedented ability to zoom in up to 14 times to view and analyze data—all without needing a PC.

- Two terminal 50 ohm range with 1 milliohm resolution, 10 mA source current. Useful for measuring and comparing differences in motor winding resistance or contact resistance (289)
- Low-pass filter for accurate voltage and frequency measurements on adjustable speed motor drives and other electrically noisy equipment (289)
- Add the wireless data logging capabilities of Fluke Connect® with Share-Live™ video call with the if3000 FC connector
- True-rms ac bandwidth 100 kHz; dBV/dBm; dc mV resolution 1 µV; Megohm range up to 500 MΩ
- Conductance 50.00 nS
- Min/Max/Avg/duty cycle/pulse width
- Isolated optical DMM interface with USB PC connection
- Over 200 hours logging capacity with new power saving function
- Lo Ohm capability; Lo Z volts; Lo Pass Filter

Specifications

Functions	Range and resolution	Basic accuracy
AC or dc voltage	50.000 mV, 500.00 mV, 5.0000 V, 50.000 V, 500.00 V, 1000.0 V	0.025% 0.4% (true-rms) (ac)
AC current dc current	500.00 µA, 5000.0 µA, 50.000 mA, 400.00 mA, 5.0000 A, 10.000 A	0.15% 0.7% (true-rms)
Temperature (excluding probe)	-200.0 °C to 1350.0 °C (-328.0 °F to 2462.0 °F)	1.0%
Resistance	50.000 Ω, 500.00 Ω, 5.0000 kΩ, 50.000 kΩ, 500.00 kΩ, 5.0000 MΩ, 50.00 MΩ, 500.0 MΩ	0.05%
Capacitance	1.000 nF,10.00 nF, 100.0 nF, 1.000 µF, 10.00 µF, 100.0 µF, 1000 µF, 10.00 mF, 100 mF	1.0%
Frequency	99.999 Hz, 999.99 Hz, 9.9999 kHz, 99.999 kHz, 999.99 kHz	.005%

Ordering information

Models	Included accessories
FLUKE-289 True-rms Industrial Logging Multimeter with TrendCapture	Test leads, alligator clips, holster, AA batteries installed, information packet
FLUKE-287 True-rms Electronics Logging Multimeter with TrendCapture	Test leads, alligator clips, holster, AA batteries installed, information packet

FLUKE CONNECT®

Kits—buy more, save more

289/FVF True-rms Industrial Logging Multimeter Combo Kit with TrendCapture

Recommended accessories

TL175 TwistGuard™ Test Leads

ir3000 FC Connector

TECHNOLOGY PROMOTION ASSOCIATION (THAILAND-JAPAN)
CORPORATE SERVICES 3: EQUIPMENT CALIBRATION AND TESTING SERVICES
534/4 PATTANAKARN ROAD SOI 18, SUANLUANG, SUANLUANG, BANGKOK 10250
TEL. 0-2717-3000-24 FAX. 0-2719-9484

ilac-MRA

NSC-TISI-TIS17025
CALIBRATION 0008

Certificate of Calibration

Certificate No. : 22E810

Equipment : True RMS Multimeter
Manufacturer: Fluke
Model : 289
Serial No.: 19880078
ID No.: -
Condition As-Received: Used Item
Received Date: 02 March 2022
Calibration Date: 07 March 2022

Reference: 2203-0114WN
Ambient Temperature: (23 ± 2) °C
Relative Humidity: (50 ± 10) %

Submitted by: CPE Engineering and Service Co., Ltd.
164/620 Moo 1 Bangkruy-Sainoi Rd., Pimonraj,
Bangbuathong, Nonthaburi 11110

Procedure used: Calibration were conducted using In-house calibration Procedure CP-E15, E16, E17, E18, E19, E24 According to direct measurement method with Multi-Product Calibrator and calibrated by direct measurement method with Synthesized Function Generator for Frequency function.

Condition of this result of calibration

1.Reference standards instuments :

Instrument	Model	Serial No.	Certificate No.	Due Date
1) Synthesized Function Generator	FG110	27XW0013A	EF-0001-22	13 Jan 2023
2) Multi-Product Calibrator	5500A	6440007	21E1444	07 May 2022

2.This result of calibration was made on requested at the point specified by customer.

3.The certificate is valid only to the item calibrated on date and place of calibration.

4.This Certification is traceable to the International System of Unit maintained at:-

-National Institute of Metrology Thailand (NIMT)

Calibrated by : Nuntawat Khamchai
Issue Date : 09 March 2022

Approved Signatory :
[✓] Phalinee Prabpaipal
[ ] Nuntawat Khamchai
[ ] Pornthippa Tameyakul

B 0283091

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : DC voltage measurement **Range :** 50 mV

Standard Value (mV)	UUC* Reading (mV)	Error (mV)	Uncertainty (± µV)
-45.0000	-45.001	-0.001	6.9
0.0000	0.002	0.002	3.7
45.0000	45.005	0.005	6.9

Function : DC voltage measurement **Range :** 500 mV

Standard Value (mV)	UUC* Reading (mV)	Error (mV)	Uncertainty (± µV)
-450.000	-450.02	-0.02	35
0.0000	-0.01	-0.01	6.9
450.000	450.00	0.00	35

Function : DC voltage measurement **Range :** 5 V

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± mV)
-4.50000	-4.4999	0.0001	0.35
0.00000	-0.0001	-0.0001	0.058
4.50000	4.4998	-0.0002	0.35

Function : DC voltage measurement **Range :** 50 V

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± mV)
-45.0000	-44.997	0.003	3.7
0.0000	0.001	0.001	0.58
45.0000	44.999	-0.001	3.7

Function : DC voltage measurement **Range :** 500 V

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± mV)
-450.000	-449.97	0.03	35
0.0000	0.01	0.01	5.8
450.000	449.98	-0.02	35

UUC* = Unit Under Calibration.

a 1098605

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : DC voltage measurement **Range :** 1000 V

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± V)
-900.000	-899.7	0.3	0.12
0.0000	0.0	0.0	0.058
900.000	899.8	-0.2	0.12

Function : AC voltage measurement **Range :** 50 mV @ 60 Hz

Standard Value (mV)	UUC* Reading (mV)	Error (mV)	Uncertainty (± µV)
5.000	5.012	0.012	33
45.000	45.074	0.074	51

Function : AC voltage measurement **Range :** 500 mV @ 60 Hz

Standard Value (mV)	UUC* Reading (mV)	Error (mV)	Uncertainty (± mV)
50.000	50.11	0.11	0.053
450.000	450.77	0.77	0.23

Function : AC voltage measurement **Range :** 5 V @ 50 Hz

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± mV)
0.50000	0.5015	0.0015	0.27
4.5000	4.5095	0.0095	2.8

Function : AC voltage measurement **Range :** 50 V @ 50 Hz

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± mV)
5.0000	5.014	0.014	3.3
45.000	45.093	0.093	34

Function : AC voltage measurement **Range :** 500 V @ 50 Hz

Standard Value (V)	UUC* Reading (V)	Error (V)	Uncertainty (± V)
50.000	50.16	0.16	0.037
450.00	450.78	0.78	0.36

UUC* = Unit Under Calibration.

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Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : AC voltage measurement **Range :** 1000 V @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(V)	(V)	(V)	(± V)
100.000	100.2	0.2	0.12
900.00	901.5	1.5	0.63

Function : DC current measurement **Range :** 500 µA

Standard Value	UUC* Reading	Error	Uncertainty
(µA)	(µA)	(µA)	(± µA)
Open	0.00	0.00	0.0058
450.00	449.98	-0.02	0.13

Function : DC current measurement **Range :** 5000 µA

Standard Value	UUC* Reading	Error	Uncertainty
(µA)	(µA)	(µA)	(± µA)
Open	0.0	0.0	0.058
4500.0	4499.7	-0.3	0.84

Function : DC current measurement **Range :** 50 mA

Standard Value	UUC* Reading	Error	Uncertainty
(mA)	(mA)	(mA)	(± µA)
Open	0.000	0.000	0.58
45.000	45.143	0.143	9.4

Function : DC current measurement **Range :** 400 mA

Standard Value	UUC* Reading	Error	Uncertainty
(mA)	(mA)	(mA)	(± mA)
Open	0.00	0.00	0.0058
360.00	360.99	0.99	0.18

Function : DC current measurement **Range :** 5 A

Standard Value	UUC* Reading	Error	Uncertainty
(A)	(A)	(A)	(± mA)
Open	0.0000	0.0000	0.058
4.5000	4.4986	-0.0014	3.6

UUC* = Unit Under Calibration.

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : DC current measurement **Range :** 10 A

Standard Value	UUC* Reading	Error	Uncertainty
(A)	(A)	(A)	(± mA)
Open	0.000	0.000	0.58
9.0000	8.998	-0.002	7.0

Function : AC current measurement **Range :** 500 µA @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(µA)	(µA)	(µA)	(± µA)
50.00	50.10	0.10	0.37
450.00	450.51	0.51	0.90

Function : AC current measurement **Range :** 5000 µA @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(µA)	(µA)	(µA)	(± µA)
500.00	501.2	1.2	0.96
4500.0	4509.5	9.5	8.2

Function : AC current measurement **Range :** 50 mA @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(mA)	(mA)	(mA)	(± µA)
5.0000	5.029	0.029	8.8
45.000	45.190	0.190	82

Function : AC current measurement **Range :** 400 mA @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(mA)	(mA)	(mA)	(± mA)
40.000	40.22	0.22	0.077
360.00	361.99	1.99	0.80

Function : AC current measurement **Range :** 5 A @ 50 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(A)	(A)	(A)	(± mA)
0.50000	0.5013	0.0013	0.96
4.5000	4.5021	0.0021	5.6

UUC* = Unit Under Calibration.

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : AC current measurement **Range :** 10 A @ 50 Hz

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(A)	(A)	(A)	(± mA)
1.00000	1.013	0.013	1.9
9.0000	9.012	0.012	8.7

Function : Resistance measurement **Range :** 500 Ω

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(Ω)	(Ω)	(Ω)	(± Ω)
Short	0.00	0.00	0.0058
450.00	449.88	-0.12	0.12

Function : Resistance measurement **Range :** 5 kΩ

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(kΩ)	(kΩ)	(kΩ)	(± Ω)
Short	0.0000	0.0000	0.058
4.5000	4.4998	-0.0002	1.2

Function : Resistance measurement **Range :** 50 kΩ

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(kΩ)	(kΩ)	(kΩ)	(± Ω)
Short	0.000	0.000	0.58
45.000	44.990	-0.010	13

Function : Resistance measurement **Range :** 500 kΩ

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(kΩ)	(kΩ)	(kΩ)	(± kΩ)
Short	0.00	0.00	0.0058
450.00	449.65	-0.35	0.15

Function : Resistance measurement **Range :** 5 MΩ

Standard Value	**UUC* Reading**	**Error**	**Uncertainty**
(MΩ)	(MΩ)	(MΩ)	(± kΩ)
Short	0.0000	0.0000	0.058
4.5000	4.4953	-0.0047	3.8

UUC* = Unit Under Calibration.

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Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : Resistance measurement **Range :** 30 MΩ

Standard Value (MΩ)	UUC* Reading (MΩ)	Error (MΩ)	Uncertainty (± MΩ)
Short	0.000	0.000	0.00058
27.0000	26.950	-0.050	0.17

Function : Resistance measurement **Range :** 50 MΩ

Standard Value (MΩ)	UUC* Reading (MΩ)	Error (MΩ)	Uncertainty (± MΩ)
Short	0.00	0.00	0.0058
45.0000	44.91	-0.09	0.27

Function : Resistance measurement **Range :** 500 MΩ

Standard Value (MΩ)	UUC* Reading (MΩ)	Error (MΩ)	Uncertainty (± MΩ)
Short	0.0	0.0	0.058
330.000	326.1	-3.9	2.0

Function : Capacitance measurement **Range :** 1 nF

Standard Value (nF)	UUC* Reading (nF)	Error (nF)	Uncertainty (± pF)
0.5000	0.507	0.007	61
0.9000	0.908	0.008	64

Function : Capacitance measurement **Range :** 10 nF

Standard Value (nF)	UUC* Reading (nF)	Error (nF)	Uncertainty (± pF)
1.0000	1.02	0.02	64
9.000	9.01	0.01	66

Function : Capacitance measurement **Range :** 100 nF

Standard Value (nF)	UUC* Reading (nF)	Error (nF)	Uncertainty (± nF)
10.000	10.0	0.0	0.12
90.00	89.9	-0.1	0.40

UUC* = Unit Under Calibration.

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : Capacitance measurement **Range :** 1 μF

Standard Value	UUC* Reading	Error	Uncertainty
(μF)	(μF)	(μF)	(± nF)
0.10000	0.100	0.000	0.88
0.9000	0.900	0.000	4.0

Function : Capacitance measurement **Range :** 10 μF

Standard Value	UUC* Reading	Error	Uncertainty
(μF)	(μF)	(μF)	(± nF)
1.0000	1.00	0.00	8.8
9.000	9.00	0.00	50

Function : Capacitance measurement **Range :** 100 μF

Standard Value	UUC* Reading	Error	Uncertainty
(μF)	(μF)	(μF)	(± μF)
10.000	10.0	0.0	0.10
90.00	89.9	-0.1	0.66

Function : Capacitance measurement **Range :** 1000 μF

Standard Value	UUC* Reading	Error	Uncertainty
(μF)	(μF)	(μF)	(± μF)
100.00	100	0	1.2
900.0	898	-2	12

Function : Frequency measurement # **Range :** 99.999 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(Hz)	(Hz)	(Hz)	(± mHz)
10.000000	10.000	0.000	0.58
90.000000	89.999	-0.001	0.58

Function : Frequency measurement **Range :** 999.99 Hz

Standard Value	UUC* Reading	Error	Uncertainty
(Hz)	(Hz)	(Hz)	(± mHz)
100.000000	100.00	0.00	5.8
900.000000	899.99	-0.01	5.8

UUC* = Unit Under Calibration.

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Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : Frequency measurement **Range :** 9.9999 kHz

Standard Value (kHz)	UUC* Reading (kHz)	Error (kHz)	Uncertainty (± mHz)
1.000000	1.0000	0.0000	58
9.000000	8.9999	-0.0001	58

Function : Frequency measurement **Range :** 99.999 kHz

Standard Value (kHz)	UUC* Reading (kHz)	Error (kHz)	Uncertainty (± Hz)
10.000000	10.000	0.000	0.58
90.000000	89.999	-0.001	0.58

Function : Frequency measurement **Range :** 999.99 kHz

Standard Value (kHz)	UUC* Reading (kHz)	Error (kHz)	Uncertainty (± Hz)
100.000000	100.00	0.00	5.8
900.000000	899.99	-0.01	5.8

The reported uncertainty of measurement was based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %

UUC* = Unit Under Calibration.

 # Not NSC-ONSC Accredited.

Remark : The Calibration result include test lead resistance offset and user shall concern test lead resistance offset compensation.

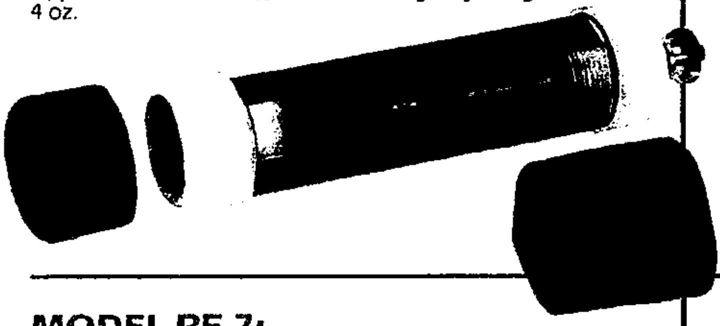
-o0o-

The MCM Line of Electrodes

CPE Engineering and Service

MODEL RE-5:

Standard Model. Flat CPT Porous Plug, for general use in soil and (with Submersible Adapter) for use in water. Approx. Overall Size: 1 3/8" dia. X 6" long. Dry Weight: 4 oz.



MODEL RE-5C:

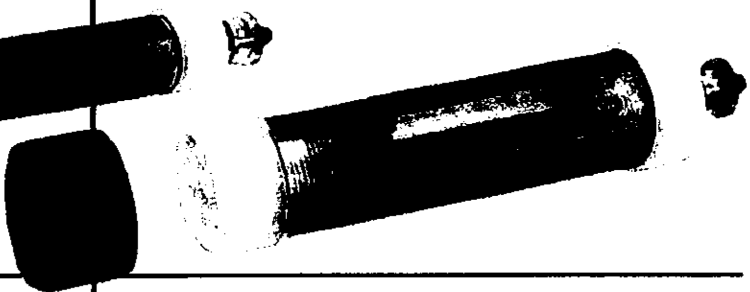
Similar to Model RE-5 **except** supplied with a cone-shaped CPT porous plug. For use in soft soils. Provides lower contact resistance. When pushed into soft soils the shape of the plug helps the electrode to "stand up". Approx. Overall Size: 1 3/8" dia. X 6 3/4" long. Dry Weight: 5 oz.

MODEL RE-7:

Long, slim model with beveled CPT porous plug. For general purpose use in soil or in a 1" diameter augered hole in pavement. Approx. Overall Size: 1" dia. X 8 1/2" long. Dry Weight: 5 oz.

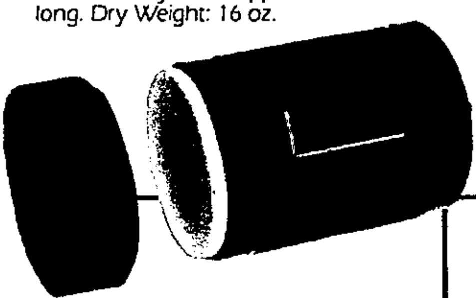
MODEL RE-5/U:

For use on underside of bridge decks, parking garages, etc. in upside-down position.



MODEL RE-3A:

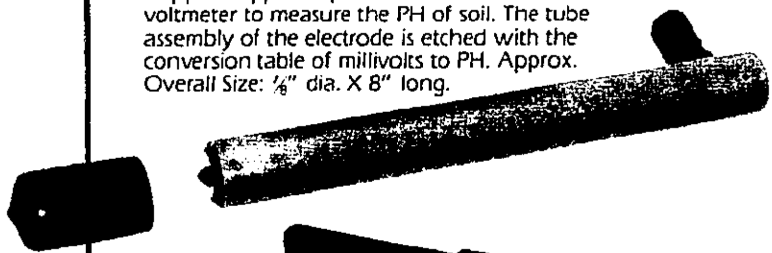
Large diameter (3") flat CPT porous plug provides greater contact area. Flat plug provides lower contact resistance than rounded or serrated plug when placed in direct contact with flat surfaces. Especially useful on pavements, dry sand, frozen soil, etc. Stands by itself. Approx. Overall Size: 3" dia. X 5" long. Dry Weight: 16 oz.



MODEL PH-50:

Antimony Reference Electrode

Antimony electrode used in conjunction with a Copper/Copper Sulphate reference electrode and voltmeter to measure the PH of soil. The tube assembly of the electrode is etched with the conversion table of millivolts to PH. Approx. Overall Size: 7/8" dia. X 8" long.

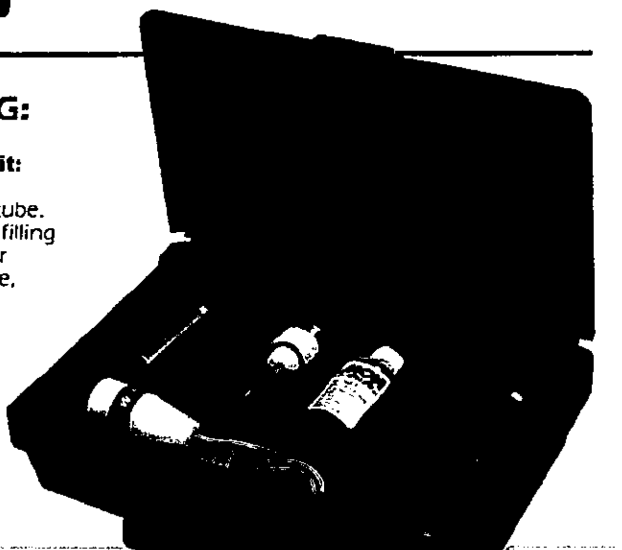


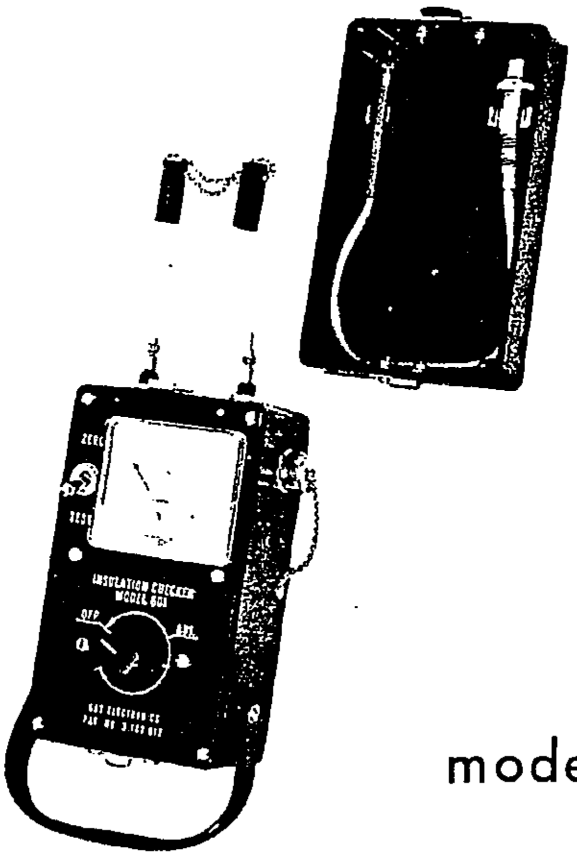
All copper sulphate electrodes are shipped dry, but include a charge of high-purity copper sulphate crystals. A protective cap for the CPT porous plug is also supplied. Special lengths of RE-5, RE-5C and RE-7 are available on order. Use and Maintenance Instructions furnished with each electrode.

MODEL RE-7AG:

Silver/Silver Chloride Reference Electrode Kit: Land/Sea

Used on land with Lexan tube. CPT ceramic plug and KCL filling solution. Used in sea water with perforated Lexan tube, brass submersible weights (any number of weights can be attached together; two included in kit) and standard 8' submersible adapter (available in additional lengths).





CPE Engineering and Service

Thru Modern Technology

GAS ELECTRONICS

presents a UNIQUE PATENTED Corrosion Test Instrument, utilizing Radio Frequency skin-effect to perform 100% accurate insulation tests on all types of insulators.

model 601

INSULATION CHECKER

- ❋ CHECKS ALL TYPES AND SIZES OF INSULATORS

  Flanges, Dressers, Couplings, Unions, whether parallel or in series.

- ❋ LOCATES SHORTED BOLTS

  Eliminates costly and unnecessary replacement of good bolt insulators.

- ❋ EVALUATES PARTIALLY SHORTED INSULATORS

  Measures the degree and seriousness of short.

- ❋ SIMPLE TO OPERATE

  Simplified operation procedure reduces training time to 10 minutes, following step by step instruction sheet.

- ❋ QUICK--

  Fast "touch probe" operation eliminates guesswork and additional wires, coils, etc.

Built to provide years of dependable service, this precision instrument is light, compact, and housed in a rugged case 3 3/4 x 6 1/4 x 3 1/4, providing adequate protection under all normal field conditions. Operates on 2 C Cells.

TECHNOLOGY PROMOTION ASSOCIATION (THAILAND-JAPAN)
CORPORATE SERVICES 3: EQUIPMENT CALIBRATION AND TESTING SERVICES
534/4 PATTANAKARN ROAD SOI 18, SUANLUANG, SUANLUANG, BANGKOK 10250
TEL. 0-2717-3000-24 FAX. 0-2719-9484

NSC-TISI-TIS17025
CALIBRATION 0008

Certificate of Calibration

Certificate No. : 22E811

Equipment :	Insulation Checker
Manufacturer:	MC MILLER
Model :	601
Serial No.:	5806
ID No.:	-
Condition As-Received:	Used Item
Received Date:	02 March 2022
Calibration Date:	07 March 2022
Reference:	2203-0114WN
Ambient Temperature:	(23 ± 2) °C
Relative Humidity:	(50 ± 10) %

Submitted by: CPE Engineering and Service Co., Ltd.

164/620 Moo 1 Bangkruy-Sainoi Rd., Pimonraj,
Bangbuathong, Nonthaburi 11110

Procedure used: Calibration were conducted using in-house calibration Procedure CP-E19 According to direct measurement method with Multi-Product Calibrator.

Condition of this result of calibration

1.Reference standards instuments :

Instrument	Model	Serial No.	Certificate No.	Due Date
1) Multi-Product Calibrator	5500A	6440007	21E1444	07 May 2022

2.This result of calibration was made on requested at the point specified by customer.

3.The certificate is valid only to the item calibrated on date and place of calibration.

4.This Certification is traceable to the International System of Unit maintained at:-

-National Institute of Metrology Thailand (NIMT)

Calibrated by : Nuntawat Khamchai
Issue Date : 09 March 2022

Approved Signatory :

[/] Phalinee Prabpaipal
[ ] Nuntawat Khamchai
[ ] Pornthippa Tameyakul

B 0283092

Result of calibration :- (*) Whithout adjustment ( ) After adjustment

Function : DC current measurement **Range :** 1.0 mA

UUC* Reading (mA)	**Standard Value** (mA)	**Error** (mA)	**Uncertainty** (± µA)
0	-	-	-
0.2	0.19400	0.00600	0.090
0.4	0.39300	0.00700	0.12
0.6	0.59300	0.00700	0.15
0.8	0.80300	-0.00300	0.18
1.0	1.03000	-0.03000	0.21

The reported uncertainty of measurement was based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %

UUC* = Unit Under Calibration.

-o0o-

a 1098924

5. DATA RECORD SHEET

5.1. Data Record Sheet No. 1 Cathodic Protection Pipe to Soil/Sea Water Potential Measurement

5.2. Data Record Sheet No. 2 Cathodic Protection Insulation Flange Check

Data Record Sheet No.1

CATHODIC PROTECTION
PIPE TO SOIL POTENTIAL MEASUREMENT

TEST INSTRUMENT : *$Cu/CuSO_4$ Reference Electrode*
: *Ag/AgCl Reference Electrode*
: *Digital Multimeter*

NACE Standard SP0169 criterion#1 "Potential more negative than -0.850 V vs. $Cu/CuSO_4$ and -0.800 V vs. Ag/AgCl with CP applied"

Pipe to Soil/Sea Water Potential Measurement (Vdc)							
Station No.	$Cu/CuSO_4$ Ref.				Ag/AgCl Ref.		Remarks
	On Shore Rack		Middle Line Island		Loading Jetty		
	GPS Datum : WGS84		GPS Datum : WGS84		GPS Datum : WGS84		
	North	East	North	East	North	East	
	7.23968	100.55970	7.23610	100.56683	7.23713	100.56520	
	P/S	Accept?	P/S	Accept?	P/SW	Accept?	
Dia. 8", FW	-0.857	Yes	-1.049	Yes	-0.969	Yes	Primus Liner / Diesel & Mogas Shell
Dia. 8", Diesel	-0.857	Yes	-1.005	Yes	-0.969	Yes	
Dia. 8", Mogas	-0.865	Yes	-1.048	Yes	-0.967	Yes	Diesel Liner / Mogas Chevron & Esso
Dia. 8", Blind Flange	-0.857	Yes	-1.029	Yes	-0.970	Yes	not used

Note/Comment :

	Test By	Witness By	Acceptance By
Company	*CPE*	*New Star*	*Chevron*
Name	L.Salatan		
Title	Engineer		
Signature			
Date	14 July 2022		

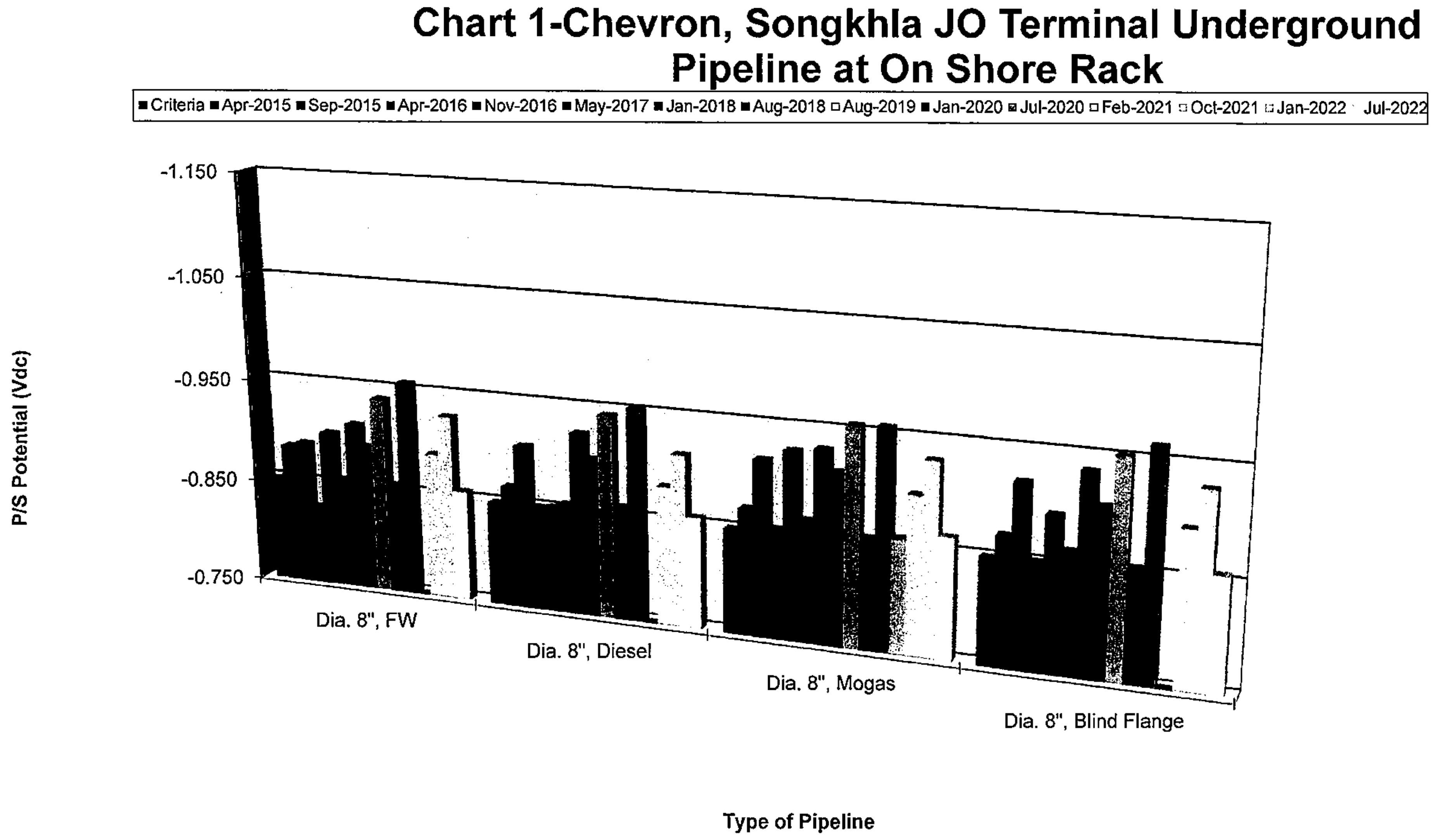
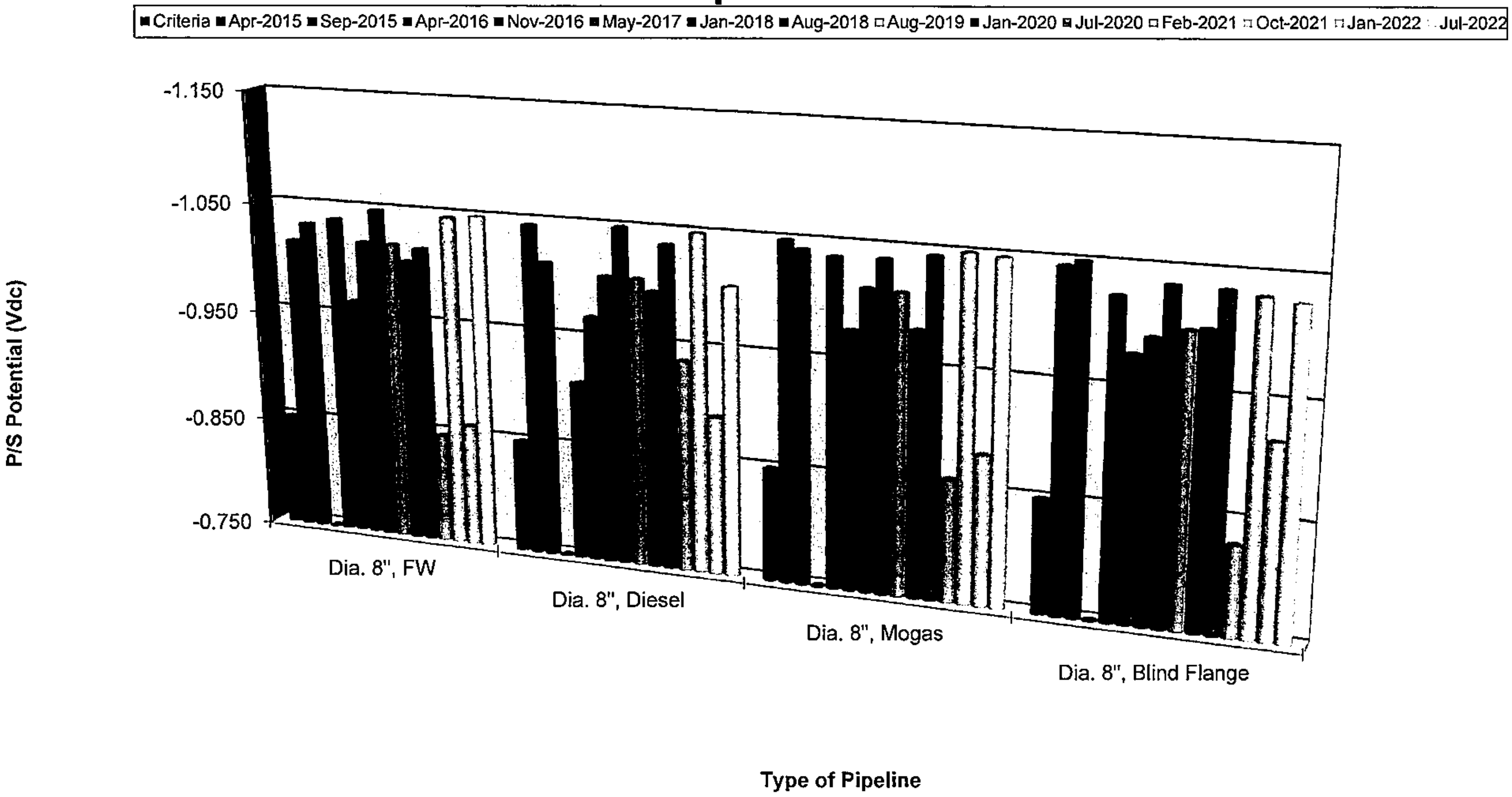


Chart 1-Chevron, Songkhla JO Terminal Underground Pipeline at On Shore Rack
Criteria
Apr-2015
Sep-2015
Apr-2016
Nov-2016
May-2017
Jan-2018
Aug-2018
Aug-2019
Jan-2020
Jul-2020
Feb-2021
Oct-2021
Jan-2022
Jul-2022
-1.150
-1.050
-0.950
-0.850
-0.750
P/S Potential (Vdc)
Dia. 8", FW
Dia. 8", Diesel
Dia. 8", Mogas
Dia. 8", Blind Flange
Type of Pipeline

Chart 2-Chevron, Songkhla JO Terminal Underground Pipeline at Middle Line Island



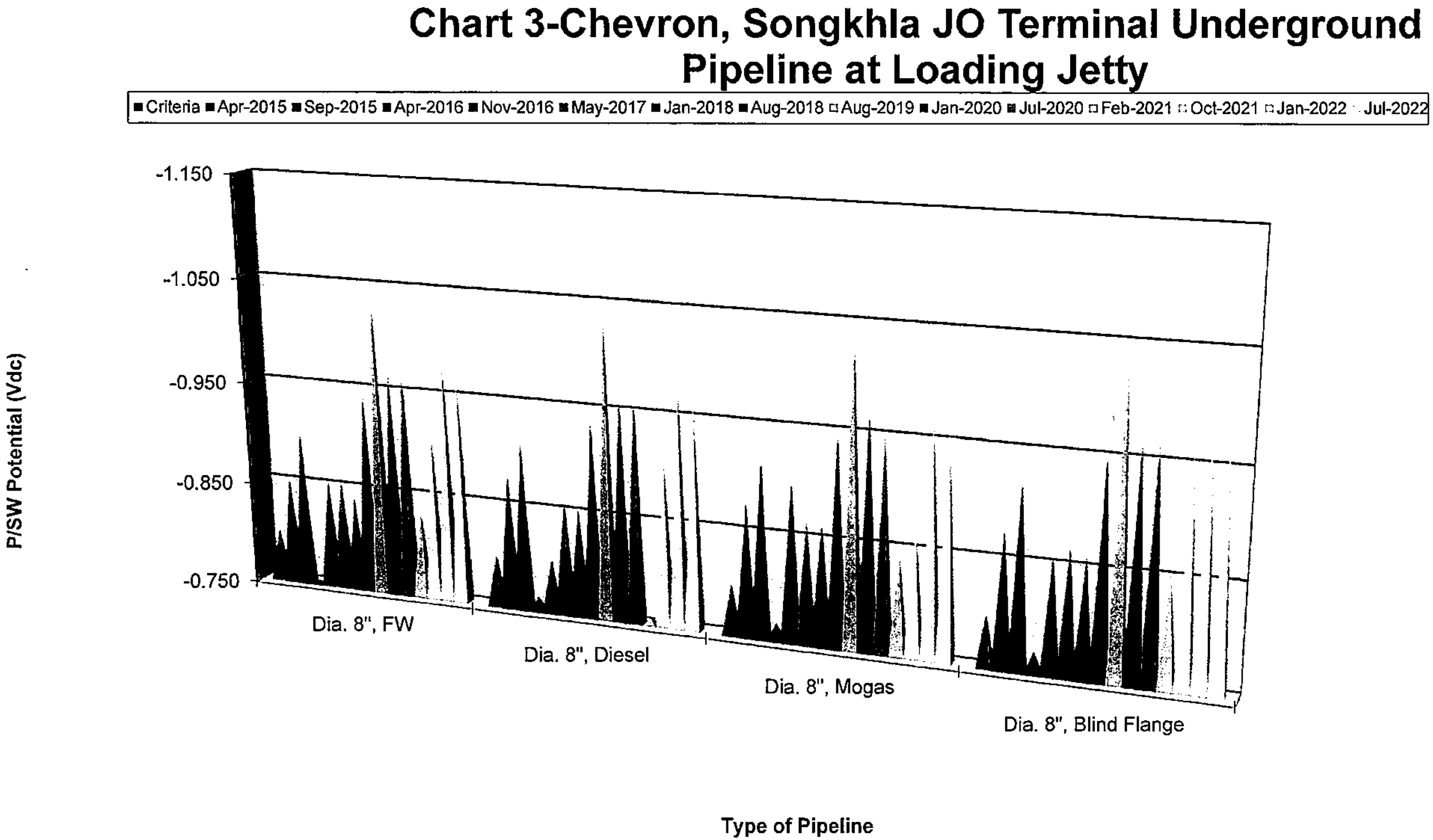


Chart 3-Chevron, Songkhla JO Terminal Underground Pipeline at Loading Jetty
Criteria
Apr-2015
Sep-2015
Apr-2016
Nov-2016
May-2017
Jan-2018
Aug-2018
Aug-2019
Jan-2020
Jul-2020
Feb-2021
Oct-2021
Jan-2022
Jul-2022
-1.150
-1.050
-0.950
-0.850
-0.750
P/SW Potential (Vdc)
Dia. 8", FW
Dia. 8", Diesel
Dia. 8", Mogas
Dia. 8", Blind Flange
Type of Pipeline

Data Record Sheet No.2

CATHODIC PROTECTION
INSULATION FLANGE CHECK

TEST INSTRUMENT *: Insulation Checker Model 601*

Insulation Flange Check						
IF Tag No.	**% insulation (by checker)**	**Can isolate?**	**P/S or P/Sea water**		**Spark Gap**	**Remarks**
			U/G side	**A/G side**		
On Shore Rack						
Dia. 8", FW	100%	Yes	-0.857	-0.421	Ok	
Dia. 8", Diesel	100%	Yes	-0.857	-0.428	Ok	Primus Liner / Diesel & Mogas Shell
Dia. 8", Mogas	100%	Yes	-0.865	-0.420	Ok	Diesel Liner / Mogas Chevron & Esso
Dia. 8", Blind Flange	blind flange (no I/F)	-	-0.857		-	not used
Loading Jetty						
Dia. 8", FW	100%	Yes	-0.964	-0.733	Ok	
Dia. 8", Diesel	100%	Yes	-0.969	-0.744	Ok	Primus Liner / Diesel & Mogas Shell
Dia. 8", Mogas	100%	Yes	-0.967	-0.969	Ok	Diesel Liner / Mogas Chevron & Esso
Dia. 8", Blind Flange	100%	Yes	-0.970	-0.742	Ok	not used
Static at Loading Jetty						
Dia. 8", Diesel	100%	Yes	-0.824	-0.742	-	Primus Liner / Diesel & Mogas Shell
Dia. 8", Mogas	100%	Yes	-1.071	-0.929	-	Diesel Liner / Mogas Chevron & Esso
Dia. 8", Blind Flange	100%	Yes	-0.686	-0.745	-	not used

Note/Comment :

	Test By	Witness By	Acceptance By
Company	*CPE*	*New Star*	*Chevron*
Name	L.Salatan		
Title	Engineer		
Signature			
Date	14 July 2022		

6. CONCLUSION

Refer to Data Sheet No.1 and No.2, we can conclude that

<u>**On Shore Rack (Depot)**</u>

-Pipe to Soil Potentiall Measurement

Pipe to soil potential for all pipes is more negative than criteria.

<u>It is acceptable.</u>

-Insulation Flange Kit Check

All insulation flanges can completely electrically isolate.

<u>**Middle Line Island**</u>

-Pipe to Soil Potential Measurement

Pipe to soil potential for all pipes is more negative than criteria.

<u>It is acceptable.</u>

<u>**Loading Jetty**</u>

-Pipe to Sea Water Potential Measurement

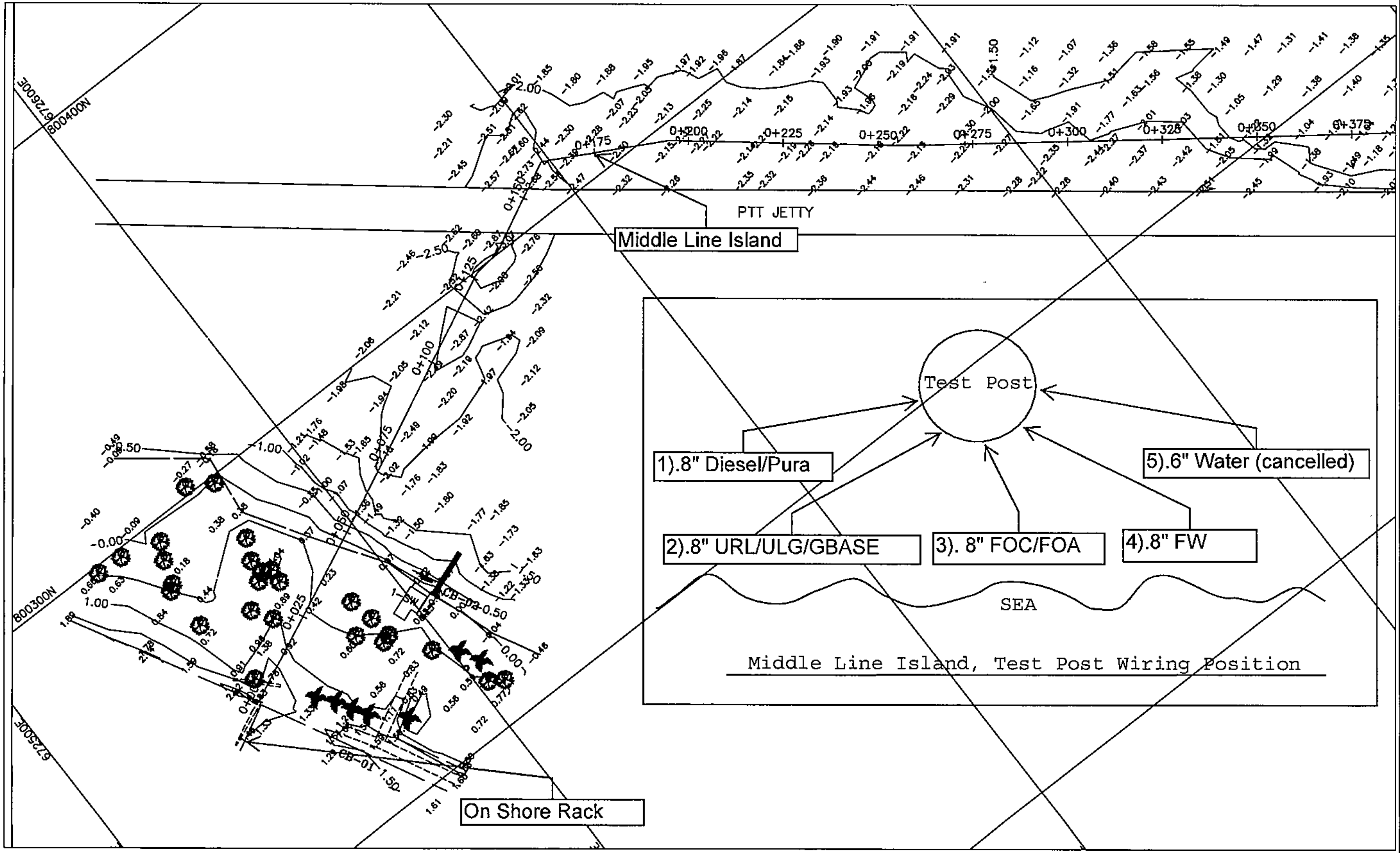
Pipe to soil potential for all pipes is more negative than criteria.

<u>It is acceptable.</u>

-Insulation Flange Kit Check

All insulation flanges can completely electrically isolate.

7. PIPELINE LAY OUT



REFERENCE DRAWING	REVISION	DESCRIPTION	DATE
		REVISION RECORD	
	0	ISSUE FOR REVIEW	18/07/05

CPE Engineering and Service

CPE Engineering and Service Co.,Ltd.
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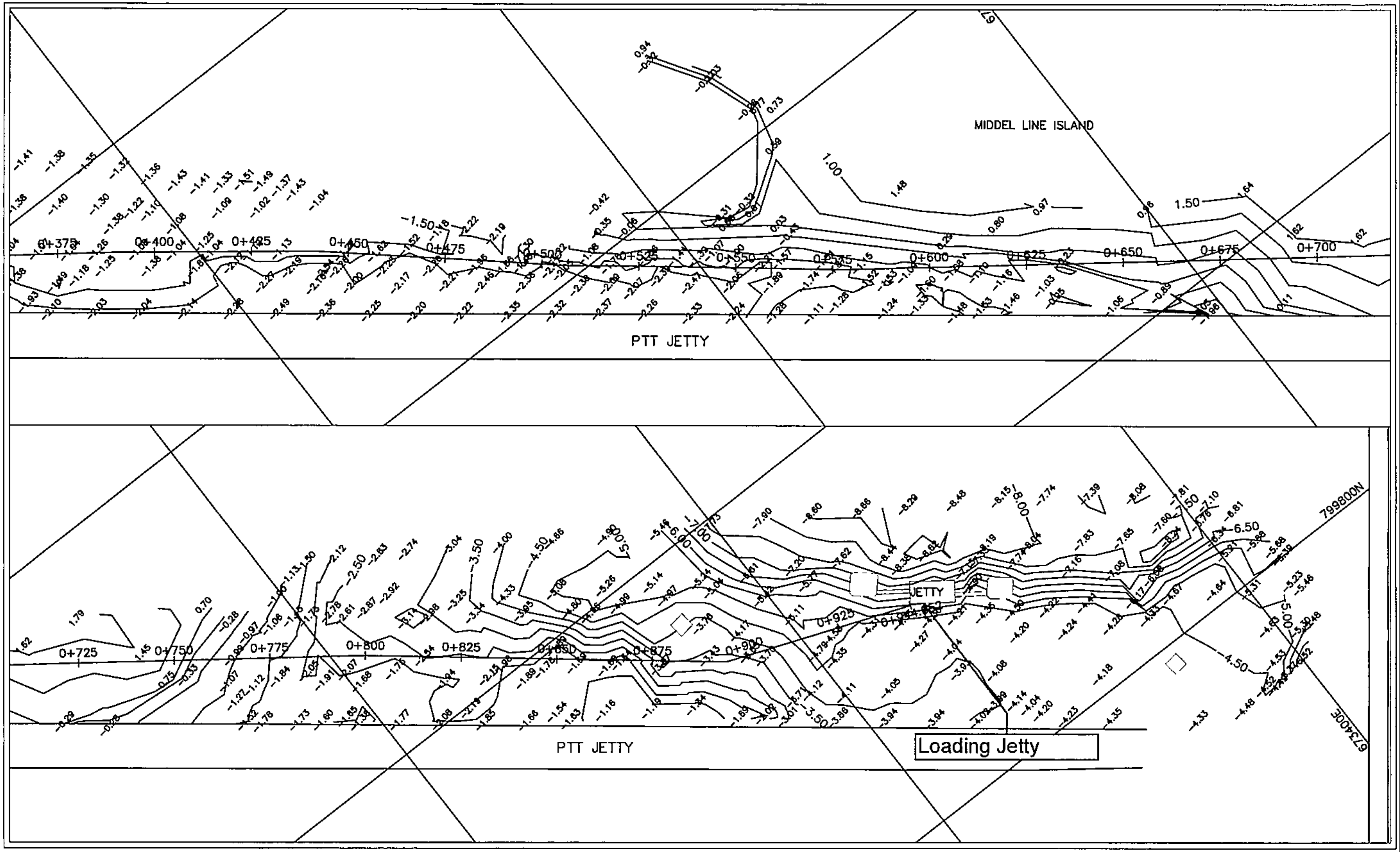
DRAW BY	CHECKED BY	ENGINEER	CERTIFIED
KRU	KVA	SPO	KCH
DATE 18/07/05	DATE 18/07/05	DATE 18/07/05	DATE 18/07/05

TITLE : CATHODIC PROTECTION
SONGKLA JV TERMINAL
SUBMARINE PIPELINE LAY-OUT

SCALE	PROJ. NO.	PAGE NO.	DRAWING NO.	REV.
N/A		01/02		0



REFERENCE DRAWING	REVISION RECORD		
	REVISION	DESCRIPTION	DATE
	0	ISSUE FOR REVIEW	18/07/05

CPE Engineering and Service

CPE Engineering and Service Co.,Ltd.
184/620 Moo.1 Bangkruy-Trinoi Rd., Pimolraj,
Bangbuathong Nondraburi. 11110
Tel.: 0-2924-3024, 0-2924-9553-4
Fax.: 0-2924-1744

DRAW BY	CHECKED BY	ENGINEER	CERTIFIED
KRU	KVA	SPO	KCH
DATE 18/07/05	DATE 18/07/05	DATE 18/07/05	DATE 18/07/05

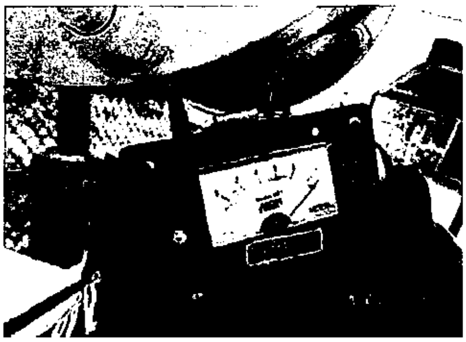
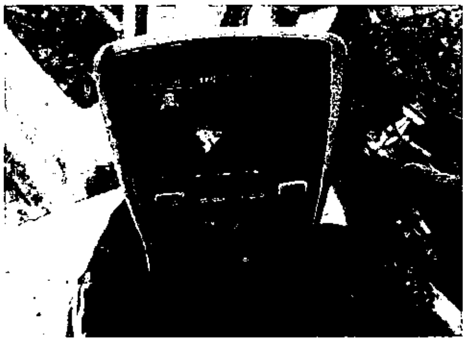
TITLE : CATHODIC PROTECTION

SONGKLA JV TERMINAL

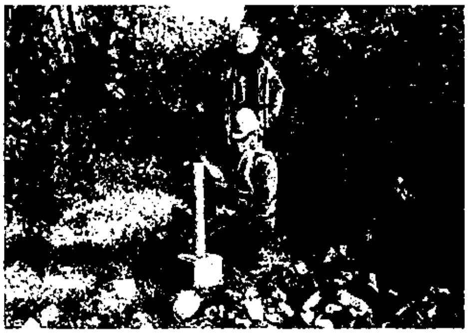
SUBMARINE PIPELINE LAY-OUT

SCALE	PROJ. NO.	PAGE NO.	DRAWING NO.	REV.
N/A		02/02		0

8. PHOTOGRAPH

On shore rack (Depot)

Middle line island


Loading jetty

9. APPENDIX

- **NACE SP0169-2007** Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- **NACE SP0286-2007** Electrical Isolation of Cathodically Protected Pipelines

NACE INTERNATIONAL

NACE SP0169-2007
(formerly RP0169-2002)
Item No. 21001

Standard Practice

Control of External Corrosion on Underground or Submerged Metallic Piping Systems

Reaffirmed 2007-03-15
Reaffirmed 2002-04-11
Reaffirmed 1996-09-13
Revised April 1992
Revised January 1983
Revised September 1976
Revised January 1972
Approved April 1969
NACE International
1440 South Creek Drive
Houston, Texas 77084-4906
+1 281/228-6200
ISBN 1-57590-035-1

Foreword

This standard practice presents procedures and practices for achieving effective control of external corrosion on buried or submerged metallic piping systems. These recommendations are also applicable to many other buried or submerged metallic structures. It is intended for use by corrosion control personnel concerned with the corrosion of buried or submerged piping systems, including oil, gas, water, and similar structures. This standard describes the use of electrically insulating coatings, electrical isolation, and cathodic protection (CP) as external corrosion control methods. It contains specific provisions for the application of CP to existing bare, existing coated, and new piping systems. Also included are procedures for control of interference currents on pipelines.

This standard should be used in conjunction with the practices described in the following NACE standards and publications, when appropriate (use latest revisions):

SP0572[1] RP0177[2] RP0285[3] SP0186[4] SP0286[5] SP0387[6] SP0188[7] TPC 11[8] TM0497[9]

For accurate and correct application of this standard, the standard must be used in its entirety. Using or citing only specific paragraphs or sections can lead to misinterpretation and misapplication of the recommendations and practices contained in this standard.

This standard does not designate practices for every specific situation because of the complexity of conditions to which buried or submerged piping systems are exposed.

This standard was originally published in 1969, and was revised by NACE Task Group (TG) T-10-1 in 1972, 1976, 1983, and 1992. It was reaffirmed in 1996 by NACE Unit Committee T-10A on Cathodic Protection, and in 2002 and 2007 by Specific Technology Group (STG) 35 on Pipelines, Tanks, and Well Casings. This standard is issued by NACE International under the auspices of STG 35, which is composed of corrosion control personnel from oil and gas transmission companies, gas distribution companies, power companies, corrosion consultants, and others concerned with external corrosion control of buried or submerged metallic piping systems.

In NACE standards, the terms *shall*, *must*, *should*, and may are used in accordance with the definitions of these terms in the NACE Publications Style Manual, 4th ed., Paragraph 7.4.1.9. *Shall* and *must* are used to state mandatory requirements. The term should is used to state something considered good and is recommended but is not mandatory. The term may is used to state something considered optional.

NACE International
Standard Practice

Control of External Corrosion on Underground or Submerged Metallic Piping Systems

Contents

Section 1: General

1.1 This standard presents acknowledged practices for the control of external corrosion on buried or submerged steel, cast iron, ductile iron, copper, and aluminum piping systems.

1.2 This standard is intended to serve as a guide for establishing minimum requirements for control of external corrosion on the following systems:

1.2.1 New piping systems: Corrosion control by a coating supplemented with CP, or by some other proven method, should be provided in the initial design and maintained during the service life of the piping system, unless investigations indicate that corrosion control is not required. Consideration should be given to the construction of pipelines in a manner that facilitates the use of in-line inspection tools.

1.2.2 Existing coated piping systems: CP should be provided and maintained, unless investigations indicate that CP is not required.

1.2.3 Existing bare piping systems: Studies should be made to determine the extent and rate of corrosion on existing bare piping systems. When these studies indicate that corrosion will affect the safe or economic operation of the system, adequate corrosion control measures shall be taken.

1.3 The provisions of this standard should be applied under the direction of competent persons who, by reason of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by education and related practical experience, are qualified to engage in the practice of corrosion control on buried or submerged metallic piping systems. Such persons may be registered professional engineers or persons recognized as corrosion specialists or CP specialists by NACE if their professional activities include suitable experience in external corrosion control of buried or submerged metallic piping systems.

1.4 Special conditions in which CP is ineffective or only partially effective sometimes exist. Such conditions may include elevated temperatures, disbonded coatings, thermal insulating coatings, shielding, bacterial attack, and unusual contaminants in the electrolyte. Deviation from this standard may be warranted in specific situations provided that corrosion control personnel in responsible charge are able to demonstrate that the objectives expressed in this standard have been achieved.

1.5 This standard does not include corrosion control methods based on chemical control of the environment, on the use of electrically conductive coatings, or on control of internal corrosion.

Section 2: Definitions [(1)]

Amphoteric Metal: A metal that is susceptible to corrosion in both acid and alkaline environments.

Anode: The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter solution at the anode.

Anodic Polarization: The change of the electrode potential in the noble (positive) direction caused by current across the electrode/electrolyte interface. (See *Polarization.*)

Backfill: Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system.

Beta Curve: A plot of dynamic (fluctuating) interference current or related proportional voltage (ordinate) versus the corresponding structure-to-electrolyte potentials at a selected location on the affected structure (abscissa) (see Appendix A [nonmandatory]).

Cable: One conductor or multiple conductors insulated from one another.

Cathode: The electrode of an electrochemical cell at which reduction is the principal reaction. Electrons flow toward the cathode in the external circuit.

Cathodic Disbondment: The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

[(1)] Definitions in this section reflect common usage among practicing corrosion control personnel and apply specifically to how the terms are used in this standard. In many cases, in the interests of brevity and practical usefulness, the scientific definitions are abbreviated or paraphrased.

Cathodic Polarization: The change of electrode potential in the active (negative) direction caused by current across the electrode/electrolyte interface. See *Polarization.*

Cathodic Protection: A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

Coating: A liquid, liquefiable, or mastic composition that, after application to a surface, is converted into a solid protective, decorative, or functional adherent film.

Coating Disbondment: The loss of adhesion between a coating and the pipe surface.

Conductor: A material suitable for carrying an electric current. It may be bare or insulated.

Continuity Bond: A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.

Corrosion: The deterioration of a material, usually a metal, that results from a reaction with its environment.

Corrosion Potential (E_{corr}): The potential of a corroding surface in an electrolyte relative to a reference electrode under open-circuit conditions (also known as *rest potential, open-circuit potential*, or *freely corroding potential*).

Corrosion Rate: The rate at which corrosion proceeds.

Criterion: Standard for assessment of the effectiveness of a cathodic protection system.

Current Density: The current to or from a unit area of an electrode surface.

Diode: A bipolar semiconducting device having a low resistance in one direction and a high resistance in the other.

Distributed-Anode Impressed Current System: An impressed current anode configuration in which the anodes are "distributed" along the structure at relatively close intervals such that the structure is within each anode's voltage gradient. This anode configuration causes the electrolyte around the structure to become positive with respect to remote earth.

Electrical Isolation: The condition of being electrically separated from other metallic structures or the environment.

Electrical Survey: Any technique that involves coordinated electrical measurements taken to provide a basis for deduction concerning a particular electrochemical condition relating to corrosion or corrosion control.

Electrode: A conductor used to establish contact with an electrolyte and through which current is transferred to or from an electrolyte.

Electroosmotic Effect: Passage of a charged particle through a membrane under the influence of a voltage. Soil or coatings may act as the membrane.

Electrolyte: A chemical substance containing ions that migrate in an electric field. For the purpose of this standard, electrolyte refers to the soil or liquid adjacent to and in contact with a buried or submerged metallic piping system, including the moisture and other chemicals contained therein.

Foreign Structure: Any metallic structure that is not intended as a part of a system under cathodic protection.

Galvanic Anode: A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

Galvanic Series: A list of metals and alloys arranged according to their corrosion potentials in a given environment.

Groundbed: One or more anodes installed below the earth's surface for the purpose of supplying cathodic protection.

Holiday: A discontinuity in a protective coating that exposes unprotected surface to the environment.

Impressed Current: An electric current supplied by a device employing a power source that is external to the electrode system. (An example is direct current for cathodic protection.)

In-Line Inspection: The inspection of a steel pipeline using an electronic instrument or tool that travels along the interior of the pipeline.

Insulating Coating System: All components of the protective coating, the sum of which provides effective electrical isolation of the coated structure.

Interference: Any electrical disturbance on a metallic structure as a result of stray current.

Interference Bond: An intentional metallic connection, between metallic systems in contact with a common electrolyte, designed to control electrical current interchange between the systems.

IR Drop: The voltage across a resistance in accordance with Ohm's Law.

Isolation: See *Electrical Isolation.*

Line Current: The direct current flowing on a pipeline.

Long-Line Current: Current through the earth between an anodic and a cathodic area that returns along an underground metallic structure.

Mixed Potential: A potential resulting from two or more electrochemical reactions occurring simultaneously on one metal surface.

Pipe-to-Electrolyte Potential: See Structure-to-Electrolyte Potential.

Polarization: The change from the open-circuit potential as a result of current across the electrode/electrolyte interface.

Polarized Potential: The potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

Reference Electrode: An electrode whose open-circuit potential is constant under similar conditions of measurement, which is used for measuring the relative potentials of other electrodes.

Reverse-Current Switch: A device that prevents the reversal of direct current through a metallic conductor.

Shielding: (1) Protecting; protective cover against mechanical damage. (2) Preventing or diverting the cathodic protection current from its intended path.

Shorted Pipeline Casing: A casing that is in direct metallic contact with the carrier pipe.

Sound Engineering Practices: Reasoning exhibited or based on thorough knowledge and experience, logically valid and having technically correct premises that demonstrate good judgment or sense in the application of science.

Stray Current: Current through paths other than the intended circuit.

Stray-Current Corrosion: Corrosion resulting from current through paths other than the intended circuit, e.g., by any extraneous current in the earth.

Structure-to-Electrolyte Potential: The potential difference between the surface of a buried or submerged metallic structure and electrolyte that is measured with reference to an electrode in contact with the electrolyte.

Telluric Current: Current in the earth as a result of geomagnetic fluctuations.

Voltage: An electromotive force or a difference in electrode potentials expressed in volts.

Wire: A slender rod or filament of drawn metal. In practice, the term is also used for smaller-gauge conductors (6 mm^2 [No. 10 AWG[(2)]] or smaller).

Section 3: Determination of Need for External Corrosion Control

3.1 Introduction

3.1.1 This section recommends practices for determining when an underground or submerged metallic piping system requires external corrosion control.

3.1.2 Metallic structures, buried or submerged, are subject to corrosion. Adequate corrosion control procedures should be adopted to ensure metal integrity for safe and economical operation.

3.2 The need for external corrosion control should be based on data obtained from one or more of the following: corrosion surveys, operating records, visual observations, test results from similar systems in similar environments, in-line inspections, engineering and design specifications, and operating, safety, and economic requirements. The absence of leaks alone is insufficient evidence that corrosion control is not required.

3.2.1 Environmental and physical factors include the following:

3.2.1.1 Corrosion rate of the particular metallic piping system in a specific environment (see Appendix B [nonmandatory]);

3.2.1.2 Nature of the product being transported, the working temperature, temperature differentials within the pipeline causing thermal expansion and contraction, tendency of backfill to produce soil stress, and working pressure of the piping system as related to design specification;

(2) American Wire Gauge.

3.2.1.3 Location of the piping system as related to population density and frequency of visits by personnel;

3.2.1.4 Location of the piping system as related to other facilities; and

3.2.1.5 Stray current sources foreign to the system.

3.2.2 Economic factors include the following:

3.2.2.1 Costs of maintaining the piping system in service for its expected life (see Appendix B [nonmandatory])

3.2.2.2 Contingent costs of corrosion (see Appendix C [nonmandatory]); and

3.2.2.3 Costs of corrosion control (see Appendix D [nonmandatory]).

Section 4: Piping System Design

4.1 Introduction

4.1.1 This section provides accepted corrosion control practices in the design of an underground or submerged piping system. A person qualified to engage in the practice of corrosion control should be consulted during all phases of pipeline design and construction (see Paragraph 1.3). These recommendations should not be construed as taking precedence over recognized electrical safety practices.

4.2 External Corrosion Control

4.2.1 External corrosion control must be a primary consideration during the design of a piping system. Materials selection and coatings are the first line of defense against external corrosion. Because perfect coatings are not feasible, CP must be used in conjunction with coatings. For additional information, see Sections 5 and 6.

4.2.2 New piping systems should be externally coated unless thorough investigation indicates that coatings are not required (see Section 5).

4.2.3 Materials and construction practices that create electrical shielding should not be used on the pipeline. Pipelines should be installed at locations where proximity to other structures and subsurface formations do not cause shielding.

4.3 Electrical Isolation

4.3.1 Isolation devices such as flange assemblies, prefabricated joint unions, or couplings should be installed within piping systems in which electrical isolation of portions of the system is required to facilitate the application of external corrosion control. These devices should be properly selected for temperature, pressure, chemical resistance, dielectric resistance, and mechanical strength. Installation of isolation devices should be avoided or safeguarded in areas in which combustible atmospheres are likely to be present. Locations at which electrical isolating devices should be considered include, but are not limited to, the following:

4.3.1.1 Points at which facilities change ownership, such as meter stations and well heads;

4.3.1.2 Connections to mainline piping systems, such as gathering or distribution system laterals;

4.3.1.3 Inlet and outlet piping of in-line measuring and pressure regulating stations;

4.3.1.4 Compressor or pumping stations, either in the suction and discharge piping or in the main line immediately upstream and downstream from the station;

4.3.1.5 Stray current areas;

4.3.1.6 The junction of dissimilar metals;

4.3.1.7 The termination of service line connections and entrance piping;

4.3.1.8 The junction of a coated pipe and a bare pipe; and

4.3.1.9 Locations at which electrical grounding is used, such as motorized valves and instrumentation.

4.3.2 The need for lightning and fault current protection at isolating devices should be considered. Cable connections from isolating devices to arresters should be short, direct, and of a size suitable for short-term high-current loading.

4.3.3 When metallic casings are required as part of the underground piping system, the pipeline should be electrically isolated from such casings. Casing insulators must be properly sized and spaced and be tightened securely on the pipeline to withstand insertion stresses without sliding on the pipe. Inspection should be made to verify that the leading insulator has remained in position. Concrete coatings on the carrier pipe could preclude the use of casing insulators. Consideration should be given to the use of support under the pipeline at each end of the casing to minimize settlement. The type of support selected should not cause damage to the pipe coating or act as a shield to CP current.

4.3.4 Casing seals should be installed to resist the entry of foreign matter into the casing.

4.3.5 When electrical contact would adversely affect CP, piping systems should be electrically isolated from supporting pipe stanchions, bridge structures, tunnel enclosures, pilings, offshore structures, or reinforcing steel in concrete. However, piping can be attached directly to a bridge without isolation if isolating devices are installed in the pipe system on each side of the bridge to isolate the bridge piping electrically from adjacent underground piping.

4.3.6 When an isolating joint is required, a device manufactured to perform this function should be used, or, if permissible, a section of nonconductive pipe, such as plastic pipe, may be installed. In either case, these should be properly rated and installed in accordance with the manufacturer's instructions.

4.3.7 River weights, pipeline anchors, and metallic reinforcement in weight coatings should be electrically isolated from the carrier pipe and designed and installed so that coating damage does not occur and the carrier pipe is not electrically shielded.

4.3.8 Metallic curb boxes and valve enclosures should be designed, fabricated, and installed in such a manner that electrical isolation from the piping system is maintained.

4.3.9 Insulating spacing materials should be used when it is intended to maintain electrical isolation between a metallic wall sleeve and the pipe.

4.3.10 Underground piping systems should be installed so that they are physically separated from all foreign underground metallic structures at crossings and parallel installations and in such a way that electrical isolation could be maintained if desired.

4.3.11 Based on voltage rating of alternating current (AC) transmission lines, adequate separation should be maintained between pipelines and electric transmission tower footings, ground cables, and counterpoise. Regardless of separation, consideration should always be given to lightning and fault current protection of pipeline(s) and personnel safety (see NACE Standard RP0177[2]).

4.4 Electrical Continuity

4.4.1 Nonwelded pipe joints may not be electrically continuous. Electrical continuity can be ensured by the use of fittings manufactured for this purpose or by bonding across and to the mechanical joints in an effective manner.

4.5 Corrosion Control Test Stations

4.5.1 Test stations for potential, current, or resistance measurements should be provided at sufficient locations to facilitate CP testing. Such locations may include, but are not limited to, the following:

4.5.1.1 Pipe casing installations,

4.5.1.2 Metallic structure crossings,

4.5.1.3 Isolating joints,

4.5.1.4 Waterway crossings,

4.5.1.5 Bridge crossings,

4.5.1.6 Valve stations,

4.5.1.7 Galvanic anode installations,

4.5.1.8 Road crossings,

4.5.1.9 Stray-current areas, and

4.5.1.10 Rectifier installations.

4.5.2 The span of pipe used for line current test stations should exclude:

4.5.2.1 Foreign metallic structure crossings;

4.5.2.2 Lateral connections;

4.5.2.3 Mechanical couplings or connections such as screwed joints, transition pieces, valves, flanges, anode or rectifier attachments, or metallic bonds; and

4.5.2.4 Changes in pipe wall thickness and diameter.

4.5.3 Attachment of Copper Test Lead Wires to Steel and Other Ferrous Pipes

4.5.3.1 Test lead wires may be used both for periodic testing and for current-carrying purposes. As such, the wire/pipe attachment should be mechanically strong and electrically conductive.

4.5.3.2 Methods of attaching wires to the pipe include (a) thermit welding process, (b) soldering, and (c) mechanical means.

4.5.3.3 Particular attention must be given to the attachment method to avoid (a) damaging or penetrating the pipe, (b) sensitizing or altering of pipe properties, (c) weakening the test lead wire, (d) damaging internal or external pipe coatings, and (e) creating hazardous conditions in explosive environments.

4.5.3.4 Attachment by mechanical means is the least desirable method. Such a connection may loosen, become highly resistant, or lose electrical continuity.

4.5.3.5 The connection should be tested for mechanical strength and electrical continuity. All exposed portions of the connection should be thoroughly cleaned of all welding slag, dirt, oils, etc.; primed, if needed; and coated with materials compatible with the cable insulation, pipe coating, and environment.

4.5.4 Attachment of Aluminum Test Lead Wire to Aluminum Pipes

4.5.4.1 Aluminum test lead wire, or aluminum tabs attached to aluminum wire, may be welded to aluminum pipe using the tungsten inert-gas shielded arc (TIG) or metal inert-gas shielded arc (MIG) process. Welded attachments should be made to flanges or at butt weld joints. Attachment at other sites may adversely affect the mechanical properties of the pipe because of the heat of welding.

4.5.4.2 Test lead wire may be attached to aluminum pipe by soldering. If low-melting-point soft solders are used, a flux is required. Flux residues may cause corrosion unless removed.

NOTE: The use of copper test lead wire may cause preferential galvanic attack on the aluminum pipe. When copper wire or flux is used, care must be taken to seal the attachment areas against moisture. In the presence of moisture, the connection may disbond and be damaged by corrosion.

4.5.4.3 Aluminum tabs to which test lead wires have been TIG welded can be attached by an explosive bonding technique called high-energy joining.

4.5.4.4 Mechanical connections that remain secure and electrically conductive may be used.

4.5.5 Attachment of Copper Test Lead Wire to Copper Pipe.

4.5.5.1 Copper test lead wire, or copper tabs attached to copper wire, may be attached to copper pipe by one of the following methods. The relative thickness of the wire and the pipe wall dictates, in part, which of the methods can be used.

4.5.5.1.1 Arc welding (TIG, MIG, or shielded metal);

4.5.5.1.2 Electrical resistance (spot) welding;

4.5.5.1.3 Brazing;

4.5.5.1.4 Soldering; or

4.5.5.1.5 Mechanical connection.

4.5.5.2 Attention should be given to proper joining procedures to avoid possible embrittlement or loss of mechanical properties of the metals from the heat of welding or brazing.

4.5.5.3 A flux may be required, or self-produced, when brazing with some filler metals or soldering with some low-melting-point soft solders. Because flux residues may cause corrosion, they should be removed.

Section 5: External Coatings

5.1 Introduction

5.1.1 This section recommends practices for selecting, testing and evaluating, handling, storing, inspecting, and installing external coating systems for external corrosion control on piping systems.

The function of external coatings is to control corrosion by isolating the external surface of the underground or submerged piping from the environment, to reduce CP current requirements, and to improve current distribution.

5.1.2 External coatings must be properly selected and applied and the coated piping carefully handled and installed to fulfill these functions. Various types of external coatings can accomplish the desired functions.

5.1.2.1 Desirable characteristics of external coatings include the following:

5.1.2.1.1 Effective electrical insulator;

5.1.2.1.2 Effective moisture barrier;

5.1.2.1.3 Application to pipe by a method that does not adversely affect the properties of the pipe;

5.1.2.1.4 Application to pipe with a minimum of defects;

5.1.2.1.5 Good adhesion to pipe surface;

5.1.2.1.6 Ability to resist development of holidays with time;

5.1.2.1.7 Ability to resist damage during handling, storage, and installation;

5.1.2.1.8 Ability to maintain substantially constant electrical resistivity with time;

5.1.2.1.9 Resistance to disbonding;

5.1.2.1.10 Resistance to chemical degradation;

5.1.2.1.11 Ease of repair;

5.1.2.1.12 Retention of physical characteristics;

5.1.2.1.13 Nontoxic to the environment; and

5.1.2.1.14 Resistance to changes and deterioration during aboveground storage and long-distance transportation.

5.1.2.2 Typical factors to consider when selecting an external pipe coating include:

5.1.2.2.1 Type of environment;

5.1.2.2.2 Accessibility of piping system;

5.1.2.2.3 Operating temperature of piping system;

5.1.2.2.4 Ambient temperatures during application, shipping, storage, construction, installation, and pressure testing;

5.1.2.2.5 Geographical and physical location;

5.1.2.2.6 Type of external coating on existing pipe in the system;

5.1.2.2.7 Handling and storage;

5.1.2.2.8 Pipeline installation methods;

5.1.2.2.9 Costs; and

5.1.2.2.10 Pipe surface preparation requirements.

5.1.2.3 Pipeline external coating systems shall be properly selected and applied to ensure that adequate bonding is obtained. Unbonded coatings can create electrical shielding of the pipeline that could jeopardize the effectiveness of the CP system.

5.1.3 Information in this section is primarily by reference to other documents. It is important that the latest revision of the pertinent reference be used.

5.1.3.1 Table 1 is a listing of types of external coating systems, showing the appropriate references for material specifications and recommended practices for application.

5.1.3.2 Table 2 is a grouping of references for general use during installation and inspection, regardless of coating type.

5.1.3.3 Table 3 is a list of external coating system characteristics related to environmental conditions containing suggested laboratory test references for various properties.

5.1.3.4 Table 4 is a list of external coating system characteristics related to design and construction, with recommended laboratory tests for evaluating these properties.

5.1.3.5 Table 5 lists the references that are useful in field evaluation of external coating systems after the pipeline has been installed.

5.2 Storage, Handling, Inspection, and Installation

5.2.1 Storage and Handling

5.2.1.1 Coated pipe to be stored should be protected internally and externally from atmospheric corrosion and coating deterioration.

5.2.1.2 Damage to coating can be minimized by careful handling and by using proper pads and slings.

TABLE 1

Generic External Coating Systems with Material Requirements and Recommended Practices for Application[(A)]

Generic External Coating System	Reference
Coal Tar	ANSI[(B)]/AWWA[(C)] C 203[10]
Wax	NACE Standard RP0375[11]
Prefabricated Films	ANSI/AWWA C 214[12] ANSI/AWWA C 209[13]
Fusion-Bonded Epoxy Coatings	*Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API[(D)] RP 5L7[16] CSA[(E)]Z245.20M[17] NACE Standard RP0394[18]
Polyolefin Coatings	NACE Standard RP0185[19] DIN[(F)] 30 670[20] ANSI/AWWA C 215[21]

[(A)] NOTE: Many other references are available, and this table is not comprehensive. Listing does not constitute endorsement of any external coating system in preference to another. Omission of a system may be due to unavailability of reference standards or lack of data.
[(B)] American National Standards Institute (ANSI), 1819 L St. NW, Washington, DC 20036.
[(C)] American Water Works Association (AWWA), 6666 West Quincy Ave., Denver, CO 80235.
[(D)] American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.
[(E)] CSA International, 178 Rexdale Blvd., Toronto, Ontario, Canada M9W 1R3.
[(F)] Deutsches Institut fur Normung (DIN), Burggrafenstrasse 6, D-10787 Berlin, Germany.

TABLE 2

References for General Use in the Installation and Inspection of External Coating Systems for Underground Piping

Subject	Reference
Application of Organic Pipeline Coatings	ANSI/AWWA C 203[10] NACE Standard RP0375[11] *Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API RP 5L7[16] CSA Z245.20M[17]
Film Thickness of Pipeline Coatings	ASTM[(A)] G 128[22]
Inspection of Pipeline Coatings	NACE Standard RP0274[23]

[(A)] ASTM, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

TABLE 3
External Coating System Characteristics Relative to Environmental Conditions[(A)]

Environmental Factor	Recommended Test Methods[(B)]
General underground exposure with or without CP	*Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API RP 5L7[16] CSA Z245.20M[17] ASTM G 8[24] ASTM G 19[25] ASTM G 42[26] ASTM G 95[27]
Resistance to water penetration and its effect on choice of coating thickness	ASTM G 9[28]
Resistance to penetration by stones in backfill	ASTM G 17[29] ASTM D 2240[30] ASTM G 13[31] ASTM G 14[32]
Soil stress	*Underground Corrosion*[33] ASTM D 427[34]
Resistance to specific liquid not normally encountered in virgin soil	ASTM D 543[35] Federal Test Standard[(C)] No. 406A, Method 7011[36] ASTM G 20[37]
Resistance to thermal effects	ASTM D 2304[38] ASTM D 2454[39] ASTM D 2485[40]
Suitability of supplementary materials for joint coating and field repairs	ASTM G 8[24] ASTM G 19[25] ASTM G 42[26] ASTM G 95[27] ASTM G 9[28] ASTM G 18[41] ASTM G 55[42]
Resistance to microorganisms	ASTM G 21[43] Federal Test Standard No. 406A, Method 6091[44]

[(A)] NOTE: Apply only those factors pertinent to the installation.
[(B)] No specific criteria are available. Comparative tests are recommended for use and evaluation as supplementary information only.
[(C)] Available from General Services Administration, Business Service Center, Washington, DC 20025.

TABLE 4
External Coating System Characteristics Related to Design and Construction

Design and Construction Factor	Recommended Test Methods[A]
Yard Storage, Weathering	ASTM G 11[45]
Yard Storage, Penetration Under Load	ASTM G 17[29] ASTM D 2240[30]
Handling Resistance, Abrasion	ASTM G 6[46]
Handling Resistance, Impact	ASTM G 13[31] ASTM G 14[32]
Field Bending Ability	ASTM G 10[47]
Driving Ability (Resistance to Sliding Abrasion)	ASTM G 6[46] ASTM D 2197[48]
Special Requirements for Mill-Applied Coating	ANSI/AWWA C 203[10] NACE Standard RP0375[11] ANSI/AWWA C 214[12] ANSI/AWWA C 209[13] *Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API RP 5L7[16] CSA Z245.20M[17] NACE Standard RP0185[19] DIN 30 670[20] ANSI/AWWA C 215[21]
Special Requirements for Application of Coating Over the Ditch	ANSI/AWWA C 203[10] NACE Standard RP0375[11] ANSI/AWWA C 214[12] ANSI/AWWA C 209[13] *Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API RP 5L7[16] CSA Z245.20M[17]
Backfill Resistance	ASTM G 13[31] ASTM G 14[32]
Resistance to Thermal Effects	ASTM G 8[24] ASTM G 19[25] ASTM G 42[26] ASTM G 95[27] ASTM D 2304[38] ASTM D 2454[39] ASTM D 2485[40]
Suitability of Joint Coatings and Field Repairs	*Peabody's Control of Pipeline Corrosion*[14] ANSI/AWWA C 213[15] API RP 5L7[16] CSA Z245.20M[17] ASTM G 8[24] ASTM G 19[25] ASTM G 42[26] ASTM G 95[27] ASTM G 9[28] ASTM G 18[41] ASTM G 55[42]

[A] No specific criteria are available. Comparative tests are recommended for use and evaluation as supplementary information only.

TABLE 5
Methods for Evaluating In-Service Field Performance of External Coatings

Title or Subject of Method	Reference	Basis for Rating
(1) Rate of Change in Current Required for CP	*Underground Corrosion*[33]	Comparison of initial current requirement with subsequent periodic determination of current requirement
(2) Inspection of Pipeline Coating	NACE Standard RP0274[23]	(a) With CP: no active corrosion found (b) Without CP: no new holidays showing active corrosion
(3) Cathodic Disbondment	ASTM G 8[24] ASTM G 19[25] ASTM G 42[26] ASTM G 95[27]	Purpose is to obtain data relative to specific conditions for comparison with laboratory data

5.2.2 Inspection

5.2.2.1 Qualified personnel should keep every phase of the coating operation and piping installation under surveillance.

5.2.2.2 Surface preparation, primer application, coating thickness, temperature, bonding, and other specific requirements should be checked periodically, using suitable test procedures, for conformance to specifications.

5.2.2.3 The use of holiday detectors is recommended to detect coating flaws that would not be observed visually. The holiday detector should be operated in accordance with the manufacturer's instructions and at a voltage level appropriate to the electrical characteristics of the coating system.

5.2.3 Installation

5.2.3.1 Joints, fittings, and tie-ins must be coated with a material compatible with the existing coating.

5.2.3.2 Coating defects should be repaired.

5.2.3.3 Materials used to repair coatings must be compatible with the existing pipe coating.

5.2.3.4 The ditch bottom should be graded and free of rock or other foreign matter that could damage the external coating or cause electrical shielding. Under difficult conditions, consideration should be given to padding the pipe or the ditch bottom.

5.2.3.5 Pipe should be lowered carefully into the ditch to avoid external coating damage.

5.2.3.6 Care should be taken during backfilling so that rocks and debris do not strike and damage the pipe coating.

5.2.3.7 Care shall be exercised when using materials such as loose wrappers, nonconducting urethane foam, and rock shield around pipelines as protection against physical damage or for other purposes, because these materials may create an electrical shielding effect that would be detrimental to the effectiveness of CP.

5.2.3.8 When a pipeline comes above ground, it must be cleaned and externally coated, or jacketed with a suitable material, for the prevention of atmospheric corrosion.

5.3 Methods for Evaluating External Coating Systems

5.3.1 Established Systems Proven by Successful Use

5.3.1.1 Visual and electrical inspection of in-service pipeline coatings should be used to evaluate the performance of an external coating system. These inspections can be conducted wherever the pipeline is excavated or at bell holes made for inspection purposes.

5.3.2 Established or Modified Systems for New Environments

5.3.2.1 This method is intended for use when external coating systems will continue to be used and are qualified under Paragraph 5.3.1, but when application will be extended to new environments or when it is desired to revise a system to make use of new developments, one of the following should be used:

5.3.2.1.1 The use of applicable material requirements, material specifications, standards, and recommended practices for application, as given in Table 1, is recommended.

5.3.2.1.2 The use of applicable references in Table 2 is recommended unless previously covered in applicable references in Table 1.

5.3.3 New External Coating System Qualification

5.3.3.1 The purpose of this method is to qualify a new external coating material by subjecting it to laboratory tests appropriate for the intended service. After laboratory tests have been conducted and indicate that the external coating system appears to be suitable, application and installation are conducted in accordance with recommended practices. In-service field performance tests are made to confirm the success of the previous steps. The steps of the method are (1) laboratory tests, (2) application under recommended practices, (3) installation under recommended practices, and (4) in-service field performance tests. If good results are obtained after five years, only Steps 2 and 3 are required thereafter.

5.3.3.1.1 Applicable sections of Tables 3 and 4 are recommended for the initial laboratory test methods.

5.3.3.1.2 Applicable sections of Tables 1 and 2 are recommended for conditional use during Steps 2 and 3.

5.3.3.1.3 During a period of five years or more, the use of the evaluation methods given in Table 5, Item 1 or 2 are recommended. The test method in Item 3 may be used as a supplementary means for obtaining data for correlation with laboratory tests.

5.3.4 Method for Evaluating an External Coating System by In-Service Field Performance Only

5.3.4.1 The purpose of this method is to qualify an external coating system when none of the first three methods given in Paragraph 5.3 has been or will be used. It is intended that this method should be limited to minor pilot installations.

5.3.4.1.1 The use of at least one of the first two methods given in Table 5 is recommended on the basis of at least one investigation per year for five consecutive years.

Section 6: Criteria and Other Considerations for CP

6.1 Introduction

6.1.1 This section lists criteria and other considerations for CP that indicate, when used either separately or in combination, whether adequate CP of a metallic piping system has been achieved (see also Section 1, Paragraphs 1.2 and 1.4).

6.1.2 The effectiveness of CP or other external corrosion control measures can be confirmed by visual observation, by measurements of pipe wall thickness, or by use of internal inspection devices. Because such methods sometimes are not practical, meeting any criterion or combination of criteria in this section is evidence that adequate CP has been achieved. When excavations are made for any purpose, the pipe should be inspected for evidence of corrosion and coating condition.

6.1.3 The criteria in this section have been developed through laboratory experiments or verified by evaluating data obtained from successfully operated CP systems. Situations in which a single criterion for evaluating the effectiveness of CP may not be satisfactory for all conditions may exist. Often a combination of criteria is needed for a single structure.

6.1.4 Sound engineering practices shall be used to determine the methods and frequency of testing required to satisfy these criteria.

6.1.5 Corrosion leak history is valuable in assessing the effectiveness of CP. Corrosion leak history by itself, however, shall not be used to determine whether adequate levels of CP have been achieved unless it is impractical to make electrical surveys.

6.2 Criteria

6.2.1 It is not intended that persons responsible for external corrosion control be limited to the criteria listed below. Criteria that have been successfully applied on existing piping systems can continue to be used on those piping systems. Any other criteria used must achieve corrosion control comparable to that attained with the criteria herein.

6.2.2 Steel and Cast Iron Piping

6.2.2.1 External corrosion control can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of specific data that demonstrate that adequate CP has been achieved, one or more of the following shall apply:

6.2.2.1.1 A negative (cathodic) potential of at least 850 mV with the CP applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement.

NOTE: Consideration is understood to mean the application of sound engineering practice in determining the significance of voltage drops by methods such as:

6.2.2.1.1.1 Measuring or calculating the voltage drop(s);

6.2.2.1.1.2 Reviewing the historical performance of the CP system;

6.2.2.1.1.3 Evaluating the physical and electrical characteristics of the pipe and its environment; and

6.2.2.1.1.4 Determining whether or not there is physical evidence of corrosion.

6.2.2.1.2 A negative polarized potential (see definition in Section 2) of at least 850 mV relative to a saturated copper/copper sulfate reference electrode.

6.2.2.1.3 A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.

6.2.2.2 Special Conditions

6.2.2.2.1 On bare or ineffectively coated pipelines when long-line corrosion activity is of primary concern, the measurement of a net protective current at predetermined current discharge points from the electrolyte to the pipe surface, as measured by an earth current technique, may be sufficient.

6.2.2.2.2 In some situations, such as the presence of sulfides, bacteria, elevated temperatures, acid environments, and dissimilar metals, the criteria in Paragraph 6.2.2.1 may not be sufficient.

6.2.2.2.3 When a pipeline is encased in concrete or buried in dry or aerated high-resistivity soil, values less negative than the criteria listed in Paragraph 6.2.2.1 may be sufficient.

6.2.2.3 PRECAUTIONARY NOTES

6.2.2.3.1 The earth current technique is often meaningless in multiple pipe rights-of-way, in high-resistivity surface soil, for deeply buried pipe, in stray-current areas, or where local corrosion cell action predominates.

6.2.2.3.2 Caution is advised against using polarized potentials less negative than -850 mV for CP of pipelines when operating pressures and conditions are conducive to stress corrosion cracking (see references on stress corrosion cracking at the end of this section).

6.2.2.3.3 The use of excessive polarized potentials on externally coated pipelines should be avoided to minimize cathodic disbondment of the coating.

6.2.2.3.4 Polarized potentials that result in excessive generation of hydrogen should be avoided on all metals, particularly higher-strength steel, certain grades of stainless steel, titanium, aluminum alloys, and prestressed concrete pipe.

6.2.3 Aluminum Piping

6.2.3.1 The following criterion shall apply: a minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of this polarization can be used in this criterion.

6.2.3.2 PRECAUTIONARY NOTES

6.2.3.2.1 Excessive Voltages: Notwithstanding the minimum criterion in Paragraph 6.2.3.1, if aluminum is cathodically protected at voltages more negative than -1,200 mV measured between the pipe surface and a saturated copper/copper sulfate reference electrode contacting the electrolyte and compensation is made for the voltage drops other than those across the pipe-electrolyte boundary, it may suffer corrosion as the result of the buildup of alkali on the metal surface. A polarized potential more negative than -1,200 mV should not be used unless previous test results indicate that no appreciable corrosion will occur in the particular environment.

6.2.3.2.2 Alkaline Conditions: Aluminum may suffer from corrosion under high-pH conditions, and application of CP tends to increase the pH at the metal surface. Therefore, careful investigation or testing should be done before applying CP to stop pitting attack on aluminum in environments with a natural pH in excess of 8.0.

6.2.4 Copper Piping

6.2.4.1 The following criterion shall apply: a minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of this polarization can be used in this criterion.

6.2.5 Dissimilar Metal Piping

6.2.5.1 A negative voltage between all pipe surfaces and a stable reference electrode contacting the electrolyte equal to that required for the protection of the most anodic metal should be maintained.

6.2.5.2 PRECAUTIONARY NOTE

6.2.5.2.1 Amphoteric materials that could be damaged by high alkalinity created by CP should be electrically isolated and separately protected.

6.3 Other Considerations

6.3.1 Methods for determining voltage drop(s) shall be selected and applied using sound engineering practices. Once determined, the voltage drop(s) may be used for correcting future measurements at the same location, provided conditions such as pipe and CP system operating conditions, soil characteristics, and external coating quality remain similar. (Note: Placing the reference electrode next to the pipe surface may not be at the pipe-electrolyte interface. A reference electrode placed at an externally coated pipe surface may not significantly reduce soil voltage drop in the measurement if the nearest coating holiday is remote from the reference electrode location.)

6.3.2 When it is impractical or considered unnecessary to disconnect all current sources to correct for voltage drop(s) in the structure-to-electrolyte potential measurements, sound engineering practices should be used to ensure that adequate CP has been achieved.

6.3.3 When feasible and practicable, in-line inspection of pipelines may be helpful in determining the presence or absence of pitting corrosion damage. Absence of external corrosion damage or the halting of its growth may indicate adequate external corrosion control. The in-line inspection technique, however, may not be capable of detecting all types of external corrosion damage, has limitations in its accuracy, and may report as anomalies items that are not external corrosion. For example, longitudinal seam corrosion and general corrosion may not be readily detected by in-line inspection. Also, possible thickness variations, dents, gouges, and external ferrous objects may be detected as corrosion. The appropriate use of in-line inspection must be carefully considered.

6.3.4 Situations involving stray currents and stray electrical gradients that require special analysis may exist. For additional information, see Section 9, "Control of Interference Currents."

6.4 Alternative Reference Electrodes

6.4.1 Other standard reference electrodes may be substituted for the saturated copper/copper sulfate reference electrode. Two commonly used reference electrodes are listed below along with their voltage equivalent (at 25°C [77°F]) to -850 mV referred to a saturated copper/copper sulfate reference electrode:

6.4.1.1 Saturated KCl calomel reference electrode: -780 mV; and

6.4.1.2 Saturated silver/silver chloride reference electrode used in 25 ohm-cm seawater: -800 mV.

6.4.2 In addition to these standard reference electrodes, an alternative metallic material or structure may be used in place of the saturated copper/copper sulfate reference electrode if the stability of its electrode potential is ensured and if its voltage equivalent referred to a saturated copper/copper sulfate reference electrode is established.

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Section 7: Design of Cathodic Protection Systems

7.1 Introduction

7.1.1 This section recommends procedures for designing CP systems that will provide effective external corrosion control by satisfying one or more of the criteria listed in Section 6 and exhibiting maximum reliability over the intended operating life of the systems.

7.1.2 In the design of a CP system, the following should be considered:

7.1.2.1 Recognition of hazardous conditions prevailing at the proposed installation site(s) and the selection and specification of materials and installation practices that ensure safe installation and operation.

7.1.2.2 Specification of materials and installation practices to conform to the latest editions of applicable codes, National Electrical Manufacturers Association (NEMA)[7] standards, National Electrical Code (NEC),[8] appropriate international standards, and NACE standards.

7.1.2.3 Selection and specification of materials and installation practices that ensure dependable and economical operation throughout the intended operating life.

7.1.2.4 Selection of locations for proposed installations to minimize currents or earth potential gradients, which can cause detrimental effects on foreign buried or submerged metallic structures.

7.1.2.5 Cooperative investigations to determine mutually satisfactory solution(s) of interference problems (see Section 9).

7.1.2.6 Special consideration should be given to the presence of sulfides, bacteria, disbonded coatings, thermal insulating coatings, elevated temperatures, shielding, acid environments, and dissimilar metals.

7.1.2.7 Excessive levels of CP that can cause external coating disbondment and possible damage to high-strength steels as a result of hydrogen evolution should be avoided.

7.1.2.8 When amphoteric metals are involved, care should be taken so that high-pH conditions that could cause cathodic corrosion of the metal are not established.

7.2 Major objectives of CP system design include the following:

7.2.1 To provide sufficient current to the structure to be protected and distribute this current so that the selected criteria for CP are effectively attained;

[7] National Electrical Manufacturers Association (NEMA), 1300 North 17th St., Suite 1752, Rosslyn, Virginia 22209.
[8] National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

7.2.2 To minimize the interference currents on neighboring underground structures (see Section 9);

7.2.3 To provide a design life of the anode system commensurate with the required life of the protected structure, or to provide for periodic rehabilitation of the anode system;

7.2.4 To provide adequate allowance for anticipated changes in current requirements with time;

7.2.5 To install anodes when the possibility of disturbance or damage is minimal; and

7.2.6 To provide adequate monitoring facilities to test and evaluate the system performance.

7.3 Information Useful for Design

7.3.1 Useful piping system specifications and information include the following:

7.3.1.1 Route maps and atlas sheets;

7.3.1.2 Construction dates;

7.3.1.3 Pipe, fittings, and other appurtenances;

7.3.1.4 External coatings;

7.3.1.5 Casings;

7.3.1.6 Corrosion control test stations;

7.3.1.7 Electrically isolating devices;

7.3.1.8 Electrical bonds; and

7.3.1.9 Aerial, bridge, and underwater crossings.

7.3.2 Useful information on piping system site conditions includes the following:

7.3.2.1 Existing and proposed CP systems;

7.3.2.2 Possible interference sources (see Section 9);

7.3.2.3 Special environmental conditions;

7.3.2.4 Neighboring buried metallic structures (including location, ownership, and corrosion control practices);

7.3.2.5 Structure accessibility;

7.3.2.6 Power availability; and

7.3.2.7 Feasibility of electrical isolation from foreign structures.

7.3.3 Useful information from field surveys, corrosion test data, and operating experience includes the following:

7.3.3.1 Protective current requirements to meet applicable criteria;

7.3.3.2 Electrical resistivity of the electrolyte;

7.3.3.3 Electrical continuity;

7.3.3.4 Electrical isolation;

7.3.3.5 External coating integrity;

7.3.3.6 Cumulative leak history;

7.3.3.7 Interference currents;

7.3.3.8 Deviation from construction specifications; and

7.3.3.9 Other maintenance and operating data.

7.3.4 Field survey work prior to actual application of CP is not always required if prior experience or test data are available to estimate current requirements, electrical resistivity of the electrolyte, and other design factors.

7.4 Types of CP Systems

7.4.1 Galvanic Anode Systems

7.4.1.1 Galvanic anodes can be made of materials such as alloys of magnesium, zinc, or aluminum. The anodes are connected to the pipe, either individually or in groups. Galvanic anodes are limited in current output by the anode-to-pipe driving voltage and the electrolyte resistivity.

7.4.2 Impressed Current Anode Systems

7.4.2.1 Impressed current anodes can be of materials such as graphite, high-silicon cast iron, lead-silver alloy, precious metals, or steel. They are connected with an insulated cable, either individually or in groups, to the positive terminal of a direct-current (DC) source, such as a rectifier or generator. The pipeline is connected to the negative terminal of the DC source.

7.5 Considerations influencing selection of the type of CP system include the following:

7.5.1 Magnitude of protective current required;

7.5.2 Stray currents causing significant potential fluctuations between the pipeline and earth that may preclude the use of galvanic anodes;

7.5.3 Effects of CP interference currents on adjacent structures that may limit the use of impressed current CP systems;

7.5.4 Availability of electrical power;

7.5.5 Physical space available, proximity of foreign structures, easement procurement, surface conditions, presence of streets and buildings, river crossings, and other construction and maintenance concerns.

7.5.6 Future development of the right-of-way area and future extensions to the pipeline system;

7.5.7 Costs of installation, operation, and maintenance; and

7.5.8 Electrical resistivity of the environment.

7.6 Factors Influencing Design of CP Systems

7.6.1 Various anode materials have different rates of deterioration when discharging a given current density from the anode surface in a specific environment. Therefore, for a given current output, the anode life depends on the environment and anode material, as well as the anode weight and the number of anodes in the CP system. Established anode performance data may be used to calculate the probable deterioration rate.

7.6.2 Data on the dimensions, depth, and configuration of the anodes and the electrolyte resistivity may be used to calculate the resultant resistance to electrolyte of the anode system. Formulas and graphs relating to these factors are available in the bibliography literature and from most anode manufacturers.

7.6.3 Design of galvanic anode systems should consider anode-to-pipe potential, electrolyte resisivity, current output, and in special cases, anode lead-wire resistance. A separate design for each anode or anode system may not be necessary.

7.6.4 Galvanic anode performance in most soils can be improved by using special backfill material. Mixtures of gypsum, bentonite, and anhydrous sodium sulfate are most commonly used.

7.6.5 The number of impressed current anodes required can be reduced and their useful life lengthened by the use of special backfill around the anodes. The most common materials are coal coke, calcined petroleum coke, and natural or manufactured graphite.

7.6.6 In the design of an extensive distributed-anode impressed current system, the voltage and current attenuation along the anode-connecting (header) cable should be considered. In such cases, the design objective is to optimize anode system length, anode spacing and size, and cable size in order to achieve efficient external corrosion control at the extremities of the protected structure.

7.6.7 When it is anticipated that entrapment of gas generated by anodic reactions could impair the ability of the impressed current groundbed to deliver the required current, suitable provisions should be made for venting the anodes. For the same current output of the system, an increase in the surface area of the special backfill material or an increase in the number of anodes may reduce gas blockage.

7.6.8 When it is anticipated that electroosmotic effects could impair the ability of the impressed current groundbed to deliver the required current output, suitable provisions should be made to ensure adequate soil moisture around the anodes. Increasing the number of impressed current anodes or increasing the surface area of the special backfill materials may further reduce the electroosmotic effect.

7.7 Design Drawings and Specifications

7.7.1 Suitable drawings should be prepared to designate the overall layout of the piping to be protected and the location of significant items of structure hardware, corrosion control test stations, electrical bonds, electrical isolation devices, and neighboring buried or submerged metallic structures.

7.7.2 Layout drawings should be prepared for each impressed current CP installation, showing the details and location of the components of the CP system with respect to the protected structure(s) and to major physical landmarks. These drawings should include right-of-way information.

7.7.3 The locations of galvanic anode installations should be recorded on drawings or in tabular form, with appropriate notes on anode type, weight, spacing, depth, and backfill.

7.7.4 Specifications should be prepared for all materials and installation practices that are to be incorporated in construction of the CP system.

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Section 8: Installation of CP Systems

8.1 Introduction

8.1.1 This section recommends procedures that will result in the installation of CP systems that achieve protection of the structure. The design considerations recommended in Sections 4 and 7 should be followed.

8.2 Construction Specifications

8.2.1 All construction work on CP systems should be performed in accordance with construction drawings and specifications. The construction specifications should be in accordance with recommended practices in Sections 4 and 7.

8.3 Construction Supervision

8.3.1 All construction work on CP systems should be performed under the surveillance of trained and qualified personnel to verify that the installation is in strict accordance with the drawings and specifications. Exceptions may be made only with the approval of qualified personnel responsible for external corrosion control.

8.3.2 All deviations from construction specifications should be noted on as-built drawings.

8.4 Galvanic Anodes

8.4.1 Inspection, Handling, and Storage

8.4.1.1 Packaged anodes should be inspected and steps taken to ensure that backfill material completely surrounds the anode. The individual container for the backfill material and anode should be intact. If individually packaged anodes are supplied in waterproof containers, the containers must be removed before installation. Packaged anodes should be kept dry during storage.

8.4.1.2 Lead wire must be securely connected to the anode. Lead wire should be inspected for assurance that it is not damaged.

8.4.1.3 Other galvanic anodes, such as the unpackaged "bracelet" or ribbon type, should be inspected to ensure that dimensions conform to design specifications and that any damage during handling does not affect application. If a coating is used on bands and the inner side of bracelet anode segments, it should be inspected and, if damaged, repaired before the anodes are installed.

8.4.2 Installing Anodes

8.4.2.1 Anodes should be installed according to construction specifications.

8.4.2.2 Packaged galvanic anodes should be backfilled with appropriately compacted material. When anodes and special chemical backfill are provided separately, anodes should be centered in special backfill, which should be compacted prior to backfilling. Care should be exercised during all operations so that lead wires and connections are not damaged. Sufficient slack should exist in lead wires to avoid strain.

8.4.2.3 When anodes in bracelet form are used, external pipe coating beneath the anode should be free of holidays. Care should be taken to prevent damage to the external coating when bracelet anodes are installed. After application of concrete (if used) to pipe, all coating and concrete should be removed from the anode surface. If reinforced concrete is used, there must be no metallic contact between the anode and the reinforcing mesh or between the reinforcing mesh and the pipe.

8.4.2.4 When a ribbon-type anode is used, it can be trenched or plowed in, with or without special chemical backfill as required, generally parallel to the section of pipeline to be protected.

8.5 Impressed Current Systems

8.5.1 Inspection and Handling

8.5.1.1 The rectifier or other power source should be inspected to ensure that internal connections are mechanically secure and that the unit is free of damage. Rating of the DC power source should comply with the construction specification. Care should be exercised in handling and installing the power source.

8.5.1.2 Impressed current anodes should be inspected for conformance to specifications concerning anode material, size, length of lead cable, anode lead connection, and integrity of seal. Care should be exercised to avoid cracking or damaging anodes during handling and installation.

8.5.1.3 All cables should be carefully inspected to detect defects in insulation. Care should be taken to avoid damage to cable insulation. Defects in the cable insulation must be repaired.

8.5.1.4 Anode backfill material should conform to specifications.

8.5.2 Installation Provisions

8.5.2.1 A rectifier or other power source should be installed so that the possibility of damage or vandalism is minimized.

8.5.2.2 Wiring to rectifiers shall comply with local and national electrical codes and requirements of the utility supplying power. An external disconnect switch should be provided in the AC circuit. A rectifier case shall be properly grounded.

8.5.2.3 On thermoelectric generators, a reverse current device should be installed to prevent galvanic action between the anode bed and the pipe if the flame is extinguished.

8.5.2.4 Impressed current anodes can be buried vertically, horizontally, or in deep holes (see NACE Standard RP0572[1]) as indicated in construction specifications. Backfill material should be installed to ensure that there are no voids around anodes. Care should be exercised during backfilling to avoid damage to the anode and cable.

8.5.2.5 The cable from the rectifier negative terminal to the pipe should be connected to the pipe as described in Paragraph 8.6. Cable connections to the rectifier must be mechanically secure and electrically conductive. Before the power source is energized, it must be verified that the negative cable is connected to the structure to be protected and that the positive cable is connected to the anodes. After the DC power source has been energized, suitable measurements should be made to verify that these connections are correct.

8.5.2.6 Underground splices on the header (positive) cable to the groundbed should be kept to a minimum. Connections between the header and anode cables should be mechanically secure and electrically conductive. If buried or submerged, these connections must be sealed to prevent moisture penetration so that electrical isolation from the environment is ensured.

8.5.2.7 Care must be taken during installation of direct-burial cable to the anodes (positive cable) to avoid damage to insulation. Sufficient slack should be left to avoid strain on all cables. Backfill material around the cable should be free of rocks and foreign matter that might cause damage to the insulation when the cable is installed in a trench. Cable can be installed by plowing if proper precautions are taken.

8.5.2.8 If insulation integrity on the buried or submerged header cable, including splices, is not maintained, this cable may fail because of corrosion.

8.6 Corrosion Control Test Stations, Connections, and Bonds (see Paragraph 4.5)

8.6.1 Pipe and test lead wires should be clean, dry, and free of foreign materials at points of connection when the connections are made. Connections of test lead wires to the pipe must be installed so they will remain mechanically secure and electrically conductive.

8.6.2 All buried or submerged lead-wire attachments should be coated with an electrically insulating material, compatible with the external pipe coating and wire insulation.

8.6.3 Test lead wires should be color coded or otherwise permanently identified. Wires should be installed with slack. Damage to insulation should be avoided and repairs made if damage occurs. Test leads should not be exposed to excessive heat and sunlight. Aboveground test stations are preferred. If test stations are flush with the ground, adequate slack should be provided within the test station to facilitate test connections.

8.6.4 Cable connections at bonds to other structures or across isolating joints should be mechanically secure, electrically conductive, and suitably coated. Bond connections should be accessible for testing.

8.7 Electrical Isolation

8.7.1 Inspection and electrical measurements should ensure that electrical isolation is adequate (see NACE SP0286[5]).

Section 9: Control of Interference Currents

9.1 Introduction

9.1.1 This section recommends practices for the detection and control of interference currents. The mechanism and its detrimental effects are described.

9.2 Mechanism of Interference-Current Corrosion (Stray-Current Corrosion)

9.2.1 Interference-current corrosion on buried or submerged metallic structures differs from other causes of corrosion damage in that the direct current, which causes the corrosion, has a source foreign to the affected structure. Usually the interfering current is collected from the electrolyte by the affected structure from a DC source not metallically bonded to the affected structure.

9.2.1.1 Detrimental effects of interference currents usually occur at locations where the currents transfer between the affected structures and the electrolyte.

9.2.1.2 Structures made of amphoteric metals such as aluminum and lead may be subject to corrosion damage from a buildup of alkalinity at or near the metal surface collecting interference currents.

9.2.1.3 Coatings may become disbonded at areas where voltage gradients in the electrolyte force current onto the affected structure. However, as the external coating becomes disbonded, a larger area of metal may be exposed, which would increase the demand for a CP current. This disbondment may create shielding problems.

9.2.2 The severity of external corrosion resulting from interference currents depends on several factors:

9.2.2.1 Separation and routing of the interfering and affected structures and location of the interfering current source;

9.2.2.2 Magnitude and density of the current;

9.2.2.3 Quality of the external coating or absence of an external coating on the structures involved; and

9.2.2.4 Presence and location of mechanical joints having high electrical resistance.

9.2.3 Typical sources of interference currents include the following:

9.2.3.1 Direct current: CP rectifiers, thermoelectric generators, DC electrified railway and transit systems, coal mine haulage systems and pumps, welding machines, and other DC power systems;

9.2.3.2 Alternating current: AC power systems and AC electrified railway systems; and

9.2.3.3 Telluric current.

9.3 Detection of Interference Currents

9.3.1 During external corrosion control surveys, personnel should be alert for electrical or physical observations that could indicate interference from a foreign source such as the following:

9.3.1.1 Pipe-electrolyte potential changes on the affected structure caused by the foreign DC source;

9.3.1.2 Changes in the line current magnitude or direction caused by the foreign DC source;

9.3.1.3 Localized pitting in areas near or immediately adjacent to a foreign structure; and

9.3.1.4 Damage to external coatings in a localized area near an anode bed or near any other source of stray direct current.

9.3.2 In areas in which interference currents are suspected, appropriate tests should be conducted. All affected parties shall be notified before tests are conducted. Notification should be channeled through corrosion control coordinating committees, when they exist (see NACE Publication TPC 11[8]). Any one or a combination of the following test methods can be used.

9.3.2.1 Measurement of structure-electrolyte potentials with recording or indicating instruments;

9.3.2.2 Measurement of current flowing on the structure with recording or indicating instruments;

9.3.2.3 Development of beta curves to locate the area of maximum current discharge from the affected structure (see Appendix A); and

9.3.2.4 Measurement of the variations in current output of the suspected source of interference current and correlations with measurements obtained in Paragraphs 9.3.2.1 and 9.3.2.2.

9.4 Methods for Mitigating Interference Corrosion Problems

9.4.1 Interference problems are individual in nature and the solution should be mutually satisfactory to the parties involved. These methods may be used individually or in combination.

9.4.2 Design and installation of electrical bonds of proper resistance between the affected structures is a technique for interference control. The bond electrically conducts interference current from an affected structure to the interfering structure or current source.

9.4.2.1 Unidirectional control devices, such as diodes or reverse current switches, may be required in conjunction with electrical bonds if fluctuating currents are present. These devices prevent reversal of current flow.

9.4.2.2 A resistor may be necessary in the bond circuit to control the flow of electrical current from the affected structure to the interfering structure.

9.4.2.3 The attachment of electrical bonds can reduce the level of CP on the interfering structure. Supplementary CP may then be required on the interfering structure to compensate for this effect.

9.4.2.4 A bond may not effectively mitigate the interference problem in the case of a cathodically protected bare or poorly externally coated pipeline that is causing interference on an externally coated pipeline.

9.4.3 CP current can be applied to the affected structure at those locations at which the interfering current is being discharged. The source of CP current may be galvanic or impressed current anodes.

9.4.4 Adjustment of the current output from interfering CP rectifiers may resolve interference problems.

9.4.5 Relocation of the groundbeds of cathodic protection rectifiers can reduce or eliminate the pickup of interference currents on nearby structures.

9.4.6 Rerouting of proposed pipelines may avoid sources of interference current.

9.4.7 Properly located isolating fittings in the affected structure may reduce or resolve interference problems.

9.4.8 Application of external coating to current pick-up area(s) may reduce or resolve interference problems.

9.5 Indications of Resolved Interference Problems

9.5.1 Restoration of the structure-electrolyte potentials on the affected structure to those values that existed prior to the interference.

9.5.2 Measured line currents on the affected structure that show that the interference current is not being discharged to the electrolyte.

9.5.3 Adjustment of the slope of the beta curve to show that current discharge has been eliminated at the location of maximum exposure (see Appendix A).

Section 10: Operation and Maintenance of CP Systems

10.1 Introduction

10.1.1 This section recommends procedures and practices for energizing and maintaining continuous, effective, and efficient operation of CP systems.

10.1.1.1 Electrical measurements and inspection are necessary to determine that protection has been established according to applicable criteria and that each part of the CP system is operating properly. Conditions that affect protection are subject to change. Correspondingly, changes may be required in the CP system to maintain protection. Periodic measurements and inspections are necessary to detect changes in the CP system. Conditions in which operating experience indicates that testing and inspections need to be made more frequently than recommended herein may exist.

10.1.1.2 Care should be exercised in selecting the location, number, and type of electrical measurements used to determine the adequacy of CP.

10.1.1.3 When practicable and determined necessary by sound engineering practice, a detailed (close-interval) potential survey should be conducted to:

(a) assess the effectiveness of the CP system;

(b) provide base line operating data;

(c) locate areas of inadequate protection levels;

(d) identify locations likely to be adversely affected by construction, stray currents, or other unusual environmental conditions; or

(e) select areas to be monitored periodically.

10.1.1.4 Adjustments to a CP system should be accompanied by sufficient testing to assure the criteria remain satisfied and to reassess interference to other structures or isolation points.

10.2 A survey should be conducted after each CP system is energized or adjusted to determine whether the applicable criterion or criteria from Section 6 have been satisfied.

10.3 The effectiveness of the CP system should be monitored annually. Longer or shorter intervals for monitoring may be appropriate, depending on the variability of CP factors, safety considerations, and economics of monitoring.

10.4 Inspection and tests of CP facilities should be made to ensure their proper operation and maintenance as follows:

10.4.1 All sources of impressed current should be checked at intervals of two months. Longer or shorter intervals for monitoring may be appropriate. Evidence of proper functioning may be current output, normal power consumption, a signal indicating normal operation, or satisfactory CP levels on the pipe.

10.4.2 All impressed current protective facilities should be inspected annually as part of a preventive maintenance program to minimize in-service failure. Longer or shorter intervals for monitoring may be appropriate. Inspections may include a check for electrical malfunctions, safety ground connections, meter accuracy, efficiency, and circuit resistance.

10.4.3 Reverse current switches, diodes, interference bonds, and other protective devices, whose failures would jeopardize structure protection, should be inspected for proper functioning at intervals of two months. Longer or shorter intervals for monitoring may be appropriate.

10.4.4 The effectiveness of isolating fittings, continuity bonds, and casing isolation should be evaluated during the periodic surveys. This may be accomplished by electrical measurements.

10.5 When pipe has been uncovered, it should be examined for evidence of external corrosion and, if externally coated, for condition of the external coating.

10.6 The test equipment used for obtaining each electrical value should be of an appropriate type. Instruments and related equipment should be maintained in good operating condition and checked for accuracy.

10.7 Remedial measures should be taken when periodic tests and inspections indicate that CP is no longer adequate. These measures may include the following:

10.7.1 Repair, replace, or adjust components of CP systems;

10.7.2 Provide supplementary facilities in which additional CP is necessary;

10.7.3 Thoroughly clean and properly coat bare structures if required to attain CP;

10.7.4 Repair, replace, or adjust continuity and interference bonds;

10.7.5 Remove accidental metallic contacts; and

10.7.6 Repair defective isolating devices.

10.8 An electrical short circuit between a casing and carrier pipe can result in inadequate CP of the pipeline outside the casing due to reduction of protective current to the pipeline.

10.8.1 When a short results in inadequate CP of the pipeline outside the casing, steps must be taken to restore CP to a level required to meet the CP criterion. These steps may include eliminating the short between the casing and carrier pipe, supplementing CP, or improving the quality of the external coating on the pipeline outside the casing. None of these steps will ensure that external corrosion will not occur on the carrier pipe inside the casing; however, a shorted casing does not necessarily result in external corrosion of the carrier pipe inside the casing.

10.9 When the effects of electrical shielding of CP current are detected, the situation should be evaluated and appropriate action taken.

Section 11: External Corrosion Control Records

11.1 Introduction

11.1.1 This section describes external corrosion control records that will document in a clear, concise, workable manner data that are pertinent to the design, installation, operation, maintenance, and effectiveness of external corrosion control measures.

11.2 Relative to the determination of the need for external corrosion control, the following should be recorded:

11.2.1 Corrosion leaks, breaks, and pipe replacements; and

11.2.2 Pipe and external coating condition observed when a buried structure is exposed.

11.3 Relative to structure design, the following should be recorded:

11.3.1 External coating material and application specifications; and

11.3.2 Design and location of isolating devices, test leads and other test facilities, and details of other special external corrosion control measures taken.

11.4 Relative to the design of external corrosion control facilities, the following should be recorded:

11.4.1 Results of current requirement tests;

11.4.2 Results of soil resistivity surveys;

11.4.3 Location of foreign structures; and

11.4.4 Interference tests and design of interference bonds and reverse current switch installations.

11.4.4.1 Scheduling of interference tests, correspondence with corrosion control coordinating committees, and direct communication with the concerned companies.

11.4.4.2 Record of interference tests conducted, including location of tests, name of company involved, and results.

11.5 Relative to the installation of external corrosion control facilities, the following should be recorded:

11.5.1 Installation of CP facilities:

11.5.1.1 Impressed current systems:

11.5.1.1.1 Location and date placed in service;

11.5.1.1.2 Number, type, size, depth, backfill, and spacing of anodes;

11.5.1.1.3 Specifications of rectifier or other energy source; and

11.5.1.1.4 Cable size and type of insulation.

11.5.1.2 Galvanic anode systems:

11.5.1.2.1 Location and date placed in service;

11.5.1.2.2 Number, type, size, backfill, and spacing of anodes; and

11.5.1.2.3 Wire size and type of insulation.

11.5.2 Installation of interference mitigation facilities:

11.5.2.1 Details of interference bond installation:

11.5.2.1.1 Location and name of company involved;

11.5.2.1.2 Resistance value or other pertinent information; and

11.5.2.1.3 Magnitude and polarity of drainage current.

11.5.2.2 Details of reverse current switch:

11.5.2.2.1 Location and name of companies;

11.5.2.2.2 Type of switch or equivalent device; and

11.5.2.2.3 Data showing effective operating adjustment.

11.5.2.3 Details of other remedial measures.

11.6 Records of surveys, inspections, and tests should be maintained to demonstrate that applicable criteria for interference control and CP have been satisfied.

11.7 Relative to the maintenance of external corrosion control facilities, the following information should be recorded:

11.7.1 Maintenance of CP facilities:

11.7.1.1 Repair of rectifiers and other DC power sources; and

11.7.1.2 Repair or replacement of anodes, connections, wires, and cables.

11.7.2 Maintenance of interference bonds and reverse current switches:

11.7.2.1 Repair of interference bonds; and

11.7.2.2 Repair of reverse current switches or equivalent devices.

11.7.3 Maintenance, repair, and replacement of external coating, isolating devices, test leads, and other test facilities.

11.8 Records sufficient to demonstrate the evaluation of the need for and the effectiveness of external corrosion control measures should be maintained as long as the facility involved remains in service. Other related external corrosion control records should be retained for such a period that satisfies individual company needs.

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25. ASTM G 19 (latest revision), "Standard Test Method for Disbonding Characteristics of Pipeline Coatings by Direct Soil Burial" (West Conshohocken, PA: ASTM).

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Appendix A—Interference Testing

A beta curve is a plot of dynamic (fluctuating) interference current or related proportional voltage (ordinate) versus values of corresponding structure-to-soil potentials at a selected location on the affected structure (abscissa). If the correlation is reasonably linear, the plot will indicate whether the affected structure is receiving or discharging current at the location where the structure-to-soil potential was measured. Dynamic interference investigation involves many beta curve plots to search for the point of maximum interference-current discharge. Interference is resolved when the correlation of maximum current discharge has been changed to a correlation that shows that current pickup is being achieved in the exposure area by the corrective measures taken. These corrective measures may be accomplished by metallic bonding or other interference control techniques.

Appendix B—Method for Determining Probable Corrosion Rate and Costs of Maintaining Service

Maintenance of a piping system may include repairing corrosion leaks and reconditioning or replacing all or portions of the system.

In order to make estimates of the costs involved, it is necessary to determine the probability of corrosion or the rate at which corrosion is proceeding. The usual methods of predicting the probability or rate of corrosion are as follows:

(a) Study of corrosion history on the piping system in question or on other systems of the same material in the same general area or in similar environments. Cumulative leak-frequency curves are valuable in this respect.

(b) Study of the environment surrounding a piping system: resistivity, pH, and composition. Redox potential tests may also be used to a limited extent. Once the nature of the environment has been determined, the probable corrosiveness is estimated by reference to actual corrosion experience on similar metallic structures, when environmental conditions are similar. Consideration of possible environmental changes such as might result from irrigation, spillage of corrosive substances, pollution, and seasonal changes in soil moisture content should be included in such a study.

(c) Investigation for corrosion on a piping system by visual inspection of the pipe or by instruments that mechanically or electrically inspect the condition of the pipe. Condition of the piping system should be carefully determined and recorded each time a portion of the line is excavated for any reason.

(d) Maintenance records detailing leak locations, soil studies, structure-to-electrolyte potential surveys, surface potential surveys, line current studies, and wall thickness surveys used as a guide for locating areas of maximum corrosion.

(e) Statistical treatment of available data.

(f) Results of pressure testing. Under certain conditions, this may help to determine the existence of corrosion.

Appendix C—Contingent Costs of Corrosion

In addition to the direct costs that result from corrosion, contingent costs include:

(a) Public liability claims;

(b) Property damage claims;

(c) Damage to natural facilities, such as municipal or irrigation water supplies, forests, parks, and scenic areas;

(d) Cleanup of product lost to surroundings;

(e) Plant shutdown and startup costs;

(f) Cost of lost product;

(g) Loss of revenue through interruption of service;

(h) Loss of contract or goodwill through interruption of service; and

(i) Loss of reclaim or salvage value of piping system.

Appendix D—Costs of Corrosion Control

The usual costs for protecting buried or submerged metallic structures are for complete or partial CP or for external coatings supplemented with cathodic protection. Other corrosion control costs include:

(a) Relocation of piping to avoid known corrosive conditions (this may include installing lines above ground);

(b) Reconditioning and externally coating the piping system;

(c) Use of corrosion-resistant materials;

(d) Use of selected or inhibited backfill;

(e) Electrical isolation to limit possible galvanic action; and

(f) Correction of conditions in or on the pipe that might accelerate corrosion.

NACE SP0286-2007
(formerly RP0286)
Item no. 21032

Standard Practice

Electrical Isolation of Cathodically Protected Pipelines

Reaffirmed 2007-03-10
Reaffirmed 2002-04-11
Revised 1997-June-27
Approved 1986
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ISBN 1-57590-041-6

Foreword

This standard practice is to be used in conjunction with the latest revisions of NACE SP0169[1] and SP0177.[2] Each of these standards refers to electrical isolation or isolation joints, but details are not provided. This standard, which was prepared to supplement those standards, provides engineers, designers, and technical personnel dealing with pipelines the necessary information to isolate cathodically protected pipelines electrically.

This standard was originally prepared in 1986 and revised in 1997 by former Task Group T-10A-15 on Electrical Isolation of Cathodically Protected Pipelines, a component of Unit Committee T-10A on Cathodic Protection. The standard was reaffirmed in 2002 and 2007 by Specific Technology Group (STG) 35 on Pipelines, Tanks, and Well Casings. It is issued by NACE International under the auspices of STG 35.

> In NACE Standards, the terms *shall*, *must*, *should*, and *may* are used in accordance with the definitions of these terms in the NACE Publications Style Manual, 4th ed., Paragraph 7.4.1.9. *Shall* and *must* are used to state mandatory requirements. The term *should* is used to state something good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

NACE International
Standard Practice
Electrical Isolation of Cathodically Protected Pipelines

Contents

Section 1: General

1.1 This standard explains the importance of pipeline electrical isolation in achieving and maintaining adequate, reliable, and economical corrosion control. The standard outlines the types of devices used for isolation; precautions to be observed; and selection of devices based on pipeline characteristics, site, and contents. The standard describes isolating flanges, gaskets, sleeves, washers, joints, unions, couplings, and spools, and discusses materials for pipeline casing isolation. Installation, field testing, and maintenance of isolating devices are also included.

1.2 This standard describes the application of isolating devices intended only for cathodic protection (CP) purposes when voltages across the isolating device are 1 to 2 volts direct current (DC) and the alternating current (AC) exposure does not exceed 15 volts root mean square (rms).[3]

1.3 This standard does not discuss situations in which isolating devices are incorporated purely for safety reasons; in those situations, reference should be made to relevant electrical safety codes. Isolating devices shall not be used in enclosed areas where combustible atmospheres are likely to be present.

1.4 Isolation of cathodically protected pipelines is recommended to minimize current requirements, facilitate testing and troubleshooting, and improve current distribution.

Section 2: Definitions

Refer to the NACE International Glossary of Corrosion-Related Terms[4] for definitions.

Section 3: Need for Isolation

3.1 CP current intended for a given pipeline can flow to other underground facilities or equipment electrically connected to the pipeline. If protection of the other underground facilities is not intended, significant CP current can be lost unless preventive measures are taken. Generally called a current drain, this current loss can be reduced through electrical isolation of the pipeline.

3.2 CP even of well coated pipelines may not be economical or practical unless electrical isolation is achieved.

3.3 Pipeline casings should be electrically isolated from the carrier pipe.

3.4 If a pipeline passes through the wall of a valve pit or a building, metallic contact can occur between the pipe and the steel reinforcement in the concrete, causing a significant loss of protective current.

3.5 Electrical isolation can minimize or eliminate galvanic corrosion caused by dissimilar metals in contact with each other or caused by similar metals in contact with each other when one metal is bare or has a dielectric coating system while the other has a permeable (e.g., concrete or mortar) coating system.

3.6 If a pipeline is designed to be electrically continuous but is supported by another metallic structure in contact with soil or groundwater, the pipeline should be isolated from that structure. The isolating supports must prevent damage to the pipeline coating and must accommodate relative movement, vibration, and temperature differential.

3.7 Isolation of power and instrumentation grounding systems may be required when electrically operated valves and similar components form part of a pipeline system. All applicable safety codes and standards must be followed.

3.8 If a pipeline is to be protected by more than one type of CP system, isolation of one or more sections may be desirable.

3.9 Isolation of pipelines can be beneficial in controlling or limiting the effect of stray currents such as telluric currents, currents associated with an electric traction system, or currents from nearby structures under CP.

Section 4: Methods of Isolation

4.1 Electrically isolating devices may be specially manufactured or prefabricated. It may be possible for existing fittings to be retrofitted with isolating materials to serve as isolating devices. Selection of the type of isolating device depends on the mechanical forces due to its position in the system, the operating temperature range, pressure constraints, and other considerations. Provisions should be made for the connection of test wires for testing these isolating devices.

4.2 Flanges

4.2.1 A bolted pair of pipeline flanges may be converted into an electrically isolating device by inserting an isolating gasket between the flanges and isolating sleeves over the shanks of the bolts, and placing isolating washers under the external steel washers to isolate the bolts (see Figures 1a and 1b). Isolating gaskets may have diameters equal to or greater than the outside diameter of the flanges, or they may fit within the bolt circle of the flange faces or into the groove of ring-type joint flanges. Isolating sleeves (around bolts) and washers (over bolts and under nuts and bolt heads) may also be combined as one-piece units. In some underground applications, the nuts and bolts may be isolated from one flange only so that CP will also protect all bolts and nuts. In some applications, isolating flanges are required to be pressure tested after assembly. When isolating flanges are being considered for use below ground, special consideration should be given to the installation (see Paragraph 7.2.5). If circumstances indicate that this type of installation would not be effective, an alternative device should be used.

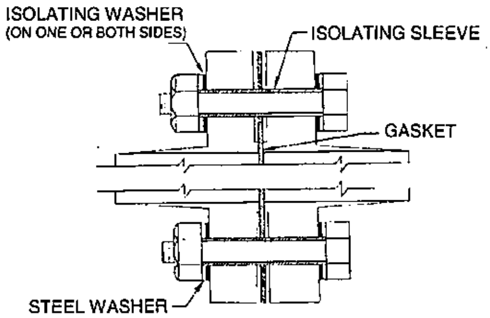

FIGURE 1a:
Full-Length Bolt Sleeves
This figure shows the use of full-length bolt sleeves.

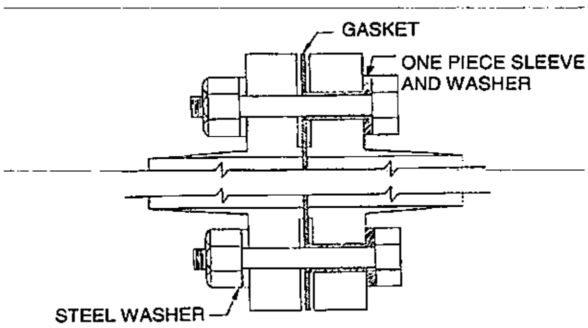

FIGURE 1b:
Half-Length Bolt Sleeves
This figure shows the use of half-length bolt sleeves.

4.3 Prefabricated Isolating Joints

4.3.1 Pressure and electrical test certificates should be provided with any specially manufactured isolating joints. Unless the isolating device is pressure tested as part of the pipeline system, a pressure test certificate may be required in order to comply with applicable codes. These codes include Parts 192 and 195 of U.S. Department of Transportation[(1)] Regulations,[5] ANSI[(2)] B31.3,[6] ANSI B31.4,[7] and ANSI B31.8.[8]

4.3.2 Isolating monolithic joints for pressure services over 1,000 kPa[(3)] (150 psi) (see Figure 2) consist of a pair of hubs on short pipe lengths; one hub is extended at its periphery by a barrel that overlaps the other hub. The two sections are aligned with the isolating materials and held in position with a large compressive force that is locked by welding, wedging, or swaging and is pressure sealed. These units do not include any threaded components and cannot be disassembled on site.

4.3.3 Isolating monolithic joints for pressure services below 1,000 kPa (150 psi) are generally one of two types. One type consists of short lengths of pipe. The end of one length is enlarged and its internal surface serrated. An isolating sleeve bonded to the external serrated surface of the other pipe fits into the enlarged pipe, which is swaged to hold the assembly in position. The second type (see Figure 3) is similar to the higher-pressure joint described in Paragraph 3.3.2.

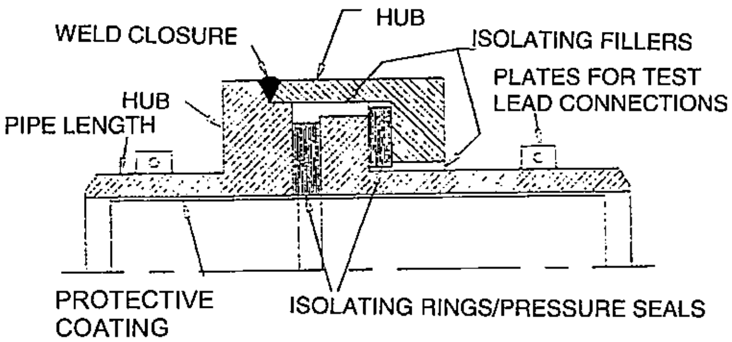

FIGURE 2:
Typical Isolating Monolithic Device
High Pressure—Over 1,000 kPa (150 psi)

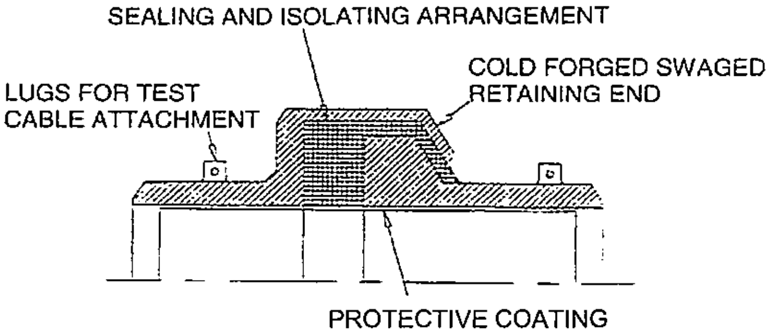

FIGURE 3:
Typical Isolating Monolithic Joint
Pressure Service—Below 1,000 kPa (150 psi)
(Other methods of construction are available.)

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(1) U.S. Department of Transportation (DOT), 400 7th St. SW, Washington, DC 20590.
(2) American National Standards Institute (ANSI), 11 West 42nd St., New York, NY 10036.
(3) 1 kPa = 0.01 bar.

4.3.4 Isolating yoke-type joints (see Figure 4) include two hub assemblies. The back of one hub is conical. The two hubs are sealed using O-rings and isolating rings or spacers. The hubs are held together under pressure by an encircling yoke clamped by bolts through lugs that are normally tack welded.

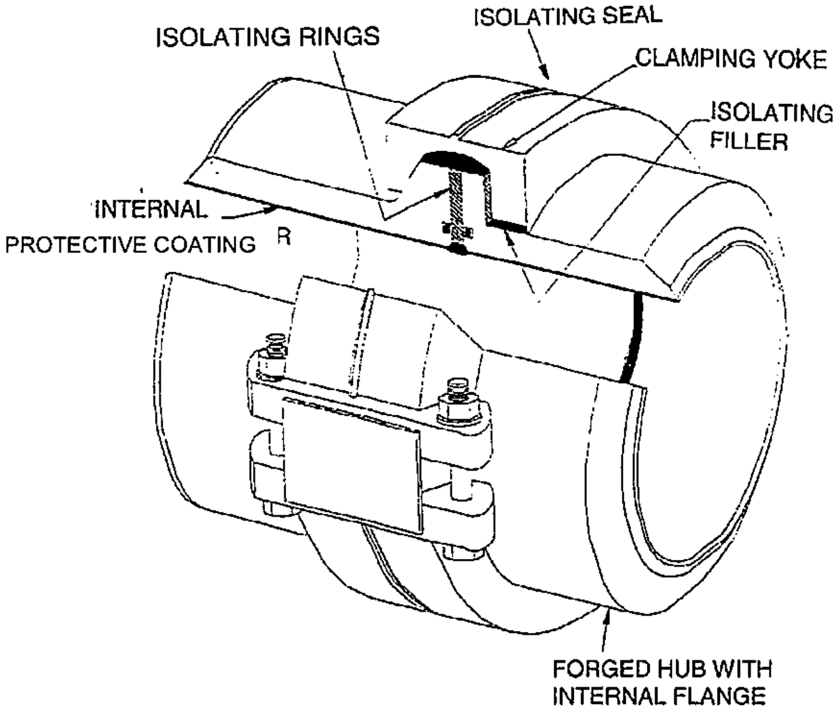


FIGURE 4:
Typical Isolating Yoke-Type Device

4.3.5 Prefabricated isolating flanges are factory assembled isolating devices that are welded to a short pipe length with welded or screwed end preparations.

4.4 Unions (see Figure 5)

An isolating union consists of two flanged bodies screwed onto the end of each connecting pipe. One flanged end is externally threaded, and the joint is held in position by a nut that is electrically isolated from the other end. The pressure seal may be achieved by using a molded seal or a gasket between mating faces.

4.5 Spools (see Figure 6)

An isolating spool for pipelines carrying fluids may be made either by inserting a long piece of nonmetallic pipe into a piping system or by inserting a long piece of metallic pipe into the pipeline in combination with one or two of the devices described in Paragraphs 3.2 through 3.6. One of the isolating devices described in those paragraphs may also be used with an extended pipe length that has a high-electrical-resistance lining bonded to the isolating flange or joint and to the inside of the extended pipe length. When using this design, the extended length should also be the protected length.

4.6 Couplings (see Figure 7)

4.6.1 Bolted couplings consist of a cylindrical steel middle ring, two resilient gaskets, and steel follower rings connected by a set of steel trackhead bolts. Isolation may be provided by an isolating gasket under one of the follower rings and an isolating sleeve for one pipe end.

4.6.2 Screwed couplings consist of a forged steel or malleable iron body, an isolating gasket, two retainer cups, and two end nuts, with a combined isolating sleeve and end spacer provided for one pipe end.

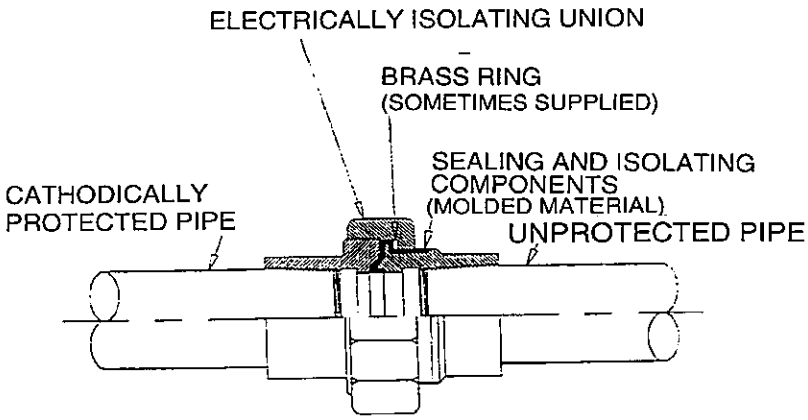


FIGURE 5:
Typical Isolating Union

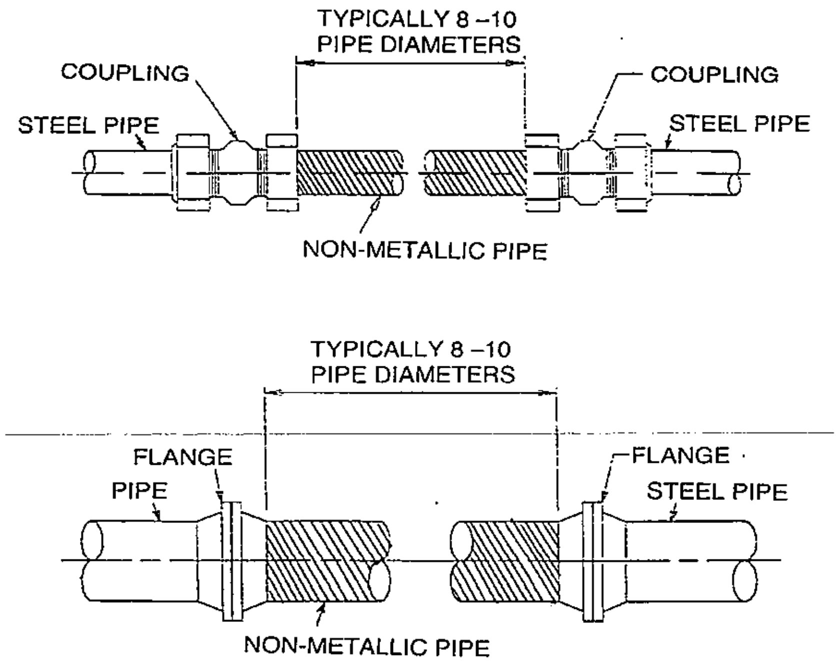


FIGURE 6:
Typical Isolating Spools

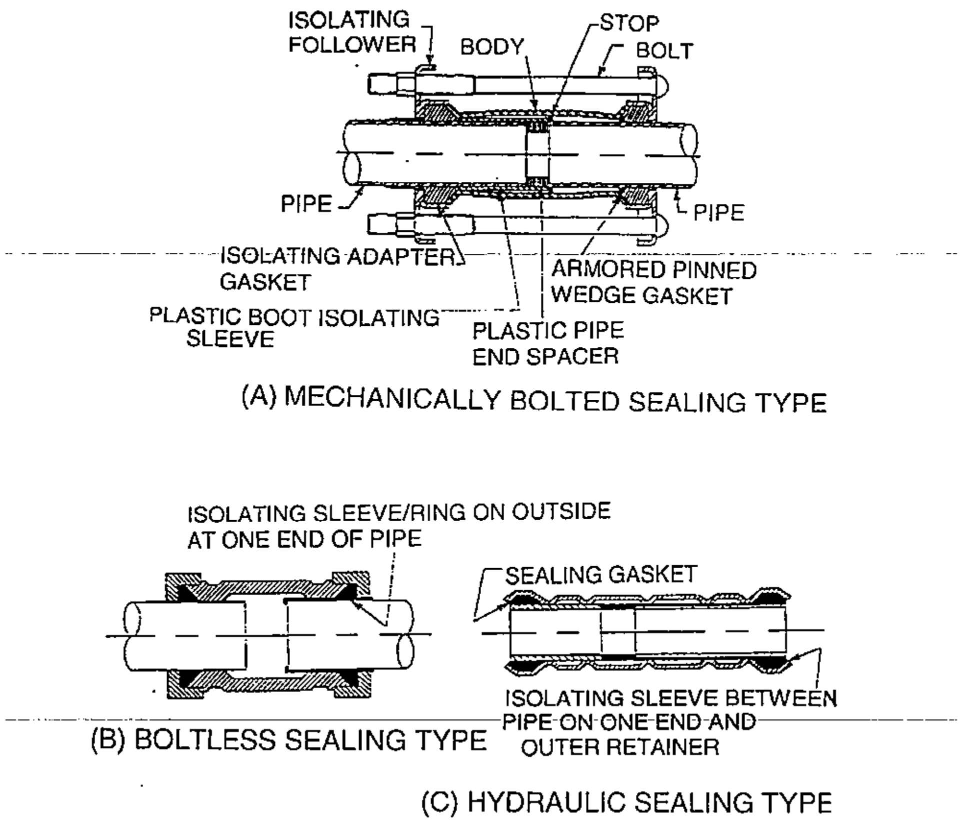


FIGURE 7:
Typical Isolating Couplings

4.6.3 A sleeved coupling with a hydraulic sealing system consists of a steel sleeve inside a pipe coupling with two isolating gaskets sealed by internal and external hydraulic pressure to the sleeve. The sleeve is equipped with an isolating gasket, an isolating sleeve, and an isolating pipe spacer.

4.7 Isolating Tapping Sleeve (see Figure 8)

4.7.1 An isolating tapping sleeve consists of a split sleeve installed over a pipe with the two halves connected by bolts and gaskets. One end of the fitting is equipped with isolating material.

4.8 Isolating Transition Fittings

4.8.1 Isolating transition fittings include a dielectric pipe fitting or a section of pipe or tubing that may be inserted in low-pressure pipeline systems.

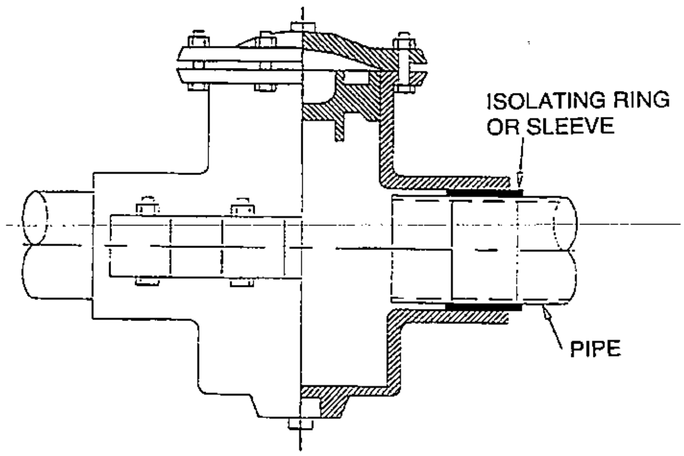


FIGURE 8:
Typical Isolating Tapping Sleeve

Section 5: Isolation from Other Metallic Structures

5.1 Pipelines to be cathodically protected must be isolated from other metallic structures unless the CP system has incorporated sufficient current drain for other metallic structures.

5.1.1 Casings

5.1.1.1 Pipelines are commonly routed under roads and railways in steel casings. The casings are normally electrically isolated from the pipeline. Isolation is provided by isolating spacers located circumferentially around the pipe. After these isolators are placed at intervals along the carrier pipe, the pipe is inserted into the casing (see Figure 9). NOTE: Other methods, such as coating pipes with concrete, are also used for isolation. The effectiveness of methods other than isolating spacers should be evaluated on a case-by-case basis.

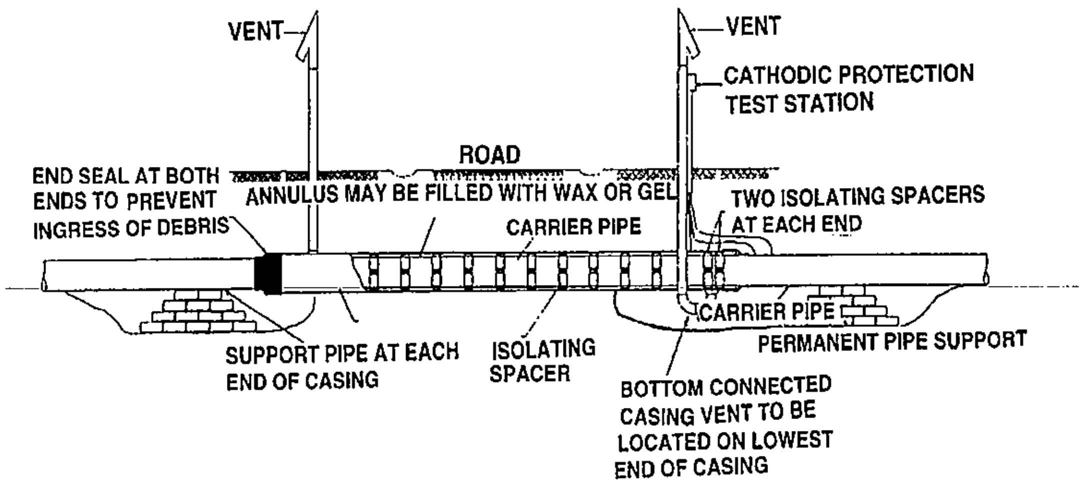


FIGURE 9:
Typical Casing/Sleeve Installation

5.1.1.2 Electrical isolation of the casing and carrier pipe provided by the isolating spacers may be relied on only as long as the carrier pipe remains physically separated from the casing pipe. Isolating spacers should be designed and spaced to withstand the loads caused by the movement of the carrier pipe under operational conditions.

5.1.1.3 The use of proper end-sealing and casing-filling methods can prevent possible contacts as well as the ingress of foreign substances.

5.1.2 Pipe Bridges

5.1.2.1 Pipeline supports on a metallic pipe bridge shall be provided with pads to isolate the pipe electrically from the support cradles. Plastics, neoprene, fiberglass reinforced plastic, or glazed ceramics may be used for these pads. The material chosen should be the most suitable for the pipeline service and environmental conditions.

5.1.2.2 If the CP system is designed so that the portion of the pipeline on the pipe bridge is isolated from the underground portion of the pipeline, a jumper wire can be bonded to the pipeline at the isolating device (see Figure 10) to provide electrical continuity around the isolated section on the bridge. The jumper wire must be sized to conduct the required CP current.

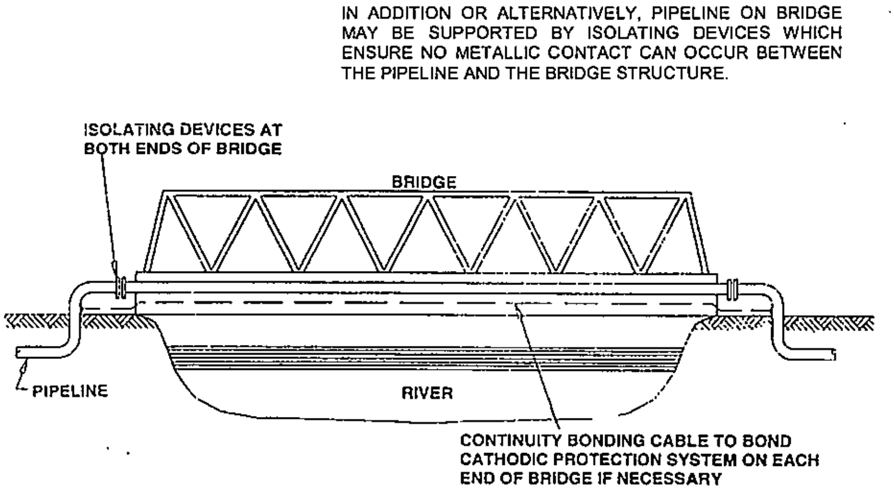


FIGURE 10:
Typical Use of Isolating Devices at Each End of a Bridge for a Cathodically Protected Pipeline

5.1.3 Pipeline Crossings

5.1.3.1 A minimum separation of 0.3 m (12 in.) should be maintained between all buried metallic structures at pipeline crossings. When this is not possible, consideration should be given to installation of isolating materials between the structures.

5.1.4 Offshore Platform Riser Pipes

5.1.4.1 Pipelines rising from the ocean bed onto offshore platforms may require electrical isolation from the structure's steel jacket, support legs, or, in the case of concrete platforms, the concrete reinforcing steel. If the riser support is designed to allow movement of the riser pipe, then roller guides, flexible collars, or other suitable parts made of isolating materials can be used to ensure effective electrical isolation.

5.1.5 Electrical Grounds and Supply Cable Sheathing

5.1.5.1 Installation of electric motorized valves and instrumentation transducers in a pipeline connects the pipeline with the electrical supply earth grounding. Electrical isolation can be obtained by using one of the following methods. Any measure taken should not conflict with applicable electrical codes.

5.1.5.1.1 Install a continuity bond cable around the assembly; then provide isolating joints on each side of the valve.

5.1.5.1.2 Ground the valve with appropriate devices; then isolate the electrical supply earth grounding from the valve.

5.1.5.1.3 Separately ground and connect the secondary side of the circuit to approved isolating equipment; then isolate the electrical supply earth grounding from the motor by terminating the supply on an isolating transformer or equipment approved for that application.

5.1.5.1.4 Ground separately, if necessary; then isolate the instrumentation transducer screen from the transducer.

5.1.5.1.5 Connect an approved electrical equipment device; then connect the electrical supply earth grounding by that means.

Section 6: Selection of Isolation Device or Method

6.1 The following factors should be carefully considered when selecting the isolating device or method to be used in any particular application.

6.1.1 Pipeline contents;

6.1.2 Pipeline temperature;

6.1.3 Pipeline pressure rating;

6.1.4 Location and orientation of isolating devices;

6.1.5 Piping configuration;

6.1.6 Isolation from foreign contact;

6.1.7 Necessity for field repair; and

6.1.8 Tensile, compression, and bending load requirements of the isolating devices.

Section 7: Equipment Specifications

7.1 This section defines the general requirements for materials for isolating devices and for the design and testing of isolating devices.

7.2 Isolating Flanges

7.2.1 Specifications—Material, design, manufacturing, testing, and marking specifications shall be agreed on by the customer and the vendor.

7.2.2 Procurement Information—The following information is normally required for purchasing:

7.2.2.1 Pipe nominal diameter and material;

7.2.2.2 Flange standard;

7.2.2.3 Pressure class;

7.2.2.4 Product carried;

7.2.2.5 Operating temperature range;

7.2.2.6 Wall thickness of pipe;

7.2.2.7 Flange dimensions, pitch circle diameter, bolt size, number of bolts, etc., if nonstandard;

7.2.2.8 Flange face details (e.g., raised or full face, ring joint);

7.2.2.9 Test requirements; and

7.2.2.10 Isolating materials.

7.2.3 Design

7.2.3.1 Gaskets may either be full face or may fit inside the bolt circle. They should be a minimum of 3.0 mm (120 mil) thick and may protrude into the bore of the pipe by 1.5 mm (60 mil) to prevent electrically conductive bridging over the isolation material. Thinner gaskets may be appropriate to reduce blowout potential.

7.2.3.2 Isolating bolt sleeves are normally designed for standard bolting in standard bolt holes and should be of sufficient length to extend halfway inside the steel washer. Care should be taken to ensure that the dimensions selected will allow the use of the standard size bolt.

7.2.3.3 Isolating bolt washers should be sized internally to accommodate the bolt sleeve, and the outside diameter (OD) should be sized so that the washer will fit inside the flange spot facing.

7.2.3.4 Steel washers should be the same size as the isolating washer and should be treated to prevent corrosion.

7.2.3.5 A combined isolating sleeve/isolating washer may be used.

7.2.4 Materials

7.2.4.1 Gaskets should be manufactured from isolating material having low cold-flow characteristics, low water absorption, and high compressive strength. Preference should be given to materials with low *y* and *m* factors. The *y* factor is a measure of the compressive load required to establish an initial seal, while the *m* factor is an indication of the additional load required to hold the fluid pressure needed to keep the seal in operation. The smaller these factors are, the less pressure is required to establish and maintain the seal. (The *m* and *y* factors for various materials are included in the ASME[(4)] Boiler and Pressure Vessel Code, Section 8,[9] ANSI B16.5,[10] and BS[(5)] 1560.[11]) For pipelines carrying water or water-containing fluids, gaskets may consist of a laminate core material faced with a suitable sealing material (e.g., neoprene-faced phenolic), or with seals set into the laminate core material. For cryogenics, the core should be a suitable epoxy with either polytetrafluoroethylene (PTFE) or fluorinated ethylene propylene (FEP) seals, depending on the product and temperature. For high-pressure, high-temperature steam, gasket manufacturers should be consulted. For pipelines carrying hydrocarbons and other fluids, the gasket selected should be suitable for the particular application (product, pressure, temperature, etc.). Gaskets should have the highest compressive strength suitable for the service conditions.

7.2.4.2 Isolating bolt sleeves should be manufactured from materials having low water absorption (because of the limitations on thickness), high dielectric strength, and low cold-flow characteristics. They should be suitable for the service conditions of the particular application.

7.2.4.3 Isolating washers should be manufactured from materials having high compressive strength, low water absorption, high dielectric strength, and low cold-flow characteristics.

7.2.4.4 All materials should be selected to suit the operating conditions (product, pressure, temperature, etc.). Special consideration should be given to ensuring that the materials selected for the isolating sleeves and washers are not damaged during tightening at the time of installation.

7.2.5 Testing—The materials used should be supplied with suitable test certificates, if required, stating the compressive strength, *m* and *y* factors, temperature rating, pressure rating, water absorption, and dielectric strength.

7.3 Other Devices

7.3.1 Specifications—Material, design, manufacturing, testing, and marking generally shall be agreed upon by the customer and the vendor.

7.3.2 Procurement Information—The following information is normally required for purchasing:

7.3.2.1 Pressure class;

7.3.2.2 Service temperature range;

7.3.2.3 Product carried;

7.3.2.4 Grade of pipe material;

7.3.2.5 Pipe dimensions;

7.3.2.6 Mandatory design standards and any unusual or high external forces (e.g., tension, bending, torsion, or thermal forces);

7.3.2.7 Internal and external coating;

7.3.2.8 Overall length of device;

7.3.2.9 Test/inspection requirements; and

7.3.2.10 Packing requirements.

7.3.3 Design

7.3.3.1 The design shall be such that under maximum working conditions, stress in any part of the device shall not exceed the specified minimum yield strength of that part.

7.3.3.2 The procedures used by manufacturers in final assembly shall ensure that the joint sealing does not allow leakage and that the joint seal is not damaged during fabrication or by testing conditions. Elastomer seals shall have permanent residual elasticity to ensure leak tightness.

7.3.4 Manufacture

7.3.4.1 The manufacturer shall be responsible for the integrity of the manufacturing procedures and conformance to the specifications provided by the customer.

[(4)] ASME International (ASME), Three Park Ave., New York, NY 10016-5990.
[(5)] British Standards Institution (BSI), 389 Chiswick High Rd, London W4 4AL, United Kingdom.

7.3.4.2.1 General arrangement drawing and material safety data sheets (MSDS);

7.3.4.2.2 Detailed drawings showing all parts with material identification and stress/design calculations;

7.3.4.2.3 Full details of the manufacturing procedure;

7.3.4.2.4 Fabrication details including welding and inspection procedures;

7.3.4.2.5 Installation and maintenance instructions; and

7.3.4.2.6 Material and test certification, etc.

7.3.5 Testing—The acceptance criteria shall be set in accordance with the requirements of the customer and of applicable codes.

7.3.5.1 Prototype testing should be conducted to prove the integrity of the design and manufacturing procedures; alternatively, independently witnessed test data may be satisfactory. For most applications, the following tests are conducted:

7.3.5.1.1 Hydrostatic cyclic pressure test;

7.3.5.1.2 Hydrostatic pressure plus bending test;

7.3.5.1.3 Vacuum test, when appropriate; and

7.3.5.1.4 Torsional test.

7.3.5.2 Common acceptance tests to be conducted on each device are:

7.3.5.2.1 Hydrostatic pressure test;

7.3.5.2.2 Dielectric and resistance tests; and

7.3.5.2.3 Holiday test on coatings/linings.

7.3.6 Marking—Each device may be identified using marking methods approved by the customer. The information given to identify the device could be as follows:

7.3.6.1 Purchase order number;

7.3.6.2 Joint serial number;

7.3.6.3 Manufacturer's name;

7.3.6.4 Nominal diameter;

7.3.6.5 Specification number;

7.3.6.6 Maximum design pressure;

7.3.6.7 Test pressure; and

7.3.6.8 Temperature rating.

7.4 Casing Isolator Spacers and End Seals

7.4.1 All isolating materials must be selected for the long-term retention of their compressive strength, dielectric properties, and resistance to ambient conditions. The primary function of the casing isolator is to isolate electrically and support the carrier pipe in the casing and protect the pipeline coating. The carrier pipe should be fully supported within each end of the casing and externally to the casing at either end (see Figure 9).

7.4.1.1 Specifications for the casing isolator should provide the following information:

7.4.1.1.1 Width and thickness of the casing isolator;

7.4.1.1.2 Coating specifications for metallic components;

7.4.1.1.3 Dielectric material composition, physical characteristics, and compressive strength;

7.4.1.1.4 Number and spacing of isolating segments of casing isolator;

7.4.1.1.5 Carrier pipe insulator inner liner isolating material and dimensions; and

7.4.1.1.6 Attachment hardware.

7.4.2 Procurement Information—The following information is normally required for purchasing:

7.4.2.1 Actual carrier pipe outside diameter, including coating;

7.4.2.2 Casing inside diameter;

7.4.2.3 Bell or flange diameter (if applicable);

7.4.2.4 Clearance desired between the outside diameter of the pipe, including any flange, bells, or protective coatings, and the casing inside diameter;

7.4.2.5 Position within casing (standard, centered, or restrained);

7.4.2.6 Casing length and the weight per linear meter (foot) of the carrier pipe;

7.4.2.7 Density of the fluid/product carried, and

7.4.2.8 Operating temperatures and environment.

7.4.3 Materials

7.4.3.1 The materials selected must be compatible with the carrier pipe coating, the environment, and all operating conditions. The thickness, spacing, and components of the casing isolator should be designed to prevent contact between the carrier pipe and the casing.

Section 8: Equipment Installation

8.1 This section discusses the procedures to be used when installing the equipment described in Section 3. The procedures are designed to ensure that:

8.1.1 A satisfactory degree of electrical isolation is achieved at the time of installation and that the joint is not damaged so as to cause an accelerated degradation rate with time;

8.1.2 The installed equipment is adequately protected against the effects of stray DC or induced AC voltages;

8.1.3 There is adequate provision for test wires to allow for field testing and maintenance (typical arrangements are shown in Figure 11); and

8.1.4 Electrical continuity is provided to all parts of bolted isolated couplings to ensure their inclusion in the CP system.

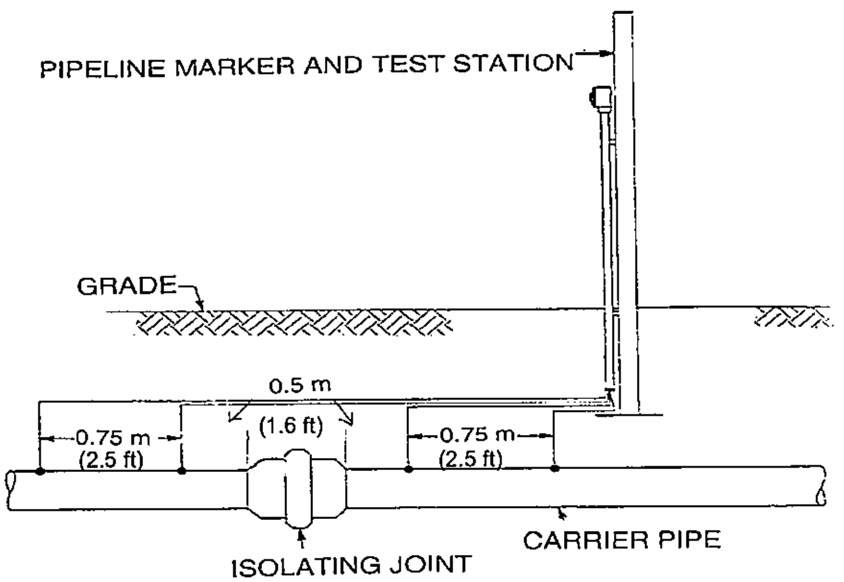


FIGURE 11:
Isolating Joint Test Station

8.2 Installation

8.2.1 General—When installed, all equipment items should be properly supported and aligned so that any forces transferred from the adjoining pipe are minimized. This should be considered when equipment locations are selected. The equipment chosen must be suitable for the mechanical forces to be encountered at the selected site. Isolating devices should not be installed in gas systems at locations where the accumulation of internal moisture is likely. When feasible, the flanges and isolating devices should be assembled and tested before and after installation.

8.2.2 Monolithic Isolating Devices (see Figures 2 and 3)

8.2.2.1 Monolithic isolating devices may be supplied in a form suitable for welded, flanged, or threaded ends.

8.2.2.2 Monolithic isolating devices for welding should be ordered with the weld end preparation conforming to the main pipe-laying specifications. The manufacturer's special installation instructions must always be followed, particularly when welding joints with short overall lengths, to ensure that the heat generated does not damage the isolating materials used in the joint construction.

8.2.3 Yoke-Type Isolating Joints (see Figure 4)—These joints should be installed as described in Paragraph 7.2.1. Particular care should be taken in supporting the yoke joint and adjacent pipe to ensure that minimum strain is applied during welding and backfilling.

8.2.4 Isolating Spools (see Figure 6)—These joints must be installed as described in Paragraph 7.2.1. In the case of linings, additional care should be taken to ensure that the direction of the joint is correct. The side of the joint that has the longer length of internal lining must be attached to the protected side of the pipeline. Linings must be fused or bonded to the internal surface of the pipe.

8.2.5 Isolating Flange Joints (see Figures 1a and 1b)

8.2.5.1 Factory Preassembled Joints—These are supplied with weld ends and should be installed as described in Paragraph 7.2.1.

8.2.5.2 Isolating Gasket Kits

8.2.5.2.1 Flanges are welded or screwed onto the pipeline, and the isolating gasket is supplied as a kit for on-site installation. Ideally, the installation should take place in clean, dry conditions. Flanges on which isolating gaskets are to be installed should be supplied as matched pairs or reamed on site to ensure correct alignment of bolt holes.

8.2.5.2.2 The flange faces should be clean and correctly aligned. Misaligned flanges will result in damage to the isolating sleeve during assembly or subsequent springing of the pipe. Flange faces should be square and free of burrs to allow for correct sealing of nuts, bolts, and washers.

8.2.5.2.3 The isolating gasket should be carefully aligned between the flange faces and the bolt holes. It may be easier to use one size smaller diameter, high-tensile-strength steel bolts, or special thin-walled sleeving to assist alignment.

8.2.5.2.4 Alignment pins should be inserted to ensure that flange alignment is maintained during installation of the isolating sleeves.

8.2.5.2.5 The isolating sleeves are then positioned in the correctly aligned holes. Isolating sleeves must be of the correct length. If isolating sleeves are too long, they may be damaged when the bolt nuts are finally tightened. If they are too short, they may fail to provide proper isolation. The length of the isolating sleeve shall normally include the two isolating washers, except when alignment allows only one flange to be isolated.

8.2.5.2.6 The bolts, complete with isolating washers adjacent to the flange and steel washers under the bolt or nut heads, are inserted through the sleeves and tightened by hand.

8.2.5.2.7 The original alignment pins may then be removed and bolts installed, complete with sleeves and washers as described above.

8.2.5.2.8 Final tightening to the tension recommended for the diameter and pressure rating of the flange shall be done in a sequence that provides for equal tension without distortion.

8.2.5.2.9 Before measures are taken to protect against the ingress of moisture, the effectiveness of the isolation achieved should be checked using appropriate methods such as the example provided in Figure 12.

8.2.5.3 Protection Against Ingress of External Moisture—The materials used for the isolating sleeves, washers, and gaskets may absorb water, and the construction of the joint may allow for moisture ingress, both of which reduce the electrical resistance of the assembly. Therefore, providing a protective coating is essential. A suitable material may be applied to fill in the crevices and gaps between flange faces and mold around the flange faces in underground installations. In this way, a smooth profile that may be coated or wrapped to the same standard as the pipeline, together with the adjacent pipe work, is achieved.

8.2.6 Pipeline Casing Isolators (see Figure 9)

8.2.6.1 Pipeline casing isolators must be installed in accordance with the manufacturer's instructions. Special care should be taken to ensure that all subcomponents are correctly assembled and tightened and that no damage occurs during insertion of the carrier pipe.

8.2.6.2 The annulus between the carrier pipe and the casing should be sealed at each end of the casing to prevent electrolyte, debris, and the surrounding soil from entering the casing.

8.2.6.3 There must be no metallic contact between the casing and the carrier pipe. The spacing of isolators should ensure that the carrier pipe is adequately supported throughout its length, particularly at the ends, to prevent settling and possible electrical shorting of the pipe and casing.

8.2.7 Pipeline Support Isolators—Care should be taken to ensure that isolating materials used in isolating supports are adequately secured so as to eliminate the possibility of dislodging, which would render the isolation ineffective.

8.3 High-Voltage Protection

8.3.1 Isolating devices and supports should be protected against damage from high-voltage surges. These surges may be caused by lightning, induced AC from adjacent or overhead high-voltage cables, fault conditions, power pipeline conditions, or switching surges (see NACE SP0177[2]). If isolating joints exist in these corridors and must be maintained for CP design reasons, then they must be made conductive to AC currents by the use of capacitors, polarization cells, or any equivalent solid-state product. (See EPRI[(6)] Report EL 904[12] for more information.) Protective devices (surge suppressors, lightning arresters, etc.) are usually designed for a specific purpose. Protective equipment must be selected and used in accordance with the intended purpose, following all manufacturer's specifications.

8.3.2 High-voltage surges may permanently damage the isolating materials used in the joint construction.

8.3.3 Isolating devices and supports may be protected with lightning arresters, electrolytic grounding cells, polarization cells, equivalent solid-state products, or combinations of these.

8.3.4 Electrical surges and fault currents of all types are potentially hazardous. Pipelines equipped with isolating devices may be protected from stray-current hazards originating from electrical power supplies through the use of grounding media or isolation protection equipment. Grounding media that should be considered for the discharge of induced AC, lightning, and fault current from a pipeline to earth include packaged galvanic anodes of magnesium or zinc and extruded ribbon of magnesium or zinc, with or without backfill. Electrically isolated bare steel pipeline casing, grounding grids, and ground rods should also be considered suitable grounds but must be separated from the cathodically protected pipeline by capacitors, zinc grounding cells, polarization cells, or equivalent solid-state products.

8.3.5 The manufacturer's instructions must be followed strictly when installing protective devices. In particular, the devices shall be physically secured and the connection cables properly sized.

8.3.6 The threshold rating of the protective device must be such that, even allowing for tolerances, the potential applied across the isolating device is below the device's minimum dielectric strength.

8.3.7 Lightning arresters and other protective devices shall be located to prevent the collection of dirt and moisture, which could lead to an external flashover at a relatively low surge voltage. Applicable electrical codes shall be consulted. To prevent incendiary spark hazards at fuel transfer facilities, electrical isolation shall be avoided in areas where a combustible atmosphere may exist.

8.4 Provision for Field Testing

8.4.1 Methods of testing the effectiveness of the electrical isolation are described in Section 8. The following paragraphs describe the provision of test wires to facilitate these measurements. Test wires on buried devices should be attached on both sides of any isolating device and on the carrier pipe and casing of sleeved systems.

8.4.2 Attachment of Test Wires

8.4.2.1 Test wires on buried isolating devices shall be installed in accordance with NACE SP0169.[1]

8.4.2.2 Care should be taken when attaching test wires to prevent damage to the internal coating or lining by excessive heat.

8.4.3 Wire Type

8.4.3.1 The wire cross section and type of sheath insulation must be selected to take into account the location and expected (or future) current to be carried. Wires should be labeled for permanent identification.

[(6)] Electric Power Research Institute (EPRI), 3412 Hillview Ave., Palo Alto, CA 94304-1395.

Section 9: Field Testing and Maintenance

9.1 This section deals with the testing and maintenance of electrical isolation facilities. In testing the effectiveness of isolating devices installed on buried piping systems, the effect of pipe grounding and other equivalent electrical parallel circuit conditions that may exist must be considered. Conventional ohmic resistance measurements, as applied to the total isolating device, are not conclusive under field conditions. However, ohmic resistance measurements may have validity in checking individual components of an isolating device.

9.2 Field Testing

9.2.1 Several tests may be used to determine the effectiveness of an isolating device, depending on the following:

9.2.1.1 The experience and training of the staff conducting the tests;

9.2.1.2 The environment and location of the device; and

9.2.1.3 The local potential and magnitude of any cathodic or anodic electrical currents.

9.2.2 If the isolating device is installed and connected on both sides, a test may be conducted in which current is applied to the pipe on one side of the assembly and effectiveness is judged by the resulting difference in pipe-to-soil potentials measured on both sides of the device.

9.2.3 When desired, a test can be conducted to obtain the percent of leakage at an isolating device (see Figure 12). However, if the isolating device is located adjacent to a section of above-grade piping, a voltage drop measurement can be readily taken to determine isolating effectiveness.

9.2.4 When the isolating device incorporates bolts that require full isolation from all other metal work (e.g., bolts used in an isolated flanged joint in which an isolating washer is used beneath each bolt head or nut), it may be possible to check for proper isolation of each bolt. This check has considerable validity because bolt isolation is normally the part of the assembly that is most susceptible to failure. The test should be conducted by using an ohmmeter or other device to prove isolation between each bolt or stud and the metal against which it is to be isolated.

9.2.5 For cathodically protected pipelines, a good indication of performance may be the change in protection level adjacent to the isolating device that occurs when the isolating device is deliberately shorted. The results from such a test depend on the resistance to earth of the unprotected structure from which the protected pipeline is isolated. When this resistance to earth is very low, a significant reduction in the level of protection may be expected.

9.2.6 Audio frequency pipe locators may indicate the effectiveness of isolating devices.

9.2.7 Radio frequency meters may also indicate the effectiveness of isolating devices.

9.2.8 A magnetometer system may be used for testing the effectiveness of isolating devices.

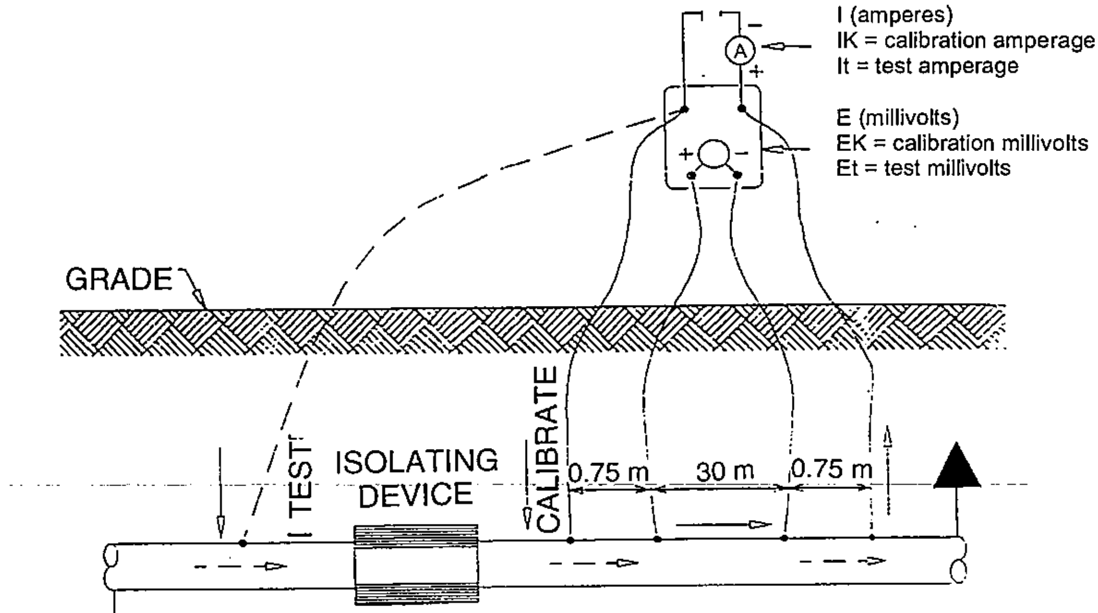
9.3 Isolating Devices in Parallel—When a number of isolating devices are installed in parallel (e.g., several flanged joints at a manifold), IR drops or current measurements in each line may be the only method of proving effectiveness of an individual device. Techniques that measure magnetic fields in the flange area may also serve as an indication of the device's effectiveness. The use of audio frequency and radio frequency instruments may indicate the comparative effectiveness of each individual device.

9.4 Maintenance

9.4.1 Test stations and test wires attached at isolating devices should be subject to a regular maintenance program. Figure 11 shows the typical configuration of test stations.

9.4.2 Isolating devices that are aboveground and open to the weather should be inspected periodically and cleared of accumulated debris, which could bridge isolating material. Any protective barrier coatings provided to prevent water absorption by isolating materials should be kept in good condition. Paints, thermal barriers, and tracers and reinforcements with a metallic content such as aluminum or zinc should not be used as barrier coatings.

9.4.3 When the effectiveness of isolating devices is tested on site, the effectiveness of any high-voltage protection device should also be checked.



1. Calculate the calibration factor: $K = \Delta IK/\Delta EK$ = Amps/mV

2. Calculate the percentage leakage: $\%\ \text{leakage} = \dfrac{K \times \Delta Et \times 100}{It}$

Example: Given the following data:

Calibration: IK = +6.42 Amps
EK = +3.55 mV

Test: It = +1.61 Amps
ΔEt = +0.14 mV

Calculate:

$$K = \frac{6.42\ \text{Amps}}{3.55\ \text{mV}} = 1.81\ \text{A/mV}$$

$$\%\ \text{leakage} = \frac{K \times \Delta Et \times 100}{It}$$

$$= \frac{1.81\ \text{A/mV} \times 0.14\ \text{mV} \times 100}{1.61\ \text{Amps}}$$

$$= 15.7\%$$

FIGURE 12:
Isolating Device Leakage Test

References

1. NACE SP0169 (latest revision), "Control of External Corrosion on Underground or Submerged Metallic Piping Systems" (Houston, TX: NACE International).

2. NACE SP0177 (latest revision), "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems" (Houston, TX: NACE).

3. CAN/CSA-C22.3 No. 6 (latest revision), "Principles and Practices of Electrical Coordination Between Pipelines and Electrical Supply Lines" (Rexdale, Ontario: Canadian Standards Association).

4. NACE International Glossary of Corrosion-Related Terms (latest revision) (Houston, TX: NACE International).

5. U.S. Code of Federal Regulations (CFR) Title 49, "Protection Against Accidental Overpressure," Parts 192 and 195 (Washington DC: Office of the Federal Register).

6. ANSI B31.3 (latest revision), "Process Piping" (New York, NY: ASME).

7. ANSI B31.4 (latest revision), "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols" (New York, NY: ASME).

8. ANSI B31.8 (latest revision), "Gas Transmission and Distribution Piping Systems" (New York, NY: ASME).

9. ASME Boiler and Pressure Vessel Code, Section 8, "Rules for Construction of Pressure Vessels" (New York, NY: ASME).

10. ANSI B16.5 (latest revision), "Pipe Flanges and Flanged Fittings" (New York, NY: ASME).

11. BS 1560 (latest revision), "Steel Pipe Flanges and Flanged Fittings" (London: British Standards Institution).

12. EPRI Report EL 904, "Mutual Design Considerations for Overhead AC Transmission Lines and Gas Transmission Lines" (Palo Alto, CA: Electric Power Research Institute).

ภาคผนวก ข-6

ข้อมูลการทำ Hydrotest

สรุปรายการตรวจสอบ RUBBER HOSES INSPECTION ประจำเดือน September 2022

Item	Date	Description	Product	Location	Result	Remarks
1	6/9/2022	RUBBER HOSES 8"	Diesel / Mogas Chevron & Esso	Jetty	ใช้งานได้	มีรอยถลอยเล็กน้อย
2	6/9/2022	RUBBER HOSES 8"	Diesel / Mogas Shell	Jetty	ใช้งานได้	มีรอยถลอยเล็กน้อย
3	/9/2022	RUBBER HOSES 3"	Ethanal	จุดรับรถ Ethanal		
4	/9/2022	RUBBER HOSES 3"	B-100	จุดรับรถ B-100		

CHECK SHEET FOR PM WORKS

Owner : Chevron (Thai) Ltd.

Contractor : New Star International Co., Ltd.

Ref. Job Spec. No. : JS-PM-035	**Description :** RUBBER HOSES INSPECTION			**Page No. :**	1
	PM. Date :	6/9/2022	**Next PM. Date:** 20/9/2023	**Frequency :**	Yearly

MEASURING INSTRUMENT		**DOCK HOSE DATA**	
Pressure gauge	: Nuova fima	Manufacture	: Continental
Serial No.	: 11658143/2017	Model	: FLEXDOCK225
Certificate No	: 21P2563	Serial No.	: 105488065
Insulation Tester	: Hioki	Size	: 8"
Serial No.	: 190914359	Overall length (cm.)	: 987 cm
Certificate No	: Cal01000-21	Product	: Diesel / Mogas Chevron & Esso

1 ถอด Hose ออกจากที่ยึด และ ทำการตรวจสอบสภาพทั่วไป วัดความยาว — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

ความยาว 987 cm.

2 ทำ Hydrostatic test at 10 PSI คงที่แรงดันไว้ 10 นาที — [√] ปกติ [ ] ผิดปกติ

วัดค่าความยาวของสาย ค่าที่วัดได้ไม่ควรเกิน ±1% ของการวัดครั้งแรก — ความยาวที่วัดได้ = 995 cm.

คิดเป็น 0.99% ของการวัดครั้งแรก

3 ทำ Hydrostatic test at 150 PSI คงที่แรงดันไว้ 10 นาที — [√] ปกติ [ ] ผิดปกติ

ความยาวที่วัดได้ = 1,010 cm.

วัดค่าความยาวของสาย ค่าที่วัดได้ไม่ควรเกิน ±7.5% ของการวัดครั้งที่สอง

คิดเป็น 6.9% ของการวัดครั้งสอง

4 ตรวจสอบจุดรั่วซึม — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

5 ตรวจสอบหน้าแปลน จุดต่อของสาย — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

6 วัดค่าความต้านทานสายไม่ควรเกิน 100Ω — [√] ปกติ [ ] ผิดปกติ

ค่าที่วัดได้ 3.0Ω

7 ประกอบหน้าแปลนพร้อมทั้งขันแน่นหน้าแปลน — [√] ปกติ [ ] ผิดปกติ

หมายเหตุ : 1. หากพบความผิดปกติเกิดขึ้นให้วินิจฉัยถึงสาเหตุและแจ้งวิศวกร, ผู้ควบคุมงานทราบ พร้อมกับทำการเสนอแนะแนวทางแก้ไข ให้สามารถใช้งานได้ตามปกติ

2. อะไหล่ใดที่จะเปลี่ยน เนื่องจากเสื่อมสภาพ หรือเสียหาย ให้ผู้รับจ้างแจ้งผู้ว่าจ้าง เพื่อเสนอราคาขออนุมัติก่อนทุกครั้ง

บันทึกเพิ่มเติม สาย Hose มีรอยถลอก บริเวณผิวยาง จากการเทสไม่พบรอยรั่วสามารถใช้งานได้ปกติ

Report By : จตุพล ใจสม	**Inspected By :** สุรณัฏฐ แซ่ลิ้ม
Date : 6/9/2022	**Date :** 6/9/2022

CHECK SHEET FOR PM WORKS

Owner : Chevron (Thai) Ltd.
Contractor : New Star International Co., Ltd

Ref. Job Spec. No. :JS-PM-035	Description :RUBBER HOSES INSPECTION		Page No. : 2
	PM. Date :6/9/2022	Next PM. Date :20/9/2023	Frequency :Yearly

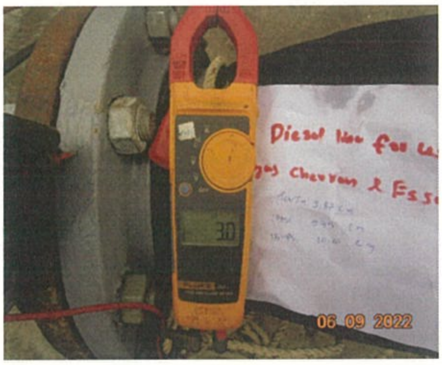
LOCATION : Chevron SKL	PRODUCT : Diesel	No. Diesel Hose 8"

PRIMARY DATA

DESCRIPTION	

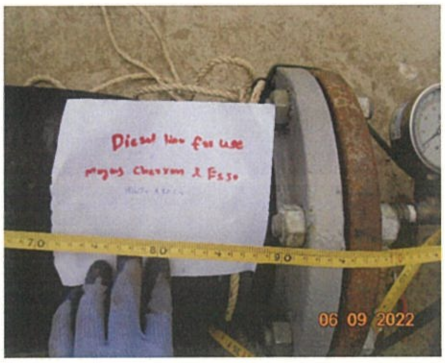
รายงานสภาพที่ตรวจพบ

ความยาวของสาย Hoses ก่อน Test ได้ 987 cm

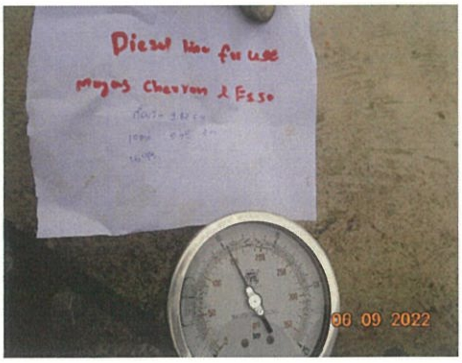


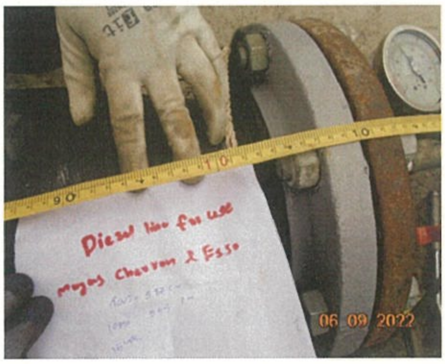
วัดค่าความต้านทานสาย ค่าที่วัดได้ 3.0 Ω

Hydrostatic test at 10 PSI



วัดค่าความยาวสาย Hoses ได้ 995 CM





Hydrostatic test at 150 PSI วัดค่าความยาวสาย Hoses ได้ 1010 CM

CHECK SHEET FOR PM WORKS

Owner : **Chevron (Thai) Ltd.**

Contractor : **New Star International Co., Ltd.**

Ref. Job Spec. No. : JS-PM-035	**Description :** RUBBER HOSES INSPECTION			**Page No. :**	3
	PM. Date :	6/9/2022	**Next PM. Date:** 20/9/2023	**Frequency :**	Yearly

MEASURING INSTRUMENT		**DOCK HOSE DATA**	
Pressure gauge	: Nuova fima	Manufacture	: CONTINENTAL
Serial No.	: 11658143/2017	Model	: FLEXDOCK225
Certificate No	: 21P2563	Serial No.	: 10158035
Insulation Tester	: Hioki	Size	: 8"
Serial No.	: 190914359	Overall length (cm.)	: 979 cm
Certificate No	: Cal01000-21	Product	: Diesel / Mogas Shell

1 ถอด Hose ออกจากที่ยึด และ ทำการตรวจสอบสภาพทั่วไป วัดความยาว — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

ความยาว 979 cm.

2 ทำ Hydrostatic test at 10 PSI คงที่แรงดันไว้ 10 นาที — [√] ปกติ [ ] ผิดปกติ

วัดค่าความยาวของสาย ค่าที่วัดได้ไม่ควรเกิน ±1% ของการวัดครั้งแรก — ความยาวที่วัดได้ = 994 cm.

คิดเป็น 0.99% ของการวัดครั้งแรก

3 ทำ Hydrostatic test at 150 PSI คงที่แรงดันไว้ 10 นาที — [√] ปกติ [ ] ผิดปกติ

ความยาวที่วัดได้ = 1,006 cm.

วัดค่าความยาวของสาย ค่าที่วัดได้ไม่ควรเกิน ±7.5% ของการวัดครั้งที่สอง

คิดเป็น 0.9% ของการวัดครั้งสอง

4 ตรวจสอบจุดรั่วซึม — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

5 ตรวจสอบหน้าแปลน จุดต่อของสาย — [√] ปกติ [ ] ผิดปกติ

ปัญหาที่พบ ______

6 วัดค่าความต้านทานสายไม่ควรเกิน 100Ω — [√] ปกติ [ ] ผิดปกติ

ค่าที่วัดได้ 38.5 Ω

7 ประกอบหน้าแปลนพร้อมทั้งขันแน่นหน้าแปลน — [√] ปกติ [ ] ผิดปกติ

หมายเหตุ : 1. หากพบความผิดปกติเกิดขึ้นให้วินิจฉัยถึงสาเหตุและแจ้งวิศวกร, ผู้ควบคุมงานทราบ พร้อมกับทำการเสนอแนะแนวทางแก้ไข ให้สามารถใช้งานได้ตามปกติ

2. อะไหล่ใดที่จะเปลี่ยน เนื่องจากเสื่อมสภาพ หรือเสียหาย ให้ผู้รับจ้างแจ้งผู้ว่าจ้าง เพื่อเสนอราคาขออนุมัติก่อนทุกครั้ง

บันทึกเพิ่มเติม สาย Hose มีรอยถลอก บริเวณผิวยาง จากการเทสไม่พบรอยรั่วสามารถใช้งานได้ปกติ

Report By : **จตุพล ใจสม**	**Inspected By :** **สุรณัฏฐ แซ่ลิ่ม**
Date : **6/9/2022**	**Date :** **6/9/2022**

CHECK SHEET FOR PM WORKS

Owner : Chevron (Thai) Ltd.
Contractor : New Star International Co., Ltd

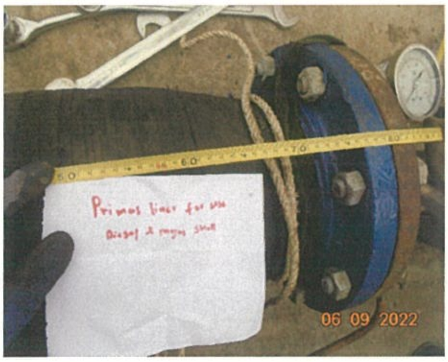
Ref. Job Spec. No. :JS-PM-035	Description :RUBBER HOSES INSPECTION		Page No. : 4
	PM. Date :6/9/2022	Next PM. Date :20/9/2023	Frequency :Yearly

LOCATION : Chevron SKL	PRODUCT : Mogas	No. Mogas Hose 8''

PRIMARY DATA

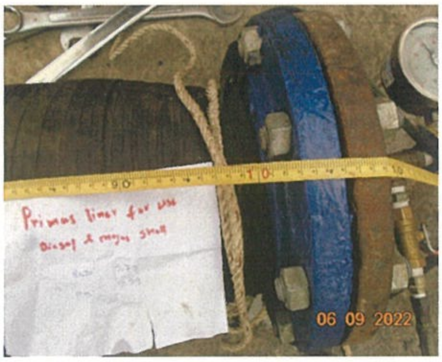
DESCRIPTION	

รายงานสภาพที่ตรวจพบ



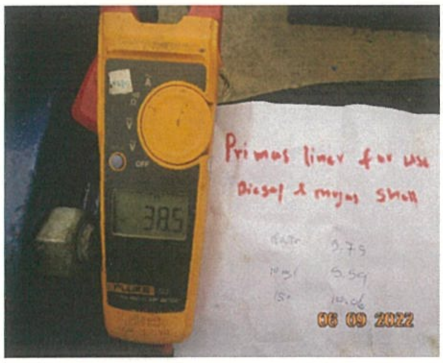
ความยาวของสาย Hoses ก่อน Test ได้ 979 cm

Hydrostatic test at 10 PSI
วัดค่าความยาวสาย Hoses ได้ 994 CM



Hydrostatic test at 150 PSI
วัดค่าความยาวสาย Hoses ได้ 1006 CM

ทำความสะอาดหน้าแปลน และ เปลี่ยนปะเก็นใหม่



วัดค่าความต้านทานสาย ค่าที่วัดได้ 38.5 Ω