CATHODIC PROTECTION SYSTEM DESIGN

Prepared for:

Vermont Gas System

12" Addison Natural Gas Project

Chittendon & Addison Counties, Vermont

Prepared By:

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ISSUED FOR CONSTRUCTION

EXECUTIVE SUMMARY

This Cathodic Protection system design package is for the 12" Addison Gas Project in Chittendon and Addison Counties, Vermont. These designs consist of three (3) rectifier groundbed systems. These systems will protect the approximately forty-two (42) miles of 12" pipe from the Colchester Tie-In site to the Middlebury Station site.

ARK Engineering is proposing to use sites in the following three (3) areas for these systems:

Milepost 6.75 (North of Rt. 117)
Main Line Valve 4 (MLV-4), Milepost 24.8
North of Main Line Valve 7 (MLV-7), Milepost 40.7

Each system will protect approximately 14 miles of pipeline.

The rectifier groundbed system proposed for Milepost 6.75 is designed to protect the pipeline from milepost 0.0 to approximately milepost 14.

The rectifier groundbed system proposed for MLV-4 (milepost 24.8) is designed to protect the pipeline from approximately milepost 14 to approximately milepost 28.

The rectifier groundbed system proposed near Milepost 40.7 is designed to protect the pipeline from approximately milepost 28 to the end of the pipeline at milepost 41.24.

This is a total distance of approximately 41.5 miles (219,120 feet).

These cathodic protection system designs have been prepared based upon soil resistivity measurements obtained at forty (40) locations along the proposed pipeline route. All relevant codes including U.S Department of Transportation (DOT), National Association of Corrosion Engineers (NACE), ASTM standards, etc. have been taken into consideration while preparing this design.

After investigation, analysis, and consideration of numerous technical aspects of the pipeline system, a complete design has been prepared to provide effective corrosion protection for the 12" Addison Natural Gas project.

These three (3) rectifier / groundbed locations have been selected based upon soil resistivity measurements, access, and system effectiveness.

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1. INTRODUCTION

1.0 Introduction

This cathodic protection system design package is for the 12" Addison Natural Gas project. The 12" pipeline is proposed to be approximately 41.5 miles (219,120 feet). This new pipeline begins at the Colchester tie-in site (milepost 0.0) in Chittenden County and terminates at the proposed Middlebury Station (milepost 41.24) in Addison County.

Three (3) groundbed / rectifier locations are proposed at approximately milepost 6.75, MLV-4 and near milepost 40.7.

The proposed rectifier/groundbed system at approximately milepost 6.75 is designed to cathodically protect the pipeline from approximately milepost 0.0 to milepost 14. This is a distance of 14 miles.

The rectifier/groundbed system at MLV-4 is designed to cathodically protect the pipeline from approximately milepost 14 to milepost 28. This is a distance of 14 miles.

The rectifier/groundbed system at milepost 40.7 is designed to cathodically protect the pipeline from approximately milepost 28 to the end at milepost 41.24. This is a distance of approximately 13.5 miles.

The proposed pipeline will be shop coated with Pritec 10/40 or Warrior 100 coating. All weld joints will be coated during installation using equivalent materials and standards. These joints will be inspected using holiday detection equipment, prior to burial.

The pipeline will have dielectric isolation flanges installed at each end and at the meter stations. The meter station piping will be cathodically protected with separate cathodic protection systems.

These cathodic protection system designs are based upon a current density of 1 mA/square foot and a maximum of 1.0 % bare surface area.

1.1 Objective and Tasks

The primary objective of this design is to provide adequate levels of cathodic protection current on this proposed pipeline, for corrosion control and regulatory compliance.

The project tasks associated with this cathodic protection design are the following:

a) Review the pipeline design plans and specifications.

b) Perform a pre-construction route survey. This survey includes:

- Soil resistivity measurements.
- Determination of the availability of local electrical power, or other methods for operation of the rectifier.
- The location of other foreign buried structures and pipelines.
- The observation of the general topography of the area.

c) Review available data on other underground facilities along the pipeline route and any AC transmission lines in the pipeline corridor.

c) Prepare the conceptual design for corrosion control of this pipeline.

d) Investigate the location of the proposed corrosion test stations.

e) Prepare the specifications for the corrosion control materials, and for the construction specifications and drawings for installation of the cathodic protection systems during construction of the pipeline system.

1.2 Soil Resistivity Measurements

Soil resistivity measurements were conducted at forty (40) locations along this proposed pipeline for the cathodic protection designs and the AC interference analysis.

The soil resistivity measurements conducted in the area of the (3) proposed rectifier/groundbed locations are listed in Table 1-1 below:

Table 1-1: Proposed Rectifier/Groundbed Locations

Location	Mile Point	Soil Resistivity Test Site Number
Milepost 6.75	6.75	Soil Test Site 09
MLV-4	24.8	Soil Test Site 25
North of MLV-7	40.7	Soil Test Site 40

The Four-Pin Wenner method was used for these measurements in accordance with IEEE Standard 81 and ASTM Standard G57. Measurements were taken at the following spacings (in feet): 0.5, 1.0, 2.5, 5.0, 7.5, 10,16.5, 24.5, 49, 82, 164.

This soil resistivity measurement data for each site is included in Appendix B. All other soil resistivity measurement data for this pipeline is included in ARK Engineering's AC Interference Analysis report for this pipeline.

Soil resistivity measurements recorded at Site No. 09 indicated that from a depth of 1 foot to a depth of approximately 5 feet, the resistivity decreases from 9,770 ohm-cm to 3,160 ohm-cm. From 5 feet to 164 feet the resistivity increases to 26,380 ohm-cm.

Soil resistivity measurements recorded at Site No. 25 indicated that from the surface to a depth of 5 feet the resistivity decreases from 28,820 ohm-cm to 8,860 ohm-cm. From 5 feet to 164 feet the resistivity increases to 92,030 ohm-cm.

Soil resistivity measurements recorded at Site No. 40 indicated that from a depth of 1 foot to 7.5 feet, the resistivity decreases from 28,520 ohm-cm to 2,690 ohm-cm. From 7.5 feet to 164 feet the resistivity increases to 34,230 ohm-cm.

2. CATHODIC PROTECTION DESIGN

2.0 Cathodic Protection Design

ARK Engineering has designed three (3) impressed current cathodic protection groundbeds to protect the proposed 12" Addison Natural Gas pipeline at the following locations:

Table 2-1: Cathodic Protection System Locations

Location Number	Mile Point	Location Description
1	6.75	North of Route 117
2	35.2	Main Line Valve 4
3	40.7	North of Main Line Valve 7

Vertical anode groundbed systems were designed at these locations due to soil conditions and remoteness from the pipeline.

These cathodic protection systems were designed to be remote from the pipeline. It is recommended that the anodes be located a minimum distance of 200 feet remote from the pipeline.

A detailed design calculation for each proposed groundbed system is included in Appendix A.

2.1 Design Criteria for the Cathodic Protection System

NACE International (NACE) Standard RP0169 was referenced in the design of these three (3) impressed current groundbed systems. These designs provide for a minimum "polarized" potential of –0.850 volts DC on all sections of the buried structures, when measured with a high impedance DC Volt meter with respect to standard saturated Copper / Copper Sulfate electrode, placed on the ground directly above the buried pipeline. This procedure also meets the U.S. Federal Government, DOT regulation 49 CFR Part 192.

2.2 Estimating The Current Requirements

The pipeline's DC current requirements for each of the cathodic protection systems have been determined using the pipeline dimensions and the cathodic protection design requirements. This design is based upon a current density of 1 mA/square foot and a maximum of 1.0 % bare surface area. An allowance of 50 % has been made to account for future coating deterioration of the pipeline. Electrical continuity of the pipeline from milepost 0.00 to milepost 41.24 is required for proper operation of these systems. Insulation flanges are installed at each end of the pipeline and at the inlet and outlet of each meter station.

The life expectancies for the cathodic protection systems have been designed for a minimum of 40 years.

The following factors were investigated for the site selection for the proposed groundbeds:

a) Minimum soil resistance values to install the anodes at the specified depth.

b) Efficiency factor.

c) Uniform current distribution to the pipeline.

d) To achieve low operating power costs for the entire system.

e) Close proximity to electric power for rectifier operation and remote monitoring capability.

2.3 Current Requirements Calculations

2.3.1 Rectifier / Groundbed Site Number 1: Approximately Milepost 6.75, North of Route 117.

The output from this proposed rectifier / groundbed is designed to cathodically protect approximately 14.3 miles of 12" diameter pipeline from milepost 0.0 to milepost 14.3, along the proposed Addison Natural Gas pipeline.

2.3.1.1 The following factors were considered in calculating the attenuation of the current flow and voltage drop along the pipeline section away from the rectifier location.

a) The pipeline wall thickness. Wall thickness for this pipeline section includes 75,504 feet of 0.312" pipe.

b) The soil resistivity pattern along the pipeline route.

c) The total surface area of this pipeline section. The section of pipe requiring cathodic protection is approximately 237,083 square feet.

2.3.1.2 A current density design criteria of 1.0 mA per sq. ft. and a maximum of 1.0 % bare surface area were used for this design. The total current requirement is 4 Amperes.

We have selected a 20 Ampere / 40 Volt rectifier for this location at approximately milepost 6.75. (Reference Appendix C, ARK Engineering Drawing No. 12145-100)

2.3.2 Rectifier / Groundbed Site Number 2: Main Line Valve 4, Milepost 24.8

The output from this proposed rectifier / groundbed will cathodically protect approximately 18.24 miles of 12" diameter pipeline from approximately milepost 14.3 to milepost 32.54 (MLV-5).

2.3.2.1 The following factors were considered in calculating the attenuation of the current flow and voltage drop along the pipeline sections away from the rectifier location.

a) The pipeline wall thickness. Wall thickness for this pipeline section includes 96,308 feet of 0.312" pipe.

b) The soil resistivity pattern along the pipeline route.

c) The total surface area of these pipeline sections. The section of pipe requiring cathodic protection is approximately 302,407 square feet.

2.3.2.2 A current density design criteria of 1.0 mA per sq. ft. and a maximum of 1.0 % bare surface area were used for this design. The total current requirement is 5 Amperes. We have selected a 20 Ampere / 40 volt rectifier for this location at MLV-4. (Reference Appendix C, ARK Engineering Drawing No. 12145-200).

2.3.3 Rectifier / Groundbed Site Number 3: North of Main Line Valve 7, Milepost 40.7

The output from this proposed rectifier / groundbed will cathodically protect approximately 8.7 miles of 12" diameter pipeline from approximately milepost 32.54 to milepost 41.24 (MLV-7).

2.3.3.1 The following factors were considered in calculating the attenuation of the current flow and voltage drop along the pipeline sections away from the rectifier location.

a) The pipeline wall thickness. Wall thickness for this pipeline section includes 45,936 feet of 0.312" pipe.

b) The soil resistivity pattern along the pipeline route.

c) The total surface area of these pipeline sections. The section of pipe requiring cathodic protection is approximately 144,239 square feet.

2.3.3.2 A current density design criteria of 1.0 mA per sq. ft. and a maximum of 1.0 % bare surface area were used for this design. The total current requirement is 3 Amperes. We have selected a 20 Ampere / 40 volt rectifier for this location at Milepost 40.7. (Reference Appendix C, ARK Engineering Drawing No. 12145-300).

2.4 Vertical Anode Groundbed Designs

The proposed vertical anode groundbed systems located at the three (3) proposed sites will consist of separate 8-inch diameter holes to a depth of approximately 7.5 feet. Five (5) or ten (10) 3" x 60" mixed metal oxide (MMO) anodes are proposed to be installed at a separation distance of 15 or 20 feet between each anode (center-to-center). Individual anode cables are brought back and terminated at a junction box. The top of each anode is buried a minimum of 2 feet below grade. The beginning and end of this groundbed will be marked with aboveground test stations.

Table 2-2: Summary of the Proposed Cathodic Protection Systems

Location	Miles Protected	Cathodic Protection From:	Cathodic Protection To:	Groundbed Length	Current Required	Rectifier Voltage/Current
Milepost 6.75	14.3	M.P. 0.0	M.P. 14.3	60'	4 amps	40 V / 20 A
MLV-4	18.24	M.P. 14.3	M.P. 32.54	135'	5 amps	40 V / 20 A
Milepost 40.7	8.7	M.P. 32.54	M.P. 41.24	60'	3 amps	40 V / 20 A

2.5 Cathodic Protection Locations

2.5.1 Rectifier Number 1 at milepost 6.75, (Reference Appendix C – ARK Engineering Drawing No. 12145-100)

ARK Engineering is proposing a cathodic protection rectifier / groundbed system in the area of milepost 6.75. ARK Engineering Drawing No. 12145-100 details the approximate location of the rectifier and groundbed. The proposed rectifier is a 20 Ampere / 40 Volt DC output unit. Details and calculations of the rectifier and groundbed anodes are included in Appendix A. The cathodic protection system design, once installed, will protect the section of the proposed 12" Addison Natural Gas pipeline from milepost 0.0 to approximately milepost 14.3. AC electric power for the rectifier is proposed to come from a power pole located near the proposed site.

2.5.2 Rectifier Number 2 at Main Line Valve 4 (MLV-4), (Reference Appendix C – ARK Engineering Drawing No. 12145-200)

ARK Engineering is proposing a cathodic protection rectifier / groundbed system in the area of main line valve 4 (MLV-4) at milepost 24.8. ARK Engineering Drawing No. 12145-200 details the approximate location of the rectifier and groundbed. The proposed rectifier is a 20 Ampere / 40 Volt DC output unit. Details and calculations of the rectifier and the groundbed anodes are included in Appendix A. The cathodic protection system design, once installed, will protect the section of the proposed 12" Addison Natural Gas pipeline from approximately milepost 14.3 to approximately milepost 32.54. AC electric power for the rectifier is proposed to come from a power source at the valve site.

2.5.3 Rectifier Number 3 at Milepost 40.7 North of Main Line Valve 7 (MLV-7), (Reference Appendix C – ARK Engineering Drawing No. 12145-300)

ARK Engineering is proposing a cathodic protection rectifier / groundbed system in the area of milepost 40.7, north of MLV-7. ARK Engineering Drawing No. 12145-300 details the approximate location of the rectifier and groundbed. The proposed rectifier is a 20 Ampere / 40 Volt DC output unit. Details and calculations of the rectifier and the groundbed anodes are included in Appendix A. The cathodic protection system design, once installed, will protect the section of the proposed 12" Addison Natural Gas pipeline from approximately milepost 32.54 to milepost 41.24. AC electric power for the rectifier is proposed to come from a pole along Route 7.

APPENDIX A –
CATHODIC PROTECTION SYSTEM CALCULATIONS

CATHODIC PROTECTION SYSTEM CALCULATIONS FOR 12" ADDISON NATURAL GAS PROJECT

LOCATION 1 - RECTIFIER GROUNDBED AT MILEPOST 6.75

1.0 CURRENT REQUIREMENT CALCULATIONS

The following are DC current requirement calculations to provide effective cathodic protection to the buried metallic systems along the 12" Addison Natural Gas pipeline from milepost 0.00 to approximately milepost 14.3.

Total Length: Approximately 75,504 ft

To determine the current requirements for this cathodic protection system the following data was used:

a) Calculation of the surface area of the pipe.
b) Coating quality of the pipeline.

1.1 DC CURRENT REQUIREMENTS

The following are the DC current requirements for the 12" Addison Natural Gas pipeline from milepost 0.00 to approximately milepost 14.3.

1.1.1 Total surface area (A) of the buried piping for cathodic protection consideration:

Using the formula:

$A = \pi DL$

Where:

π = 3.14 (constant)
D = Diameter of pipe in feet
L = Length of pipe in feet

Values:

D = 1 ft. (12 inches)
L = 75,504 ft.
A = 237,083 sq. ft.

Total surface area = 237,083 square feet

1.1.2 Assuming excellent coating quality for the pipe, a current density requirement of 1.0 mA /ft^2, based upon a maximum of 1.0 % bare surface area was specified.

Total coated pipe surface area = 237,083 square feet
1.0% bare surface area = 237,083 square feet x .01 = 2,371 square feet
Current Requirement = 2,371 ft^2 x 1.0 mA/ ft^2 = 2,371 mA (2.37 A)
The current requirement will be approximately 2.5 Amperes for this section of the 12" pipeline.

1.1.3 Considering a safety factor of 50 %, the minimum current requirement will be approximately 4 Amperes.

1.2 ANODE TO ELECTROLYTE RESISTANCE

The vertical anode ground bed at milepost 6.75 was designed using mixed metal oxide anodes. The ground bed is proposed to be located off the right-of way, perpendicular to the pipeline.

Using Dwight's Formula for multiple vertical anodes, as follows:

1.2.1 $R_v = (0.00521\ \rho / NL)\ \{\ln 8L/d - 1 + 2L/S \ln 0.656\ N\}$.

Where:

R_v = Resistance to earth, in ohms, of vertical anodes
ρ = Soil resistivity in Ω-cm.
L = Length of anode in feet.
d = Diameter of anode in feet
S = Anode spacing in feet
N = Number of anodes in parallel

Values:

ρ = 3,100 ohm-cm
L = 5 feet
d = 3 inches (0.25) feet
N = 5
S = 15 feet

R_v = 3.14 ohms

1.3 CABLE RESISTANCE

The negative and positive header cable resistance is calculated below. The estimated length, and calculations are as follows:

1.3.1 $R_c = R_{Neg} + R_{Pos} + R_{Anode}$

Where:

R_c = Total cable resistance, in ohms
R_{Neg} = Length of Negative Cable (No. 2 AWG cable) x Resistance per foot of cable
R_{Pos} = Length of Positive Cable (No. 8 AWG cable) x Resistance per foot of cable
R_{Anode} = Length of Anode Cables (No. 8 AWG cable) x Resistance per foot of cable

Values:

R_{Neg} = 100 feet x 0.162 milliohms/ft. = 0.0162 ohms
R_{Pos} = 200 feet x 0.654 milliohms/ft. = 0.1308 ohms
R_{Anode} = 300 feet x 0.654 milliohms/ft. = 0.1962 ohms

R_c = 0.34 ohms

1.4 RECTIFIER DRIVING VOLTAGE

The Rectifier voltage was calculated utilizing the following formula:

1.4.1 $V_{rect} = R_v \times I_{req}$

Where:

V_{rect} = Rectifier driving voltage in volts.
R_v = Resistance to earth of the anodes in ohms.
I_{req} = Current required in amps.

Values:

R_v = 3.14 ohms
I_{req} = 4 Amps

V_{rect} = 3.14 x 4
V_{rect} = 12.56 Volts

Including total ground bed resistance, cable resistance, pipe-to-earth resistance, and rectifier back voltage, the total voltage requirement will be 30 Volts.

A standard rectifier with a 40 Volt / 20 Ampere output is recommended.

1.5 POWER CONSUMPTION OF THE RECTIFIER

The power consumption of the rectifier was calculated utilizing the following formula:

1.5.1 $I_{Line} = (1.2\ E_{DC} + 4\ N) \times (1.2\ I_{DC}) / E_{Line}$

Where:

I_{Line} = Input AC current of rectifier in Amps
N = Constant
E_{DC} = Output DC voltage of rectifier in Volts
I_{DC} = Output DC current of rectifier in Amps
E_{Line} = Input AC voltage of rectifier in Volts

Values:

I_{Line} = 1.6 Amps
N = 1
E_{DC} = 30 Volts
I_{DC} = 4 Amps
E_{Line} = 120 Volts

Total Wattage:

= (E_{Line}) x (I_{Line}) / 1000 = kilowatts

= (120 x 1.6) / 1000

= 0.192 kilowatts

The estimated annual power cost to maintain Cathodic Protection System (Assuming $ 0.40 per Kilowatt – hr) = $ 673

1.6 ATTENUATION CALCULATIONS

The attenuation for this pipeline section was calculated using the following formulas:

1.6.1 Weight per foot of pipe:

W = ((D-T) x T) x 10.68

Where:

W = weight per foot of pipe
D = diameter of pipe
T = minimum thickness of pipe
10.68 = π x 12" x 0.283 (0.283 is the constant for bare iron)

Values:

D = 12" (1 foot)
T = 0.312"

W = 46.56 lbs. per foot

1.6.2 Resistivity per foot of pipe:

R_{ft} = (16.061 x R_s) / W

Where:

R_{ft} = resistivity per foot^2
R_s = resistivity of steel
W = weight per foot of pipe
16.061 (A.W. Peabody, Peabody's Control of Pipeline Corrosion, 2nd Edition, 2001)

Values:

W = 46.56 lbs per foot
R_s = 18 micro ohm-cm

R_{ft} = 6.2 micro ohm-cm

1.6.3 Resistance of pipeline section:

$R_{sec} = R_{ft} \times L_{sec}$

Where:

R_{sec} = resistance of section
R_{ft} = resistivity per square foot
L_{sec} = length of pipe section

Values:

R_{ft} = 6.2 micro ohm-cm
L_{sec} = 75,504 feet

R_{sec} = 0.47 ohm

1.6.4 Voltage loss of pipeline section:

$V_{sec} = I_{req} \times R_{sec}$

Where:

V_{sec} = voltage loss across a pipeline section
I_{req} = rectifier current output
R_{sec} = resistance of pipe section

Values:

I_{req} = 2.5 amperes
R_{sec} = 0.47 ohm

V_{sec} = 1.18 volts

1.6.5 Voltage at end of pipeline section:

$V = V_{rec} - V_{sec}$

Where:

V = voltage on pipeline
V_{rec} = rectifier voltage
V_{sec} = voltage loss across pipeline section

Values:

V_{rec} = 30 volts
V_{sec} = 1.18 volts

V = 28.82 volts

1.6.6 Attenuation calculations:

Attenuation = $(V / V_{rec}) \times 100$

Where:

Attenuation = percentage of voltage lost along pipeline
V = voltage at end of pipeline section
V_{rec} = voltage of rectifier

Values:

V = 28.82 Volts
V_{rec} = 30 volts

Attenuation of pipeline section: 96 %

1.6.7 Voltage requirements:

Assume: -1.0 V at Rectifier Location at milepost 0.00

V_r = (attenuation / 100) × -1.0 V

Voltage at milepost 19:

V_r = -0.96 volts

These voltages satisfy the minimum "polarized" potential of - 0.85 volts.

LOCATION 2 - RECTIFIER GROUNDBED AT MAIN LINE VALVE 4

2.0 CURRENT REQUIREMENT CALCULATIONS

The following are DC current requirement calculations to provide effective cathodic protection to the buried metallic systems along the 12" Addison Natural Gas pipeline from approximately mileposts 14.3 to 32.54.

Total Length: Approximately 96,308 ft

To determine the current requirements for this cathodic protection system the following data was used:

a) Calculation of the surface area of the pipe.
b) Coating quality of the pipeline.

2.1 DC CURRENT REQUIREMENTS

The following are the DC current requirements for the 12" Addison Natural Gas pipeline from mileposts 14.3 to 32.54.

2.1.1 Total surface area (A) of the buried piping for cathodic protection consideration:

Using the formula:

$A = \pi DL$

Where:

$\pi = 3.14$ (constant)
D = Diameter of pipe in feet
L = Length of pipe in feet

Values:

D = 1 ft. (12 inches)
L = 96,308 ft.
A = 302,407 sq. ft

Total surface area = 302,407 square feet

2.1.2 Assuming excellent coating quality for the pipe, a current density requirement of 1.0 mA /ft^2, based upon a maximum of 1.0 % bare surface area was specified.

Total coated pipe surface area = 302,407 square feet
1.0% bare surface area = 302,407 square feet x .01 = 3,024.1 square feet
Current Requirement = 3,024.1 ft^2 x 1.0 mA/ ft^2 = 3,024 mA (3.0 A)
The current requirement will be approximately 3 Amperes for this section of the 12" pipeline.

2.1.3 Considering a safety factor of 50 %, the minimum current requirement will be approximately 5 Amperes.

2.2 ANODE TO ELECTROLYTE RESISTANCE

The vertical anode ground bed at MLV-4 was designed using mixed metal oxide anodes. The ground bed is proposed to be located perpendicular to the pipeline in the area of the valve site.

Using Dwight's Formula for a single vertical anode, as follows:

2.2.1 $R_v = (0.00521\ \rho / NL) \{\ln 8L/d - 1 + 2L/S \ln 0.656\ N\}$.

Where:

R_v = Resistance to earth, in ohms, of vertical anodes
ρ = Soil resistivity in Ω-cm.
L = Length of anode in feet.
d = Diameter of anode in feet
S = Anode spacing in feet
N = Number of anodes in parallel

Values:

ρ = 8,860 ohm-cm
L = 5 feet
d = 3 inches (0.25) feet
N = 10
S = 20 feet

R_v = 3.99 ohms

2.3 CABLE RESISTANCE

The negative and positive header cable resistance is calculated below. The estimated length, and calculations are as follows:

2.3.1 $R_c = R_{Neg} + R_{Pos} + R_{Anode}$

Where:

R_c = Total cable resistance, in ohms
R_{Neg} = Length of Negative Cable (No. 2 AWG cable) x Resistance per foot of cable
R_{Pos} = Length of Positive Cable (No. 8 AWG cable) x Resistance per foot of cable
R_{Anode} = Length of Anode Cables (No. 8 AWG cable) x Resistance per foot of cable

Values:

R_{Neg} = 100 feet x 0.162 milliohms/ft. = 0.0162 ohms
R_{Pos} = 200 feet x 0.654 milliohms/ft. = 0.1308 ohms
R_{Anode} = 300 feet x 0.654 milliohms/ft. = 0.1962 ohms

R_c = 0.34 ohms

2.4 RECTIFIER DRIVING VOLTAGE

The Rectifier voltage was calculated utilizing the following formula:

2.4.1 $V_{rect} = R_v \times I_{req}$

Where:

V_{rect} = Rectifier driving voltage in volts.
R_v = Resistance to earth of the anodes in ohms.
I_{req} = Current required in amps.

Values:

R_v = 3.99 ohms
I_{req} = 5 Amps

V_{rect} = 3.99 x 5
V_{rect} = 19.95 Volts

Including total ground bed resistance, cable resistance, pipe-to-earth resistance, and rectifier back voltage, the total voltage requirement will be 30 Volts.

A standard rectifier with a 40 Volt / 20 Ampere output is recommended.

2.5 POWER CONSUMPTION OF THE RECTIFIER

The power consumption of the rectifier was calculated utilizing the following formula:

2.5.1 $I_{Line} = (1.2\ E_{DC} + 4\ N) \times (1.2\ I_{DC}) / E_{Line}$

Where:

I_{Line} = Input AC current of rectifier in Amps
N = Constant
E_{DC} = Output DC voltage of rectifier in Volts
I_{DC} = Output DC current of rectifier in Amps
E_{Line} = Input AC voltage of rectifier in Volts

Values:

I_{Line} = 2.0 Amps
N = 1
E_{DC} = 30 Volts
I_{DC} = 5 Amps
E_{Line} = 120 Volts

Total Wattage:

$= (E_{Line}) \times (I_{Line}) / 1000$ = kilowatts

$= (120 \times 2.0) / 1000$

= 0.24 kilowatts

The estimated annual power cost to maintain Cathodic Protection System (Assuming $ 0.40 per Kilowatt – hr) = $ 841

2.6 ATTENUATION CALCULATIONS

The attenuation for this pipeline section was calculated using the following formulas:

2.6.1 Weight per foot of pipe:

$W = ((D-T) \times T) \times 10.68$

Where:

W = weight per foot of pipe
D = diameter of pipe
T = minimum thickness of pipe
10.68 = π x 12" x 0.283 (0.283 is the constant for bare iron)

Values:

D = 12" (1 foot)
T = 0.312"

W = 46.56 lbs. per foot

2.6.2 Resistivity per foot of pipe:

$R_{ft} = (16.061 \times R_s) / W$

Where:

R_{ft} = resistivity per foot^2
R_s = resistivity of steel
W = weight per foot of pipe
16.061 (A.W. Peabody, Peabody's Control of Pipeline Corrosion, 2nd Edition, 2001)

Values:

W = 46.56 lbs per foot
R_s = 18 micro ohm-cm

R_{ft} = 6.2 micro ohm-cm

2.6.3 Resistance of pipeline section:

$R_{sec} = R_{ft} \times L_{sec}$

Where:

R_{sec} = resistance of section
R_{ft} = resistivity per square foot
L_{sec} = length of pipe section

Values:

R_{ft} = 6.2 micro ohm-cm
L_{sec} = 96,308 feet (milepost 14.3 to 32.54)

R_{sec} = 0.60 ohm

2.6.4 Voltage loss of pipeline section:

$V_{sec} = I_{req} \times R_{sec}$

Where:

V_{sec} = voltage loss across a pipeline section
I_{req} = rectifier current output
R_{sec} = resistance of pipe section

Values:

I_{req} = 3 amperes
R_{sec} = 0.60 ohm

V_{sec} = 1.8 volts

2.6.5 Voltage at end of pipeline section:

$V = V_{rec} - V_{sec}$

Where:

V = voltage on pipeline
V_{rec} = rectifier voltage
V_{sec}= voltage loss across pipeline section

Values:

V_{rec} = 30 volts
V_{sec} = 1.8 volts

V = 28.2 volts

2.6.6 Attenuation calculations:

Attenuation = $(V / V_{rec}) \times 100$

Where:

Attenuation = percentage of voltage lost along pipeline
V_{sec} = voltage at end of pipeline section
V_{rec} = voltage of rectifier

Values:

V = 28.2 Volts
V_{rec} = 30 volts

Attenuation of pipeline section: 94 %

2.6.7 Voltage requirements:

Assume: -1.0 V at Rectifier Location at milepost 0.00

V_r = (attenuation / 100) × -1.0 V

Voltage at milepost 19:
V_r = -0.94 volts

These voltages satisfy the minimum "polarized" potential of - 0.85 volts.

LOCATION 3 - RECTIFIER GROUNDBED AT Milepost 40.7

3.0 CURRENT REQUIREMENT CALCULATIONS

The following are DC current requirement calculations to provide effective cathodic protection to the buried metallic systems along the 12" Addison Natural Gas pipeline from approximately mileposts 32.54 to 41.24.

Total Length: Approximately 45,936 ft

To determine the current requirements for this cathodic protection system the following data was used:

a) Calculation of the surface area of the pipe.
b) Coating quality of the pipeline.

3.1 DC CURRENT REQUIREMENTS

The following are the DC current requirements for the 12" Addison Natural Gas pipeline from mileposts 32.54 to 41.24.

3.1.1 Total surface area (A) of the buried piping for cathodic protection consideration:

Using the formula:

$A = \pi DL$

Where:

π = 3.14 (constant)
D = Diameter of pipe in feet
L = Length of pipe in feet

Values:

D = 1 ft. (12 inches)
L = 45,936 ft.
A = 144,239 sq. ft

Total surface area = 144,239 square feet

3.1.2 Assuming excellent coating quality for the pipe, a current density requirement of 1.0 mA /ft^2, based upon a maximum of 1.0 % bare surface area was specified.

Total coated pipe surface area = 144,239 square feet
1.0% bare surface area = 144,239 square feet x .01 = 1,442,4 square feet
Current Requirement = 1,442.4 ft^2 x 1.0 mA/ ft^2 = 1,442,4 mA (1.44 A)
The current requirement will be approximately 2 Amperes for this section of the 12" pipeline.

3.1.3 Considering a safety factor of 50 %, the minimum current requirement will be approximately 3 Amperes.

3.2 ANODE TO ELECTROLYTE RESISTANCE

The vertical anode ground bed at milepost 40.7 was designed using mixed metal oxide anodes. The ground bed is proposed to be located perpendicular to the pipeline in the area of the valve site.

Using Dwight's Formula for a single vertical anode, as follows:

3.2.1 $R_v = (0.00521\ \rho / NL) \{\ln 8L/d - 1 + 2L/S \ln 0.656\ N\}$.

Where:

R_v = Resistance to earth, in ohms, of vertical anodes
ρ = Soil resistivity in Ω-cm.
L = Length of anode in feet.
d = Diameter of anode in feet
S = Anode spacing in feet
N = Number of anodes in parallel

Values:

ρ = 2,980 ohm-cm
L = 5 feet
d = 3 inches (0.25) feet
N = 5
S = 15 feet

R_v = 2.59 ohms

3.3 CABLE RESISTANCE

The negative and positive header cable resistance is calculated below. The estimated length, and calculations are as follows:

3.3.1 $R_c = R_{Neg} + R_{Pos} + R_{Anode}$

Where:

R_c = Total cable resistance, in ohms
R_{Neg} = Length of Negative Cable (No. 2 AWG cable) x Resistance per foot of cable
R_{Pos} = Length of Positive Cable (No. 8 AWG cable) x Resistance per foot of cable
R_{Anode} = Length of Anode Cables (No. 8 AWG cable) x Resistance per foot of cable

Values:

R_{Neg} = 100 feet x 0.162 milliohms/ft. = 0.0162 ohms
R_{Pos} = 200 feet x 0.654 milliohms/ft. = 0.1308 ohms
R_{Anode} = 300 feet x 0.654 milliohms/ft. = 0.1962 ohms

R_c = 0.34 ohms

3.4 RECTIFIER DRIVING VOLTAGE

The Rectifier voltage was calculated utilizing the following formula:

3.4.1 $V_{rect} = R_v \times I_{req}$

Where:

V_{rect} = Rectifier driving voltage in volts.
R_v = Resistance to earth of the anodes in ohms.
I_{req} = Current required in amps.

Values:

R_v = 2.59 ohms
I_{req} = 3 Amps

V_{rect} = 2.59 x 3
V_{rect} = 7.77 Volts

Including total ground bed resistance, cable resistance, pipe-to-earth resistance, and rectifier back voltage, the total voltage requirement will be 20 Volts.

A standard rectifier with a 40 Volt / 20 Ampere output is recommended.

3.5 POWER CONSUMPTION OF THE RECTIFIER

The power consumption of the rectifier was calculated utilizing the following formula:

3.5.1 $I_{Line} = (1.2\ E_{DC} + 4\ N) \times (1.2\ I_{DC}) / E_{Line}$

Where:

I_{Line} = Input AC current of rectifier in Amps
N = Constant
E_{DC} = Output DC voltage of rectifier in Volts
I_{DC} = Output DC current of rectifier in Amps
E_{Line} = Input AC voltage of rectifier in Volts

Values:

I_{Line} = 0.84 Amps
N = 1
E_{DC} = 20 Volts
I_{DC} = 3 Amps
E_{Line} = 120 Volts

Total Wattage:

$= (E_{Line}) \times (I_{Line}) / 1000$ = kilowatts

$= (120 \times 0.84) / 1000$

= 0.10 kilowatts

The estimated annual power cost to maintain Cathodic Protection System (Assuming $ 0.40 per Kilowatt – hr) = $ 354

3.6 ATTENUATION CALCULATIONS

The attenuation for this pipeline section was calculated using the following formulas:

3.6.1 Weight per foot of pipe:

$W = ((D-T) \times T) \times 10.68$

Where:

W = weight per foot of pipe
D = diameter of pipe
T = minimum thickness of pipe
10.68 = π x 12" x 0.283 (0.283 is the constant for bare iron)

Values:

D = 12" (1 foot)
T = 0.312"

W = 46.56 lbs. per foot

3.6.2 Resistivity per foot of pipe:

$R_{ft} = (16.061 \times R_s) / W$

Where:

R_{ft} = resistivity per foot^2
R_s = resistivity of steel
W = weight per foot of pipe
16.061 (A.W. Peabody, Peabody's Control of Pipeline Corrosion, 2nd Edition, 2001)

Values:

W = 46.56 lbs per foot
R_s = 18 micro ohm-cm

R_{ft} = 6.2 micro ohm-cm

3.6.3 Resistance of pipeline section:

$R_{sec} = R_{ft} \times L_{sec}$

Where:

R_{sec} = resistance of section
R_{ft} = resistivity per square foot
L_{sec} = length of pipe section

Values:

R_{ft} = 6.2 micro ohm-cm
L_{sec} = 45,936 feet (milepost 32.54 to 41.24)

R_{sec} = 0.28 ohm

3.6.4 Voltage loss of pipeline section:

$V_{sec} = I_{req} \times R_{sec}$

Where:

V_{sec} = voltage loss across a pipeline section
I_{req} = rectifier current output
R_{sec} = resistance of pipe section

Values:

I_{req} = 3 amperes
R_{sec} = 0.28 ohm

V_{sec} = 0.84 volts

3.6.5 Voltage at end of pipeline section:

$V = V_{rec} - V_{sec}$

Where:

V = voltage on pipeline
V_{rec} = rectifier voltage
V_{sec}= voltage loss across pipeline section

Values:

V_{rec} = 20 volts
V_{sec} = 0.84 volts

V = 19.16 volts

3.6.6 Attenuation calculations:

Attenuation = $(V / V_{rec}) \times 100$

Where:

Attenuation = percentage of voltage lost along pipeline
V = voltage at end of pipeline section
V_{rec} = voltage of rectifier

Values:

V = 19.16 Volts
V_{rec} = 20 volts

Attenuation of pipeline section: 95.8 %

3.6.7 Voltage requirements:

Assume: -1.0 V at Rectifier Location at milepost 41.24

V_r = (attenuation / 100) × -1.0 V

Voltage at milepost 32.54:

$V_{r =}$ -0.95 volts

These voltages satisfy the minimum "polarized" potential of - 0.85 volts.

APPENDIX B –
SOIL RESISTIVITY MEASUREMENTS

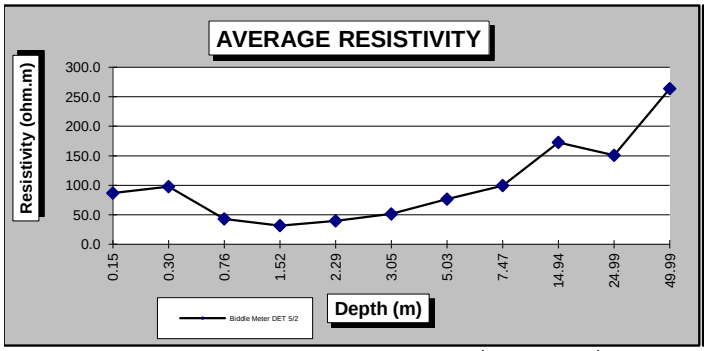
SOIL RESISTIVITY DATA

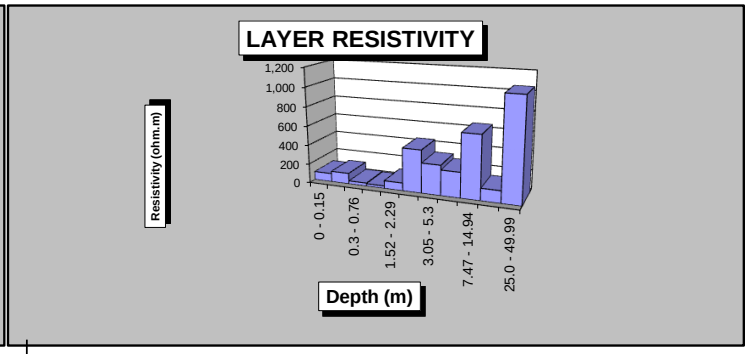
Project Name:	Vermont Gas Project
	12-144-09
Date:	5/2/2013
Location:	Rd Sd off Redmond Rd
	44 28.277N, 73 5.082W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	80F/Clear
Soil Description	Moist dark sodded

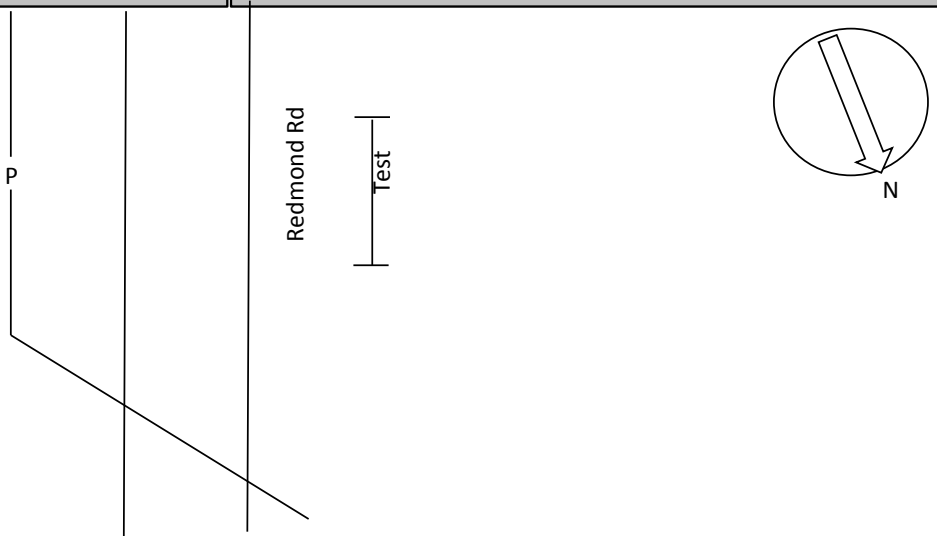
ENGINEERING & TECHNICAL SERVICES, INC.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	90.600	1	86.8	0.01104	n/a	n/a	n/a	0 - 0.15	87
1.00	0.30	51.000	2	97.7	0.01961	0.00857	116.682	1	0.15 - 0.3	112
2.50	0.76	8.970	5	42.9	0.11148	0.09187	10.884	3	0.3 - 0.76	31
5.00	1.52	3.300	10	31.6	0.30303	0.19155	5.221	5	0.76 - 1.52	25
7.50	2.29	2.760	14	39.6	0.36232	0.05929	16.867	5	1.52 - 2.29	81
10.00	3.05	2.680	19	51.3	0.37313	0.01082	92.460	5	2.29 - 3.05	443
16.50	5.03	2.420	32	76.5	0.41322	0.04009	24.945	12	3.05 - 5.3	311
24.50	7.47	2.120	47	99.5	0.47170	0.05847	17.101	15	5.03 - 7.47	262
49.00	14.94	1.840	94	172.7	0.54348	0.07178	13.931	47	7.47 - 14.94	654
82.00	24.99	0.960	157	150.8	1.04167	0.49819	2.007	63	14.94 - 25.0	127
164.00	49.99	0.840	314	263.8	1.19048	0.14881	6.720	157	25.0 - 49.99	1,055

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth







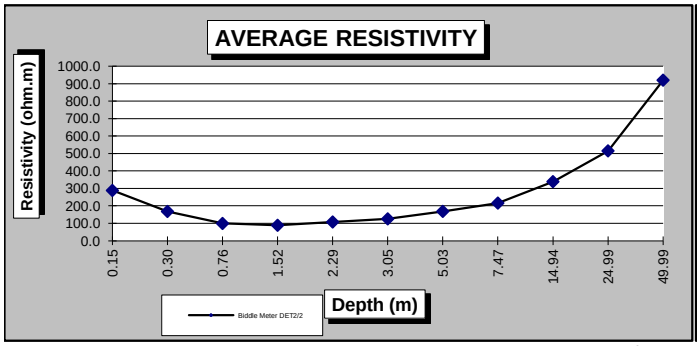
SOIL RESISTIVITY DATA

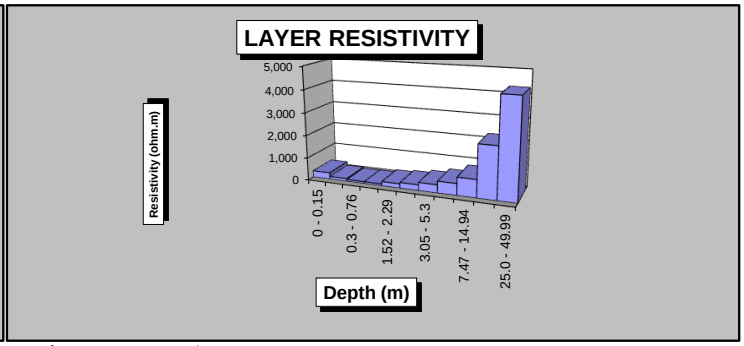
Project Name:	Vermont Gas Project
	12-144-25
Date:	5/3/2013
Location:	Rd Sd off Pond Rd
	44 15.096N, 73 8.382W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	69F/Clear
Soil Description	Dry sand and rock

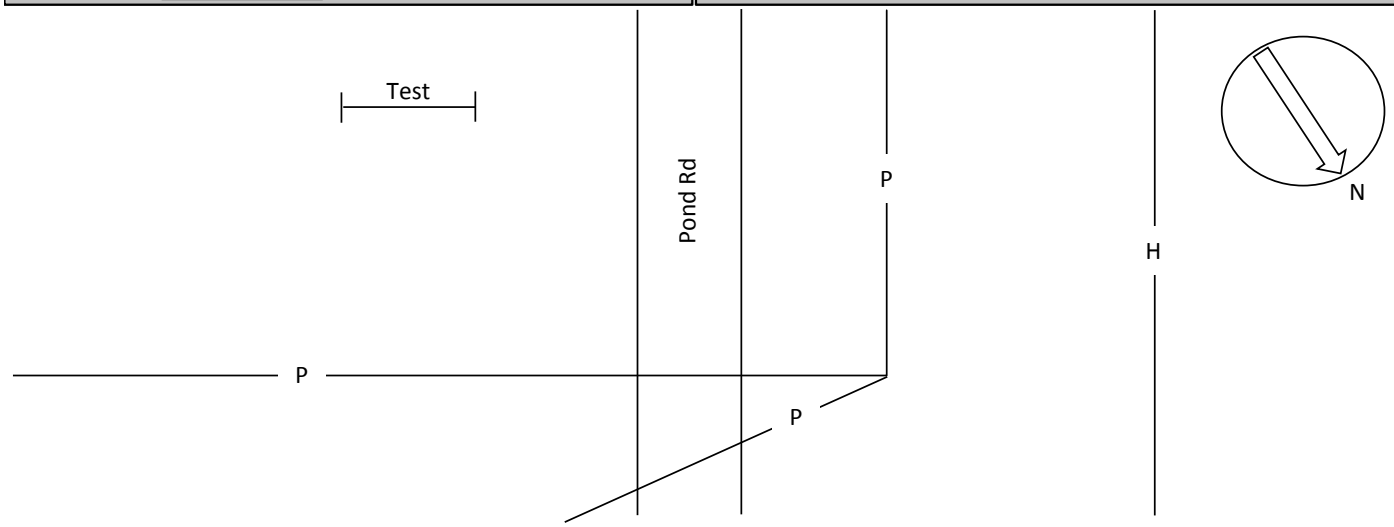
ARK ENGINEERING & TECHNICAL SERVICES, INC.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	Layer Resistivity* ohm.m
0.50	0.15	301.000	1	288.2	0.00332	n/a	n/a	n/a	0 - 0.15	288
1.00	0.30	87.700	2	168.0	0.01140	0.00808	123.759	1	0.15 - 0.3	119
2.50	0.76	20.700	5	99.1	0.04831	0.03691	27.095	3	0.3 - 0.76	78
5.00	1.52	9.250	10	88.6	0.10811	0.05980	16.723	5	0.76 - 1.52	80
7.50	2.29	7.490	14	107.6	0.13351	0.02540	39.365	5	1.52 - 2.29	188
10.00	3.05	6.550	19	125.4	0.15267	0.01916	52.191	5	2.29 - 3.05	250
16.50	5.03	5.330	32	168.4	0.18762	0.03495	28.616	12	3.05 - 5.3	356
24.50	7.47	4.600	47	215.8	0.21739	0.02977	33.586	15	5.03 - 7.47	515
49.00	14.94	3.610	94	338.8	0.27701	0.05962	16.774	47	7.47 - 14.94	787
82.00	24.99	3.280	157	515.1	0.30488	0.02787	35.881	63	14.94 - 25.0	2,268
164.00	49.99	2.930	314	920.3	0.34130	0.03642	27.458	157	25.0 - 49.99	4,312

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth







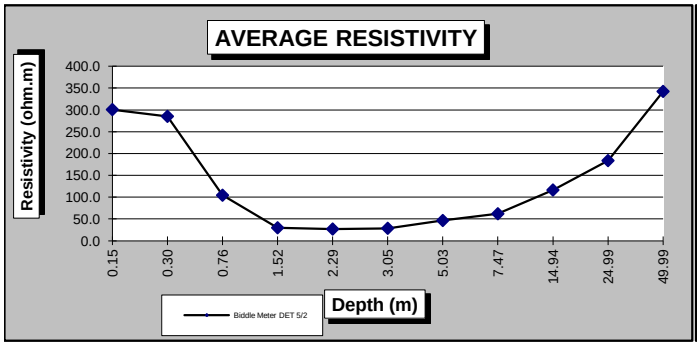
SOIL RESISTIVITY DATA

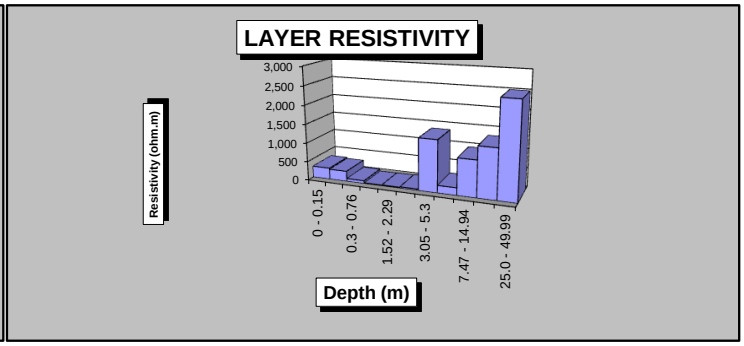
Project Name:	Vermont Gas Project
	12-144-40
Date:	5/5/2013
Location:	Rd Sd off US 7
	44 2.3630N, 73 9.7127W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	61F/Clear
Soil Description	Hard packed, rocky and vegetation

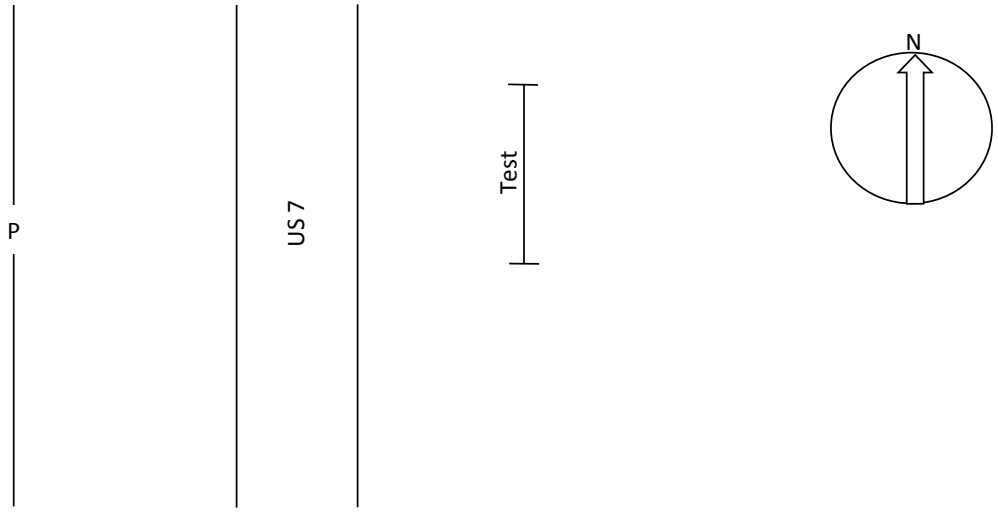
ARK ENGINEERING & TECHNICAL SERVICES, INC.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	Layer Resistivity* ohm.m
0.50	0.15	314.000	1	300.7	0.00318	n/a	n/a	n/a	0 - 0.15	301
1.00	0.30	148.900	2	285.2	0.00672	0.00353	283.190	1	0.15 - 0.3	271
2.50	0.76	21.800	5	104.4	0.04587	0.03916	25.539	3	0.3 - 0.76	73
5.00	1.52	3.110	10	29.8	0.32154	0.27567	3.628	5	0.76 - 1.52	17
7.50	2.29	1.870	14	26.9	0.53476	0.21322	4.690	5	1.52 - 2.29	22
10.00	3.05	1.490	19	28.5	0.67114	0.13638	7.332	5	2.29 - 3.05	35
16.50	5.03	1.470	32	46.5	0.68027	0.00913	109.515	12	3.05 - 5.3	1,363
24.50	7.47	1.320	47	61.9	0.75758	0.07730	12.936	15	5.03 - 7.47	198
49.00	14.94	1.240	94	116.4	0.80645	0.04888	20.460	47	7.47 - 14.94	960
82.00	24.99	1.170	157	183.7	0.85470	0.04825	20.726	63	14.94 - 25.0	1,310
164.00	49.99	1.090	314	342.3	0.91743	0.06273	15.941	157	25.0 - 49.99	2,503

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth

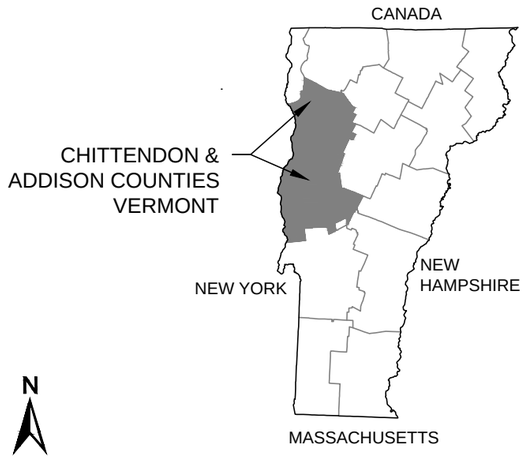






APPENDIX C –
CATHODIC PROTECTION SYSTEM DESIGN DRAWINGS

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



CHA

VERMONT GAS SYSTEMS, INC

ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION SYSTEM DESIGN
INSTALLATION DRAWINGS
CHITTENDON & ADDISON COUNTIES, VERMONT

PROJECT DRAWING LISTING

DRAWING NO.	SHEETS	REV	TITLE
12145-100	1	C	COVER SHEET
12145-200	1	C	GROUNDING PLAN - WILLISTON RECTIFIER BED
12145-201	1	C	GROUNDING PLAN - MONKTON RECTIFIER BED
12145-202	1	C	GROUNDING PLAN - MIDDLEBURY RECTIFIER BED MILE POST 40.7
12145-300	1	C	ANODE INSTALLATION DETAIL
12145-301	1	C	ANODE JUNCTION BOX AND RECTIFIER INSTALLATION DETAILS
12145-302	3	C	TEST STATION INSTALLATION & LOCATIONS
12145-303	1	C	WIRE TO PIPE CONNECTION DETAILS
12145-400	1	C	MATERIALS LIST

ISSUED FOR CONSTRUCTION

CLIENT: CHA

SITE: VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO.: 12-E-145-CP

ARK ENGINEERING & TECHNICAL SERVICES, INC.

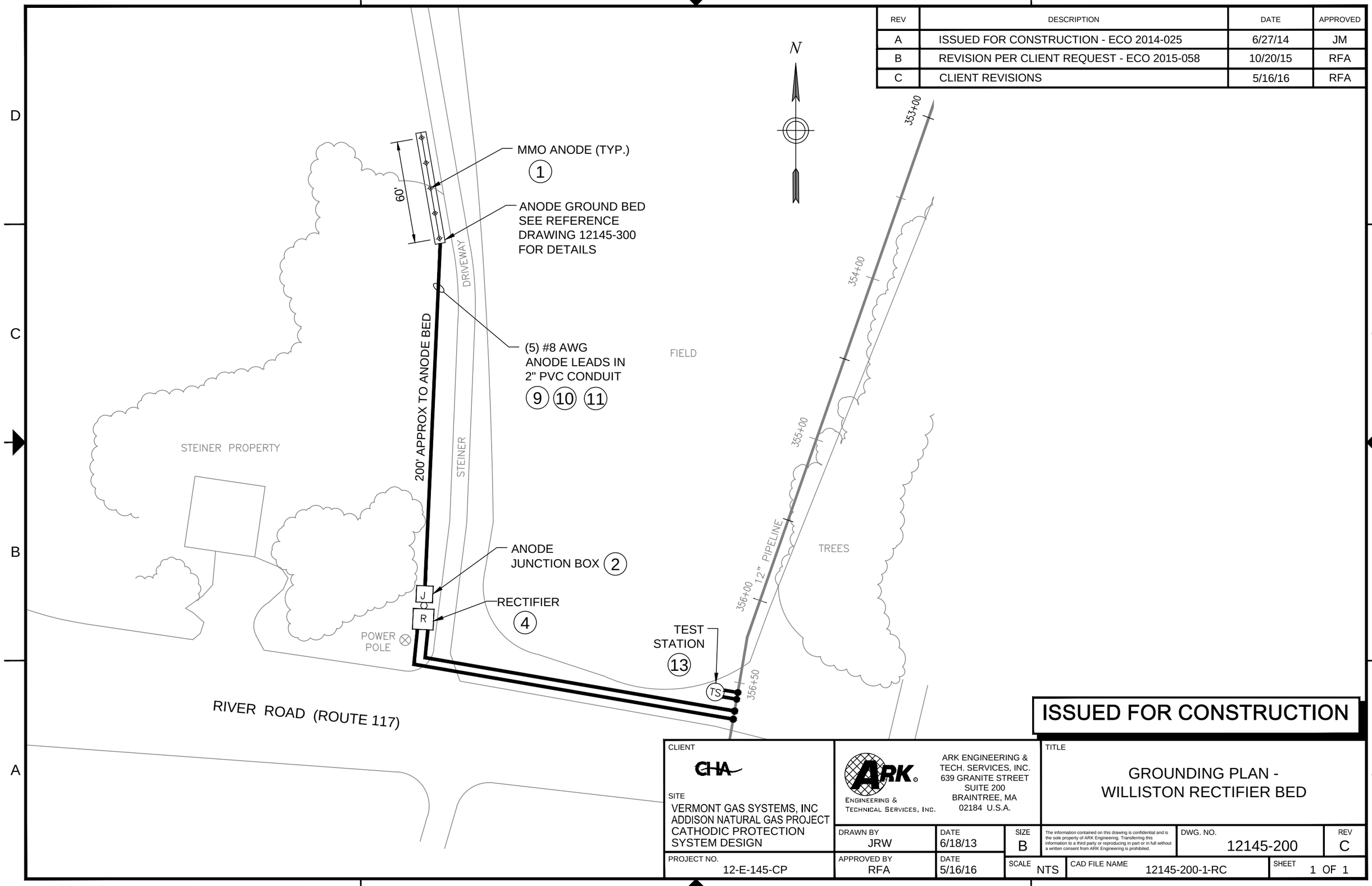
ARK ENGINEERING &
TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

DRAWN BY: JRW | DATE: 6/18/13 | SIZE: B
APPROVED BY: RFA | DATE: 5/16/16 | SCALE: NTS

TITLE: COVER SHEET

DWG. NO.: 12145-100 | REV: C
CAD FILE NAME: 12145-100-1-RC
SHEET: 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



ISSUED FOR CONSTRUCTION

CLIENT
CHA

SITE
VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO. 12-E-145-CP

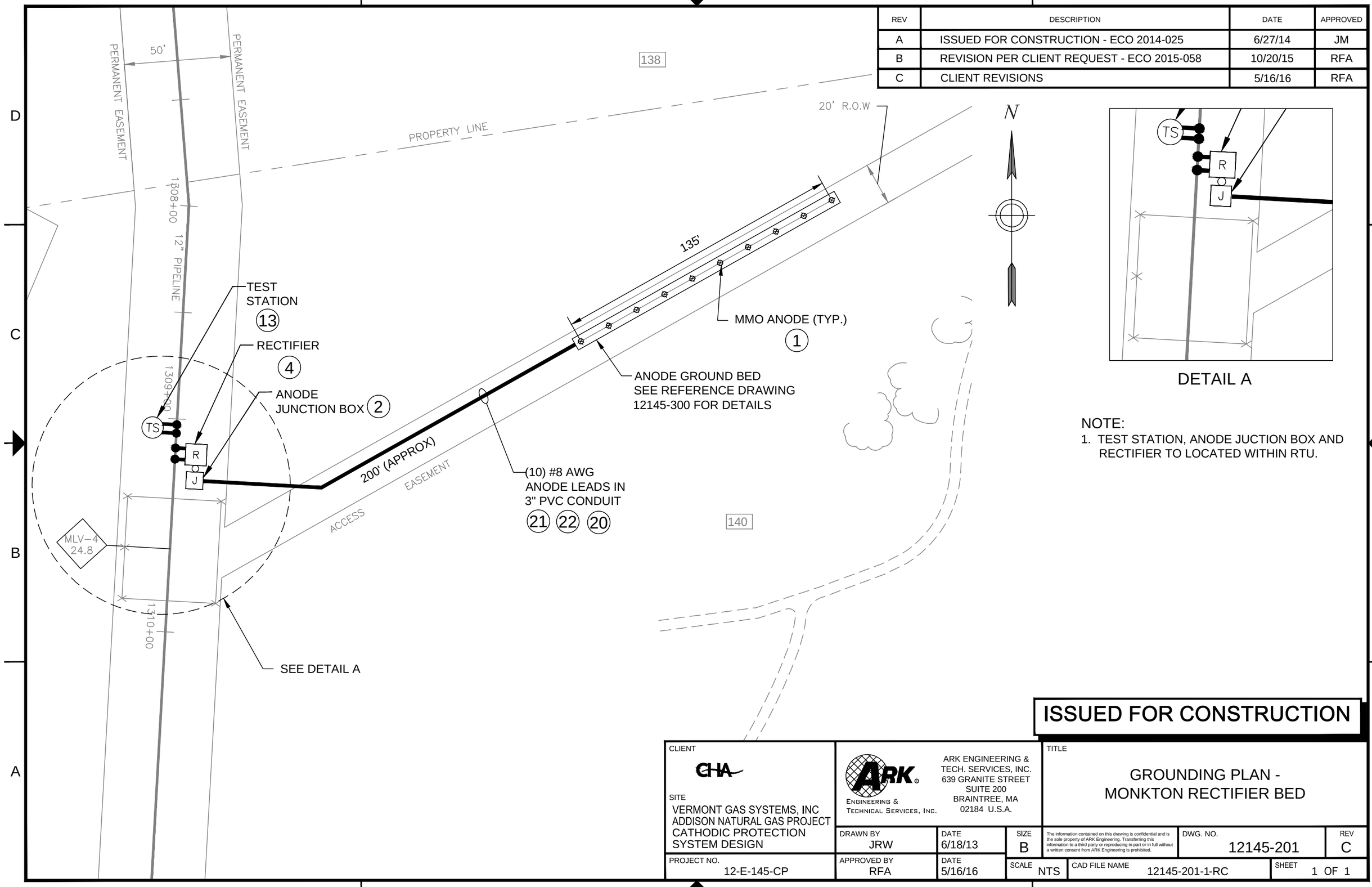
ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING &
TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
GROUNDING PLAN -
WILLISTON RECTIFIER BED

DRAWN BY	DATE	SIZE	DWG. NO.	REV
JRW	6/18/13	B	12145-200	C
APPROVED BY	DATE	SCALE	CAD FILE NAME	SHEET
RFA	5/16/16	NTS	12145-200-1-RC	1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



DETAIL A

NOTE:
1. TEST STATION, ANODE JUCTION BOX AND RECTIFIER TO LOCATED WITHIN RTU.

ISSUED FOR CONSTRUCTION

CLIENT: CHA

SITE: VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO.: 12-E-145-CP

ARK ENGINEERING & TECHNICAL SERVICES, INC.
ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

DRAWN BY: JRW | DATE: 6/18/13
APPROVED BY: RFA | DATE: 5/16/16

SIZE: B | SCALE: NTS

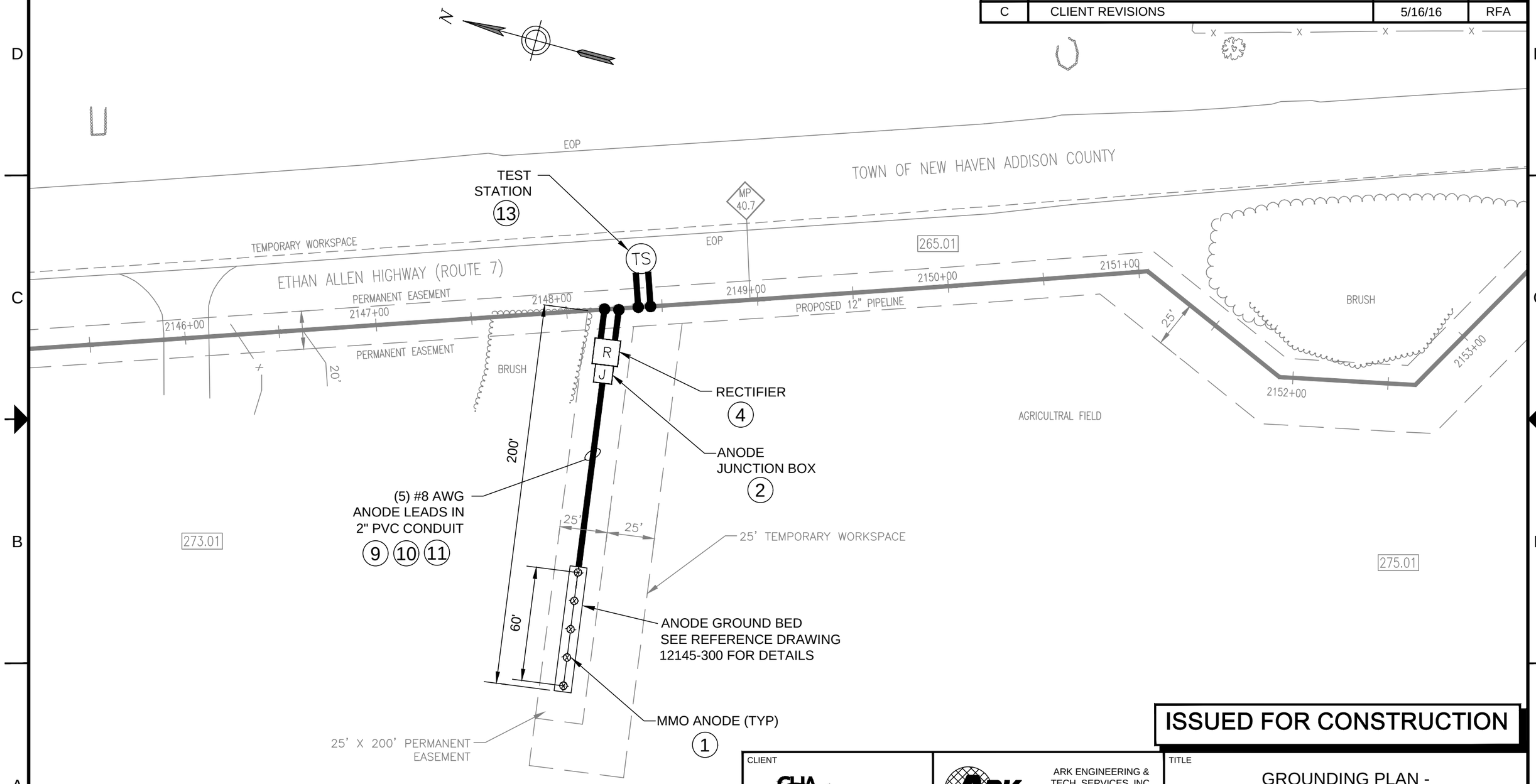
TITLE: GROUNDING PLAN - MONKTON RECTIFIER BED

DWG. NO.: 12145-201 | REV: C

CAD FILE NAME: 12145-201-1-RC

SHEET: 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



ISSUED FOR CONSTRUCTION

CLIENT
CHA

SITE
VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO. 12-E-145-CP

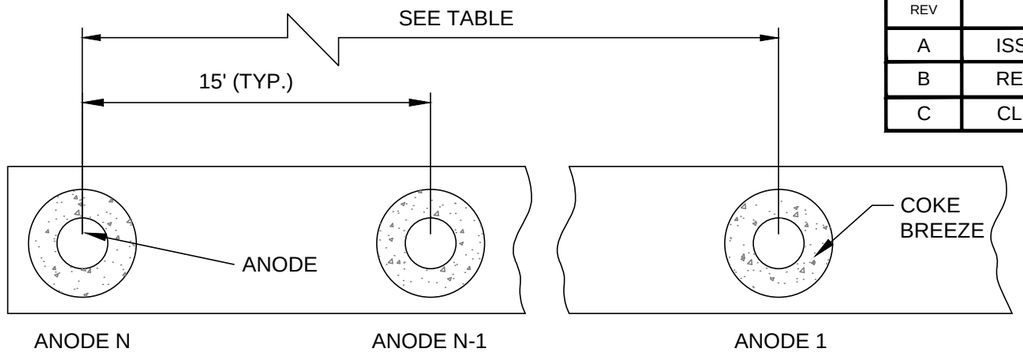
ARK ENGINEERING & TECHNICAL SERVICES, INC.
ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

DRAWN BY JRW | DATE 6/18/13
APPROVED BY RFA | DATE 5/16/16

TITLE
GROUNDING PLAN -
MIDDLEBURY RECTIFIER BED
MILE POST 40.7

SIZE B | SCALE NTS | DWG. NO. 12145-202 | REV C | CAD FILE NAME 12145-202-1-RC | SHEET 1 OF 1

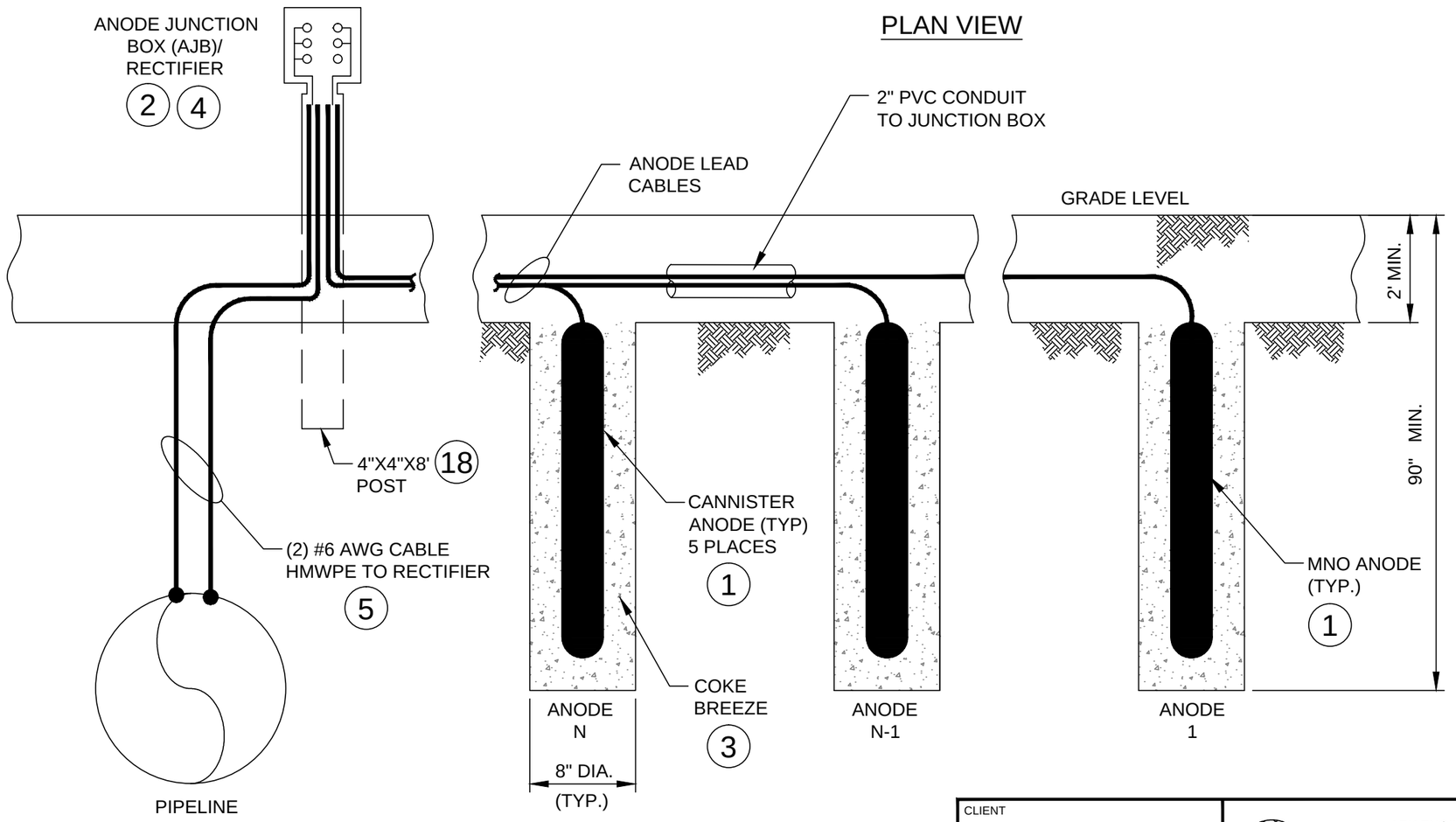
REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



NOTES:

1. ROUTE ANODE LEADS IN PVC CONDUIT FROM INSTALLATION LOCATION TO RECTIFIER JUNCTION BOX.
2. BACKFILL DITCH WITH NATIVE SOIL.

PLAN VIEW



CANNISTER ANODE BED SECTION

RECTIFIER BEDS		
RECTIFIER	NUMBER OF ANODES (N)	FEET
MIDDLEBURY	5	60'
WILLISTON	5	60'
MONKTON	10	135'

ISSUED FOR CONSTRUCTION

CLIENT: CHA

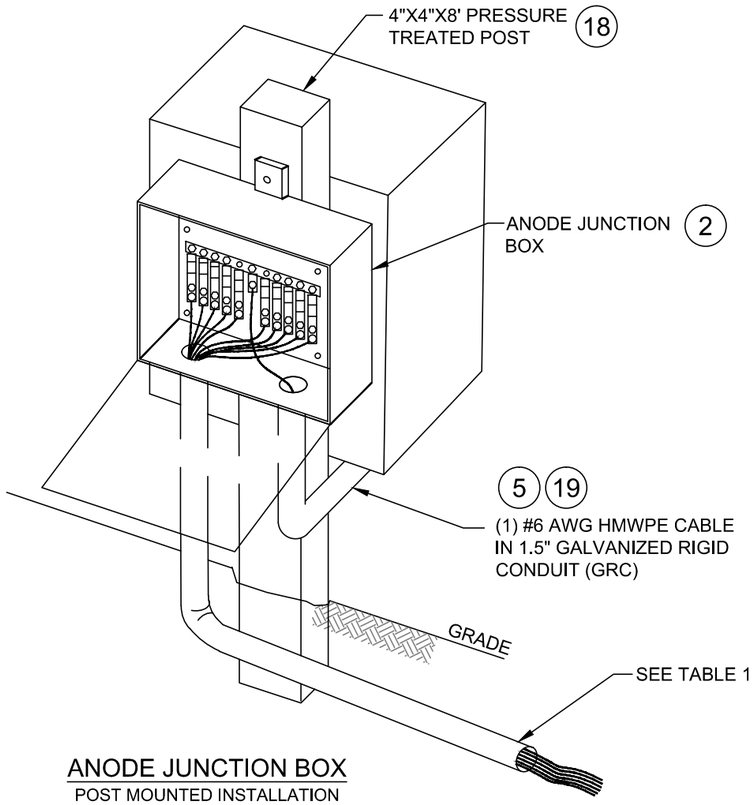
SITE: VERMONT GAS SYSTEMS, INC ADDISON NATURAL GAS PROJECT CATHODIC PROTECTION SYSTEM DESIGN

ARK ENGINEERING & TECHNICAL SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE: ANODE INSTALLATION DETAIL

DRAWN BY	DATE	SIZE	DWG. NO.	REV
JRW	6/18/13	B	12145-300	C
PROJECT NO.	APPROVED BY	DATE	SCALE	CAD FILE NAME	SHEET
12-E-145-CP	RFA	5/16/16	NTS	12145-300-1-RC	1 OF 1

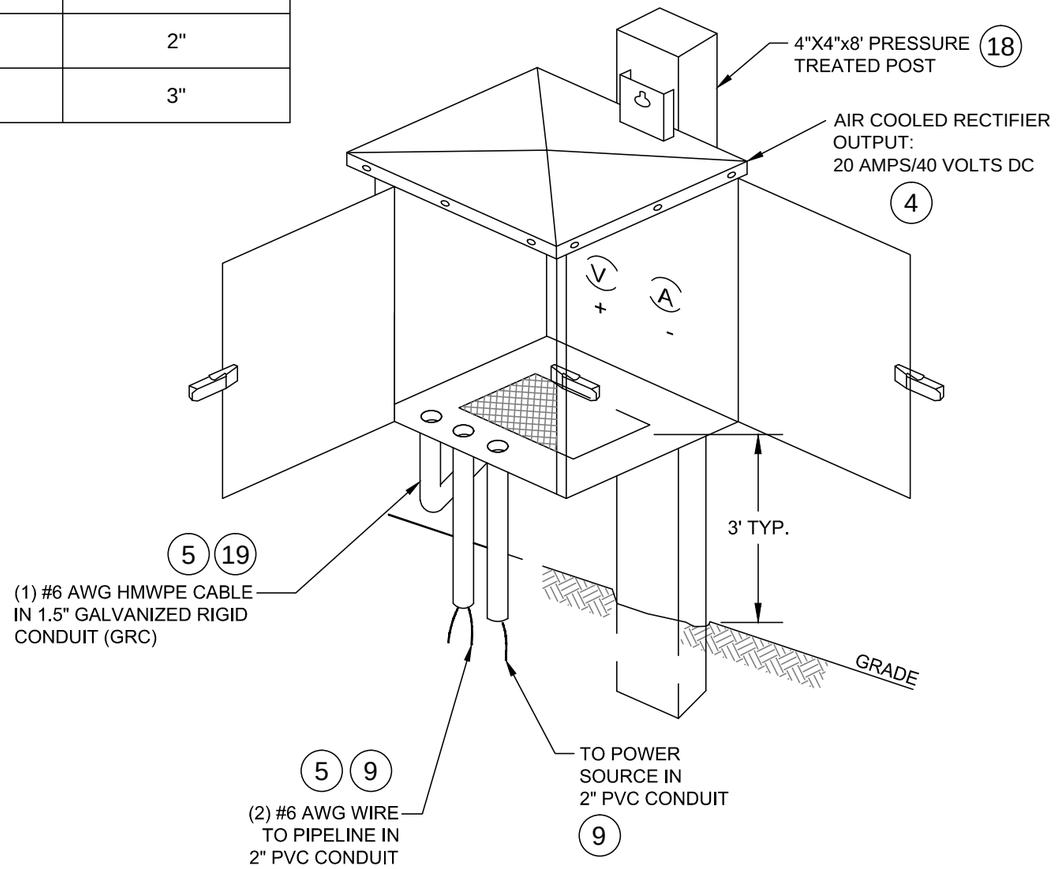
REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



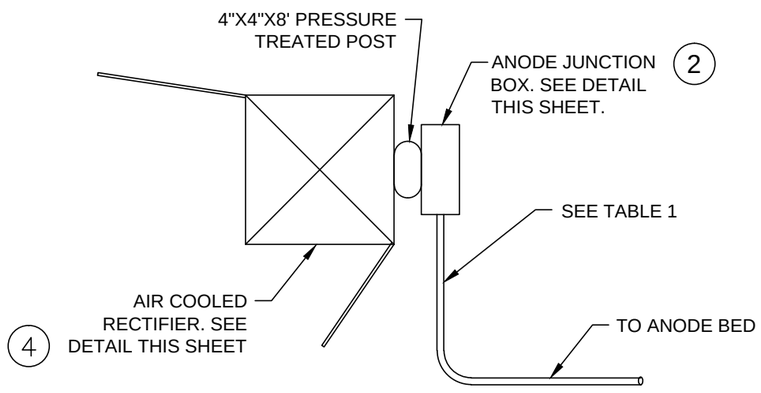
ANODE JUNCTION BOX
POST MOUNTED INSTALLATION
ELEVATION

TABLE 1		
	NO. OF ANODES	CONDUIT SIZE
MIDDLEBURY	5	2"
WILLISTON	5	2"
MONKTON	10	3"

NOTES:
1. INSTALL WARNING TAPE 1' BELOW GRADE FOR ALL UNDERGROUND WIRING.



AIR COOLED RECTIFIER
POST MOUNTED INSTALLATION
ELEVATION



ANODE BED & AIR COOLED RECTIFIER ARRANGEMENT
PLAN VIEW

ISSUED FOR CONSTRUCTION

CLIENT: CHA

SITE: VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO.: 12-E-145-CP

ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

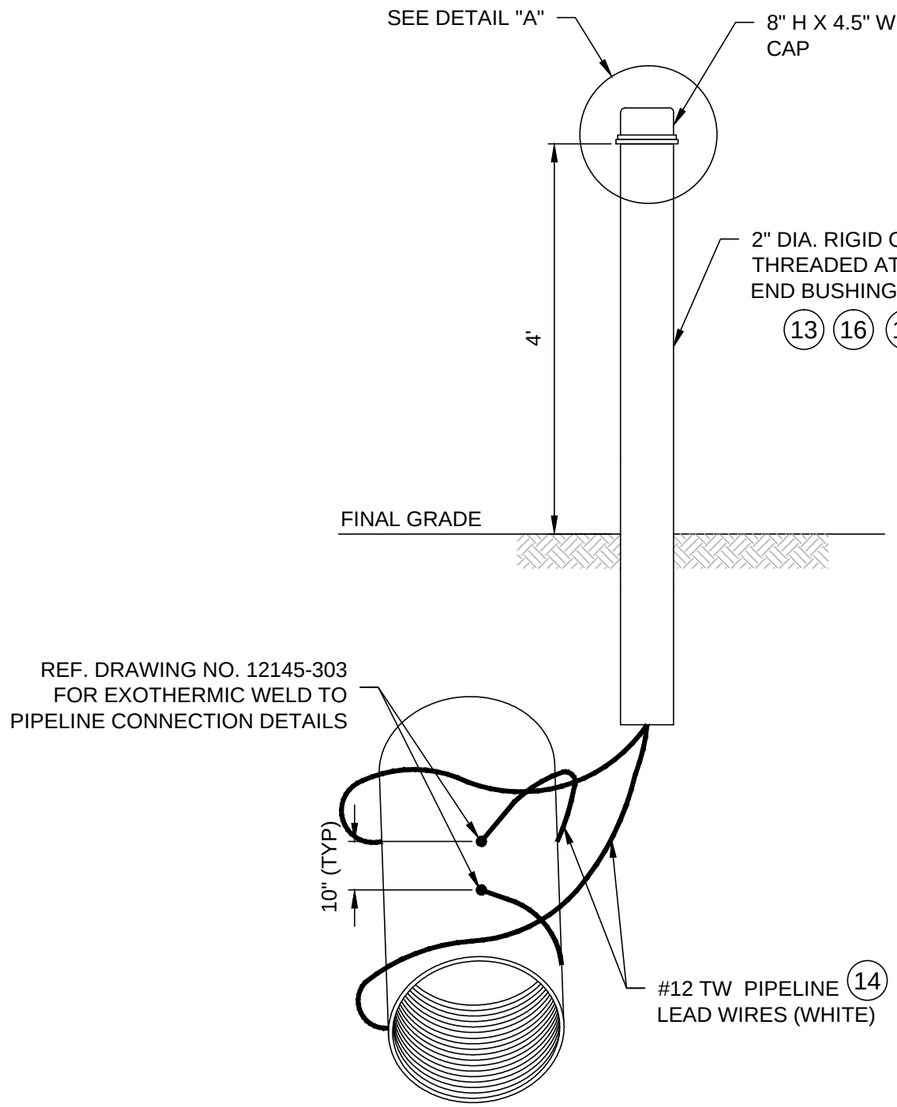
DRAWN BY: JRW
DATE: 6/18/13
APPROVED BY: RFA
DATE: 5/16/16

TITLE: ANODE JUNCTION BOX AND RECTIFIER INSTALLATION DETAILS

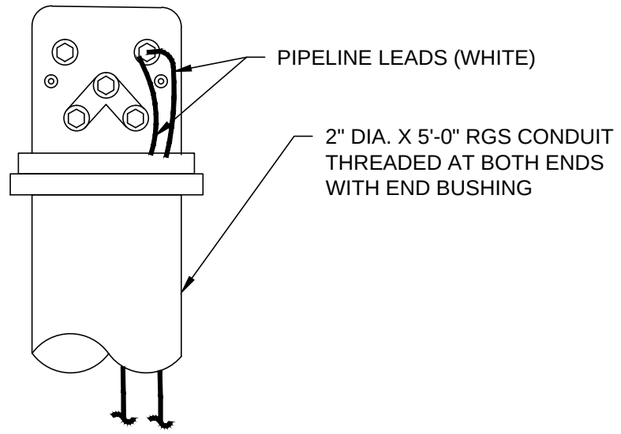
SIZE: B

DWG. NO.: 12145-301
REV: C
SCALE: NTS
CAD FILE NAME: 12145-301-1-RC
SHEET: 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



TEST STATION



DETAIL A
STANDARD TEST STATION
CONNECTION DETAIL
(TESTOX MODEL 715)

NOTES:

1. REMOVE PIPELINE COATING AND CLEAN TO BARE METAL.
2. LOOP & HITCH WIRE AROUND PIPE WITHOUT DAMAGING PIPE COATING, BEFORE THERMITE WELDING.
3. USE 15 GRAM CHARGE FOR EACH EXOTHERMIC WELD AND FOLLOW PROCEDURE RECOMMENDED BY THERMITE WELD MANUFACTURER.
4. USE THERMOWELD ADAPTER SLEEVE P/N 38-0200-00 OR EQUAL FOR EXOTHERMIC WELD CONNECTIONS OF #12 TW LEADS TO PIPELINE.
5. TEST STATION LEAD WIRES ARE TO BE WHITE.

ISSUED FOR CONSTRUCTION

CLIENT: CHA

SITE: VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

PROJECT NO.: 12-E-145-CP

ARK ENGINEERING & TECHNICAL SERVICES, INC.
ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

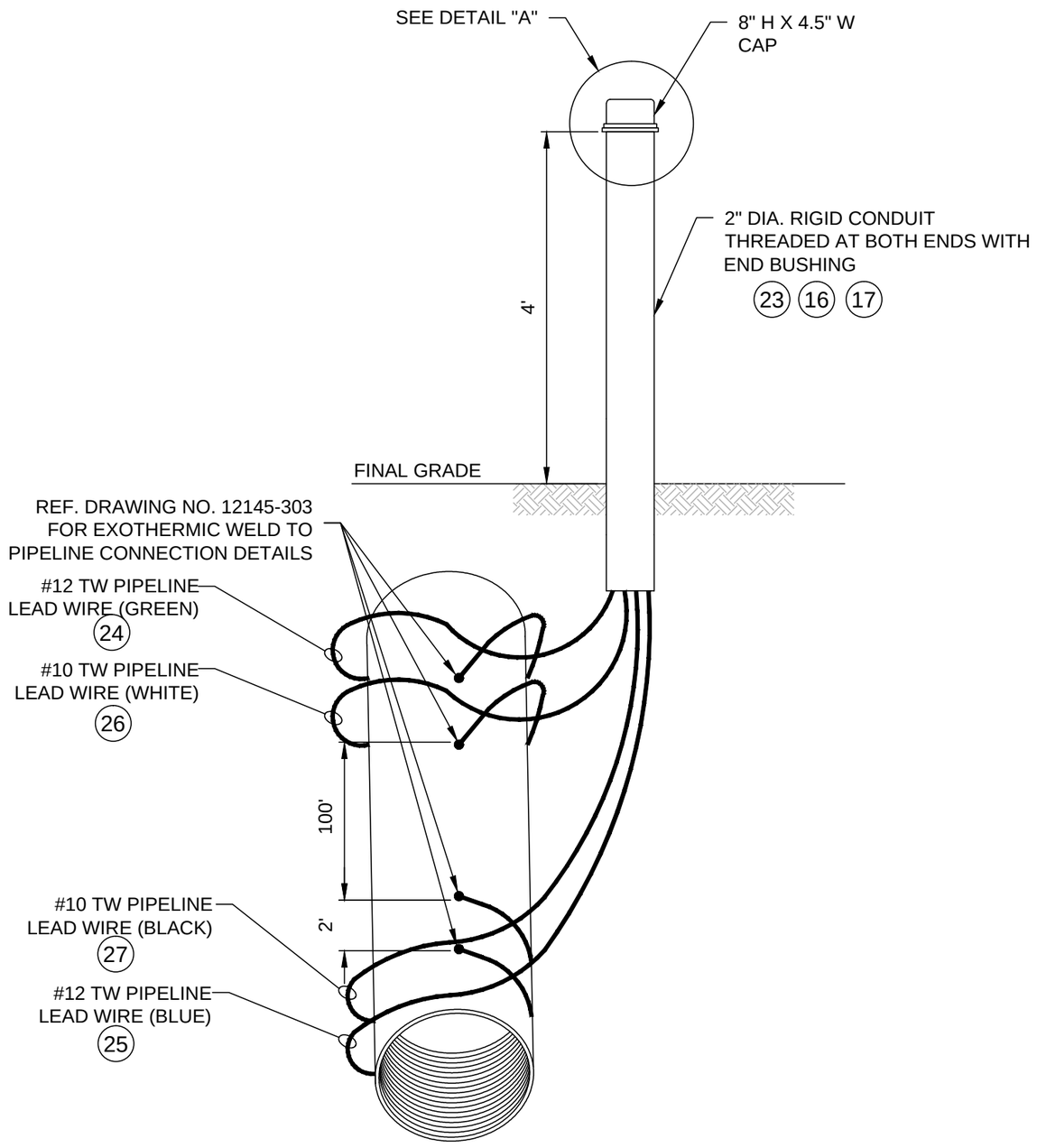
DRAWN BY	DATE	APPROVED BY	DATE
JRW	6/18/13	RFA	5/16/16

TITLE: TEST STATION INSTALLATION & LOCATIONS

SIZE	DWG. NO.	REV
B	12145-302	C

SCALE	CAD FILE NAME	SHEET
NTS	12145-302-1-RC	1 OF 3

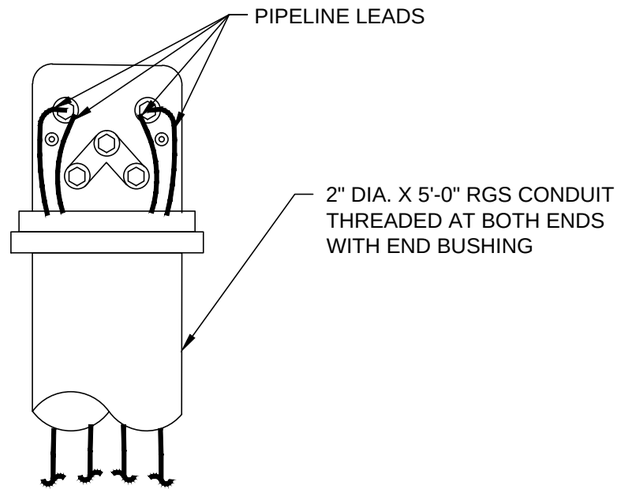
REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA



T-3 CP TEST STATION

NOTES:

1. REMOVE PIPELINE COATING AND CLEAN TO BARE METAL.
2. LOOP & HITCH WIRE AROUND PIPE TWICE WITHOUT DAMAGING PIPE COATING, BEFORE THERMITE WELDING.
3. USE 15 GRAM CHARGE FOR EACH EXOTHERMIC WELD AND FOLLOW PROCEDURE RECOMMENDED BY THERMITE WELD MANUFACTURER.
4. USE THERMOWELD ADAPTER SLEEVE P/N 38-0200-00 OR EQUAL FOR EXOTHERMIC WELD CONNECTIONS OF #10 TW & #12 TW LEADS TO PIPELINE.



DETAIL A
FOUR WIRE TEST STATION CONNECTION DETAIL
(T-3 CP MODEL)

ISSUED FOR CONSTRUCTION

ARK ENGINEERING & TECHNICAL SERVICES, INC.

SIZE	DWG. NO.	REV
	12145-302	C
SCALE	CAD FILE NAME	SHEET
	12145-302-2-RC	2 OF 3

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA

TEST STATION INSTALLATION LOCATIONS

BOX #	APPROX.STATION	APPROX.MILE POST	DISTANCE BETWEEN BOXES	STATION TYPE	LOCATION DESCRIPTION	TOWN	LL #	LANDOWNER
0	0+00	0	0	TWO WIRE	COLCHESTER LAUNCHER	COLCHESTER	1.03	CADE
1	26+00	0.49	0.49	FOUR WIRE	MILL POND ROAD CROSSING	COLCHESTER	2.02	TOWN OF COLCHESTER
2	67+00	1.26	0.77	TWO WIRE	ACCESS ROAD "C"	COLCHESTER	3	STATE OF VERMONT
3	109+00	2.06	0.8	TWO WIRE	RT 2A CROSSING	ESSEX	5	STATE OF VERMONT
4	158+00	2.99	0.93	TWO WIRE	VELCO 289 CROSSING	ESSEX	6	STATE OF VERMONT
5	214+00	4.05	1.06	TWO WIRE	RT. 15 CROSSING	ESSEX	9	STATE OF VERMONT
6	240+50	4.55	0.5	TWO WIRE	ESSEX WAY CROSSING	ESSEX	9	STATE OF VERMONT
7	302+00	5.71	1.16	FOUR WIRE	I-89 "JUGHANDLE"	ESSEX	9	STATE OF VERMONT
8	356+00	6.74	1.03	TWO WIRE	WINOOSKI RIVER HDD BEGIN	ESSEX	14	STEINER
9	374+00	7.08	0.34	TWO WIRE	RR CROSSING	WILLISTON	21	CSWD
10	399+50	7.57	0.49	TWO WIRE	REDMOND ROAD	WILLISTON	23	CSWD
11	443+50	8.4	0.83	TWO WIRE	REDMOND ROAD	WILLISTON	30	CSWD
12	481+00	9.1	0.7	TWO WIRE	MOUNTAIN VIEW RD CROSSING	WILLISTON	36	TOWN OF WILLISTON
13	518+50	9.82	0.72	TWO WIRE	WEST OF CATAMOUNT CC, BIKE PATH	WILLISTON	38	STATE OF VERMONT
14	551+00	10.43	0.61	FOUR WIRE	WILLISTON STATION	WILLISTON	41	TOWN OF WILLISTON
15	605+50	11.47	1.04	TWO WIRE	HURRICANE LANE	WILLISTON	53	HURRICANE LANE
16	655+50	12.42	0.95	TWO WIRE	ROUTE 2A	WILLISTON	58	ST. GEORGE ROAD
17	719+00	13.61	1.19	FOUR WIRE	VELCO SUBSTATION	WILLISTON	71	VERMONT TRANSCO LLC
18	756+50	14.33	0.72	TWO WIRE	LINCOLN ROAD	WILLISTON	80	CAVANAUGH
19	787+75	14.92	0.59	TWO WIRE	BREEZY VALLEY DRIVE	ST. GEORGE	82	PILLSBURY
20	867+00	16.42	4	FOUR WIRE	ROUTE 2A	ST. GEORGE	85	BOVAT
21	892+75	16.91	0.49	TWO WIRE	ROUTE 116	ST. GEORGE	85.05	BOVAT
22	948+00	17.96	1.05	TWO WIRE	HICKORY PLACE	HINESBURG	100	PRENGLER
23	1000+00	18.94	0.98	TWO WIRE	SHELBURNE FALLS ROAD	HINESBURG	105	SHELBURNE FALLS ROAD
	1071+00			COUPON TEST STATION				
24	1114+00	21.1	3.14	FOUR WIRE	BALDWIN ROAD	HINESBURG	113	LAVALLEE
25	1180+50	22.35	22.35	TWO WIRE	DRINKWATER	HINESBURG	120	BALDWIN
26	1221+50	23.14	0.79	TWO WIRE	EDGE OF FIELD NEAR TEMP. ACCESS	HINESBURG	124	AMES
27	1294+25	24.51	3.41	FOUR WIRE	ROTAX ROAD	MONKTON	138	LATREILLE
28	1398+00	26.47	26.47	TWO WIRE	HOLLOW ROAD	MONKTON	160	COUSINO
29	1525+50	28.89	28.89	FOUR WIRE	OLD STAGE	MONKTON	181	HURLBURT
30	1565+00	29.64	0.75	TWO WIRE	OLD STAGE @ BEND INTO HURLBURT	MONKTON	181	HURLBURT
31	1769+00	33.5	12.4	FOUR WIRE	QUARRY ROAD	NEW HAVEN	221	FARNSWORTH
32	2010+00	38.07	11.6	FOUR WIRE	HUNT ROAD	NEW HAVEN	246	SWEENEY
33	2047+00	38.77	0.7	TWO WIRE	FOUR HILL FARMS	NEW HAVEN	252	FOUR HILLS FARM
	2172+50			COUPON TEST STATION	ALONG ROUTE 7			
34	2179+88	41.24	7.74	FOUR WIRE	AT MIDDLEBURY GATE STATION	MIDDLEBURY	277.01	CORBIN

28

ISSUED FOR CONSTRUCTION

ARK ENGINEERING & TECHNICAL SERVICES, INC.

SIZE

DWG. NO. 12145-302

REV C

SCALE

CAD FILE NAME 12145-302-3-RC

SHEET 3 OF 3

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA

EXOTHERMIC WELD INSTRUCTIONS:

1. FIRST DETERMINE IF THE PIPELINE IS SUITABLE FOR EXOTHERMIC WELDING BY CONDUCTING THE FOLLOWING TESTS:

   A) DETERMINE THAT THE PIPELINE SYMS (SPECIFIED MINIMUM YIELD STRENGTH) IS <80,000 PSI.
   B) DETERMINE THAT PIPELINE WALL THICKNESS IS ⅛" (0.125") OR GREATER.
   C) PERFORM ULTRASONIC TESTING TO PIPELINE TO DETERMINE THAT NO SURFACE OR INTERNAL DEFECTS EXIST.

2. FOR EACH CABLE TO PIPELINE CONNECTION (EXOTHERMIC WELD), REMOVE A 3"X3" MAX AREA OF PIPELINE COATING AT THE 12:00 O'CLOCK POSITION ON THE PIPELINE AND BRUSH UNTIL SHINY. ANY ADJACENT CABLE CONNECTIONS SHALL BE NO CLOSER THAN 9" AND NO FURTHER THAN 18".

3. USING A FILE, PREPARE A CROSSHATCH PATTERN IN THE AREA WHERE THE WELD CONNECTION WILL SIT.

4. PROVIDE CABLE STRAIN RELIEF BY WRAPPING CABLE ONCE AROUND THE PIPE AS SHOWN IN CABLE CONNECTION DETAIL. (SEE ABOVE)

5. STRIP BACK ANY CABLE INSULATION 1"-2" AND TAPE CABLE TO PIPE.

6. ENSURE THAT THE PIPELINE WELD AREA AND CABLE ARE CLEAN AND DRY PRIOR TO WELDING.

7. USE SPECIFIC WELD MOLD AND WELD METAL AS INDICATED IN DRAWING MATERIAL LIST.

8. IF INDICATED, USE COPPER HEAT SLEEVE ON CABLE END TO BE WELDED.

9. USE ONLY A 15 GRAM MELDING CHARGE. DO NOT EXCEED.

10. PLACE THE METAL RETAINER DISK IN THE SPECIFIED WELD MOLD AND DUMP (DO NOT POUR) WELD METAL POWDER ONTO THE DISK. MAKE SURE THAT ALL OF THE FINE STARTING POWDER IS IN THE MOLD. IF ANY POWDER REMAINS IN THE CARTRIDGE BOTTOM, SQUEEZE OUT INTO MOLD AND BREAK UP.

11. CLOSE MOLD LID.

12. REPLACE CAP ON EMPTY WELD METAL CARTRIDGE AND PLACE BACK INTO CARTRIDGE PACK BOX UPSIDE DOWN TO KEEP THE REMAINING CARTRIDGES UPRIGHT.

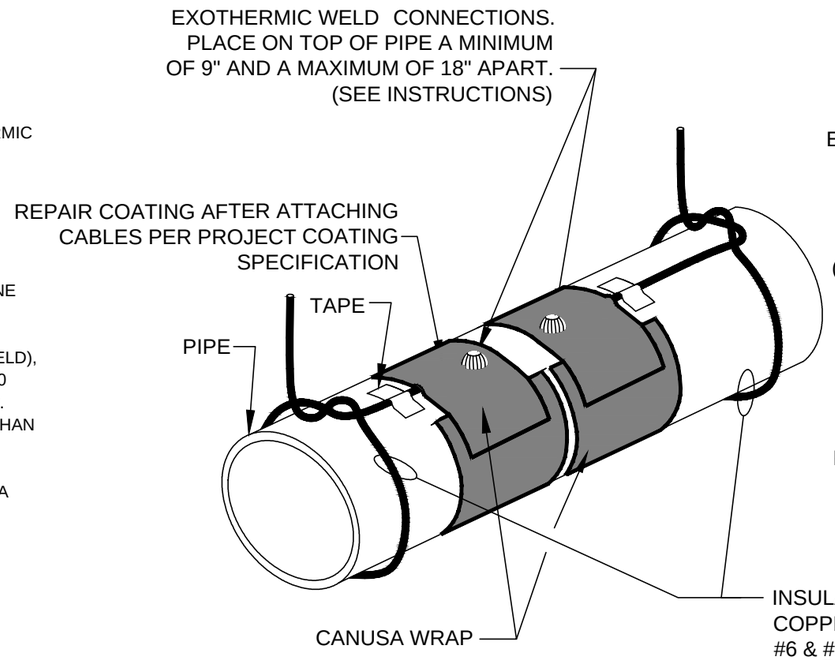
13. LAY THE CABLE END ON THE CROSSHATCHED PIPE SURFACE USING A SPRING LOADED CHAIN CLAMP TO HOLD CRUCIBLE TIGHT TO PIPELINE.

14. USING EYE AND HAND PROTECTION, STAND ON THE OPPOSITE SIDE OF THE CRUCIBLE FROM THE TOUCH HOLE AND IGNITE POWDER WITH SPARK FROM FLINT GUN. *CAUTION: POWDER WILL FLASH WHEN IGNITED*

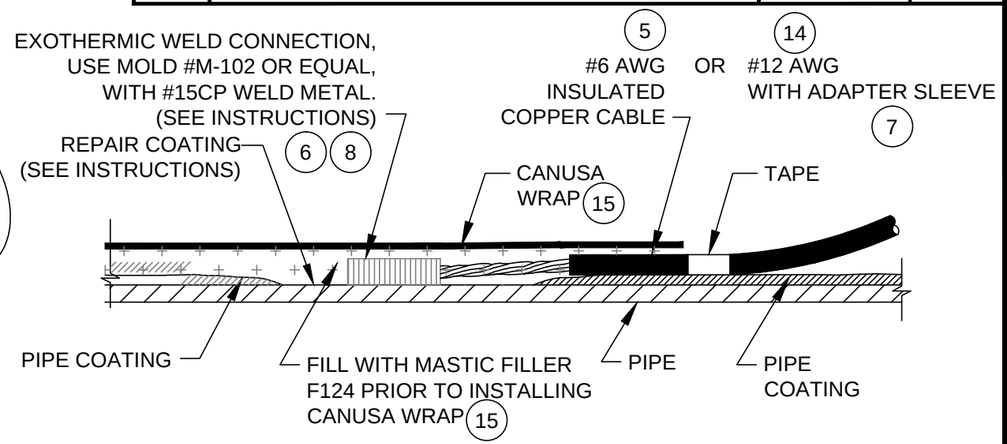
15. WHEN WELD HAS SET, REMOVE WELD MOLD AND TEST CONNECTION BY RAPPING SHARPLY WITH A SLAG HAMMER. IF THERE IS ANY INDICATION THAT A COMPLETE WELD HAS NOT BEEN ACHIEVED, REMOVE THE WELD AND RE-APPLY.

16. IF WELD IS GOOD, REMOVE ANY SLAG WITH HAMMER AND CLEAN USING A WIRE BRUSH.

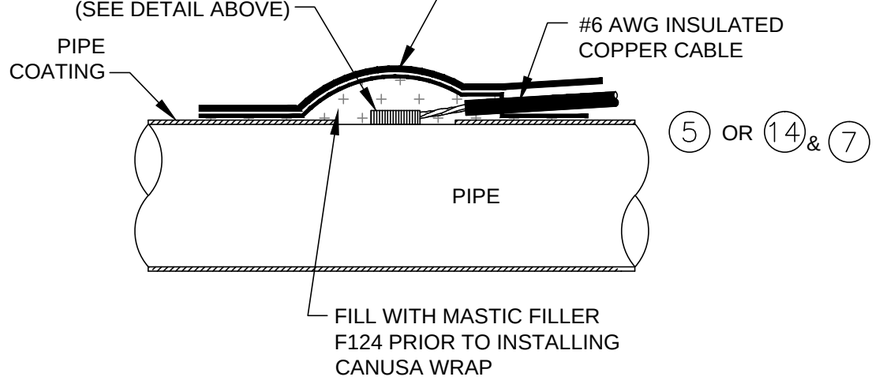
17. ONCE THE WELD CONNECTION AND AREA HAVE BEEN CLEANED, REPAIR WITH FULL CIRCUMFERENCE CUNUSA WRAP REFER TO VERMONT GAS SPECIFICATIONS TO DETERMINE IF REPAIR IS ACCEPTABLE.



CABLE TO PIPELINE ATTACHMENT DETAIL



EXOTHERMIC WELD CONNECTION



CORROSION PROTECTION SEAL

ISSUED FOR CONSTRUCTION

CLIENT: CHA SITE: VERMONT GAS SYSTEMS, INC ADDISON NATURAL GAS PROJECT CATHODIC PROTECTION SYSTEM DESIGN	ARK ENGINEERING & TECHNICAL SERVICES, INC. ARK ENGINEERING & TECH. SERVICES, INC. 639 GRANITE STREET SUITE 200 BRAINTREE, MA 02184 U.S.A.			TITLE: WIRE TO PIPE CONNECTION DETAILS	
PROJECT NO. 12-E-145-CP	DRAWN BY JRW	DATE 6/18/13	SIZE B	DWG. NO. 12145-303	REV C
	APPROVED BY RFA	DATE 5/16/16	SCALE NTS	CAD FILE NAME 12145-303-1-RC	SHEET 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION - ECO 2014-025	6/27/14	JM
B	REVISION PER CLIENT REQUEST - ECO 2015-058	10/20/15	RFA
C	CLIENT REVISIONS	5/16/16	RFA

ITEM	QUANTITY	DESCRIPTION
1	20	IMPRESSED CURRENT ANODES. MIXED METAL OXIDE (MMO) ANODES, IN 3"X60" CANISTER WITH THE FOLLOWING LENGTH OF #8 HMWPE STRANDED COPPER CABLE. (5) @ 350 FOOT #8 HMWPE CABLE (8) @ 275 FOOT #8 HMWPE CABLE (7) @215 FOOT #8 HMWPE CABLE
2	3	CATHODIC PROTECTION JUNCTION BOX. 16"X14"X6" FIBERGLASS BOX FOR POLE MOUNTING, 10-CIRCUIT,1" DIA. KO BOTTOM, 2.5" DIA. KO BOTTOM, 0.001 OHM, J.B. SHUNTS, KA4C LUGS, KA25 COMMON, LEXAN PANEL, LOCKABLE LATCH.
3	160	LORESCO SC-3 BACKFILL, 50 POUND BAGS, P/N SC-3.
4	3	CATHODIC PROTECTION RECTIFIER: MODEL SASY40-20DACM, AIR COOLED, 40 VOLT DC, 20 AMP. OUTPUT, AMMETER, 3 COURSE & 6 FINE TAPS, LIGHTINING PROTECTION & (1) 110VAC OUTLET. REMOTE MONITORING OPTION INCLUDED. INPUT VOLTAGE 120/240 AC.
5	550'	#6 HMWPE INSULATED COPPER CABLE. FOR PIPELINE CONNECTIONS AND JUNCTION BOX TO RECTIFIER.
6	1	EXOTHERMIC WELD MOLD, TYPE CS-32, THERMOWELD P/N M102 (OR EQUAL). HANDLE CLAMP AND FLINT IGNITOR ARE INCLUDED. USED FOR WELDING #6 & #12 CABLE TO PIPE.
7	68	ADAPTER SLEEVE FOR USE WITH THERMOWELD TYPE CS-32, MOLD #M-102 P/N 38-0200-00 (OR EQUAL). USED FOR THERMITE WELD CONNECTION OF #12 AWG SOLID COPPER CABLE TO PIPE
8	1 BOX	EXOTHERMIC WELD METAL, #15CP, F-33 ALLOY (ERICO OR EQUAL) (BOX OF 20) BONDS #6 & #12 AWG CABLE TO PIPELINE.
9	700'	PVC CONDUIT - 2" SCHEDULE 80. CUT TO PROPER LENGTH IN FIELD. CABLE FROM RECTIFIER TO PIPE.
10	7	PVC ELBOW, 2". 90 DEGREE. SCHEDULE 80 - PLAIN END.
11	70	PVC COUPLING, 2". JOINS PVC ELBOW TO STRAIGHT CONDUIT.
12	2 ROLLS	CABLE WARNING TAPE. 2' WIDE (MIN.), YELLOW IN COLOR AND MARKED "WARNING ELECTRICAL CABLE BELOW", 12" ABOVE CABLE (1000')
13	23	CATHODIC PROTECTION TEST STATION. P/N TESTOX 715 5 TERMINALS.
14	1,700'	#12 TW INSULATED SOLID COPPER CABLE. FOR USE AS TEST STATION LEADS, COLOR WHITE.
15	4 ROLLS	PIPELINE COATING REPAIR: COVER EXOTHERMIC WELD WITH MASTIC F124 FILLER PRIOR TO WRAPPING PIPE WITH CANUSA WRAP P/N CPS K60 OR APPROVED EQUAL. FOR REPAIRING PIPE AT #6 & #12 AWG CONNECTIONS TO PIPE.
16	3	2"GRC CONDUIT, 5' LONG, THREADED BOTH ENDS.
17	3	2" PVC END BUSHINGS FOR GRC CONDUIT.
18	3	4" X 4" X 8' PRESSURE TREATED POST
19	3	1.5" GALVANIZED RIGID CONDUIT (GRC), CUT TO LENGTH IN FIELD. CONTAINS CABLE FROM RECTIFIER TO JUNCTION BOX.
20	220	PVC CONDUIT - 3" SCHEDULE 80. CUT TO PROPER LENGTH IN FIELD. CABLE FROM RECTIFIER TO PIPE.
21	2	PVC ELBOW, 3". 90 DEGREE. SCHEDULE 80 - PLAIN END.
22	22	PVC COUPLING, 3". JOINS PVC ELBOW TO STRAIGHT CONDUIT.
23	11	T-3 CP FOUR WIRE TEST STATION
24	1,700'	#12 TW INSULATED SOLID COPPER CABLE. FOR USE AS TEST STATION LEADS, COLOR GREEN.
25	1,700'	#12 TW INSULATED SOLID COPPER CABLE. FOR USE AS TEST STATION LEADS, COLOR BLUE.
26	1,700'	#10 TW INSULATED SOLID COPPER CABLE. FOR USE AS TEST STATION LEADS, COLOR WHITE.
27	1,700'	#10 TW INSULATED SOLID COPPER CABLE. FOR USE AS TEST STATION LEADS, COLOR BLACK.
28	2	COUPON TEST STATION: MESA PRODUCTS MODEL # CS-3100. COUPON TEST STATION TO BE 8 FEET TALL AND THE KIT TO INCLUDE (2) 1.4 SQUARE INCH STEEL COUPONS, WIRING, AND TERMINAL HEAD.

NOTE:

ARK ENGINEERING CAN PROVIDE ALL MATERIALS LISTED ABOVE AND INSTALLATION SERVICES. PLEASE CALL 1-800-469-3436 FOR A MATERIAL OR INSTALLATION QUOTATION.

ISSUED FOR CONSTRUCTION

CLIENT: CHA

SITE: VERMONT GAS SYSTEMS, INC
ADDISON NATURAL GAS PROJECT
CATHODIC PROTECTION
SYSTEM DESIGN

ARK ENGINEERING & TECHNICAL SERVICES, INC.
ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE: MATERIALS LIST

DRAWN BY	DATE	SIZE	DWG. NO.	REV
JRW	6/18/13	B	12145-400	C
PROJECT NO. 12-E-145-CP	APPROVED BY RFA	DATE 5/16/16	SCALE NTS	CAD FILE NAME 12145-400-1-RC	SHEET 1 OF 1