<u>Pipe Load Due to Surface Wheel Load</u>

Spangler computed the load transmitted to the pipe due to surface wheel load using Boussinesq theory for a surface point load based on numerical integration performed by Hall (see Spangler and Hennessy, 1946) as follows:

$$W_{wheel} = 4 \cdot C_t \cdot \frac{W}{L} \tag{2.4}$$

where C_t is a wheel load coefficient, W is the wheel load (including an impact factor) and L is the effective length of pipe (most references to this equation use an effective length L=3 feet). Values of the wheel load coefficient C_t are tabulated for different trench geometries (i.e., based on the ratios of $D/2H$ and $L/2H$) in several references (e.g., Spangler and Hennessy, 1946, Spangler, 1954, etc.).

<u>Pipe Load Due to Surface Rectangular Footprint Load</u>

Spangler computed the load transmitted to the pipe due to surface load with a rectangular footprint using Boussinesq theory based on numerical integration performed by Newmark (see Newmark, 1935) as follows:

$$W_{rectangular} = 4 \cdot C_t \cdot \frac{W \cdot D}{A} \tag{2.5}$$

where C_t is a rectangular load coefficient, W the total load on a rectangular footprint (including an impact factor), D is the pipe diameter, and A is the area of the rectangular footprint. Values of the rectangular load coefficient C_t are tabulated for different trench geometries and rectangular footprints in several references (e.g., AWWA M11, Spangler 1964, etc.).

Given the computed loading on the buried pipe from either fill or traffic loads (i.e., W_{fill}, W_{wheel}, or $W_{rectangular}$ or as a more general vertical load term $W_{vertical}$), the Spangler stress and Iowa formulas can be used directly.

2.3.2 A Proposed Modification to the Spangler Stress Equation

Based on our experience with the available methods to evaluate fill and surface loading effects on buried pipelines, we favor the use of industry accepted Boussinesq-type expressions that relate the fraction of surface load transferred to the pipe at the depth of soil cover combined with "Spangler type" calculations to compute pipe stresses due to fill and/or surface loads (as discussed in Sections 2.3.1 and 2.3.2) over the step-by-step evaluation procedure provided in the 1993 version of API RP 1102, especially for the purposes of initial screening evaluations.

The Spangler stress formula can be extended to include the beneficial effects of lateral soil restraint based on Watkins work (see Watkins and Spangler, 1968). This first-principles approach can be applied to a variety of equipment loads and are not limited to particular ranges of physical variables. It also provides a means of removing some of the conservatism inherent in the original Spangler stress equation by including lateral soil restraint even if only for the purpose of performing "what if" analyses. In order to modify the Spangler circumferential stress formula to include a soil resistance term that is consistent with the one used in the Iowa Formula, it is necessary to manipulate the stress and ovality Equations (2.1) and (2.2). This is accomplished using a relationship between ovality and circumferential stress. Based on information provided in Spangler, 1964, it can be shown that the maximum through-wall circumferential bending stress due to ovality ΔX is:

$$\sigma = \frac{K_b}{2 \cdot K_z} \cdot \frac{\Delta X \cdot E \cdot t}{r^2} \qquad (2.6)$$

where all of the variables are as previously defined. Solving Equation (2.6) for ΔX and substituting the circumferential stress σ from Equation (2.1) leads to the following expression of the Spangler stress formula in terms of ovality:

$$\Delta X = \frac{12 \cdot K_z \cdot W_{vertical} \cdot r^3}{E \cdot t^3 + 24 \cdot K_z \cdot P \cdot r^3} \qquad (2.7)$$

Recall that the 0.108 (K_Z) coefficient in the Iowa formula corresponds to a 30° bedding angle. Setting K_Z=0.108 in Equation (2.7), then aligning the resulting expression next to the Iowa formula yields the following:

Spangler Stress Expression	Iowa Formula	
$\Delta X = \frac{1.296 \cdot W_{vertical} \cdot r^3}{E \cdot t^3 + 2.592 \cdot P \cdot r^3}$	$\Delta X = \frac{0.108 \cdot W^*_{vertical} \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3}$	(2.8)

Recognizing that $E \cdot t^3$ is equal to $12 \cdot E \cdot I$, the numerator and denominator of the Spangler stress expression for ΔX (on the left) can be multiplied by 1/12 in order to cast the denominator of both expressions in terms of the pipe wall bending stiffness (E·I):

$$\Delta X = \frac{0.108 \cdot W_{vertical} \cdot r^3}{E \cdot I + 0.216 \cdot P \cdot r^3} \qquad \Delta X = \frac{0.108 \cdot W^*_{vertical} \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3} \qquad (2.9)$$

Note that the only difference between the numerators of these two expressions is that the one based on the Iowa formula (on the right) includes a load term $W^*_{vertical}$ which is equal to $W_{vertical}$ multiplied by the deflection lag factor. By scaling the deflection lag factor as a ratio of the two denominators (discussed later), the soil term from the Iowa formula can be added directly to the denominator of the Spangler stress expression for ovality to obtain a combined ovality expression (dropping the * on the vertical load term):

$$\Delta X = \frac{0.108 \cdot W_{vertical} \cdot r^3}{E \cdot I + 0.216 \cdot P \cdot r^3 + 0.061 \cdot E' \cdot r^3} \quad (2.10)$$

It is worth noting here that Rodabaugh (Rodabaugh, 1968) suggested a very similar expression to qualitatively combine pressure stiffening and soil restraint effects:

$$\Delta X = \frac{0.135 \cdot W_{vertical} \cdot r^3}{E \cdot I + 0.216 \cdot P \cdot r^3 + 0.061 \cdot E' \cdot r^3} \quad (2.11)$$

where the coefficient of 0.135 in the numerator corresponds to a bedding angle of 30° with an effective deflection lag factor of 1.25 (i.e., 0.135=0.108·1.25).

Multiplying both the numerator and denominator of the combined ovality expression (2.10) by 12 gives:

$$\Delta X = \frac{1.296 \cdot W_{vertical} \cdot r^3}{E \cdot t^3 + 2.592 \cdot P \cdot r^3 + 0.732 \cdot E' \cdot r^3} \quad (2.13)$$

Then converting back to stress using Equation (2.6) results in the following combined expression for circumferential pipe stress:

$$\sigma = \frac{1.41 \cdot W_{vertical} \cdot E \cdot t \cdot r}{E \cdot t^3 + 2.592 \cdot P \cdot r^3 + 0.732 \cdot E' \cdot r^3} \quad (2.14)$$

NOTE: The above equation has both (K_z & K_b) "hardwired" based on a bedding angle of 30° (i.e., K_z=0.108, K_b=0.235) which is considered conservative. The equation in it's full form is as follows:

$$\sigma = \frac{6 \cdot K_b \cdot W_{vertical} \cdot E \cdot t \cdot r}{E \cdot t^3 + 24 \cdot K_z \cdot P \cdot r^3 + 0.732 \cdot E' \cdot r^3} \quad (2.15)$$

Notice that if the term *E'* in the denominator is set equal to zero, Equation (2.14) reduces to the original Spangler stress formula. If the *P* term in the denominator is set equal to zero, this expression reduces to a stress that is consistent with the Iowa formula (when the load term $W_{vertical}$ includes the deflection lag factor).

As previously noted, we believe that it would be reasonable and appropriate to consider the use of a different deflection lag factor for fill loads which act on the pipe for long time periods instead of traffic loads which act on the pipe for short periods of time (i.e., during the vehicle passage). Recall that the lag factor is used to account for Spangler's observations that ovality due to earth fill can increase by up to 30% over long time periods. Spangler recommended a value of 1.5 as a conservative design procedure. Moser, 1990 and AWWA M11, 1999 refer to a range from 1.0 to 1.5, and Rodabaugh (Rodabaugh, 1968) suggested a value of 1.25. If the modified Spangler stress formula is used, we recommend a deflection lag factor for fill loads equal to the lesser of 1.30 or the ratio of the denominator in the modified Spangler stress formula to the denominator in the original Spangler stress formula. Since surface traffic loads act on the pipe for short time periods (i.e., during the vehicle passage) a deflection lag factor of 1.0 is recommended for short-term vehicle loading.

2.3.3 Review of Recent Pipeline Industry Research

Pipeline industry research on the subject of loads on buried pipes has continued from the Spangler era to the present day. Without undertaking a totally comprehensive review of this work, we have elected to highlight some of the more important modern references on this subject, some of which contain their own literature reviews.

In a multi-year project sponsored by the Gas Research Institute, researchers at Cornell University:

- performed a review of current practices for pipeline crossings at highways and railways,
- reviewed existing analytical models to estimate buried pipe stresses,
- undertook detailed finite element analysis (FEA) of buried pipe configurations subject to fill and surface loads, and
- performed experimental evaluations of augerbored pipelines at rail road crossings.

The primary reports from this research are:

- GRI, 1987. Gas Research Institute, "*Analytical Study of Stresses in Transmission and Distribution Pipelines Beneath Railroads*", Topical Report of Task 2, June 1985-February 1987, Department of Structural Engineering, Cornell University, September 15, 1987.

- GRI, 1988. Gas Research Institute, "*State-of-the-Art Review: Practices for Pipelines Crossings at Highways*", Topical Report, June 1987-June 1988, School of Civil and Environmental Engineering, Cornell University, September, 1988.

- GRI, 1991. Ingraffea, A. R., O'Rourke, T. D., and Stewart, H. E., "*Technical Summary and Database for Guidelines for Pipelines Crossing Railroads and Highways*", Cornell University School of Civil and Environmental Engineering Final Report to Gas Research Institute, GRI-91/0285, Dec. 1991.

Each of these references is focused on pipes installed via bored-in-place construction which is common for highway and railway crossings. This research provides a very useful summary of the important factors affecting buried pipe response to fill and surface loads as well as a review of the existing analysis methods (i.e., the Spangler stress formula and the Iowa formula) for evaluating the pipe response to fill and surface loads. The main findings from the review of the existing methods were:

- The Boussinesq theory used to estimate the surface load experienced by the pipe assumes that the loaded soil mass is homogeneous and neglects the presence of the pipe within the soil.
- The Spangler stress formula and the Iowa formulas have an inconsistent treatment for pressure stiffening and soil resistance effects.

Reference (GRI, 1987) provides modified expressions for the loads due to fill (analogous to Equation 2.3) and the loads due to surface loads (analogous to Equations 2.4 and 2.5) for pipe installed via bored-in-place construction. This reference also proposes a modified version of the Spangler stress formula (analogous to Equation 2.14) for pipe installed via bored-in-place construction with three resistance terms in the denominator (one for pipe stiffness, one for pressure stiffening, and one for soil resistance). A significant contribution of the Cornell/GRI research is that in addition to providing equations to compute pipe circumferential stresses on buried pipes due to fill and surface loads, it also highlights:

- the possible development of longitudinal stresses due to bending of the pipe under surface loads,
- the evaluation of combined or bi-axial (e.g., von Mises) stress conditions with respect to appropriate stress limits, and
- the evaluation of cyclic stresses with respect to a fatigue endurance stress limit.

The Cornell/GRI work led to the development of guidelines for the design and evaluation of uncased pipelines that cross railroads and highways, which have been implemented into a personal computer program called PC-PISCES. The results of the Cornell/GRI work are also embodied in the following pipeline industry recommended practice document:

- API RP 1102, 1993. American Petroleum Institute, "*Steel Pipelines Crossing Railroads and Highways*", API Recommended Practice 1102, Sixth Edition, April 1993 (reaffirmed 2003).

The Cornell/GRI/API guidelines consist of a set of equations for the circumferential and longitudinal pipe stresses that are created by surface live load, earth dead load, and internal pressure. The equations for the live load stresses are nonlinear, with functions/curves that were fit to the results of a series of FEA simulations. The FEA results were validated through comparisons with experimental data from tests on two full-scale auger bored pipeline crossings.

Various combinations of the computed pipe stresses are checked to guard against fatigue damage of longitudinal and girth welds and to guard against excessive yielding.

While these guidelines were developed from tests and analyses of uncased pipelines that are installed with auger boring beneath railroads and highways, they are often employed by pipeline engineers for the more common case of pipelines installed via trenched construction. The procedure is also restricted to cover depths greater than or equal to 3 feet and has been specifically developed based on AASHTO H20 truck loads with small footprints associated with tire pressures typically in excess of 550 kPa (80 psig). Several important limitations are inherent to these guidelines, namely that the approach cannot be extrapolated to shallow cover situations. It also may not scale correctly to different types of equipment that ride on floatation tires or caterpillar tracks where ground surface pressures are less than 50 psig. Further, it determines pipeline stresses in a non-traditional manner. These issues may create a barrier to uniform adoption by pipeline companies.

Several ongoing research programs have been undertaken by the Pipeline Research Council International, Inc. (PRCI) and SoCalGas with an emphasis on the determination of stresses developed in pipes with shallow cover and subject to extreme loading situations. The first project is Project Number PR-15-9521 (Phase 1) and PRCI-15-9911 (Phase 2): *Effects of Non-Typical Loading Conditions on Buried Pipelines* being performed by Southwest Research Institute (SwRI). This work includes full-scale tests of shallow covered pipes buried in sand and clay with diameters ranging from 16 to 36 inches and subjected to fill, concentrated, and distributed surface loads. A related follow-on project, Project Number GRI-8442: "*Centrifuge and Full-Scale Modeling Comparison for Pipeline Stress Due To Heavy Equipment Encroachment,*" is currently being undertaken by C-CORE. This project includes full-scale tests of 16-inch diameter, shallow pipe subject to concentrated surface loads and complementary centrifuge modeling. Results of this study will be used to determine if small-scale testing performed in a centrifuge is a reliable means for expanding the data set developed by SwRI for surface model/guidelines development. Another approach to database development is being studied in a project titled "*Buried Pipelines Subjected to Surcharge Loads: Finite-Element Simulations.*" This study is being undertaken by the University of Texas-Austin, and involves the development and validation of a finite element analysis procedure for simulating shallow covered pipelines subjected to rectangular footprint surface loadings based on the SwRI distributed load tests. The most recent follow-on project, led by C-FER Technologies, is Project Number PR-244-03158: "*Effects of Static and Cyclic Surface Loadings on the Performance of Welds in Pre-1970 Pipelines.*" It is intended to apply the SwRI shallow cover test database and all other related databases in the development of analysis tools with special emphasis on the evaluation of welds in pre-1970's pipelines. Unfortunately, none of these ongoing projects have been completed or documented at the time of this study. We recommend that this work be reviewed as the reports become available.

2.3.4 Review of CSA Standard Z183 Working Group on Crossings Position Paper

The paper CSA Standard Z183 Working Group on Crossings, *"Position Paper on Recommended Technical Specifications for Pipeline Crossings of Railways,"* provides a useful overview of issues surrounding oil and gas pipeline crossings at railroads as well as other crossings in Canada. This document provides a review of applicable standards and regulations in other countries, compiles a list of references that an engineer could use for a site-specific crossing analysis, and develops a summary recommendation for a conservative design for common crossings that could be incorporated into a standard or regulation. It also provides useful commentary and background on the procedures for the analysis of buried pipe loads and stresses, design approaches (including the Spangler stress and Iowa formulas), and the selection of design variables. Several key points from this reference are summarized as follows:

- For computing pipe stresses, the CSA Z183 Working Group advocated the use of both the Spangler stress formula and the Iowa formula to superimpose the results such that the Iowa formula would be used to establish the maximum bending stress of the pipe. The Spangler pressured formula would be utilized if the resultant stress was less than the result of the Iowa formula. Recommended values of various design parameters (e.g., soil density, soil type, impact factor, load coefficient, etc.) are provided.
- The Working Group points out that the computed pipe stress should be compared to allowable pipe stresses, including an appropriate safety factor, and the potential for fatigue damage due to the cyclic loading on the longitudinal or spiral pipe seam should be addressed.
- The Working Group paper also provided discussion on the fatigue capacity of pipes. The fatigue endurance limit ultimately adopted in CSA Z662 was 69 MPa (10 ksi).
- The Working Group provides a recommended limit on the D/t ratio for railroad crossings to a maximum of 85.
- The Working Group recommended the following stress limits with respect to railroad crossings: a maximum hoop stress due to internal pressure of 50% specified minimum yield stress (SMYS), a maximum combined circumferential stress (due to pressure, fill and traffic) of 72% SMYS, and a maximum combined equivalent stress of 90% SMYS.

2.4 Summary of Principle Methods for Evaluating Vertical Loading Effects on Buried Pipelines

Section 2.3 of this report provided a review of what we believe are the principle methods for evaluating the effects of fill and surface loads on buried pipes. Any method for evaluating these loading effects must consider the following:

- The pipe properties including diameter D, wall thickness t, and modulus of elasticity E
- The internal pressure P
- The depth of soil cover H, the effective trench width B_d, and the soil type
- The effective length of the pipe L
- The construction method and the pipe bedding angle
- The modulus of soil resistance E'
- The magnitude of the surface load W
- The footprint of the load (e.g., point load or rectangular load)
- The impact factor corresponding to a given surface load
- The effective number of cycles corresponding to a given surface load

Given these parameters, it is possible to develop estimates of the pipe stresses and ovalling deflections that result from fill and surface loads. With the stress and deflection estimates, the engineer must make decisions regarding the safety of the buried pipe which requires additional information including:

- The specified minimum yield stress (SMYS) of the pipe
- The type of longitudinal weld
- The quality of the girth welds
- The possible presence of corrosion or other anomalies
- Stresses due to other loads including:
  - internal pressure
  - temperature differential
  - longitudinal bending or roping of the pipe

The results of the evaluation should be checked for various pipe stress demand-capacity measures, including the total circumferential stress due to internal pressure, fill and surface loads. The results should also be checked for biaxial stress combinations of the circumferential and the longitudinal stress due to temperature differential and Poisson's effect and bending. There should also be cyclic stress range demand-capacity checks to guard against fatigue damage. The following process flow diagram entitled "Pipeline Surface Loading Acceptability" (Figure 2-1) has been developed to illustrate the recommended process to be followed in determining the acceptability of surface loading. The following sections address the development of a simplified screening process that embodies the process identified in the diagram.

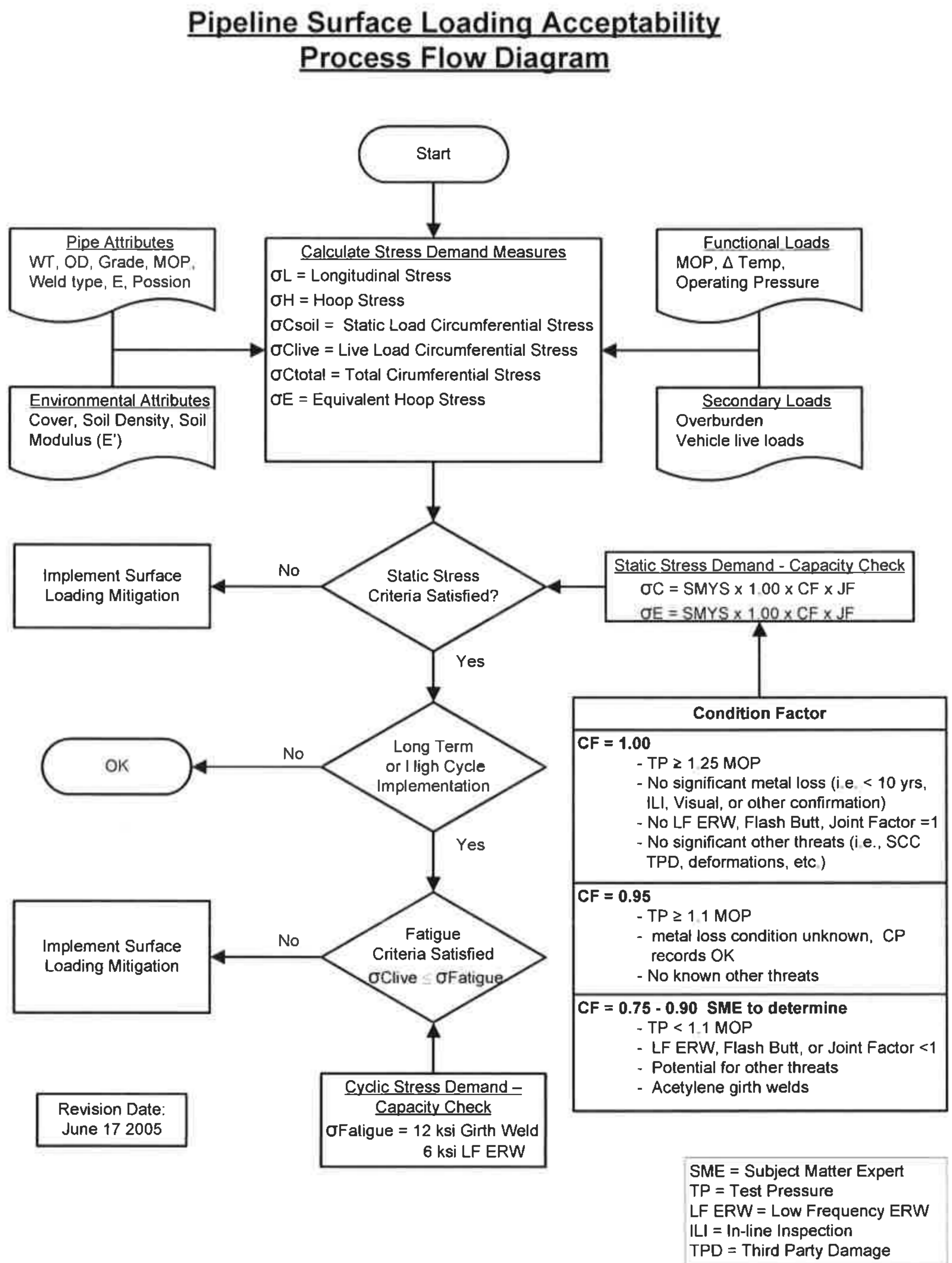

Figure 2-1. Pipeline Surface Loading Acceptability Process Flow Diagram

2.5 Proposed Development of Screening Process

Once all of the information described in this section is gathered, an engineer can perform the necessary calculations required to make an evaluation of the buried pipe situation at hand. In addition, by having an understanding of the theory behind and the limitations of the calculations used to develop the estimated stresses, the engineer must utilize judgment and experience to make decisions regarding the pipeline integrity and safety.

Despite all of the information required to make an assessment of a buried pipe subject to fill and surface loads, it is feasible to develop a relatively simple buried pipe screening procedure based on parametric analyses of various combinations of the input information. The idea is to use the developed theory to develop a series of charts that can evaluate a range of practical buried pipe and loading configurations on a simple "pass/no pass" basis. Situations which pass this initial screening would require no additional analysis, while situations that do not pass the initial screening may need to be evaluated on a more detailed basis. The development of this screening procedure will obviously have to rely on the existing methods for evaluating vertical load effects on buried pipe. Ideally the calculations will be reasonably conservative. Table 2-4, which was developed as a starting point to selecting the appropriate calculation method, provides a comparative assessment of the principle methods.

The second task of the proposed work for this project (see Section 3) is the development of a simple screening method which will allow a pipeline operator to determine whether or not a given crossing application requires added protection or whether a more detailed calculation is appropriate. The goal of the screening method is to implement a relatively simple procedure based on easily obtainable attributes such as wheel or axle load, ground surface contact area and/or surface loading pressure, depth of cover, maximum allowable operating pressure and design factor.

Table 2-4. Comparison of Principle Methods for Evaluating Vertical Loading Effects on Buried Pipelines

Method	Strength	Limitation	Comments
Spangler Stress Formula	• Easy to program • Includes pressure stiffening • Applies for full range of bedding angles	• Neglects soil restraint	• Requires coefficients from Boussinesq theory to estimate load at top of pipe • Considered to be conservative
Iowa Formula	• Easy to program • Includes lateral soil restraint	• Computes deflection, not stress • Neglects pressure stiffening • Need to select soil parameter E' • Need to select lag factor • Hardwired to 30 degree bedding angle	• Requires coefficients from Boussinesq theory to estimate load at top of pipe
API RP 1102, 1993	• Provides detailed flow chart • Computes multiple stress components • Performs stress demand-capacity checks • Includes check for fatigue	• Limited to auger bore construction • Limited to cover depths ≥ 3 feet • Hardwired to AASHTO H20 truck loads with tire pressures typically in-excess of 550 kPa (80 psig).	• Difficult to manually perform calculations • Requires PC-PISCES or technical toolbox
Modified Spangler Stress Equation with Soil Restraint	• Easy to program • Includes pressure stiffening • Includes lateral soil restraint	• Need to select soil parameter E' • Need to select lag factor	• Requires coefficients from Boussinesq theory to estimate load at top of pipe. • Inclusion of soil restraint term removes some conservatism

2.6 References

- American Lifelines Alliance, "*Guidelines for the Design of Buried Steel Pipe*", Published by the ASCE American Lifelines Alliance, www.americanlifelinesalliance.org, July 2001.
- American Petroleum Institute, "*Steel Pipelines Crossing Railroads and Highways*", API Recommended Practice 1102, Fifth Edition, November 1981.
- American Petroleum Institute, "*Steel Pipelines Crossing Railroads and Highways*", API Recommended Practice 1102, Sixth Edition, April 1993.
- American Water Works Association, "*Steel Pipe – A Guide for Design and Installation*",
- ASME, "*Criteria of the ASME Boiler and Pressure Vessel Code for Design by Analysis in Sections III and VIII, Division 2*", 1969, American Society of Mechanical Engineers
- ASME Boiler and Pressure Vessel Code, Section VIII Rules for Construction of Pressure Vessels Division 2-Alternative Rules, 2007, American Society of Mechanical Engineers
- AWWA Manual M11, 3rd Edition, 1999.
- CSA Standard Z662-03, Oil and Gas Pipeline Systems, 2003, Canadian Standards Association
- CSA Standard Z183 Working Group on Crossings, "*Position Paper on Recommended Technical Specifications for Pipeline Crossings of Railways*"
- Gas Research Institute, "*State of the Art Review: Practices for Pipeline Crossings at Highways*", Topical Report 6/87-6/88.
- GPTC Guide for Gas Transmission and Distribution Piping Systems, 1990-1991, American Gas Association, Arlington, VA.
- Hartley, J.D. and Duncan, J.M., "*E' and its Variation with Depth*", ASCE Journal of Transportation Engineering, Vol. 113, No. 5, September, 1987.
- Ingraffea, A. R., O'Rourke, T. D., and Stewart, H. E., "*Technical Summary and Database for Guidelines for Pipelines Crossing Railroads and Highways*", Cornell University School of Civil and Environmental Engineering Final Report to Gas Research Institute, GRI-91/0285, Dec. 1991.
- Marston, A. and Anderson, A.O., "*The Theory of Loads on Pipes in Ditches and Tests of Cement and Clay Drain Tile and Sewer Pipe*", Bulletin 31, Iowa Engineering Experiment Station, Ames, Iowa, 1913.
- Moser, A.P., "*Buried Pipe Design*", McGraw Hill, 1990.

- Newmark, N.M., "*Simplified Computation of Vertical Pressures in Elastic Foundations*", No. 24, Engineering Experimental Station, University of Illinois, Champaign-Urbana, Ill, 1935.
- Rodabaugh, E.C., "*Design Procedure for Uncased Pipeline Crossings*", A Letter from Battelle Memorial Institute, to W.F. Quinn, Research Council on Pipeline Crossings of Railroads and Highways, May 1, 1968.
- Spangler, M. G., "*The Structural Design of Flexible Pipe Culverts*", Bulletin 153, Iowa Engineering Experiment Station, Ames, Iowa, 1941.
- Spangler, M.G. and Hennessy, R.L., "*A Method of Computing Live Loads Transmitted to Underground Conduits*", Proceedings Highway Research Board, 26:179, 1946.
- Spangler, M.G., "*Secondary Stresses in Buried High Pressure Pipe Lines*", The Petroleum Engineer, November, 1954.
- Spangler, M.G., "*Pipeline Crossings Under Railroads and Highways*", Journal of the AWWA, August, 1964.
- Warman, D. J., "*Personal Notes and Documentation Related to CSA Working Group on Crossings*", 1986-1987.
- Watkins, R. K., and Spangler, M. G., "*Some Characteristics of the Modulus of Passive Resistance of Soil – A Study in Similitude*", Highway Research Board Proceedings, Vol. 37m 1958, pp. 576-583.
- Spangler, M.G. and Handy, R.L., Soil Engineering, Third Edition, Intext Educational Publishers, 1973

3.0 PROPOSED APPROACH FOR SCREENING BURIED PIPELINES SUBJECTED TO SURFACE TRAFFIC

3.1 Introduction

Section 2 provided a *Literature Search Summary* which documented the available methods for evaluating the effects of fill and surface loads on buried pipelines. Using this information as a starting point, the second work task was to develop a simple screening method. This method will allow a pipeline operator to determine whether or not a given crossing application requires added protection or if a more detailed calculation is appropriate. The goal of the screening method is to use relatively simple and easily obtainable attributes (e.g., wheel or axle load, ground surface contact area and/or surface loading pressure, depth of cover, maximum allowable operating pressure and design factor). The screening calculations are summarized in the next section.

3.2 Overview of Screening Approach

A modified version of the Spangler stress formula was presented in Section 2. The modified formula is:

$$\sigma = \frac{6 \cdot K_b \cdot W_{vertical} \cdot E \cdot t \cdot r}{E \cdot t^3 + 24 \cdot K_z \cdot P \cdot r^3 + 0.732 \cdot E' \cdot r^3} \qquad (3.1)$$

where $W_{vertical}$ is the vertical load due to fill and surface loads including an impact factor (lb/in), E is the pipe modulus of elasticity (psi), t is the pipe wall thickness (inches), r is the mean pipe radius (inches), P is the internal pressure (psi), and E' is the modulus of soil reaction (psi). The terms K_b and K_z are bending moment and deflection parameters respectively (based on theory of elasticity solutions for elastic ring bending) which depend on the bedding angle. The right hand side of Equation (3.1) has been manipulated into the following form by dividing both the numerator and the denominator by $E \cdot t^3$ and substituting D/2 for r, where D equals the outside diameter of the pipe.

$$\sigma = \frac{3 \cdot K_b \cdot \frac{W_{vertical}}{D} \cdot \left(\frac{D}{t}\right)^2}{1 + 3 \cdot K_z \cdot \frac{P}{E} \cdot \left(\frac{D}{t}\right)^3 + 0.0915 \cdot \frac{E'}{E} \cdot \left(\frac{D}{t}\right)^3} \qquad (3.2)$$

The stress relationship from Equation (3.2) is plotted at different levels of internal pressure as a function of D/t ratio in Figure 3-1 below. The fixed parameters are shown in the figure box.

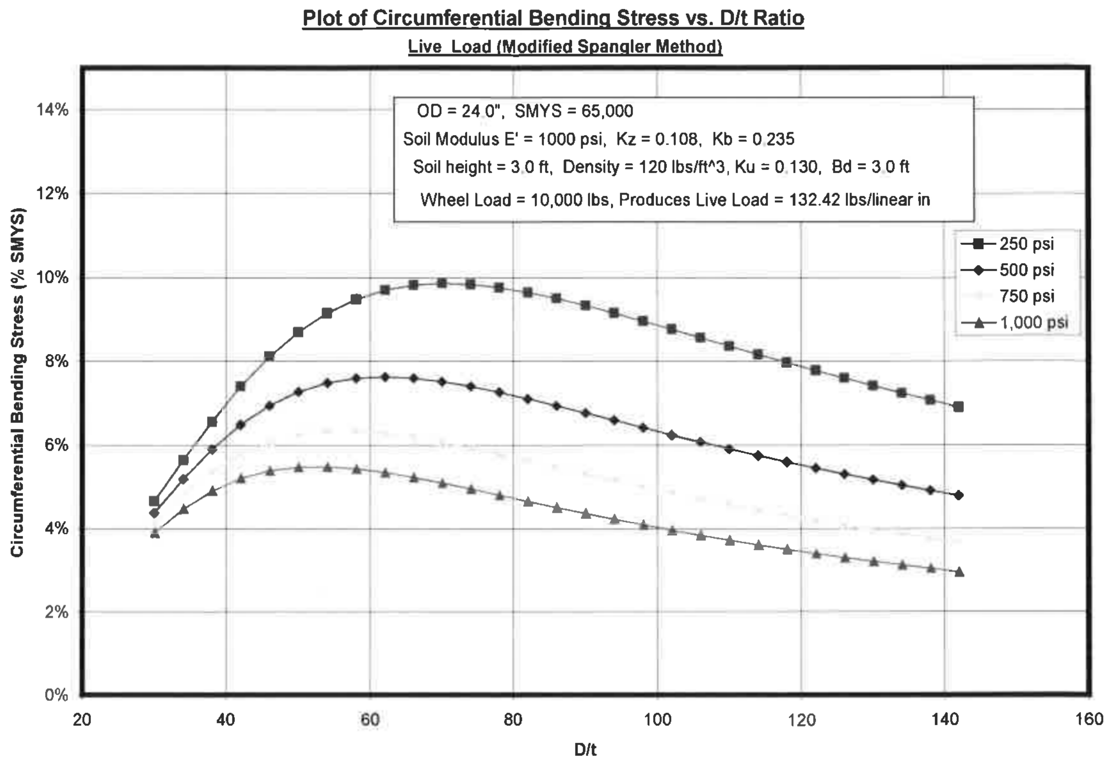

Figure 3-1. Plot of Circumferential Bending Stress vs. D/t Ratio

3.3 Review of Loading Terms

The stress formula described above (Equation 3.2) requires a load per unit length of pipe, $W_{vertical}$ resulting from either fill and/or surface loads. Section 2.3.1.3 provides an overview of how Spangler computed these load terms.

The load transmitted to the pipe in a ditch due to earth (fill) load can be computed based on Marston's load theory as follows:

$$W_{fill} = C_d \cdot \gamma \cdot B_d^2 \qquad (3.3)$$

$$C_d = \frac{1-e^{-2K\mu'\left(\frac{H}{B_d}\right)}}{2K\mu'} \qquad (3.4)$$

where C_d is a fill coefficient, γ is the soil density, B_d is the effective trench width, K is the ratio of active lateral unit pressure to vertical unit pressure, μ' is the coefficient of friction between the fill material and sides of the ditch and H is the height of fill over the pipe. Kμ' can vary between 0.111 and 0.165 depending on the soil conditions. Equation 3.4 is for ditch loading on the pipe. It is recommended that the reader refer to Spangler and Handy's book *Soil Engineering* to ensure that they fully understand how to use Equations 3.3 and 3.4. An alternative method for determining the fill load is to use the prism equation recommended by Moser in *Buried Pipe Design*. The prism formula is:

$$W_{fill} = \gamma \cdot H \cdot D \qquad (3.5)$$

No deflection lag factor is required if the prism formula is used.

Note that in Equation (3.2), the pipe diameter (to the extent possible) has been rearranged into the non-dimensional form D/t. The only place that the pipe diameter appears in Equation (3.2) is as a normalizing factor for the load term $W_{vertical}$ (i.e., $W_{vertical}/D$). Hence, other than in the $W_{vertical}/D$ term, Equation (3.2) is independent of the pipe diameter.

The fill loads from Equation (3.3) have been plotted in Figure 3-2 for W_{fill}/D as a function of diameter so that a representative value of W_{fill}/D can be selected that is independent of diameter. A B_d value of D + 10 cm (4 inches) has been selected to represent the long term consolidation of soil around the pipe. The dashed lines represent the value W_{fill}/D selected to be constant for all pipe diameters.

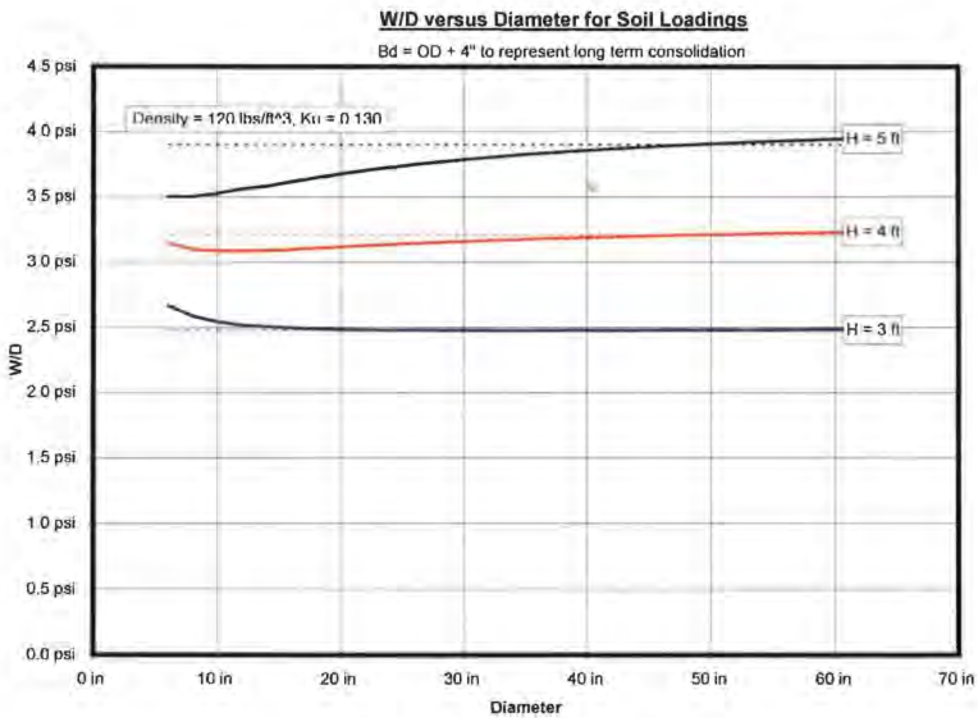

Figure 3-2. W/D versus Diameter for Soil Loadings

The load transmitted to the pipe due to surface wheel load is developed using a numerical integration of the Boussinesq theory for a surface point load:

$$W_{wheel} = 4 \cdot C_l \cdot \frac{W}{L} \tag{3.6}$$

where C_l is a wheel load coefficient, W is the wheel load (including an impact factor) and L is the effective length of pipe (most references to this equation use an effective length L=3 feet). Values of the wheel load coefficient C_l are tabulated for different trench geometries (i.e., based on the ratios of $D/2H$ and $L/2H$) in several references. A formula to compute the coefficient C_l as a function of $D/2H$ and $L/2H$ has been developed as follows:

$$C_l = 0.25 - \frac{1}{2\pi}\left[\left(\sin^{-1} H \sqrt{\frac{\left(\frac{D}{2}\right)^2 + \left(\frac{L}{2}\right)^2 + H^2}{\left(\left(\frac{D}{2}\right)^2 + H^2\right)\left(\left(\frac{L}{2}\right)^2 + H^2\right)}}\right) - \frac{\left(\frac{D}{2}\right)\left(\frac{L}{2}\right)H}{\sqrt{\left(\left(\frac{D}{2}\right)^2 + \left(\frac{L}{2}\right)^2 + H^2\right)}}\left(\frac{1}{\left(\frac{D}{2}\right)^2 + H^2} + \frac{1}{\left(\frac{L}{2}\right)^2 + H^2}\right)\right] \tag{3.7}$$

As stated previously, the D/t value as defined by Equation (3.2) has been made non-dimensional with respect to pipe diameter. Therefore, if a representative value of the W_{wheel}/D term can be selected to cover a full range of diameters, then Equation (3.2) would be fully independent of the pipe diameter.

The wheel loads from Equation (3.6) have been plotted in Figure 3-3 for W_{wheel}/D as a function of diameter so that a representative value of W_{wheel}/D can be selected that represents a full range of diameters independent of pipe diameter. The dashed lines represent the value W_{wheel}/D selected to be constant for all pipe diameters.

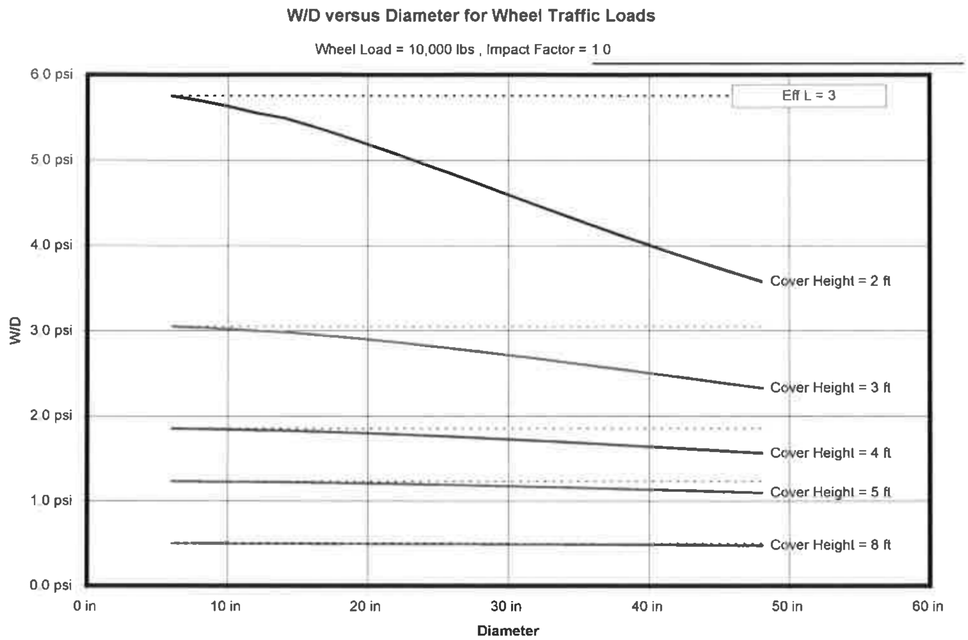

Figure 3-3. W/D versus Diameter for Wheel Traffic Loads

The load transmitted to the pipe due to surface load with a rectangular footprint based on numerical integration of the Boussinesq theory is:

$$W_{rectangular} = 4 \cdot C_t \cdot \frac{W \cdot D}{A} \tag{3.8}$$

where C_t is a rectangular load coefficient, W the total load on a rectangular footprint (including an impact factor), D is the pipe diameter and A is the area of the rectangular footprint. C_t is a function of the length and width of the rectangular footprint (L_{rect} and B_{rect}) and the depth of cover H. Although equations 3.8 and 3.6 are the solutions for different loading scenarios, Spangler points out (Spangler and Handy, 1973) that C_t in Equation 3.8 can be determined from Equation 3.7 by replacing L/2 with L_{rect} /2 and D/2 with $B_{rect}/2$.

Note that because Equation (3.8) for $W_{rectangular}$ has a pipe diameter D term in the numerator, normalizing by D directly removes the diameter dependence in the normalized load expression.

$$\frac{W_{rectangular}}{D} = 4 \cdot C_t \cdot \frac{W}{A} \tag{3.9}$$

The computed normalized loading on the buried pipe from either fill or traffic loads (i.e., W_{fill}/D, W_{wheel}/D, or $W_{rectangular}/D$) can be expressed as a more general vertical load term $W_{vertical}/D$ for use in Equation (3.2).

Note: A point load can be conservatively estimated by utilizing a rectangular footprint with a surface contact pressure of 550 kPa (80 psi).

3.4 Sensitivity of Surface Contact Pressure

Fixed loads spread over larger rectangular areas generally have significantly less impact on a buried pipeline. The magnitude of change is related to depth of cover with shallow cover exhibiting the larger effects. Figure 3-4 shows the effects of varying surface contact pressures.

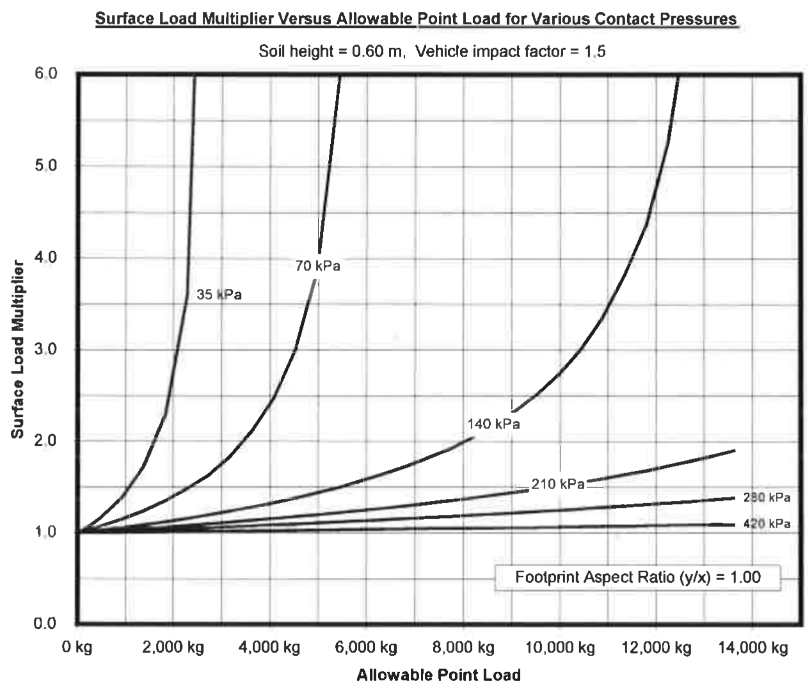

Figure 3-4. Surface Load Multiplier versus Allowable Point Load for Various Contact Pressures

Appendix C contains a full series of plots addressing contact pressures.

3.5 Multiple Wheel Factor

A key consideration in determining live load pressure on the pipe is the location of vehicle wheels relative to the pipe. A higher pressure may occur below a point between the axles or between two adjacent axles rather than directly under a single vehicle wheel. This depends on the depth of cover and the spacing of the wheels.

When depths are not greater than one meter (3 feet), a single wheel directly over the pipe generally produces the largest load. At depths greater than one meter the maximum load may shift.

The multiple wheel factor is utilized in the screening tool to account for this shift and varies with depth. The wheel factor uses the worst case scenario of a load applied by two axles of 6-foot width and a 4-foot space between the axles. The stress at pipeline depth at different locations is calculated using Boussinesq's equation. Figure 3-5 illustrates the analysis locations. The calculation considers the load at pipe level from these axles at the point directly under each wheel (1), at the center of the axle (2), between the front and rear wheels (3), and at the centroid of the four wheels (4).

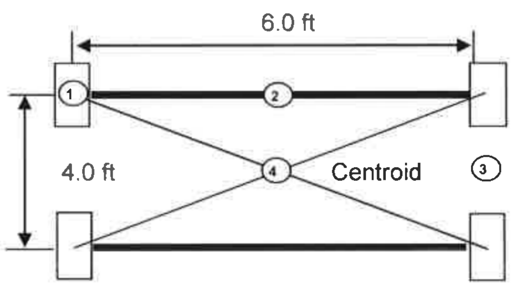

Figure 3-5. Four Locations Analyzed to Determine Worst-Case Loading for Various Depths

Note: This configuration is conservative in cases where the actual axle length is greater and the axle spacing is longer.

3.6 Application of the Proposed Approach

The stress calculation approach explained above is described in the following steps:

1. Determine the pipe steel grade, the design factor (0.72, 0.80), the maximum allowable circumferential stress (the authors recommend that a value of 1.00 SMYS is a reasonable maximum combined circumferential stress at pipeline vehicular crossings, see Appendix C "Design Loading Criteria"), D/t_{max}= 125, and the other pertinent analysis parameters (E', cover depth, etc.).
2. For a selected internal pressure, compute the D/t ratio corresponding to $D/t = 2 \cdot \sigma_y \cdot DF/P$. Then compute the circumferential stress due to combined internal pressure using Barlow's formula and fill load. The fill load is calculated from Equation (3.2) with $W_{vertical}$ set equal to W_{fill} in Equation (3.3).
3. Compute the difference between the circumferential stress due to combined internal pressure and fill loads and the allowable circumferential stress. This is the "available circumferential stress capacity" for surface load.
4. Check to see if the available circumferential stress capacity is greater than the established fatigue limits. If so, determine if the loads are frequent and adjust appropriately.

5. Set the right hand side (the stress) of Equation (3.2) equal to the "available circumferential stress capacity" for surface load computed in Step 3 above and solve for the corresponding $W_{vertical}$
6. If the surface loading is a point (wheel) load, set W_{wheel} equal to $W_{vertical}$ and use Equation (3.6) to solve for the allowable point load W. If the surface loading is a rectangular footprint load, set $W_{rectangular}$ equal to $W_{vertical}$ and use Equation (3.8) to solve for the allowable load on the rectangular footprint W.
7. Repeat steps 2 through 6 for a range of pressures.

Application of this approach for a wheel loading example was used to develop the plot shown in Figure 3-6. The figure shows allowable wheel load versus internal pressure for cover of 0.9 meters (3 ft) and for Grades of pipe ranging from 207 MPa to 483 MPa (Grade A to X70).

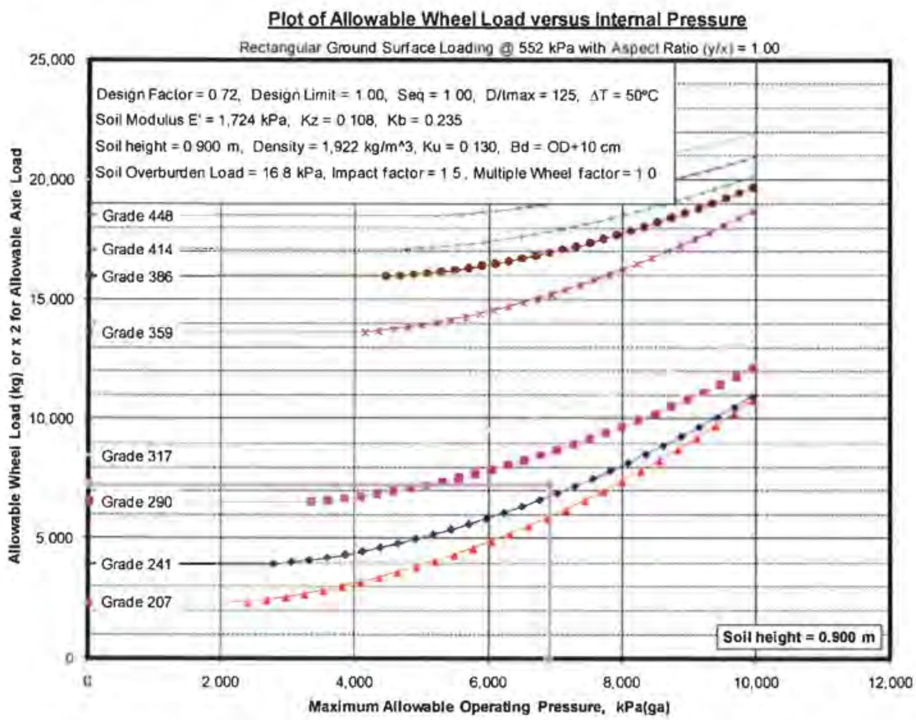

Figure 3-6. Plot of Allowable Wheel Load versus Internal Pressure

This same approach has been utilized for 1.2 meters (4 ft) of cover as shown in Figure 3-7.

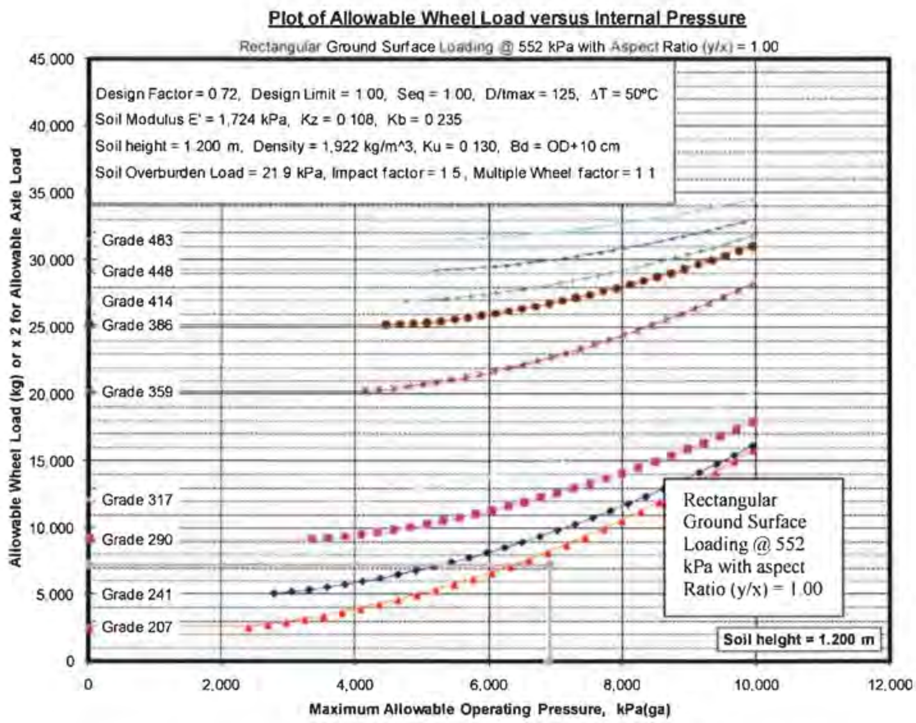

Figure 3-7. Plot of Allowable Wheel Load versus Internal Pressure

The graphs shown in Figures 3-6 and 3-7 represent an initial screening tool that can be utilized by a pipeline operator to determine whether or not a given crossing application requires added protection, or whether a more detailed calculation is appropriate. Appendix C contains a series of plots addressing a full range of conditions.

3.7 Sample Calculation

The following is a sample of how the screening tool can be utilized.

A Pipeline Company operates a pipeline in northern Canada. A gravel haul contractor has requested a temporary road crossing over the pipeline to transport bank run gravel over the pipeline. They report that the truck will have an effective wheel load of 7,250 kg (16,000 lbs).

Pipe Attributes:

- OD = 610 mm (24-inch)
- WT = 8.14 mm (0.321-inch)
- Grade = 359 MPa, (X-52)
- DF = 0.72
- MOP = 6,895 kPa (ga) (1,000 psig)

- Depth of cover 0.9 meters (2.95 ft)

The initial screening requires the following minimum information:

Grade, MOP, DF ≤ 0.72, depth of cover, competent soil (i.e., non-saturated clay), and knowledge of pipeline condition (i.e., should not utilize screen tool for pipelines with other known threats such as may be associated with LF ERW or poor corrosion condition, etc.)

> Note: The pipeline OD and WT are not required. This approach can be used as a quick screening tool for nontechnical persons but it is very conservative. The user should refer to the procedure outlined above to develop a less conservative approach.

From Figure 3-6 it has been determined that the stress imposed on the pipeline as a result of this wheel loading is acceptable for grades equal to or greater than 290 MPa (42,000 psi). Therefore, the crossing is acceptable. For grades below 290 MPa (42,000 psi), the initial screening tool identified that this loading condition has the potential to exceed the allowable limits. If the grade is lower than 290 the following options are available:

- Perform a more detailed calculation;
- Find a location with additional cover and/or place additional cover over the pipeline. Figure 3-7 indicates that 4 feet of cover will be adequate for pipeline grades equal to or greater than 241 MPa (35,000 psi);
- Provide supplemental protection (concrete slab, etc.).

4.0 ASSESSMENT OF MITIGATION OPTIONS FOR BURIED PIPELINES SUBJECTED TO SURFACE TRAFFIC

4.1 Introduction

The first task of this project for CEPA was a "*Literature Search Summary*" which documented the available methods for evaluating the effects of fill and surface loads on buried pipelines as summarized in Section 2. Using Section 2 as a starting point, the second work task developed a simple screening method which allows a pipeline operator to determine if a given crossing application requires added protection or if a more detailed calculation is appropriate. The goal of the screening method is to use relatively simple and easily obtainable attributes (e.g., wheel or axle load, ground surface contact area and/or surface loading pressure, depth of cover, maximum allowable operating pressure and design factor). The screening calculations are summarized in the Section 3.

Building on these two previous work tasks, the third work task is to evaluate various temporary surface load-dispersal techniques and other mitigation approaches that are often used as a means to lessen the effects of surface loading. The effectiveness of various methods will be investigated with the goal of ranking the methods based on their capabilities for reducing adverse effects on the pipeline and ease of installation. This task will also define minimum requirements such as slab or mat stiffness, thickness, and length necessary in order to provide the desired protection and identify situations where a given technique may be ineffective.

4.2 Overview of Mitigation Measures

Pipeline engineers have a number of options available to reduce the stresses on buried pipelines subjected to fill and surface traffic loading. Table 4-1 provides a listing of different mitigation measures that we have seen utilized along with their relative advantages and disadvantages. The following sections provide a more detailed discussion of these mitigation methods.

4.3 Reduction of Pipe Internal Pressure during Vehicle Passage

Mitigation scenarios which reduce the pipe internal pressure to reduce hoop stress due to pressure are worthy of consideration even though reducing the internal pressure tends to increase the circumferential stresses due to fill and traffic loads. Fill and surface traffic stress analyses of the total circumferential stress (i.e., hoop stress plus fill and traffic stress) over a range of pipe internal pressures will show an optimum pressure that results in the minimum total circumferential stress. At the "trough point" of a plot of the total circumferential stress versus internal pressure, the increases in fill and traffic load induced stresses due to reduced internal pressure are offset by the reduction in hoop stress. In addition to the total circumferential stress, this approach should also be evaluated by comparing the traffic component of the circumferential stress to a fatigue endurance limit. Reducing the pipe internal pressure is attractive as a short-term solution (e.g., for mitigating a limited number passages of a crane over a buried line near a construction site). However, because a reduction of line pressure can have a direct impact on pipeline throughput, it is not attractive as a long-term or permanent solution.

4.4 Surface Protection via Limiting Surface Vehicle Footprint Pressure

Several of the mitigation methods listed in Table 4-1 (i.e., steel plates, timber mats, concrete slab) can be classified as "Surface Protection" methods. These methods deploy a flat surface structure (e.g., plate, mat or slab) on the ground surface as a means of dispersing the surface vehicle load over a wider area. The idea behind these methods is that they distribute the surface loads over a larger "footprint" area than that provided by the surface vehicle alone. The effective footprint area of the vehicle load would be distributed uniformly over the entire footprint of the surface structure for a rigid flat surface structure centered under a vehicle load. In cases where the vehicle load is applied eccentrically on the flat surface structure, for very large surface vehicle loads and/or relatively flexible flat surface structures, the actual distribution of pressure on the ground surface may be far from uniform. In fact, portions of the flat surface structure can actually lift off of the ground surface. The behavior of flat surface structure mitigation methods can be investigated using beam on elastic foundation analysis methods. The analysis considers the distribution of the vehicle load on top of the flat surface structure, the bending flexibility of the flat surface structure, and the stiffness of the soil below the flat surface structure. Given this information, it is possible to estimate an effective footprint for the loading situation, which may be significantly less than the full footprint of the pad, mat, or plate.

Under ideal circumstances, a heavy vehicle crossing a buried pipeline would be arranged such that the heavy vehicle's path of travel crosses the pipeline at a 90^{o} angle. For a beam on elastic foundation analysis, the essential structural characteristic of the flat surface structure (i.e., the "beam") are the modulus of elasticity and the moment of inertia (E and I). The moment of inertia is usually based on a unit width of the flat surface structure in the direction perpendicular to the pipeline. The foundation component of the model can be developed based on the soil spring computation procedures used for strip foundation analysis and design. For previous applications, we have modeled the "bearing" spring stiffness values using the procedures described in [ALA]. The required input properties include the soil density, soil friction angle, and soil cohesion. The resulting "spring" properties include the ultimate resistance of the "strip" foundation (in force per unit length, e.g., klf), the "yield" displacement (usually taken as some fraction of the strip foundation width, e.g., inches), and the corresponding elastic stiffness (in force per unit length per unit displacement, e.g., klf per inch). The loading on the model includes a uniform self-weight of the surface structure plus the vehicle load (e.g., a point load or short uniform load) that acts on top of the unit width of the surface structure.

The results of this type of analysis include the deflection profile of the flat surface structure and the distribution of bearing force along the length of the flat surface structure and along the pipeline. In general, the results show a distribution of bearing force and downward deflection of the surface structure that is largest directly under the center of the vehicle load and diminishes with distance away from the center of the vehicle load. Depending on the relative stiffnesses of the flat surface structure and the soil foundation, it is possible for portions (e.g., the ends) of the flat surface structure to deflect upward, creating a gap between the bottom of the flat surface structure and the top of the soil surface which reduces the length that is in contact with the ground surface. Based on this information, the engineer can perform additional surface traffic stress calculations using a range of rectangular load footprint assumptions to approximate the bearing pressure distribution. The bounding assumptions are to apply the entire vehicle load over the portion of the surface structure that remains in contact with the ground surface (e.g., use an effective along-the pipe length) or apply a load that generates an equivalent maximum bearing pressure over a shorter along-the pipe length (e.g., use an effective bearing pressure).

We have adopted the following formula to determine the revised footprint of the dispersed load. This formula is referred to as the radius of stiffness and is commonly utilized to determine the pressure intensity on rigid pavements.

$$L = \sqrt[4]{\frac{E \cdot h^3}{12 \cdot (1 - v^2) \cdot Es'}} \qquad (4.1)$$

where:

- L = radius of stiffness of slab/plate
- E = modulus of elasticity of slab/plate
- h = thickness of slab/plate
- v = Poisson's ratio of slab/plate
- E_s' = Elastic modulus of soil in contact with the slab

A review of the formula shows that the thickness of the slab plays the most significant role in spreading the surface load. Figures 4-1 through 4-4 show the effects of placing slabs on the ground surface as a means to spread the surface load over a larger area for steel and concrete slabs. Based on a review of these figures, a 7.6 cm (3-inch) thick steel slab provides the same surface load spread as does a 15.2 cm (6-inch) thick concrete slab. Since steel is significantly more costly to use than concrete this comparison suggests that concrete may be more cost effective to utilize. We have also performed a similar review of timber mats. The results indicate that a 20 cm (8-inch) thick timber mat results in a similar load spread to the 15.2 (6-inch) concrete slab. Based on this information, a timber mat may be more cost effective to use than either steel or concrete. Figures 4.5 and 4.6 show the effects of placing timber mats on the on the ground surface as a means of spreading the surface load over a larger area. It is important to note that the individual timbers within the mat must be tied in a manner that provides for a uniformly transfer of load between timbers making up the mat.

Equation 4.1 can be used to determine the minimum size of the surface protection mat. At a minimum the protection must extend a distance of L/2 beyond the wheel/track in all directions. To ensure the proper load transfer we recommend 1.5 times this value.

Table 4-1. Surface Loading Mitigation Measures

Method	Advantages	Disadvantages
Reduce the operating pressure of the pipeline.	Provides a direct reduction of the hoop stress due to internal pressure. This reduction allows for additional circumferential stress due to equipment loads	Reduces the beneficial effect of internal pressure on the pipe circumferential bending stresses due to fill and traffic loads. Could reduce the overall capacity of the pipeline and therefore should not be considered as a long term fix.
Limit surface pressures under vehicles (e.g., using floatation tires or caterpillar tracks)	Spreads the surface load over a larger area and reduces the overall load to the pipe.	Depends on equipment. May not be possible or too costly to implement
Consider the beneficial effect of lateral soil restraint on circumferential stress	Has effect similar to pressure stiffening	Requires estimates of soil stiffness parameter, E'
Provide additional soil fill over the pipeline in the vicinity of the crossing	Reduces circumferential stresses due to traffic loads.	Increases circumferential stresses due to fill loads.
Deploy steel plates over the crossing	Easy to install.	Flexibility of steel plates can result in bending of the plate with a corresponding reduction in loaded footprint. Need to consider required thickness.
Deploy timber mats over the crossing area	Provides large loading footprint. Relatively easy to deploy.	Flexibility of timber mats can result in bending of the mats with a corresponding reduction in loaded footprint.
Construct a concrete slab with steel reinforcement over the crossing area	Provides large loading footprint. Slab can provide high bending stiffness	Relatively expensive. Usually reserved for permanent crossings. Slab limits access to pipeline for inspections and repairs.
Construct a short bridge crossing over the pipeline	Completely uncouples the traffic loading from the buried pipeline.	Requires construction of foundation structures. Expensive to construct. Usually reserved for permanent crossings. Bridge structure may limit access to pipeline for inspections and repairs.
Relocate the pipeline	Removes pipeline from loaded area.	Expensive to construct. Usually considered only as a last resort.
Lower pipeline	Reduces circumferential stresses due to traffic loads.	Expensive to perform. Usually considered only as a last resort.

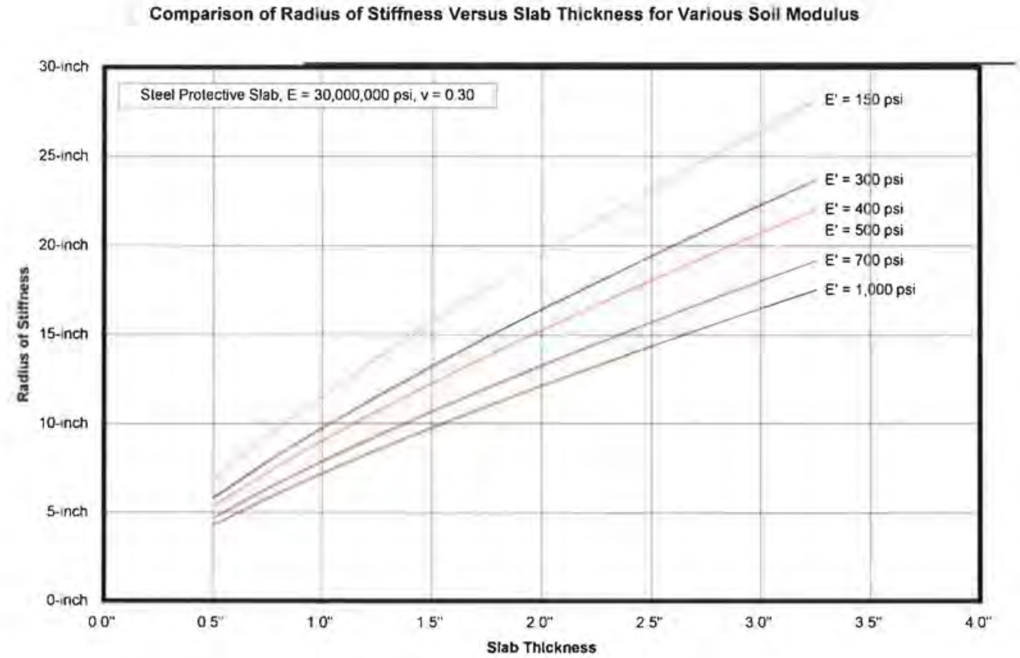

Figure 4-1. Comparison of Radius of Stiffness versus Steel Slab thickness for Various Soil Modulus

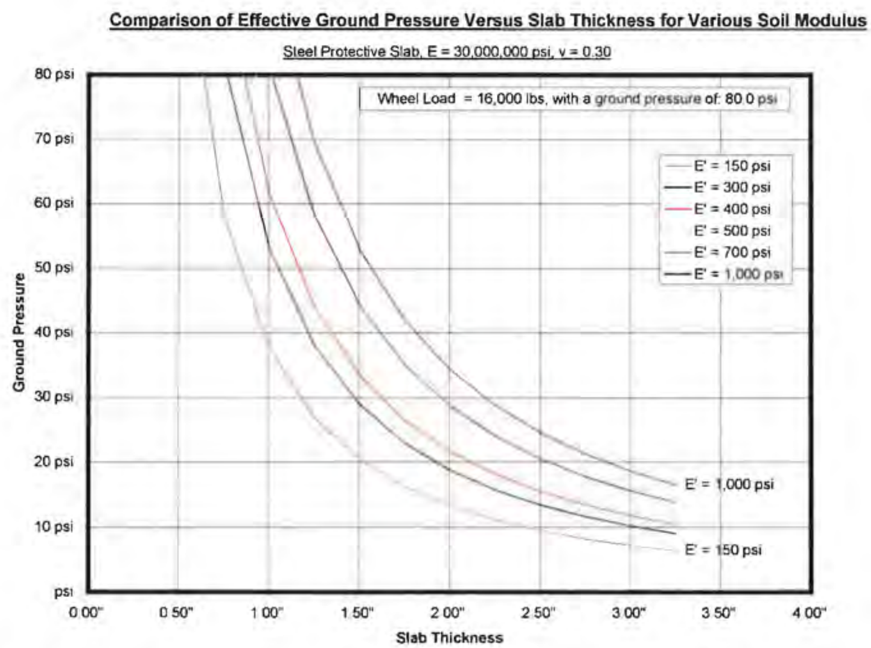

Figure 4-2. Comparison of Effective Ground Pressure versus Steel Slab thickness for Various Soil Modulus

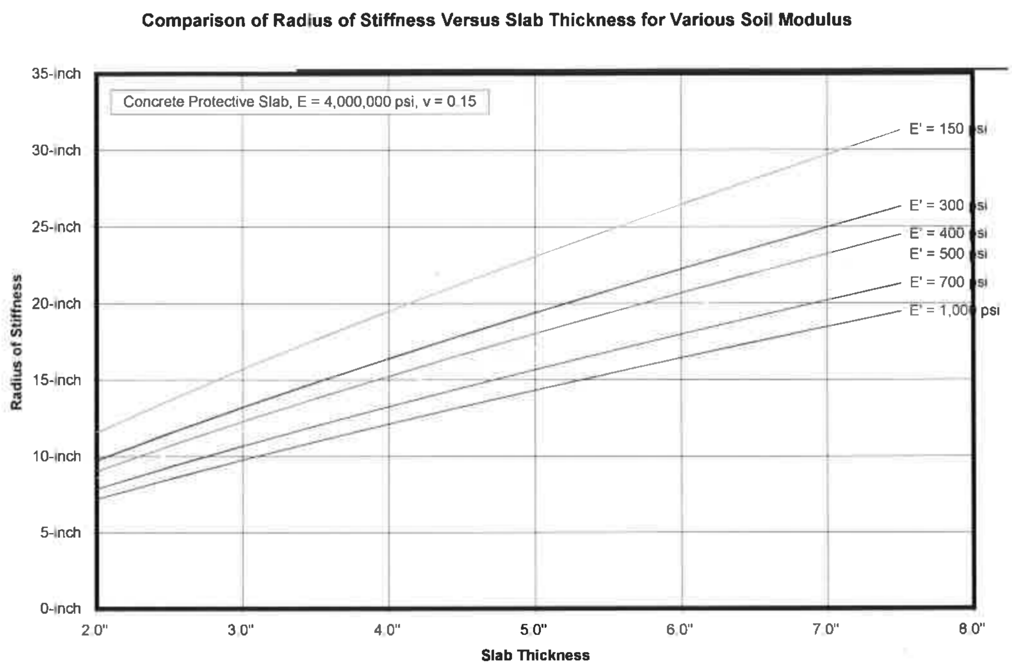

Figure 4-3. Comparison of Radius of Stiffness versus Concrete Slab Thickness for Various Soil Modulus

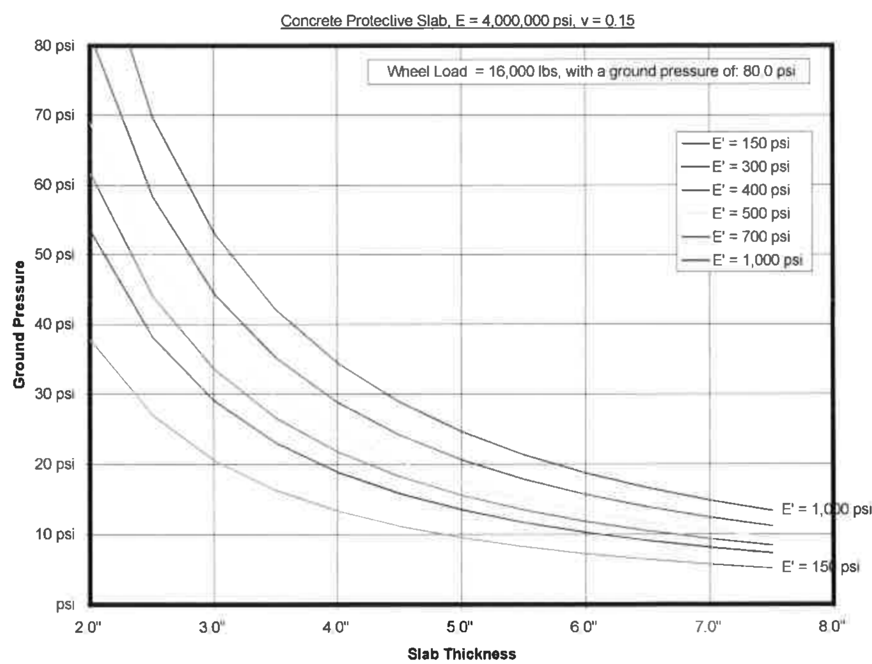

Figure 4-4. Comparison of Effective Ground Pressure versus Concrete Slab thickness for Various Soil Modulus

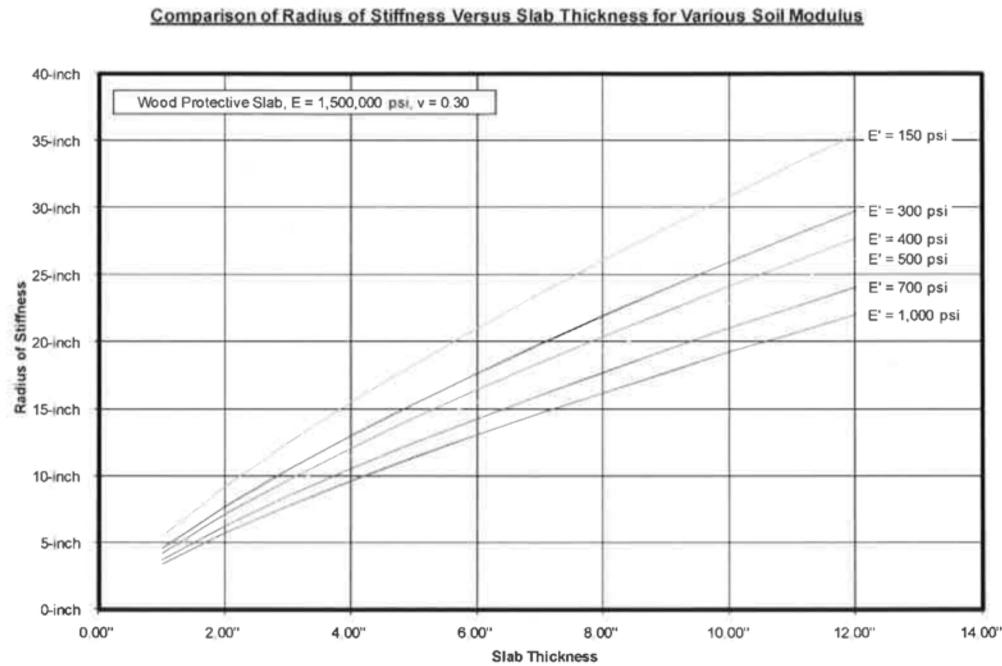

Figure 4-5. Comparison of Radius of Stiffness versus Wood Slab Thickness for Various Soil Modulus

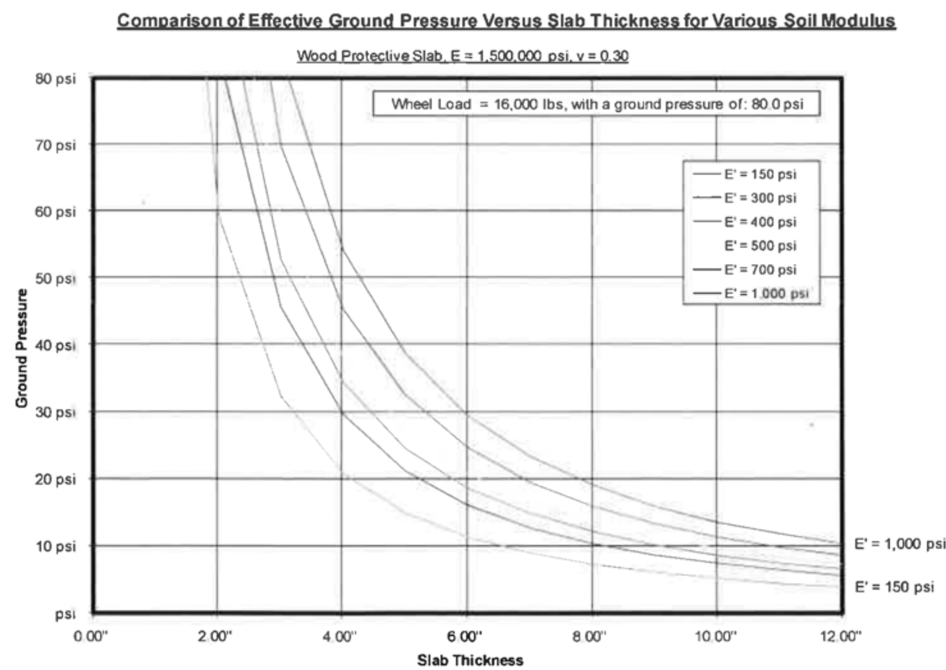

Figure 4-6. Comparison of Effective Ground Pressure versus Wood Slab thickness for Various Soil Modulus

4.5 Consideration of Ovalling Restraint Provided By Soil

Sections 2 and 3 give equations that show the effect of ovalling restraint resulting from the soil around the pipe as a function of the modulus of soil restraint, E'. When E' is set equal to zero, the equations decompose to those which neglect soil restraint while non-zero values of E' allow the beneficial effect of soil restraint to be considered. Cases that barely exceed the allowable stress check(s) when soil restraint is neglected or set as a lower bound may be able to pass the allowable stress check(s) when modest levels of soil stiffness are considered. Therefore, the ability to include or exclude the effects of soil restraint in the screening calculations provides the engineer with the ability to easily perform "what if" analyses of a given configuration as a basis for assessing a given crossing scheme.

4.6 Provide Additional Fill over Pipeline at Crossing

A relatively popular procedure that has been utilized for mitigating pipe stresses due to surface vehicle loading is to provide additional soil fill over the pipeline at the crossing. This mitigation method increases the total depth of cover used in the pipe stress calculations for fill and traffic loads. This has a direct positive effect of reducing the circumferential stresses due to vehicle loads. It also has a direct negative effect of increasing the circumferential stresses due to fill loads. For many applications (e.g., situations with high impact factors and/or high traffic stress but with relative low stresses due to fill), the beneficial effect of the reduction in traffic stress can far exceed the negative effect of increased fill stress. This tradeoff can easily be investigated by performing pipe stress calculations for a range of cover depths. One can compare the effect of fill and traffic load on the total circumferential stress against appropriate total stress limits and compare the traffic stress range against appropriate fatigue stress limits.

4.7 Combination of Mitigation Methods

Additional mitigation can be provided by using combinations of the various measures described above to reduce the overall stress level on the pipeline.

4.8 References

[ALA] ASCE American Lifelines Alliance *"Guidelines for the Design of Buried Steel Pipe"*, Published by the ASCE American Lifelines Alliance, www.americanlifelinesalliance.org, July 2001.

APPENDIX A:

A-1 Design Loading Criteria

The governing code for Canadian pipelines is CSA Z662-03.

1. Design Pressure to be Calculated using:

CSA Z662-03 Section 4.3.3.1 specifies:

$P = (2(SMYS)t/D) \times F \times J \times L \times T$

where:

- F = Design Factor
- J = Joint Factor
- L = Location Factor
- T = Temperature Factor
- t = pipe wall thickness
- D = Pipe diameter
- P = Pressure

The design factor is specified as 0.8

The joint factor is 1.0 unless continuous welded pipe is used

The location factor is 1.0 for class 1 locations for both non-sour gas and HVP and LVP. The temperature factor is 1.0 unless design temperature exceeds 120 deg. C.

2. Combined Hoop and Longitudinal Stress

CSA Z662-03 Section 4.6.2.1

Unless special design measures are implemented to ensure the stability of the pipeline, the hoop stress due to design pressure combined with the net longitudinal stress due to the pipe temperature changes and internal fluid pressure shall be limited in accordance with the following formula.

$S_h - S_L \leq 0.90\ S \times T$

Note: This formula does not apply if S_L is positive (i.e., tension)

where

S_h = hoop stress due to design pressure, units

S_L = longitudinal compression stress, MPa, as determine using the following formula:

$S_L = \nu\ S_h - E_c\ \alpha(T_2 - T_1)$

Where

ν = Poisson's ratio
E_c = modulus of elasticity of steel, MPa
α = linear coefficient of thermal expansion, units
T_2 = maximum operating temperature, °C
T_1 = ambient temperature at time of restraint, °C
S = SMYS

T = Temperature Factor

Allowable $T_2 - T_1$

Grade		**Allowable T_2-T_1 σ_h=0.80 SMYS**		**Allowable T_2-T_1 σ_h=0.72 SMYS**	
X-207	X-30	28.3 C	51. F	33. C	59.4 F
X-241	X-35	33.1 C	59.5 F	38.5 C	69.3 F
X-290	X-42	39.7 C	71.4 F	46.2 C	83.2 F
X-317	X-46	43.4 C	78.2 F	50.6 C	91.1 F
X-359	X-52	49.1 C	88.4 F	57.2 C	103. F
X-386	X-56	52.9 C	95.2 F	61.6 C	110.9 F
X-414	X-60	56.7 C	102. F	66. C	118.8 F
X-448	X-65	61.4 C	110.5 F	71.5 C	128.7 F
X-483	X-70	66.1 C	119. F	77. C	138.6 F
Pipe Attributes:					
Youngs Modulus (E) =			206.8 GPa	30,000 ksi	
Thermal Expansion Coef. (α) =			12.0×10^6 m/m/C	6.67×10^6 in/in/F	
Poisson's Ratio (υ) =			0.3		

> Note: The provisions of Clause 4.6.2.1 places restrictions on the combination of hoop stress based on Barlow's equation and longitudinal stress based on the Poisson effect of Barlow's equation and temperature differential. You will note that additional loads such as external circumferential stresses have not specifically been included in this restriction. As a result, the provisions of Clause 4.6.2.1 are independent of the additional circumferential stresses as a result of overburden loads and traffic loads.

3. Other Loadings and Dynamic Effects

CSA Z662-03 Section 4.2.4.1 states:

The stress design requirements in this Standard are specifically limited to design conditions for operating pressure, thermal expansion ranges, temperature differential, and sustained force and wind loadings. Additional loadings other than the specified operating loads are not specifically addressed in this Standard; however, the designer shall determine whether supplemental design criteria are necessary for such loadings and whether additional strength or protection against damage modes, or both, should be provided. Examples of such loadings include:...

h) Excessive overburden loads and cyclical traffic loads.

Circumferential stresses as a result of traffic loads are considered additional loads in CSA, and therefore the designer shall determine whether additional design criteria are necessary. The follow sections address the additional design criteria.

4. Maximum Combined Effective Stress

CSA Z662-03 Section 4.2.4.1 specifies that all relevant loads need to be assessed using good engineering practices. CSA does not directly provide a limit to the maximum combined effective stress allowed for onshore pipelines however Section 11.2.4.2.2.5 allows for a combined effective stress of up to the SMYS for offshore pipelines. Further guidance for the allowable limit for the combined effective stress can be found in the ASME Boiler and Pressure Vessel Code Sections VIII Division 2 (BPVC). The BPVC differentiates between membrane and bending stresses. In the case of a pipeline, the membrane stress is the stress resulting from the internal pressure in the pipe. This stress is limited in CSA Z662-03 to the design factor of 0.8 SMYS. The additional stress that results from overburden and surface loading are bending stresses. An object can obtain yield at the outer surface in bending and still have a large amount of residual load carrying capacity as a result of the bending stress distribution. For example, the moment on a beam in bending at the outer fiber yield is 2/3 of the collapse moment. There is also additional load carrying capacity resulting from the strain hardening of the steel. For this reason, the BPVC allows the combination of membrane and bending stresses to go as high as the yield strength of the material.

Based on the above argument the screening tool has adopted the following as the limit for the combined effective stress:

$S_{eq} \leq 1.00 \text{ S x T}$

where

Seq = the combined effective stress.

5. Maximum Allowable Sum of Circumferential Stress

CSA Z662-03 does not specifically have a clause that places a limit on maximum allowable sum of circumferential stresses. If the longitudinal stress is greater than zero the circumferential stress can exceed the yield stress of the material and the combined effective stress still remain below the yield stress of the material. If the longitudinal stress is reduced there could be yielding beyond the surface of the pipe. In order to insure that there is no gross yielding in the pipe wall, the sum of the circumferential stress should also be limited to the SMYS of the pipe.

Based on the above the screening tool has adopted the following:

$S_h + S_{cb} \leq 1.00 \text{ S x T}$

where

S_h = hoop stress due to design pressure,

S_{cb} = circumferential through-wall bending stress caused by surface vehicle loads or other local loads.

6. Fatigue Strength of Line Pipe

The fatigue strength of line pipe depends on whether the pipe is seamless, has an electric-resistance weld (ERW) seam, or has a double submerged arc weld (DSAW) seam in either the longitudinal or spiral direction. Data on line pipe from the German Standard DIN 2413 showed that the limiting variable stress was about 138 MPa (20 ksi) for ERW or seamless line pipe and 83 MPa (12 ksi) for DSAW line pipe. This data compares favorably with information from the International Institute of Welding, the American Institute of Steel Construction, and the AREA Manual for Railway Engineering. The version of CSA 662-2003 Section 4.8.3.2 Uncased Railway Crossings has established a fluctuating stress limitation of 69 MPa (10 ksi) based on 2 million cycles. This value is conservative as it applies to new facilities; however, it may be more appropriate with regard to older facilities. Certain pipe seam types such as LF ERW and EFW may be subject to seam susceptibility. The operator should consider these factors if heavy equipment cross the pipeline at high frequencies.

APPENDIX B:

Sensitivity Analysis of Factors Utilized in Screening Model with Regards to Equipment with Low Surface Contact Pressures

This section provides for a sensitivity analysis of factors utilized in the Screening Model, which when applied to equipment with low surface contact pressures, have the potential to provide for additional conservatism.

B-1 Impact Factor

We recommend using a reduced impact factor of 1.25 for slow moving equipment with low pressure tires. This value meets the AASHTO specification for cover depths greater than 0.3 m. An impact factor of 1.5 has been used in the model to address the dynamic nature of traffic loads on flexible surfaces. This value is based on a recommendation by the ASME committee on Pipeline Crossings of Railways and Highway. The specification called for an impact factor of 1.5 to be applied to traffic live loads for roads with flexible pavements. No impact factor is required for roads with rigid pavements.

It is important to note that AASHTO recommends impact factors in its specifications. Impact factors of 1.3, 1.2, 1.1, and 1.0 are applied at depths of 0, 0.1 to 1 ft, 1.1 to 2.0 ft and 2.1 to 3.0 ft, respectively. It is noted that the concrete design manual utilized by many in the industry also uses the same factors.

The variables that govern the magnitude of impact factor are as follows:

- Impact factors increase with increasing vehicle speed,
- Impact factors increase with increased tire pressure
- Impact factors increase with increased roughness of the ground.

With respect to the above factors, equipment with low surface contact pressures will produce less of an impact than that of a truck for the following reasons:

- The equipment are specifically design to have low ground surface pressure to reduce compacting of the soil strata;
- Equipment of this design normally utilize low pressure pneumatic tires with contact pressure << 200 kPa(ga) (30 psig);
- This type of equipment typically operates at lower velocities < 15 kph (10 mph).

Figures B-1 through B-6 show the effects of reducing the impact factor from 1.5 to 1.25 for equipment with low surface contact pressures. It is noted that the effects are constant based on the ratio of 1.5/1.25 or 1.2 for the results shown.

B-2 Bedding Angle of Support

The terms K_b and K_z are bending moment and deflection parameters respectively based on theory of elasticity solutions for elastic ring bending, which depend on the bedding angle as shown in Table B-1.

Table B-1. Spangler Stress Formula Parameters K_b and K_z

Bedding Angle (deg)	Moment Parameter K_b	Deflection Parameter K_z
0	0.294	0.110
30	0.235	0.108
60	0.189	0.103
90	0.157	0.096
120	0.138	0.089
150	0.128	0.085
180	0.125	0.083

Bedding angles of 0, 30 and 90 degrees are taken as corresponding to consolidated rock, open trench, and bored trench conditions respectively. A 30 degree angle is typically utilized and is representative of open trench construction with relatively unconsolidated backfill such that fully bearing support of the pipe is not achieved. While this is an acceptable and generally conservative value to utilize for a newly constructed pipeline, one could argue that as the soil re-consolidates around the pipeline over time the actual bearing support will be much greater.

Figures B-1 through B-6 show the effects of increasing the bedding support angles from 30 to 60 degrees as well as from 30 to 90 degrees. The effects of changing the bedding support angle are significant and range from 1.28 to 1.75 for a change from 30 to 60 degrees and from 1.47 to 2.37 for a change from 30 to 90 degrees.

B-3 Modulus of Soil Reaction E' (or Z)

The modulus of soil reaction, *E'* (or Z) defines the soil's resistance to pipeline ovalling as a result of dead and live loads acting on the pipeline. A value of 250 psi has been utilized as a conservative number and represents fine grained soils of medium compaction. Values in the range of 1,000 psi are not uncommon. A value of 500 psi would be acceptable in soil conditions where additional soil consolidation around the pipe has occurred.

Figures B-1 through B-6 shows the effects of increasing the modulus of soil reaction from 250 psi to 500 psi. A multiplier of approximately 1.1 was observed as a result of doubling the modulus of soil reaction from 250 to 500 psi. This multiplier decreases with increased pressure.

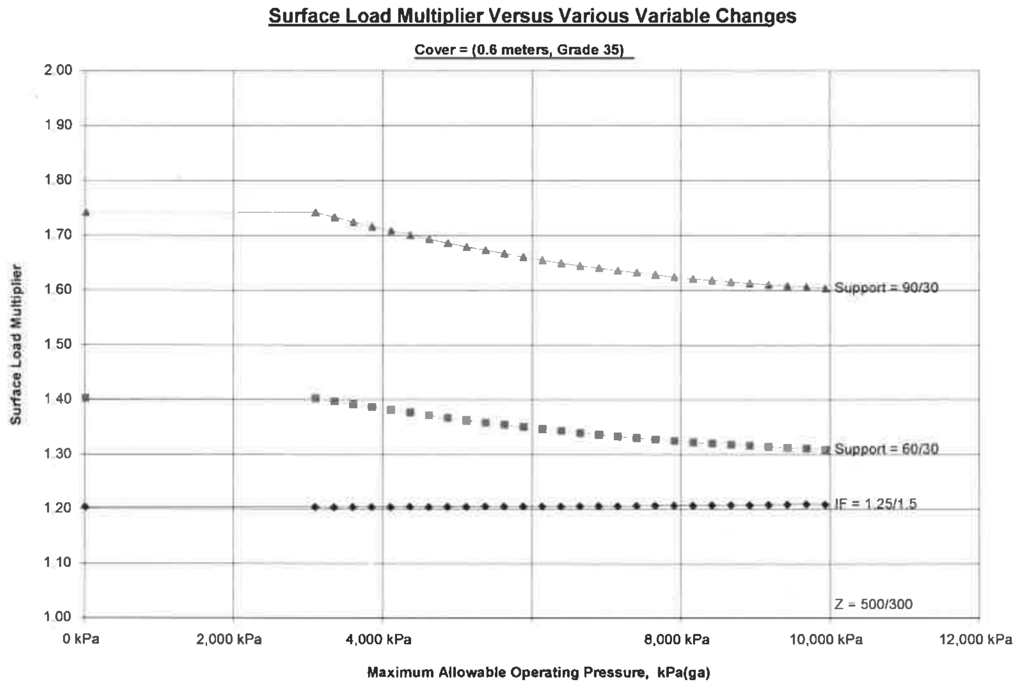

Figure B-1. Surface Load Multiplier versus Various Variable Changes

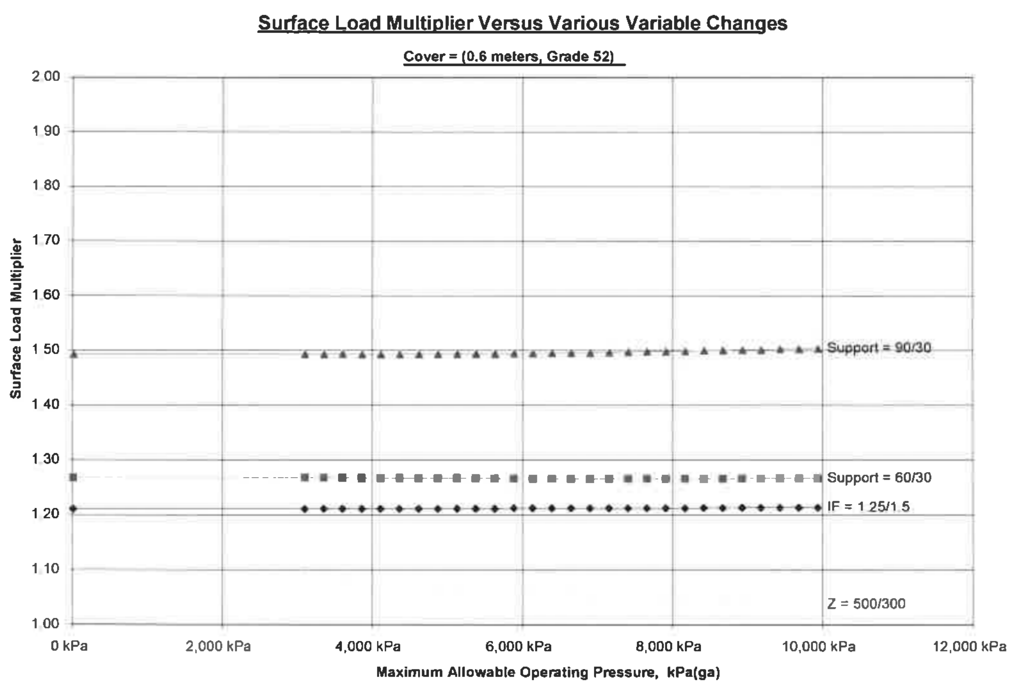

Figure B-2. Surface Load Multiplier versus Various Variable Changes

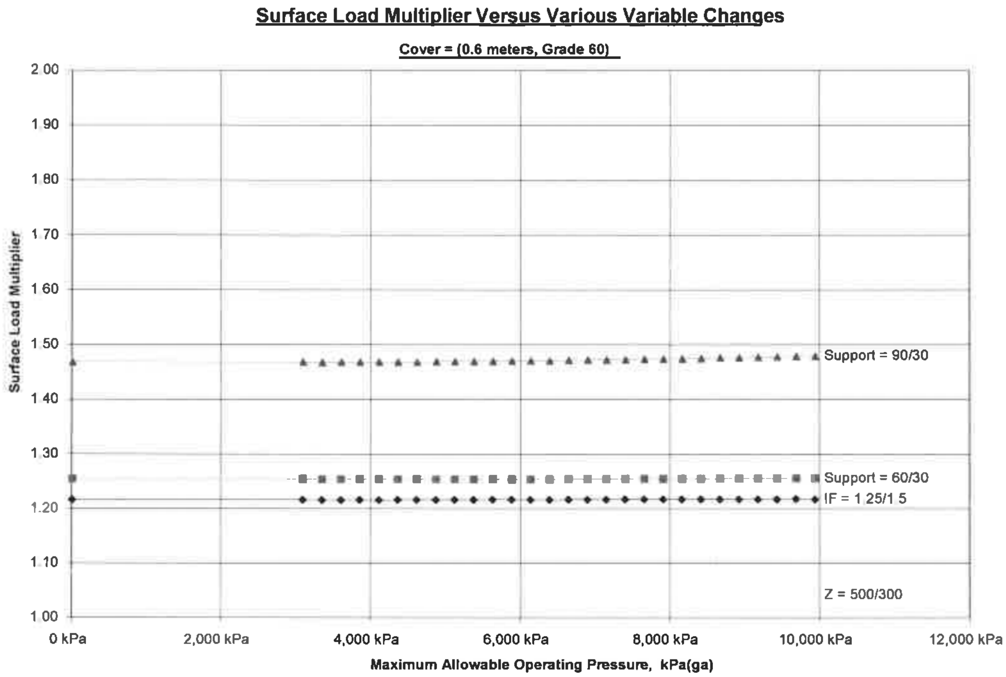

Figure B-3. Surface Load Multiplier versus Various Variable Changes

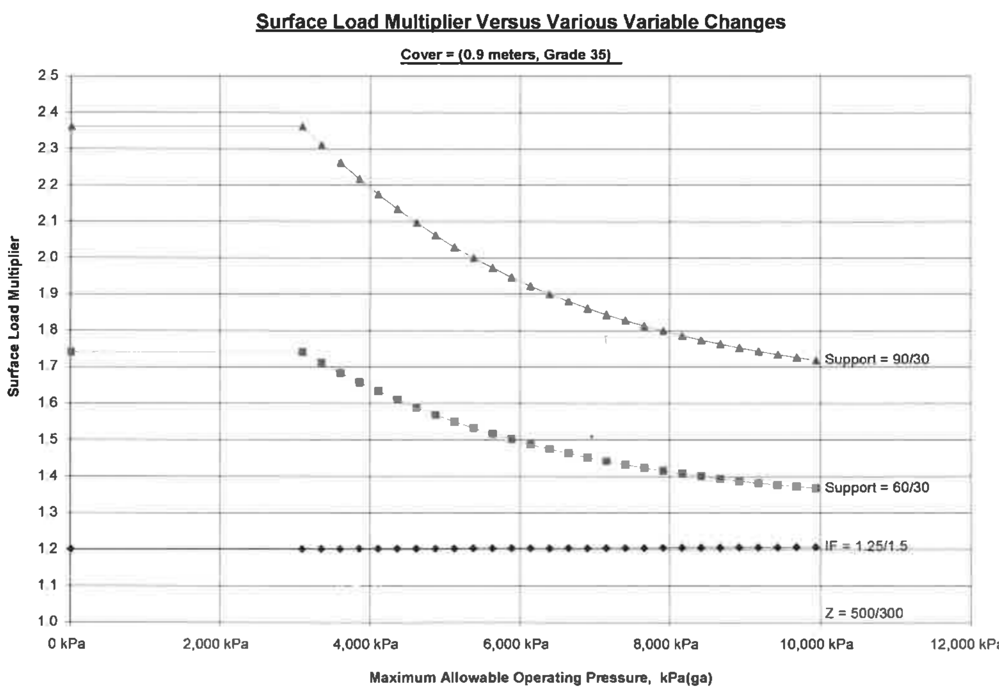

Figure B-4. Surface Load Multiplier versus Various Variable Changes

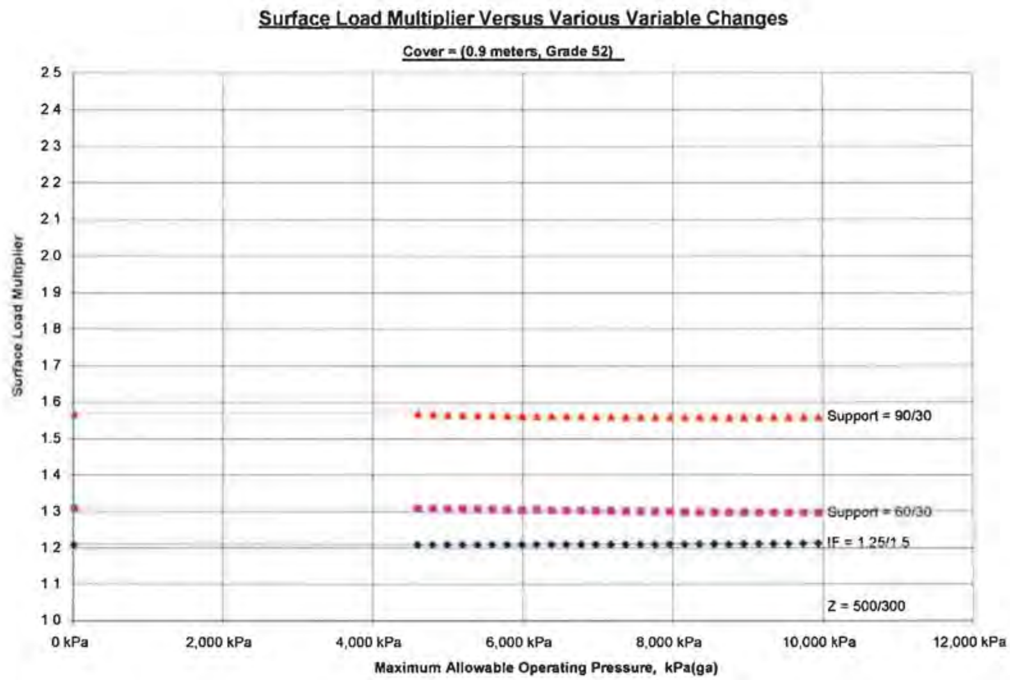

Figure B-5. Surface Load Multiplier versus Various Variable Changes

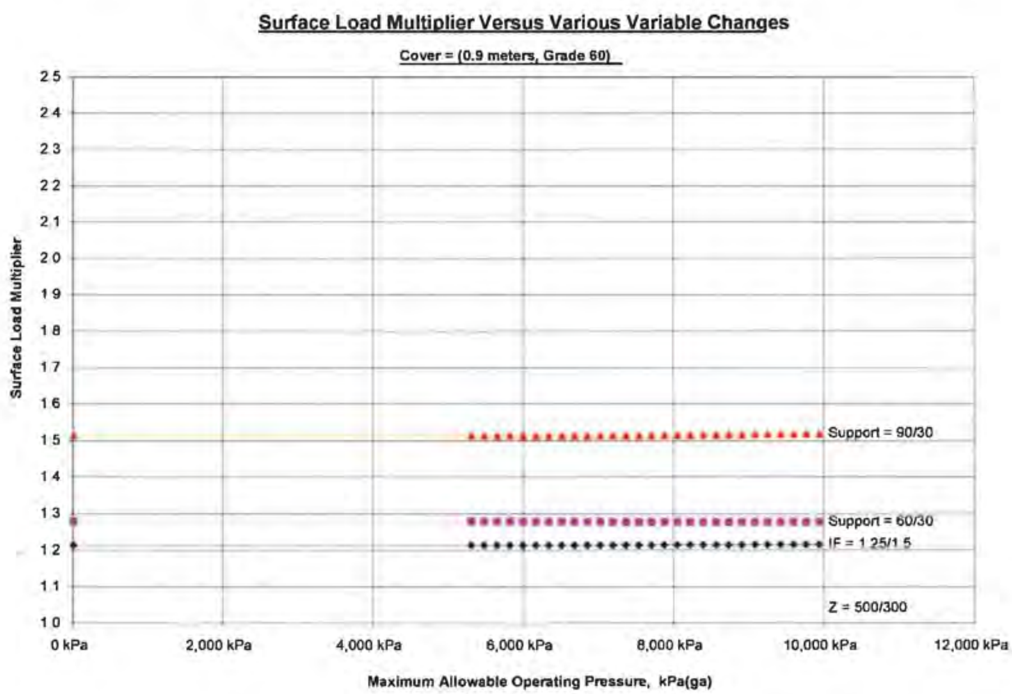

Figure B-6. Surface Load Multiplier versus Various Variable Changes

APPENDIX C:

Proposed Guideline – Infrequent Crossings of Existing Pipelines at Non-Road Locations

Where practical, crossings of pipelines shall occur at designated locations along the right-of-way preferably at purpose-built locations such as roads designed for such use. In situations where existing pipelines are to be crossed at locations not specifically designed as a crossing location, it shall be permissible to cross the pipeline by equipment imposing surface loads provided that the following requirements are met:

a. The crossing of the pipeline is infrequent and temporary.
b. The pipeline is suitable for continued service at the established operating pressure. The pipeline operator shall consider service history and anticipated service conditions in this evaluation.
c. The piping is not subjected to significant secondary stresses, other than those directly imposed by the crossing of the pipeline.
d. The anticipated surface loading given below are used in Figure C-1(a) through C-1(h) and modified by Figures C-2, C-3, or C-4.

As an alternative to Clauses a thru d, an engineering assessment of site-specific conditions is acceptable. This detailed engineering analysis shall consider the resulting combined stresses on the pipeline as a result of all loads expected to be imposed during its usage as a crossing location.

Figures C-1(a) thru C-1(h)

Figure C-1(a) through C-1(h) present the maximum live surface "point" load in kilograms for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm and design operating pressures of 72% SMYS and 80% SMYS.

Notes applicable to Figures C-1 (a - h):

(1) For intermediate operating pressure or grades, it shall be permissible to determine the surface load by interpolation.

(2) Design conditions used to develop the table are as follows:

- Depth of cover, as indicated.
- Maximum hoop stress of 72% or 80% percent SMYS, as indicated.
- Maximum combined circumferential stress of 100 percent SMYS.
- Surface loading based on a contact pressure of 550 kPa (80 psi) applied over a rectangular area with aspect ratio (y/x) = 1. This contact pressure is designated as the "point" load case.
- Fluctuating stress limitation of 82.7 MPa (12 ksi) based upon 2,000,000 cycles.

- Maximum D/t ratio of 125.
- Soil Modulus E' = 1,724 kPa (250 psi) at pipe.
- Soil Density = 1,922 kg/m^3 (120 lbs/ft^3).
- Loading criteria includes an impact factor of 1.5.
- Maximum combined effective stress of up to 100 percent SMYS.
- A temperature differential of $\Delta T = 50°$ C or the maximum temperature limitation as per CSA Clause 4.6.2.1 (section 2 above) whichever is the lower is included in the calculated the longitudinal stress.
- Multiple wheel influence factor (if applicable).

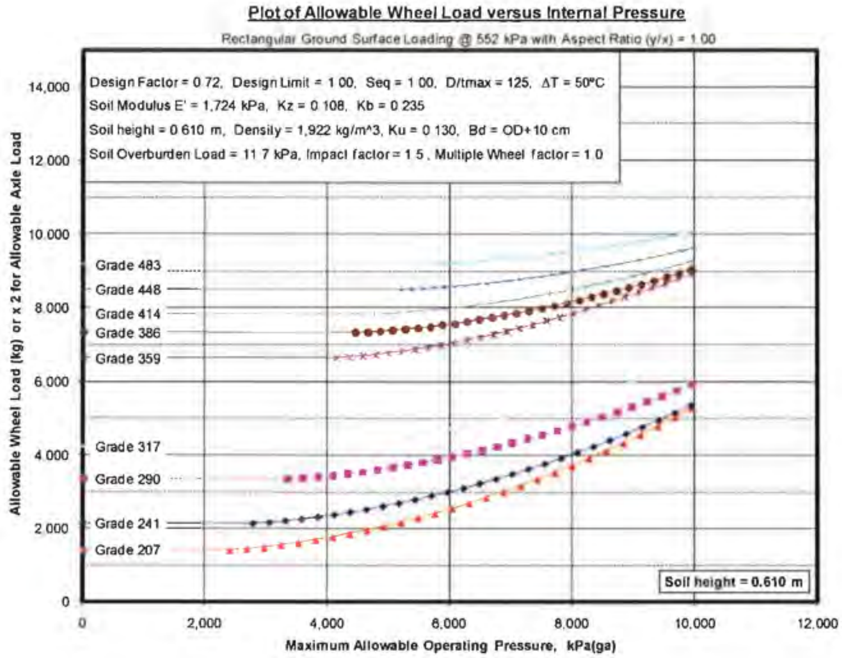

Figure C-1(a) – Soil Height = 0.61 meters, DF = 0.72

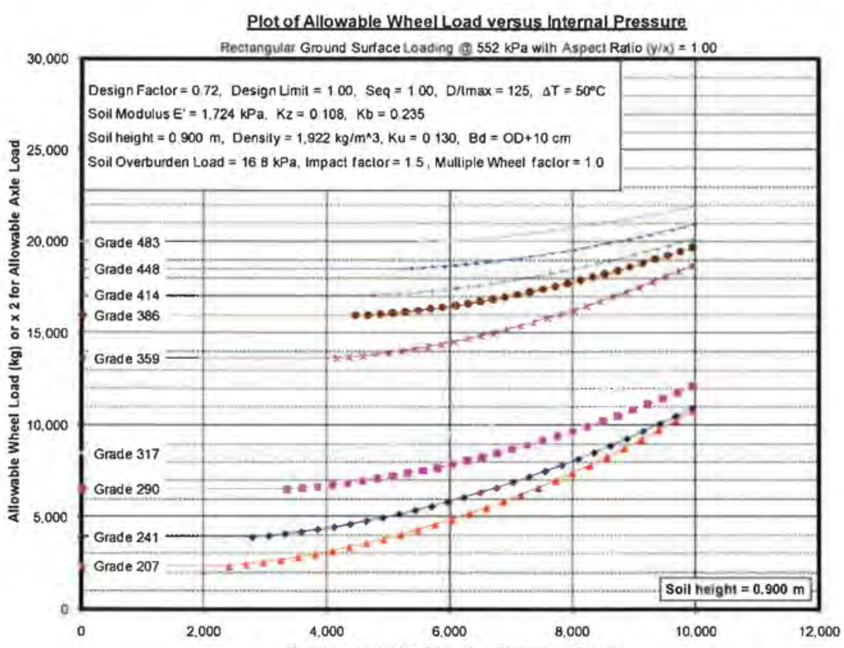

Figure C-1(b) – Soil Height = 0.90 meters, DF = 0.72

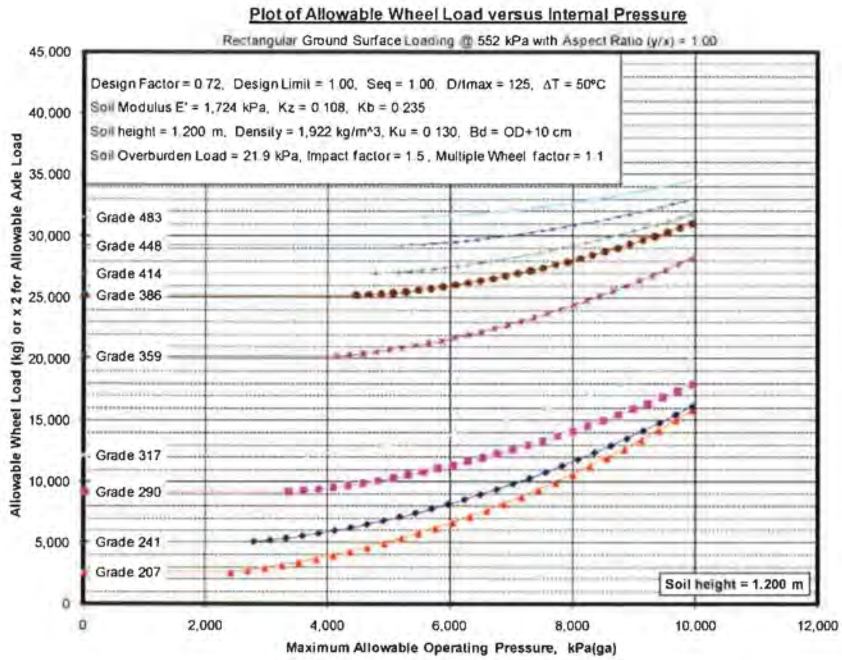

Figure C-1(c) – Soil Height = 1.2 meters, DF = 0.72

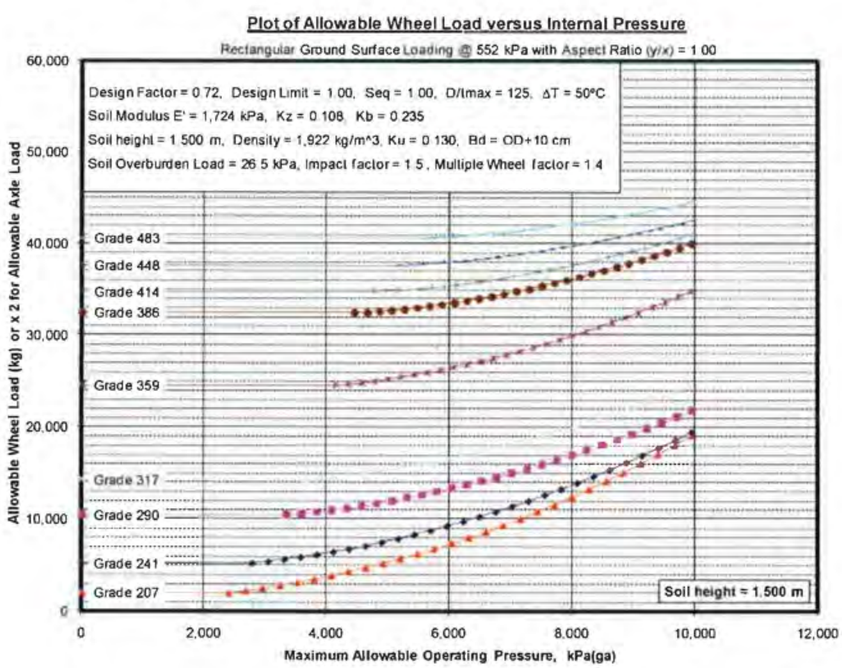

Figure C-1(d) – Soil Height = 1.5 meters, DF = 0.72

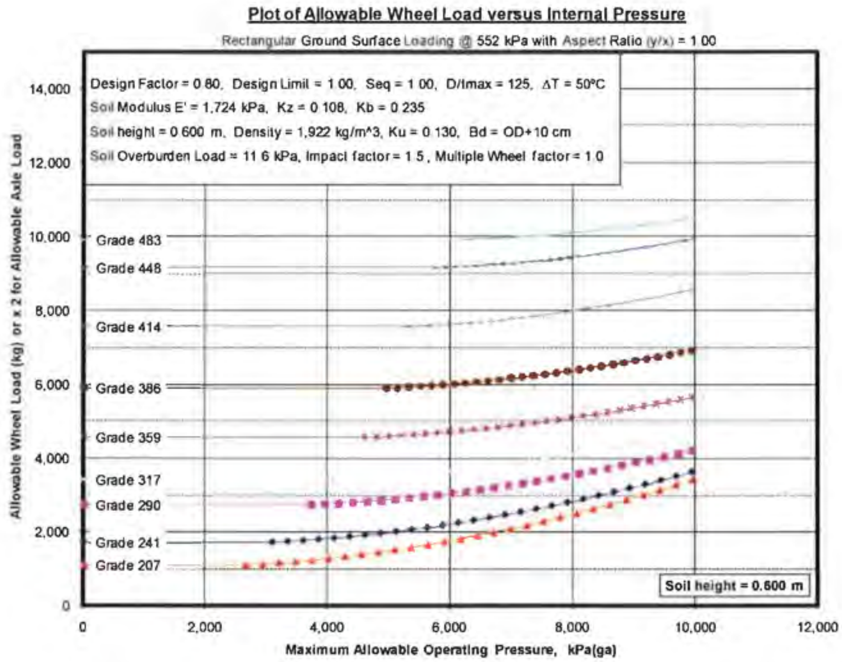

Figure C-1(e) – Soil Height = 0.6 meters, DF = 0.8

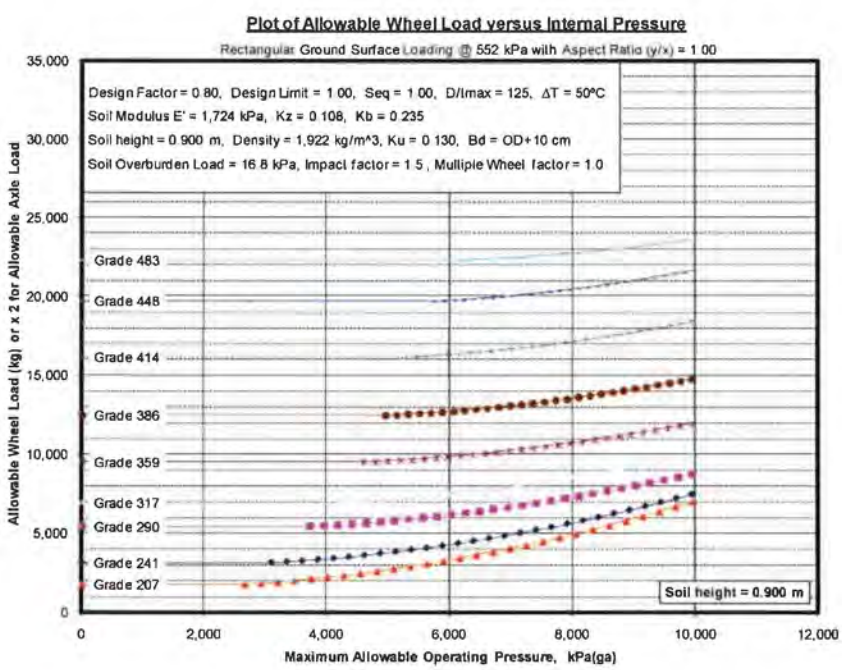

Figure C-1(f) – Soil Height = 0.9 meters, DF = 0.8

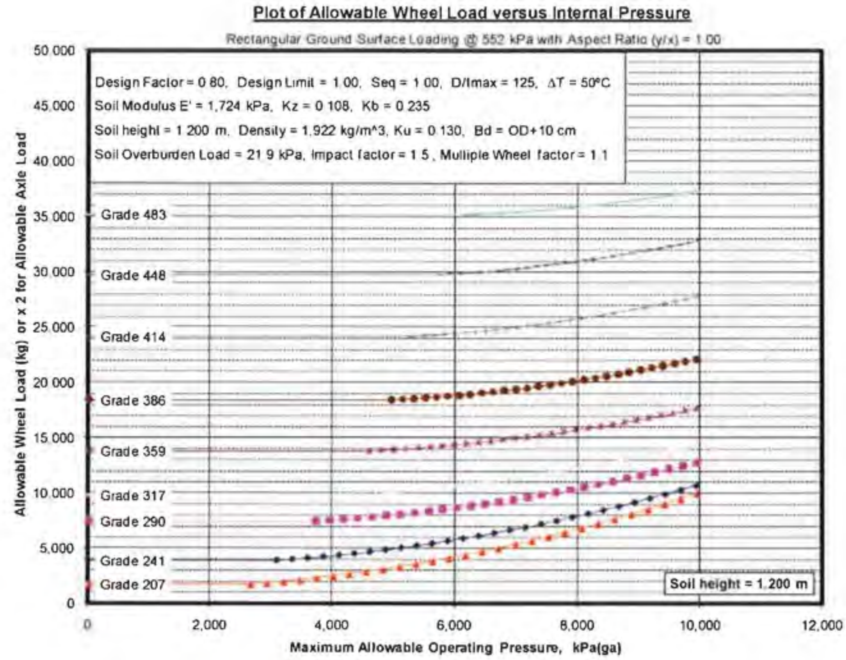

Figure C-1(g) – Soil Height = 1.2 meters, DF = 0.8

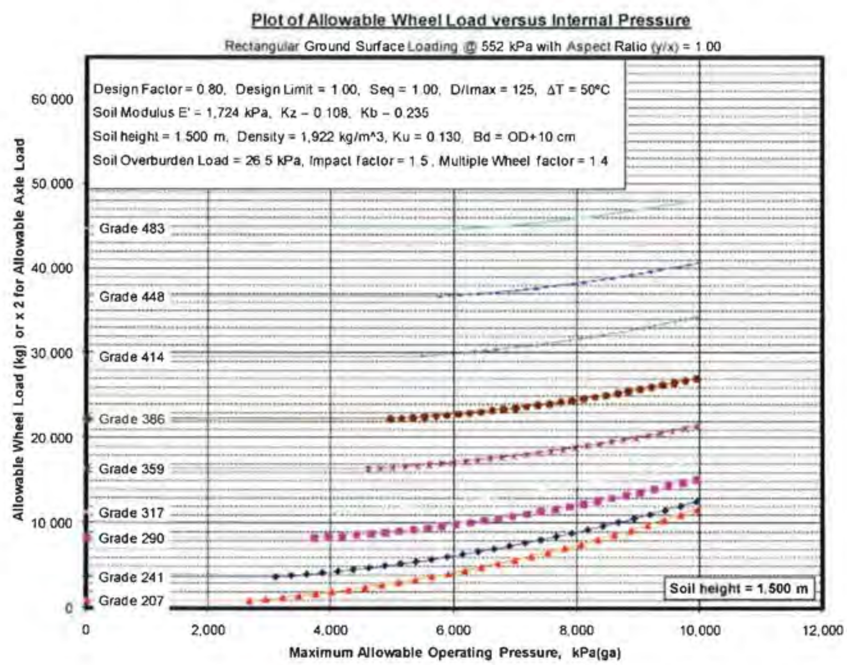

Figure C-1(h) – Soil Height = 1.5 meters, DF = 0.8

Surface Load Multiplier for Rectangular Footprint and Various Contact Pressure Figures C-2(a) through C-2(d)

Figures C-2(a) through C-2(d) present the Load Multiplier that can be applied to the previous determined allowable live surface “point” load for surface loads applied over a square footprint with contact pressures ranging from 35 kPa through 420 kPa (5 psi through 60 psi). The figures apply for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm (2ft, 3ft, 4ft, 5ft).

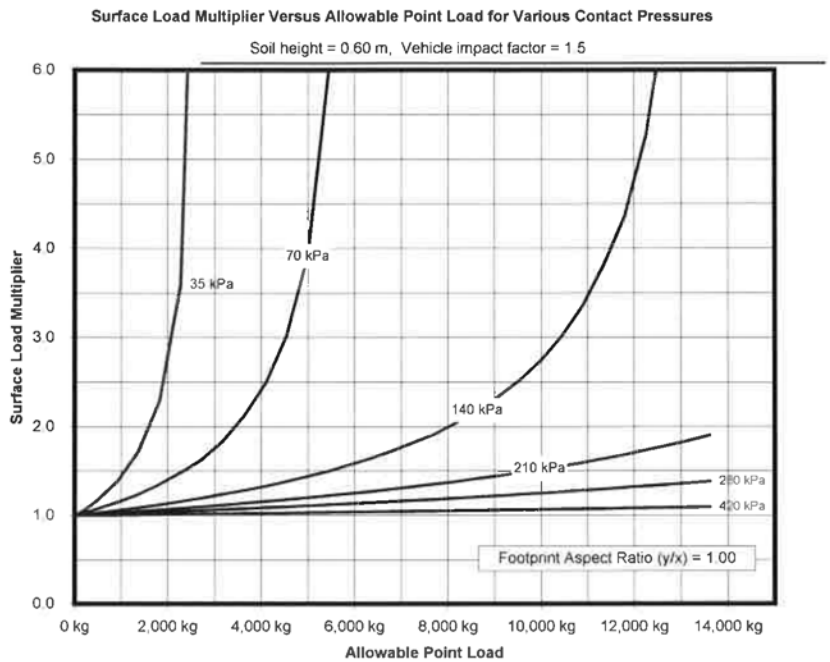

Figure C-2(a) – Soil Height = 0.6 meters

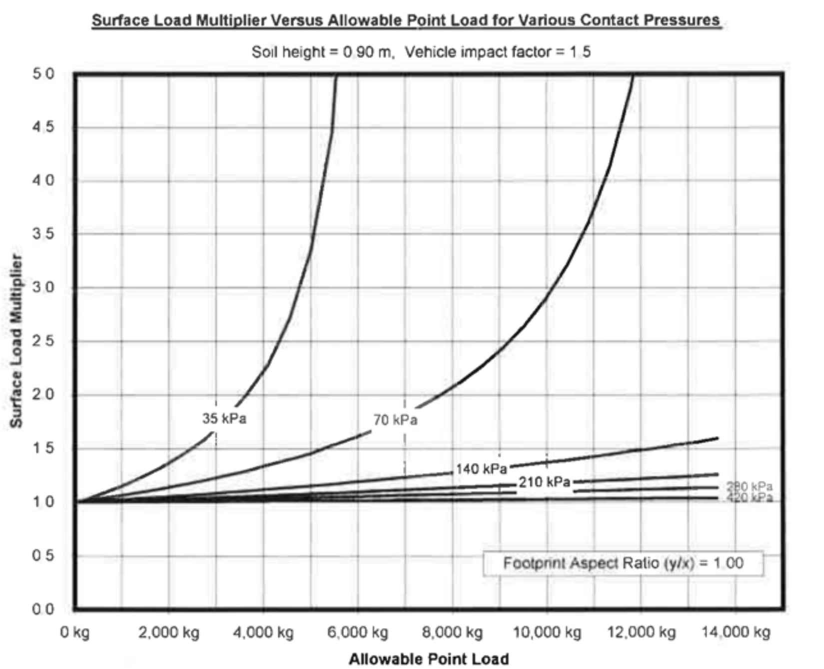

Figure C-2(b) – Soil Height = 0.9 meters

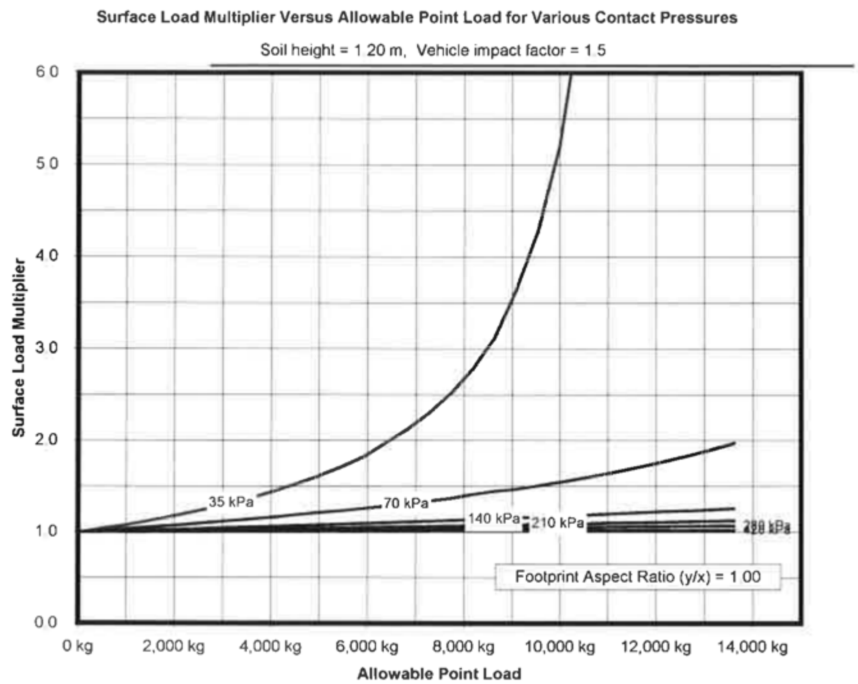

Figure C-2(c) – Soil Height = 1.2 meters

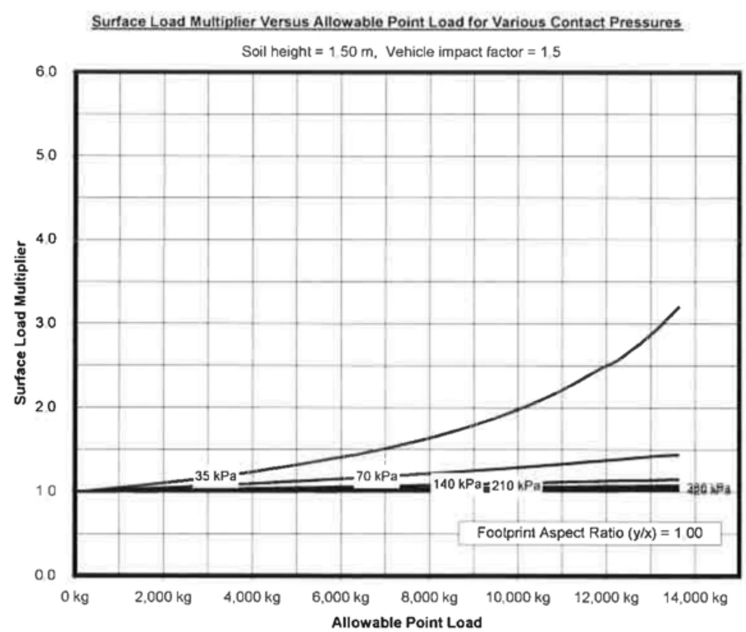

Figure C-2(d) – Soil Height = 1.5 meters

Surface Load Multiplier for Track Loads Figures C-3(a) through C-3(d)

Figures C-3(a) through C-3(d) present the Load Multiplier that can be applied to the previously determined allowable live surface "point" load for Track Loads. Track loads have been represented as surface loads applied over a rectangular footprint with an aspect ratio (Length/Width) of 4. The figures apply for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm (2ft, 3ft, 4ft, 5ft).

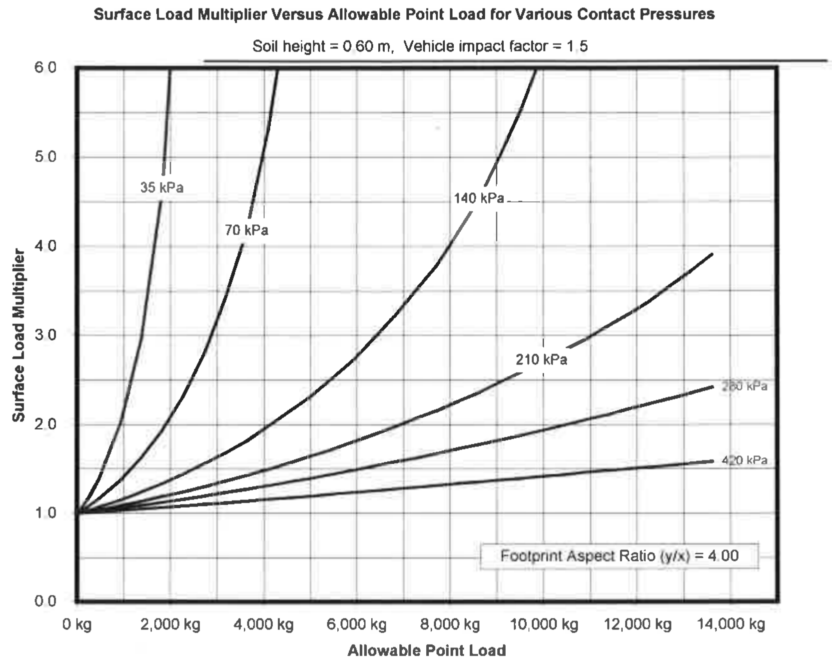

Figure C-3(a) – Soil Height = 0.6 meters

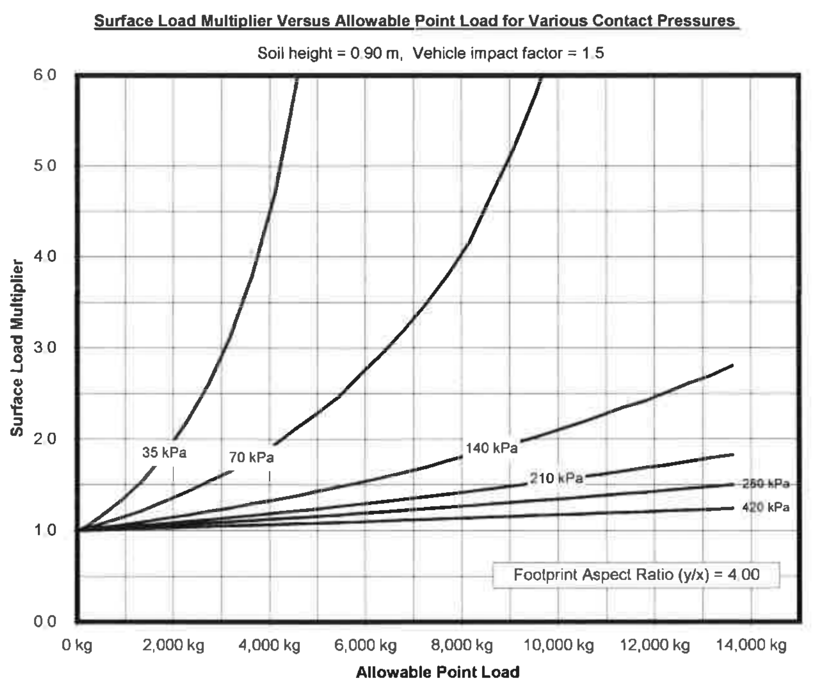

Figure C-3(b) – Soil Height = 0.9 meters

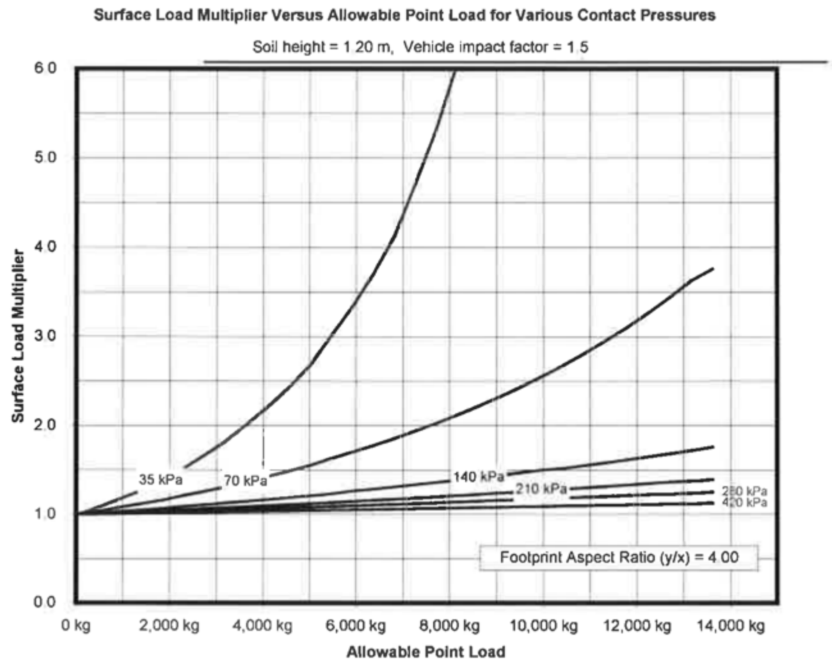

Figure C-3(c) – Soil Height = 1.2 meters

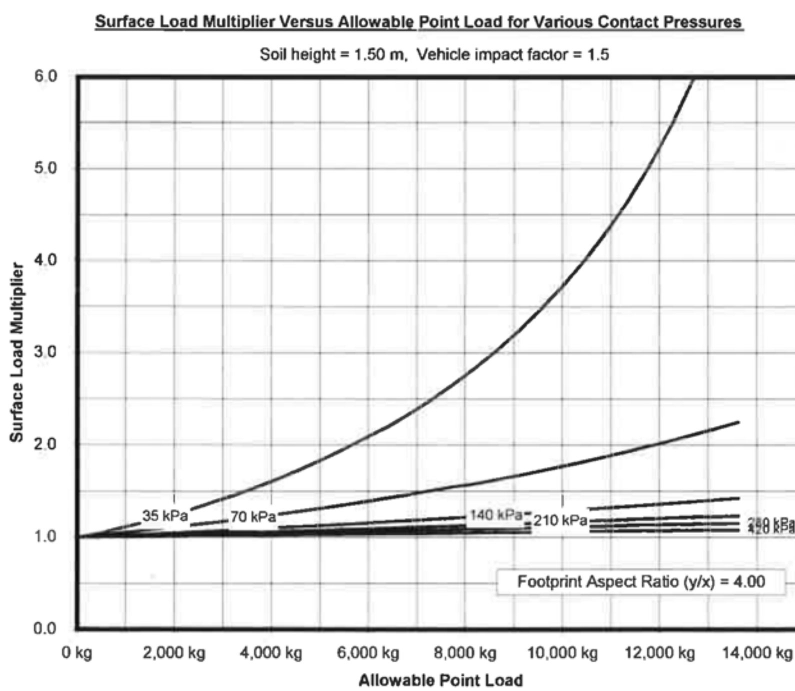

Figure C-3(d) – Soil Height = 1.5 meters

Surface Load Multiplier for Concrete Slab Figures C-4(a) through C-4(d)

Figures C-4(a) through C-4(d) present the effects of placing a concrete slab on the surface as a mitigative measure to increase the allowable surface "point" load. The figures apply for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm (2ft, 3ft, 4ft, and 5ft).

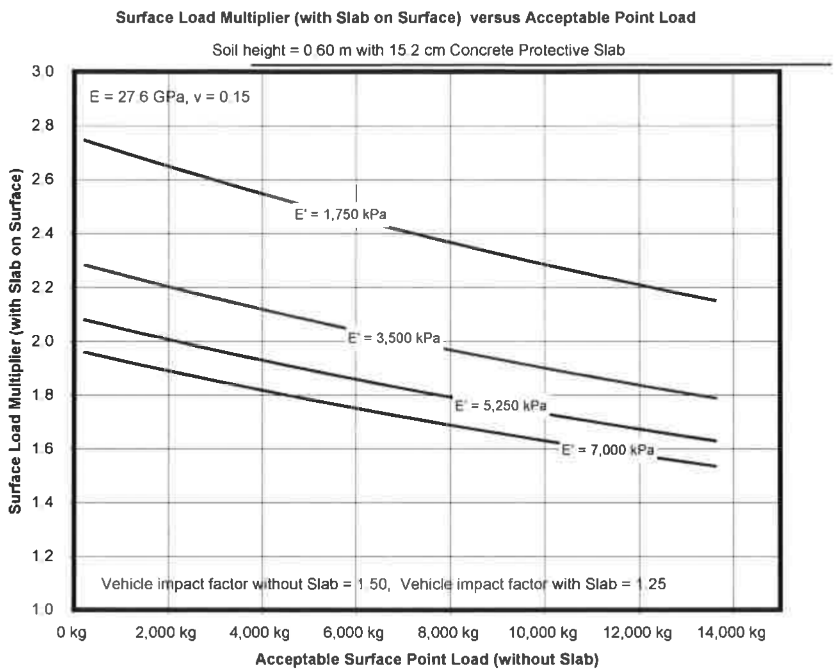

Figure C-4(a) – Soil Height = 0.6 meters

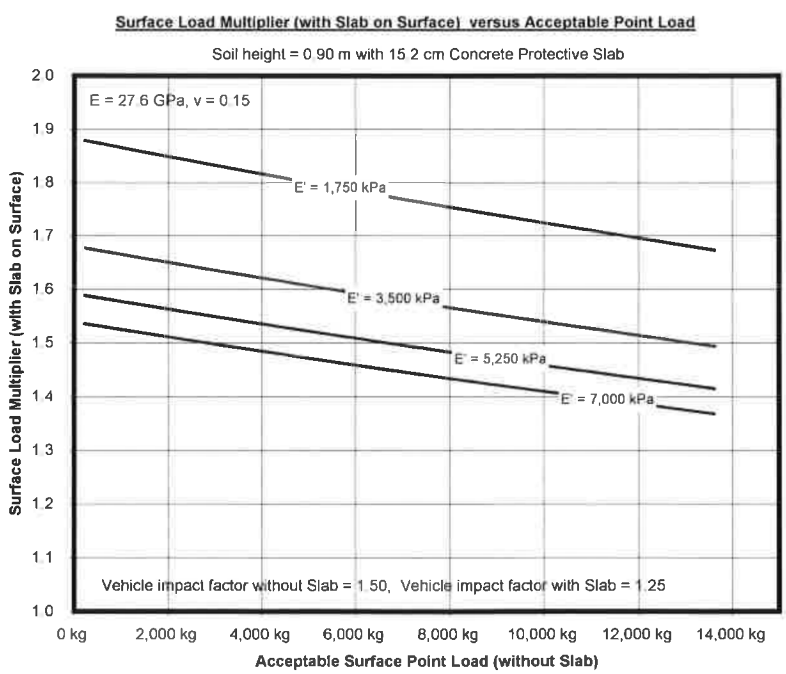

Figure C-4(b) – Soil Height = 0.9 meters

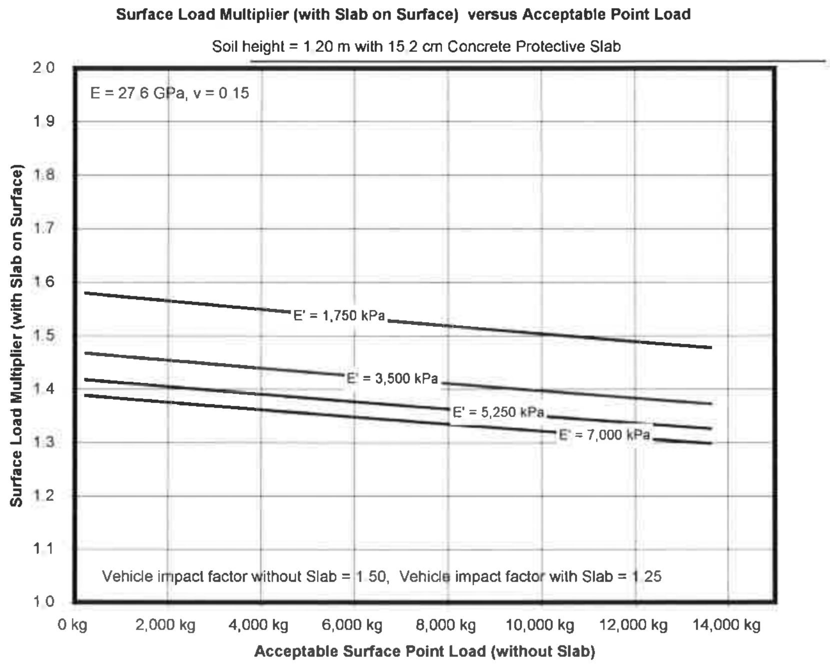

Figure C-4(c) – Soil Height = 1.2 meters

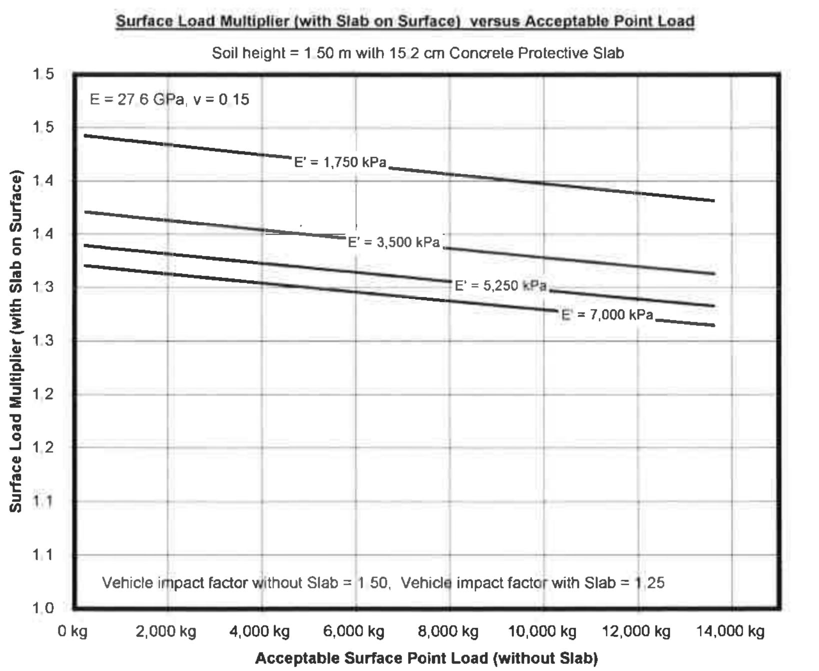

Figure C-4(d) – Soil Height = 1.5 meters

Surface Load Multiplier for Timber Mats Figures C-5(a) through C-5(d)

Figures C-5(a) through C-5(d) present the effects of placing a 20 cm (8-inch) thick timber mat on the surface as a mitigative measure to increase the allowable surface "point" load. The figures apply for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm (2 ft, 3 ft, 4 ft, 5 ft).

> **Note:** It is important to note that the individual timbers within the mat must be tied in a manner that provides for a uniformly transfer of load between timbers making up the mat.

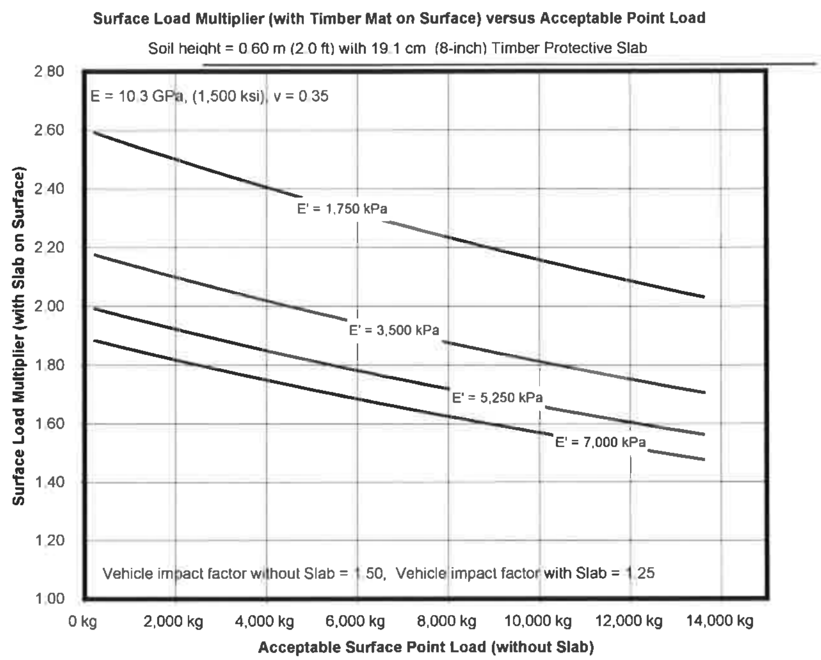

Figure C-5(a) – Soil Height = 0.6 meters

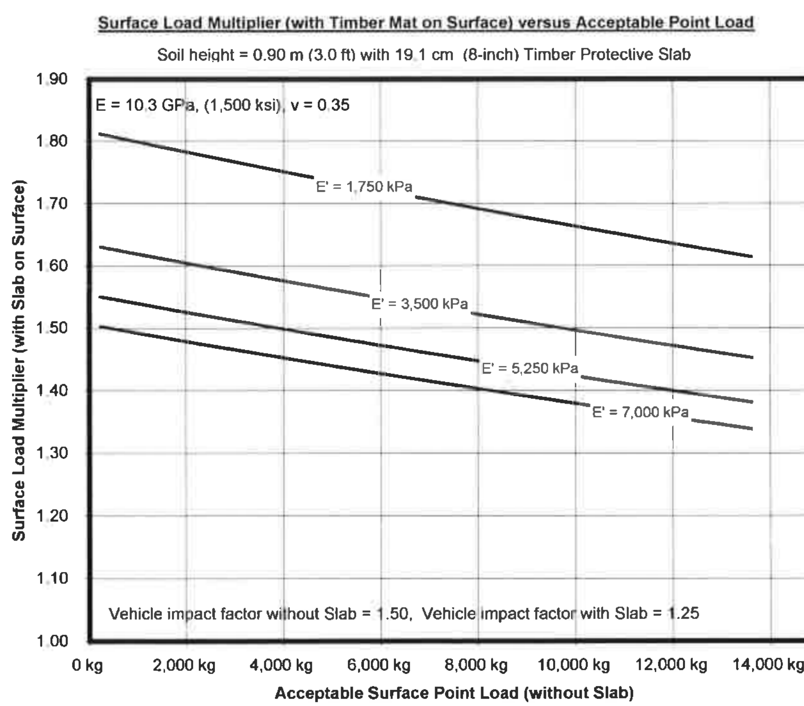

Figure C-5(b) – Soil Height = 0.9 meters

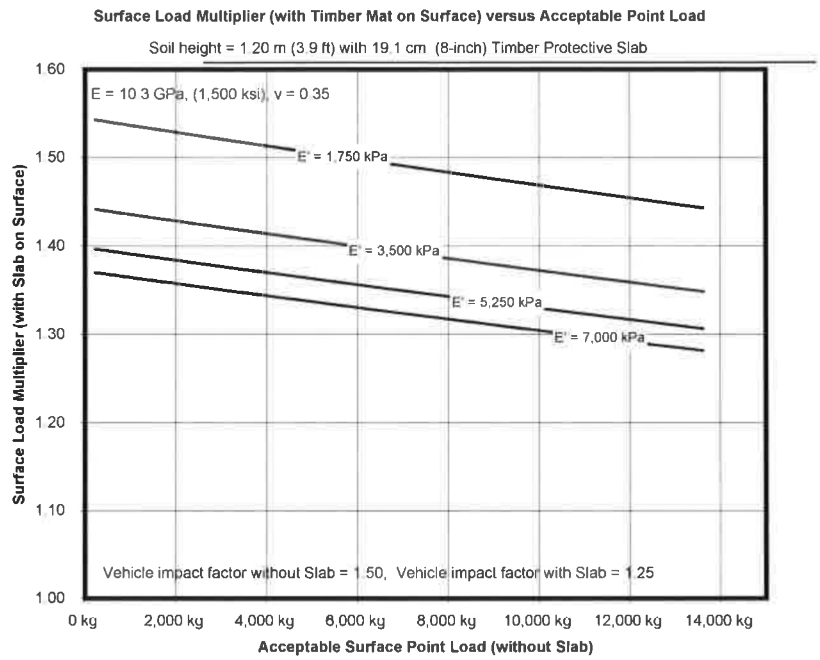

Figure C-5(c) – Soil Height = 1.2 meters

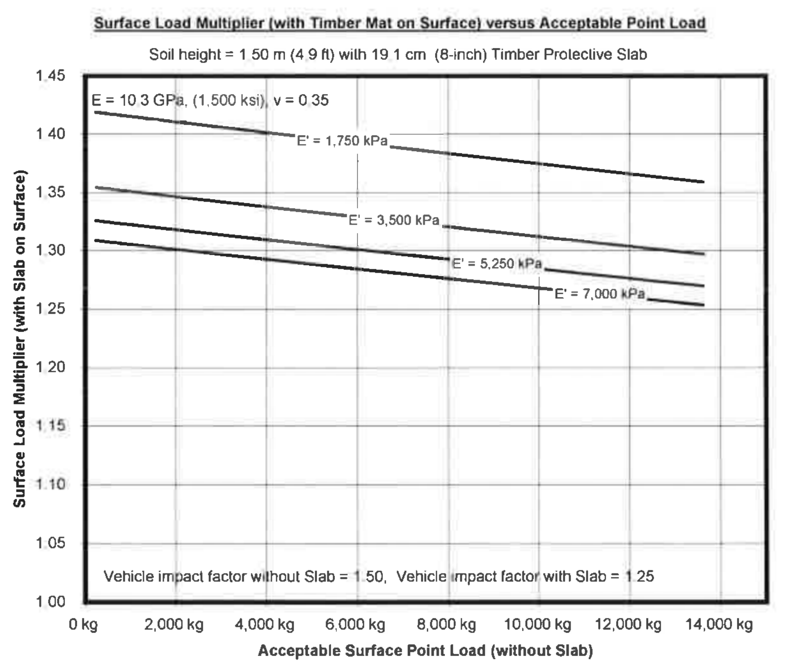

Figure C-5(d) – Soil Height = 1.5 meters

APPENDIX D:

Proposed Guideline – Equipment with Low Surface Contact Pressure Crossing of Existing Pipelines

Where practical, crossings of pipelines shall occur at designated locations along the right-of-way preferably at purpose-built locations such as roads designed for such use. In situations where existing pipelines are to be crossed at locations not specifically designed as a crossing location, it shall be permissible to cross the pipeline by equipment imposing low surface contact loads provided that the following requirements are met:

a. The crossing of the pipeline is infrequent.
b. The pipeline is suitable for continued service at the established operating pressure. The pipeline operator shall consider service history and anticipated service conditions in this evaluation.
c. The piping is not subjected to significant secondary stresses, other than those directly imposed by the crossing of the pipeline.
d. The anticipated surface loading is below that provided in Figure D-1(a) through D-1(f).

As an alternative to the above requirements, an engineering assessment of site-specific conditions is acceptable. This detailed engineering analysis shall consider the resulting combined stresses on the pipeline as a result of all loads expected to be imposed during its usage as a crossing location.

> Note: Figures D-1(a) thru D-1(f) utilize a 60 degree bedding angle. A 30 degree angle is typically utilized and is representative of open trench construction with relatively unconsolidated backfill such that the full bearing support of the pipe is not achieved. While this is an acceptable and generally conservative value to utilize for a newly constructed pipeline, a 60 degree bedding angle has been utilized to reflect a mature pipeline where soil has re-consolidated around the pipeline providing additional support.
>
> Note: Figures D-1(a) thru D-1(f) utilize an Impact Factor of 1.25 versus 1.50 to take into account that equipment with low surface contact pressures are:
>
> Typically designed not to compact the soil strata.
>
> Designed to utilize low pressure pneumatic tires with contact pressure < 200 kPa(ga) (30 psig
>
> Designed to operate at lower velocities < 15 kph. (10 mph)

Figures D-1(a) through D-1(f)

Figure D-1(a) through D-1(f) present the maximum live surface "point" load in kilograms for cover depths of 60cm, 90 cm, 120 cm & 150 cm and design operating pressures of 72% SMYS and 80% SMYS.

Notes applicable to Figures D-1(a) through (f):

1) For intermediate operating pressure or grades, it shall be permissible to determine the surface load by interpolation.
2) Design conditions used to develop the table are as follows:
    - Depth of cover as indicated
    - Maximum hoop stress of 72% or 80% percent SMYS as indicated
    - Maximum combined circumferential stress of 100 percent SMYS
    - Surface loading based on a contact pressure of 207 kPa (30 psi) applied over a rectangular area with aspect ratio (y/x) = 1
    - Fluctuating stress limitation of 82.7 MPa (12 ksi) based upon 2,000,000 cycles
    - Maximum D/t ratio of 125.
    - Soil Modulus E' = 1,724 kPa at pipe.
    - Soil Density = 1,922 kg/m^3
    - Loading criteria includes an impact factor of 1.25.
    - Maximum combined effective stress of up to 100 percent SMYS.
    - A temperature differential of $\Delta T = 50°$ C or the maximum temperature limitation as per CSA Clause 4.6.2.1 (section 2 above) whichever is the lower is included in the calculated the longitudinal stress.
    - A 60 degree bedding angle has been utilized reflecting a mature pipeline where the soil has re-consolidated around the pipeline providing additional support.
    - Multiple wheel influence factor (if applicable)

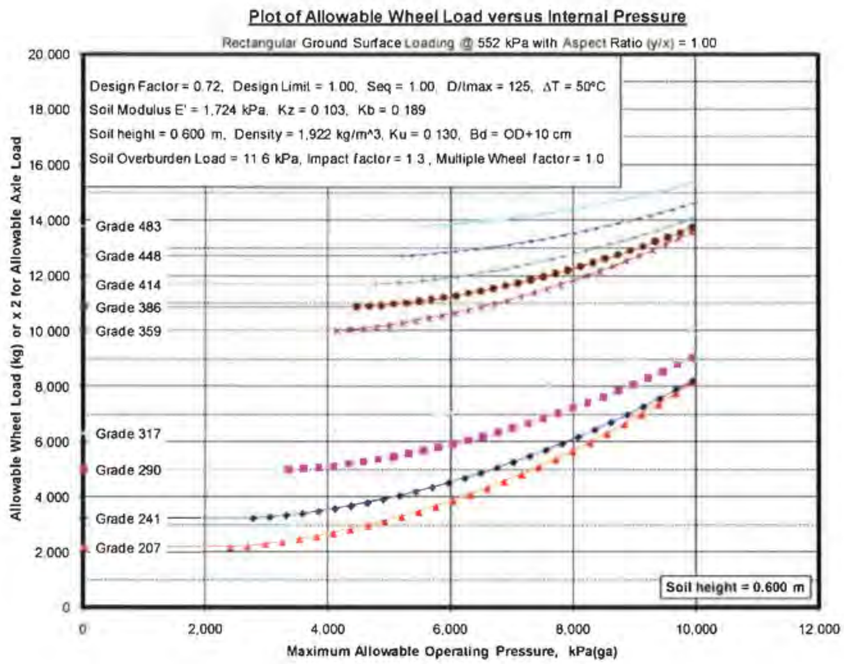

Figure D-1(a) – Soil Height = 0.60 meters, DF = 0.72

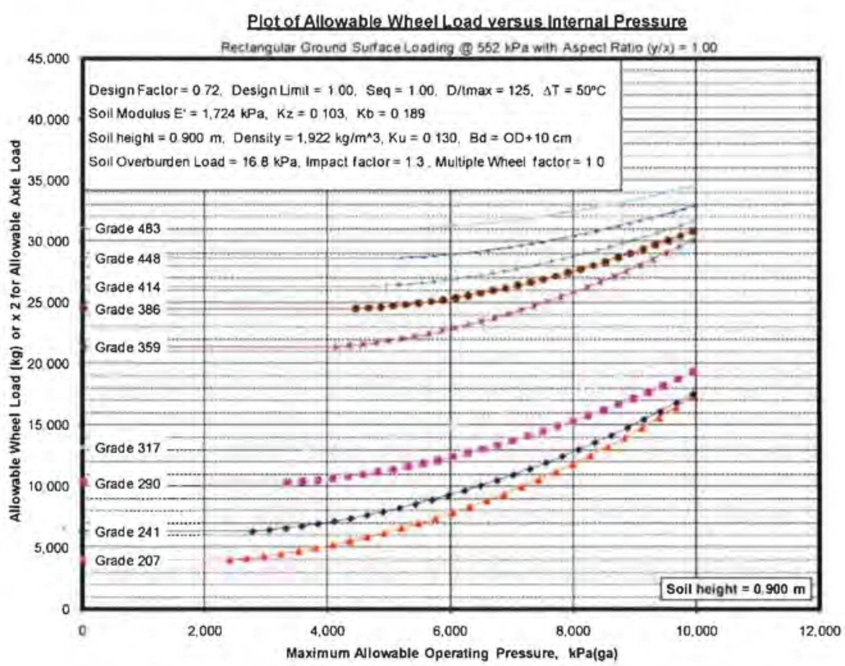

Figure D-1(b) – Soil Height = 0.90 meters, DF = 0.72

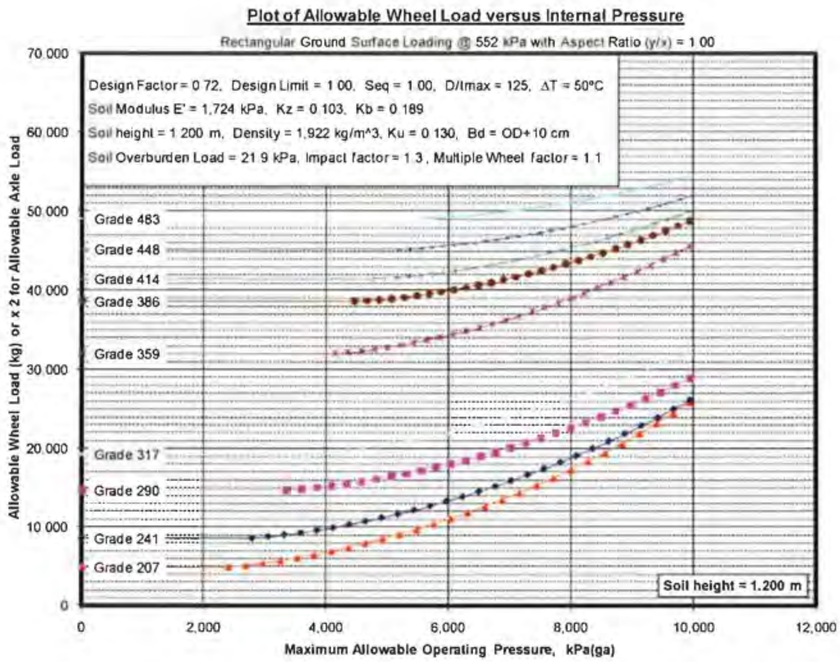

Figure D-1(c) – Soil Height = 1.2 meters, DF = 0.72

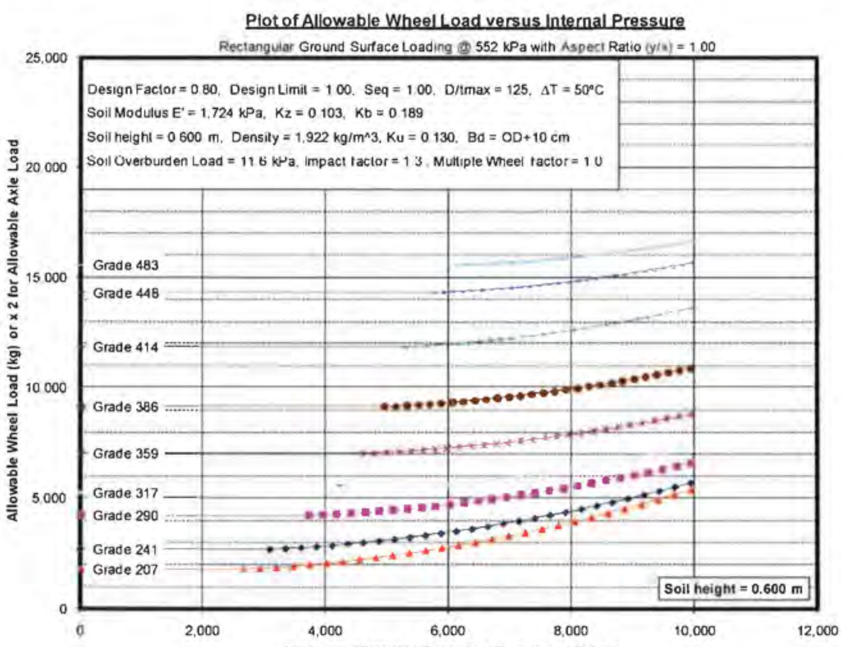

Figure D-1(d) – Soil Height = 0.6 meters, DF = 0.8

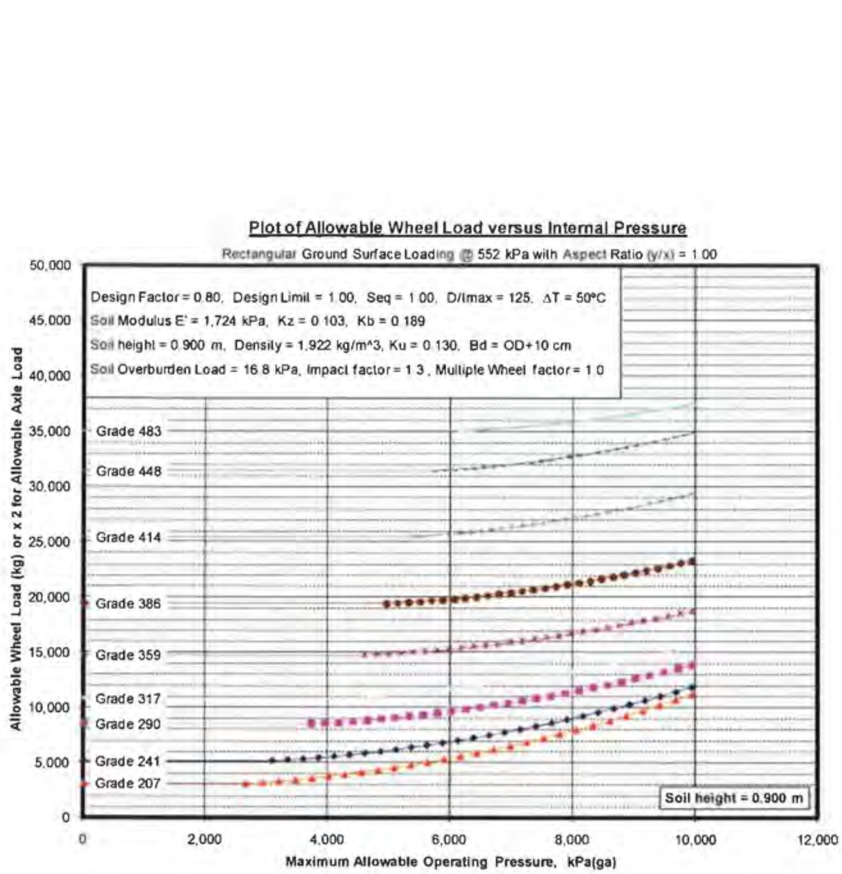

Figure D-1(e) – Soil Height = 0.9 meters, DF = 0.8

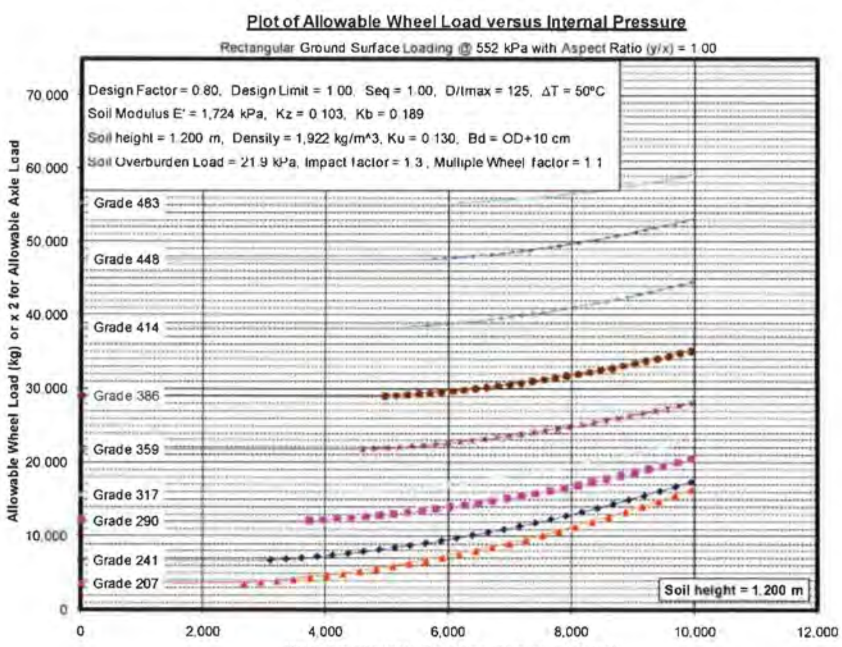

Figure D-1(f) – Soil Height = 1.2 meters, DF = 0.8

Surface Load Multiplier for Rectangular Footprint and Various Contact Pressure Figures D-2(a) through D-2(d)

Figure D-2(a) through D-2(d) present the Load Multiplier that can be applied to the previous determined allowable live surface load for surface loads applied over a square footprint with contact pressures ranging from 35 kPa through 420 kPa (5 psi through 60 psi). The figures apply for cover depths of 60 cm, 90 cm, 120 cm, and 150 cm (2ft, 3ft, 4ft, 5ft).

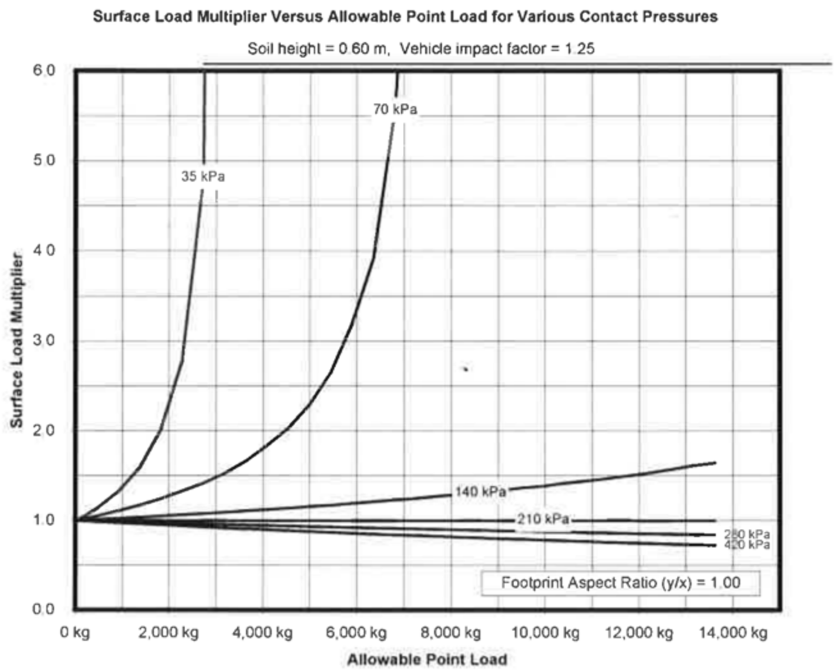

Figure D-2(a) – Soil Height = 0.6 meters

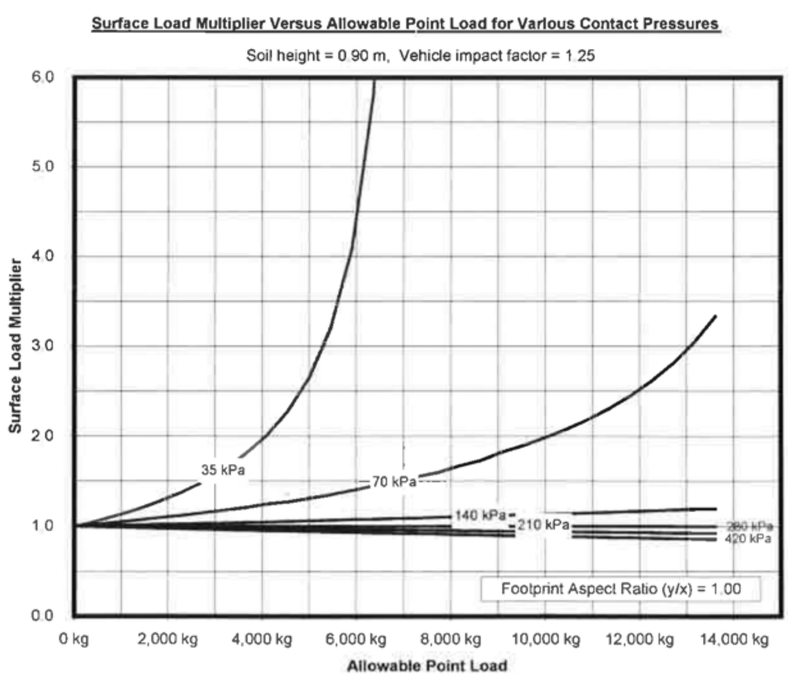

Figure D-2(b) – Soil Height = 0.9 meters

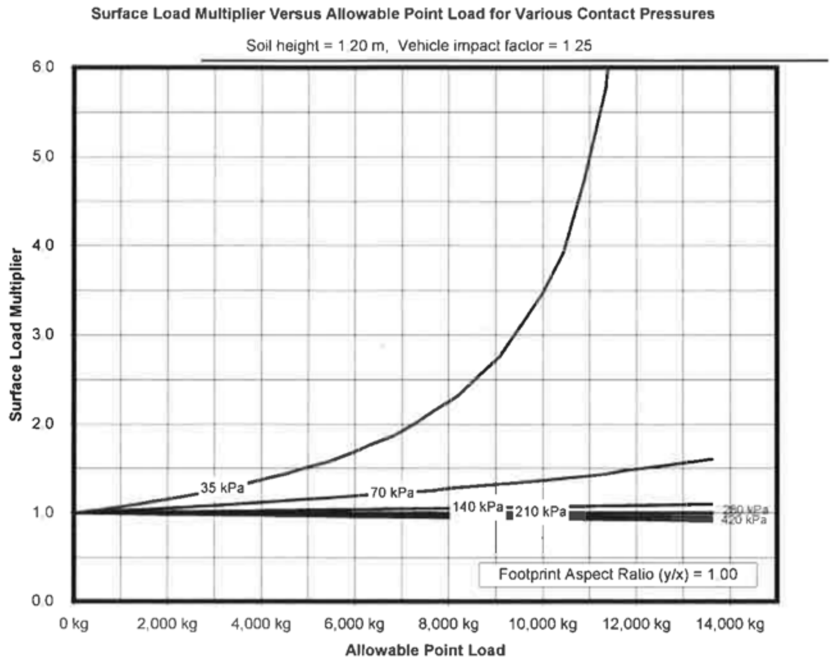

Figure D-2(c) – Soil Height = 1.2 meters

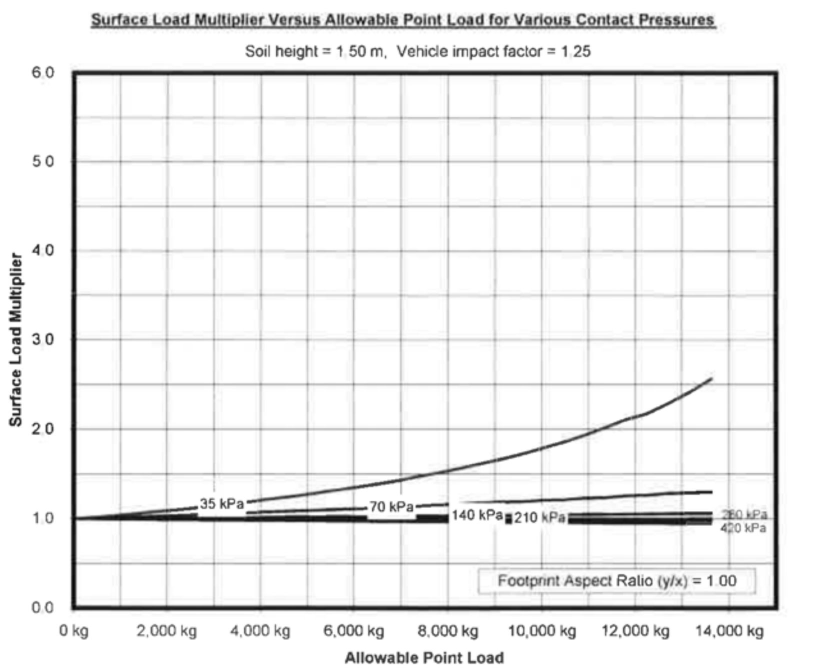

Figure D-2(d) – Soil Height = 1.5 meters

Vermont Gas

ARNGP PROJECT DIRECTIVE

Date: 8/31/2015

Subject: General Backfill Materials

Directive Number: 2015 – 007

In 2.1(B) – Materials of Section 312333 – Trenching, Pipe Laying, and Backfilling of the Technical Specifications, it states native materials containing no stones or clods larger than 3" in the longest dimension are acceptable for general backfill. This directive will serve as notice that native materials containing no stones or clods larger than 6" in the longest dimension are acceptable for general backfill.

The VGS Operations and Maintenance Manual in the Trenching and Backfilling Procedure allows for this change to the specification and now the two documents will be consistent.

Issued by (print): Kristy Oxholm (for Christopher LeForce)

Signature: KMOxholm

This directive expires on 12/31/2015 unless superseded or cancelled prior to that date.

From: John Stamatov (US - Advisory) <john.r.stamatov@pwc.com>
Sent: Tuesday, May 24, 2016 1:11 PM
To: John St.Hilaire
Subject: Compaction Test Results - Rocky Ridge
Attachments: 15303 Compaction.pdf

John,

See attached. Line items 10-12 are for Rocky Ridge (all above 90%).

VELCO (Peter Lind) has received all compaction test results to date.

--
John R. Stamatov
PwC Capital Projects & Infrastructure
774-262-9290

KNIGHT CONSULTING ENGINEERS, INC.
51 KNIGHT LANE
WILLISTON, VT 05495

FIELD COMPACTION REPORT

For Vermont Gas Systems **Project** Vermont Gas Testing **KCE #** 15303

Test No.	Date Tested	Location	Elevation	Soil Description	In-Place Dry Density (pcf)	Moisture Content (%)	Maximum Dry Density (pcf)	Optimum Moisture %	Percent Compaction %	Intl
1	09-18-15	Compaction Fill Over Gas Line – STA. 158+60	Finish Grade ±	Site Material – Thru Shaker Bucket (1½" Minus Silty Gravel)	114.1	7.0	136.4	7.1	83.7	pr
2	09-18-15	Compaction Fill Over Gas Line – STA. 158+65	18"± Below Finish Grade	Site Material – Thru Shaker Bucket (1½" Minus Silty Gravel)	113.8	5.7	136.4	7.1	83.4	pr
3	10-15-15	VELCO – Entrance Gate	6" Below Finish Grade	Site Material – Thru Shaker Bucket (1½" Minus Silty Gravel)	134.4	4.6	136.4	7.1	96.9	bjl
4	10-15-15	Center of Overhead Lines	2' Below Finish Grade	Site Material – Thru Shaker Bucket (1½" Minus Silty Gravel)	138.1	138.1	136.4	7.1	100+	bjl
5	10-15-15	Left Hand Edge VELCO Row	2' Below Finish Grade	Site Material – Thru Shaker Bucket (1½" Minus Silty Gravel)	136.0	136.0	136.4	7.1	99.7	bjl
6	10-19-15	VELCO Redmond Road – STA. 456+20	1'± Below Top of Soil	Redmond Road Native Backfill	106.1	22.7	127.1	9.7	①②83.5	kp
7	10-19-15	VELCO Redmond Road – STA. 456+60	1'± Below Top of Soil	Redmond Road Native Backfill	105.0	18.0	127.1	9.7	①②82.6	kp
8	10-19-15	VELCO Redmond Road – STA. 456+97	1'± Below Top of Soil	Redmond Road Native Backfill	109.7	19.6	127.1	9.7	①②86.3	kp
9	04-15-16	Fill Over Gas Line , 75' South of Power Line	Finish Gravel	Crushed Run Gravel	115.5	7.3	136.9	9.3	③84.4	pr
10	04-15-16	Retest of #9	Finish Gravel	Crushed Run Gravel	124.7	6.0	136.9	9.3	91.1	pr
11	04-18-16	Under Power Line	Finish Gravel	Crushed Run Gravel	124.9	3.2	136.9	9.3	91.2	bjl
12	04-18-16	75' North of Power Line	Finish Gravel	Crushed Run Gravel	127.6	4.0	136.9	9.3	93.2	bjl

Distribution List: Vermont Gas – Lesli Nichols; Wilson Consulting Engineers – Joey Wilson; Pricewaterhousecoopers – John Stamatov & Efrain Mazariegos

Remarks: ①90% Minimum compaction effort required.

②Contractor to further compact areas for retesting.

③Contractor further compacted area with larger plate compactor. Two trips to site due to retesting.

Submitted by: Brian J. Lymaster/nmv

From: Reagan, Michael J <Michael.Reagan@mottmac.com>
Sent: Wednesday, June 29, 2016 7:51 PM
To: John St.Hilaire
Cc: john.r.stamatov@pwc.com; Chris LeForce
Subject: Re: GC Issue Compaction

I did to we went thru it hope CHA did it. I though this was all set . We look into it tomorrow morning

Get Outlook for Android

On Wed, Jun 29, 2016 at 7:49 PM -0400, "John St.Hilaire" <jsthilaire@vermontgas.com> wrote:

I thought we took that out?

Sent from my iPhone

On Jun 29, 2016, at 7:49 PM, Reagan, Michael J <Michael.Reagan@mottmac.com> wrote:

> Compaction the orginal spec.
>
> Get Outlook for Android
>
> On Wed, Jun 29, 2016 at 7:47 PM -0400, "John St.Hilaire" <jsthilaire@vermontgas.com> wrote:
>
> Compaction or placing pipe on bottom of trench?
>
> Sent from my iPhone
>
> On Jun 29, 2016, at 7:45 PM, Reagan, Michael J <Michael.Reagan@mottmac.com> wrote:
>
>> Gentleman
>>
>> GC is back on the issue if compaction on the VELCO easement . Just a heads up, he talked to some operators today. So except a call tomorrow. I was just notified by the VELCO inspector
>>
>> Mike
>>
>> Get Outlook for Android
>>
>>

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AC INTERFERENCE ANALYSIS
&
MITIGATION SYSTEM DESIGN

Prepared for:

Vermont Gas System

12" Addison Natural Gas Project

Chittendon & Addison Counties, Vermont

Prepared By:

Report Issued: May 20, 2016

ARK Engineering & Technical Services, Inc.
639 Granite Street, Suite 200
Braintree, MA 02184
Phone: 781-849-3800
Fax: 781-849-3810

For information, please contact:
Mr. James Smith
Report Number: R-12144-AC
ISSUED FOR CONSTRUCTION

EXECUTIVE SUMMARY

This report summarizes the results of an AC interference analysis for Vermont Gas System on the proposed Vermont Gas 12" pipeline. This proposed pipeline will be subject to AC electrical interference effects from the following electric transmission circuits which will parallel and cross the proposed pipeline:

- Ten (10) Vermont Electric Power (VELCO) electric transmission circuits
- One (1) Green Mountain Power (GMP) electric transmission circuit

The proposed pipeline length under study is approximately 41.2 miles.

This final report presents the predicted AC interference pipeline potentials during future emergency peak load conditions on the VELCO circuits, as provided by VELCO. Fault conditions on these circuits were also simulated to determine AC inductive and conductive coupling effects to the proposed pipeline.

Green Mountain Power did not provide electric circuit data, therefore, based upon previous experience, ARK Engineering assumed peak emergency load currents and fault current values to predict worst-case scenarios caused by inductive and conductive AC electrical interference effects by the GMP transmission circuit to this proposed pipeline.

The results of this study indicate that AC steady state interference voltage levels are calculated above the design limit of thirty (30) Volts at non-exposed pipeline locations and fifteen (15) Volts at exposed pipeline locations at several locations along this proposed pipeline route.

For the proposed pipeline under study, a maximum computed induced AC pipeline potential of approximately one hundred and thirty-nine (139) Volts, with respect to remote earth, occurs at pipeline station number 2087+16. At this location, the proposed pipeline leaves the shared right-of-way with two (2) VELCO electric transmission circuits.

During simulated single phase-to-ground fault conditions on the electric transmission circuits, the maximum total pipeline coating stress voltage level was computed. This is the sum of the inductive and conductive AC interference effects on the proposed pipeline. The maximum pipeline coating stress voltage was calculated at four thousand six hundred and fourteen (4,614) Volts at pipeline station number 1547+10. At this location, the proposed 12" pipeline will parallel the VELCO 115 kV 'K43' electric transmission circuit.

This coating stress voltage level is below the design limit of five thousand (5,000) Volts.

The following six (6) aboveground pipeline appurtenances were analyzed for touch and step hazards due to their proximity to the electric transmission circuits:

- Williston M&R: MP 10.43
- MLV-2: MP 14.30
- MLV-3: MP 19.81
- MLV-4: MP 24.80
- MLV-5/ Plank Rd. M&R: MP 32.54
- MLV-6: MP 35.00

The computed touch and step voltages were above the IEEE Standard 80 design limit at each location. Additional AC mitigation is recommended at each site.

AC current density calculations associated with AC corrosion mechanisms were conducted for this proposed pipeline.

The AC mitigation system designs proposed by ARK Engineering in this report reduce the pipeline AC electrical interference effects to acceptable levels during steady state and fault conditions on the electric transmission circuits, for personnel safety and pipeline integrity.

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APPENDIX A – SOIL RESISTIVITY DATA & GPS DATA
APPENDIX B – PIPELINE STEADY STATE, AC CURRENT DENSITY & FAULT PLOTS

- Steady State Induced
- AC Current Density
- Fault – Coating Stress Voltage
- Fault – Touch & Step Voltage

APPENDIX C – POWER & PIPELINE COMPANY DATA
APPENDIX D – ARK Engineering Design Drawing

1. INTRODUCTION

1.0 Introduction

ARK Engineering & Technical Services, Inc. was contracted to investigate AC electrical interference effects on the proposed Vermont Gas 12" pipeline. AC electrical interference effects may occur on this proposed pipeline due to the proximity of ten (10) VELCO electric transmission circuits and one (1) GMP electric transmission circuit. The proposed pipeline under study is approximately 41.2 miles in total length, and is located in Chittenden and Addison Counties, Vermont.

This report presents the computed steady state induced AC pipeline potentials for this pipeline. Simulated fault conditions on the electric transmission circuits were also modeled to determine pipeline coating stress voltages for this pipeline.

Emergency peak load and fault current values, provided by VELCO or conservatively estimated by ARK Engineering, based on industry experience, were used to predict worst-case scenarios caused by inductive and conductive AC electrical interference effects to this pipeline.

This report summarizes this analysis and outlines ARK Engineering's recommendations for mitigation of AC electrical interference effects on this proposed pipeline. The proposed mitigation system design, as outlined in this report, will reduce the AC electrical interference effects on the pipeline to acceptable limits.

The conclusions in this report are based upon field data, pipeline data provided by Vermont Gas System, and power line data provided by VELCO or assumed by ARK Engineering for the GMP circuit. Calculations and analysis were performed using state-of-the-art modeling software.

1.1 Joint Facility Corridor Overview

The proposed 12" pipeline will travel through Chittenden and Addison Counties, Vermont. This proposed pipeline is approximately 41.2 miles in length. All station numbers outlined in this report are based on the pipeline alignment plans - Vermont Gas Proposed 12" Pipeline Addison Natural Gas Project - EPSC Plan issued 4/16/2013.

The areas of concern where the proposed pipeline will parallel or cross the electric transmission circuits, are outlined below:

- At pipeline station number 69+50, the pipeline will cross the VELCO 115 kV K22 electric transmission circuit.

- At pipeline station number 159+00, the pipeline will cross the VELCO 115 kV 'K21' electric transmission circuit.
- From pipeline station number 328+00 to 333+50, the pipeline will parallel and cross the 'GMP' electric transmission circuit.
- At pipeline station number 456+50, the pipeline will cross the VELCO 115 kV 'K24' electric transmission circuit.
- From pipeline station number 535+00 to 606+50, the pipeline will parallel the VELCO 115 kV 'K23' electric transmission circuit.
- At pipeline station number 606+50, the pipeline will pass in front of the VELCO 'Taft's Corner' electric substation.
- From pipeline station number 606+50 to 717+00, the pipeline will parallel and cross the VELCO 115 kV 'K27' electric transmission circuit.
- At pipeline station number 606+50, the pipeline will pass in front of the VELCO 'Williston' electric substation.
- At pipeline station number 717+50, the pipeline will pass the VELCO 115 kV 'K33' electric transmission circuit which ties into the VELCO 'Williston' electric substation.
- From pipeline station number 718+50 to 1854+50, the pipeline will parallel and cross the VELCO 115 kV 'K43' electric transmission circuit.
- From pipeline station number 1813+50 to 1854+50, the pipeline will parallel and cross the VELCO 115 kV 'K64' electric transmission circuit.
- At pipeline station number 1857+00, the pipeline will pass in front of the VELCO 'New Haven' electric substation.
- From pipeline station number 1859+00 to 2087+75, the pipeline will parallel and cross the VELCO 115 kV 'K63' electric transmission circuit.
- From pipeline station number 1859+50 to 2087+75, the pipeline will parallel and cross the VELCO 115 kV 'K370' electric transmission circuit.

When metallic pipelines are located in shared rights-of-way with high voltage electric transmission circuits, the pipelines can incur high induced voltages and currents due to

AC interference effects. This situation can cause a number of safety issues if not mitigated effectively. The possible effects of this AC interference can include: personnel subject to electric shock up to a lethal level, accelerated corrosion, arcing through pipeline coating, arcing across insulators, disbondment or degradation of coating, or possibly perforation of the pipeline.

AC interference simulation programs were used as part of this project to model the right-of-way (ROW) and estimate the levels of induced and conductive AC voltage on the proposed pipeline. These programs can also be used to evaluate the effectiveness of any proposed mitigation system design.

1.2 Objectives & Project Tasks

The primary objectives of this study were as follows:

1.2.1 Determine the AC electrical interference effects to the proposed pipeline during steady state and fault conditions on the eleven (11) electric transmission circuits.

1.2.2 If required, recommend AC mitigation methods to reduce the induced steady state AC pipeline potentials and touch voltages to less than 30 Volts at all buried locations on the pipeline.

1.2.3 If required, recommend AC mitigation methods to reduce the induced steady state AC pipeline potentials and step and touch voltages to less than 15 Volts at all above ground appurtenances.

1.2.4 If required, recommend mitigation methods to reduce fault-induced coating-stress voltages on the pipeline to less than 5,000 Volts, for protection of the pipeline coating.

1.2.5 If required, recommend mitigation methods for aboveground pipeline locations, such as valve sites and meter stations.

1.2.6 Assess the induced AC density on the pipeline for the potential threat of AC corrosion effects.

1.2.7 Perform calculations to determine the likelihood of AC corrosion effects to this proposed pipeline, based upon the installation of an AC interference mitigation system.

1.2.8 If AC corrosion effects are likely, based upon these calculations, determine if additional mitigation is required to reduce or eliminate the likelihood of AC corrosion effects.

The project tasks associated with this portion of the AC interference analysis and mitigation study consist of the following:

1.2.9 Soil Resistivity Analysis - Soil Resistivity measurements were taken along the proposed pipeline. An equivalent multi-layer soil model was obtained from these measurements using the modeling software. This model was then applied to subsequent simulation steps. This task is described in Chapter 2, and detailed results are presented in Appendix A.

1.2.10 Inductive Interference Analysis - Circuit models for the proposed pipeline and electric circuits were developed and used to determine magnetically induced pipeline potentials during steady state and fault conditions on the electric transmission circuits. This task is described in Chapter 3, and detailed results are presented in Appendix B.

1.2.11 Conductive Interference Analysis - The effects of single line-to-ground faults of nearby electric transmission circuits on the proposed pipeline in proximity was studied. These results were used to calculate coating-stress voltages along the pipeline. This task is described in Chapter 3, and detailed results are presented in Appendix B.

1.3 A BRIEF PERSPECTIVE ON ELECTROMAGNETIC INTERFERENCE MECHANISMS

The flow of energy transmitted by electric power is not totally confined within the power conductors. However, the spatial density of energy in the environment surrounding these circuits decreases sharply with an increase in distance from the conductors. Metallic conductors such as pipelines that are located near electric transmission circuits may capture a portion of the energy encompassed by the conductors' paths, particularly under unfavorable circumstances such as long parallel exposures and fault conditions. In such cases, high currents and voltages may develop along the conductors' lengths. Energy may also flow directly from power installations to pipeline installations via conductive paths common to both.

The electromagnetic interference mechanisms at low frequencies have been traditionally divided into three (3) categories: capacitive, inductive and conductive coupling. These categories and their possible effects are illustrated in Figure 1-1.

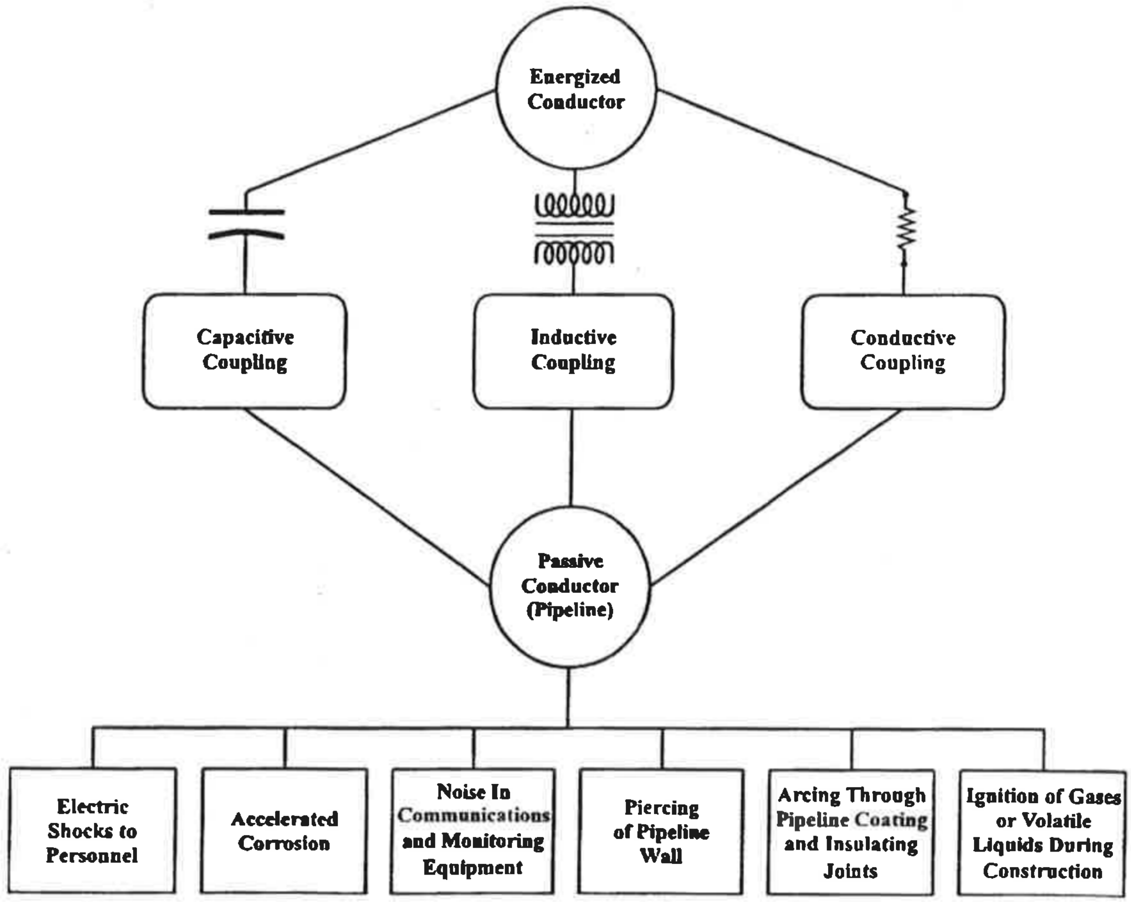


Figure 1-1: Interference Mechanisms and Effects on Pipeline

1.3.1 Capacitive Coupling

Mechanism:

Electrostatic or capacitive coupling results from the electric field gradient established between energized transmission line conductors and the earth. When the transmission line voltage is very high, a significant electric field gradient exists in the neighborhood of the transmission line. Large conductors, which are near and parallel to the transmission line and insulated from the earth, are liable to accumulate a significant electric charge, which represents a very real danger for personnel. Typically, such conductors include: equipment isolated from the earth, vehicles with rubber tires, aboveground pipelines, or pipelines under construction in dry areas when no precautions have been taken to establish adequate grounding for the pipeline lengths not yet installed in the ground. Hazards range from slight nuisance shocks to ignition of nearby volatile liquids with the accompanying risk of explosion, or electrocution of personnel.

Mitigation Measures:

Buried pipelines are relatively immune to interference due to capacitive coupling because, despite even an excellent coating, the length of exposure to the surrounding soil makes for an adequate ground to dissipate any significant charge that might otherwise accumulate. Aboveground pipelines, including pipelines under construction (which may or may not be buried in part) do not naturally have this protection. One means of protection is periodic grounding to earth, via ground rods, or other ground conductors judiciously placed so as to be unaffected by ground currents emanating from nearby towers during a fault.

1.3.2 Inductive Coupling

Mechanism:

Electromagnetic or inductive interference in a passive conductor (pipeline) results from an alternating current in another energized conductor (power line), which is more or less parallel to the first. This level of interference increases with decreasing separation and angle between the conductors, as well as with increasing current magnitude and frequency in the energized conductor. The combination of a high soil resistivity and passive conductors with good electrical characteristics (good coating, high conductivity and low permeability) also result in high-induced currents.

Peak potential values occur at discontinuities in either the energized or the passive conductor. When a transmission line and a pipeline are interacting, such discontinuities take the form of rapid changes in separation between the pipeline and transmission line, termination of the pipeline or an insulating junction in the pipeline (which amounts to the same thing), sudden changes in pipeline coating characteristics, a junction between two (2) or more pipelines or transposition of transmission line phases. Note that the induction effects on pipelines during normal power line operating conditions are small compared to the induction effects experienced by a pipeline during a power line fault. The most severe kind of fault is a single-phase-to-ground fault during which high currents circulate in one of the power line phases and are not attenuated by any similar currents in other phases. Hence, mitigation methods, which suffice for single-phase fault conditions, are often adequate for other conditions. It must be noted however, that the longer duration of the resulting potentials in the pipeline during steady state conditions makes the problem important to investigate from a perspective of human safety.

Unlike conductive interference, which tends to be a rather local phenomenon, inductive interference acts upon the entire length of the pipeline that is near to the power lines. Note, however, that conductive interference can involve long sections of a pipeline if several towers adjacent to the faulted tower discharge a significant portion of the fault current, or if a ground conductor connected to the pipeline (anode) and located near a faulted tower, picks up current from the soil.

The large potentials induced onto a pipeline during a fault can destroy insulated junctions, pierce holes in lengths of coating, and puncture pipeline walls. Equipment electrically connected to the pipeline, such as cathodic protection devices, communications equipment, and monitoring equipment can be damaged, and personnel exposed to metallic surfaces, which are continuous with the pipeline, can experience electrical shocks. Accelerated corrosion is another possible result. Implementing appropriate mitigative measures, as discussed below, can prevent this situation.

Although a pipeline equipped with mitigative measures appropriate to deal with phase-to-ground faults does not usually present a great safety hazard during normal conditions, several problems can still exist due to low magnitude induced alternating currents. Accelerated corrosion of steel can result if not offset by increased cathodic protection. This may mean a shortened life for sacrificial and impressed current anode beds. Small amounts of AC can also render impractical the use of a pipeline as a communication channel for data such as pressure and temperature readings to pumping and compressor stations.

Mitigation Measures:

Pipeline Coating Resistance - The coating resistance of the pipeline should be chosen as low as corrosion considerations permit. Pipeline coating resistance plays an important role in determining pipeline potentials during a fault condition. During a fault condition, on an electric transmission circuit, the pipeline coating conducts significant amounts of current and should be regarded more as a poor grounding system than an insulator. When this perspective is assumed, it is seen that lowering pipeline coating resistance and bonding grounded conductors to the pipeline steel are two (2) applications of the same principle.

Pipeline Section Length - In theory, the potential induced electromagnetically in a pipeline section insulated at both ends is roughly proportional to the length of the exposed region. When this relationship no longer holds, the pipeline is said to have exceeded its characteristic length. The maximum potential value in a section (with respect to remote ground) occurs at each extremity with roughly the same magnitude and opposite phase. This means that each insulating junction is subjected to a stress voltage that is double the peak value in the section. If insulating junctions are inserted frequently enough along a pipeline, then the section size is kept to a minimum, and consequently, so are the peak voltages in the pipeline. This constitutes one possible mitigation method. However, this thorough segmentation can result in very high construction and pipeline cathodic protection costs.

Grounding - Grounding of a pipeline, as a protection against the significant voltages that appear during an electrical fault condition, is one of the most effective mitigation measures available. A pipeline should be grounded at appropriate locations throughout its length. Typical grounding locations include: all termination points, both extremities of a segment which is grounded at both ends by an insulating junction, just before and just after a pipeline crosses a power line at a shallow angle, and any other important point of discontinuity likely to result in high induced voltages during a fault condition. Such points include locations where the passive conductor:

- Suddenly veers away from the power line.
- Suddenly changes coating characteristics.
- Emerges from the earth, or returns to the earth.

Other locations where high-induced voltages are likely include points where power line phases are transposed and points where two (2) or more pipelines meet.

In order not to load cathodic protection installations significantly, grounds should be made of an adequate sacrificial material such as zinc or should be made via solid-state-isolator or polarization cells. These DC decoupling devices (DCD) should be properly sized, spaced and physically secured to withstand the current resulting during a power line fault. Caution should be taken to locate grounds far enough away from any nearby power line structure, so that the soil potential near the ground does not rise to undesirable values during a power line fault condition. Soil potentials drop off rather quickly around a faulted structure injecting currents into the earth, so this is not an extremely difficult proposition.

Buried Mitigation Systems - A highly effective means of mitigating excessive AC pipeline potentials is the installation of gradient control wires or matting. These methods reduce both inductive and conductive interference. These gradient control wires consist of one or more bare conductors which are buried parallel and near to the pipeline and which are regularly connected to the pipeline. These wires provide grounding for the pipeline and thus lower the absolute value of the pipeline potential (i.e., the potential with respect to remote earth). They also raise earth potentials in the vicinity of the pipeline such that the difference in potential between the pipeline and local earth is reduced. As a result, touch voltages are significantly reduced.

1.3.3 Conductive Coupling

Mechanism:

When a single-phase-to-ground fault occurs at a power line structure, the structure injects a large magnitude current into the earth raising soil potentials in the vicinity of the structure. If a pipeline is located near such a faulted structure, then the earth around the pipeline will be at a relatively high potential with respect to the pipeline potential. The pipeline potential will typically remain relatively low, especially if the pipeline coating has a high resistance. The difference in potential between the pipeline metal and the earth surface above the pipeline is the touch voltage to which a person would be subjected when standing near the pipeline and touching an exposed metallic appurtenance of the pipeline.

If the pipeline is perpendicular to the power line, then no induction will occur and the conductive component described above will constitute the entirety of the touch voltages and coating stress voltages appearing on the pipeline. If the pipeline is not perpendicular to the power line, then an induced potential peak will appear in the pipeline near the fault location. Based on previous interference studies, the induced potential peak in the pipeline is typically on the order of one hundred and fifty-five degrees (155°) out of phase with the potential of the faulted structure and therefore with the potentials of the soil energized by the structure. Thus, the pipeline steel potential due to induction is essentially opposite in sign to the soil potentials due to conduction. Therefore, inductive and conductive effects reinforce each other in terms of coating stress voltages and touch voltages.

Mitigation Measures:

The magnitude of the conductive interference is primarily a function of the following factors:

i) GPR of Transmission Line Structure. Soil potentials and touch voltages due to conductive coupling are directly proportional to the ground potential rise (GPR) of the transmission line structure. This GPR value is a property of the entire transmission line system.

ii) Separation Distance. Although soil potentials and therefore touch voltages obviously decrease with increasing distance away from the faulted structure, the rate of decrease varies considerably from site to site, depending upon the soil structure, as described below.

iii) Size of Structure Grounding System. Soil potentials decrease much more sharply with increasing distance away from a small grounding system than that from a large grounding system. Conductive interference can be minimized by limiting the use of counterpoise conductors and ground rods, by the power company, at sites where pipelines are in close proximity to the electric transmission system structures.

iv) Soil Structure. When the soil in which the structure grounding system is buried has a significantly higher resistivity than the deeper soil layers (particularly if the lower resistivity layers are not far below the structure grounding system), earth surface potentials decay relatively sharply with increasing distance away from the structure. When the inverse is true, i.e., when the structure grounding system is in low resistivity soil, which is under laid by higher resistivity layers, earth surface potentials may decay very slowly.

v) Pipeline Coating Resistance. When a pipeline has a low ground resistance (e.g., due to coating deterioration over time), the pipeline collects a significant amount of current from the surrounding soil and rises in potential. At the same time, earth surface potentials in the vicinity of the pipeline decrease due to the influence of the pipeline. As a result, the potential difference between the pipeline and the earth surface can be significantly reduced.

When a conductive interference problem is present, touch voltages can be reduced by: either reducing earth surface potentials in the vicinity of the pipeline, raising the pipeline potentials near the faulted structure, or a combination of these two (2) actions. The most effective mitigation systems perform both of these actions.

1.4 A BRIEF PERSPECTIVE ON AC CORROSION MECHANISMS

1.4.1 AC Corrosion Mechanism

AC corrosion is the metal loss that occurs from AC current leaving a metallic pipeline at a coating holiday. The mechanism of AC corrosion occurs when AC current leaves the pipeline through a small holiday in low resistance soil conditions.

1.4.2 Mitigation of AC Corrosion

The main factors that influence the AC corrosion phenomena are:

- Induced AC pipeline voltage
- DC polarization of the pipeline
- Size of coating faults (holidays)
- Local soil resistivity at pipe depth

The induced AC pipeline voltage is considered the most important parameter when evaluating the likelihood of AC corrosion on a buried pipeline section.

The likelihood of AC corrosion can be reduced through mitigation of the induced AC pipeline voltage. The European Standard CEN/TS 15280:2006 "Evaluation of AC Corrosion Likelihood of Buried Pipelines - Application to Cathodically Protected Pipelines" recommends that AC pipeline voltages should not exceed the following:

- Ten (10) Volts where the local soil resistivity is greater than 25 ohm-meters.
- Four (4) Volts where the local soil resistivity is less than 25 ohm-meters.

These AC pipeline voltage limits are derived in part by calculating AC density at pipeline coating holidays. Since the AC current is mainly discharged to earth through the exposed steel at pipeline coating holidays, the AC corrosion rate can vary proportionately with increasing AC density at a coating holiday.

European Standard CEN/TS 15280, offers the following guidelines:
The pipeline is considered protected from AC corrosion if the root mean square (RMS) AC density is lower than 30 A/m^2. In practice, the evaluation of AC corrosion likelihood is done on a broader basis:

- Current density lower than 30 A/m^2: no or low likelihood of AC Corrosion effects
- Current density between 30 and 100 A/m^2: medium likelihood of AC Corrosion
- Current density higher than 100 A/m^2: very high likelihood of AC Corrosion

If the soil resistivity and the pipeline AC voltage are known, the risk of AC corrosion can be determined using the following formula in Equation 1 to calculate the current density at a holiday location.

$$I = (8 * Vac) / (\rho * \pi * d) \qquad \text{(Equation 1)}$$

<u>Where</u>:

- i = Current Density (A/m^2)
- V_{ac} = Pipe-to-Soil Voltage (Volts)
- ρ = Soil Resistivity (ohm-meters)
- d = Holiday diameter (meters)

1.4.3 Determining Steady State Pipeline AC Voltage Limits

The primary factor in calculating AC density at coating holidays is induced AC voltage on the pipeline at these coating holidays. Since the local soil does not significantly change, lowering the induced AC pipeline voltage (by adding mitigation) also lowers the local AC density.

To analyze the possible AC corrosion effects on this pipeline section, calculations were completed to determine the AC current density exiting the pipeline, assuming a one (1) cm^2 circular coating holiday at each soil resistivity location.

1.5 Definitions

AC Corrosion: The corrosion reaction associated with an AC electric current leaving the metal pipeline surface, due to an induced AC voltage on the pipeline.

AC Electrical Interference (Electromagnetic Interference): A coupling of energy from an electrical source (such as an electrical power line) to a metallic conductor (such as a pipeline) which at low frequencies (in the range of power system frequencies) occurs in the form of three different mechanisms; capacitive, conductive and inductive coupling. Electrical interference can produce induced voltages and currents in the metallic conductors that may result in safety hazards and/or damage to equipment.

Coating Stress Voltage: This is the potential difference between the outer surface of a conductor (e.g., pipelines, cables, etc.) coating and the metal surface of the conductor, and results from inductive and conductive potentials.

Capacitive Coupling: Capacitive coupling occurs as a result of an energized electrical source (e.g., power line) that produces a power line voltage between a conductor (such as a pipeline) and earth where the conductor is electrically insulated from the earth. An electric field gradient from the electrical source induces a voltage onto the conductor insulated from earth, which varies primarily according to the distance between the source and the conductor, the voltage of the source and the length of parallelism.

Conductive Coupling: When a fault current flows from the power line conductor to ground, a potential rise is produced in the soil with regard to remote earth. A conductor, which is located in the influence area of the ground for the power line structure, is subject to a potential difference between the local earth and the conductor potential. Conductive coupling is a localized phenomenon that acts upon the earth in the vicinity of the flow of current to ground.

Conductive Earth Potential: This is the potential that is induced onto a conductor due to the energization of the surrounding earth by the current leaking from the power line structure.

Dielectric Breakdown: The potential gradient at which electric failure or breakdown occurs. In this case, it is pertinent to the coating of the pipeline and the potential at which damage to the coating will occur.

Earth Surface Potential: When a single-phase-to-ground fault occurs at a power line structure, the structure injects a large magnitude current into the earth and therefore raises soil potentials in the vicinity of the structure. These potentials are referred to as earth surface potentials.

Fault Condition: A fault condition is a physical condition that causes a device, a component, or an element to fail to perform such as a short circuit or a broken wire. As a result, an abnormally high current flows from one conductor to ground or to another conductor.

Inductive Coupling: Inductive coupling is an association of two (2) or more circuits with one another by means of inductance mutual to the circuits. The coupling results from alternating current in an energized conductor (e.g., power line) which is more or less parallel with a passive (non-energized) conductor. Inductive coupling acts upon the entire length of a conductor.

Inductive Pipeline Potential: The potential induced onto a pipeline during steady state or fault conditions that results from the mutual coupling between the energized conductor (power line) and the pipeline.

Load Condition: A load condition for a circuit is the amount of rated operating electrical power that is transmitted in that circuit under normal operating conditions for a specific period of time.

Local Earth: Local earth is the earth in the vicinity of a conductor, which is raised to a potential, typically, as a result of the flow of fault current to ground. In the case of a pipeline, which has a good coating and does not have grounding conductors connected to the pipeline where the earth potential rise occurs, the "local" earth will be the same as the "remote" earth.

Permeability: Permeability is a term used to express various relationships between magnetic induction and magnetizing force.

Potential Difference: The relative voltage at a point in an electric circuit or field with respect to a reference point in the same circuit or field.

Remote Earth: Remote earth is a location of the earth away from where the origin of the earth potential rise occurs that represents a potential of zero Volts.

Steady State Condition: A steady state condition for a power system is a normal operating condition where there is negligible change in the electrical power transmitted in a circuit over a long period of time.

Step Voltage: The difference in surface potential experienced by a person bridging a distance of 1 meter with his feet without contacting any other grounded conducting object.

Touch Voltage: The potential difference between the Ground Potential Rise and the surface potential at a point where a person is standing with his hand in contact with a grounded structure.

1.6 AC Mitigation System Design Objectives

An AC mitigation system designed to protect a pipeline subject to AC interference effects must achieve the following four (4) objectives:

i) During worst-case steady state load conditions for each electric transmission circuit, reduce AC pipeline potentials with respect to local earth to acceptable levels for the safety of operating personnel and the public.

ii) During fault conditions on the electric transmission circuits, ensure that pipeline coating stress voltages remain within acceptable limits in order to prevent damage to the coating or even to the pipeline steel.

Damage to the coating can result in accelerated corrosion of the pipeline itself. Coating damage can occur at voltages on the order of one thousand (1,000) to two thousand (2,000) Volts for bitumen coated pipelines, whereas damage to polyethylene or fusion bonded epoxy coated pipelines occurs at higher voltages, i.e., greater than five thousand (5,000) Volts.

iii) During fault conditions on the electric transmission circuits, ensure the safety of the public and of operating personnel at exposed pipeline appurtenances. ANSI/IEEE Standard 80 specifies safety criteria for determining maximum acceptable touch and step voltages during fault conditions. Special precautions must be taken by maintenance personnel when excavating inaccessible portions of the pipeline to ensure safety in case of a fault condition.

iv) During worst-case steady state load conditions for each electric transmission circuit, reduce AC current densities through coating holidays to prevent possible AC corrosion mechanisms on the pipeline.

Table 1-1 depicts the proposed 12" pipeline design criteria

Table 1-1: Design Criteria for Personnel Safety, and Protection Against Damage to the Pipeline Coating

Criteria	Steady State Maximum[1] (Volts)	Fault Maximum (Volts)
Exposed Pipeline Appurtenance Touch Voltage	15	-----
Exposed Pipeline Appurtenance Step Voltage	15	-----
Buried Pipeline Touch Voltage	30	-----
AC Current Density Through 1 cm^2 Coating Holiday	100 A/m^2 (Current)	
Coating Stress Voltage	-----	5,000

[1] With respect to "Local Earth"

2. PHYSICAL LAYOUT

2.0 Physical Layout

The proposed 12" pipeline under study is approximately 41.2 miles in length. Eleven (11) electric transmission circuits will parallel or cross the proposed pipeline as described below:

- At pipeline station number 69+50, the pipeline will cross the VELCO 115 kV 'K22' electric transmission circuit.
- At pipeline station number 159+00, the pipeline will cross the VELCO 115 kV 'K21' electric transmission circuit.
- From pipeline station number 328+00 to 333+50, the pipeline will parallel and cross the 'GMP' electric transmission circuit.
- At pipeline station number 456+50, the pipeline will cross the VELCO 115 kV 'K24' electric transmission circuit.
- From pipeline station number 535+00 to 606+50, the pipeline will parallel the VELCO 115 kV 'K23' electric transmission circuit.
- At pipeline station number 606+50, the pipeline will pass in front of the VELCO 'Taft's Corner' electric substation.
- From pipeline station number 606+50 to 717+00, the pipeline will parallel and cross the VELCO 115 kV 'K27' electric transmission circuit.
- At pipeline station number 606+50, the pipeline will pass in front of the VELCO 'Williston' electric substation.
- At pipeline station number 717+50, the pipeline will pass the VELCO 115 kV 'K33' electric transmission circuit which ties into the VELCO 'Williston' electric substation.
- From pipeline station number 718+50 to 1854+50, the pipeline will parallel and cross the VELCO 115 kV 'K43' electric transmission circuit.
- From pipeline station number 1813+50 to 1854+50, the pipeline will parallel and cross the VELCO 115 kV 'K64' electric transmission circuit.

- At pipeline station number 1857+00, the pipeline will pass in front of the VELCO 'New Haven' electric substation.
- From pipeline station number 1859+00 to 2087+75, the pipeline will parallel and cross the VELCO 115 kV 'K63' electric transmission circuit.
- From pipeline station number 1859+50 to 2087+75, the pipeline will parallel and cross the VELCO 115 kV 'K370' electric transmission circuit.

The eleven (11) electric transmission circuits and the approximate pipeline station numbers are listed in Table 2-1.

Table 2-1: Regions of Influence by Electric Circuits on the Proposed Pipeline

Circuit Name	Power Company	Line Size (kV)	Pipeline Station Number Range
K22	VELCO	115	Crosses at 69+50
K21	VELCO	115	Crosses at 159+00
GMP	GMP	-	Parallel from 328+00 to 333+50
K24	VELCO	115	Crosses at 456+50
K23	VELCO	115	Parallel from 535+00 to 606+50
K27	VELCO	115	Parallel from 606+50 to 717+00
K33	VELCO	115	Passes at 717+50
K43	VELCO	115	Parallel from 718+50 to 1854+50
K64	VELCO	115	Parallel from 1813+50 to 1854+50
K63	VELCO	115	Parallel from 1859+00 to 2087+75
K370	VELCO	345	Parallel from 1859+50 to 2087+75

Note: All referenced pipeline station numbers are based on the pipeline alignment plans - Vermont Gas Proposed 12" Pipeline Addison Natural Gas Project - EPSC Plan issued 4/16/2013.

2.1 Pipeline Data

The effective coating resistance of a pipeline is a conservative value obtained from previous research on coating resistances for new coated pipelines.

1) Coating Resistance of 12" pipeline 1,000,000 ohm-ft^2

The characteristics used for the proposed 12" pipeline, provided by Vermont Gas System, will be as follows:

- Relative resistivity: 10 (with respect to annealed copper)
- Relative permeability: 300 (with respect to free space)
- Pipeline diameter: 12.75" OD
- Pipeline depth: Minimum 3' Cover (top of pipe to natural grade)
- Pipeline wall thickness: 0.312"
- Coatings: Pritec 10/40 or Warrior 100

2.2 Soil Resistivity Measurements

This AC electrical interference analysis was based on soil resistivity measurements recorded at locations along the proposed pipeline route, using equipment and procedures developed especially for this type of interference study. ARK Engineering personnel conducted these soil resistivity measurements on May 1-6, 2013. Soil resistivity measurements for this analysis were recorded at forty (40) sites. This measurement data is outlined in Appendix A.

Soil resistivity measurements are used to calculate the ground resistance of electric transmission line structures, assess the gradient control performance of AC mitigation systems and gradient control mats, as well as to determine the conductive coupling of the pipeline through the earth from nearby faulted electric transmission circuit structures. The conductive coupling has an important effect on touch and step voltages at proximate valve sites and on pipeline coating-stress voltages.

Past experience has shown the need for a special measurement methodology for environments that are subject to electrical noise due to the presence of nearby high voltage electric transmission circuits. When conventional methods are used, the instrumentation can pick up noise from the nearby electric power circuits and indicate resistivity values much higher than reality at large electrode spacing, suggesting that deeper soil layers offer poorer grounding than they actually may. Resistance readings can be inflated by a factor of four (4) or more. This error can result in conservative mitigation designs.

2.2.1 Soil Resistivity Measurement Methodology

Measurements conducted by ARK Engineering personnel were based upon the industry recognized Wenner four-pin method, in accordance with IEEE Standard 81, "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System", using the Miller 400D Digital Resistance Meter.

The electrode spacing varied from point one-five (0.15) meters to twenty-five (25) meters. Apparent resistivity values that correspond to the measured resistance values can be calculated using the expression:

$$\rho = 2\pi aR$$

<u>Where</u>:

ρ = Apparent soil resistivity, in ohm-meters (Ω-m)
a = Electrode separation, in meters (m)
R = Measured resistance, in ohms (Ω)

In practice, four rods are placed in a straight line at intervals "a", driven to a depth that does not exceed one-tenth of "a" (0.1*a).

This results in the approximate average resistance of the soil to a depth of "a" meters.

2.2.2 Soil Resistivity Data

Soil resistivity measurements were used to derive an equivalent soil structure model. This multilayer soil model is representative of the changing soil characteristics as a function of depth. The inductive coupling interference modeling uses the bottom-most soil resistivity layer from the multilayer model. The complete multi-layer soil characteristics are used to calculate the conductive and total AC interference effects. Touch voltage, coating stress voltage, and touch & step safety limits all use the complete multilayer soil model.

The bottom layer soil resistivity values were used for calculating electric transmission circuit parameters and inductive interference effects on the proposed pipeline.

Table 2-2: Bottom Layer Soil Resistivity Values

Soil Resistivity Location No.	Approx. Pipeline Station Number	Bottom Layer Resistivity (Ω-m)
1	20+50	67.36
2	33+00	584.54
3	105+50	246.46
4	162+00	713.14
5	207+50	735.49
6	267+00	735.56
7	315+00	197.30
8	396+25	266.40
9	433+00	258.45
10	505+50	438.88
11	458+00	248.55
12	600+50	122.09
13	657+00	299.76
14	703+50	4,484.10
15	757+00	768.91
16	817+50	249.55
17	893+75	243.58
18	961+50	387.73
19	999+25	481.45
20	1046+00	456.23
21	1111+00	500.30
22	1157+00	231.01
23	1202+50	80.85
24	1264+00	321.77
25	1343+25	1,322.32
26	1397+00	997.16
27	1425+00	164.72
28	1492+50	885.79
29	1548+00	2,340.75
30	1587+50	583.50
31	1651+00	884.52
32	1731+00	2,846.73
33	1769+00	375.09

Soil Resistivity Location No.	Approx. Pipeline Station Number	Bottom Layer Resistivity (Ω-m)
34	1841+50	995.52
35	1893+00	465.28
36	1955+00	620.99
37	2021+50	1,013.96
38	2103+50	1,606.38
39	2154+25	486.78
40	2179+88	1,182.73

Note: All referenced pipeline station numbers are based on the pipeline alignment plans - Vermont Gas Proposed 12" Pipeline Addison Natural Gas Project - EPSC Plan issued 4/16/2013.

3. STEADY STATE CONDITIONS

3.0 Steady State Conditions

The emergency peak AC load currents, provided by VELCO or assumed by ARK Engineering, were used to compute the maximum steady state inductive AC interference effects on the proposed 12" pipeline.

Although these circuits may not be loaded to this level, the data provided by VELCO or assumed by ARK Engineering constitutes a realistic scenario if other critical circuits are out of service and the load must be redirected through these circuits. Therefore, under normal conditions, the steady state AC interference levels should be significantly less than those reported in this study.

Table 3-1 indicates the load currents for this interference analysis.

Table 3-1: Transmission Circuit Peak Emergency Current Ratings

Power Company	Circuit Name	Line Size (kV)	Emergency Peak Load Current (A)
VELCO	K21	115	1,250
VELCO	K22	115	1,250
VELCO	K24	115	1,100
VELCO	K23	115	1,500
VELCO	K27	115	1,500
VELCO	K33	115	1,250
VELCO	K43	115	1,250
VELCO	K63	115	1,250
VELCO	K64	115	1,500
VELCO	K370	345	1,350
GMP	GMP	-	1,000*

Note: GMP Circuit loading was assumed by ARK Engineering, based on industry experience.

3.1 Fault Conditions

To determine the maximum AC interference effects of a faulted circuit on the proposed 12" pipeline under study, the model included assumed single phase-to-ground fault branch currents on the VELCO and GMP electric transmission circuits.

Fault conditions were simulated on the electric transmission circuits in the areas of parallelism. Single phase-to-ground branch currents, provided by VELCO or assumed by ARK Engineering based on past industry experience, were used to calculate fault currents on grounded tower structures along each electric transmission circuit.

Reference Appendix C for all fault data used in this analysis.

3.2 Safety Criteria

The safety criteria established as part of this analysis is based upon the ANSI/IEEE Standard 80, "IEEE Guide for Safety in AC Substation Grounding" and the following assumptions:

- A surface layer of six inches (6") of gravel at all aboveground pipeline locations (1,000 Ohm-meter gravel unless otherwise noted)
- A 50 kg (110 lbs.) person having a body resistance (R_b) of 1,000 Ω
- A worst case breaker failure fault clearing times, provided by VELCO were used for all fault condition scenarios.

Reference Appendix C for worst case breaker failure fault clearing times, provided by VELCO.

3.3 Modeled Interference Levels

ARK Engineering performed this AC interference analysis using state of the art modeling software. The output file plots for the steady state and simulated fault conditions on the eleven (11) electric transmission circuits are included in Appendix B.

3.3.1 Steady State Conditions

The induced AC pipeline potentials on the proposed pipeline were computed with the electric transmission circuits operating at emergency peak load conditions. The results are summarized in Appendix B.

The computed induced AC pipeline potentials were above the maximum allowable design limit of thirty (30) Volts at various locations along the proposed pipeline.

For the proposed pipeline, induced AC pipeline potentials reached a maximum of approximately one hundred and thirty-nine (139) Volts, with respect to remote earth. This peak occurs at pipeline station number 2087+16. At this location, the proposed pipeline leaves the shared right-of-way with two (2) VELCO electric transmission circuits.

Table 3-2 outlines the computed maximum induced AC pipeline potential at emergency peak load conditions on the electric transmission circuits.

Table 3-2: Maximum Induced Potentials on the Proposed 12" Pipeline at Emergency Peak Load Conditions

Pipeline		Pipeline Station Number	Maximum Induced Potential (V)	Design Limit (V)
12" Pipeline	Without AC Mitigation	2087+16	139	30
	With AC Mitigation	1951+53	25.78	30

All pipeline locations were reduced to less than the design limit.

Reference Appendix B for plots of the computed induced AC pipeline potentials on the proposed 12" pipeline.

3.3.2 Fault Conditions

As outlined in Chapter 1 of this report, when an electric transmission circuit fault occurs at a grounded structure (transmission tower) in proximity to a pipeline in a joint corridor, the induced AC pipeline potential is essentially out of phase with the earth potentials developed by conduction near the faulted structure. Therefore, inductive and conductive interference effects reinforce each other in terms of coating stress voltages and touch voltages.

3.3.2.1 Inductive Interference – Inductive interference effects to the proposed pipeline were computed and analyzed during simulated fault conditions on each of the eleven (11) electric transmission circuits. This was undertaken to determine the maximum induced AC pipeline potentials at all points along the proposed pipeline.

3.3.2.2 Conductive Interference – The configuration of the electric transmission circuit towers and their grounding systems was used to determine earth surface potentials in proximity to the structures and the pipeline during a simulated single phase-to-ground fault condition.

3.3.2.3 Total Fault Current Interference – The maximum total pipeline coating stress voltage was computed for each point along the pipeline. This is the sum of the inductive and conductive AC interference effects at each joint facility corridor area. The maximum pipeline coating stress voltage was calculated at four thousand six hundred and fourteen (4,614) Volts. This value was calculated at pipeline station number 1547+10. This occurred as a result of a simulated single phase-to-ground fault on the VELCO 115 kV 'K43' electric transmission circuit that will parallel the proposed pipeline from station numbers 1859+50 to 1854+50.

The maximum total coating stress voltage value is outlined below in Table 3-3.

Table 3-3: Maximum Coating Stress Voltage on the Pipeline under Fault Conditions

Pipeline	Transmission Circuit Faulted	Approximate Location (Station Number)	Maximum Coating Stress Voltage (V)
12" Proposed Pipeline	VELCO K43	1547+10	4,614

Appendix B includes plots of the coating stress voltage on the pipeline during simulated fault conditions on the electric transmission circuit structures.

3.3.3 AC Touch and Step Voltage

Six (6) aboveground pipeline appurtenances are proposed to be on or near the shared power line rights-of-way with this proposed pipeline. These sites were modeled with a simulated fault at the closest tower to determine the worst-case scenario for touch and step potentials. The following sites were modeled and analyzed:

- Williston M&R: MP 10.43
- MLV-2: MP 14.30
- MLV-3: MP 19.81
- MLV-4: MP 24.80
- MLV-5/ Plank Rd. M&R: MP 32.54
- MLV-6: MP 35.00

Reference Appendix B for plots of the AC Touch and Step Voltage at these locations.

Williston M&R - Mile Post Number 10.43

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-4 outlines these results.

Table 3-4: Williston M&R - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	347.46 V	58.98 V	187.30 V
Step Voltage (Volts AC)	1.48 V	17.19 V	498.10 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 187.30 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

MLV-2 - Mile Post Number 14.30

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-5 outlines these results.

Table 3-5: MLV-2 - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	1,870.85 V	148.34 V	228.20 V
Step Voltage (Volts AC)	9.30 V	69.07 V	606.10 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 228.20 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

MLV-3 - Mile Post Number 19.81

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-6 outlines these results.

Table 3-6: MLV-3 - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	1,855.42 V	186.70 V	227.60 V
Step Voltage (Volts AC)	11.43 V	71.39 V	603.4 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 227.60 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

MLV-4 - Mile Post Number 24.80

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-7 outlines these results.

Table 3-7: MLV-4 - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	1,290.12 V	252.64 V	432.80 V
Step Voltage (Volts AC)	59.51 V	102.23 V	1171.30 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 432.80 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

MLV-5/Plank Rd. M&R - Mile Post Number 32.54

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-8 outlines these results.

Table 3-8: MLV-5/Plank Rd. M&R - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	1,466 V	273.62 V	287.80 V
Step Voltage (Volts AC)	80.62 V	101.19 V	781.70 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 287.80 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

MLV-6 - Mile Post Number 35.00

Single phase-to-ground fault conditions were simulated at the towers nearest to the site on the electric transmission circuits. Touch and step voltages were calculated around the site and the boundary fence. Table 3-9 outlines these results.

Table 3-9: MLV-6 - Maximum Touch and Step Voltage Results

	Calculated With No Mitigation	Calculated With Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	797.65 V	271.9 V	298.80 V
Step Voltage (Volts AC)	8.19 V	238.26 V	825.70 V

Without an AC mitigation system installed, the computed AC touch voltage exceeds the IEEE Standard 80 design limit of 298.80 Volts.

With the recommended AC mitigation system installed at this station, the computed AC touch voltage is below the IEEE Standard 80 design limit.

3.4 AC Mitigation System

The AC mitigation system designed and recommended by ARK Engineering for the proposed 12" pipeline reduces the AC interference effects to acceptable levels during emergency peak steady state and fault conditions on the eleven (11) electric transmission circuits that will parallel or cross the pipeline route.

The proposed AC mitigation system design includes the installation of gradient control wires (zinc ribbon anode or equivalent) in the areas of computed high pipeline AC potentials. This AC mitigation system will reduce the induced steady state AC voltage and AC current density on the pipeline system.

Also included in the AC mitigation system design are 2/0 bare copper ground loop systems at the following aboveground pipeline locations:

- Williston M&R: MP 10.43
- MLV-2: MP 14.30
- MLV-3: MP 19.81
- MLV-4: MP 24.80
- MLV-5/ Plank Rd. M&R: MP 32.54
- MLV-6: MP 35.00

This portion of the AC mitigation system will reduce AC touch potentials at these locations to acceptable levels.

3.5 AC Corrosion Analysis Results

To analyze the possible AC corrosion effects to this proposed pipeline, calculations were completed to determine the AC density based upon induced AC pipeline voltages, assuming a one (1) cm^2 circular coating holiday, along the proposed pipeline.

The computed induced pipeline voltages are shown in Appendix B.

For the proposed pipeline, a maximum computed AC density of one thousand thirty-one (1,031) A/m^2 may occur at pipeline station number 2179+88. At this location, the proposed pipeline will terminate at the Middlebury M&R valve station.
With the recommended AC mitigation system installed and connected to the proposed pipeline, the maximum computed AC density was reduced to two hundred and four (204) A/m^2.

Table 3-10 outlines the computed maximum AC density at emergency load conditions on the VELCO and GMP electric transmission circuits.

Table 3-10: Maximum Coating Holiday AC Current Density

Pipeline		Pipeline Station Number	Maximum Current Density (A/m²)	Design Limit (A/m²)
12" Proposed Pipeline	Without AC Mitigation	2179+88	1,031.15	100
	With AC Mitigation	1517+91	204.93	100

Since the loading used on these electric transmission circuits are conservative resulting in AC density values above the design limit, ARK Engineering recommends installing coupon test stations and remote monitoring equipment at locations above 100 A/m^2 to monitor these locations.

Reference Appendix B for plots of the computed AC density on the proposed pipeline.

4. CONCLUSIONS

4.0 Conclusions

The proposed 12" pipeline and the eleven (11) electric transmission circuits have been modeled and analyzed as described in this report.

Computer modeling and analysis, using emergency peak load currents on the electric transmission circuits, indicate the following:

- Steady state induced AC pipeline voltages will exceed the design limit of fifteen (15) Volts for aboveground sections at several locations along the proposed pipeline under these load conditions on the electric circuits.
- Steady state induced AC pipeline voltages will exceed the design limit of thirty (30) Volts for below ground sections at several locations along the proposed pipeline under these load conditions on the electric circuits.
- Pipeline coating stress voltages will not exceed the five thousand (5,000) Volt design limit for a single phase-to-ground fault on the electric circuits.
- Touch voltages at six (6) aboveground pipeline locations will exceed the IEEE Standard 80 design limits during single phase-to-ground simulations under breaker failure conditions.
- AC density across a $1cm^2$ coating holiday will exceed the 100 A/m^2 design limit at several locations along the proposed pipeline.

AC mitigation systems were designed to effectively reduce the induced AC interference effects on the pipeline to less than the design limits. For locations where AC density is above the 100 A/m^2 design limit for maximum load conditions, ARK Engineering recommends the installation of coupon test stations and remote monitoring at these locations to monitor actual field conditions.

This analysis results in interference levels that are conservative. Under normal operating conditions, the AC interference levels on the pipeline should be less than reported in this study.

4.1 Assumptions

During the modeling and analysis of the AC interference effects on the proposed pipeline, various assumptions were required. These assumptions are outlined below in no particular order:

a. Low voltage distribution taps were not included in this analysis.

b. A coating resistance value of 1,000,000 Ω-ft^2 was used for the proposed pipeline. This is a conservative value used for new pipelines.

c. GMP did not provide power data, upon request, therefore GMP power data was assumed by ARK Engineering using conservative values based on past industry experience.

d. Simulated fault scenarios for GMP were computed using assumed fault data estimated by ARK Engineering.

e. A six (6) inch layer of crushed rock was assumed to be installed at all above ground pipeline appurtenances.

f. Ground grids for VELCO substations were not provided.

g. A coating holiday size of 1 cm^2 was used in the calculation of AC current density.

5. RECOMMENDATIONS

5.0 Recommendations

As outlined in the previous chapter, induced AC pipeline potentials were calculated at values greater than the design limits detailed in Table 1-1, for the proposed pipeline, during conservative emergency peak steady state load conditions on the eleven (11) electric transmission circuits.

Pipeline AC voltage mitigation is accomplished by installation of gradient control wire (zinc ribbon anode or equivalent) along the pipeline in the areas of computed high AC pipeline potentials and AC current density values. This method also reduces AC coating stress voltages during fault conditions on the high voltage electric circuits. This gradient control wire will be connected to the pipeline at various locations through a Solid-State decoupling (SSD) device.

DC isolation is recommended between the pipeline and the grounding conductors through the use of SSD. These devices allow AC current to flow from the pipeline to the grounding system while blocking any DC cathodic protection current from flowing off the pipeline to the ground conductors.

5.1 Proposed Safety and Mitigation System Requirements

Having performed the modeling and analysis of the AC interference effects on the proposed 12" pipeline, ARK Engineering has designed an AC mitigation system to reduce the pipeline AC interference effects to safe levels for pipeline integrity and personnel safety.

ARK Engineering recommends that gradient control wire (zinc ribbon anode or equivalent) be installed in the following areas:

Table 5-1: 12" Pipeline AC Mitigation System

SECTION NO.	STATION NO. START	STATION NO. END	TOTAL LENGTH OF ZINC RIBBON (FT)
3	451+25	457+05	580
4	612+60	623+60	1,100
5	700+68	718+87	1,790
6	801+10	819+83	1,860
7	847+85	863+75	1,590
8	888+00	892+75	475
8A	893+75	906+82	1,425
9A	1040+90	1046+50	560
9B	1048+70	1063+10	1,440

SECTION NO.	STATION NO. START	STATION NO. END	TOTAL LENGTH OF ZINC RIBBON (FT)
10	1258+00	1267+25	925
11	1308+00	1320+40	1,240
12	1379+00	1390+10	1,110
13	1424+50	1437+00	1,250
14	1477+40	1490+73	770
15	1517+95	1551+35	3,340
17	1580+00	1588+00	800
18	1641+60	1656+70	1,510
19	1712+80	1718+00	520
20	1718+59	1724+01	580
21	1798+60	1846+00	4,740
22	1873+25	1881+00	775
22A	1882+75	1888+85	610
23	1918+11	1939+29	2,118
24	1976+29	1985+59	930
25	2080+10	2126+90	4,690
26	2129+05	2132+90	385
Total			**37,113 Feet**

Note: All referenced pipeline station numbers are based on the pipeline alignment plans - Vermont Gas Proposed 12" Pipeline Addison Natural Gas Project - EPSC Plan issued 4/16/13.

Reference - ARK Engineering design drawing package number: 12144-100, in Appendix D for zinc ribbon installation details.

12144-100	Vermont Gas 12" Pipeline Project
Rev. C	AC Mitigation System Design
	Zinc Ribbon Installation Drawings

Williston M&R - Mile Post Number 10.43

ARK Engineering recommends the installation of a 2/0 copper ground loop system at the Williston M&R. This 2/0 copper ground loop system is to be electrically connected to the perimeter fence and the pipeline through a Solid State Decoupler (SSD).

MLV-2 - Mile Post Number 14.30

ARK Engineering recommends the installation of a 2/0 copper ground loop system with 3/4" x 10'copper ground rods at each corner of the MLV-2 site. This 2/0 copper ground loop system is to be electrically connected to the perimeter fence and the pipeline through a Solid State Decoupler (SSD).

MLV-3 - Mile Post Number 19.81

Due to a pipeline reroute, the distance between MLV-3 and the VELCO 115kV 'K43' electric transmission circuit increased and therefore ARK Engineering recommends the installation of a 2/0 copper ground loop system at the MLV-4 site. This 2/0 copper ground loop system is to be electrically connected to the perimeter fence and the pipeline through a Solid State Decoupler (SSD). The use of copper ground rods and additional 2/0 copper cable connections is not necessary.

MLV-4 - Mile Post Number 24.80

ARK Engineering recommends the installation of a 2/0 copper ground loop system at the MLV-4 site. This 2/0 copper ground loop system is to be electrically connected to the perimeter fence and the pipeline through a Solid State Decoupler (SSD).

MLV-5/Plank Rd. M&R - Mile Post Number 32.54

ARK Engineering recommends the installation of a 2/0 copper ground loop system with 3/4" x 10' copper ground rods, spaced 15' along the outer ground loop at the MLV-5/Plank Rd. M&R site. Three (3) additional 2/0 copper cables are connected to this loop for additional AC mitigation. This 2/0 copper ground loop system is to be electrically connected to the perimeter fence and the pipeline through a Solid State Decoupler (SSD).

MLV-6 - Mile Post Number 35.00

ARK Engineering recommends the installation of a 2/0 copper ground loop system at the MLV-6 site. This 2/0 copper ground loop system is to be electrically connected to the proposed AC mitigation system and the perimeter fence and the pipeline through a Solid State Decoupler (SSD).

Reference - ARK Engineering design drawing package number: 12144-101, in Appendix D for copper ground loop installation details.

12144-101 Rev. B	Vermont Gas 12" Pipeline Project Valves Sites: Williston M&R MLV-2 MLV-3 MLV-4 MLV-5/Plank Rd. M&R, MLV-6 Colchester Launcher Middlebury M&R

AC Mitigation System Design
Valve Site Grounding Installation Drawings

Please call the author if you have questions or require additional information regarding this report.

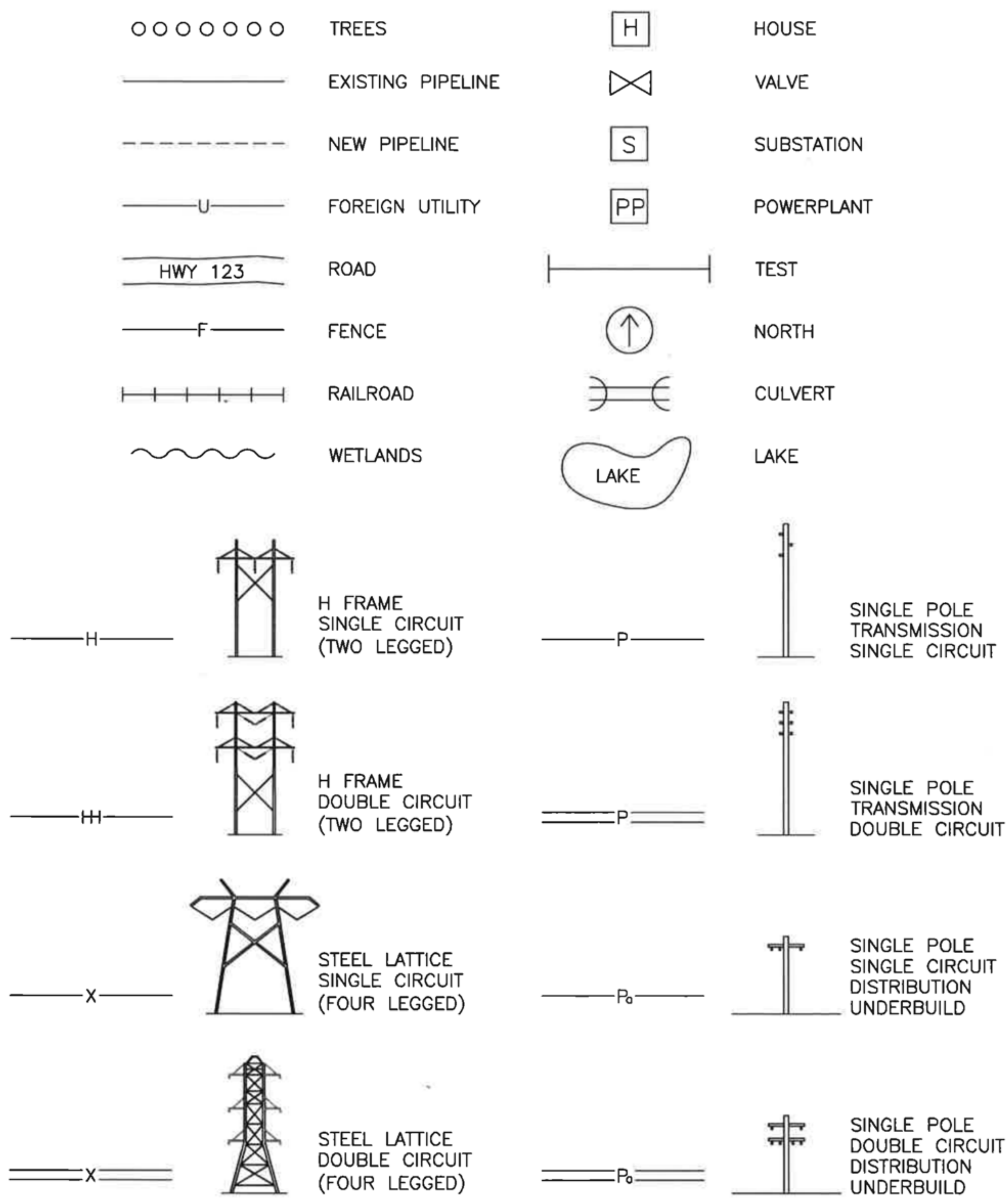
APPENDIX A –
SOIL RESISTIVITY DATA & GPS DATA

MN (14.5°W) TN

Scale 1 : 400,000

1" = 6.31 mi

Data Zoom 9-0



ARK. Engineering & Technical Services, Inc.

DRAWING KEY

F-020 1/12

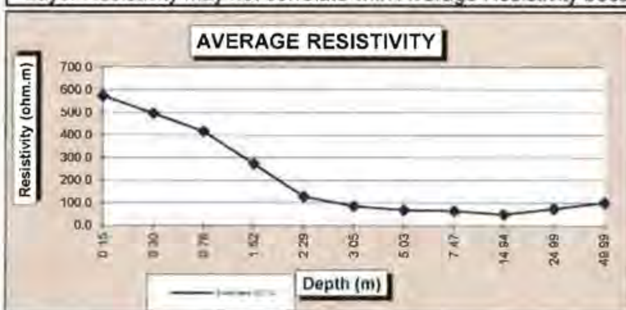
SOIL RESISTIVITY DATA

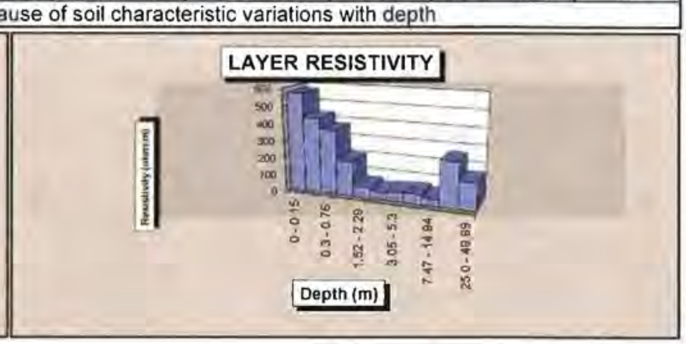
Project Name:	Vermont Gas Project
	12-144-01
Date:	5/3/2013
Location:	Rd sd off Severance Rd
	44 31.4488N, 73 9.3344W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	61F/Clear
Soil Description	Hard packed clay/Sand

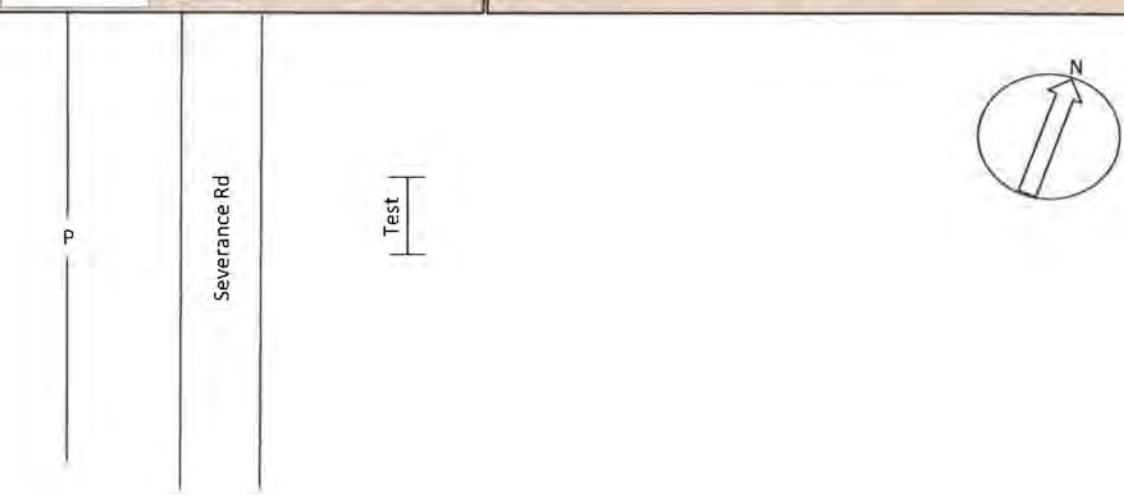
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	598.000	1	572.6	0.00167	n/a	n/a	n/a	0 - 0.15	573
1.00	0.30	259.000	2	496.0	0.00386	0.00219	456.879	1	0.15 - 0.3	437
2.50	0.76	86.900	5	416.1	0.01151	0.00765	130.779	3	0.3 - 0.76	376
5.00	1.52	28.500	10	272.9	0.03509	0.02358	42.408	5	0.76 - 1.52	203
7.50	2.29	8.920	14	128.1	0.11211	0.07702	12.984	5	1.52 - 2.29	62
10.00	3.05	4.480	19	85.8	0.22321	0.11111	9.000	5	2.29 - 3.05	43
16.50	5.03	2.170	32	68.6	0.46083	0.23762	4.208	12	3.05 - 5.3	52
24.50	7.47	1.380	47	64.8	0.72464	0.26381	3.791	15	5.03 - 7.47	58
49.00	14.94	0.530	94	49.7	1.88679	1.16215	0.860	47	7.47 - 14.94	40
82.00	24.99	0.470	157	73.8	2.12766	0.24087	4.152	63	14.94 - 25.0	262
164.00	49.99	0.320	314	100.5	3.12500	0.99734	1.003	157	25.0 - 49.99	157

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







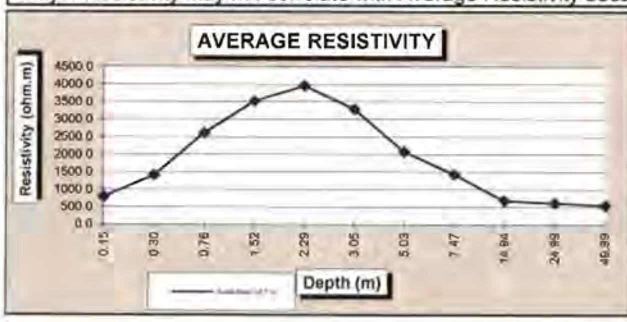
SOIL RESISTIVITY DATA

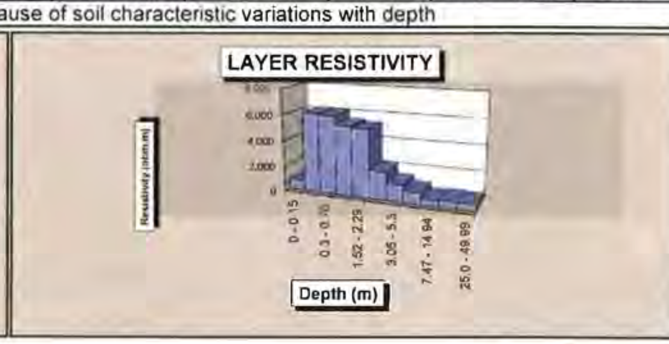
Project Name:	Vermont Gas Project
	12-144-02
Date:	5/3/2013
Location:	Open Field off Access Rd East of Severance Rd
	44 31.4187N, 73 9.0318N
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	63F/Clear
Soil Description	Hard packed clay/Sand

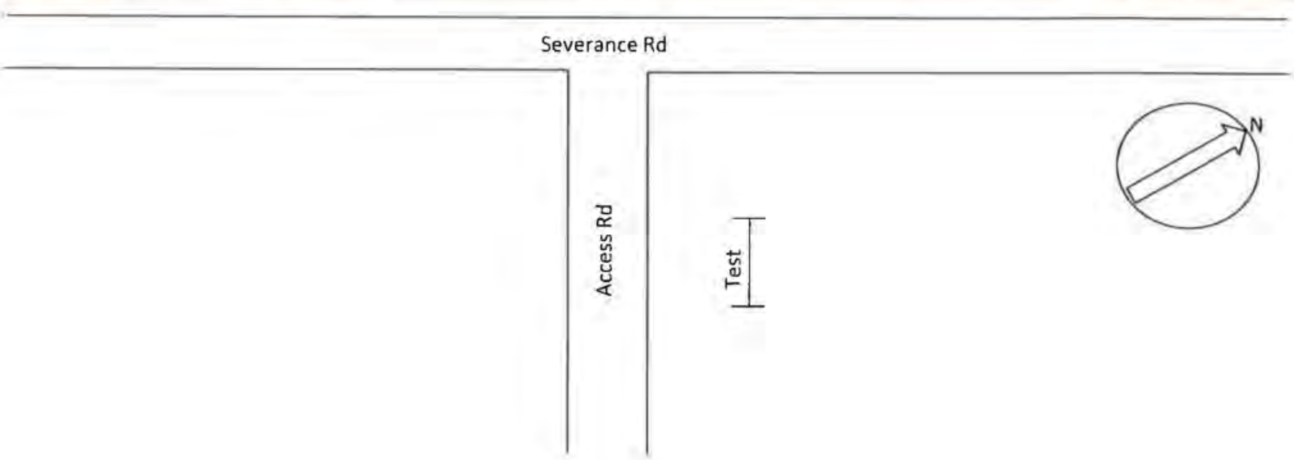
ARK Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	831.000	1	795.7	0.00120	n/a	n/a	n/a	0 - 0.15	796
1.00	0.30	736.000	2	1409.5	0.00136	0.00016	6438.063	1	0.15 - 0.3	6,165
2.50	0.76	546.000	5	2614.1	0.00183	0.00047	2115.032	3	0.3 - 0.76	6,076
5.00	1.52	368.000	10	3523.8	0.00272	0.00089	1128.809	5	0.76 - 1.52	5,404
7.50	2.29	276.000	14	3964.3	0.00362	0.00091	1104.000	5	1.52 - 2.29	5,286
10.00	3.05	172.000	19	3294.0	0.00581	0.00219	456.462	5	2.29 - 3.05	2,185
16.50	5.03	65.900	32	2082.4	0.01517	0.00936	106.831	12	3.05 - 5.3	1,330
24.50	7.47	30.600	47	1435.8	0.03268	0.01751	57.126	15	5.03 - 7.47	875
49.00	14.94	7.300	94	685.0	0.13699	0.10431	9.587	47	7.47 - 14.94	450
82.00	24.99	3.930	157	617.2	0.25445	0.11747	8.513	63	14.94 - 25.0	538
164.00	49.99	1.750	314	549.6	0.57143	0.31698	3.155	157	25.0 - 49.99	495

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







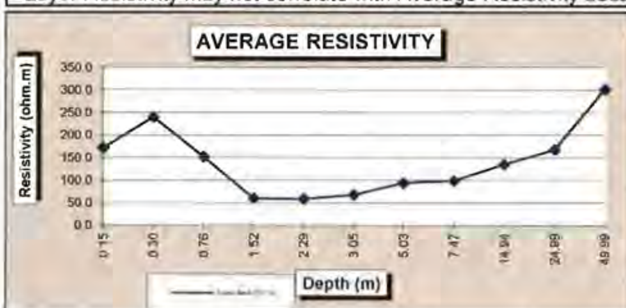
SOIL RESISTIVITY DATA

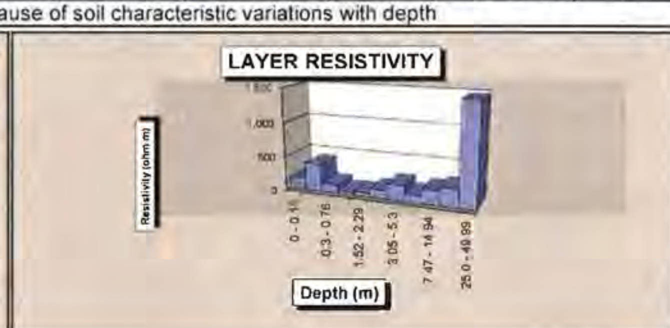
Project Name:	Vermont Gas Project
	12-144-03
Date:	5/3/2013
Location:	Rd Sd off Landfill Ln
	44 31.1464N, 73 7.4733W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	58F/Clear
Soil Description	Loose dry rocky soil

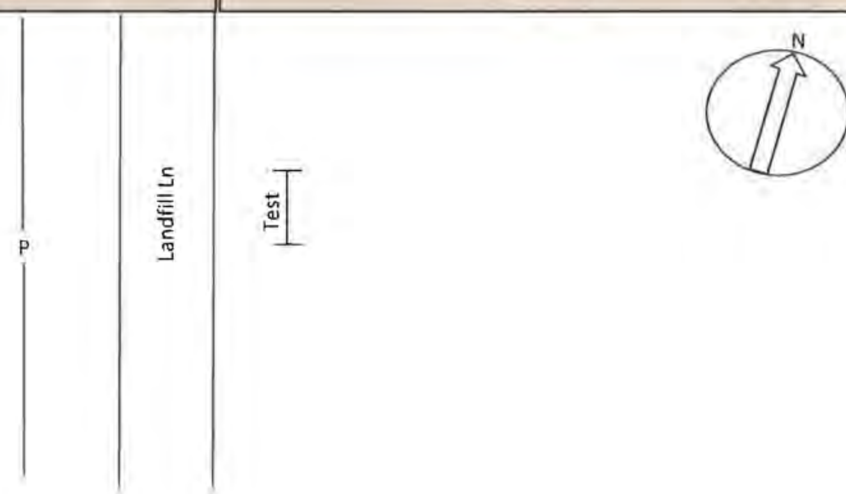
ARK Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	179.000	1	171.4	0.00559	n/a	n/a	n/a	0 - 0.15	171
1.00	0.30	125.300	2	240.0	0.00798	0.00239	417.667	1	0.15 - 0.3	400
2.50	0.76	31.700	5	151.8	0.03155	0.02356	42.436	3	0.3 - 0.76	122
5.00	1.52	6.270	10	60.0	0.15949	0.12794	7.816	5	0.76 - 1.52	37
7.50	2.29	4.100	14	58.9	0.24390	0.08441	11.847	5	1.52 - 2.29	57
10.00	3.05	3.540	19	67.8	0.28249	0.03858	25.918	5	2.29 - 3.05	124
16.50	5.03	2.970	32	93.9	0.33670	0.05421	18.445	12	3.05 - 5.3	230
24.50	7.47	2.110	47	99.0	0.47393	0.13723	7.287	15	5.03 - 7.47	112
49.00	14.94	1.440	94	135.1	0.69444	0.22051	4.535	47	7.47 - 14.94	213
82.00	24.99	1.070	157	168.0	0.93458	0.24013	4.164	63	14.94 - 25.0	263
164.00	49.99	0.960	314	301.5	1.04167	0.10709	9.338	157	25.0 - 49.99	1,466

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







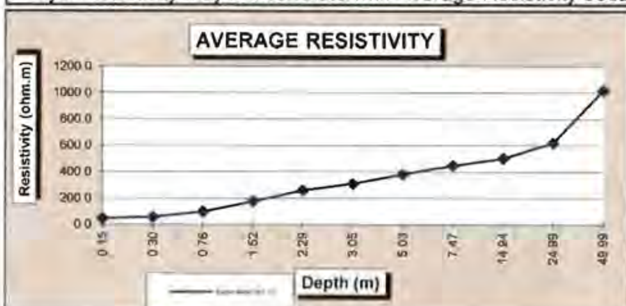
SOIL RESISTIVITY DATA

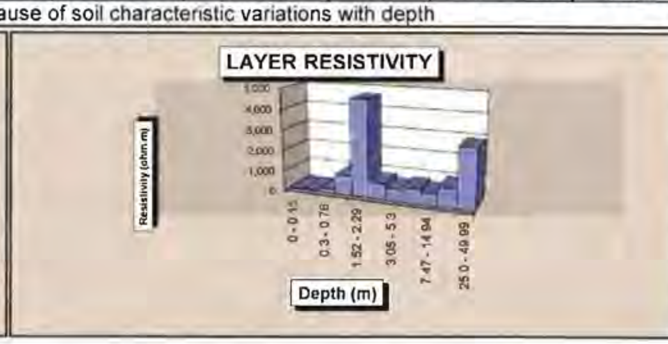
Project Name:	Vermont Gas Project
	12-144-04
Date:	5/3/2013
Location:	Rd Sd off SR 289
	44 30.866N, 73 6.228W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	55F/Clear
Soil Description	Dry rocky soil and vegetation

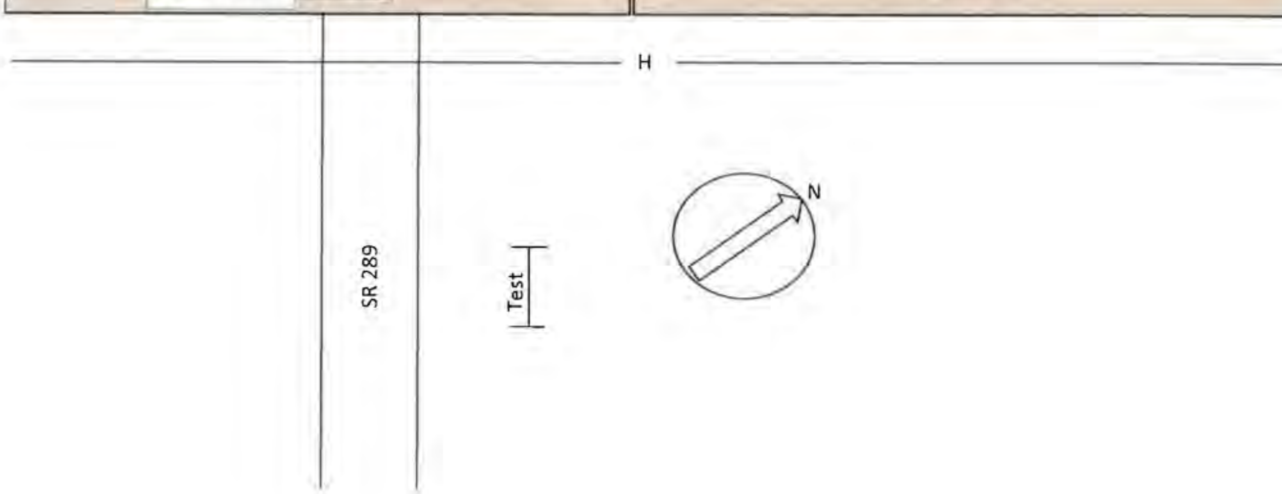
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	46.200	1	44.2	0.02165	n/a	n/a	n/a	0 - 0.15	44
1.00	0.30	29.100	2	55.7	0.03436	0.01272	78.621	1	0.15 - 0.3	75
2.50	0.76	20.200	5	96.7	0.04950	0.01514	66.047	3	0.3 - 0.76	190
5.00	1.52	18.360	10	175.8	0.05447	0.00496	201.561	5	0.76 - 1.52	965
7.50	2.29	18.020	14	258.8	0.05549	0.00103	973.080	5	1.52 - 2.29	4,659
10.00	3.05	16.190	19	310.1	0.06177	0.00627	159.423	5	2.29 - 3.05	763
16.50	5.03	12.040	32	380.5	0.08306	0.02129	46.971	12	3.05 - 5.3	585
24.50	7.47	9.600	47	450.4	0.10417	0.02111	47.370	15	5.03 - 7.47	726
49.00	14.94	5.380	94	504.9	0.18587	0.08171	12.239	47	7.47 - 14.94	574
82.00	24.99	3.940	157	618.7	0.25381	0.06793	14.720	63	14.94 - 25.0	930
164.00	49.99	3.240	314	1017.6	0.30864	0.05483	18.237	157	25.0 - 49.99	2,864

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







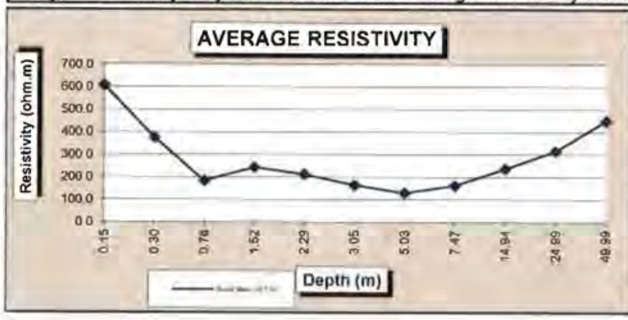
SOIL RESISTIVITY DATA

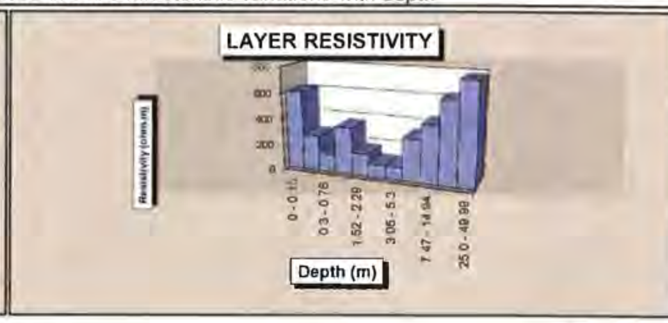
Project Name:	Vermont Gas Project
	12-144-05
Date:	5/3/2013
Location:	Open Lot off SR 289
	44 30.5592N, 73 5.3331W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	52F/Clear
Soil Description	Hard rocky soil

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)	ohm.m
0.50	0.15	634.000	1	607.1	0.00158	n/a	n/a	n/a	0 - 0.15	607
1.00	0.30	196.000	2	375.4	0.00510	0.00352	283.708	1	0.15 - 0.3	272
2.50	0.76	38.400	5	183.9	0.02604	0.02094	47.756	3	0.3 - 0.76	137
5.00	1.52	25.400	10	243.2	0.03937	0.01333	75.028	5	0.76 - 1.52	359
7.50	2.29	14.800	14	212.6	0.06757	0.02820	35.464	5	1.52 - 2.29	170
10.00	3.05	8.600	19	164.7	0.11628	0.04871	20.529	5	2.29 - 3.05	98
16.50	5.03	4.120	32	130.2	0.24272	0.12644	7.909	12	3.05 - 5.3	98
24.50	7.47	3.450	47	161.9	0.28986	0.04714	21.215	15	5.03 - 7.47	325
49.00	14.94	2.520	94	236.5	0.39683	0.10697	9.348	47	7.47 - 14.94	439
82.00	24.99	2.010	157	315.6	0.49751	0.10069	9.932	63	14.94 - 25.0	628
164.00	49.99	1.430	314	449.1	0.69930	0.20179	4.956	157	25.0 - 49.99	778

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





SR 289

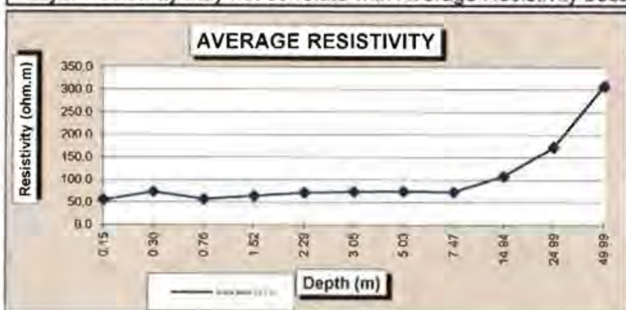
SOIL RESISTIVITY DATA

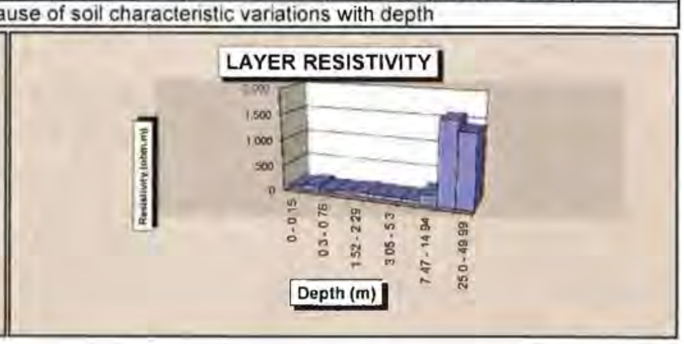
Project Name:	Vermont Gas Project
	12-144-06
Date:	5/2/2013
Location:	Rd Sd off SR 289
	44 30.0397N, 73 4.2916W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	81F/Clear
Soil Description	Dark moist soil

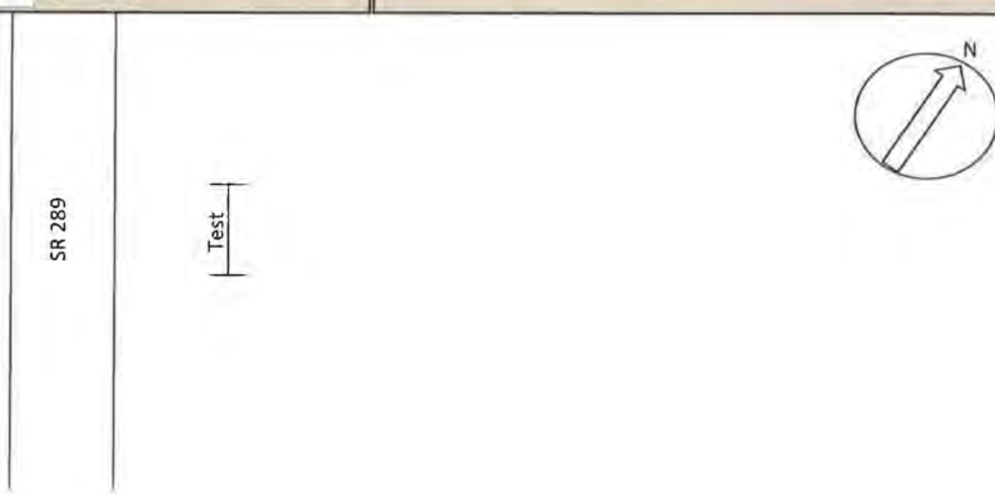
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	57.500	1	55.1	0.01739	n/a	n/a	n/a	0 - 0.15	55
1.00	0.30	38.400	2	73.5	0.02604	0.00865	115.602	1	0.15 - 0.3	111
2.50	0.76	11.880	5	56.9	0.08418	0.05813	17.202	3	0.3 - 0.76	49
5.00	1.52	6.670	10	63.9	0.14993	0.06575	15.209	5	0.76 - 1.52	73
7.50	2.29	4.990	14	71.7	0.20040	0.05048	19.811	5	1.52 - 2.29	95
10.00	3.05	3.850	19	73.7	0.25974	0.05934	16.852	5	2.29 - 3.05	81
16.50	5.03	2.350	32	74.3	0.42553	0.16579	6.032	12	3.05 - 5.3	75
24.50	7.47	1.560	47	73.2	0.64103	0.21549	4.641	15	5.03 - 7.47	71
49.00	14.94	1.150	94	107.9	0.86957	0.22854	4.376	47	7.47 - 14.94	205
82.00	24.99	1.100	157	172.7	0.90909	0.03953	25.300	63	14.94 - 25.0	1,599
120.00	49.99	0.980	314	307.8	1.02041	0.11132	8.983	157	25.0 - 49.99	1,411

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







SOIL RESISTIVITY DATA

Project Name:	Vermont Gas Project
	12-144-07
Date:	5/2/2013
Location:	Rd Sd off SR 289
	44 29.3821N, 73 3.8092W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	81F/Clear
Soil Description	Moist dark soil and vegetation

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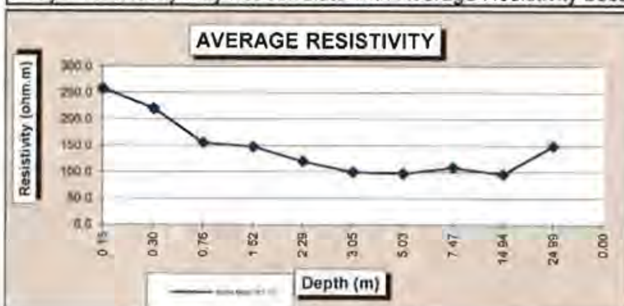
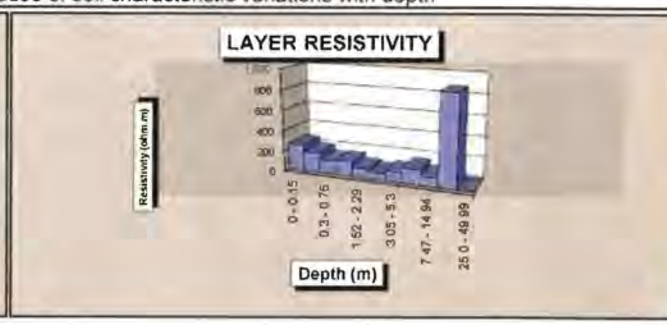
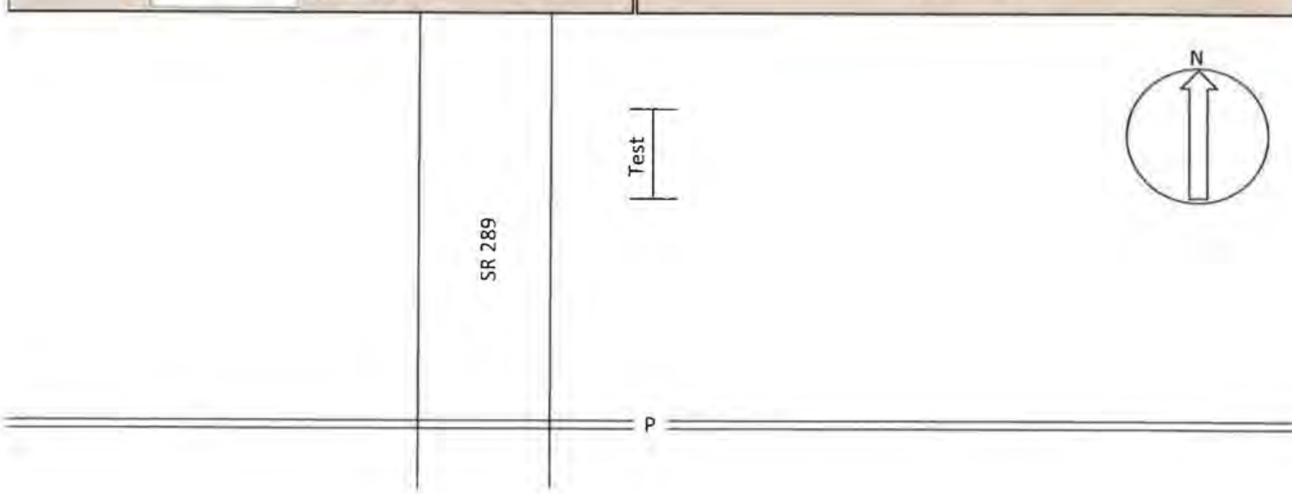
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	269.000	1	257.6	0.00372	n/a	n/a	n/a	0 - 0.15	258
1.00	0.30	115.300	2	220.8	0.00867	0.00496	201.794	1	0.15 - 0.3	193
2.50	0.76	32.500	5	155.6	0.03077	0.02210	45.257	3	0.3 - 0.76	130
5.00	1.52	15.440	10	147.8	0.06477	0.03400	29.414	5	0.76 - 1.52	141
7.50	2.29	8.370	14	120.2	0.11947	0.05471	18.279	5	1.52 - 2.29	88
10.00	3.05	5.210	19	99.8	0.19194	0.07246	13.800	5	2.29 - 3.05	66
16.50	5.03	3.080	32	97.3	0.32468	0.13274	7.534	12	3.05 - 5.3	94
24.50	7.47	2.320	47	108.9	0.43103	0.10636	9.402	15	5.03 - 7.47	144
49.00	14.94	1.020	94	95.7	0.98039	0.54936	1.820	47	7.47 - 14.94	85
82.00	24.99	0.950	157	149.2	1.05263	0.07224	13.843	63	14.94 - 25.0	875
	0.00		0		#DIV/0!	#DIV/0!	#DIV/0!	-157	25.0 - 49.99	#DIV/0!

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







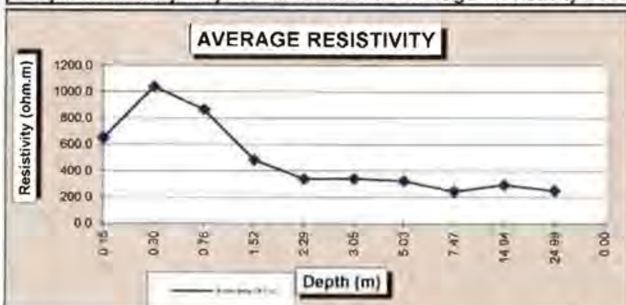
SOIL RESISTIVITY DATA

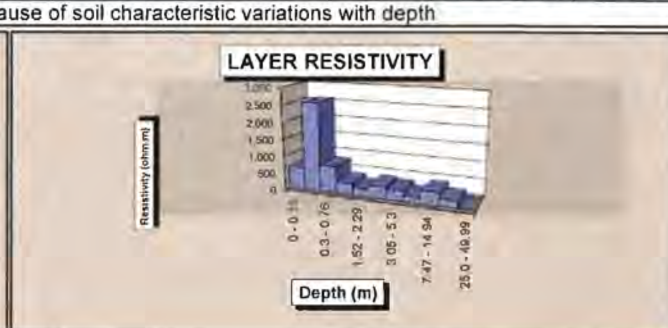
Project Name:	Vermont Gas Project
	12-144-08
Date:	5/2/2013
Location:	Rd Sd off Dump Access Rd
	44 28.6848N, 73 4.5661W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET2/2
Weather:	80F/Clear
Soil Description	Dry sand and rock

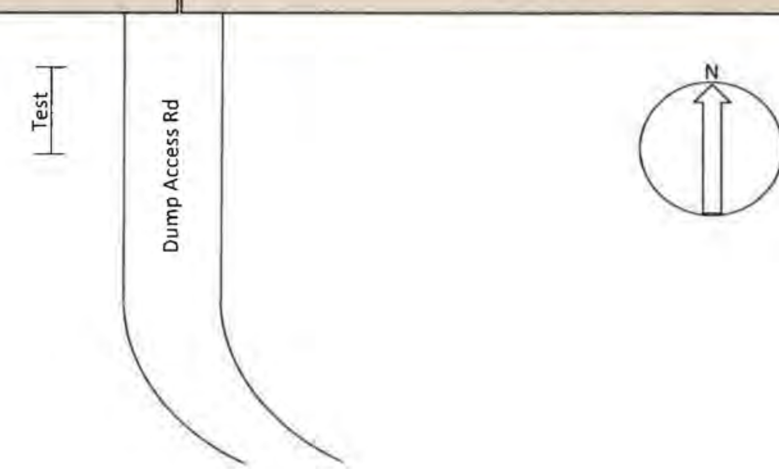
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	680.000	1	651.1	0.00147	n/a	n/a	n/a	0 - 0.15	651
1.00	0.30	543.000	2	1039.9	0.00184	0.00037	2695.182	1	0.15 - 0.3	2,581
2.50	0.76	181.000	5	866.6	0.00552	0.00368	271.500	3	0.3 - 0.76	780
5.00	1.52	50.600	10	484.5	0.01976	0.01424	70.235	5	0.76 - 1.52	336
7.50	2.29	23.600	14	339.0	0.04237	0.02261	44.228	5	1.52 - 2.29	212
10.00	3.05	17.900	19	342.8	0.05587	0.01349	74.112	5	2.29 - 3.05	355
16.50	5.03	10.300	32	325.5	0.09709	0.04122	24.259	12	3.05 - 5.3	302
24.50	7.47	5.250	47	246.3	0.19048	0.09339	10.708	15	5.03 - 7.47	164
49.00	14.94	3.160	94	296.5	0.31646	0.12598	7.938	47	7.47 - 14.94	372
82.00	24.99	1.610	157	252.8	0.62112	0.30466	3.282	63	14.94 - 25.0	207
	0.00		0		#DIV/0!	#DIV/0!	#DIV/0!	-157	25.0 - 49.99	#DIV/0!

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







SOIL RESISTIVITY DATA

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

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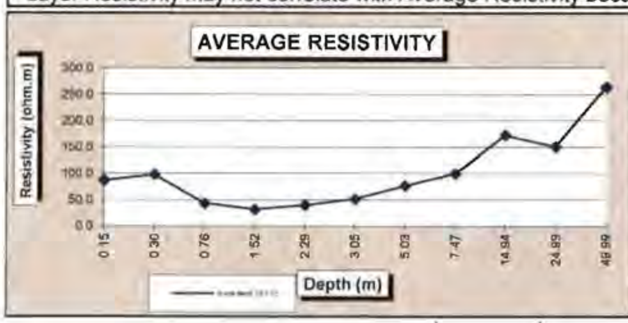
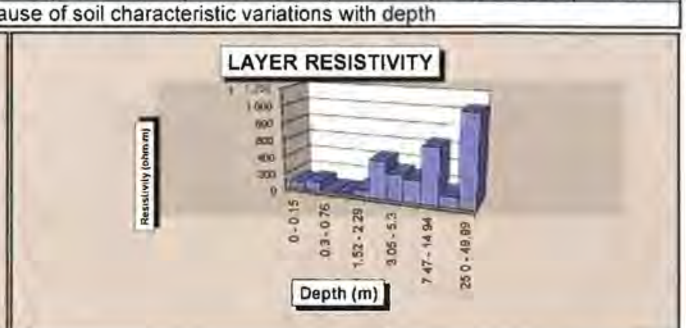
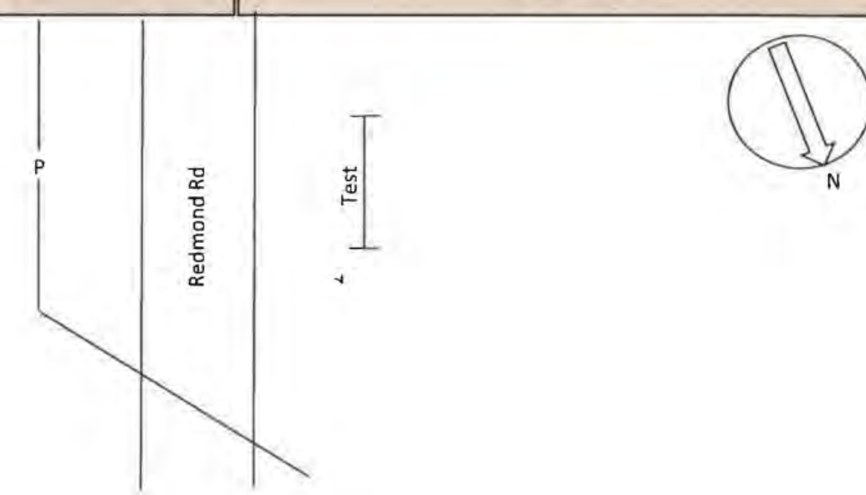
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	90.600	1	86.8	0.01104	n/a	n/a	n/a	0 - 0.15	87
1.00	0.30	51.000	2	97.7	0.01961	0.00857	116.682	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







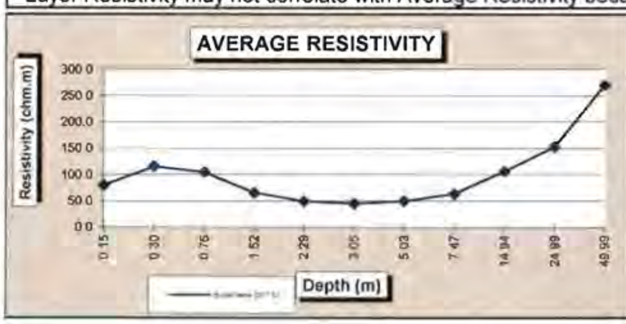
SOIL RESISTIVITY DATA

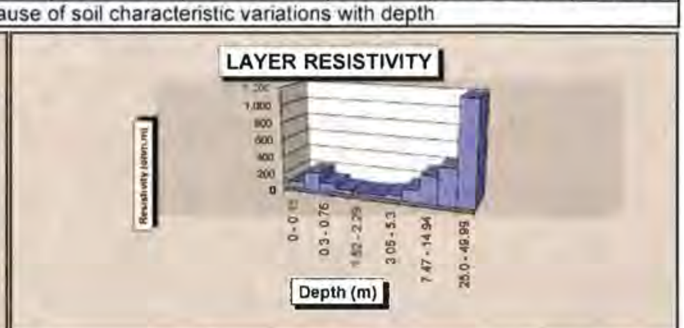
Project Name: Vermont Gas Project
12-144-10
Date: 5/2/2013
Location: Overgrown lot off Brennan Woods Dr
44 27.286N, 73 5.568W
Testers: KJ, LM
Methodology: $\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation: Biddle Meter DET 5/2
Weather: 75F/Clear
Soil Description Wet dark soil

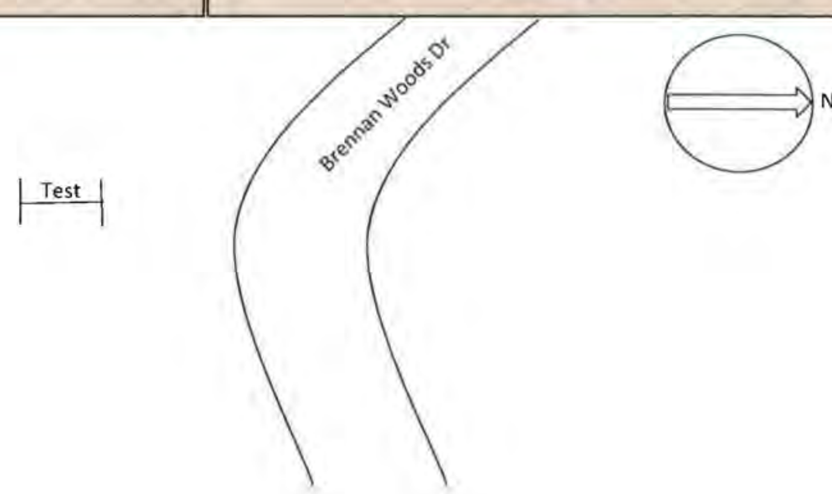
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	83.500	1	80.0	0.01198	n/a	n/a	n/a	0 - 0.15	80
1.00	0.30	60.300	2	115.5	0.01658	0.00461	217.028	1	0.15 - 0.3	208
2.50	0.76	21.900	5	104.9	0.04566	0.02908	34.390	3	0.3 - 0.76	99
5.00	1.52	6.850	10	65.6	0.14599	0.10032	9.968	5	0.76 - 1.52	48
7.50	2.29	3.450	14	49.6	0.28986	0.14387	6.951	5	1.52 - 2.29	33
10.00	3.05	2.340	19	44.8	0.42735	0.13750	7.273	5	2.29 - 3.05	35
16.50	5.03	1.580	32	49.9	0.63291	0.20556	4.865	12	3.05 - 5.3	61
24.50	7.47	1.350	47	63.3	0.74074	0.10783	9.274	15	5.03 - 7.47	142
49.00	14.94	1.130	94	106.0	0.88496	0.14422	6.934	47	7.47 - 14.94	325
82.00	24.99	0.970	157	152.3	1.03093	0.14597	6.851	63	14.94 - 25.0	433
164.00	49.99	0.860	314	270.1	1.16279	0.13186	7.584	157	25.0 - 49.99	1,191

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







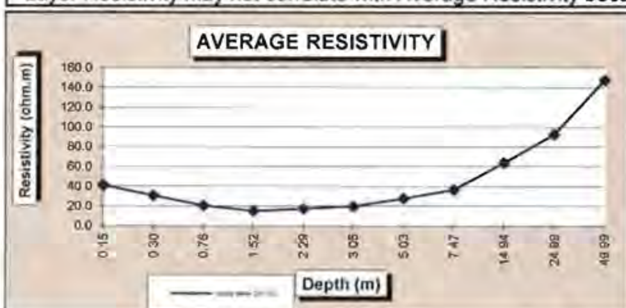
SOIL RESISTIVITY DATA

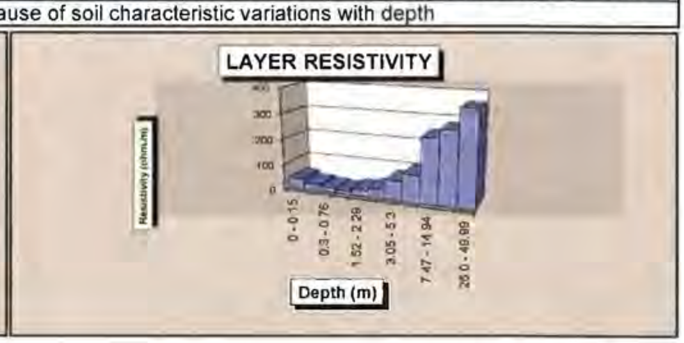
Project Name:	Vermont Gas Project
	12-144-11
Date:	5/2/2013
Location:	Rd Sd off Williston Rd
	44 26.6096N, 73 5.7963W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	74F/Clear
Soil Description	Sandy, Rocky soil

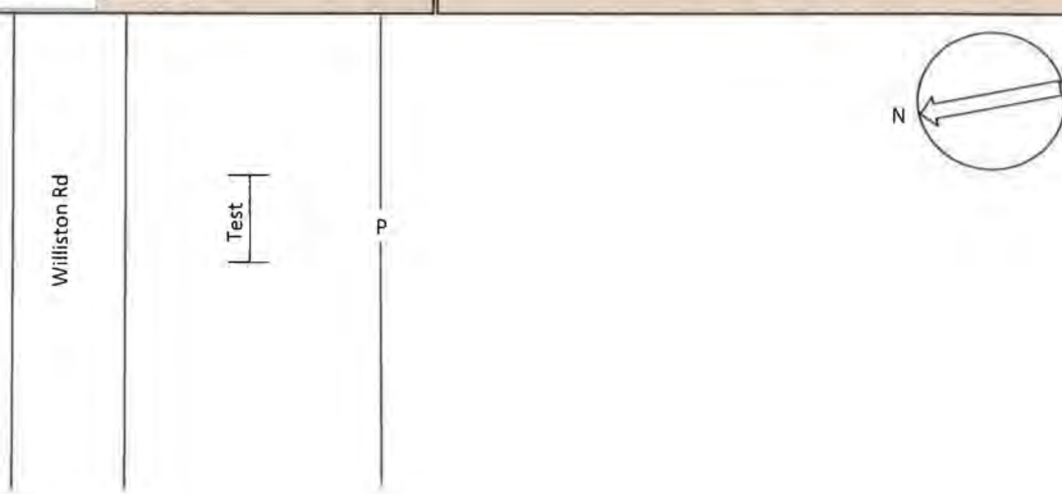
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	42.700	1	40.9	0.02342	n/a	n/a	n/a	0 - 0.15	41
1.00	0.30	15.950	2	30.5	0.06270	0.03928	25.460	1	0.15 - 0.3	24
2.50	0.76	4.300	5	20.6	0.23256	0.16986	5.887	3	0.3 - 0.76	17
5.00	1.52	1.590	10	15.2	0.62893	0.39637	2.523	5	0.76 - 1.52	12
7.50	2.29	1.210	14	17.4	0.82645	0.19752	5.063	5	1.52 - 2.29	24
10.00	3.05	1.030	19	19.7	0.97087	0.14443	6.924	5	2.29 - 3.05	33
16.50	5.03	0.880	32	27.8	1.13636	0.16549	6.043	12	3.05 - 5.3	75
24.50	7.47	0.780	47	36.6	1.28205	0.14569	6.864	15	5.03 - 7.47	105
49.00	14.94	0.680	94	63.8	1.47059	0.18854	5.304	47	7.47 - 14.94	249
82.00	24.99	0.590	157	92.7	1.69492	0.22433	4.458	63	14.94 - 25.0	282
164.00	49.99	0.470	314	147.6	2.12766	0.43274	2.311	157	25.0 - 49.99	363

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







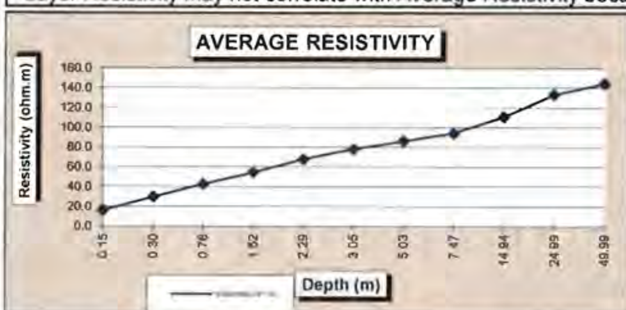
SOIL RESISTIVITY DATA

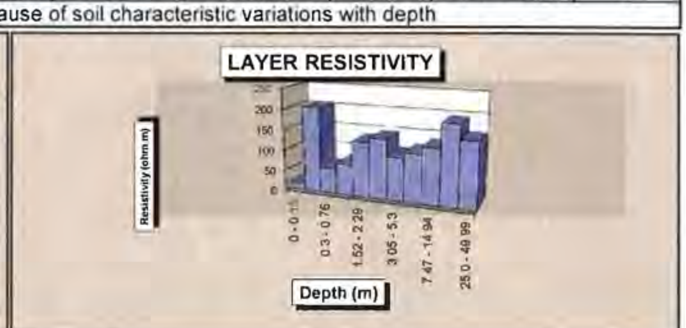
Project Name:	Vermont Gas Project
	12-144-12
Date:	5/2/2013
Location:	Rd Sd off entry ramp to I-89
	44 26.3197N, 73 6.8117W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	73F/Clear
Soil Description	Wet, dark, and rocky soil

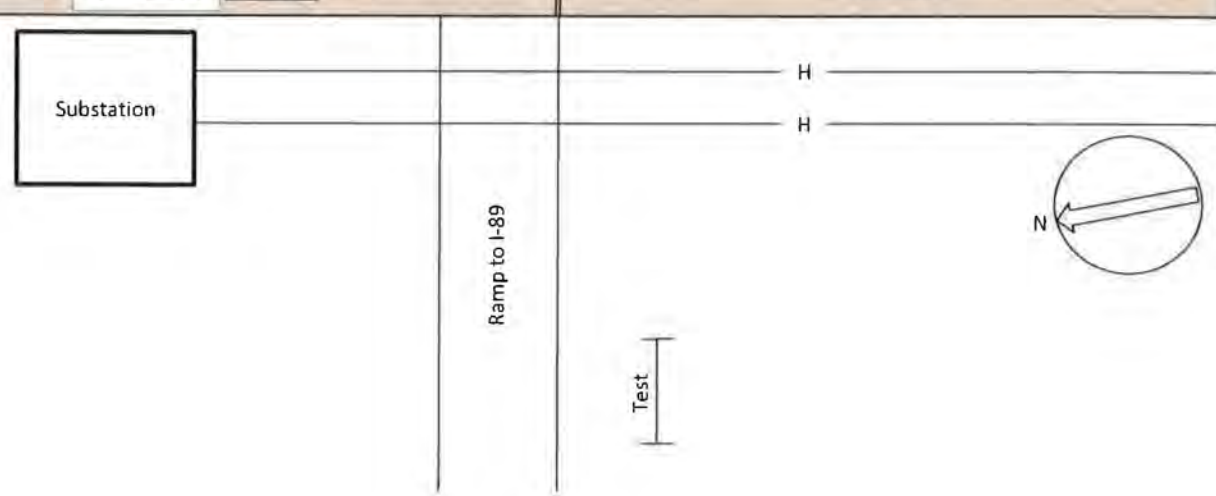
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	16.720	1	16.0	0.05981	n/a	n/a	n/a	0 - 0.15	16
1.00	0.30	15.510	2	29.7	0.06447	0.00467	214.320	1	0.15 - 0.3	205
2.50	0.76	8.930	5	42.8	0.11198	0.04751	21.049	3	0.3 - 0.76	60
5.00	1.52	5.690	10	54.5	0.17575	0.06376	15.683	5	0.76 - 1.52	75
7.50	2.29	4.720	14	67.8	0.21186	0.03612	27.687	5	1.52 - 2.29	133
10.00	3.05	4.080	19	78.1	0.24510	0.03323	30.090	5	2.29 - 3.05	144
16.50	5.03	2.730	32	86.3	0.36630	0.12120	8.251	12	3.05 - 5.3	103
24.50	7.47	2.010	47	94.3	0.49751	0.13121	7.621	15	5.03 - 7.47	117
49.00	14.94	1.180	94	110.7	0.84746	0.34995	2.858	47	7.47 - 14.94	134
82.00	24.99	0.850	157	133.5	1.17647	0.32901	3.039	63	14.94 - 25.0	192
164.00	49.99	0.460	314	144.5	2.17391	0.99744	1.003	157	25.0 - 49.99	157

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







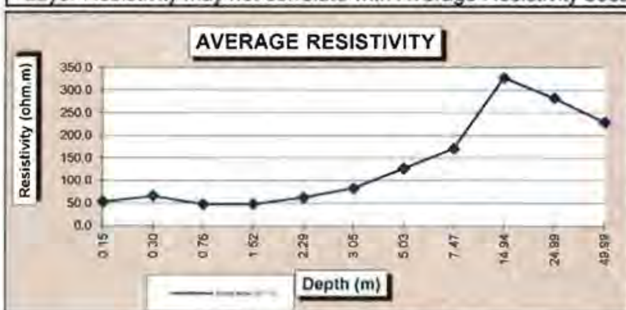
SOIL RESISTIVITY DATA

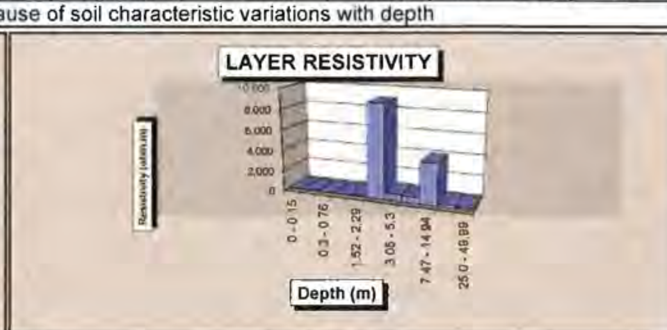
Project Name:	Vermont Gas Project
	12-144-13
Date:	5/2/2013
Location:	Rd Sd off Old Creamery Rd
	44 25.6578N, 73 7.205W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	64F/Clear
Soil Description	Wet, dark, and rocky soil

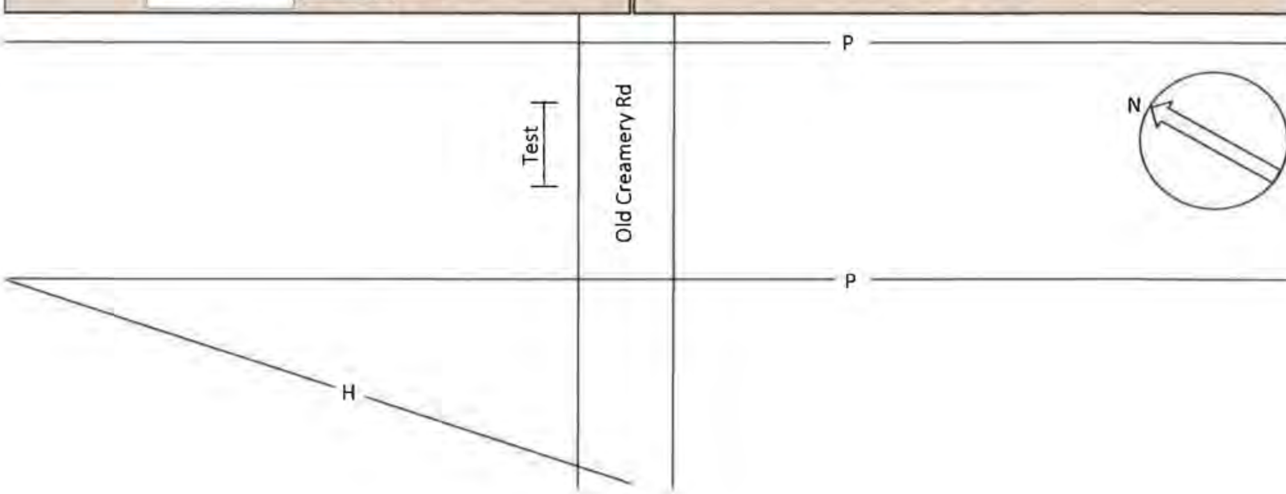
ARK. Engineering & Technical Services, Inc.

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)**	**ohm.m**
0.50	0.15	55.600	1	53.2	0.01799	n/a	n/a	n/a	0 - 0.15	53
1.00	0.30	34.500	2	66.1	0.02899	0.01100	90.910	1	0.15 - 0.3	87
2.50	0.76	9.980	5	47.8	0.10020	0.07121	14.042	3	0.3 - 0.76	40
5.00	1.52	5.010	10	48.0	0.19960	0.09940	10.060	5	0.76 - 1.52	48
7.50	2.29	4.350	14	62.5	0.22989	0.03028	33.020	5	1.52 - 2.29	158
10.00	3.05	4.340	19	83.1	0.23041	0.00053	1887.900	5	2.29 - 3.05	9,039
16.50	5.03	4.020	32	127.0	0.24876	0.01834	54.521	12	3.05 - 5.3	679
24.50	7.47	3.640	47	170.8	0.27473	0.02597	38.507	15	5.03 - 7.47	590
49.00	14.94	3.490	94	327.5	0.28653	0.01181	84.691	47	7.47 - 14.94	3,974
82.00	24.99	1.800	157	282.7	0.55556	0.26902	3.717	63	14.94 - 25.0	235
164.00	49.99	0.730	314	229.3	1.36986	0.81431	1.228	157	25.0 - 49.99	193

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







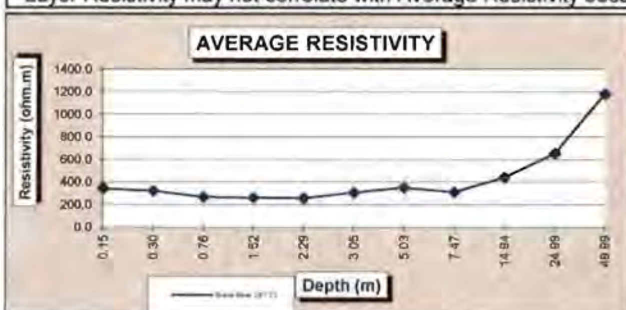
SOIL RESISTIVITY DATA

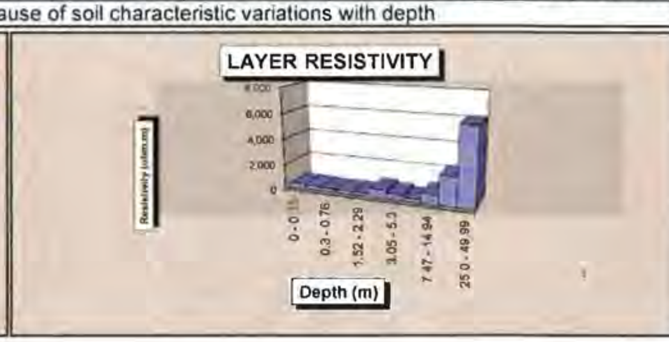
Project Name:	Vermont Gas Project
	12-144-14
Date:	5/2/2013
Location:	Rd Sd off Charles Rd
	44 25.1789N, 73 8.0221W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	64F/Clear
Soil Description	Dark, moist, and rocky soil

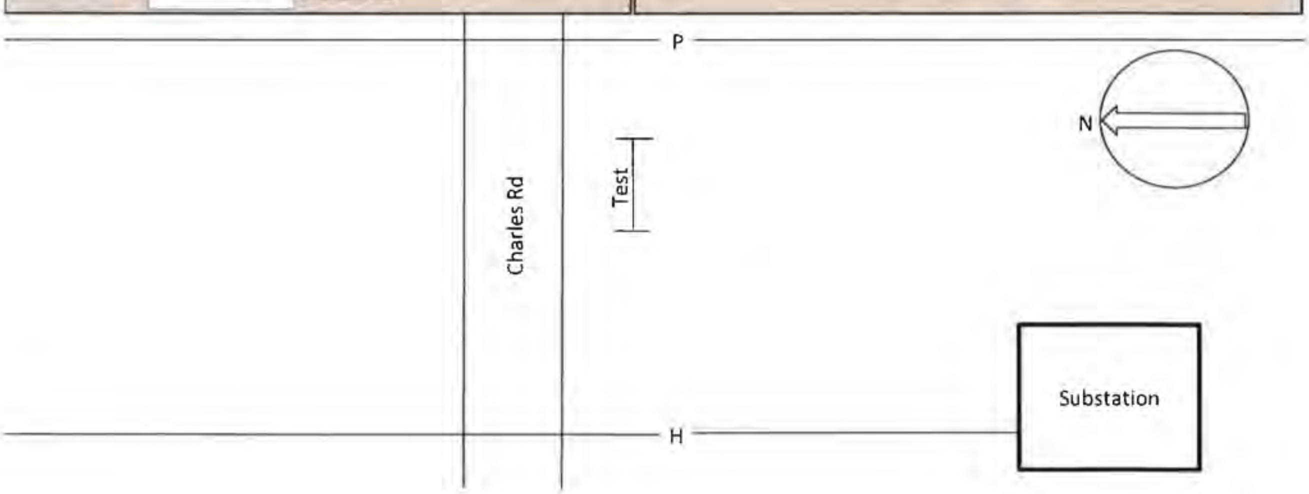
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	359.000	1	343.8	0.00279	n/a	n/a	n/a	0 - 0.15	344
1.00	0.30	167.600	2	321.0	0.00597	0.00318	314.359	1	0.15 - 0.3	301
2.50	0.76	55.900	5	267.6	0.01789	0.01192	83.875	3	0.3 - 0.76	241
5.00	1.52	27.400	10	262.4	0.03650	0.01861	53.742	5	0.76 - 1.52	257
7.50	2.29	18.050	14	259.3	0.05540	0.01891	52.895	5	1.52 - 2.29	253
10.00	3.05	15.990	19	306.2	0.06254	0.00714	140.107	5	2.29 - 3.05	671
16.50	5.03	11.100	32	350.8	0.09009	0.02755	36.296	12	3.05 - 5.3	452
24.50	7.47	6.600	47	309.7	0.15152	0.06143	16.280	15	5.03 - 7.47	249
49.00	14.94	4.690	94	440.1	0.21322	0.06170	16.206	47	7.47 - 14.94	760
82.00	24.99	4.150	157	651.7	0.24096	0.02774	36.044	63	14.94 - 25.0	2,278
164.00	49.99	3.750	314	1177.8	0.26667	0.02570	38.906	157	25.0 - 49.99	6,110

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







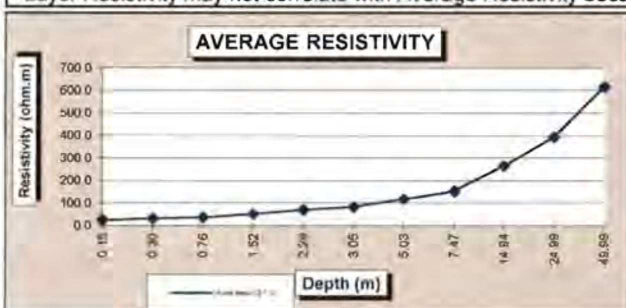
SOIL RESISTIVITY DATA

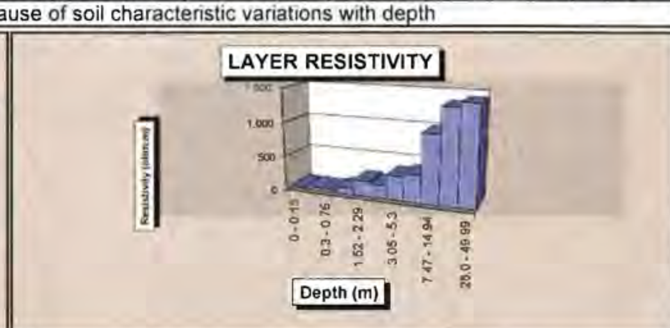
Project Name:	Vermont Gas Project
	12-144-15
Date:	5/2/2013
Location:	Rd Sd off Butternut Rd
	44 24.1525N, 73 7.5014W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	61F/Clear
Soil Description	Moist, dark, and rocky soil

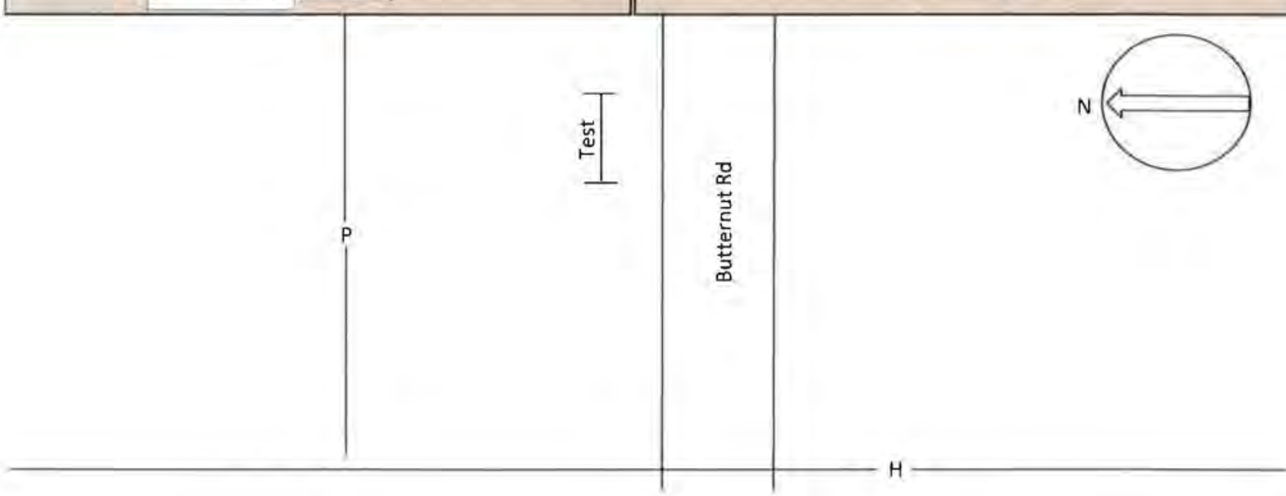
ARK ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	25.400	1	24.3	0.03937	n/a	n/a	n/a	0 - 0.15	24
1.00	0.30	16.570	2	31.7	0.06035	0.02098	47.665	1	0.15 - 0.3	46
2.50	0.76	7.650	5	36.6	0.13072	0.07037	14.211	3	0.3 - 0.76	41
5.00	1.52	5.410	10	51.8	0.18484	0.05412	18.476	5	0.76 - 1.52	88
7.50	2.29	4.850	14	69.7	0.20619	0.02134	46.854	5	1.52 - 2.29	224
10.00	3.05	4.330	19	82.9	0.23095	0.02476	40.386	5	2.29 - 3.05	193
16.50	5.03	3.750	32	118.5	0.26667	0.03572	27.996	12	3.05 - 5.3	348
24.50	7.47	3.270	47	153.4	0.30581	0.03914	25.547	15	5.03 - 7.47	391
49.00	14.94	2.830	94	265.6	0.35336	0.04755	21.032	47	7.47 - 14.94	987
82.00	24.99	2.500	157	392.6	0.40000	0.04664	21.439	63	14.94 - 25.0	1,355
164.00	49.99	1.960	314	615.6	0.51020	0.11020	9.074	157	25.0 - 49.99	1,425

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







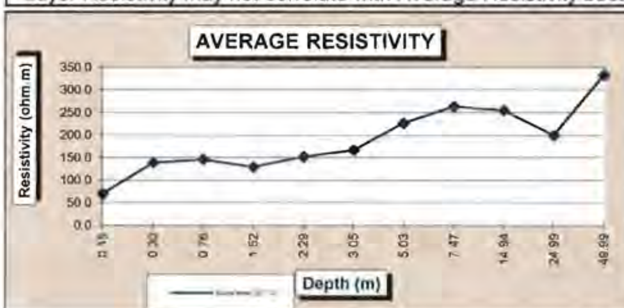
SOIL RESISTIVITY DATA

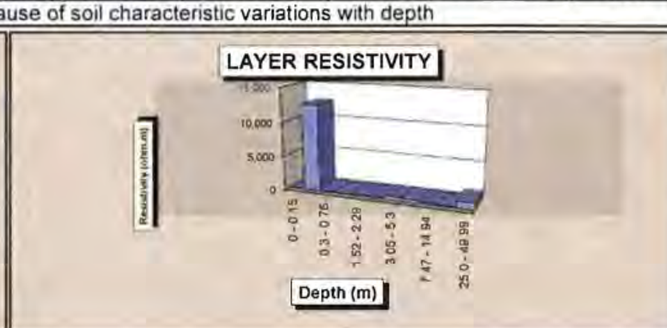
Project Name:	Vermont Gas Project
	12-144-16
Date:	5/2/2013
Location:	Rd Sd off Beliveau Rd
	44 23.2839N, 73 7.5540W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	62F/Clear
Soil Description	Dry, rocky soil

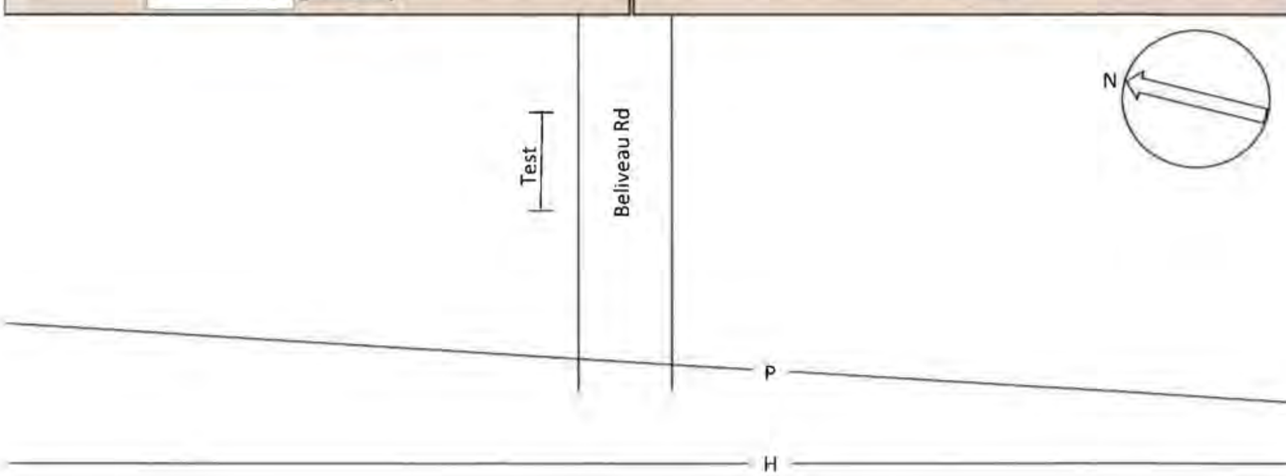
ARK. Engineering & Technical Services, Inc.

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	72.800	1	69.7	0.01374	n/a	n/a	n/a	0 - 0.15	70
1.00	0.30	72.400	2	138.7	0.01381	0.00008	13176.800	1	0.15 - 0.3	12,618
2.50	0.76	30.500	5	146.0	0.03279	0.01897	52.702	3	0.3 - 0.76	151
5.00	1.52	13.510	10	129.4	0.07402	0.04123	24.253	5	0.76 - 1.52	116
7.50	2.29	10.570	14	151.8	0.09461	0.02059	48.572	5	1.52 - 2.29	233
10.00	3.05	8.700	19	166.6	0.11494	0.02034	49.176	5	2.29 - 3.05	235
16.50	5.03	7.180	32	226.9	0.13928	0.02433	41.096	12	3.05 - 5.3	512
24.50	7.47	5.610	47	263.2	0.17825	0.03898	25.656	15	5.03 - 7.47	393
49.00	14.94	2.720	94	255.2	0.36765	0.18939	5.280	47	7.47 - 14.94	248
82.00	24.99	1.270	157	199.4	0.78740	0.41975	2.382	63	14.94 - 25.0	151
164.00	49.99	1.060	314	332.9	0.94340	0.15599	6.410	157	25.0 - 49.99	1,007

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







SOIL RESISTIVITY DATA

Project Name:	Vermont Gas Project
	12-144-17
Date:	5/1/2013
Location:	Rd Sd North of CR116
	44 22.1536N, 73 7.6751W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	76F/Clear
Soil Description	Dark, moist, sodded

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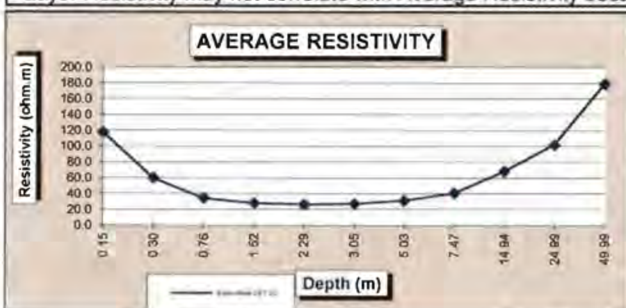
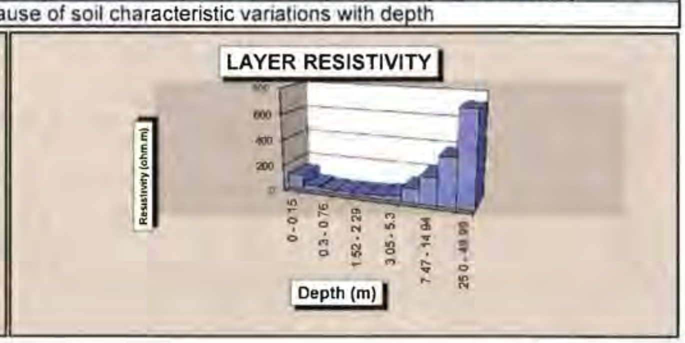
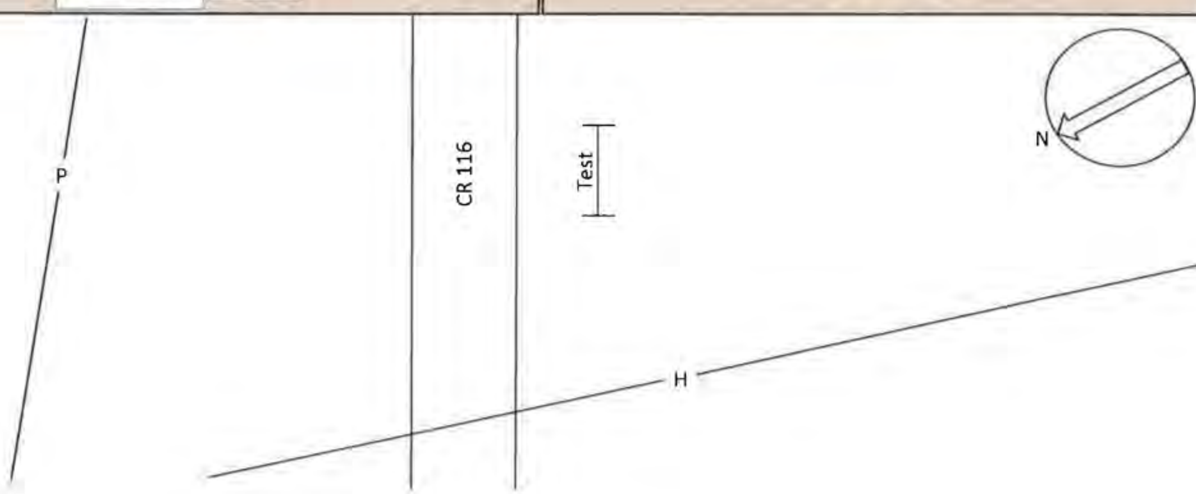
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	122.900	1	117.7	0.00814	n/a	n/a	n/a	0 - 0.15	118
1.00	0.30	31.400	2	60.1	0.03185	0.02371	42.176	1	0.15 - 0.3	40
2.50	0.76	7.200	5	34.5	0.13889	0.10704	9.342	3	0.3 - 0.76	27
5.00	1.52	2.930	10	28.1	0.34130	0.20241	4.941	5	0.76 - 1.52	24
7.50	2.29	1.840	14	26.4	0.54348	0.20218	4.946	5	1.52 - 2.29	24
10.00	3.05	1.430	19	27.4	0.69930	0.15582	6.418	5	2.29 - 3.05	31
16.50	5.03	0.990	32	31.3	1.01010	0.31080	3.218	12	3.05 - 5.3	40
24.50	7.47	0.870	47	40.8	1.14943	0.13932	7.178	15	5.03 - 7.47	110
49.00	14.94	0.730	94	68.5	1.36986	0.22044	4.536	47	7.47 - 14.94	213
82.00	24.99	0.650	157	102.1	1.53846	0.16860	5.931	63	14.94 - 25.0	375
164.00	49.99	0.570	314	179.0	1.75439	0.21592	4.631	157	25.0 - 49.99	727

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







SOIL RESISTIVITY DATA

Project Name:	Vermont Gas Project
	12-144-18
Date:	5/1/2013
Location:	Mowed pasture West of CR116
	44 21.010N, 73 7.096W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	75F/Clear
Soil Description	Wet, dark soil

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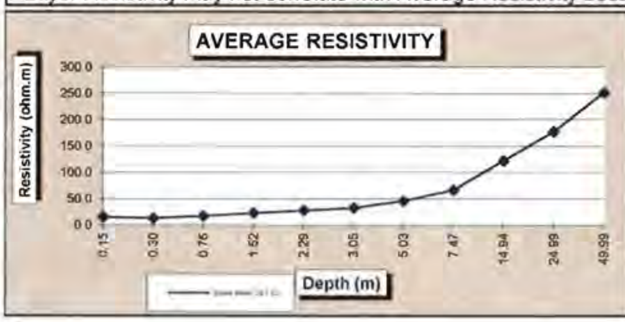
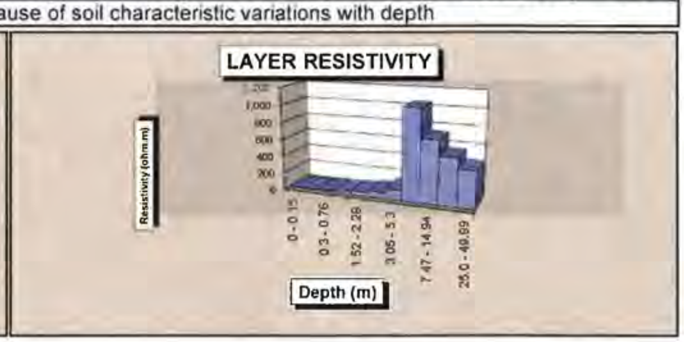
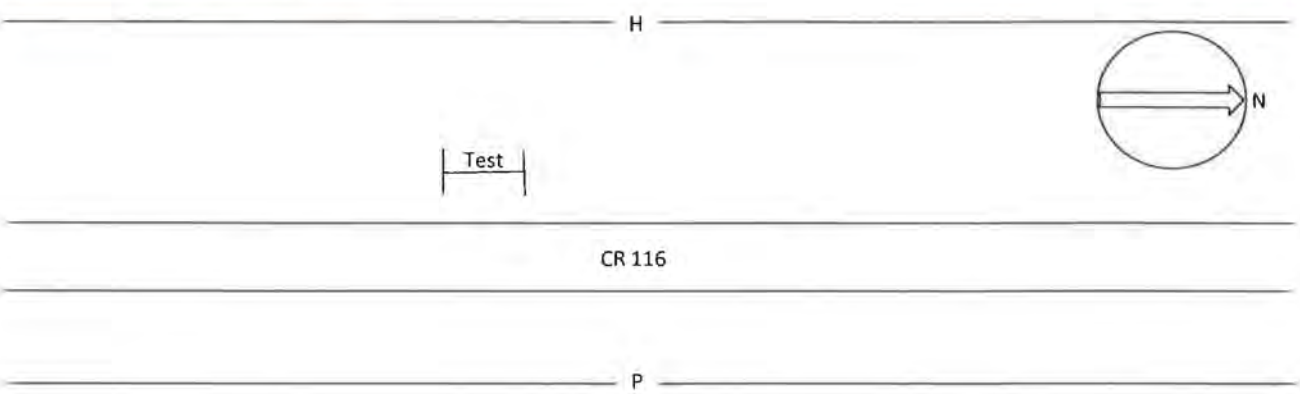
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	16.540	1	15.8	0.06046	n/a	n/a	n/a	0 - 0.15	16
1.00	0.30	6.740	2	12.9	0.14837	0.08791	11.375	1	0.15 - 0.3	11
2.50	0.76	3.650	5	17.5	0.27397	0.12560	7.961	3	0.3 - 0.76	23
5.00	1.52	2.410	10	23.1	0.41494	0.14097	7.094	5	0.76 - 1.52	34
7.50	2.29	1.940	14	27.9	0.51546	0.10053	9.948	5	1.52 - 2.29	48
10.00	3.05	1.710	19	32.7	0.58480	0.06933	14.423	5	2.29 - 3.05	69
16.50	5.03	1.450	32	45.8	0.68966	0.10486	9.537	12	3.05 - 5.3	119
24.50	7.47	1.420	47	66.6	0.70423	0.01457	68.633	15	5.03 - 7.47	1,052
49.00	14.94	1.300	94	122.0	0.76923	0.06501	15.383	47	7.47 - 14.94	722
82.00	24.99	1.130	157	177.5	0.88496	0.11572	8.641	63	14.94 - 25.0	546
164.00	49.99	0.800	314	251.3	1.25000	0.36504	2.739	157	25.0 - 49.99	430

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







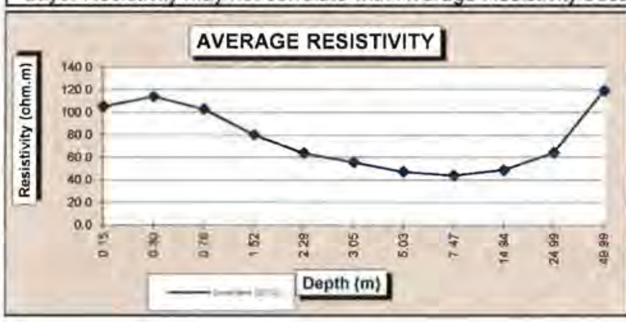
SOIL RESISTIVITY DATA

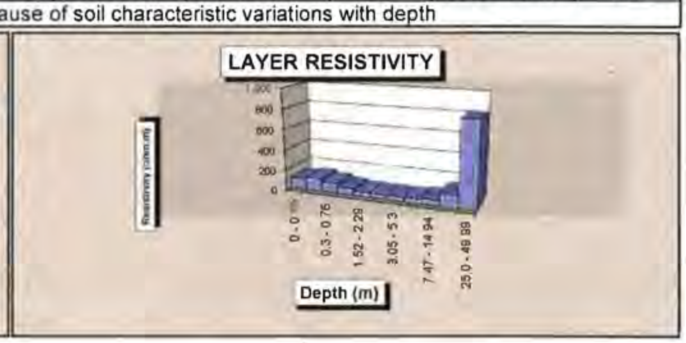
Project Name:	Vermont Gas Project
	12-144-19
Date:	5/1/2013
Location:	Mowed field off Shelburne Falls Rd
	44 20.454N, 73 7.615W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	75F/Clear
Soil Description	Dark and moist

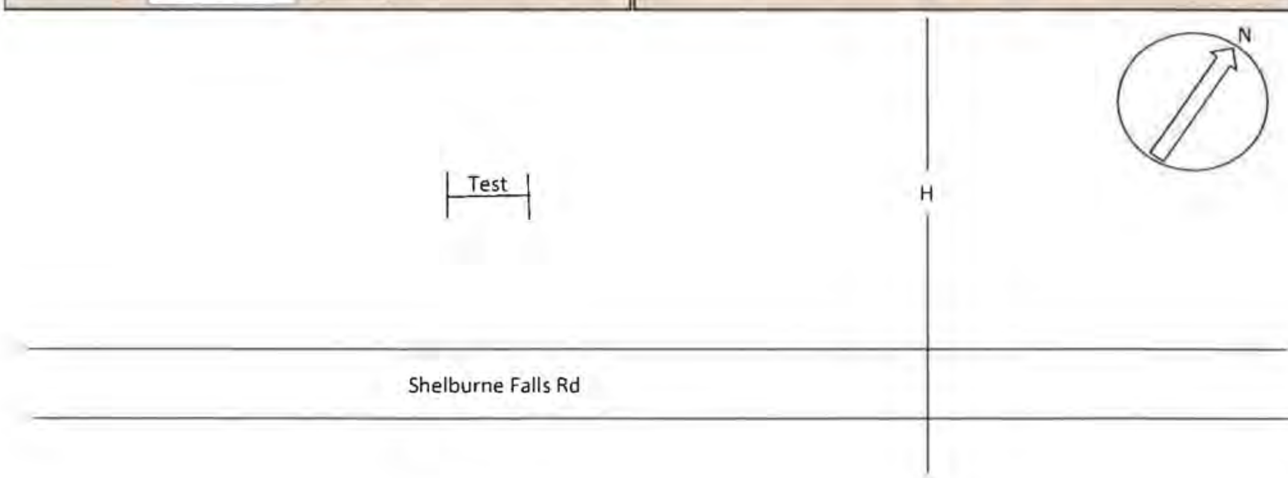
ENGINEERING & TECHNICAL SERVICES, INC

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	109.800	1	105.1	0.00911	n/a	n/a	n/a	0 - 0.15	105
1.00	0.30	59.400	2	113.8	0.01684	0.00773	129.407	1	0.15 - 0.3	124
2.50	0.76	21.500	5	102.9	0.04651	0.02968	33.697	3	0.3 - 0.76	97
5.00	1.52	8.370	10	80.1	0.11947	0.07296	13.706	5	0.76 - 1.52	66
7.50	2.29	4.440	14	63.8	0.22523	0.10575	9.456	5	1.52 - 2.29	45
10.00	3.05	2.920	19	55.9	0.34247	0.11724	8.529	5	2.29 - 3.05	41
16.50	5.03	1.500	32	47.4	0.66667	0.32420	3.085	12	3.05 - 5.3	38
24.50	7.47	0.940	47	44.1	1.06383	0.39716	2.518	15	5.03 - 7.47	39
49.00	14.94	0.520	94	48.8	1.92308	0.85925	1.164	47	7.47 - 14.94	55
82.00	24.99	0.410	157	64.4	2.43902	0.51595	1.938	63	14.94 - 25.0	122
164.00	49.99	0.380	314	119.3	2.63158	0.19255	5.193	157	25.0 - 49.99	816

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







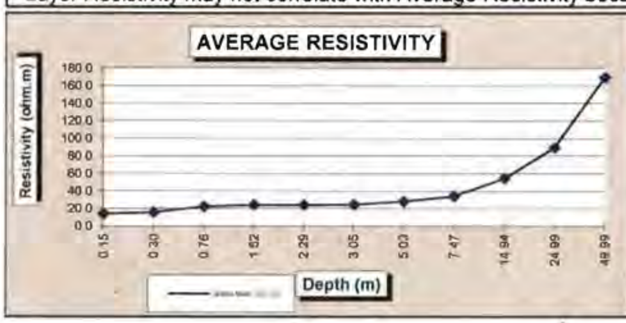
SOIL RESISTIVITY DATA

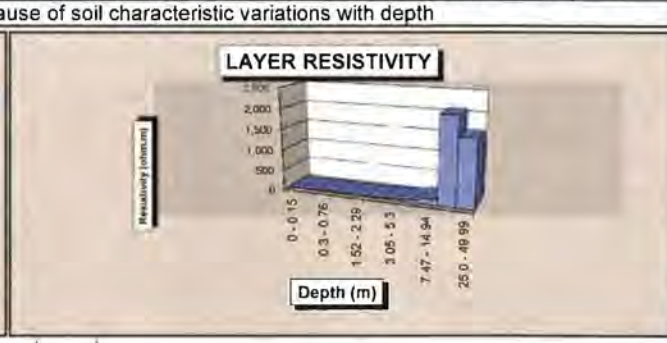
Project Name:	Vermont Gas Project
	12-144-20
Date:	5/1/2013
Location:	Mowed field off Charlotte Rd
	44 19.6814N, 73 7.9244W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	73F/Clear
Soil Description	Moist, Dark

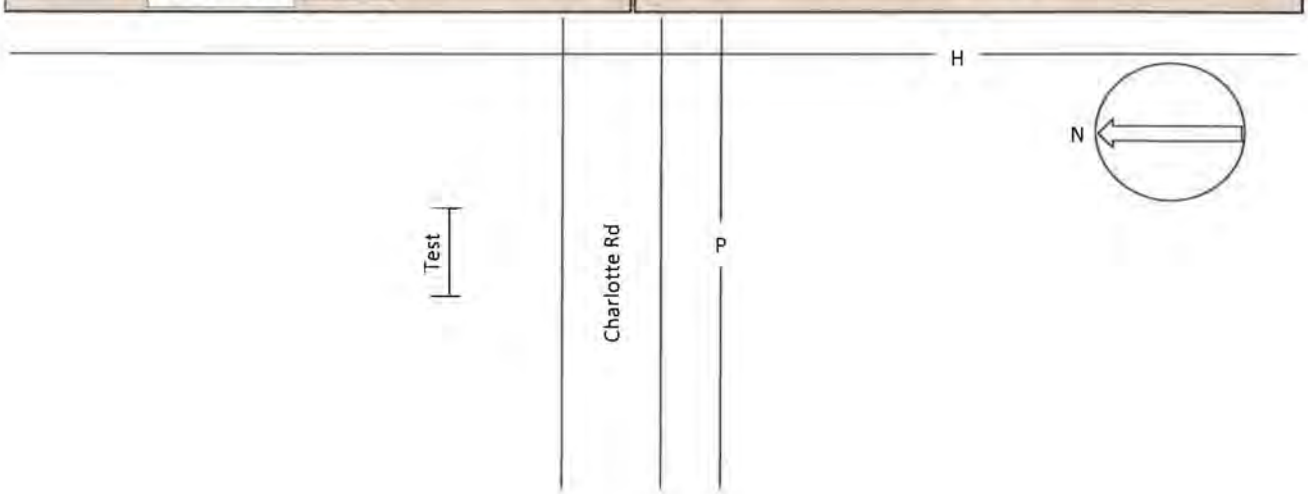
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	14.710	1	14.1	0.06798	n/a	n/a	n/a	0 - 0.15	14
1.00	0.30	8.330	2	16.0	0.12005	0.05207	19.206	1	0.15 - 0.3	18
2.50	0.76	4.670	5	22.4	0.21413	0.09408	10.629	3	0.3 - 0.76	31
5.00	1.52	2.540	10	24.3	0.39370	0.17957	5.569	5	0.76 - 1.52	27
7.50	2.29	1.690	14	24.3	0.59172	0.19802	5.050	5	1.52 - 2.29	24
10.00	3.05	1.290	19	24.7	0.77519	0.18348	5.450	5	2.29 - 3.05	26
16.50	5.03	0.890	32	28.1	1.12360	0.34840	2.870	12	3.05 - 5.3	36
24.50	7.47	0.730	47	34.3	1.36986	0.24627	4.061	15	5.03 - 7.47	62
49.00	14.94	0.580	94	54.4	1.72414	0.35427	2.823	47	7.47 - 14.94	132
82.00	24.99	0.570	157	89.5	1.75439	0.03025	33.060	63	14.94 - 25.0	2,089
164.00	49.99	0.540	314	169.6	1.85185	0.09747	10.260	157	25.0 - 49.99	1,611

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







SOIL RESISTIVITY DATA

Project Name:	Vermont Gas Project
	12-144-21
Date:	5/1/2013
Location:	Rd Sd off Burritt Rd
	44 18.7647N, 73 8.1066W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	66F/Clear
Soil Description	Dry sand and rock

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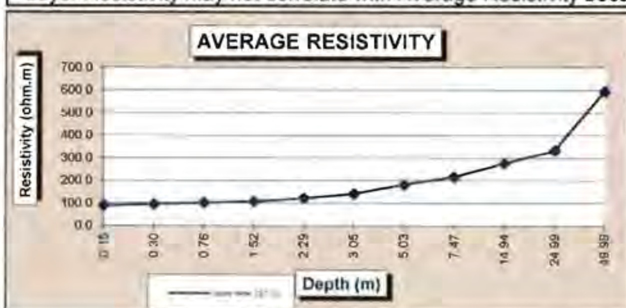
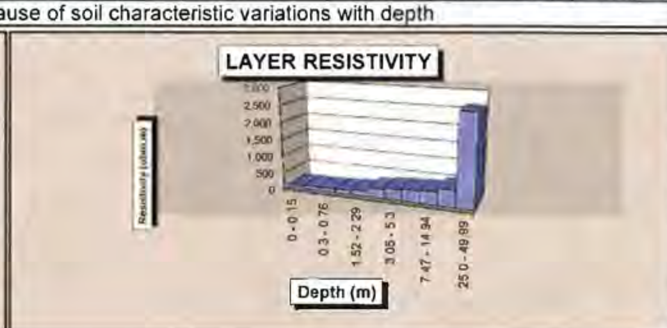
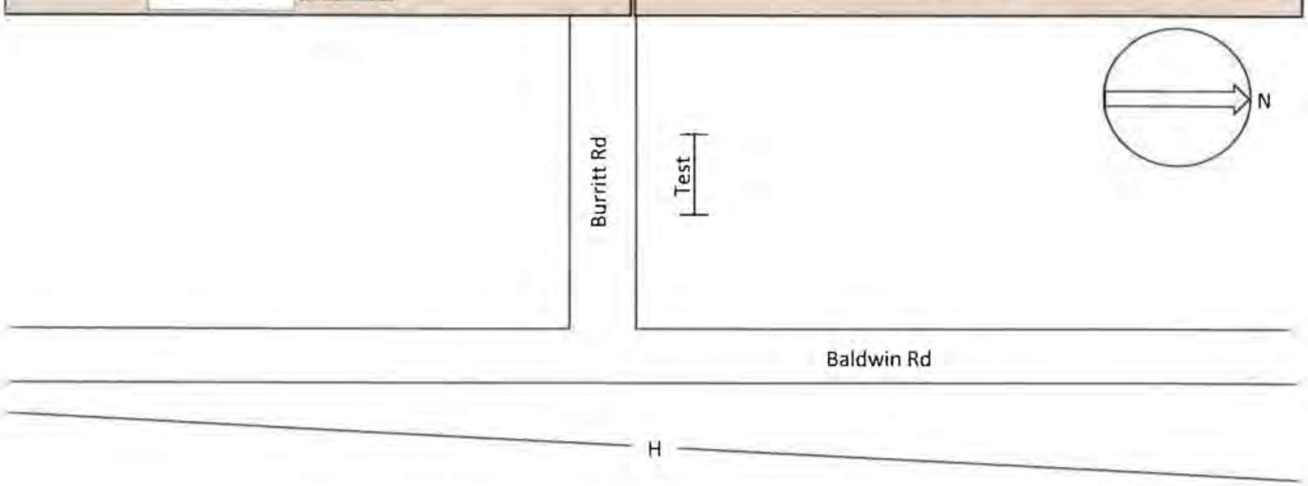
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	93.300	1	89.3	0.01072	n/a	n/a	n/a	0 - 0.15	89
1.00	0.30	49.500	2	94.8	0.02020	0.00948	105.442	1	0.15 - 0.3	101
2.50	0.76	21.100	5	101.0	0.04739	0.02719	36.776	3	0.3 - 0.76	106
5.00	1.52	11.220	10	107.4	0.08913	0.04173	23.962	5	0.76 - 1.52	115
7.50	2.29	8.450	14	121.4	0.11834	0.02922	34.227	5	1.52 - 2.29	164
10.00	3.05	7.350	19	140.8	0.13605	0.01771	56.461	5	2.29 - 3.05	270
16.50	5.03	5.740	32	181.4	0.17422	0.03816	26.204	12	3.05 - 5.3	326
24.50	7.47	4.600	47	215.8	0.21739	0.04318	23.161	15	5.03 - 7.47	355
49.00	14.94	2.940	94	275.9	0.34014	0.12274	8.147	47	7.47 - 14.94	382
82.00	24.99	2.130	157	334.5	0.46948	0.12935	7.731	63	14.94 - 25.0	489
164.00	49.99	1.890	314	593.6	0.52910	0.05962	16.774	157	25.0 - 49.99	2,634

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







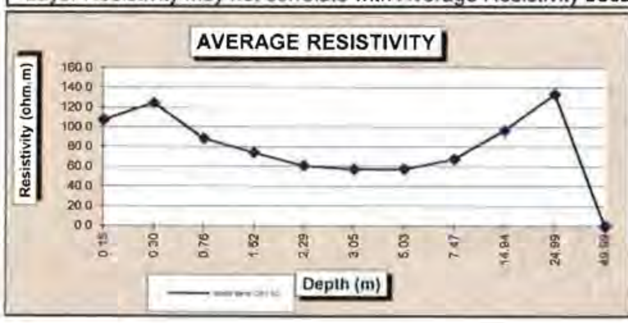
SOIL RESISTIVITY DATA

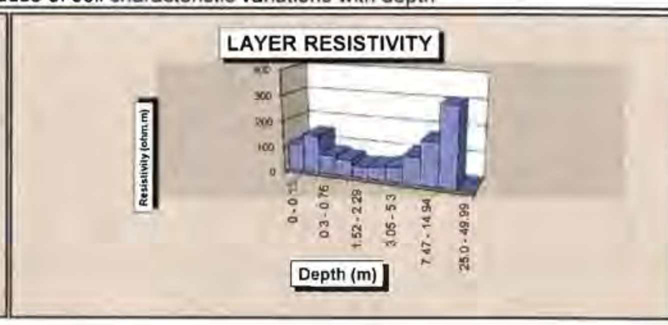
Project Name:	Vermont Gas Project
	12-144-22
Date:	5/6/2013
Location:	Rd Sd off Meade Farm Rd
	44 17.956N, 73 6.513W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	70F/Clear
Soil Description	Dark, moist and vegetation

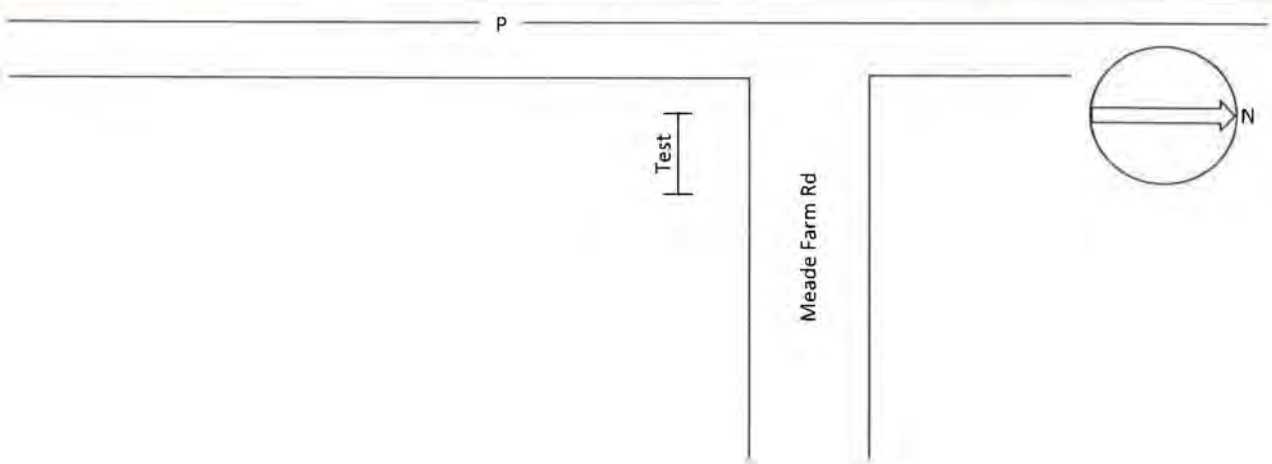
ARK Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	112.000	1	107.2	0.00893	n/a	n/a	n/a	0 - 0.15	107
1.00	0.30	64.900	2	124.3	0.01541	0.00648	154.327	1	0.15 - 0.3	148
2.50	0.76	18.430	5	88.2	0.05426	0.03885	25.739	3	0.3 - 0.76	74
5.00	1.52	7.740	10	74.1	0.12920	0.07494	13.344	5	0.76 - 1.52	64
7.50	2.29	4.240	14	60.9	0.23585	0.10665	9.376	5	1.52 - 2.29	45
10.00	3.05	2.990	19	57.3	0.33445	0.09860	10.142	5	2.29 - 3.05	49
16.50	5.03	1.820	32	57.5	0.54945	0.21500	4.651	12	3.05 - 5.3	58
24.50	7.47	1.440	47	67.6	0.69444	0.14499	6.897	15	5.03 - 7.47	106
49.00	14.94	1.030	94	96.7	0.97087	0.27643	3.618	47	7.47 - 14.94	170
82.00	24.99	0.850	157	133.5	1.17647	0.20560	4.864	63	14.94 - 25.0	307
164.00	49.99	Short Test	314	#VALUE!	#######	#VALUE!	#VALUE!	157	25.0 - 49.99	#VALUE!

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







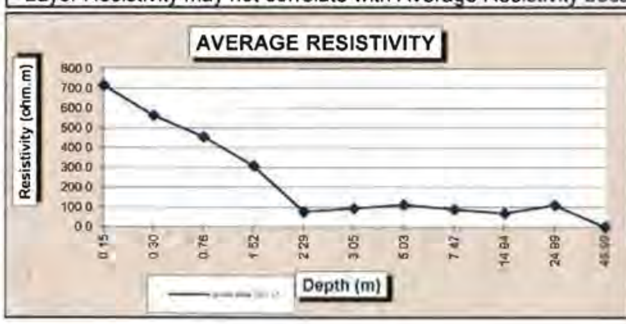
SOIL RESISTIVITY DATA

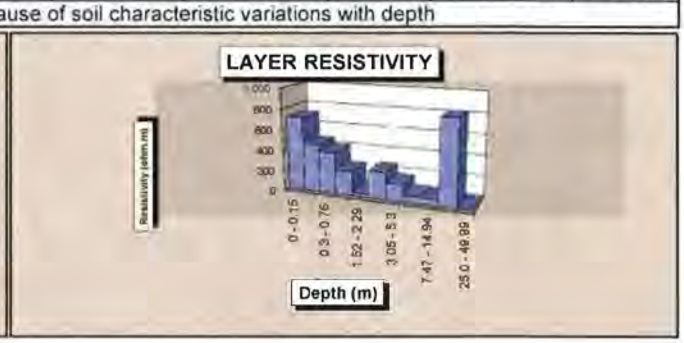
Project Name: Vermont Gas Project
12-144-23
Date: 5/6/2013
Location: Rd Sd off Deer Run Ln
44 17.238N, 73 7.823W
Testers: KJ, LM
Methodology: ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation: Biddle Meter DET 5/2
Weather: 60F/Clear
Soil Description Dark, moist, and vegetation

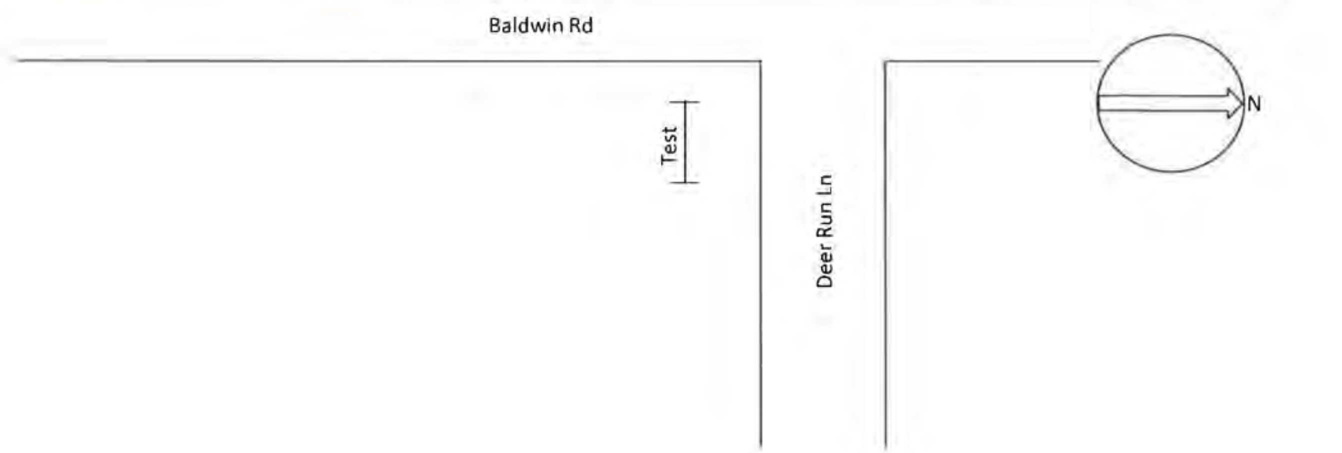
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	747.000	1	715.3	0.00134	n/a	n/a	n/a	0 - 0.15	715
1.00	0.30	294.000	2	563.0	0.00340	0.00206	484.808	1	0.15 - 0.3	464
2.50	0.76	95.000	5	454.8	0.01053	0.00712	140.352	3	0.3 - 0.76	403
5.00	1.52	32.300	10	309.3	0.03096	0.02043	48.939	5	0.76 - 1.52	234
7.50	2.29	5.350	14	76.8	0.18692	0.15596	6.412	5	1.52 - 2.29	31
10.00	3.05	4.870	19	93.3	0.20534	0.01842	54.280	5	2.29 - 3.05	260
16.50	5.03	3.530	32	111.5	0.28329	0.07795	12.829	12	3.05 - 5.3	160
24.50	7.47	1.900	47	89.1	0.52632	0.24303	4.115	15	5.03 - 7.47	63
49.00	14.94	0.740	94	69.4	1.35135	0.82504	1.212	47	7.47 - 14.94	57
82.00	24.99	0.700	157	109.9	1.42857	0.07722	12.950	63	14.94 - 25.0	818
164.00	49.99	Short Test	314	#VALUE!	#######	#VALUE!	#VALUE!	157	25.0 - 49.99	#VALUE!

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







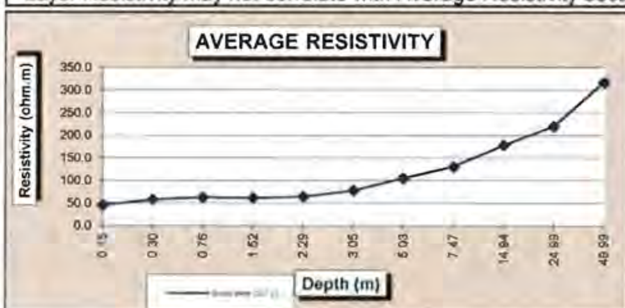
SOIL RESISTIVITY DATA

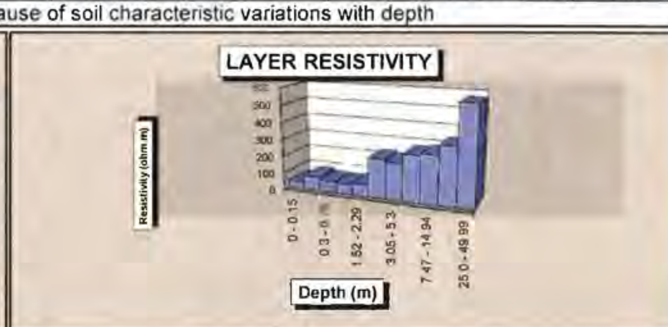
Project Name:	Vermont Gas Project
	12-144-24
Date:	5/3/2013
Location:	Rd Sd off Access Rd West of Baldwin Rd
	44 16.205N, 73 8.074W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	68F/Clear
Soil Description	Dry sand and rock

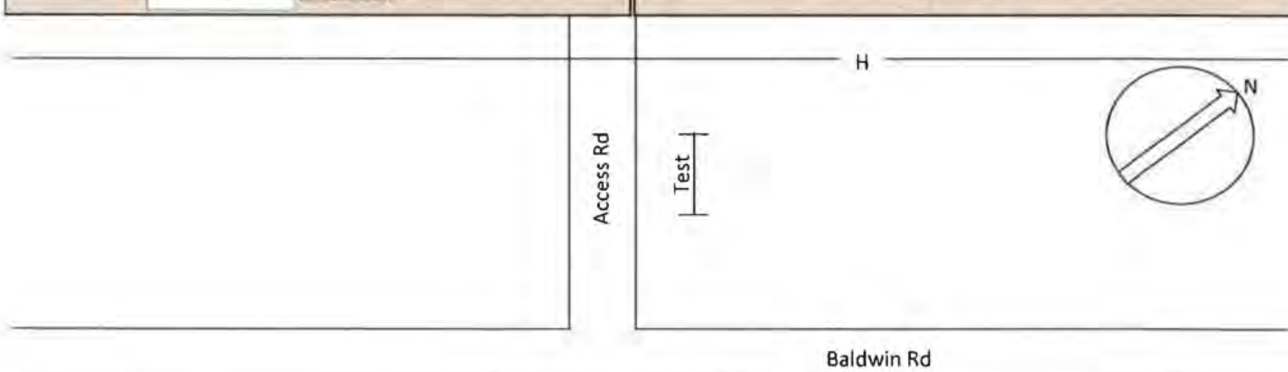
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	47.400	1	45.4	0.02110	n/a	n/a	n/a	0 - 0.15	45
1.00	0.30	30.500	2	58.4	0.03279	0.01169	85.544	1	0.15 - 0.3	82
2.50	0.76	13.080	5	62.6	0.07645	0.04367	22.901	3	0.3 - 0.76	66
5.00	1.52	6.430	10	61.6	0.15552	0.07907	12.647	5	0.76 - 1.52	61
7.50	2.29	4.450	14	63.9	0.22472	0.06920	14.451	5	1.52 - 2.29	69
10.00	3.05	4.070	19	77.9	0.24570	0.02098	47.662	5	2.29 - 3.05	228
16.50	5.03	3.300	32	104.3	0.30303	0.05733	17.443	12	3.05 - 5.3	217
24.50	7.47	2.780	47	130.4	0.35971	0.05668	17.642	15	5.03 - 7.47	270
49.00	14.94	1.900	94	178.3	0.52632	0.16660	6.002	47	7.47 - 14.94	282
82.00	24.99	1.400	157	219.9	0.71429	0.18797	5.320	63	14.94 - 25.0	336
164.00	49.99	1.010	314	317.2	0.99010	0.27581	3.626	157	25.0 - 49.99	569

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







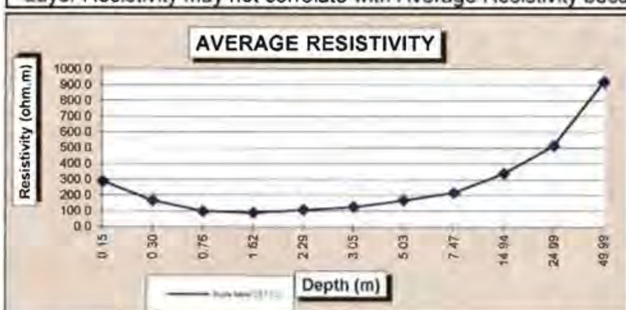
SOIL RESISTIVITY DATA

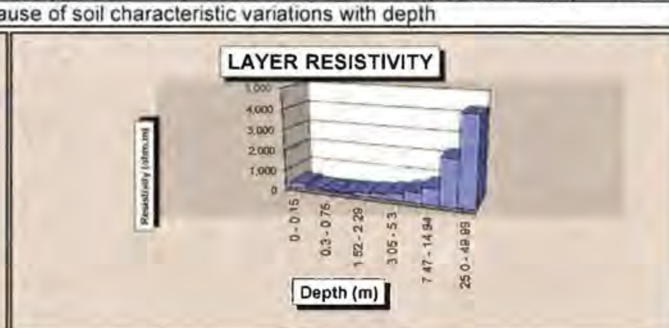
Project Name: Vermont Gas Project
12-144-25
Date: 5/3/2013
Location: Rd Sd off Pond Rd
44 15.096N, 73 8.382W
Testers: KJ, LM
Methodology: $\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation: Biddle Meter DET 5/2
Weather: 69F/Clear
Soil Description Dry sand and rock

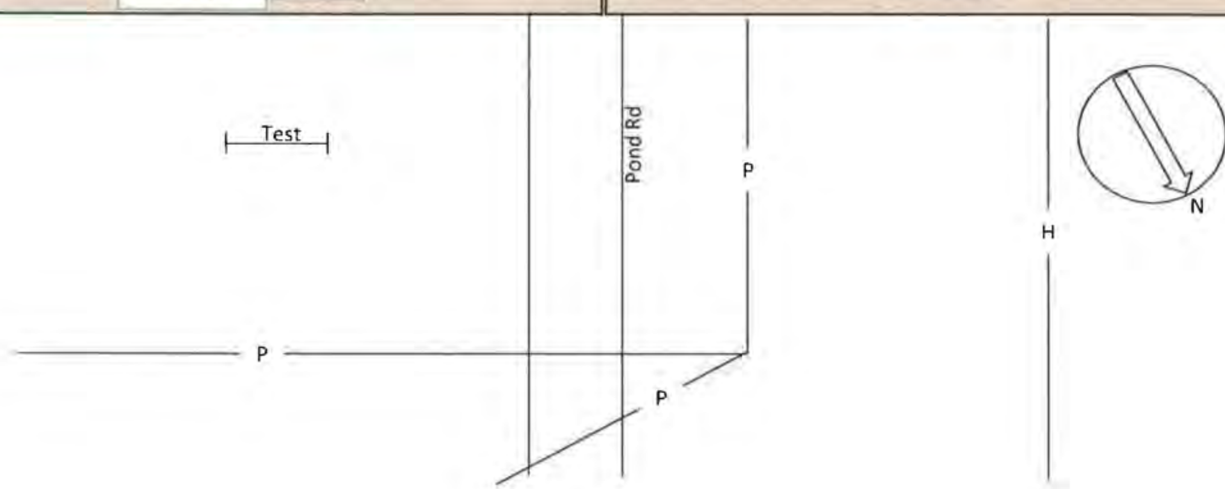
ARK. Engineering & Technical Services, Inc.

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)	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







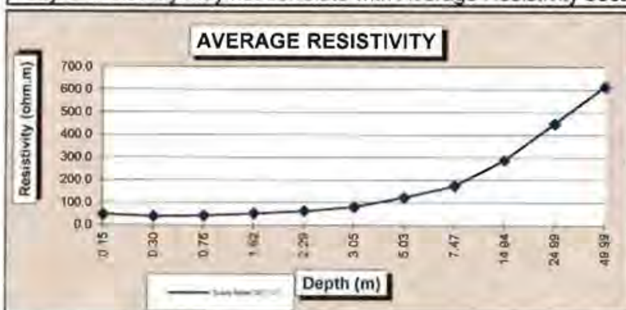
SOIL RESISTIVITY DATA

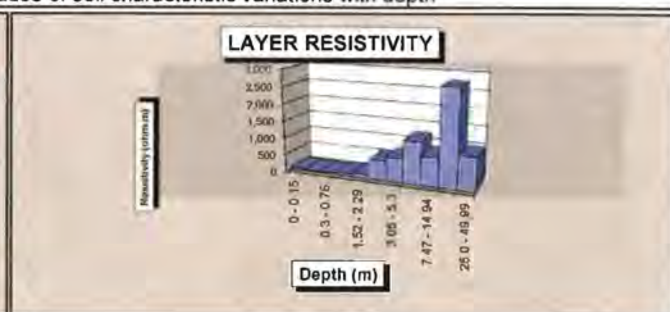
Project Name:	Vermont Gas Project
	12-144-26
Date:	5/4/2013
Location:	Rd Sd off Hollow Rd
	44 14.318N, 73 9.036W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	55F/Clear
Soil Description	Moist, dark soil

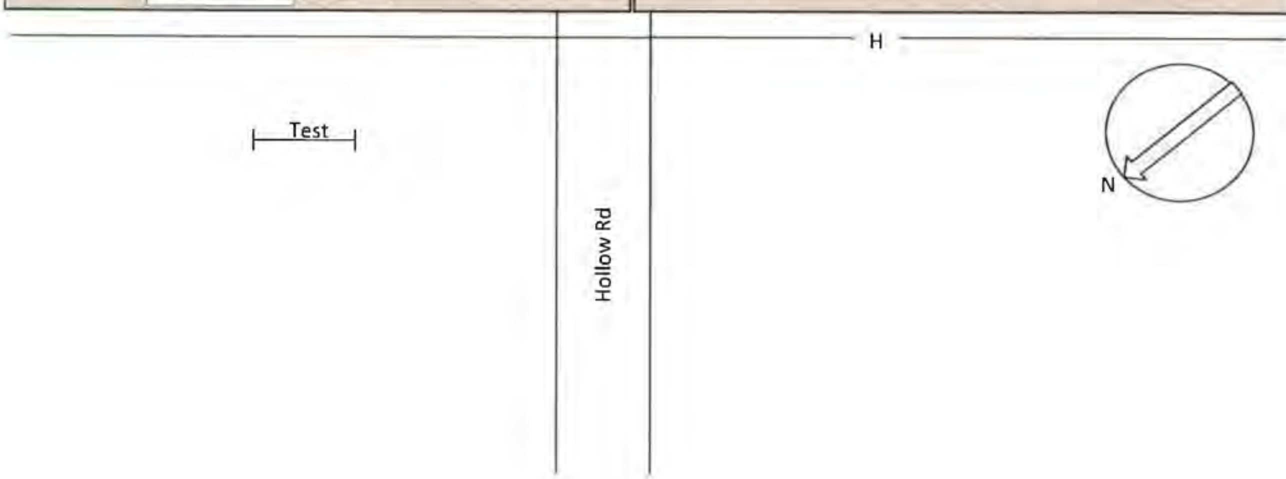
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	48.300	1	46.3	0.02070	n/a	n/a	n/a	0 - 0.15	46
1.00	0.30	20.500	2	39.3	0.04878	0.02808	35.617	1	0.15 - 0.3	34
2.50	0.76	8.690	5	41.6	0.11507	0.06629	15.084	3	0.3 - 0.76	43
5.00	1.52	5.360	10	51.3	0.18657	0.07149	13.988	5	0.76 - 1.52	67
7.50	2.29	4.320	14	62.0	0.23148	0.04491	22.265	5	1.52 - 2.29	107
10.00	3.05	4.170	19	79.9	0.23981	0.00833	120.096	5	2.29 - 3.05	575
16.50	5.03	3.880	32	122.6	0.25773	0.01792	55.792	12	3.05 - 5.3	695
24.50	7.47	3.700	47	173.6	0.27027	0.01254	79.756	15	5.03 - 7.47	1,222
49.00	14.94	3.060	94	287.2	0.32680	0.05653	17.691	47	7.47 - 14.94	830
82.00	24.99	2.860	157	449.1	0.34965	0.02285	43.758	63	14.94 - 25.0	2,765
164.00	49.99	1.950	314	612.5	0.51282	0.16317	6.129	157	25.0 - 49.99	962

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







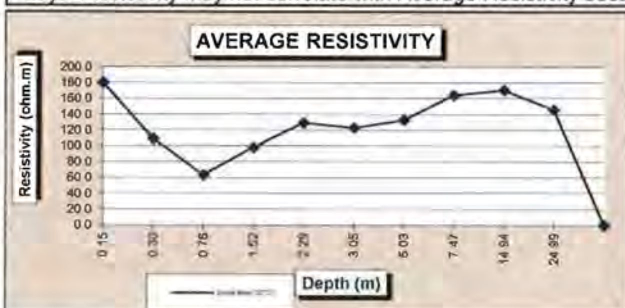
SOIL RESISTIVITY DATA

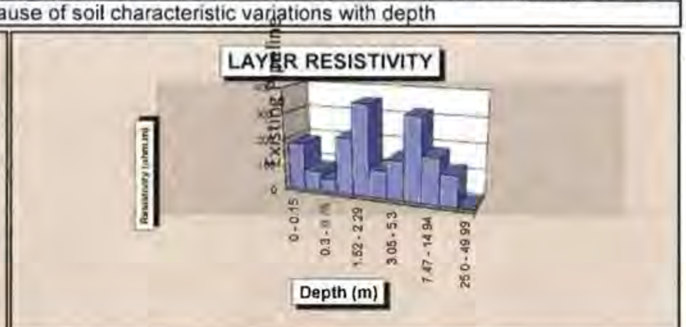
Project Name:	Vermont Gas Project
	12-144-27
Date:	5/6/2013
Location:	Rd Sd off Post Rd
	44 13.8614N, 73 9.1396W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	56F/Clear
Soil Description	Sand and rock

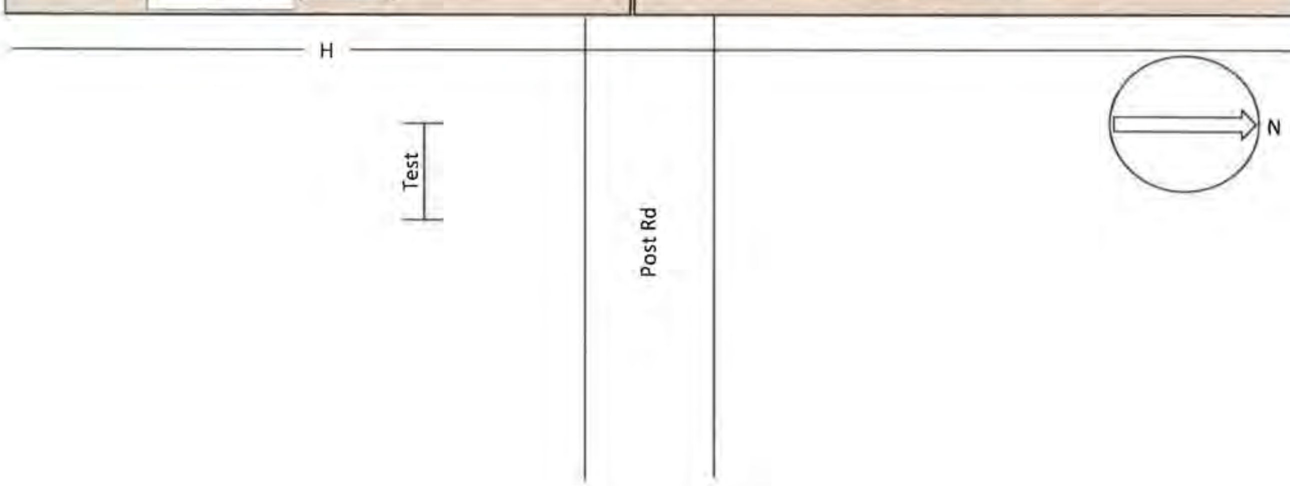
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	188.000	1	180.0	0.00532	n/a	n/a	n/a	0 - 0.15	180
1.00	0.30	57.200	2	109.5	0.01748	0.01216	82.214	1	0.15 - 0.3	79
2.50	0.76	13.220	5	63.3	0.07564	0.05816	17.194	3	0.3 - 0.76	49
5.00	1.52	10.240	10	98.1	0.09766	0.02201	45.427	5	0.76 - 1.52	217
7.50	2.29	8.990	14	129.1	0.11123	0.01358	73.646	5	1.52 - 2.29	353
10.00	3.05	6.420	19	123.0	0.15576	0.04453	22.458	5	2.29 - 3.05	108
16.50	5.03	4.200	32	132.7	0.23810	0.08233	12.146	12	3.05 - 5.3	151
24.50	7.47	3.500	47	164.2	0.28571	0.04762	21.000	15	5.03 - 7.47	322
49.00	14.94	1.820	94	170.8	0.54945	0.26374	3.792	47	7.47 - 14.94	178
82.00	24.99	0.930	157	146.0	1.07527	0.52582	1.902	63	14.94 - 25.0	120
			0	0.0	#DIV/0!	#DIV/0!	#DIV/0!	-157	25.0 - 49.99	#DIV/0!

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







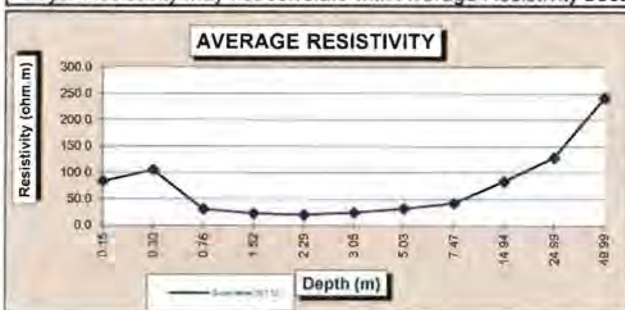
SOIL RESISTIVITY DATA

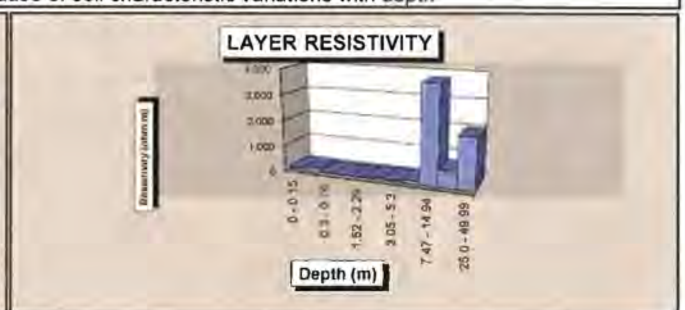
Project Name:	Vermont Gas Project
	12-144-28
Date:	5/3/2013
Location:	Rd Sd off Monkton Rd
	44 12.9201N, 73 9.5695W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	59F/Clear
Soil Description	Moist, dark soil and vegetation

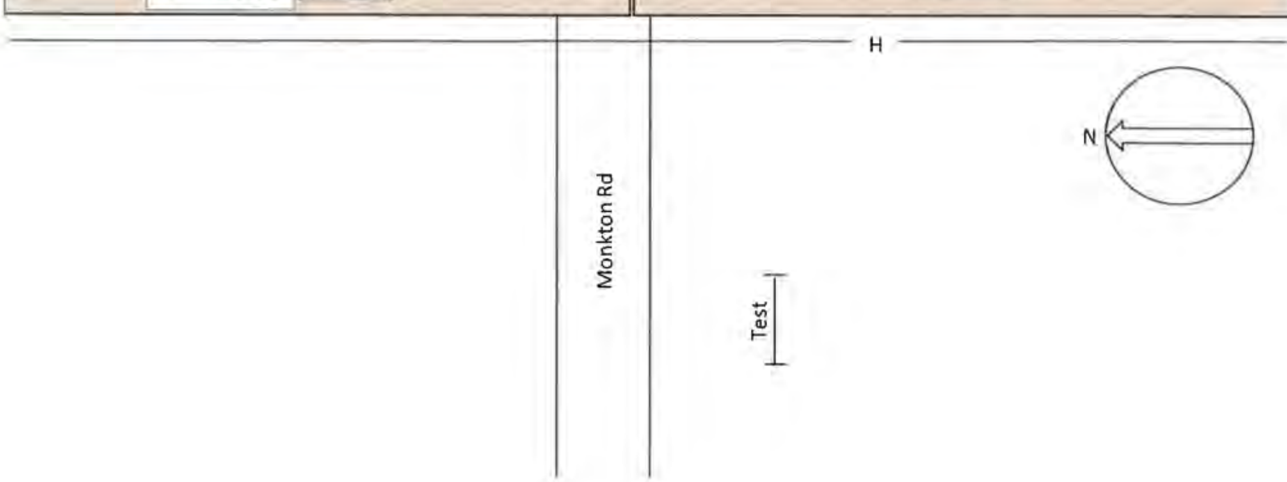
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	87.300	1	83.6	0.01145	n/a	n/a	n/a	0 - 0.15	84
1.00	0.30	54.800	2	104.9	0.01825	0.00679	147.201	1	0.15 - 0.3	141
2.50	0.76	6.460	5	30.9	0.15480	0.13655	7.323	3	0.3 - 0.76	21
5.00	1.52	2.370	10	22.7	0.42194	0.26714	3.743	5	0.76 - 1.52	18
7.50	2.29	1.380	14	19.8	0.72464	0.30270	3.304	5	1.52 - 2.29	16
10.00	3.05	1.270	19	24.3	0.78740	0.06276	15.933	5	2.29 - 3.05	76
16.50	5.03	1.010	32	31.9	0.99010	0.20270	4.933	12	3.05 - 5.3	61
24.50	7.47	0.900	47	42.2	1.11111	0.12101	8.264	15	5.03 - 7.47	127
49.00	14.94	0.890	94	83.5	1.12360	0.01248	80.100	47	7.47 - 14.94	3,758
82.00	24.99	0.820	157	128.8	1.21951	0.09592	10.426	63	14.94 - 25.0	659
164.00	49.99	0.770	314	241.8	1.29870	0.07919	12.628	157	25.0 - 49.99	1,983

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





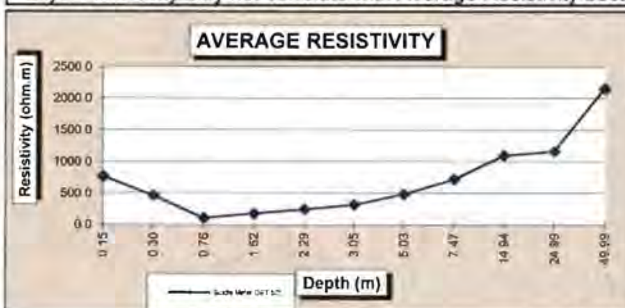


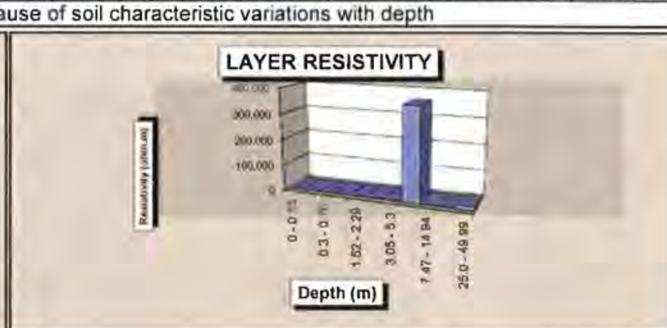
SOIL RESISTIVITY DATA

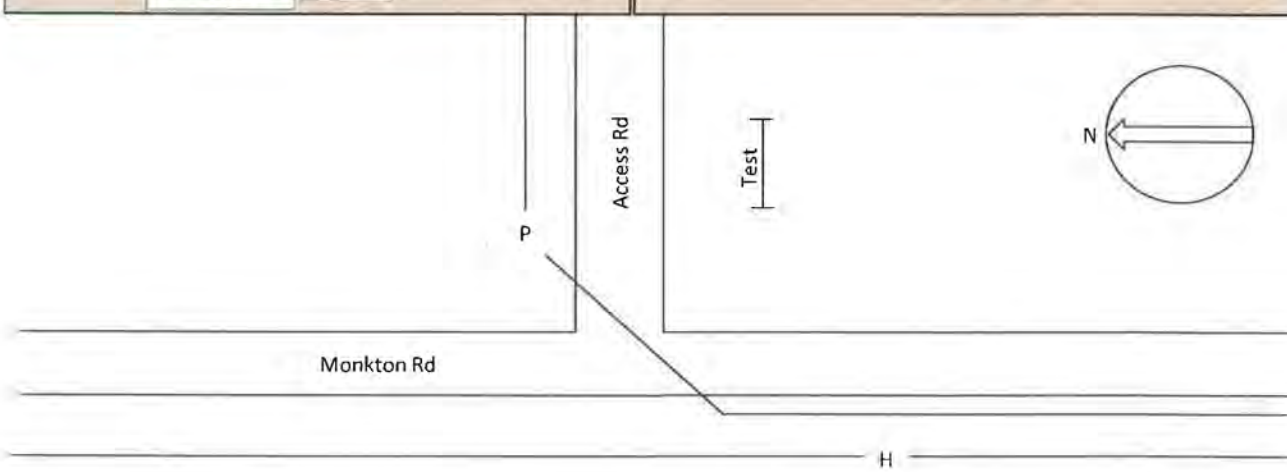
Project Name: Vermont Gas Project
12-144-29
Date: 5/4/2013
Location: Access Rd off Monkton Rd
44 11.9620N, 73 10.1339W
Testers: KJ, LM
Methodology: $\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation: Biddle Meter DET 5/2
Weather: 60F/Clear
Soil Description Dry, rocky soil

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	800.000	1	766.0	0.00125	n/a	n/a	n/a	0 - 0.15	766
1.00	0.30	243.000	2	465.4	0.00412	0.00287	349.013	1	0.15 - 0.3	334
2.50	0.76	22.900	5	109.6	0.04367	0.03955	25.283	3	0.3 - 0.76	73
5.00	1.52	18.700	10	179.1	0.05348	0.00981	101.960	5	0.76 - 1.52	488
7.50	2.29	17.120	14	245.9	0.05841	0.00494	202.623	5	1.52 - 2.29	970
10.00	3.05	16.690	19	319.6	0.05992	0.00150	664.495	5	2.29 - 3.05	3,181
16.50	5.03	15.350	32	485.1	0.06515	0.00523	191.188	12	3.05 - 5.3	2,380
24.50	7.47	15.340	47	719.8	0.06519	0.00004	23546.900	15	5.03 - 7.47	360,760
49.00	14.94	11.710	94	1098.9	0.08540	0.02021	49.485	47	7.47 - 14.94	2,322
82.00	24.99	7.400	157	1162.1	0.13514	0.04974	20.105	63	14.94 - 25.0	1,271
164.00	49.99	6.850	314	2151.4	0.14599	0.01085	92.164	157	25.0 - 49.99	14,473

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







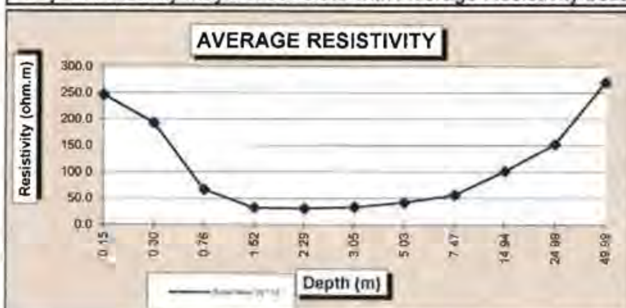
SOIL RESISTIVITY DATA

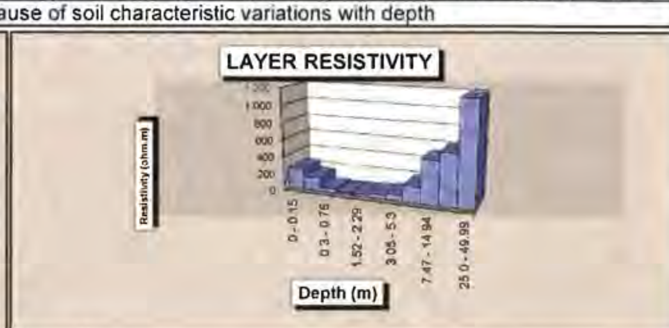
Project Name:	Vermont Gas Project
	12-144-30
Date:	5/4/2013
Location:	Rd Sd off Parks Hubert Rd
	44 11.3774N, 73 10.1006W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	63F/Clear
Soil Description	Dry sand and rock

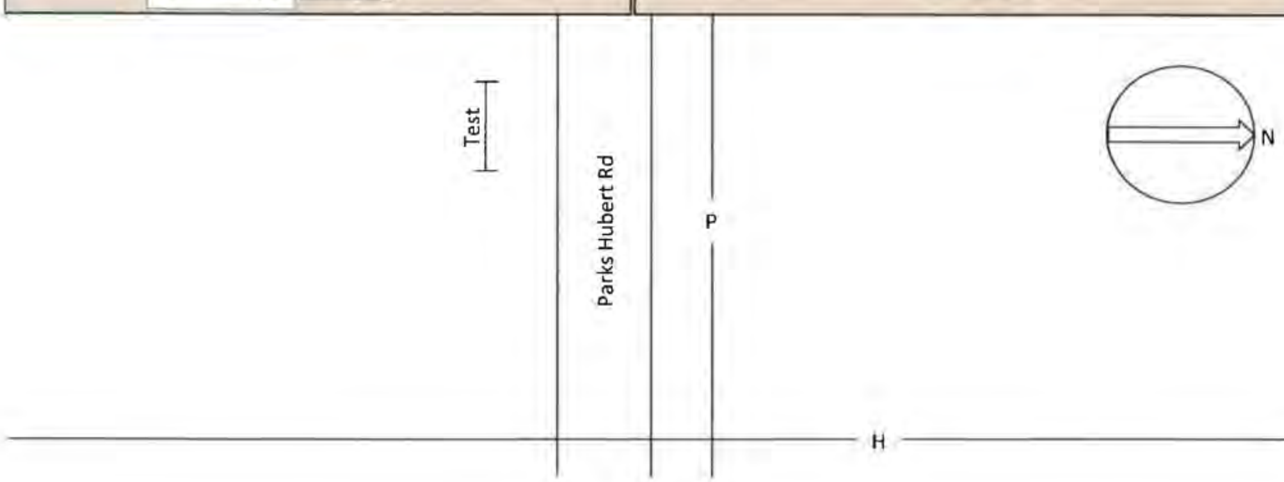
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	257.000	1	246.1	0.00389	n/a	n/a	n/a	0 - 0.15	246
1.00	0.30	100.600	2	192.7	0.00994	0.00605	165.308	1	0.15 - 0.3	158
2.50	0.76	13.870	5	66.4	0.07210	0.06216	16.088	3	0.3 - 0.76	46
5.00	1.52	3.350	10	32.1	0.29851	0.22641	4.417	5	0.76 - 1.52	21
7.50	2.29	2.110	14	30.3	0.47393	0.17543	5.700	5	1.52 - 2.29	27
10.00	3.05	1.750	19	33.5	0.57143	0.09749	10.257	5	2.29 - 3.05	49
16.50	5.03	1.330	32	42.0	0.75188	0.18045	5.542	12	3.05 - 5.3	69
24.50	7.47	1.200	47	56.3	0.83333	0.08145	12.277	15	5.03 - 7.47	188
49.00	14.94	1.080	94	101.3	0.92593	0.09259	10.800	47	7.47 - 14.94	507
82.00	24.99	0.970	157	152.3	1.03093	0.10500	9.524	63	14.94 - 25.0	602
164.00	49.99	0.860	314	270.1	1.16279	0.13186	7.584	157	25.0 - 49.99	1,191

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







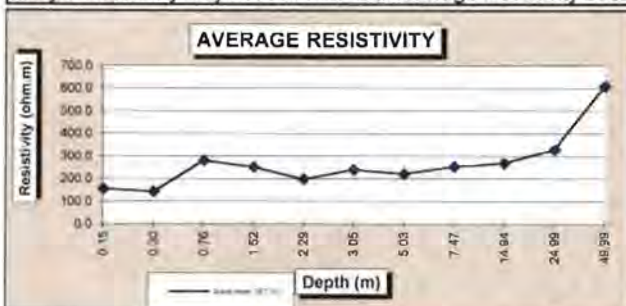
SOIL RESISTIVITY DATA

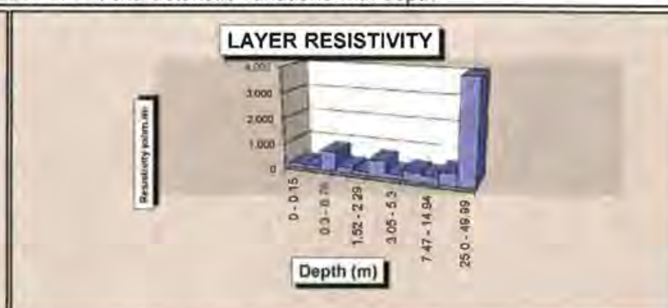
Project Name:	Vermont Gas Project
	12-144-31
Date:	5/4/2013
Location:	Rd Sd off NorthSt
	44 10.3319N, 73 9.1138W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	64F/Clear
Soil Description	Moist and rocky

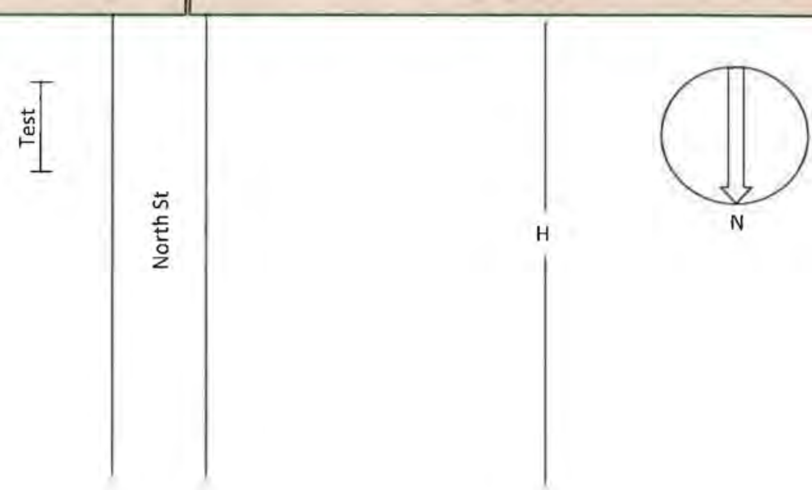
ARK. Engineering & Technical Services, Inc.

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)**	**ohm.m**
0.50	0.15	161.000	1	154.2	0.00621	n/a	n/a	n/a	0 - 0.15	154
1.00	0.30	74.800	2	143.3	0.01337	0.00716	139.708	1	0.15 - 0.3	134
2.50	0.76	58.600	5	280.6	0.01706	0.00370	270.573	3	0.3 - 0.76	777
5.00	1.52	26.300	10	251.8	0.03802	0.02096	47.715	5	0.76 - 1.52	228
7.50	2.29	13.830	14	198.6	0.07231	0.03428	29.168	5	1.52 - 2.29	140
10.00	3.05	12.540	19	240.2	0.07974	0.00744	134.440	5	2.29 - 3.05	644
16.50	5.03	7.000	32	221.2	0.14286	0.06311	15.845	12	3.05 - 5.3	197
24.50	7.47	5.430	47	254.8	0.18416	0.04130	24.210	15	5.03 - 7.47	371
49.00	14.94	2.860	94	268.4	0.34965	0.16549	6.043	47	7.47 - 14.94	284
82.00	24.99	2.100	157	329.8	0.47619	0.12654	7.903	63	14.94 - 25.0	499
164.00	49.99	1.940	314	609.3	0.51546	0.03927	25.462	157	25.0 - 49.99	3,999

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







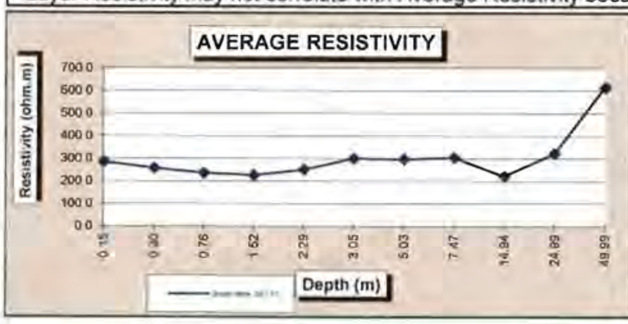
SOIL RESISTIVITY DATA

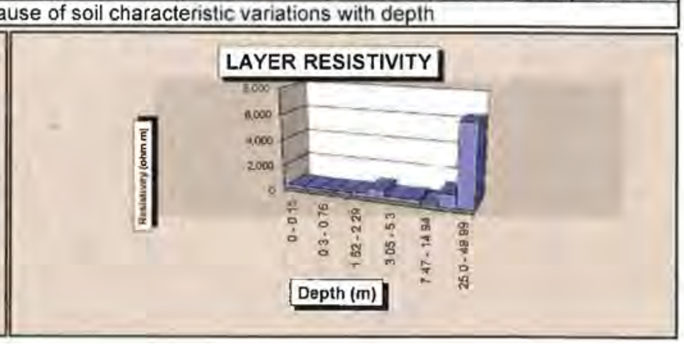
Project Name:	Vermont Gas Project
	12-144-32
Date:	5/4/2013
Location:	Planted Field off North St
	44 9.1029N, 73 9.5749W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	64F/Clear
Soil Description	Dry, rocky soil

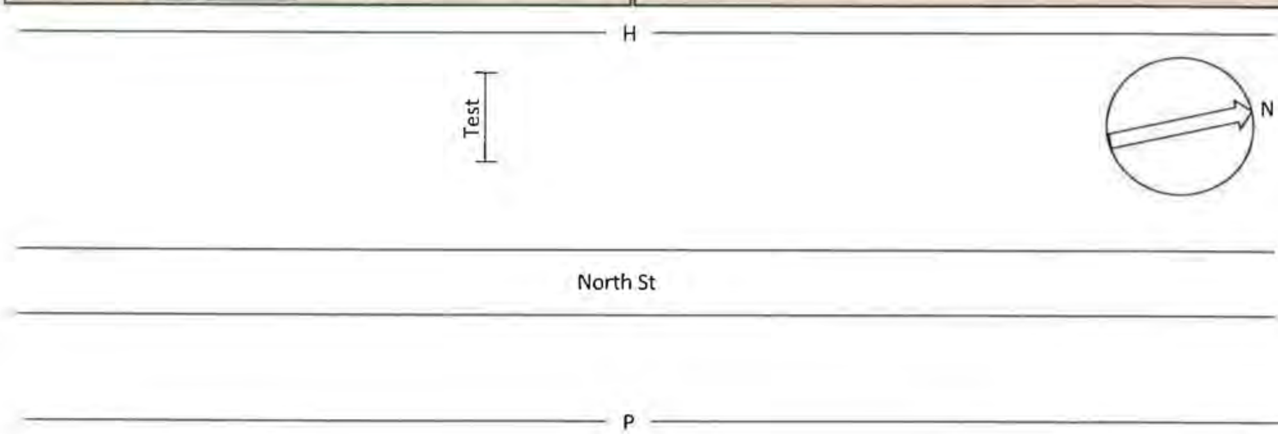
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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	297.000	1	284.4	0.00337	n/a	n/a	n/a	0 - 0.15	284
1.00	0.30	134.400	2	257.4	0.00744	0.00407	245.491	1	0.15 - 0.3	235
2.50	0.76	49.200	5	235.6	0.02033	0.01288	77.611	3	0.3 - 0.76	223
5.00	1.52	23.700	10	226.9	0.04219	0.02187	45.727	5	0.76 - 1.52	219
7.50	2.29	17.480	14	251.1	0.05721	0.01501	66.604	5	1.52 - 2.29	319
10.00	3.05	15.680	19	300.3	0.06378	0.00657	152.270	5	2.29 - 3.05	729
16.50	5.03	9.410	32	297.4	0.10627	0.04249	23.533	12	3.05 - 5.3	293
24.50	7.47	6.500	47	305.0	0.15385	0.04758	21.019	15	5.03 - 7.47	322
49.00	14.94	2.360	94	221.5	0.42373	0.26988	3.705	47	7.47 - 14.94	174
82.00	24.99	2.060	157	323.5	0.48544	0.06171	16.205	63	14.94 - 25.0	1,024
164.00	49.99	1.960	314	615.6	0.51020	0.02477	40.376	157	25.0 - 49.99	6,341

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







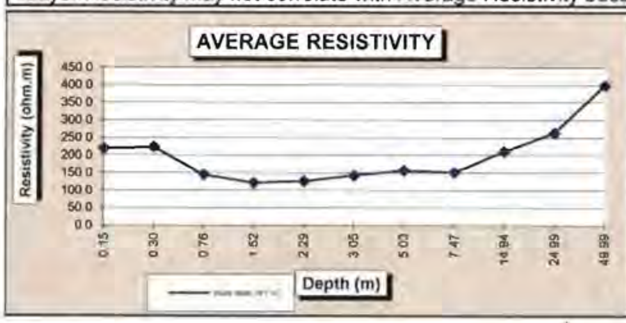
SOIL RESISTIVITY DATA

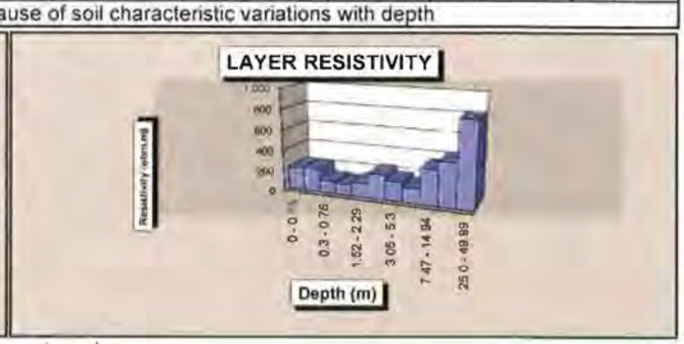
Project Name:	Vermont Gas Project
	12-144-33
Date:	5/4/2013
Location:	Rd Sd off Quarry Rd
	44 8.4956N, 73 9.6391W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	62F/Clear
Soil Description	Dry sand, rock and vegetation

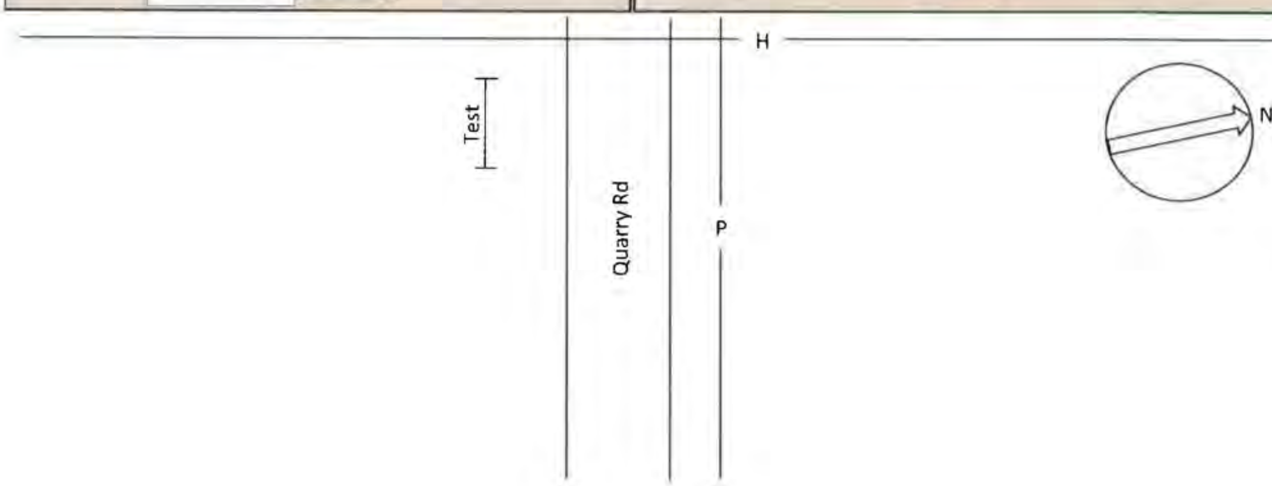
ARK. ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	229.000	1	219.3	0.00437	n/a	n/a	n/a	0 - 0.15	219
1.00	0.30	116.600	2	223.3	0.00858	0.00421	237.557	1	0.15 - 0.3	227
2.50	0.76	30.300	5	145.1	0.03300	0.02443	40.938	3	0.3 - 0.76	118
5.00	1.52	12.700	10	121.6	0.07874	0.04574	21.864	5	0.76 - 1.52	105
7.50	2.29	8.740	14	125.5	0.11442	0.03568	28.030	5	1.52 - 2.29	134
10.00	3.05	7.440	19	142.5	0.13441	0.01999	50.020	5	2.29 - 3.05	239
16.50	5.03	4.970	32	157.0	0.20121	0.06680	14.970	12	3.05 - 5.3	186
24.50	7.47	3.230	47	151.6	0.30960	0.10839	9.226	15	5.03 - 7.47	141
49.00	14.94	2.240	94	210.2	0.44643	0.13683	7.308	47	7.47 - 14.94	343
82.00	24.99	1.680	157	263.8	0.59524	0.14881	6.720	63	14.94 - 25.0	425
164.00	49.99	1.270	314	398.9	0.78740	0.19216	5.204	157	25.0 - 49.99	817

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







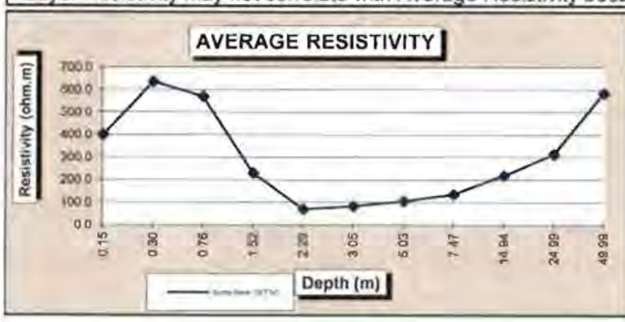
SOIL RESISTIVITY DATA

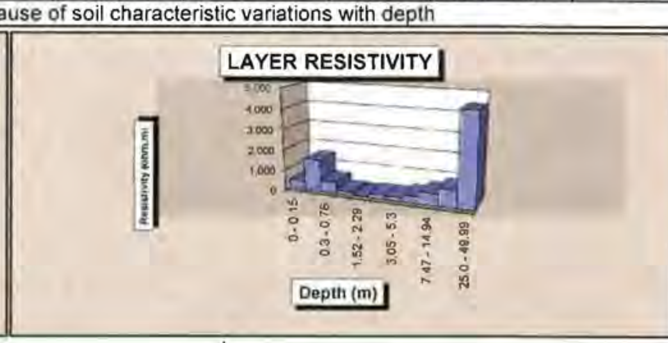
Project Name:	Vermont Gas Project
	12-144-34
Date:	5/4/2013
Location:	Rd Sd off Main St
	44 7.4123N, 73 9.8050W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	72F/Clear
Soil Description	Dry sand, rock and vegetation

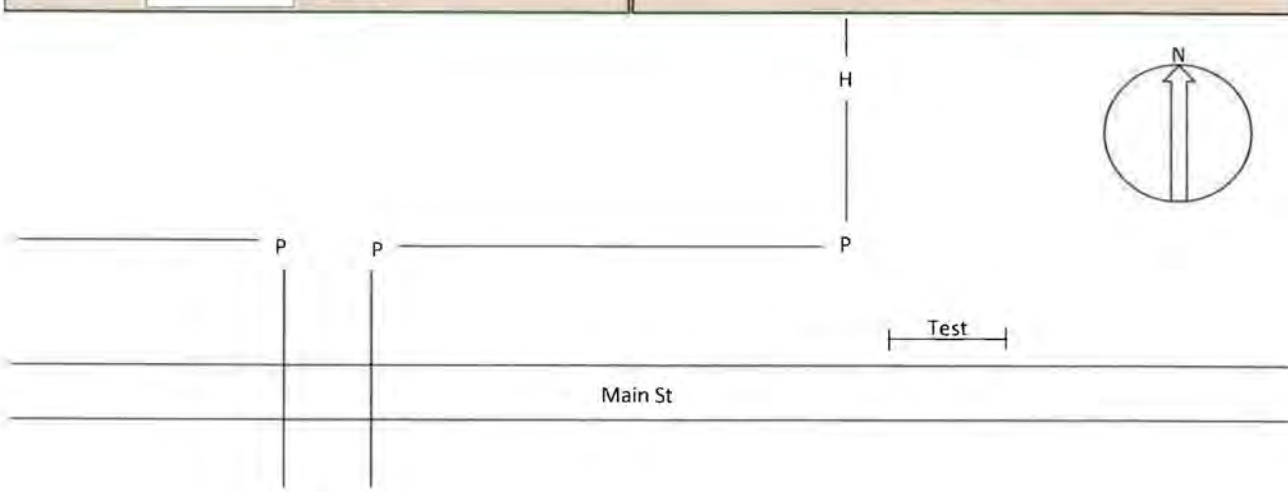
ARK ENGINEERING & TECHNICAL SERVICES, INC.

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)	ohm.m
0.50	0.15	418.000	1	400.3	0.00239	n/a	n/a	n/a	0 - 0.15	400
1.00	0.30	332.000	2	635.8	0.00301	0.00062	1613.674	1	0.15 - 0.3	1,545
2.50	0.76	119.300	5	571.2	0.00838	0.00537	186.213	3	0.3 - 0.76	535
5.00	1.52	24.200	10	231.7	0.04132	0.03294	30.358	5	0.76 - 1.52	145
7.50	2.29	4.900	14	70.4	0.20408	0.16276	6.144	5	1.52 - 2.29	29
10.00	3.05	4.330	19	82.9	0.23095	0.02687	37.223	5	2.29 - 3.05	178
16.50	5.03	3.340	32	105.5	0.29940	0.06845	14.608	12	3.05 - 5.3	182
24.50	7.47	2.890	47	135.6	0.34602	0.04662	21.450	15	5.03 - 7.47	329
49.00	14.94	2.340	94	219.6	0.42735	0.08133	12.296	47	7.47 - 14.94	577
82.00	24.99	1.990	157	312.5	0.50251	0.07516	13.305	63	14.94 - 25.0	841
164.00	49.99	1.860	314	584.2	0.53763	0.03512	28.472	157	25.0 - 49.99	4,471

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







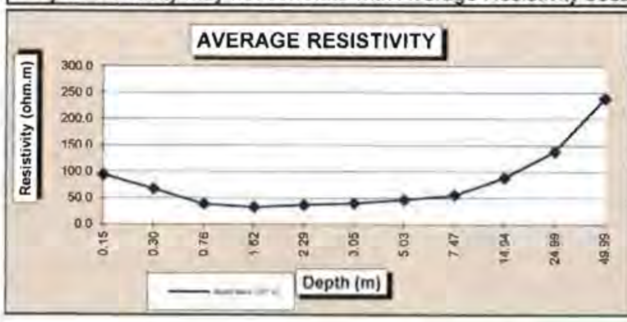
SOIL RESISTIVITY DATA

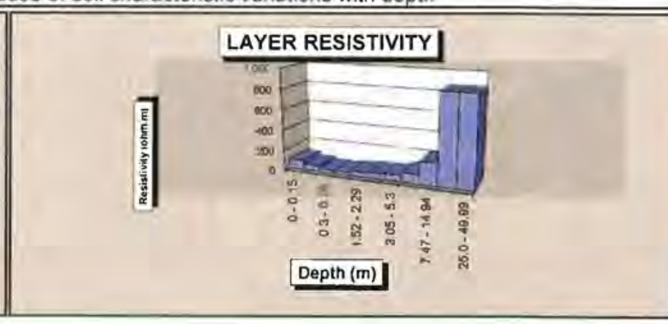
ARK. Engineering & Technical Services, Inc.

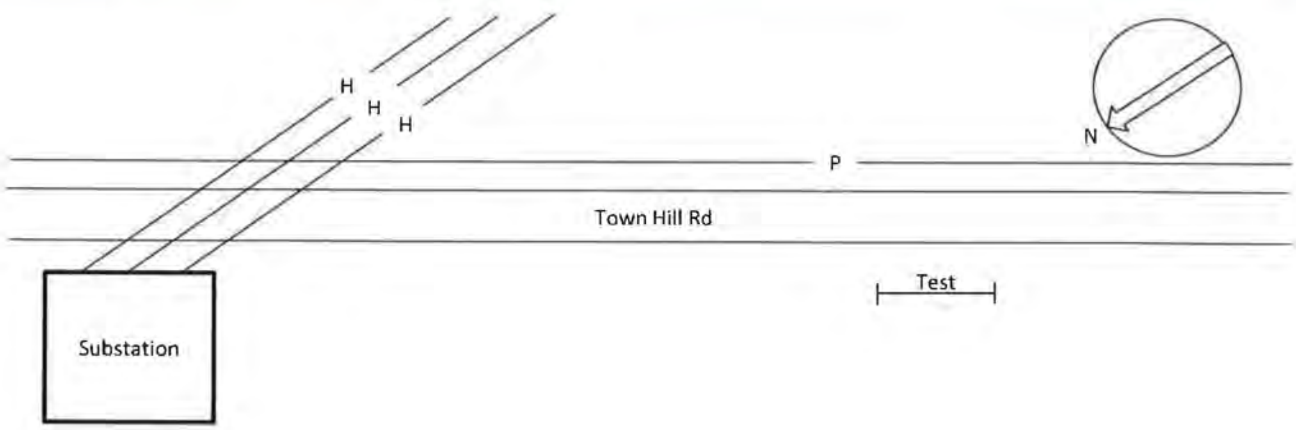
Project Name:	Vermont Gas Project
	12-144-35
Date:	5/5/2013
Location:	Rd Sd off Town Hill Rd
	44 6.5084N, 73 10.0670W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	56F/Clear
Soil Description	Hard dry and vegetation

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	97.700	1	93.6	0.01024	n/a	n/a	n/a	0 - 0.15	94
1.00	0.30	35.100	2	67.2	0.02849	0.01825	54.781	1	0.15 - 0.3	52
2.50	0.76	8.100	5	38.8	0.12346	0.09497	10.530	3	0.3 - 0.76	30
5.00	1.52	3.410	10	32.7	0.29326	0.16980	5.889	5	0.76 - 1.52	28
7.50	2.29	2.530	14	36.3	0.39526	0.10200	9.804	5	1.52 - 2.29	47
10.00	3.05	2.080	19	39.8	0.48077	0.08551	11.694	5	2.29 - 3.05	56
16.50	5.03	1.470	32	46.5	0.68027	0.19950	5.012	12	3.05 - 5.3	62
24.50	7.47	1.180	47	55.4	0.84746	0.16719	5.981	15	5.03 - 7.47	92
49.00	14.94	0.940	94	88.2	1.06383	0.21637	4.622	47	7.47 - 14.94	217
82.00	24.99	0.880	157	138.2	1.13636	0.07253	13.787	63	14.94 - 25.0	871
164.00	49.99	0.760	314	238.7	1.31579	0.17943	5.573	157	25.0 - 49.99	875

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







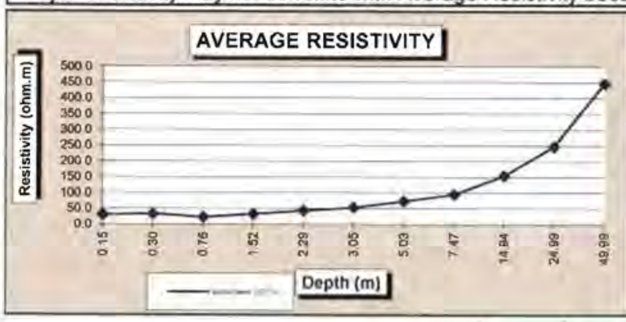
SOIL RESISTIVITY DATA

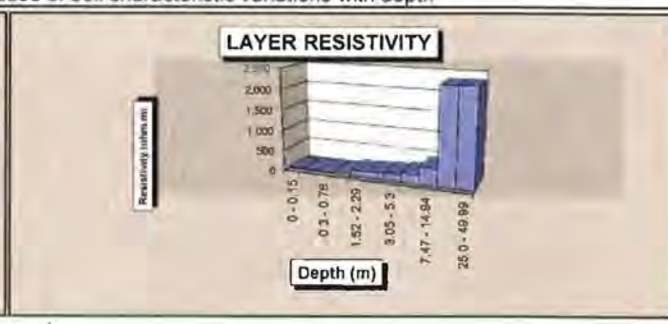
Project Name:	Vermont Gas Project
	12-144-36
Date:	5/5/2013
Location:	Rd Sd off Ethan Allen Hwy
	44 5.5455N, 73 10.4509W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	56F/Clear
Soil Description	Hard dry and vegetation

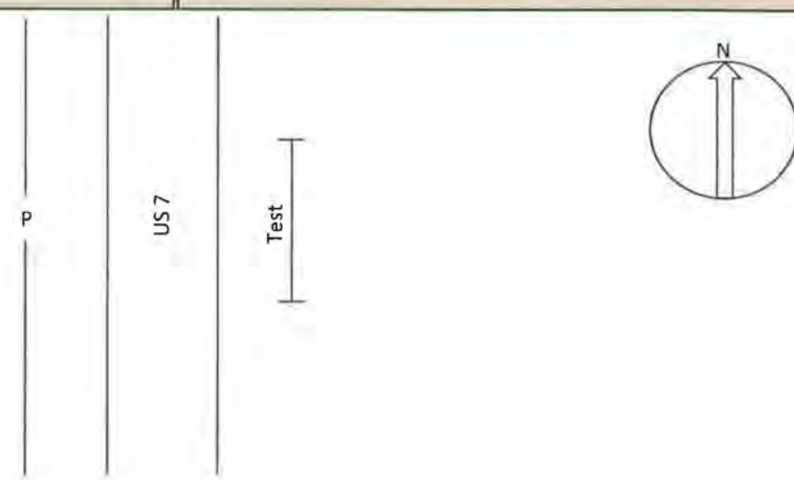
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	31.500	1	30.2	0.03175	n/a	n/a	n/a	0 - 0.15	30
1.00	0.30	17.270	2	33.1	0.05790	0.02616	38.229	1	0.15 - 0.3	37
2.50	0.76	4.700	5	22.5	0.21277	0.15486	6.457	3	0.3 - 0.76	19
5.00	1.52	3.420	10	32.7	0.29240	0.07963	12.558	5	0.76 - 1.52	60
7.50	2.29	3.060	14	44.0	0.32680	0.03440	29.070	5	1.52 - 2.29	139
10.00	3.05	2.790	19	53.4	0.35842	0.03163	31.620	5	2.29 - 3.05	151
16.50	5.03	2.340	32	73.9	0.42735	0.06893	14.508	12	3.05 - 5.3	181
24.50	7.47	2.020	47	94.8	0.49505	0.06770	14.771	15	5.03 - 7.47	226
49.00	14.94	1.640	94	153.9	0.60976	0.11471	8.718	47	7.47 - 14.94	409
82.00	24.99	1.570	157	246.6	0.63694	0.02719	36.783	63	14.94 - 25.0	2,325
164.00	49.99	1.420	314	446.0	0.70423	0.06728	14.863	157	25.0 - 49.99	2,334

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







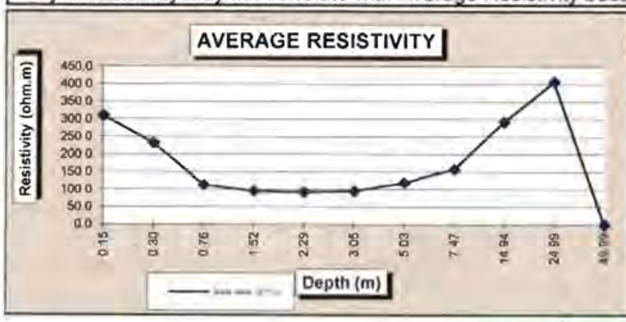
SOIL RESISTIVITY DATA

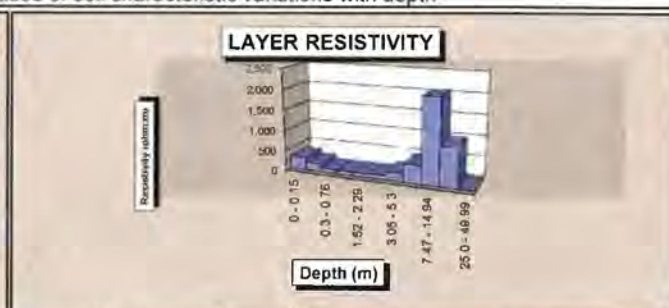
ARK Engineering & Technical Services, Inc

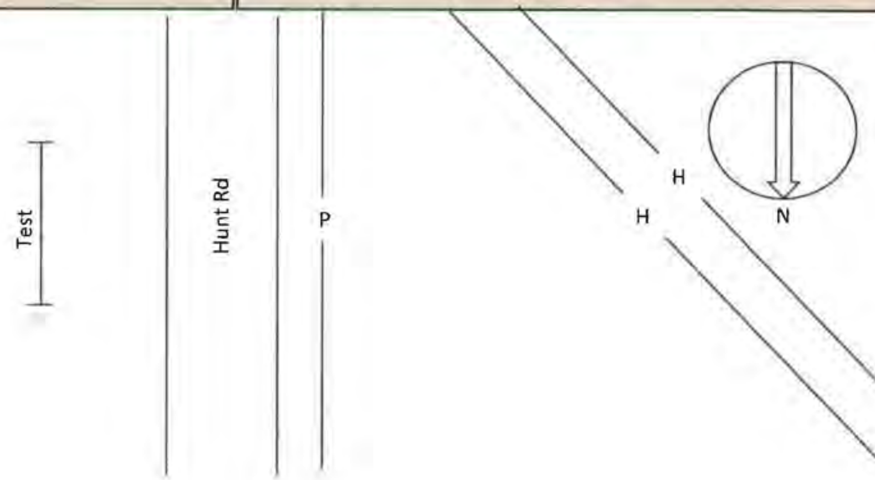
Project Name:	Vermont Gas Project
	12-144-37
Date:	5/5/2013
Location:	Rd Sd off Hunt Rd
	44 4.5951N, 73 9.5652W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	57F/Clear
Soil Description	Hard packed dark soil

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	324.000	1	310.2	0.00309	n/a	n/a	n/a	0 - 0.15	310
1.00	0.30	121.400	2	232.5	0.00824	0.00515	194.144	1	0.15 - 0.3	186
2.50	0.76	23.700	5	113.5	0.04219	0.03396	29.449	3	0.3 - 0.76	85
5.00	1.52	9.990	10	95.7	0.10010	0.05791	17.269	5	0.76 - 1.52	83
7.50	2.29	6.420	14	92.2	0.15576	0.05566	17.965	5	1.52 - 2.29	86
10.00	3.05	4.960	19	95.0	0.20161	0.04585	21.810	5	2.29 - 3.05	104
16.50	5.03	3.800	32	120.1	0.26316	0.06154	16.248	12	3.05 - 5.3	202
24.50	7.47	3.360	47	157.7	0.29762	0.03446	29.018	15	5.03 - 7.47	445
49.00	14.94	3.120	94	292.8	0.32051	0.02289	43.680	47	7.47 - 14.94	2,049
82.00	24.99	2.590	157	406.7	0.38610	0.06559	15.247	63	14.94 - 25.0	964
164.00	49.99	Short Test	314	#VALUE!	#######	#VALUE!	#VALUE!	157	25.0 - 49.99	#VALUE!

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







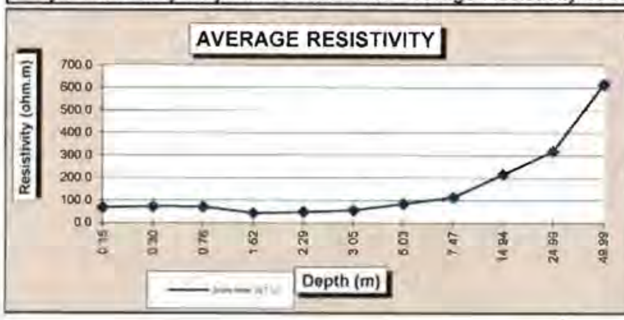
SOIL RESISTIVITY DATA

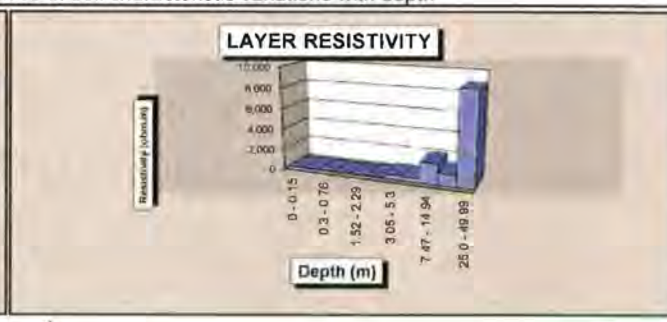
Project Name:	Vermont Gas Project
	12-144-38
Date:	5/5/2013
Location:	Open Field off River Rd
	44 3.5072N, 73 9.5358W
Testers:	KJ, LM
Methodology:	ρ = 2πdR, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	59F/Clear
Soil Description	Hard packed dark soil

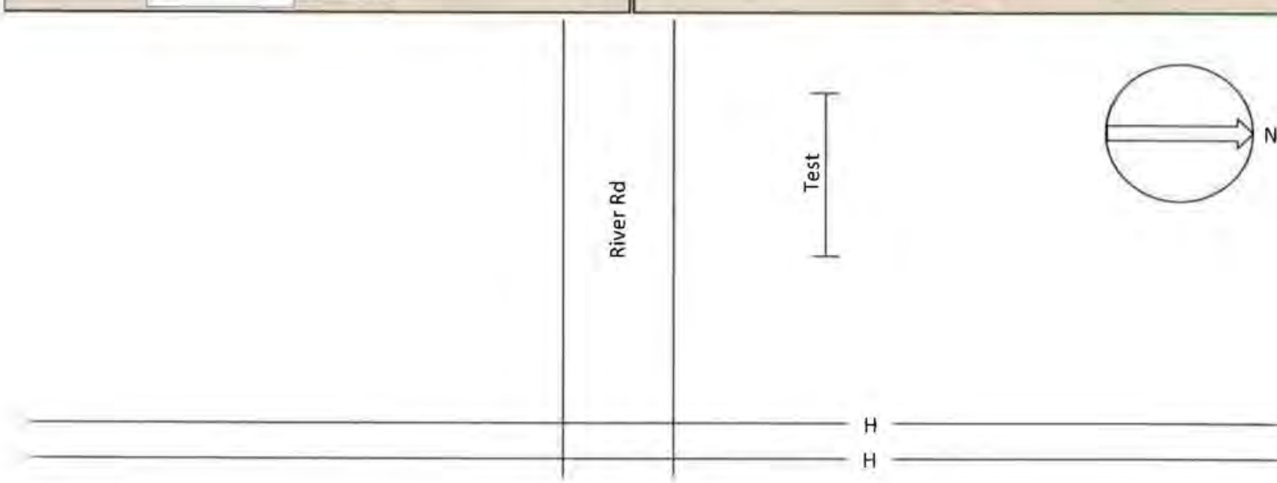
ARK. Engineering & Technical Services, Inc.

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)	ohm.m
0.50	0.15	70.000	1	67.0	0.01429	n/a	n/a	n/a	0 - 0.15	67
1.00	0.30	37.600	2	72.0	0.02660	0.01231	81.235	1	0.15 - 0.3	78
2.50	0.76	14.780	5	70.8	0.06766	0.04106	24.353	3	0.3 - 0.76	70
5.00	1.52	4.520	10	43.3	0.22124	0.15358	6.511	5	0.76 - 1.52	31
7.50	2.29	3.380	14	48.5	0.29586	0.07462	13.401	5	1.52 - 2.29	64
10.00	3.05	2.900	19	55.5	0.34483	0.04897	20.421	5	2.29 - 3.05	98
16.50	5.03	2.680	32	84.7	0.37313	0.02831	35.327	12	3.05 - 5.3	440
24.50	7.47	2.420	47	113.5	0.41322	0.04009	24.945	15	5.03 - 7.47	382
49.00	14.94	2.290	94	214.9	0.43668	0.02346	42.629	47	7.47 - 14.94	2,000
82.00	24.99	2.030	157	318.8	0.49261	0.05593	17.880	63	14.94 - 25.0	1,130
164.00	49.99	1.960	314	615.6	0.51020	0.01759	56.840	157	25.0 - 49.99	8,926

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







SOIL RESISTIVITY DATA

Project Name:	Vermont Gas Project
	12-144-39
Date:	5/5/2013
Location:	Rd Sd off US 7
	44 2.9550N, 73 9.8744W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	59F/Clear
Soil Description	Sandy, large rocks, and vegetation

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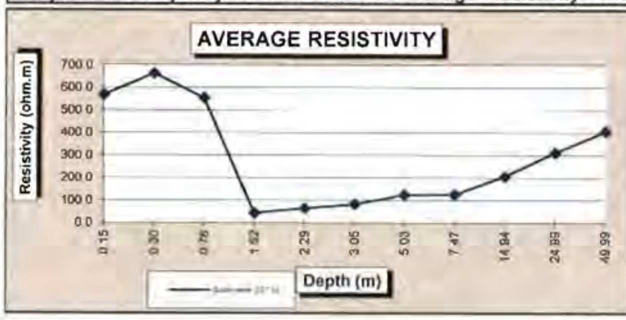
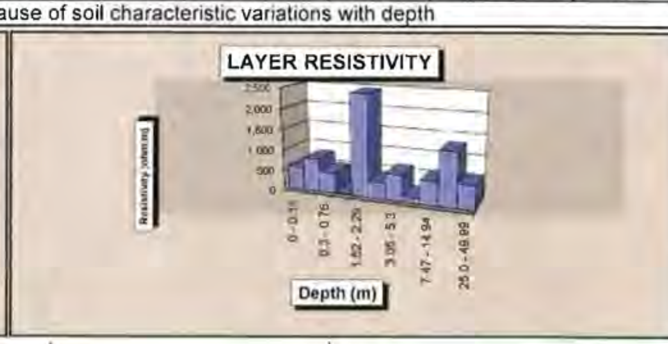
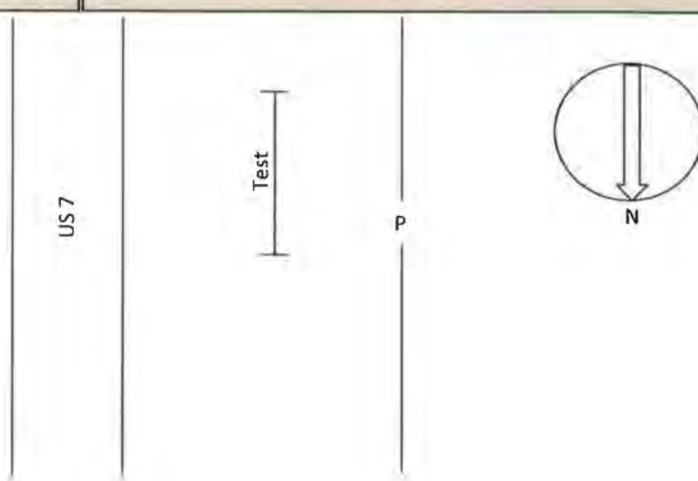
4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	593.000	1	567.8	0.00169	n/a	n/a	n/a	0 - 0.15	568
1.00	0.30	346.000	2	662.6	0.00289	0.00120	830.680	1	0.15 - 0.3	795
2.50	0.76	115.700	5	553.9	0.00864	0.00575	173.826	3	0.3 - 0.76	499
5.00	1.52	4.540	10	43.5	0.22026	0.21162	4.725	5	0.76 - 1.52	23
7.50	2.29	4.500	14	64.6	0.22222	0.00196	510.750	5	1.52 - 2.29	2,445
10.00	3.05	4.270	19	81.8	0.23419	0.01197	83.543	5	2.29 - 3.05	400
16.50	5.03	3.940	32	124.5	0.25381	0.01962	50.981	12	3.05 - 5.3	635
24.50	7.47	2.670	47	125.3	0.37453	0.12072	8.283	15	5.03 - 7.47	127
49.00	14.94	2.190	94	205.5	0.45662	0.08209	12.182	47	7.47 - 14.94	572
82.00	24.99	1.980	157	310.9	0.50505	0.04843	20.649	63	14.94 - 25.0	1,305
164.00	49.99	1.290	314	405.2	0.77519	0.27014	3.702	157	25.0 - 49.99	581

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







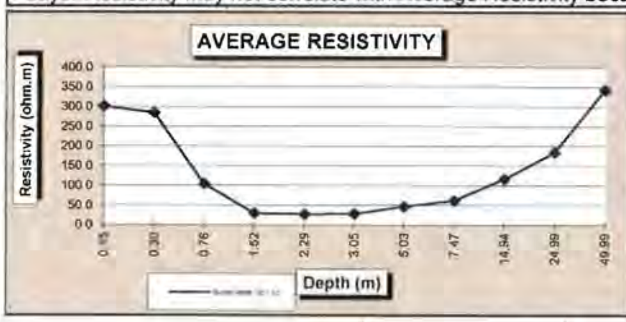
SOIL RESISTIVITY DATA

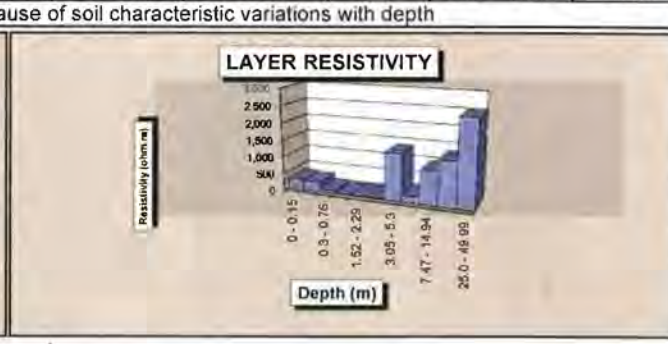
Project Name:	Vermont Gas Project
	12-144-40
Date:	5/5/2013
Location:	Rd Sd off US 7
	44 2.3630N, 73 9.7127W
Testers:	KJ, LM
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Biddle Meter DET 5/2
Weather:	61F/Clear
Soil Description	Hard packed, rocky and vegetation

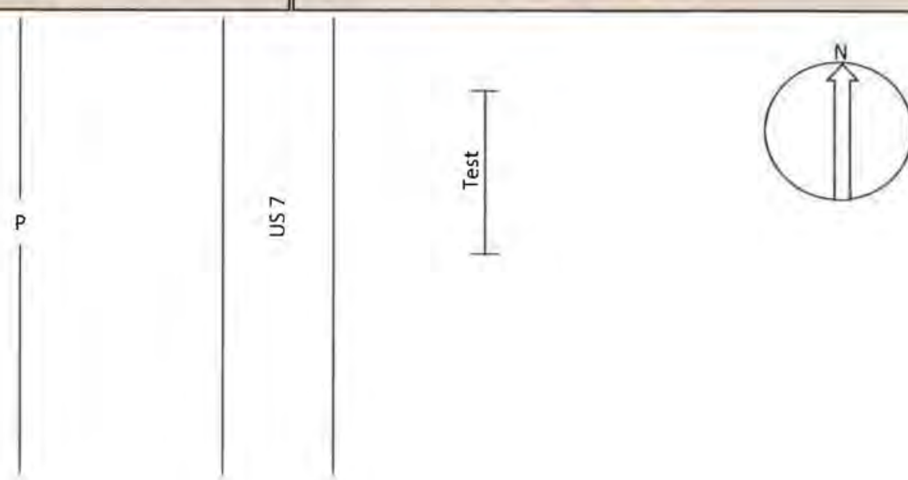
ARK. Engineering & Technical Services, Inc.

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)	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







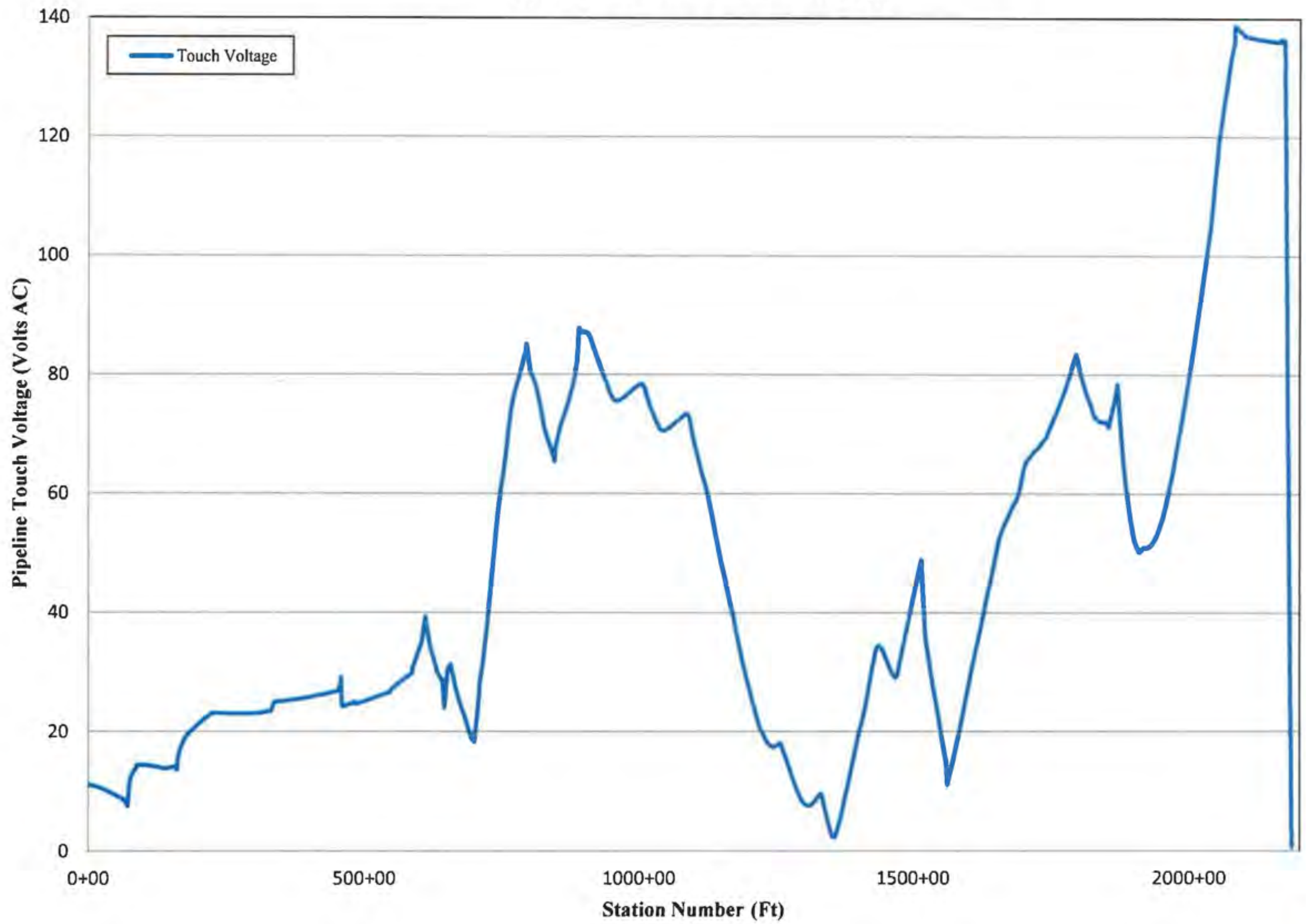
APPENDIX B –

PIPELINE STEADY STATE, AC CURRENT DENSITY & FAULT PLOTS

STEADY STATE INDUCED

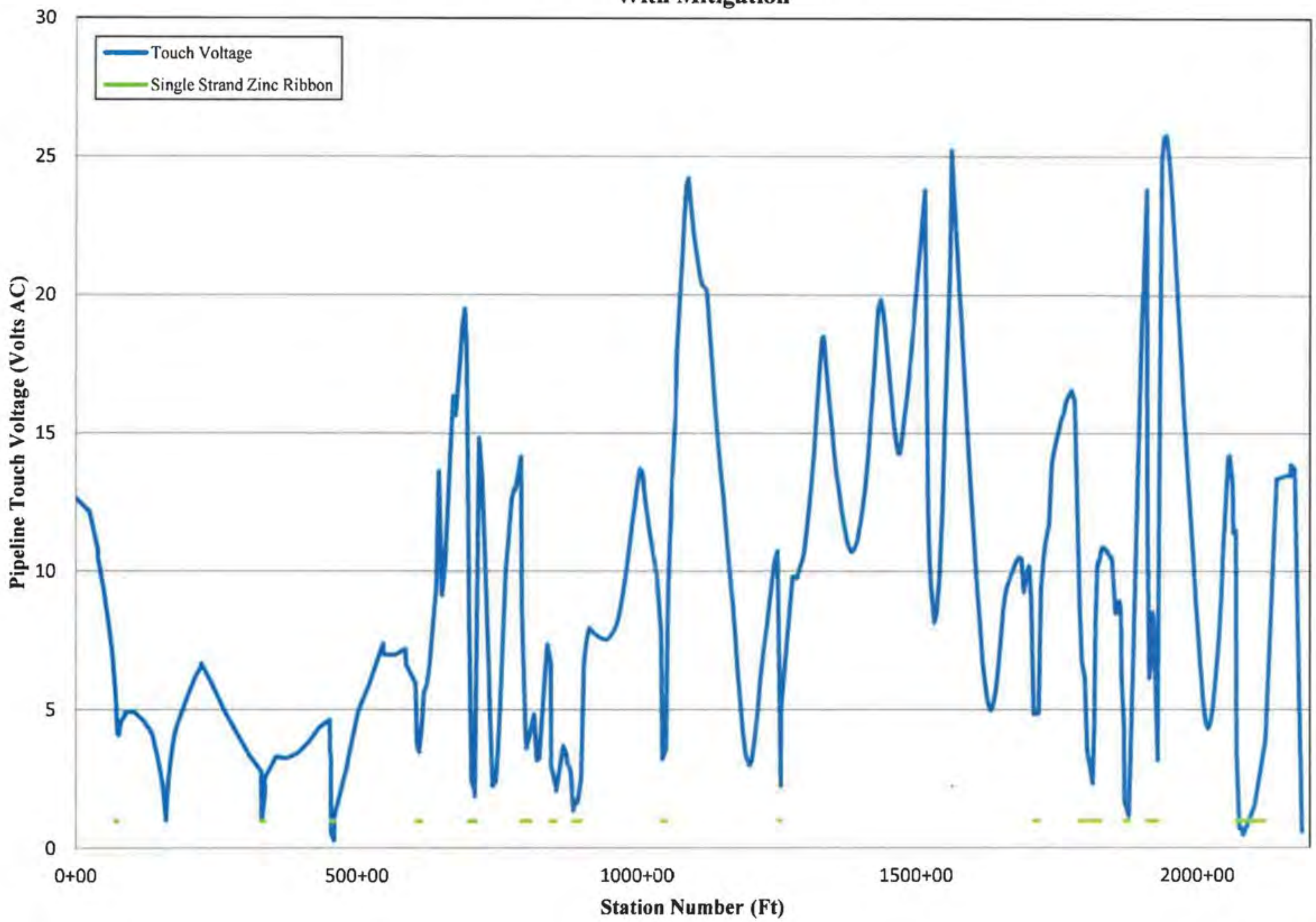
ARK.
Engineering &
Technical Services Inc.

Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Modeled AC Touch Voltage



ARK

Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline
Modeled AC Touch Voltage
With Mitigation

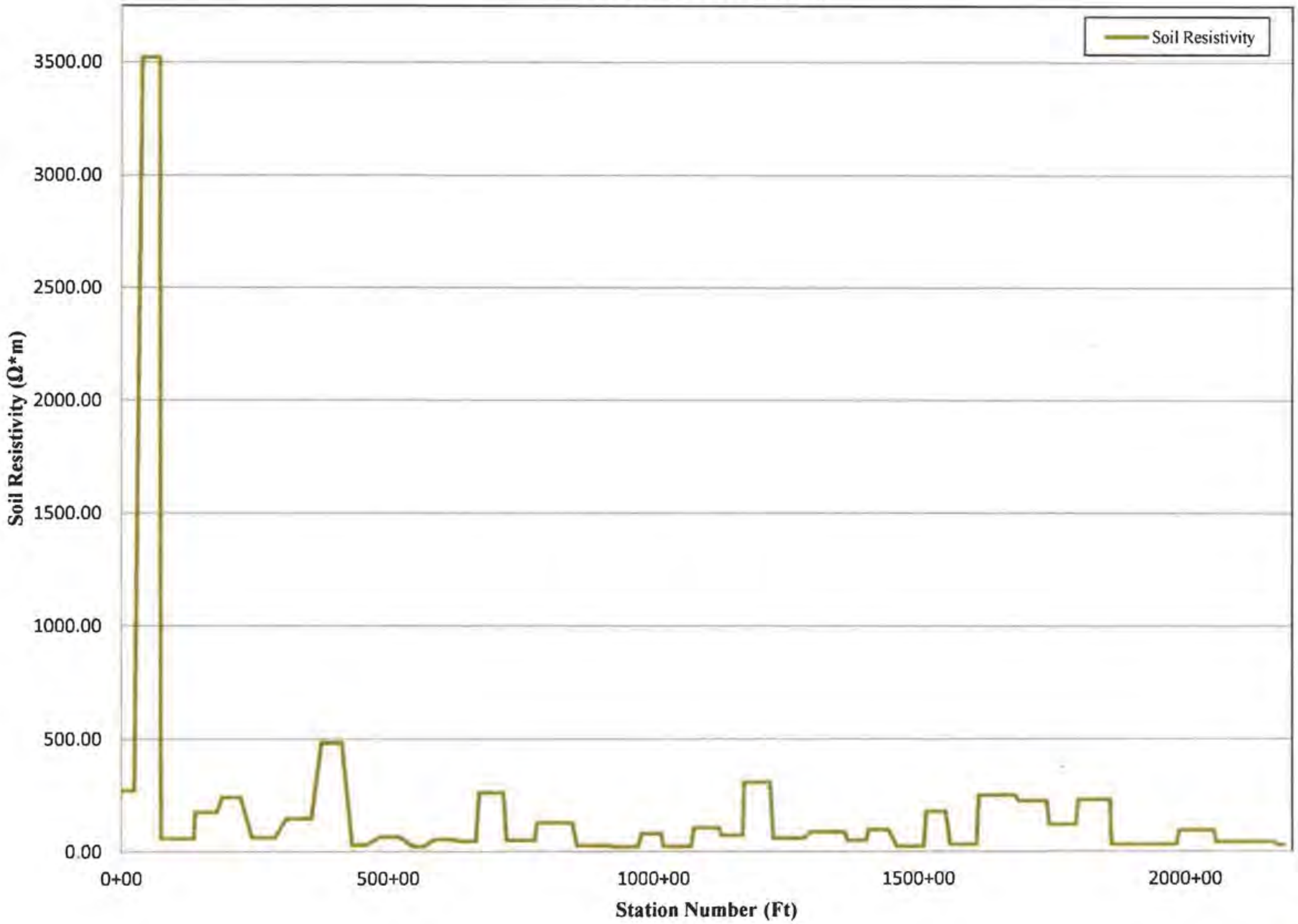


ARK.

CURRENT DENSITY

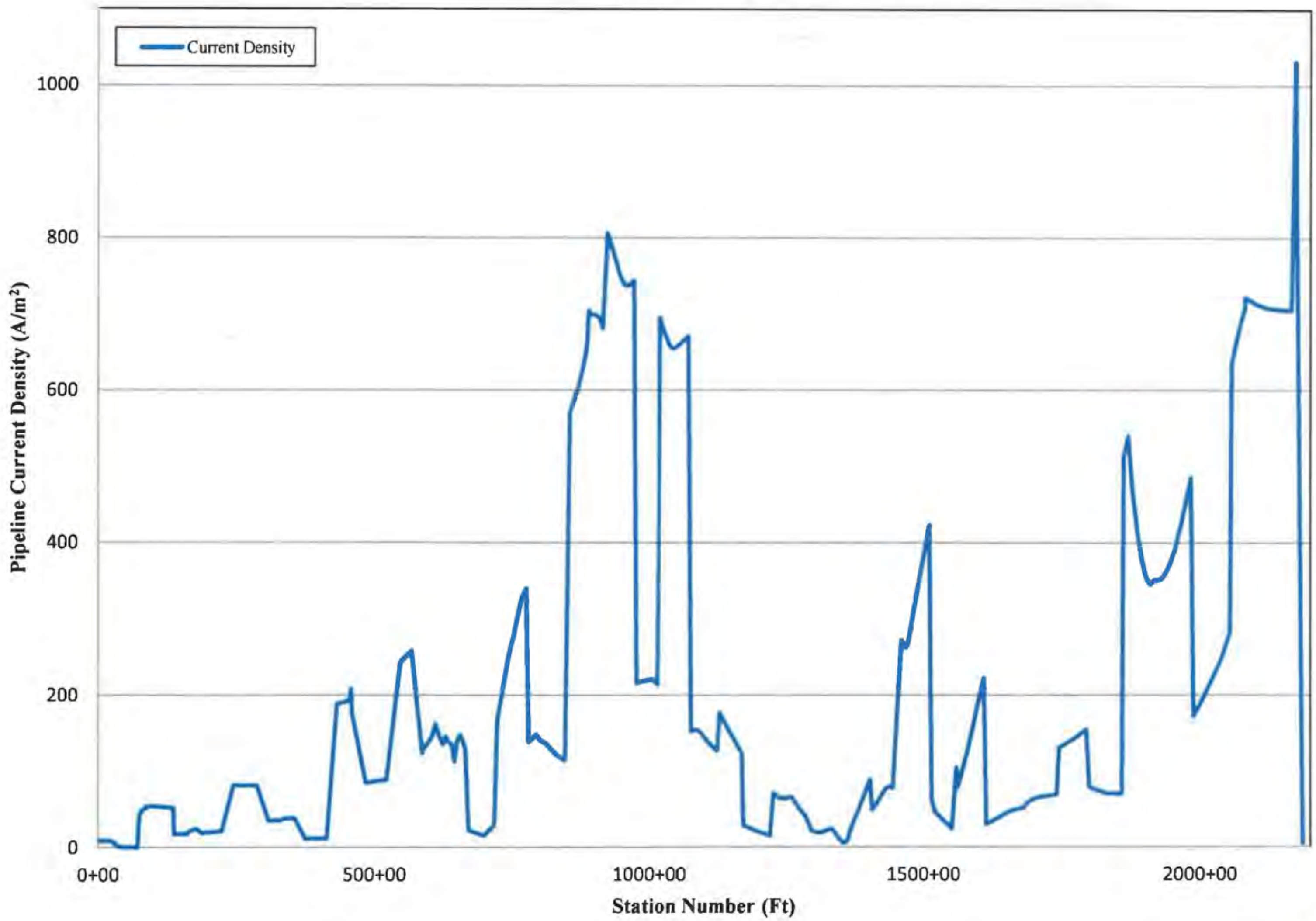
ARK
Engineering &
Technical Services, Inc.

Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline
Measured Soil Resistivity

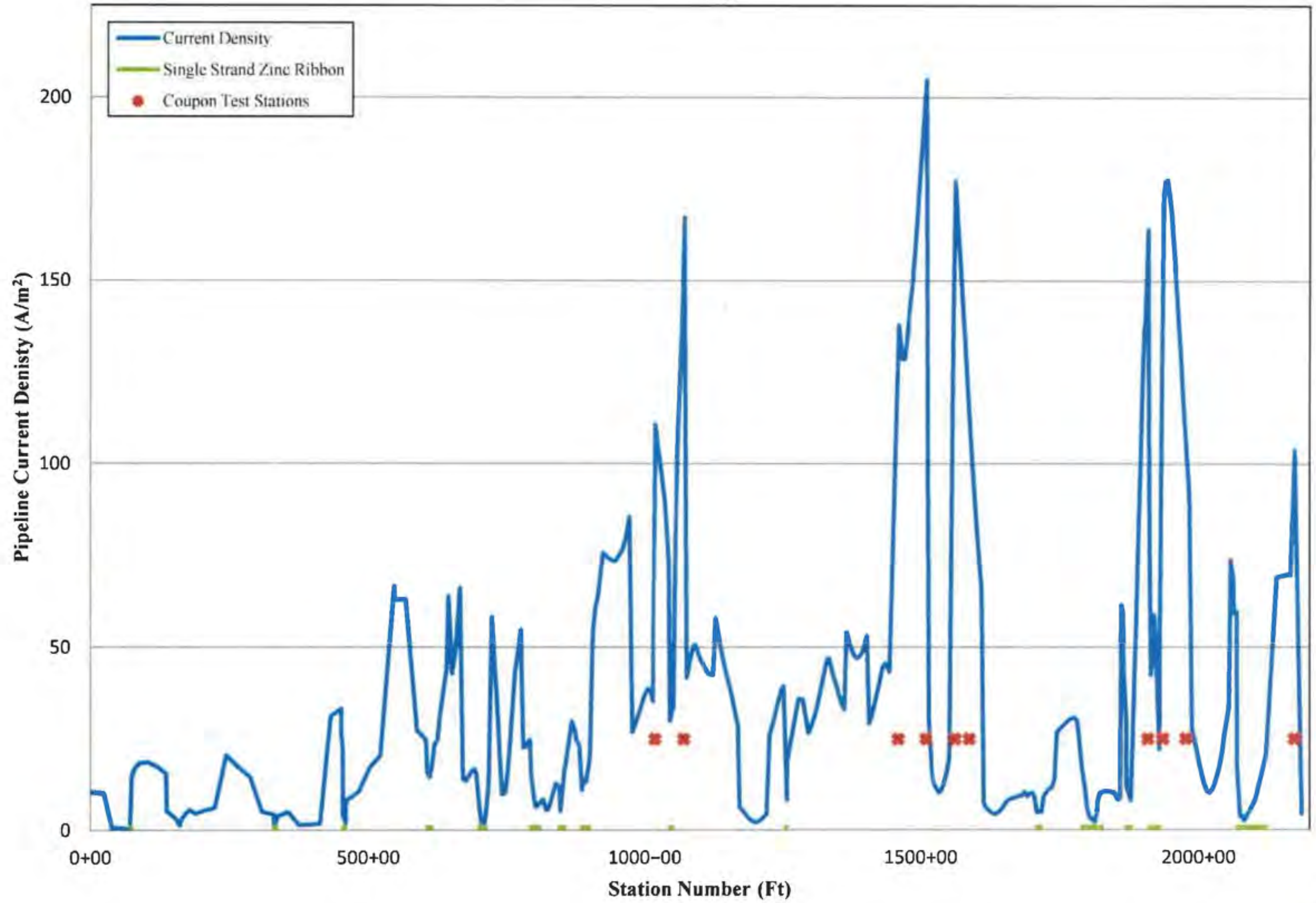


ARK

Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline
AC Current Density



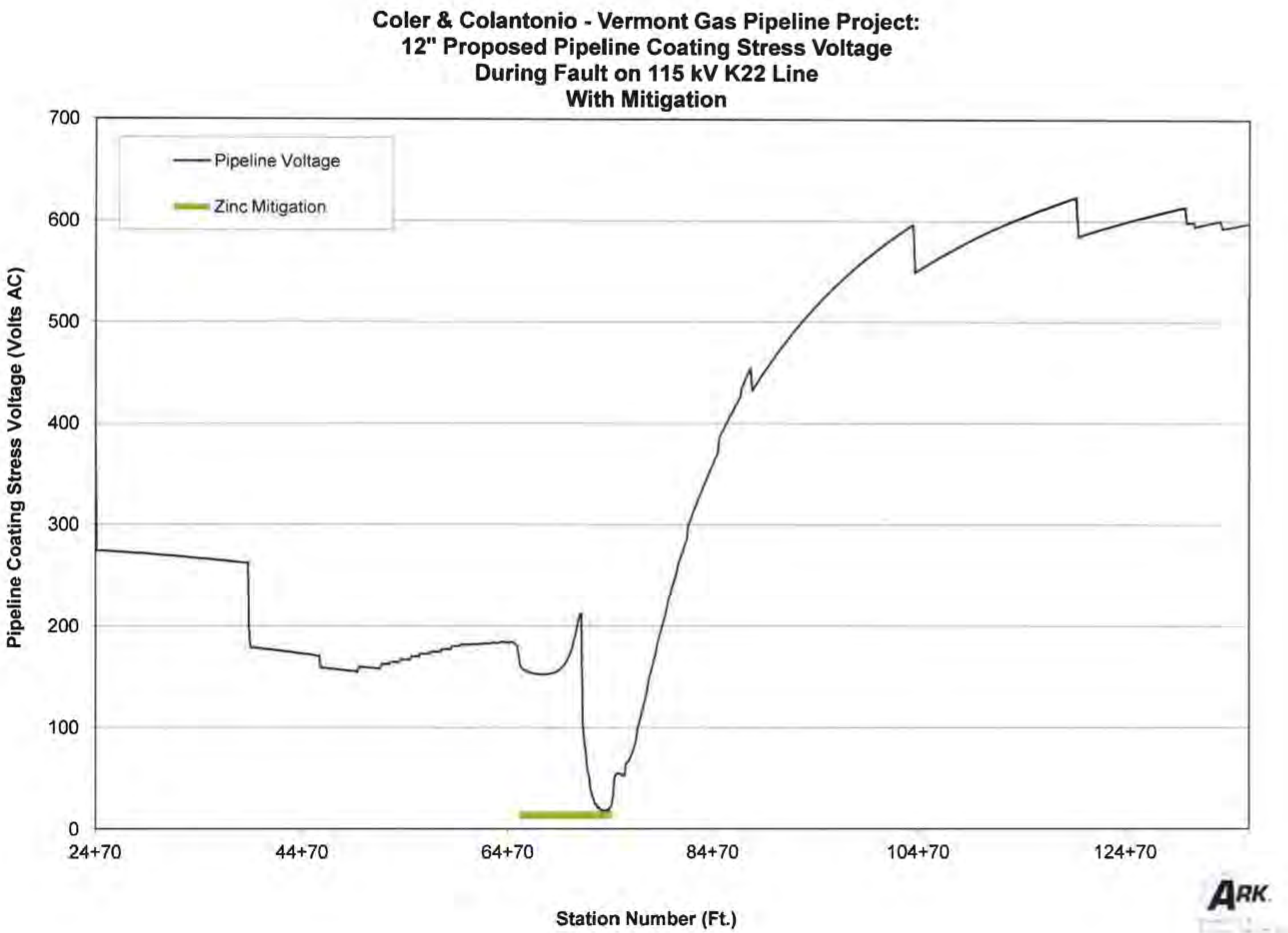
Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline
AC Current Density
With Mitigation



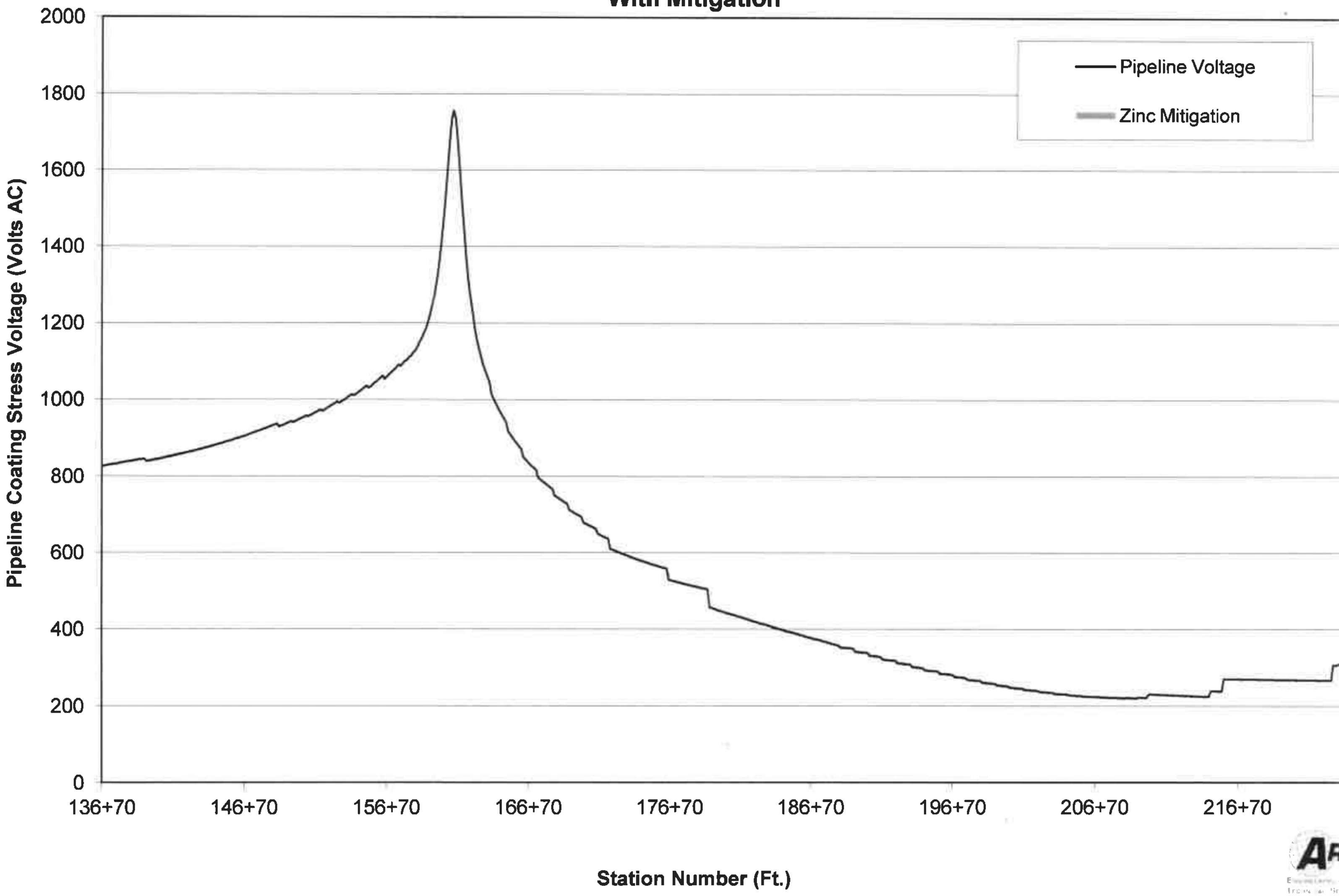
ARK

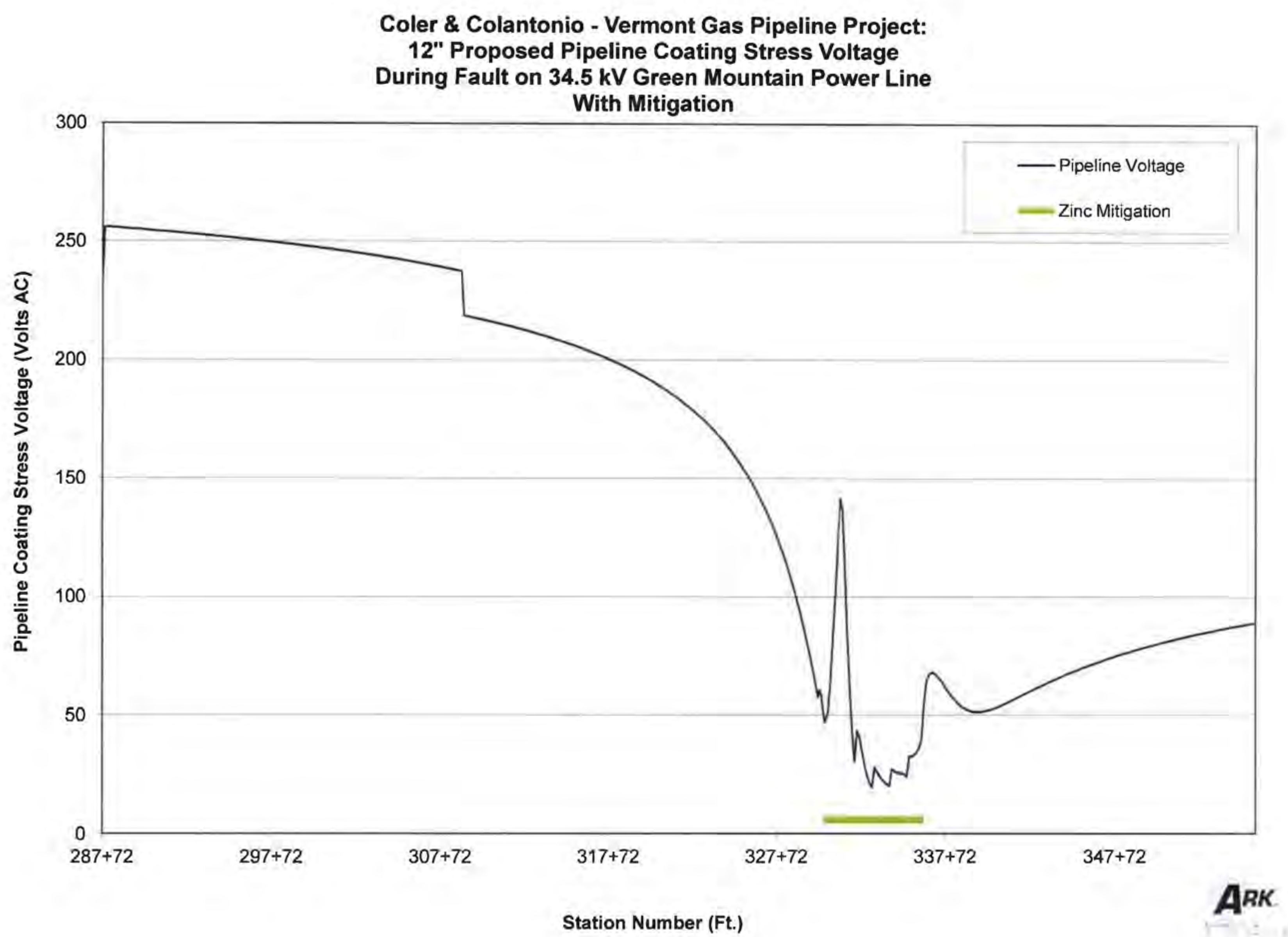
FAULT – COATING STRESS VOLTAGE

ARK.
Engineering & Technical Services, Inc.


Coler & Colantonio - Vermont Gas Pipeline Project:
12" Proposed Pipeline Coating Stress Voltage
During Fault on 115 kV K22 Line
With Mitigation
Pipeline Voltage
Zinc Mitigation
Pipeline Coating Stress Voltage (Volts AC)
700
600
500
400
300
200
100
0
24+70
44+70
64+70
84+70
104+70
124+70
Station Number (Ft.)
ARK

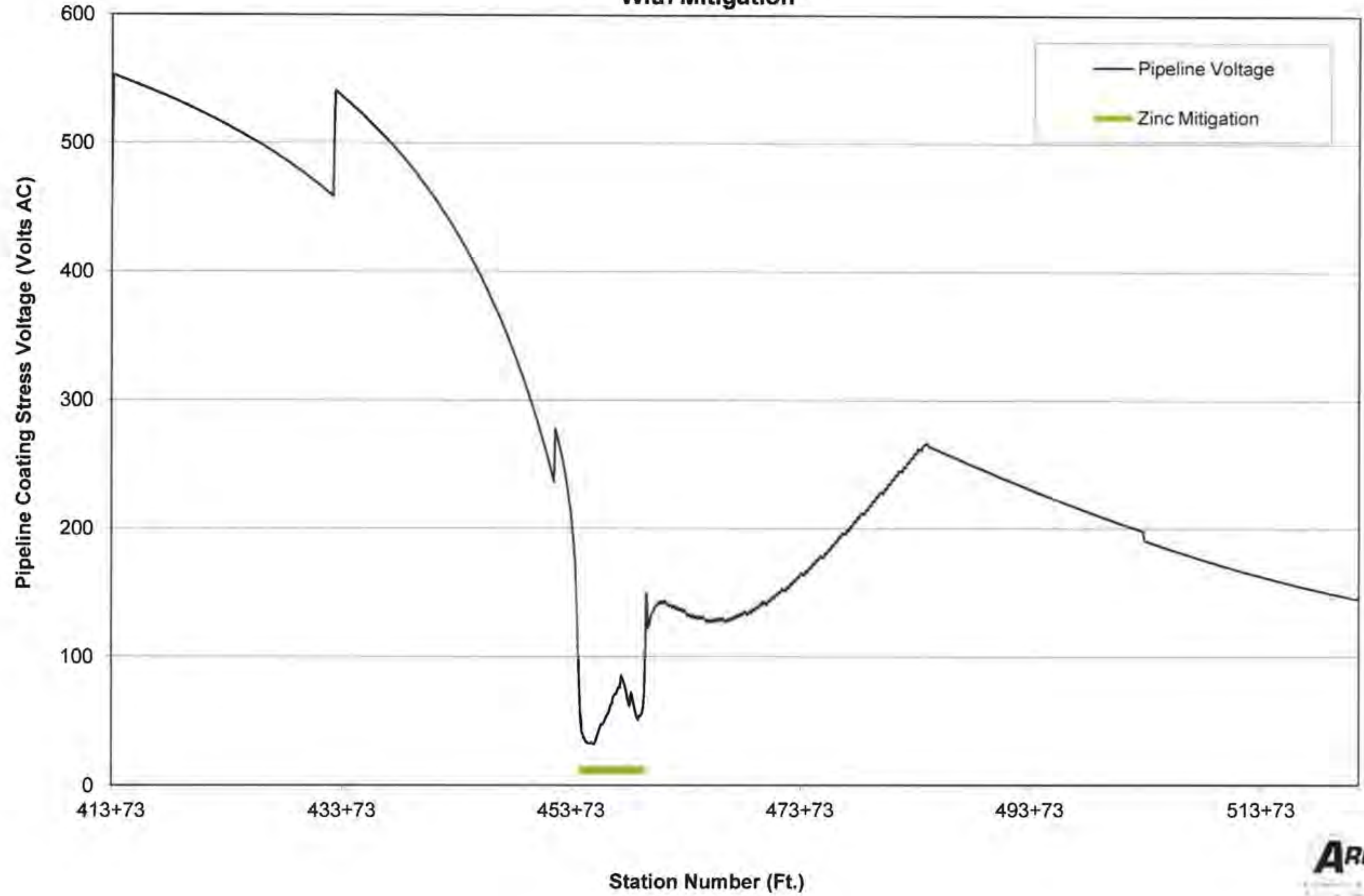
**Coler & Colantonio - Vermont Gas Pipeline Project:
12" Proposed Pipeline Coating Stress Voltage
During Fault on 115 kV K21 Line
With Mitigation**



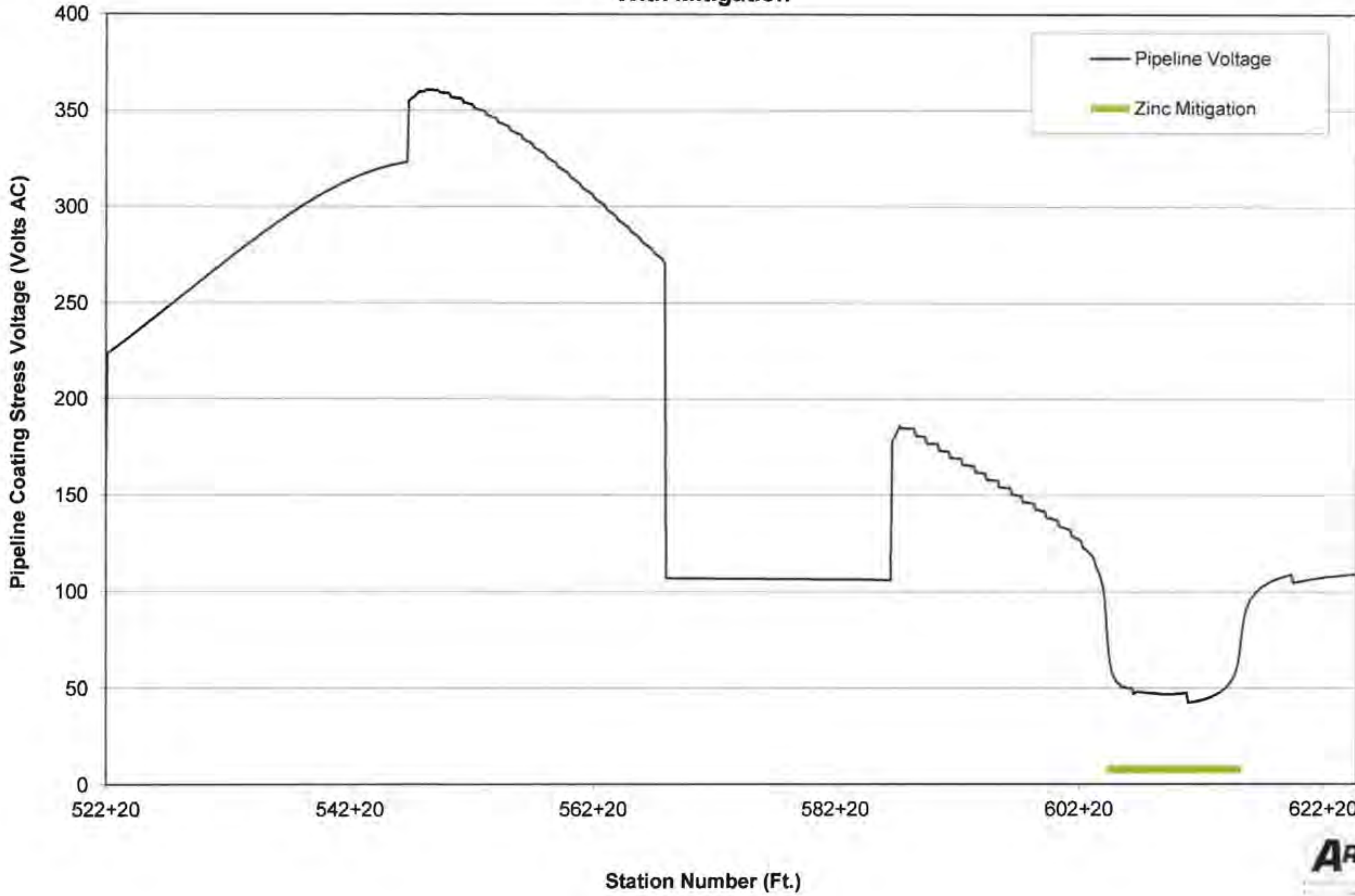


Coler & Colantonio - Vermont Gas Pipeline Project:
12" Proposed Pipeline Coating Stress Voltage
During Fault on 34.5 kV Green Mountain Power Line
With Mitigation
Pipeline Coating Stress Voltage (Volts AC)
300
250
200
150
100
50
0
287+72
297+72
307+72
317+72
327+72
337+72
347+72
Station Number (Ft.)
Pipeline Voltage
Zinc Mitigation
ARK

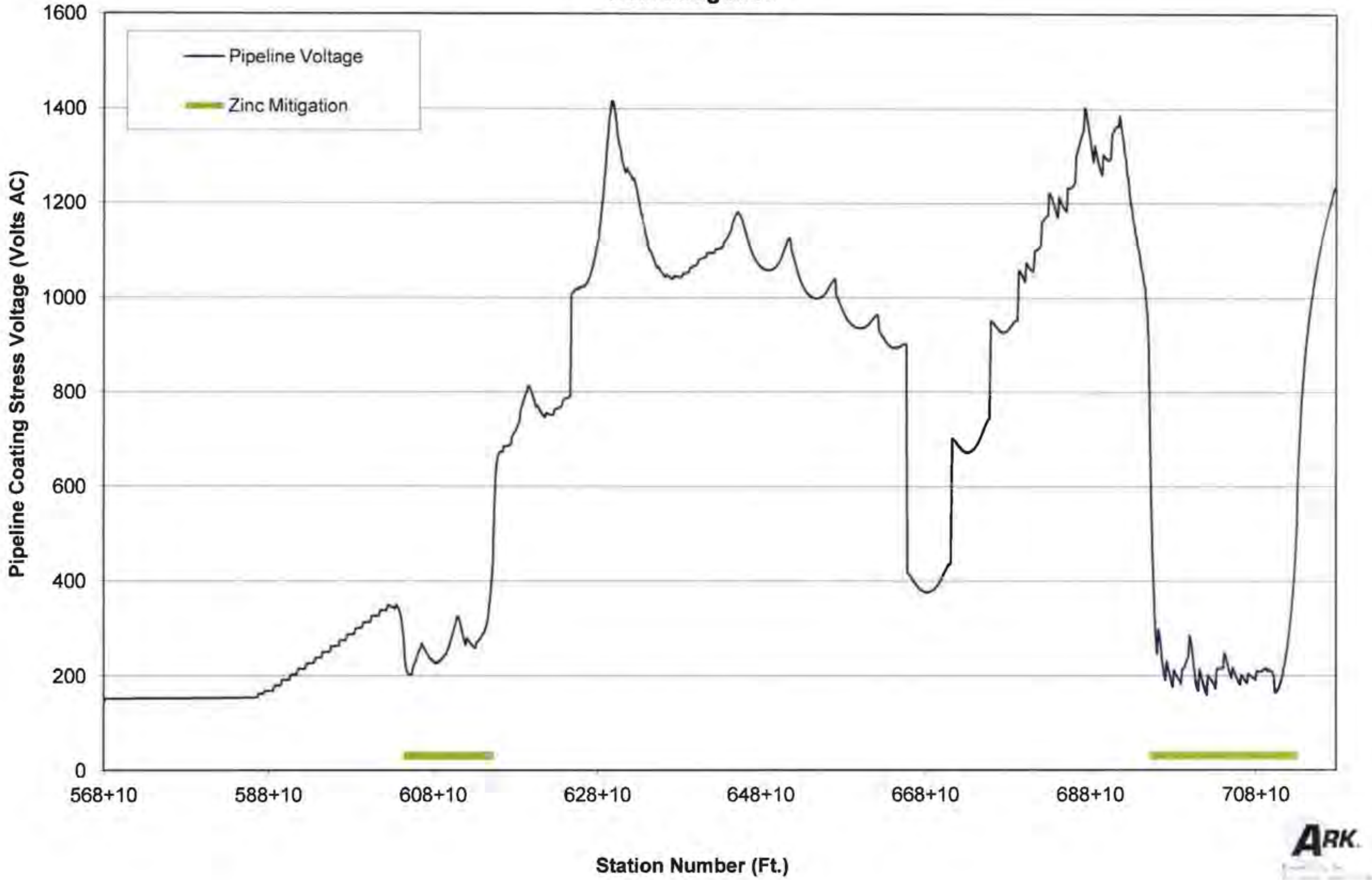
Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 115 kV K24 Line With Mitigation



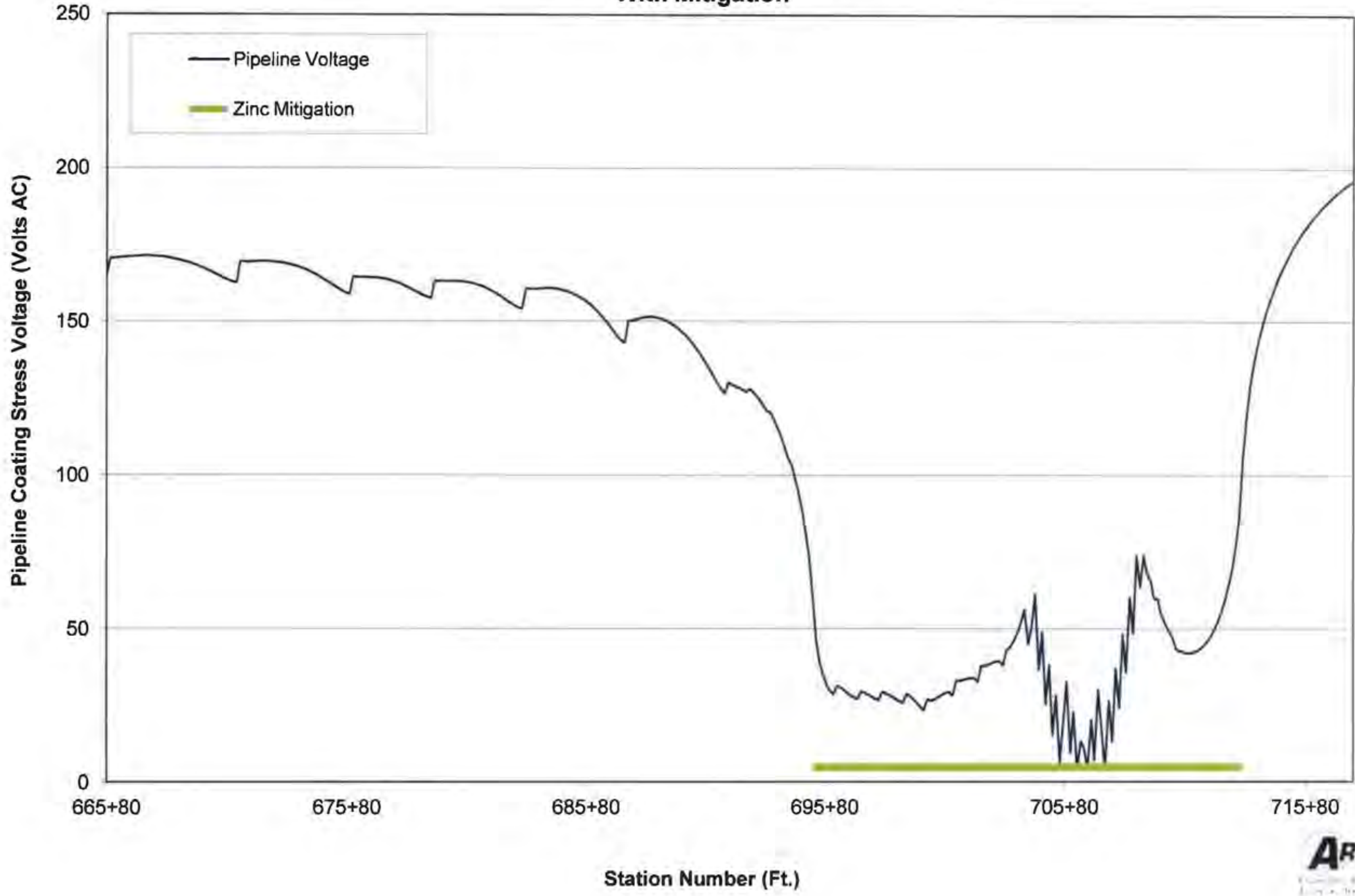
Coler & Colantonio - Vermont Gas Pipeline Project:
12" Proposed Pipeline Coating Stress Voltage
During Fault on 115 kV K23 Line
With Mitigation



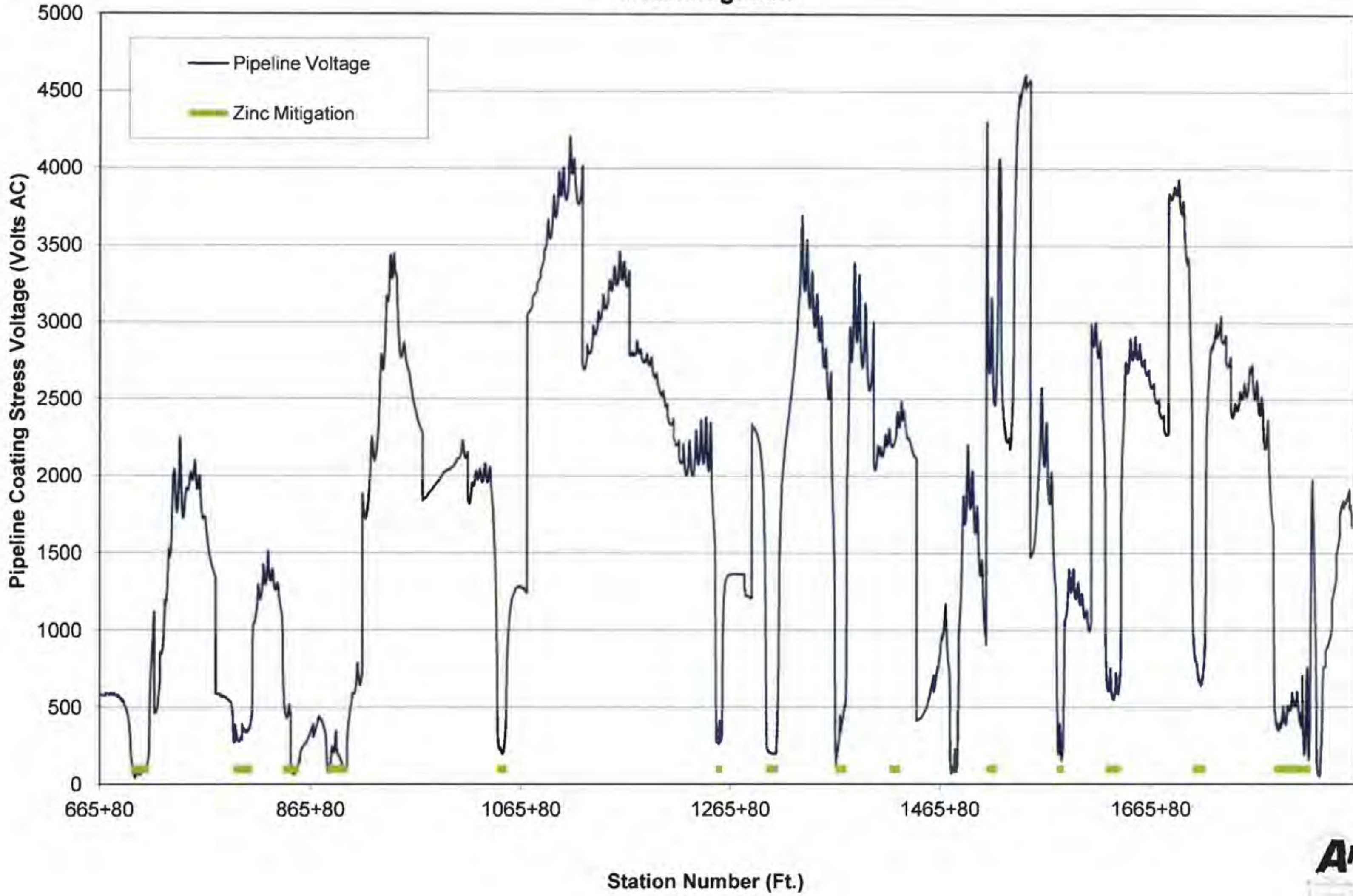
Coler & Colantonio - Vermont Gas Pipeline Project:
12" Proposed Pipeline Coating Stress Voltage
During Fault on 115 kV K27 Line
With Mitigation



Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 115 kV K33 Line With Mitigation

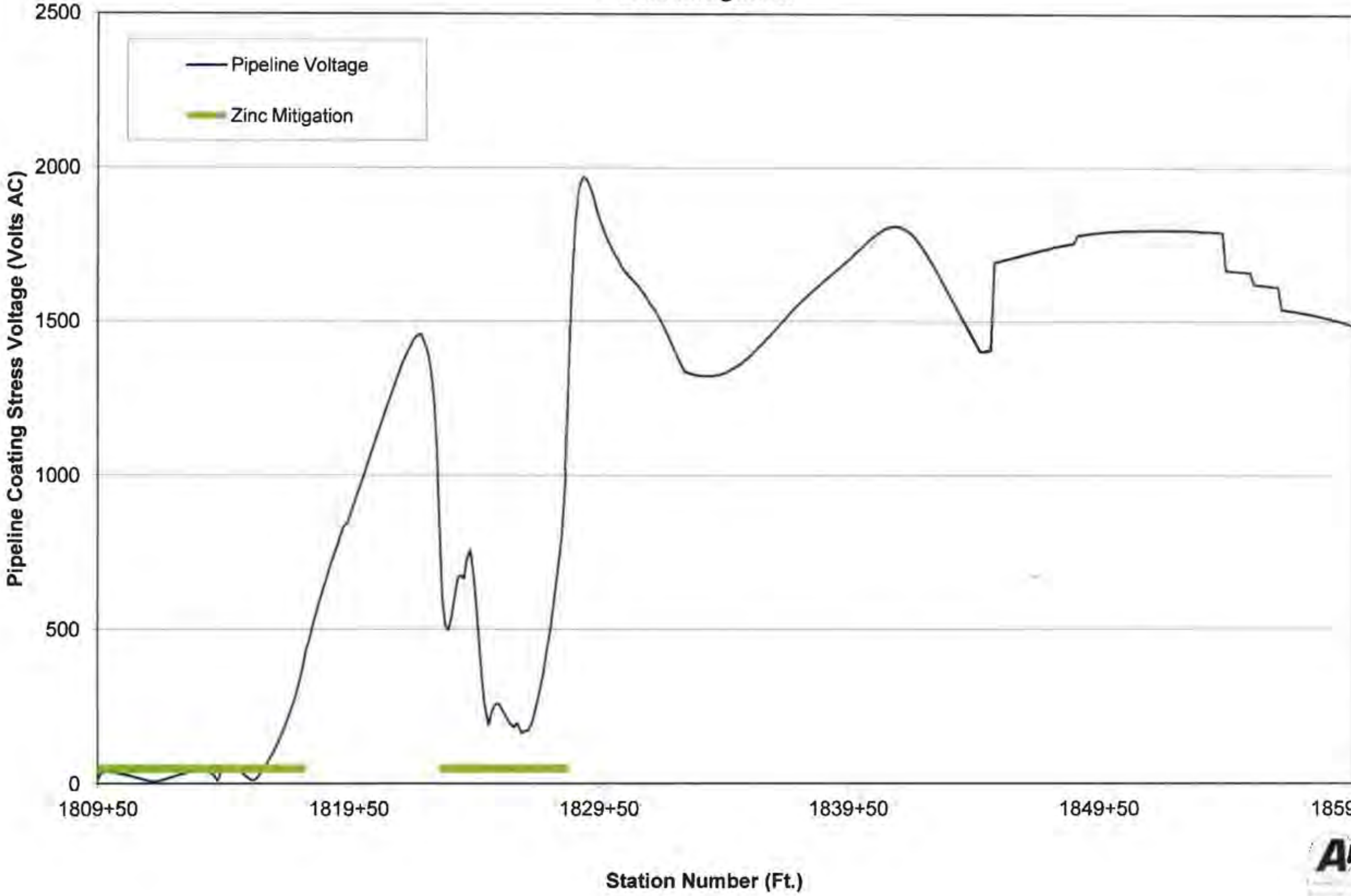


Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 115 kV K43 Line With Mitigation

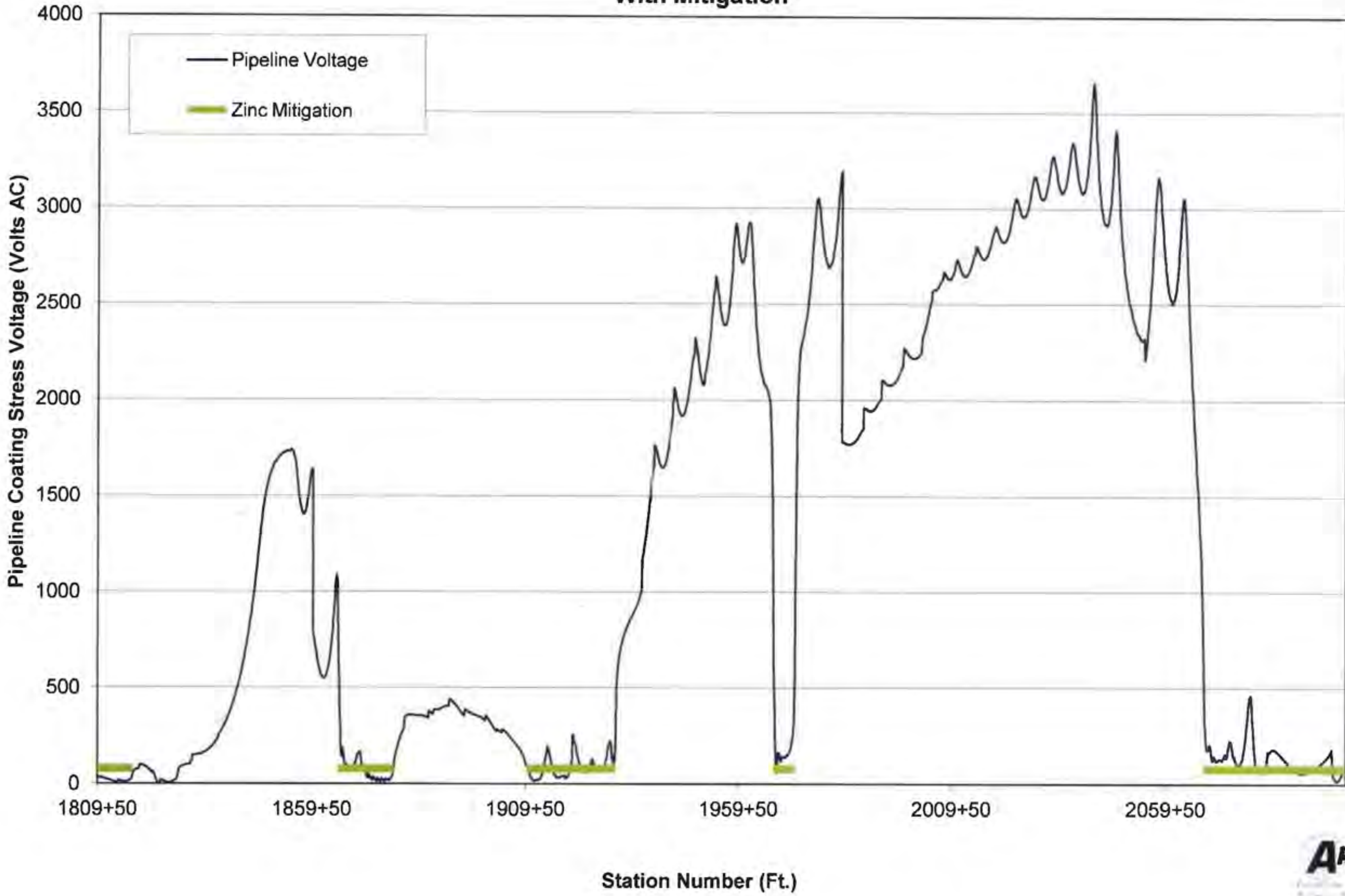


ARK.

Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 115 kV K64 Line With Mitigation

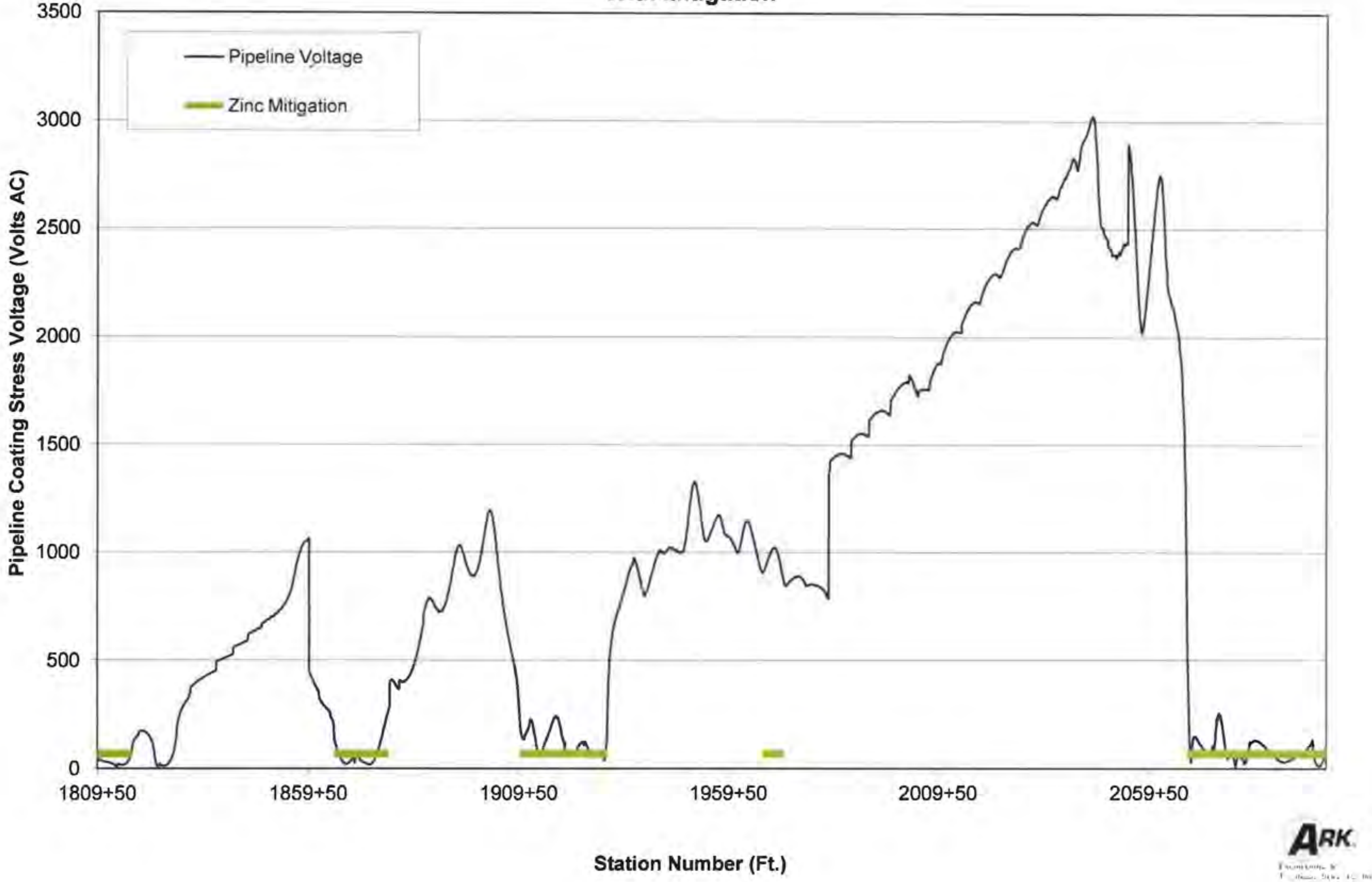


Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 115 kV K63 Line With Mitigation



ARK.

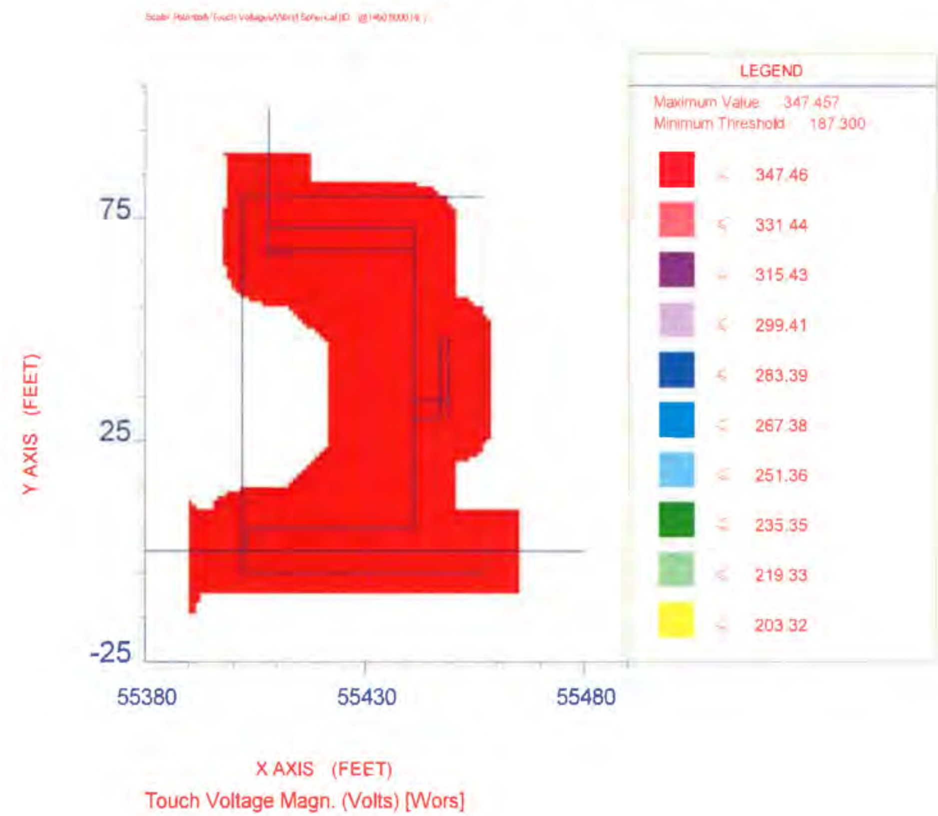
Coler & Colantonio - Vermont Gas Pipeline Project: 12" Proposed Pipeline Coating Stress Voltage During Fault on 345 kV K370 Line With Mitigation



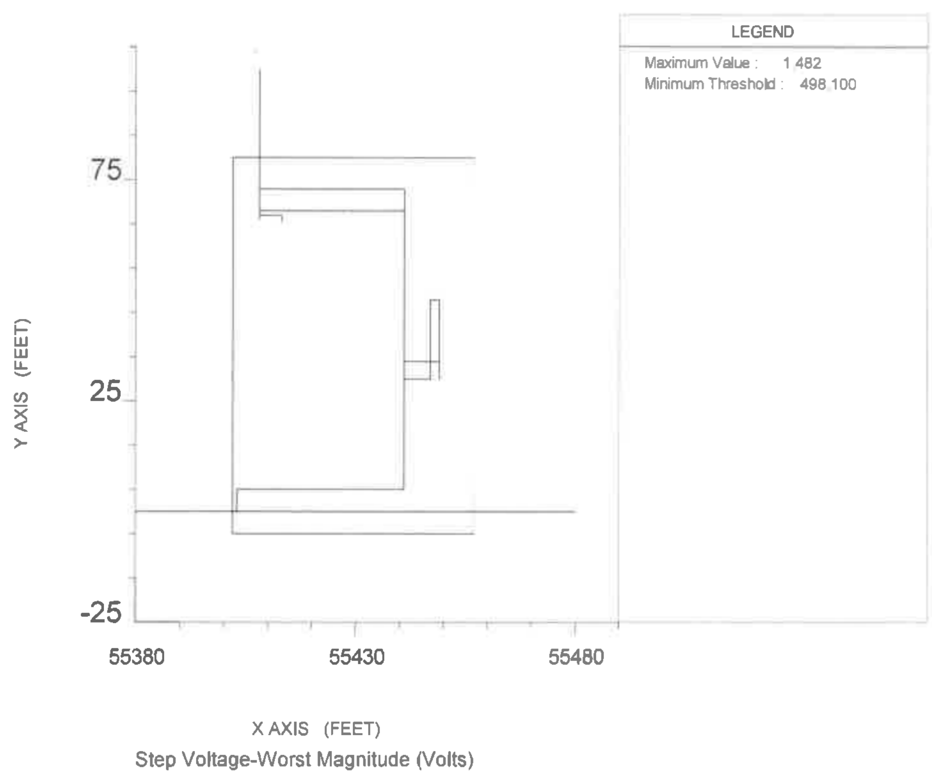
FAULT – TOUCH & STEP VOLTAGES

ARK
ENGINEERING &
TECHNICAL SERVICES INC.

Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
Williston M&R @ MP 10.43
Faulted at Velco 115 kV K23 Tower
Touch Voltages – Safety Limit 187.3 Volts.

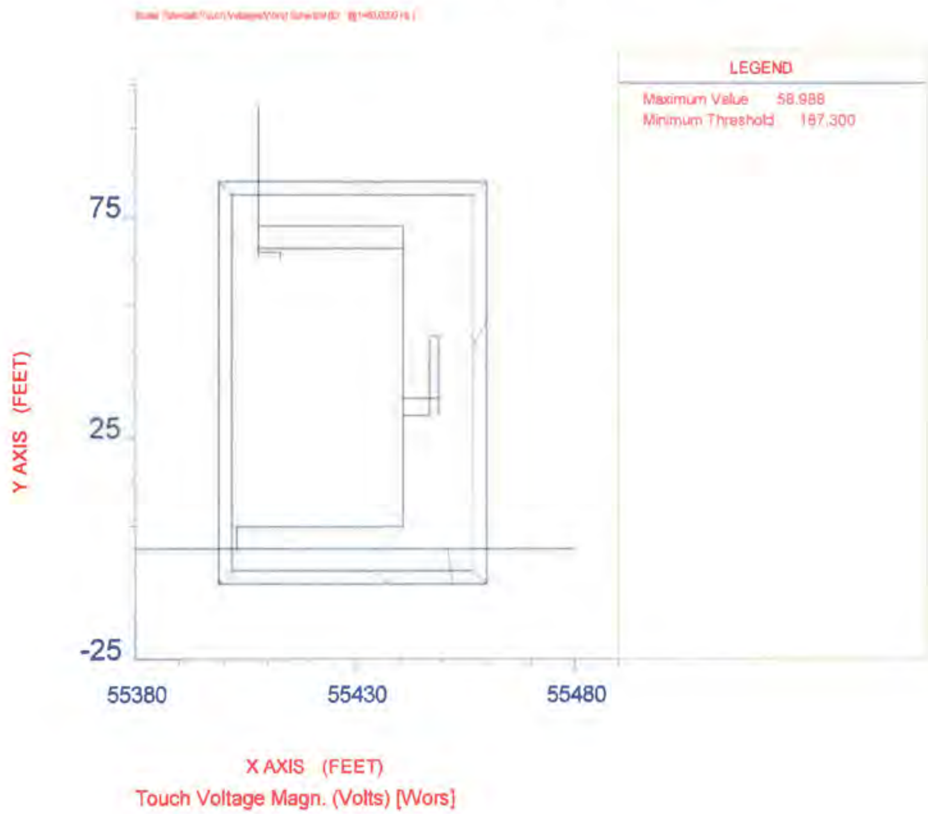


Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
Williston M&R @ MP 10.43
Faulted at Velco 115 kV K23 Tower
Step Voltages – Safety Limit 498.1 Volts.

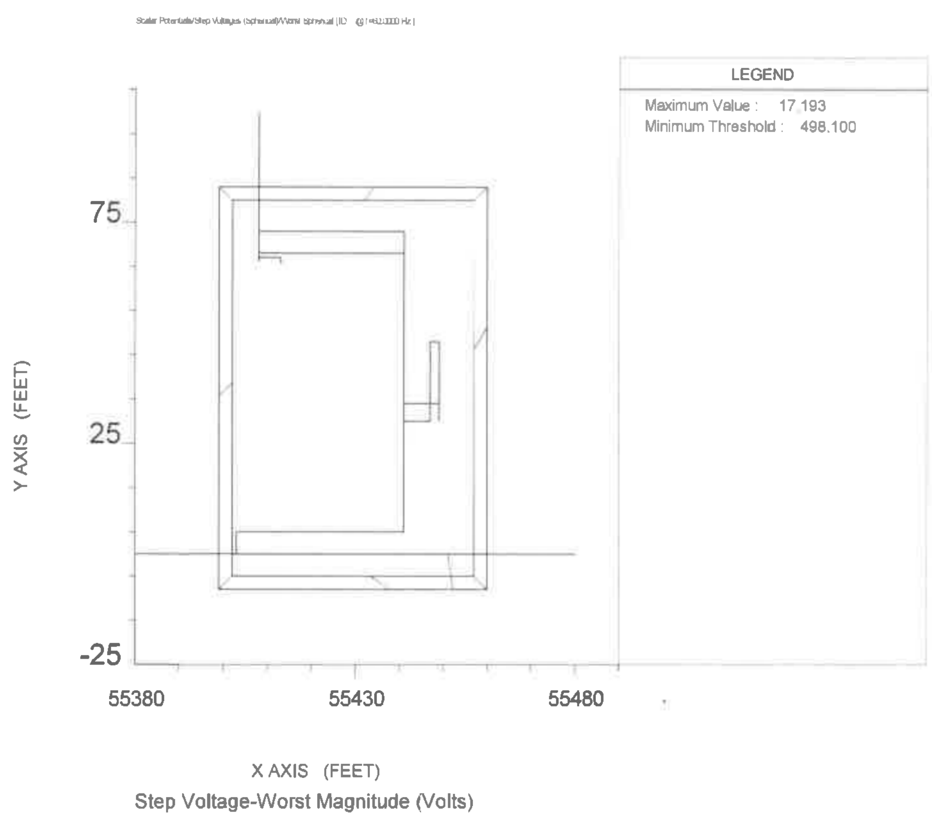


00579

Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
Williston M&R @ MP 10.43
Faulted at Velco 115 kV K23 Tower
Touch Voltages – Safety Limit 187.3 Volts.
With Mitigation



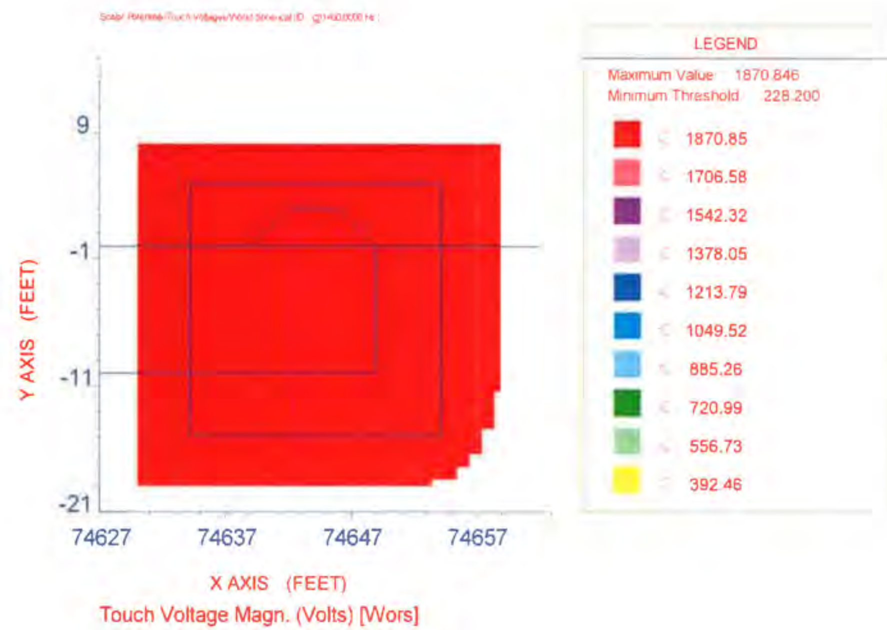
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
Williston M&R @ MP 10.43
Faulted at Velco 115 kV K23 Tower
Step Voltages – Safety Limit 498.1 Volts.
With Mitigation



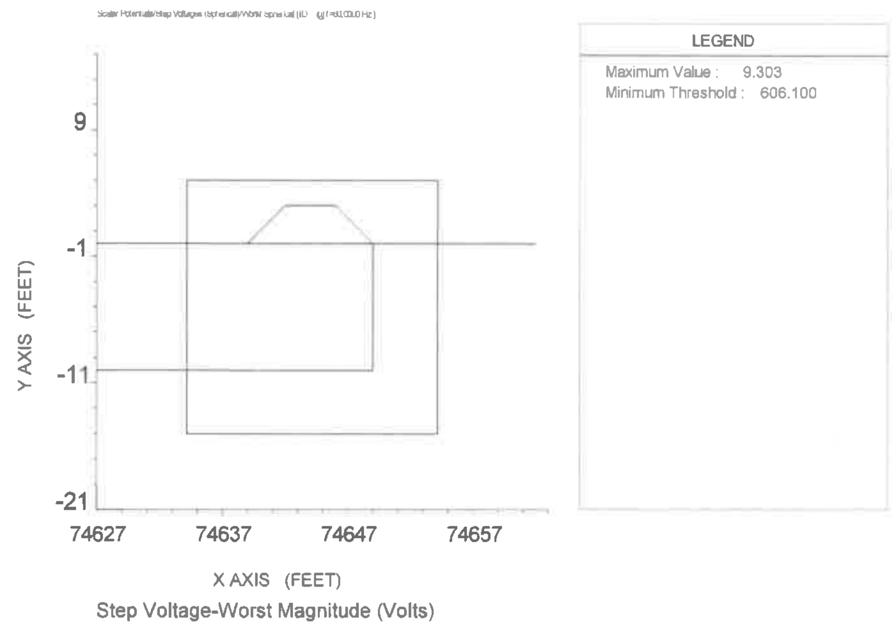
ARK Engineering & Technical Services, Inc

00581

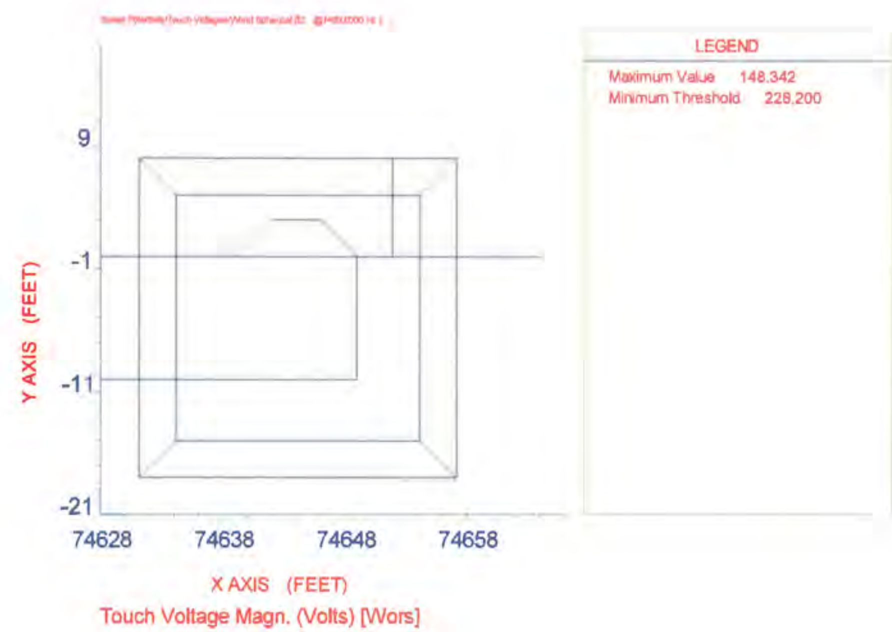
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-2 @ MP 14.3
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 228.2 Volts.



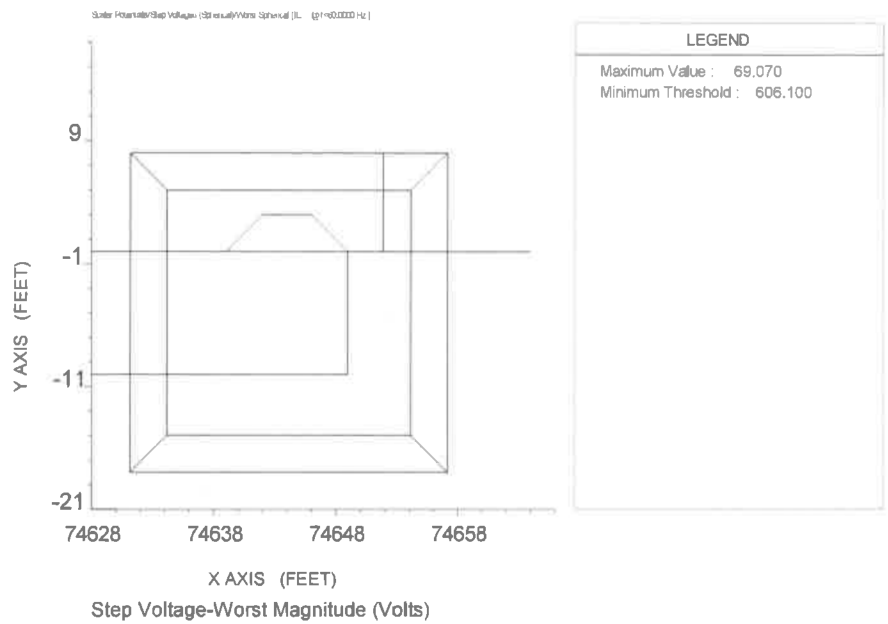
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-2 @ MP 14.3
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 606.1 Volts.



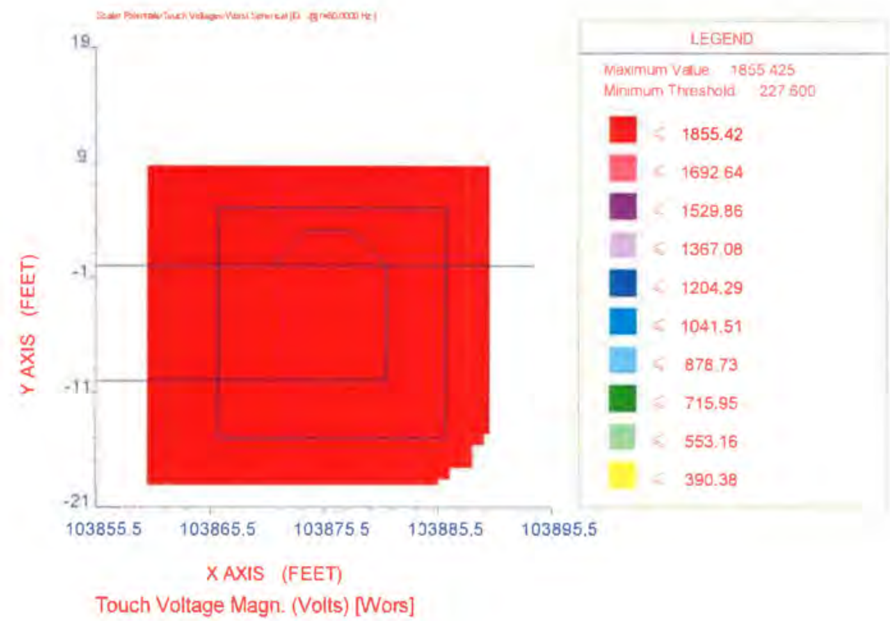
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-2 @ MP 14.3
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 228.2 Volts.
With Mitigation



Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-2 @ MP 14.3
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 606.1 Volts.
With Mitigation

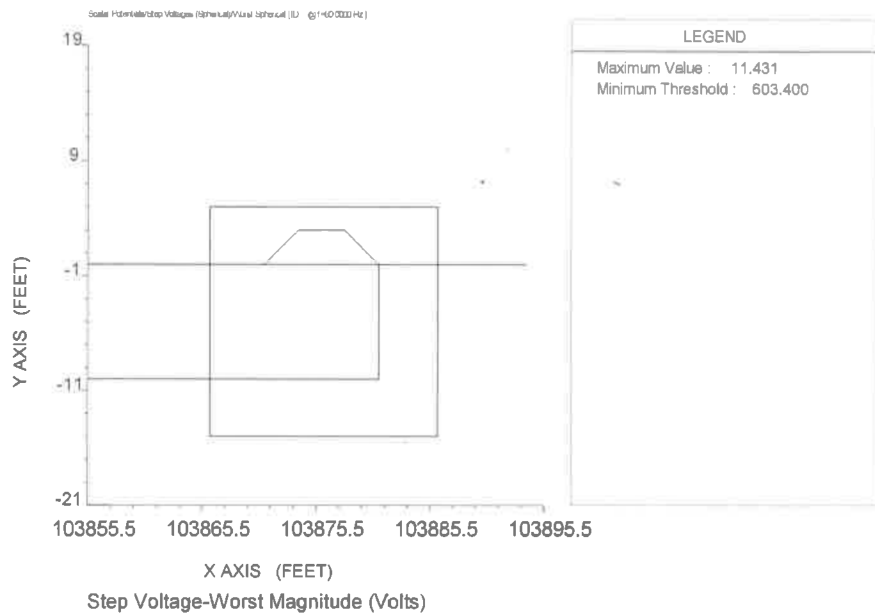


Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-3 @ MP 19.81
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 227.6 Volts.



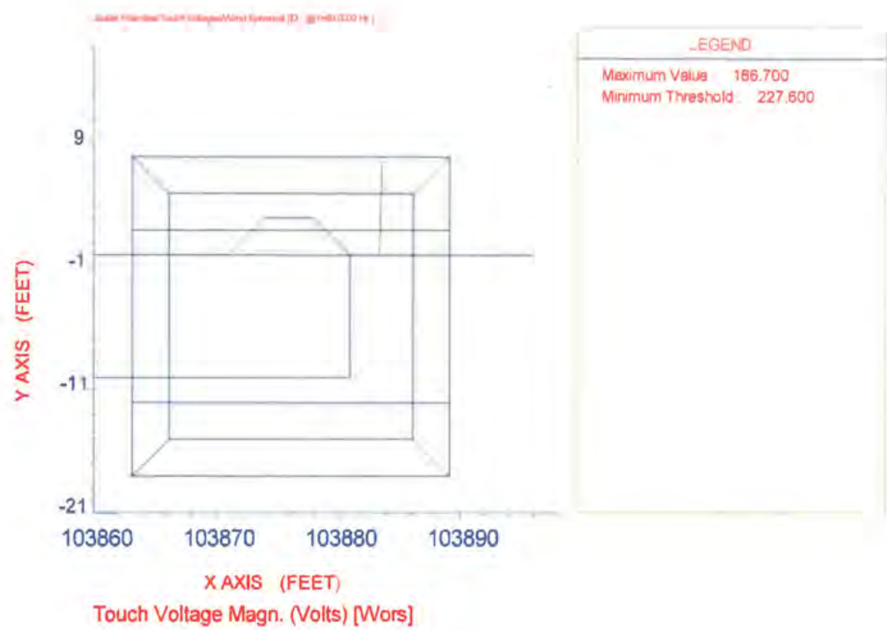
ARK

Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-3 @ MP 19.81
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 603.4 Volts.

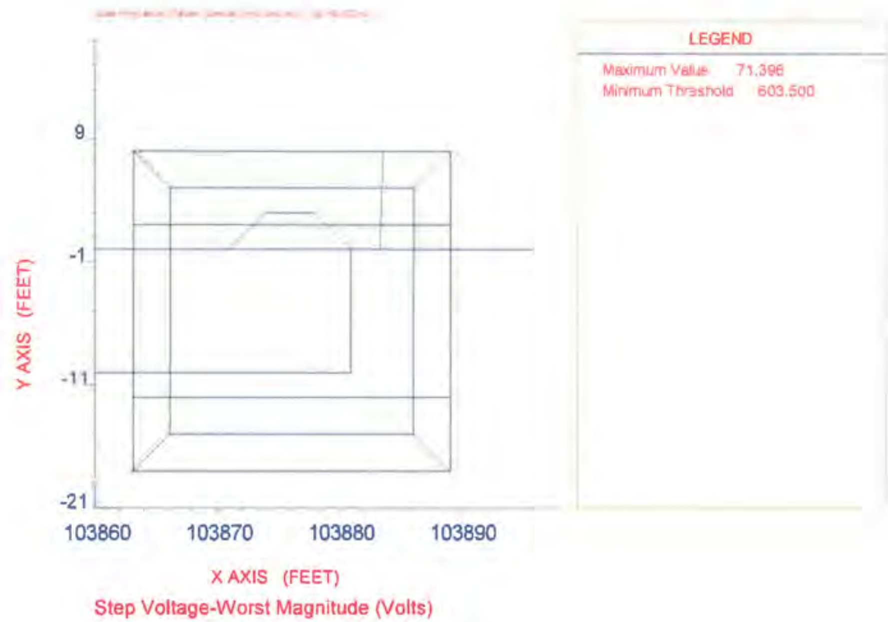


ARK Engineering & Technical Services Inc

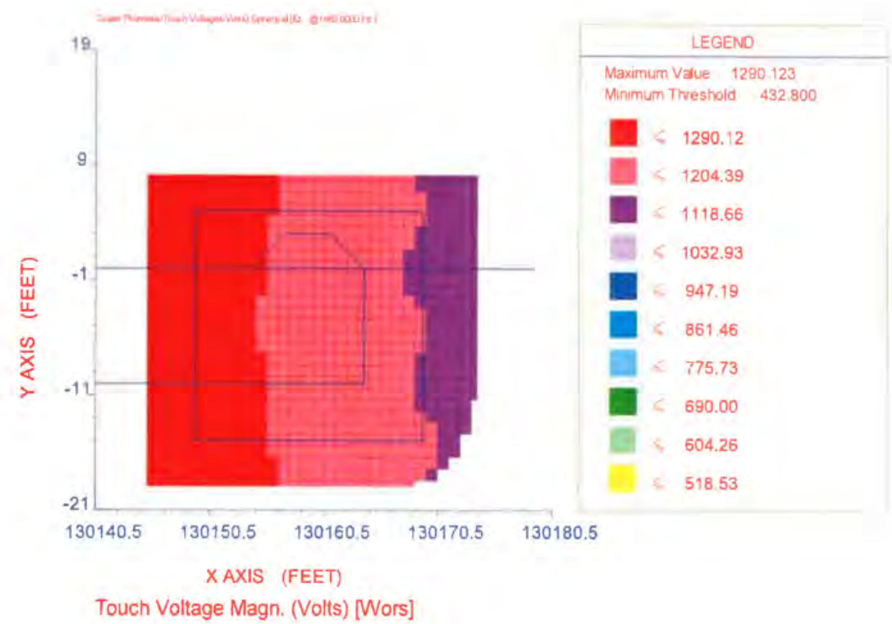
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-3 @ MP 19.81
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 227.6 Volts.
With Mitigation



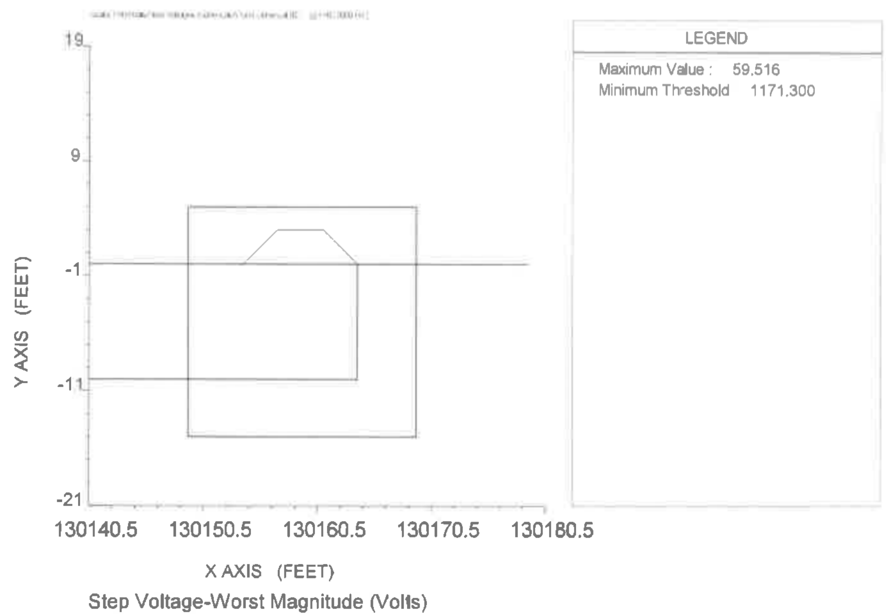
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-3 @ MP 19.81
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 603.5 Volts.
With Mitigation



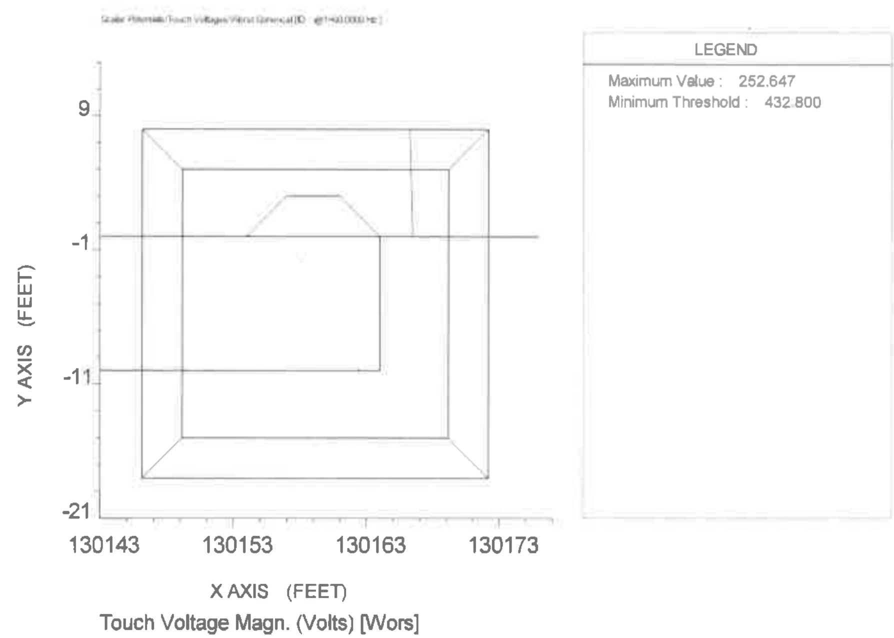
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-4 @ MP 24.8
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 432.8 Volts.



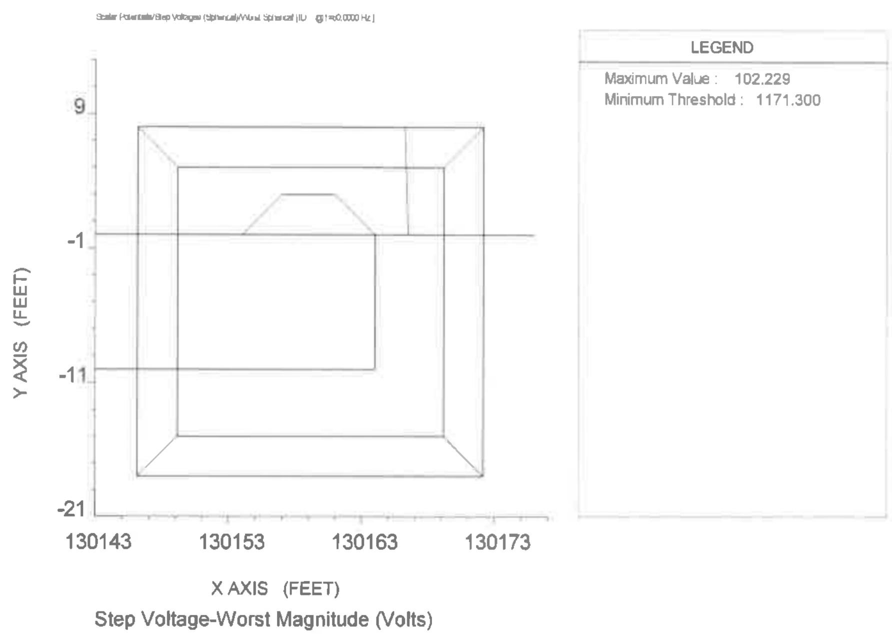
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-4 @ MP 24.8
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 1171.3 Volts.



Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-4 @ MP 24.8
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 432.8 Volts.
With Mitigation

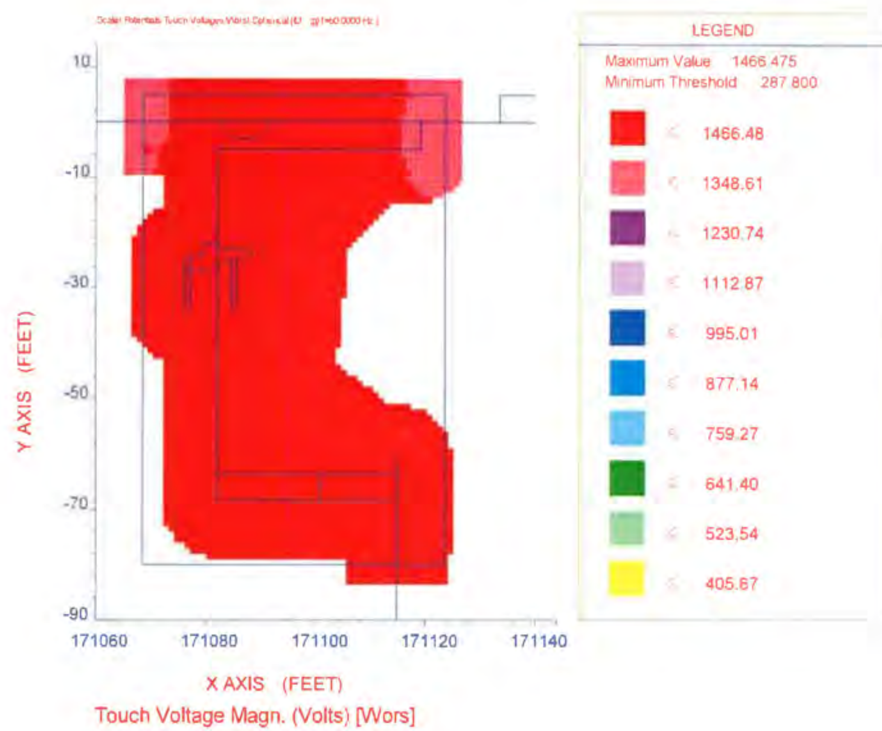


Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-4 @ MP 24.8
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 1171.3 Volts.
With Mitigation

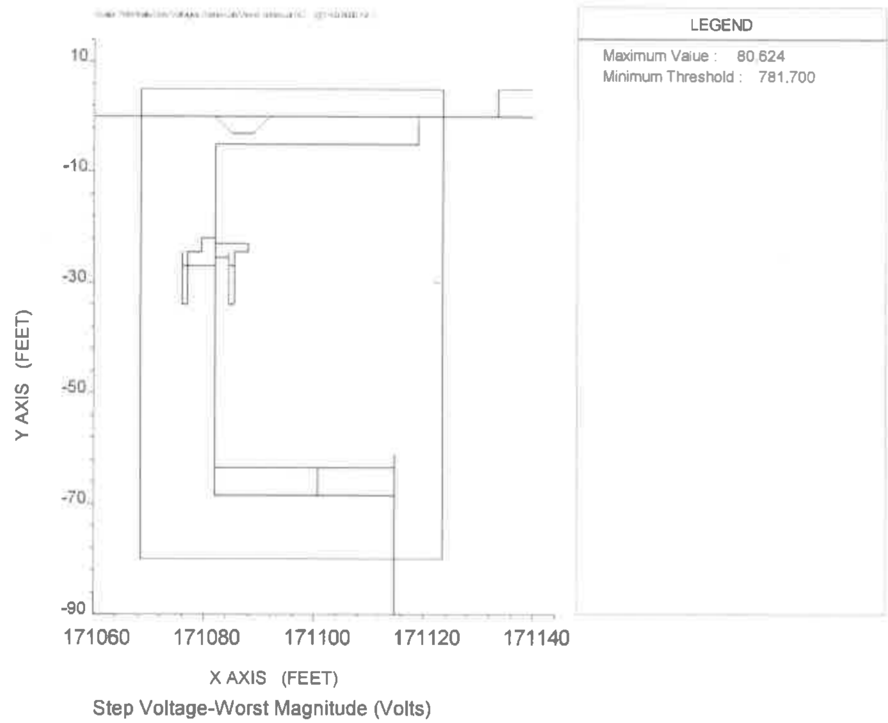


ARK Engineering & Technical Services Inc

Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-5/Plank Rd. M&R @ MP 32.54
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 287.8 Volts.

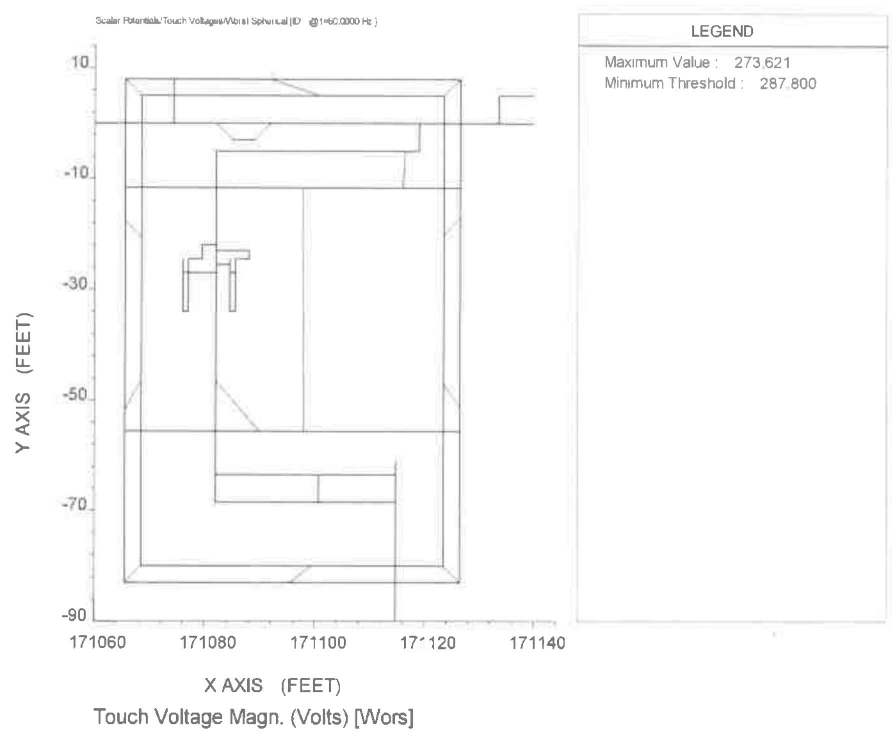


Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-5/Plank Rd. M&R @ MP 32.54
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 781.7 Volts.

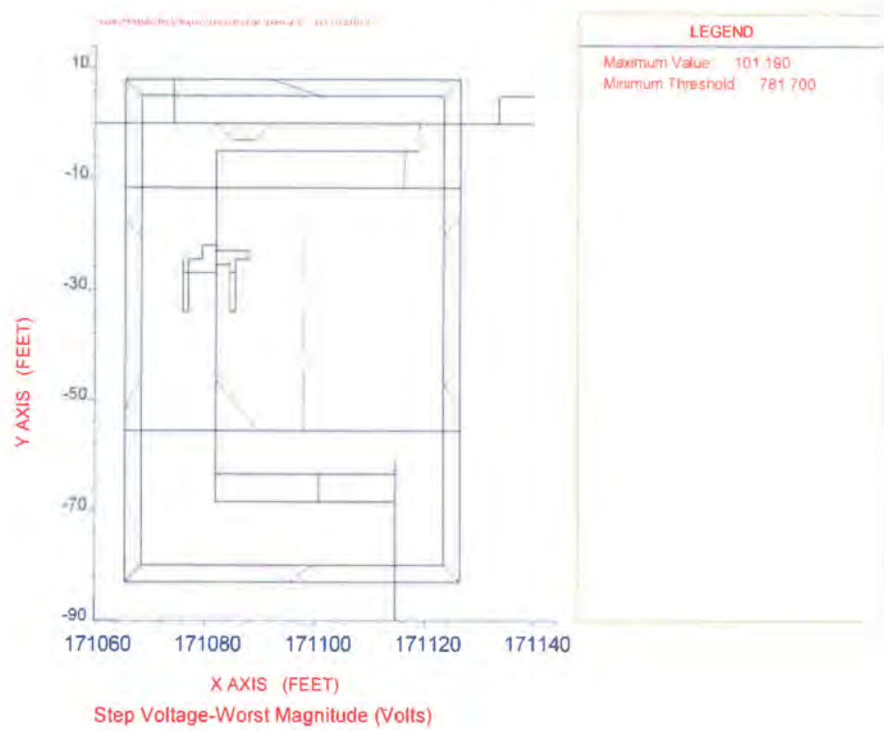


ARK. Engineering & Technical Services, Inc.

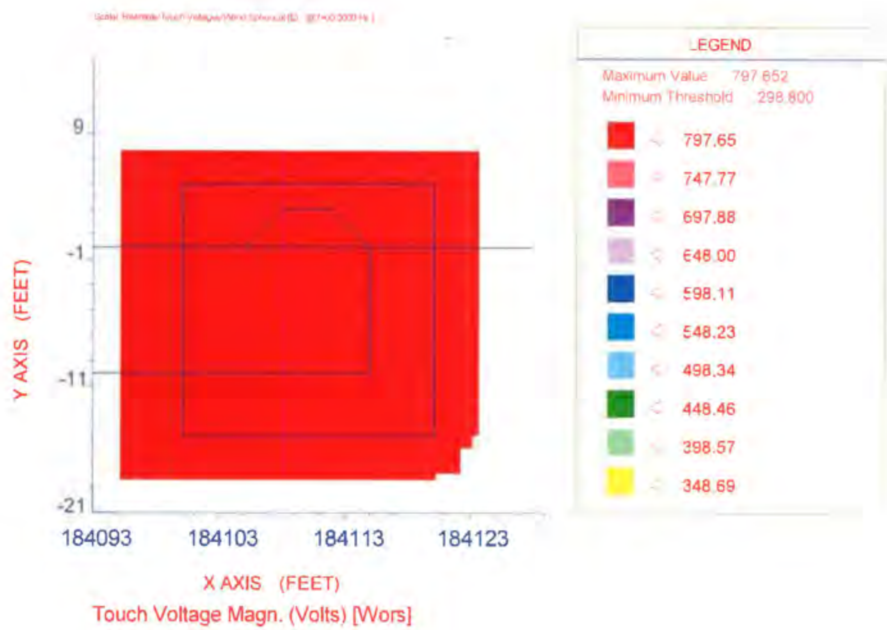
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-5/Plank Rd. M&R @ MP 32.54
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 287.8 Volts.
With Mitigation



Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-5/Plank Rd. M&R @ MP 32.54
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 781.7 Volts.
With Mitigation

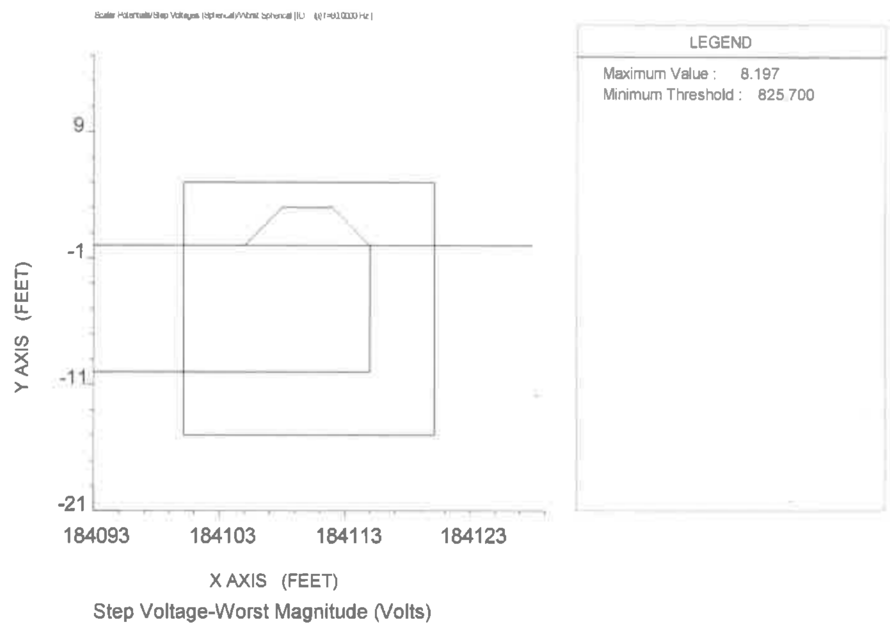


Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-6 @ MP 35
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 298.8 Volts.

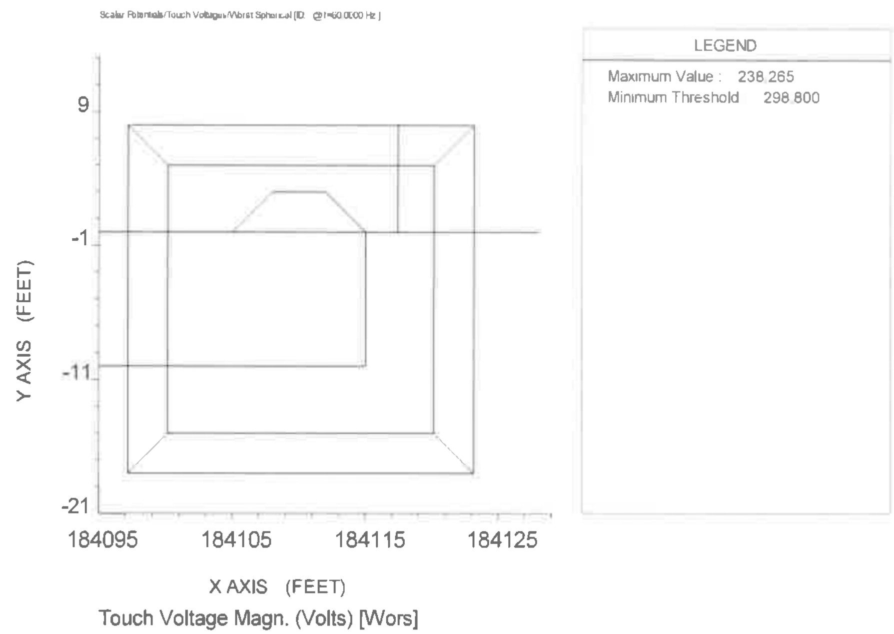


ARK

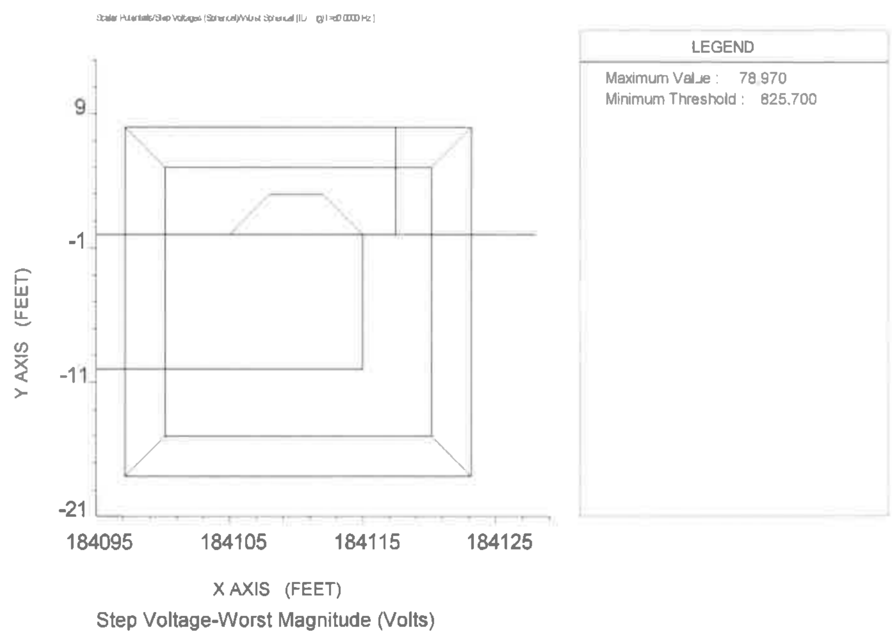
Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-6 @ MP 35
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 825.7 Volts.



Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-6 @ MP 35
Faulted at Velco 115 kV K43 Tower
Touch Voltages – Safety Limit 298.8 Volts.
With Mitigation



Coler & Colantonio - Vermont Gas Pipeline Project - 12" Proposed Pipeline
MLV-6 @ MP 35
Faulted at Velco 115 kV K43 Tower
Step Voltages – Safety Limit 825.7 Volts.
With Mitigation



APPENDIX C –
POWER & PIPELINE COMPANY DATA

Circuit Name	Voltage (kV)	Origin Substation	Destination Substation	Projected Future Maximum Load Current (A)	Projected Future Emergency Load Current (A)	Maximum [illegible] Imbalance	Maximum [illegible] Imbalance
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	345	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]							

Circuit Name	Conductor Data	[illegible]	Avg Tower Impedance (ohms)	Avg Tower Grounding Depth (feet)	[illegible]	Total Length (feet)	Average Span (ft) (Ruling Span)	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]										

Substation Name	Bus Voltage (kV)	Latitude (approx)	Longitude (approx)	Ground Grid Impedance
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]				

ARK

Transmission Line	Distance Between Substations	Contributing Substation	Single Phase to Ground Fault Current at Transm...	Single Phase to Ground Fault Angle at Transm (Degrees)	Primary Fault Clearing Time (cycles)	Breaker failure fault clearing time (cycles)	Location
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Circuit Name	Voltage (kV)	Origin Substation	Destination Substation	Assumed Future Emergency Load (MVA)
[illegible]				
[illegible]				

Transmission Line	Distance Between Substations	Contributing Substation	Single Phase to Ground Fault Current at Tower (Amps)	Single Phase to Ground Fault Angle at Tower (Degrees)	Primary Fault Clearing Time (cycles)	Breaker Failure Fault Clearing time (cycles)	Location
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	[illegible]			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	[illegible]			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	[illegible]			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	[illegible]			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]					25% of Line
		[illegible]					
	[illegible]	[illegible]					50% of Line
		[illegible]					
	[illegible]	[illegible]					75% of Line
		[illegible]					
[illegible]	At Origin Substation	Origin					
		Destination					
	25% of total line length	Origin					
		Destination					
	50% of total line length	Origin					
		Destination					
	75% of total line length	Origin					
		Destination					
	At Destination Substation	Origin					
		Destination					

INDEX TO DRAWINGS
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY JM	CHECKED BY	DATE 6/77	
SCALE none	APPROVED BY DW	DWG # 115-0.0	

DATE | CH'K BY
REVISIONS

DWG NO.	TITLE
115-12.1	Crossarm Detail - Types C, D, DA, DA-T & F
115-13.0	Pole Boring, Gaining & Pole Roof
115-14.0	Plate & Channel Detail
115-14.1	Plate & Channel Detail
115-15.0	Bayonet Detail
115-15.1	Type A, Shield Wire Deadend Detail
115-16.0	Anchor Rods, Anchor Logs & Guy Wire Connections
115-16.1	Rock Anchor & Swamp Anchor Detail
115-17.0	Ground Rod Detail
115-18.0	Guying - Types A, D & E
115-18.1	Guying - Types B, B-2, C & F
115-18.2	Guying - Type DA
115-18.3	Guying - Type DA-T
115-19.0	Guy Grounding - Types B, B-2, C & DA
115-19.1	Guy Grounding - Types D & E
115-20.0	Bog Shoe Detail - Type A
115-20.1	Bog Shoe Detail - Type B & C
115-21.0	Clearing for 150' Right of Way
115-22.0	Type F Structure - Transposition - Three Phase
115-22.1	Type F Structure - Transposition - Two Phase
115-22.2	Type F Structure - Pole Top Details

INDEX TO DRAWINGS
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY JM	CHECKED BY	DATE 6/77	
SCALE none	APPROVED BY DW	DWG # 115-0.1	
DATE	CH'K BY	REVISIONS	

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE A STRUCTURE
115 KV

Mark	Quant.	Description	Manuf.	Cat. No.
1	2	Bayonets, complete w/plate, filler washer, w/ bolts, nuts and washers 2" x 5/8" and 2½" x 5/8"	L M	LM-DN-3B2
3	4	Bolts, 5/8" x 10" for bayonet (12")	Joslyn	J 8810 J 8812
4	4	Bolts, brace 1/2" x 10"	Joslyn	J 8710
5	2	Bolts, 5/8" x 12" for crossarm brace	Joslyn	J 8812
7	3	Bolts, x-arm clamps 3/4" x 8"	Joslyn	J 8908
11	2	Bolts, machine 3/4" x 16" for crossarm	Joslyn	J 8916
19	2 pr	Brace - Wood xarm 60"	Hughes	2000CC
22	2	Preformed guy grips DE - for cross tie	Preformd	GDE-1107
23	4	Preformed "L" taps for guy to static	"	LC-MS-5963
26	2	Clevis - deadend for cross tie	Joslyn	456
33	1	Crossarm-Type A	Haley	
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
44	2	Clamps, ground rod	L M	DN 14G1
46	2	Clamps, suspension-static wire	Lapp Bethea	N95750 FS-46
49	3	Clamps, suspension - conductor w/ socket ftg.	Bethea	ACFS-114-19-25S
51	3	Clamps, crossarm	Joslyn	J 1820
53	5	Washers, coil spring 3/4"		
54	6	Washers, coil spring 5/8"		
55	4	Washers, coil spring 1/2"		
56	4	Washers, 2" x 2" x 1/8" w/9/16" hole - square	Joslyn	J 1073
57	2	Washers, 4" x 4" x 1/4" w/13/16" hole -curved	Lapp MIF	304082 P144
60	2	Washers, 3" x 3" x 3/16" w/11/16" hole -curved	Lapp MIF	304078 P143
63	2	Plates, reinforcement for xarms	Joslyn	J 4047
64	75	Staples - 3/8" x 1-3/4" (down leads)	Joslyn	J 173
67	120'	Down Lead 3/8" galv. 3-strd. (common grade)		
72	3	Ball eye - long	Lapp ~~BTC~~	6422 ~~3014~~

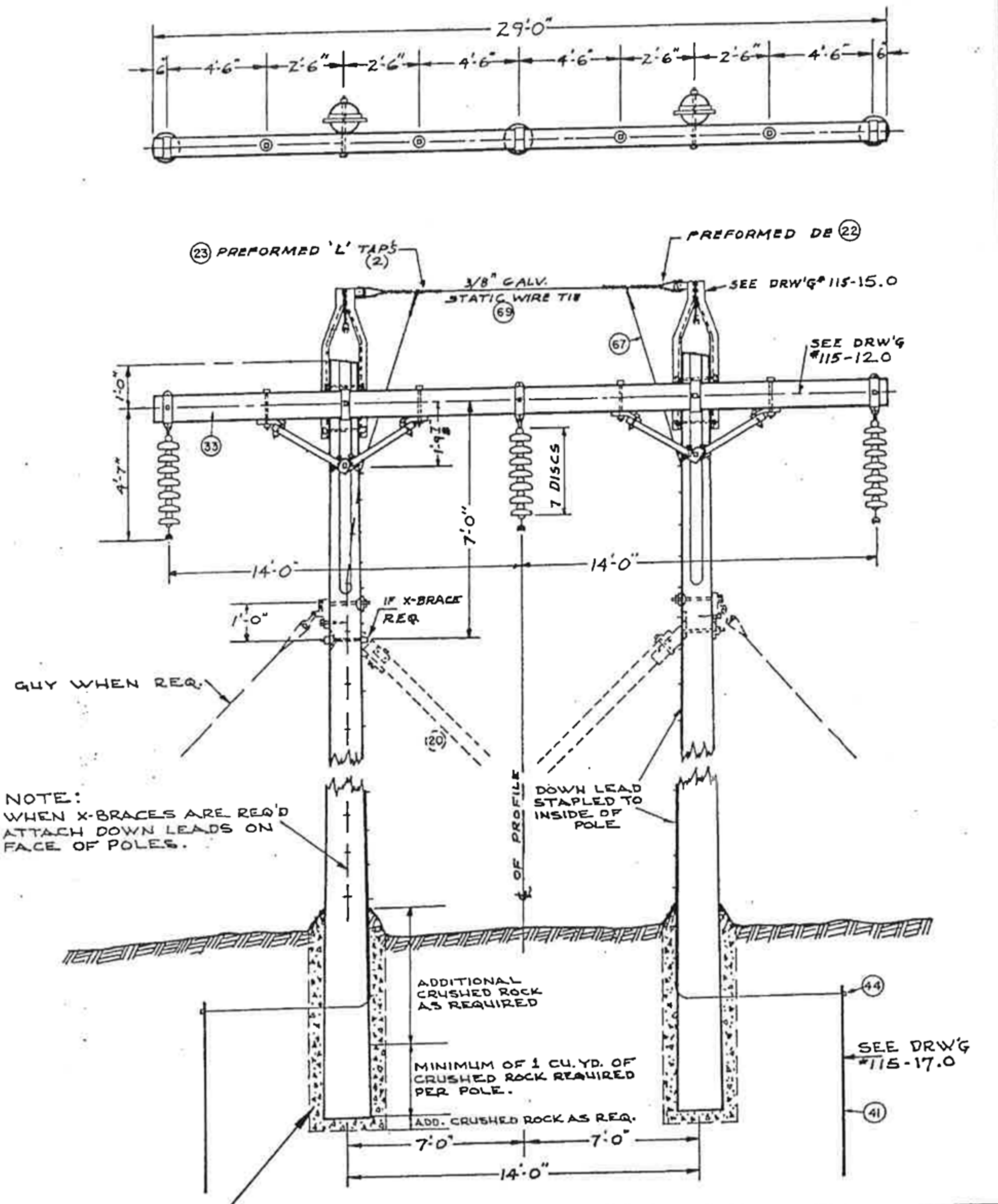
Rev. 2/77
Rev. 2/74

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE A STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
69	14'	Cable, 3/8" galv. for cross tie		Common Grade
76	2	Sheave Wheel for cross tie (roller eye)	Joslyn	J 6288
82	21	Insulators, suspension 9" disc (7 per string)	Lapp GE	9000-70 155-409- ASA-70
		When Required		
20	1	X-brace w/ mounting hardware	Hughes	1042X
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3 sets	Armor Rods		
79		Pole Roof, non metalic (used if pole cut off in field)	Joslyn	J 2108
		Side Guys - When Required		
11	2	Bolts, machine 3/4" x 16" (pole eye plate)	Joslyn	J 8916
22	4	Preformed DE guy grips	Preformed	GDE 1107
24	2	Thimble Clevis	Lapp MIF	304056 PA 271
31	2	Anchor logs 4'	Koppers	
40	2	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A		Rock anchors	Chance	R360 R 384 R372 R 396
42	4	Lags, screw 1/2" x 4"	Joslyn	8754 P
53	2	Washers, coil spring 3/4"		
55	4	Washers, coil spring 1/2"		
57	2	Washers, 4" x 4" x 1/4" w/13/16" hole- curved	Lapp MIF	304082 P144
58	2	Washers, 4" x 4" x 1/4" w/ 7/8" hole -flat	Joslyn	J 1082
61	2	Guard Guy- metal	Oliver	808
68	135'	Cable, 3/8" EHS galv. steel		
77	2	Pole Eye Plate	Lapp MIF	304021 PX 88
59	4	Washers, round 9/16"		

Rev.

REV 2/77
Rev. 2/74



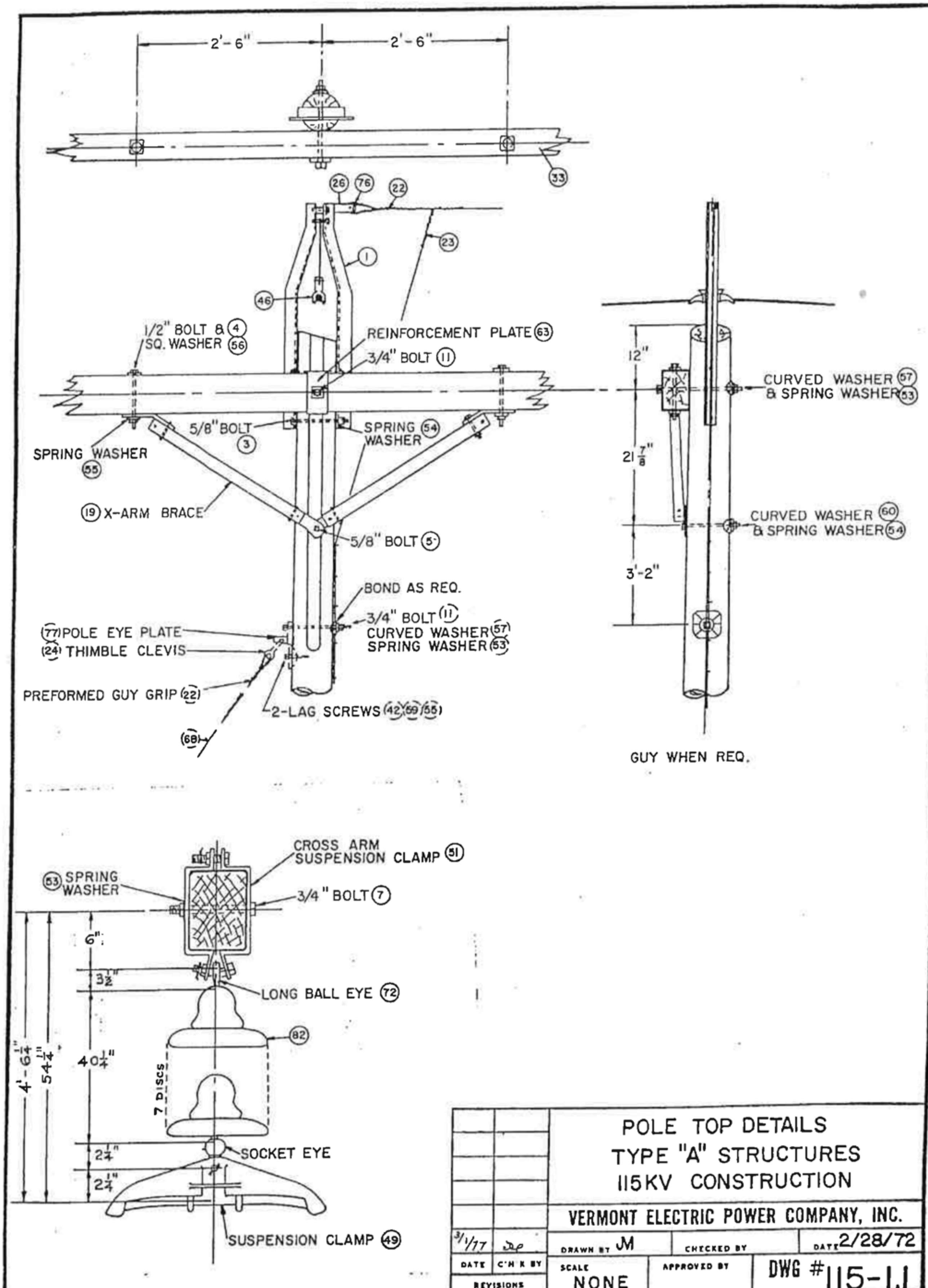
NOTE:
TYPICAL CRUSHED ROCK BACKFILL.

1. WHEN SHIELD WIRE REQUIRES DEADENDING SEE DWG# 115-15.1 FOR ASSEMBLY & CROSSARM ATTACHMENT DETAIL, AND MATERIAL LIST.

TYPE-A
TANGENT STRUCTURE
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

3/1/77	JL	DRAWN JM		DATE 4/10/72
DATE		SCALE NONE		DWG# 115-1.0
REVISIONS				



		POLE TOP DETAILS TYPE "A" STRUCTURES 115KV CONSTRUCTION
		VERMONT ELECTRIC POWER COMPANY, INC.
3/1/77	JP	DRAWN BY JM · CHECKED BY · DATE 2/28/72
DATE	C'H'K BY	SCALE NONE · APPROVED BY · DWG # 115-1.1
REVISIONS		

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE A-2 STRUCTURE
115 Kv

Mark	Quant	Description	Manuf	Cat. No.
1	2	Bayonets, complete w/plate, filler washer, w/bolts, nuts & washers	L M	DN-3B2
3	4	Bolts, 5/8" x 10" (12"). for bayonets	Joslyn	J 8810 J 8812
4	8	Bolts, brace 1/2" x 10"	Joslyn	J 8710
5	2	Bolts, 5/8" x 12" for crossarm	Joslyn	J 8812
13	2	Bolts, machine 3/4" x (24")(26") (28")	Joslyn	J 8924, 8926 J 8928
14	3	Bolts, eye - forged shoulder w/washer nut, MF locknut & Cotter pin	Joslyn	J 2180
15	6	Bolts, 5/8" x 10" for plate & channel	L M	DF 3B10
19	4pr	Brace wood - Xarm 60"	Hughes	2000CC
21	3	Channel & Plate	L M	66D901M1 DP23A3
22	2	Preformed guy grip deadend -cross tie	Preformed	GDE 1107
23	4	Preformed "L" taps for top guy to static	Preformed	LCMS 5963
26	2	Clevis - deadend for cross tie	Joslyn	J 456
28	3	Clevis - ball	Lapp OB	6227 70689
33	2	Crossarms Type D		
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
44	2	Clamps, ground rod	L M	DN14G1
46	2	Clamps, suspension - static wire	Lapp Bethea	N95750 FS-46
49	3	Clamps, suspension - conductor w/socket ftg.	Bethea	ACFS 114-19 25S
53	2	Washers, coil spring 3/4"		
54	12	Washers, coil spring 5/8"		
55	8	Washers, coil spring 1/2"		
56	8	Washers, 2" x 2" x 1/8" w/9/16" hole - square	Joslyn	J 1073

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VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE A-2 STRUCTURE
115 Kv

Mark	Quant	Description	Manuf.	Cat. No.
63	4	Plates, reinforcement for xarms	Joslyn	J 4047
64	75	Staples 3/8" x 1-3/4" (down leads)	Joslyn	J 173
67	120'	Down Lead 3/8 " galv. 3-strd. (common grade)		
69	14'	Cable, 3/8" galv. for cross tie		Common Grade
76	2	Sheave wheel (roller eye) cross tie	Joslyn	J 6288
82	21	Insulators, suspension 9" disc (7/string)	Lapp GE	9000-70 155-409- ASA-70
		When Required		
20	1	X-brace w/mounting hardware	Hughes	1042X
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3sets	Armor rods		
79		Pole roof, non metalic(used if pole cut off in the field)	Joslyn	J 2108
		Side Guys - When Required		
11	2	Bolts, machine 3/4" x 16" (pole eye plate)	Joslyn	J 8916
22	4	Preformed deadend guy grips	Preformed	GDE 1107
24	2	Thimble Clevis	Lapp MIF	304056 PA 271
31	2	Anchor logs 4'	Koppers	
40	2	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A		Rock anchors	Chance	R 360 R384 R 372 R396
42	4	Lags, screw 1/2" x 4"	Joslyn	8754P
53	2	Washers, coil spring 3/4"		
55	4	Washers, coil spring 1/2"		
57	2	Washers, 4" x 4" x 1/4" w/13/16" hole-curved	Lapp MIF	304082 P 144
58	2	Washers, 4" x 4" x 1/4" w/ 7/8 " hole - flat	Joslyn	J 1082
61	2	Guy Guards - metal	Oliver	808
59	4	Washers, round 9/16"		

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Rev 2/77
Rev. 2/74

Type A-2 Str. Sheet 2 of 2

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE A-2 STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
68	135'	Cable, 3/8" EHS galv. steel		
77	2	Pole eye plate	Lapp MIF	304021 PX 88

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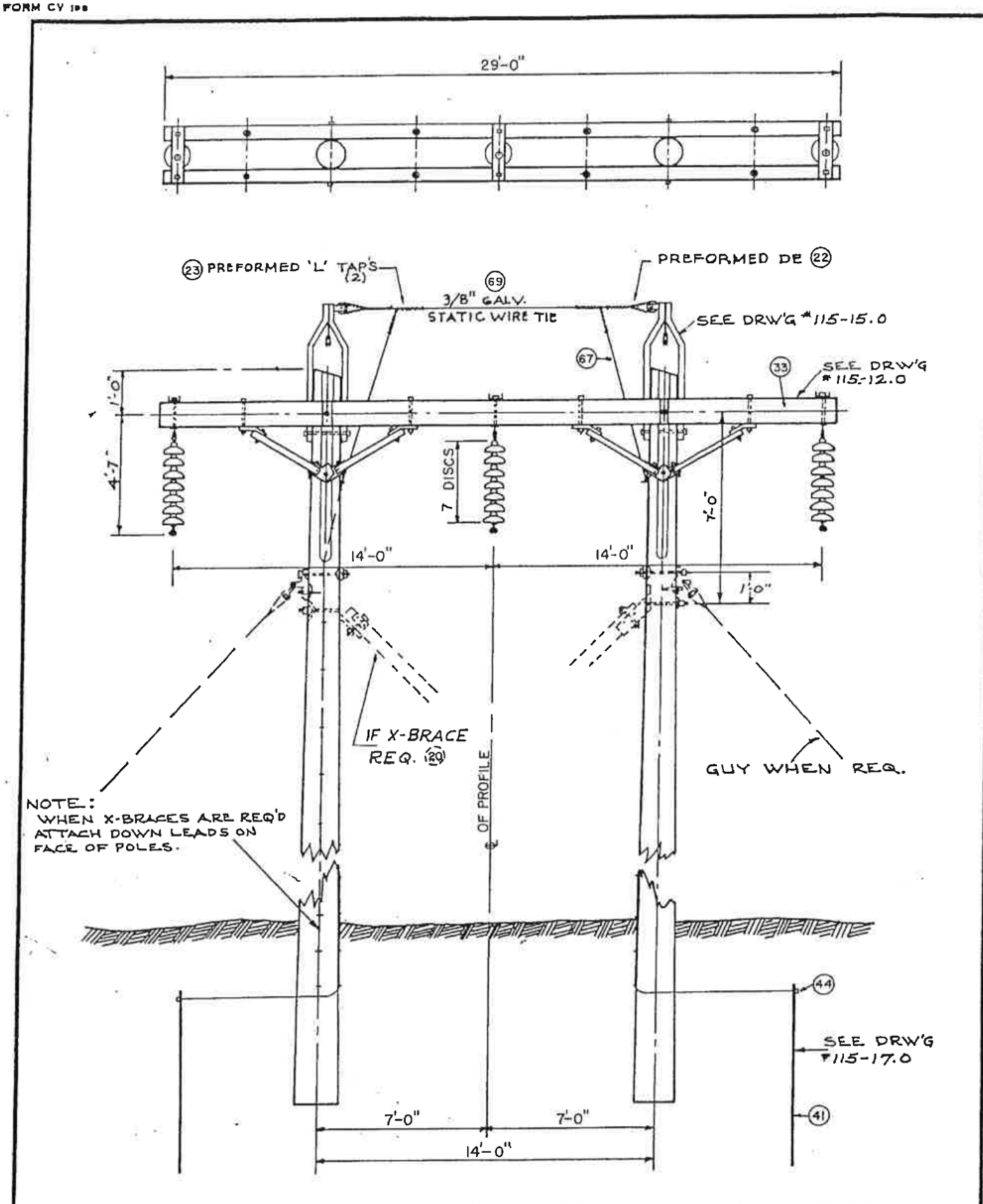
4/72

FORM CV 198

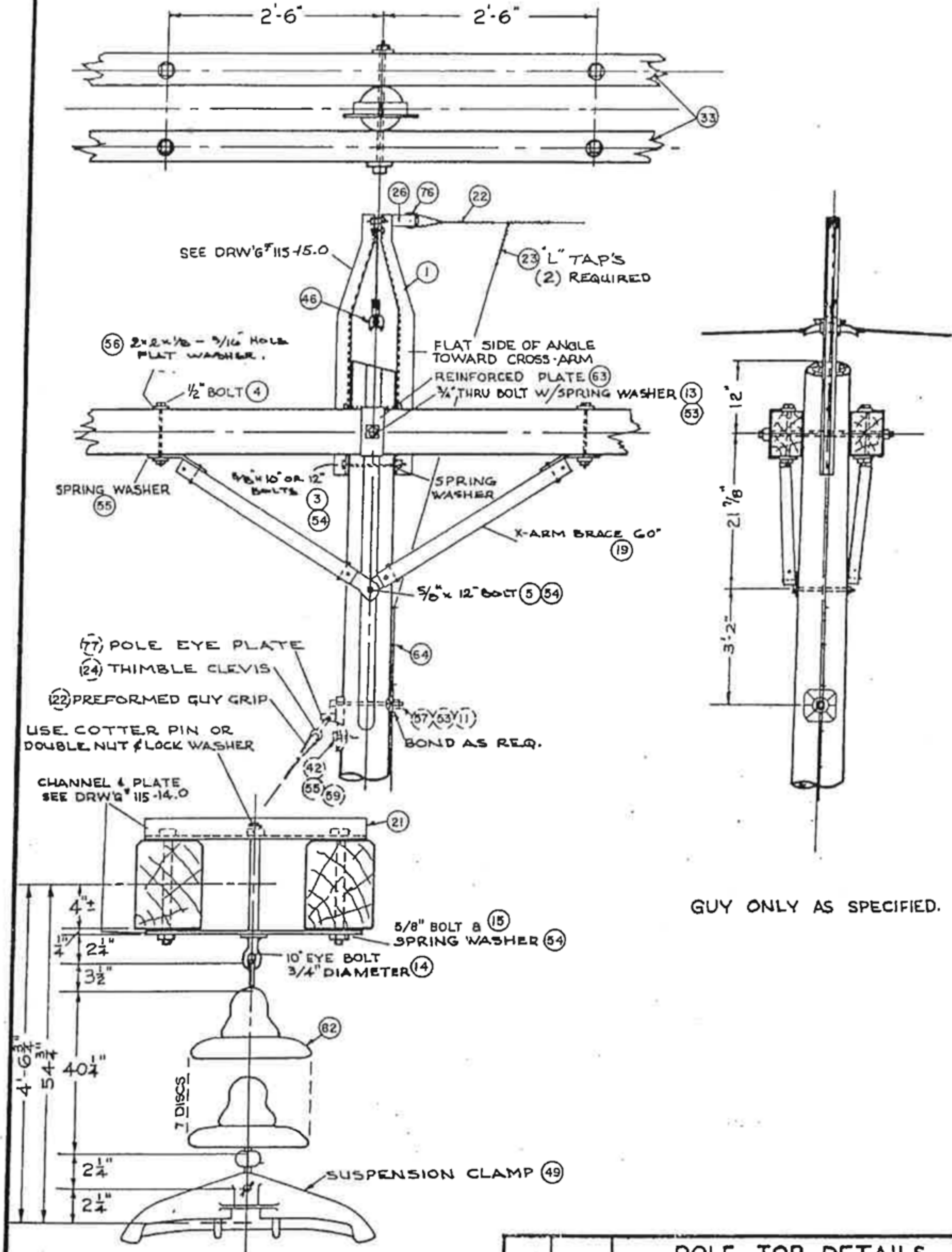


TYPE A-2
TANGENT STRUCTURE
SPECIAL SPANS
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

3/1/77	JW	DRAWN BY JM	CHECKED BY	DATE 4/11/72
DATE	CH'K BY	SCALE NONE	APPROVED BY	DWG #115-2.0
REVISIONS				

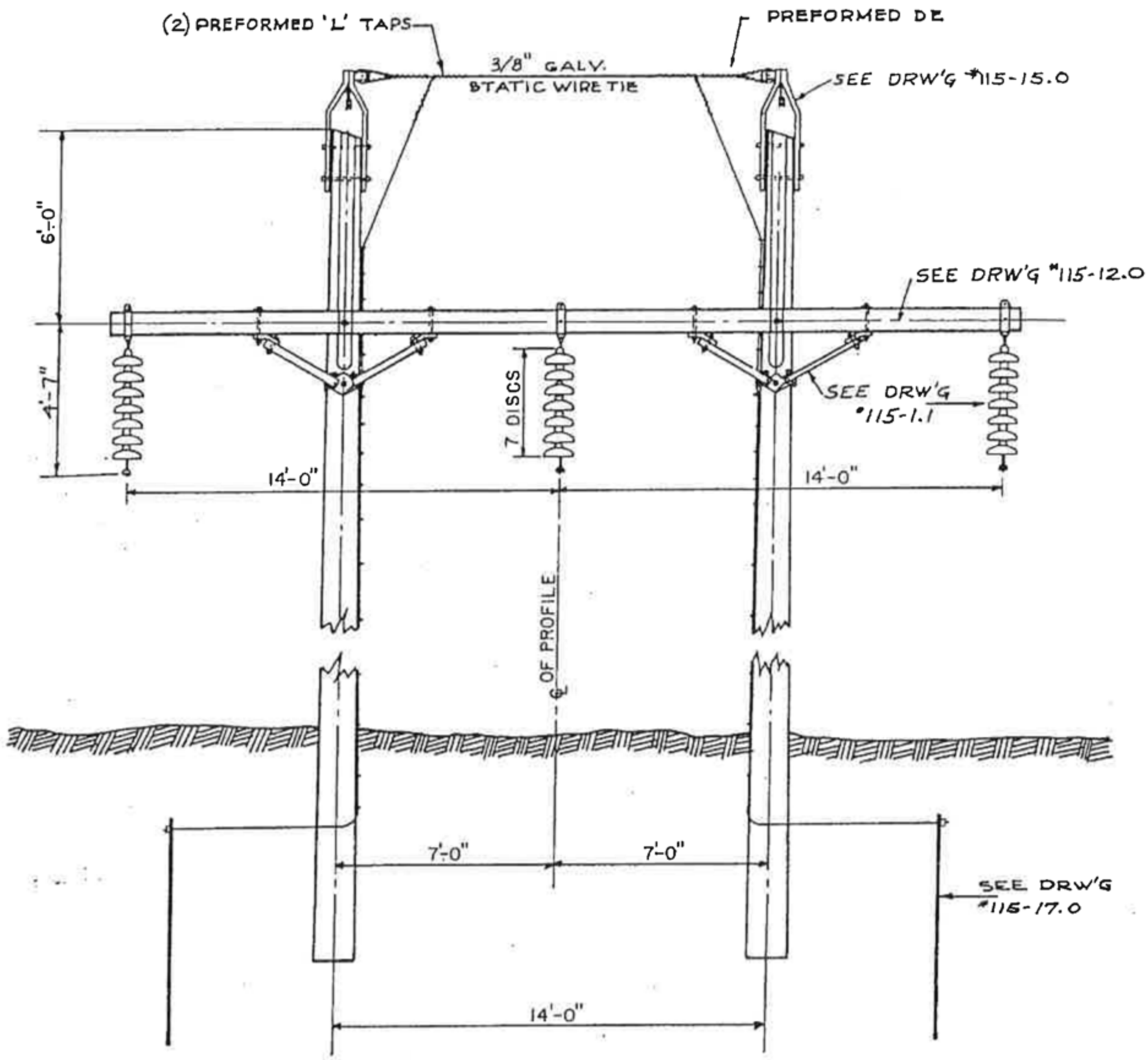
FORM CV 108



TYPE A-2 DOUBLE ARM STRUCTURE INSULATOR ASSEMBLY

POLE TOP DETAILS TYPES A-2 STRUCTURES	
115 KV. CONSTRUCTION	
VERMONT ELECTRIC POWER COMPANY, INC.	
DRAWN BY PDA	CHECKED BY
DATE 4-11-72	
SCALE NONE	APPROVED BY
DWG #115-2.1	

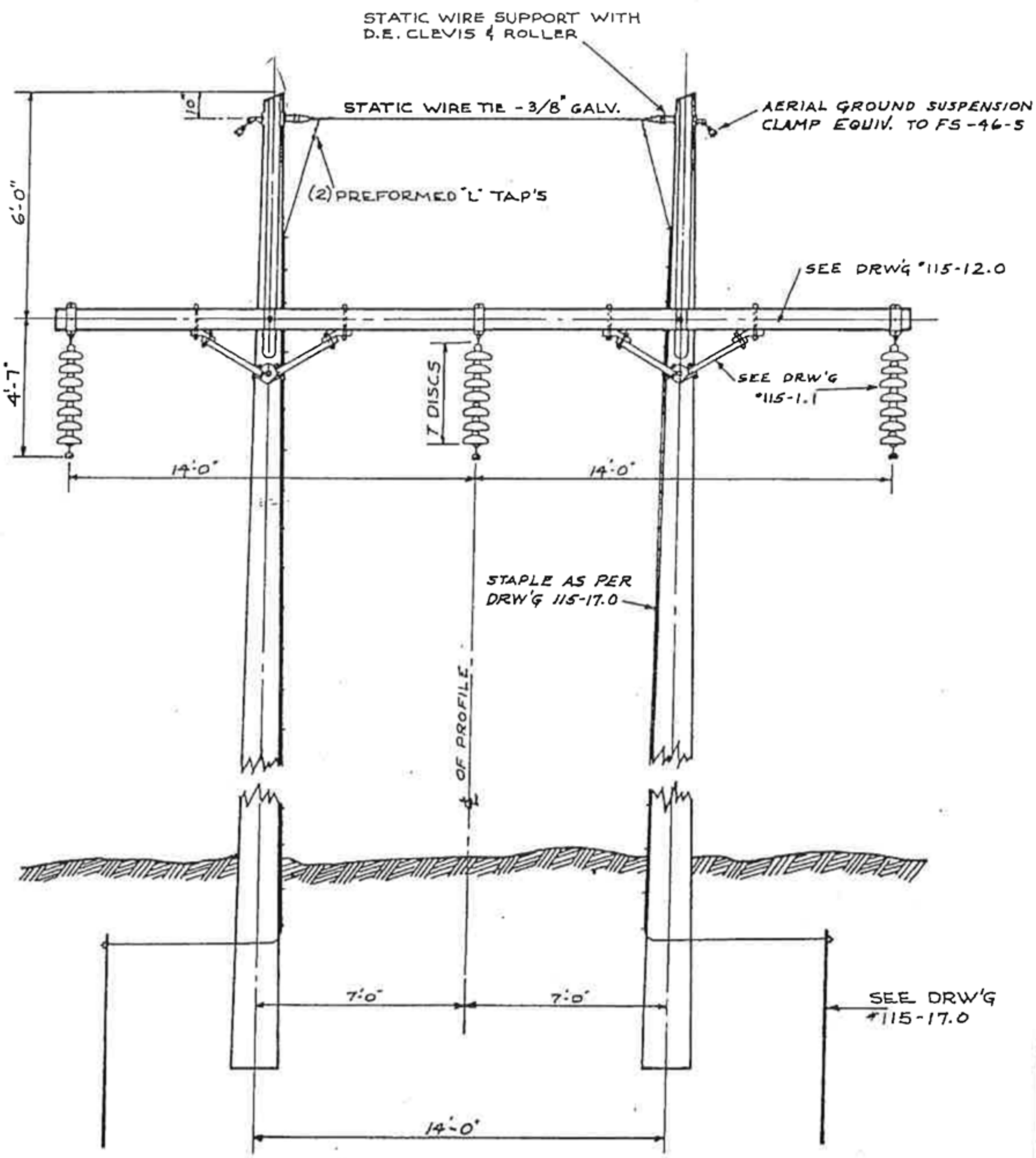
REVISIONS	
DATE	CH'K BY
3/1/77	[illegible]



NOTE: FOR DETAILS NOT INDICATED ON THIS DRW'G SEE TYPE A DRW'G 115-1.0 & 115-8.0 MATERIAL SAME AS TYPE A

		TYPE A-3 & D-3 SPECIAL FRAMING 115 KV CONSTRUCTION
		VERMONT ELECTRIC POWER COMPANY, INC.
3/1/77	[illegible]	DRAWN BY JM · CHECKED BY · DATE 4/17/72
DATE	CH'K BY	SCALE NONE · APPROVED BY · DWG #115-3.0
REVISIONS		

FORM CV 198



NOTE: FOR DETAILS NOT INDICATED ON THIS DRW'G SEE TYPE A & TYPE D DRW'G 115-1.0 & 115-8.0 RESPECTIVELY.

TYPE A-4 & D-4 SPECIAL FRAMING 115 KV. CONSTRUCTION	
VERMONT ELECTRIC POWER COMPANY, INC.	
DRAWN BY JM	CHECKED BY	DATE 4/17/72
SCALE NONE	APPROVED BY	DWG #115-4.0

DATE	CH'K BY
3/1/77	JP
2/13/74	

REVISIONS

00618

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE B STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
4	5	Bolts, brace 1/2" x 10"	Joslyn	J 8710
5	3	Bolts, machine 5/8" x 12" for crossarm brace	Joslyn	J 8812
6	6	Bolts, cone head	Joslyn	J 6277
7	3	Bolts, xarm clamps 3/4" x 8"	Joslyn	J 8908
9	1	Bolt, machine 3/4" x 10" pole top	Joslyn	J 8910
10	1	Bolt, machine 3/4" x 12"	Joslyn	J 8912
12	3	Bolts, machine 3/4" x 18" crossarm	Joslyn	J 8918
16	3	Bands, pole - small	Joslyn	J 6280
19	2½Pr	Brace, wood xarm 60"	Hughes	2000CC
22	8	Preformed DE guy grips	Preformed	GDE 1107
23	6	Preformed "L" taps top guy to static	Preformed	LC MS 5963
26	4	Clevis - deadend	Joslyn	J 456
27	1	Clevis - clevis	Lapp Chance	91597 904-0154
32	1	Anchor log 8'	Koppers	
34	1	Crossarm Type B		
40	3	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A		Rock Anchors	Chance	R 360 R384 R 372 R 396
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
42	8	Lags, screw 1/2" x 4"	Joslyn	8754P
44	2	Clamps, ground rod	L M	DN 14G1
45	1	Clamp, guy ground	Joslyn	1050
47	2	Clamps, suspension for static wire w/ socket fittings	Lapp Bethea	N95750-S FS 46 S
49	3	Clamps, suspension for conductor w/socket fittings	Bethea	ACFS 114-19 25 S
51	3	Clamps, crossarm	Joslyn	J 1820
53	8	Washers, coil spring 3/4"		

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VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE B STRUCTURE
115 Kv

Mark	Quant	Description	Manuf.	Cat. No.
54	3	Washers, coil spring 5/8"		
55	13	Washers, coil spring 1/2"		
56	5	Washers, square 2" x 2" x 1/8" 9/16" hole	Joslyn	J 1073
57	4	Washers, curved 4" x 4" x 1/4" 13/16" hole	LAPP MIF	304082 P144
58	3	Washers, square 4" x 4" x 1/4" 7/8 " hole	Joslyn	J 1082
59	8	Washers, round 9/16"		
60	3	Washers, curved 3" x 3" x 3/16" 11/16" hole	Lapp MIF	304078 P143
61	3	Guy Guards - metal	Oliver	808
62	2	Strandvise for span guys	Reliable	5152
63	3	Reinforcement plates for xarms	Joslyn	J 4047
66	20'	Cable, buried grd, 3/8" galv. 3-strd	(common grade)	
68	230'	Cable, guying 3/8" E HS galv. steel		
69	35'	Cable, cross tie 3/8" EHS		
72	2	Ball eye, long	Lapp BTC	6422 3014
70	3	Oval eye ball extension link	Lapp BTC	300024 3004 HT
76	5	Sheave wheel	Joslyn	J 6288
77	1	Pole eye plate	MIF	PX88
78	1	Guy attachment double sheave	Joslyn	J6274
82	24	Insulators, susp, 9" disc (8 per string)	Lapp GE	9000-70 155-409- ASA-70
		When Required		
20	2	X-brace w/mounting hardware	Hughes	1042X
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3 sets	Rods, armor		
79		Pole roof, non metalic (used if pole cut in field)	Joslyn	J 2108

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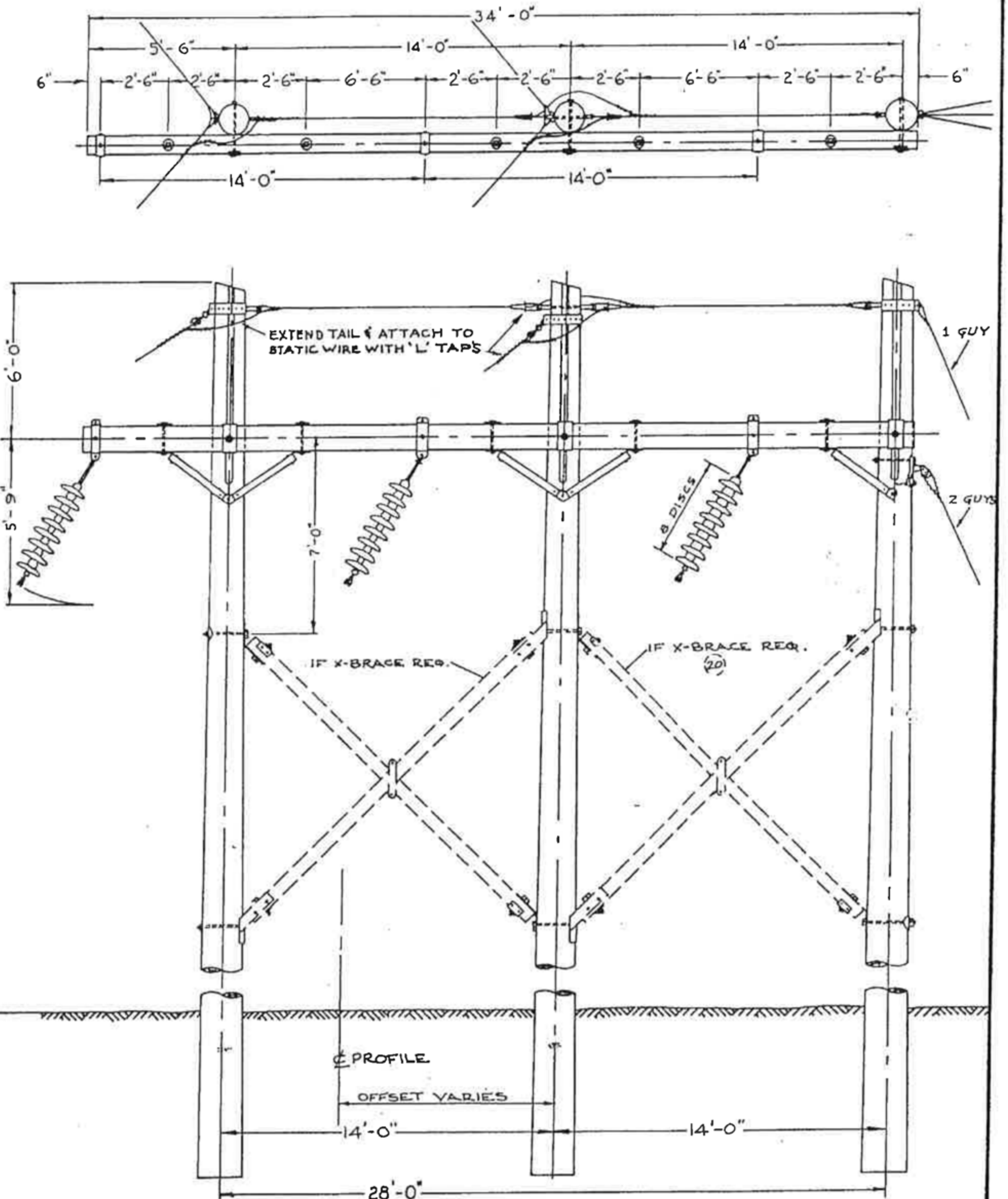
Rev 2/77
Rev. 2/74



-NOTES-

1. FOR ∠'s 0°-3° CONSIDER TYPE "A". (SEE DESIGN LIMITATIONS). GUYING DRW'G #115-18.0.

2. POLE BANDS TO BE TIGHT & LAGGED WITH 2 LAGS, ROUND WASHER & SPRING WASHERS.

3. CONE HEAD BOLTS NOT UNDER TENSION TO BE SECURED WITH LOCKNUT.

TYPE "B" STRUCTURE FOR ANGLES TO 10°

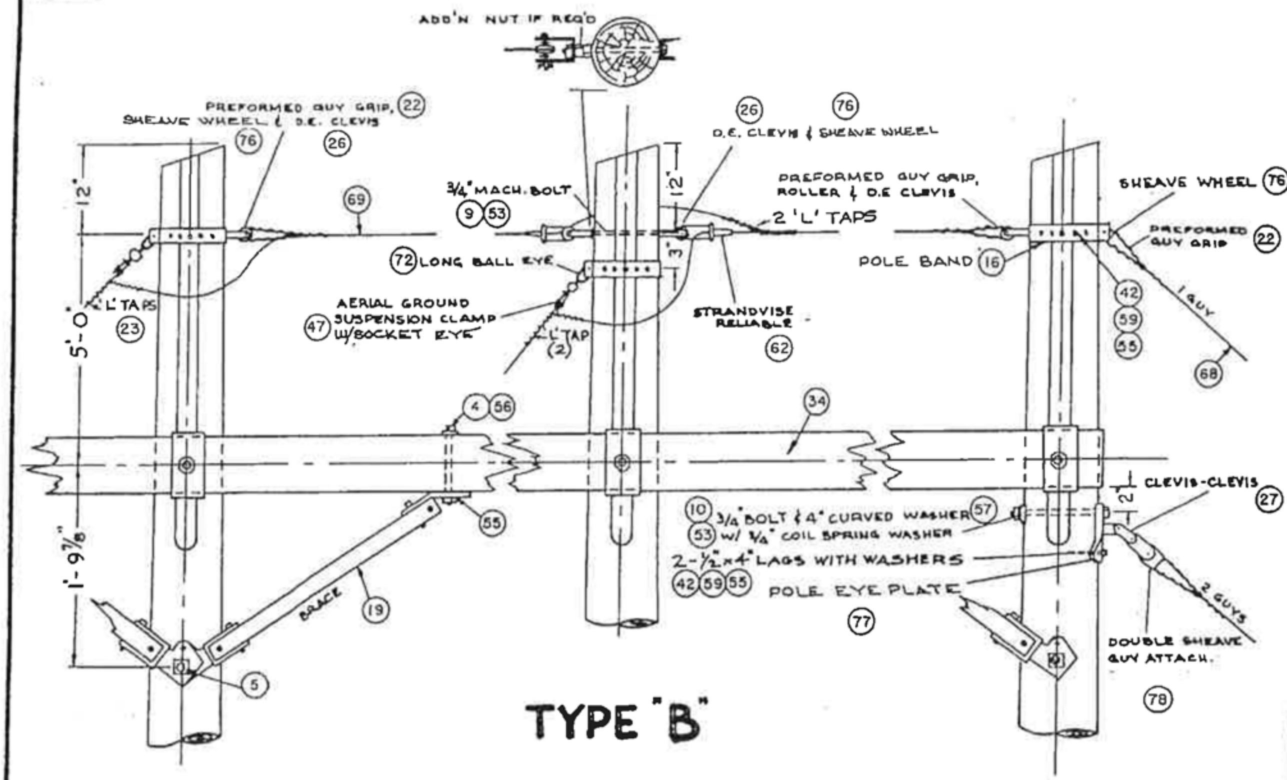
115 KV. CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

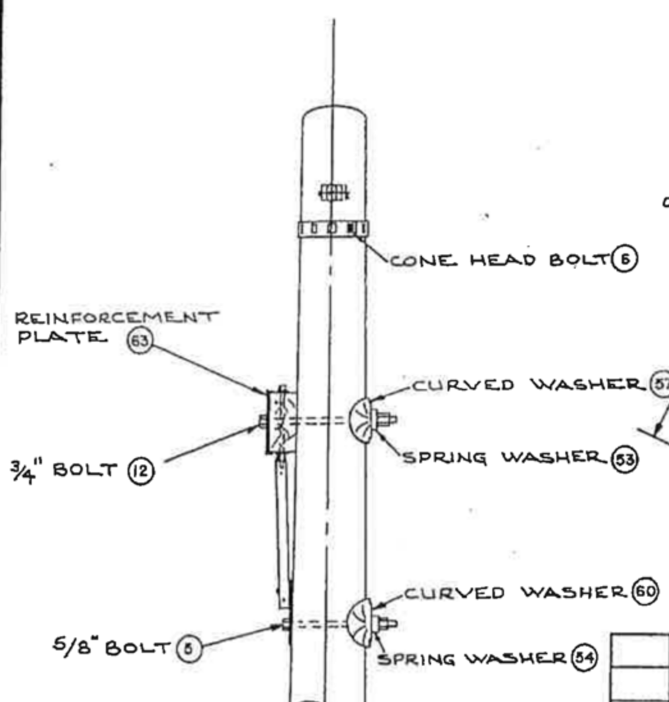
DATE	C'H'K BY
6/1/77	PR
3/1/77	
REVISIONS	

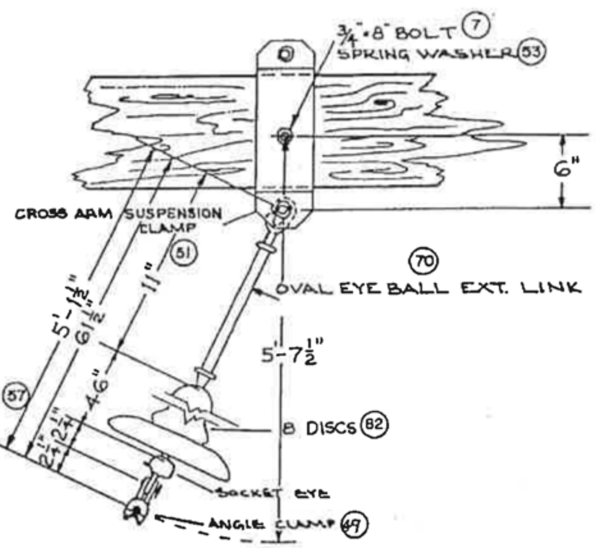
DRAWN BY P.D.A. | CHECKED BY | DATE 4-14-72

SCALE NONE | APPROVED BY | DWG #115-5.0



TYPE "B"





		POLE TOP DETAILS TYPE "B" STRUCTURES 115 KV CONSTRUCTION		
6/1/77	CROSSTIE PR	VERMONT ELECTRIC POWER COMPANY, INC.		
3/1/77	[illegible]	DRAWN BY JM	CHECKED BY	DATE 3/9/72
DATE	CH'K BY	SCALE NONE	APPROVED BY	DWG #115-5.1
REVISIONS				

Boston Blue Print Co.-100-8-57-8½ x 11

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE B-2 STRUCTURE
115 Kv

Mark	Quant	Description	Manuf.	Cat. No.
2	3	Swinging angle bracket, w/washer bolt, and locknut, washer nut	Hughes	2821.1A
4	10	Bolts, 1/2" x 10" - brace	Joslyn	J 8710
5	3	Bolts, 5/8" x 12" for crossarm brace	Joslyn	J 8812
6	6	Bolts, cone head	Joslyn	J 6277
9	1	Bolt, thru 3/4" x 10"	Joslyn	J 8910
10	1	Bolt, thru 3/4" x 12"	Joslyn	J 8912
13	3	Bolts, thru 3/4" x (24") (26") (28")	Joslyn	J 8924,8926 J 8928
14	6	Bolts, eye - forged shoulder w/washer nut MF locknut and cotter pin	Joslyn	J 2180
15	12	Bolts, 5/8" x 10" for plate and channel	L M	DF 3B10
16	3	Pole bands, small	Joslyn	J6280
19	5 prs	Xarm brace wood 60"	Hughes	2000CC
21-1	6 sets	Plate and channel 21" long		
22	8	Preformed guy grips deadend	Preformed	GDE 1107
23	6	Preformed "L" taps	Preformed	LC MS 5963
25	3	Clevis - ball extension link	Lapp BTC	90258A 3094-2
26	4	Clevis - deadend	Joslyn	456
27	1	Clevis - clevis	Lapp Chance	91597 904-0154
32	1	Anchor log 8'	Koppers	
34	2	Crossarm Type B	Haley	
40	3	Anchor rod 3/4" x 18'	Joslyn	J 7328
40A		Rock anchors	Chance	R 360 R 384 R 372 R 396
41	2	Ground rod 3/4" x 8'	Joslyn	J 5338
42	8	Lags, screw 1/2" x 4"	Joslyn	8754P
44	2	Clamps, ground rod	L M	DN14G1
45	1	Clamp, guy ground	Joslyn	J 1050

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Rev 6/7-
rev 2/77

Rev. 2/74

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE B-2 STRUCTURE
115 Kv

Mark	Quant	Description	Manuf.	Cat. No.
47	2	Clamps, suspension w/socket fittings (for S.W)	Lapp Bethea	N95750-S FS 46S
50	3	Clamps, suspension w/socket fittings (for cnnd)	Bethea	ACF 114-26-30-S
53	5	Washers, coil spring 3/4"		
54	15	Washers, coil spring 5/8"		
55	18	Washers, coil spring 1/2"		
56	10	Washers, square 2" x 2" x 1/8" 9/16" hole	Joslyn	J1073
57	1	Washer, curved 4" x 4" x 1/4" 13/16" hole	Lapp MIF	304082 P144
58	3	Washers, flat, 4" x 4" x 1/4" 7/8 " hole	Joslyn	J 1082
59	8	Washers, round 9/16" hole		
61	3	Guy Guards metal	Oliver	808
62	2	Strandvise	Reliable	5152
63	6	Reinforcement plate	Joslyn	J 4047
66	20'	Cable, 3/8" galv. 3-strd (common grade)		
68	230'	Cable, guying 3/8" EHS galv. steel		
69	35'	Cable, 3/8" galv 3-strd for cross tie EHS		
72	2	Ball eye, long	Lapp BTC	6422 3014
76	5	Sheave wheel (roller)	Joslyn	J6288
77	1	Pole eye plate	Lapp MIF	304021 PX 88
78	1	Guy attachment double sheave	Joslyn	J6274
82	24	Insulators susp. 9" disc (8 per string)	Lapp GE	9000-70 155-409-ASA-70
		<u>When Required</u>		
20	2	Xbraces - w/mounting hardware	Hughes	1042X
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3 sets	Rods, armor		
79		Pole roof, non metalic (used if pole cut in field)	Joslyn	J 2108

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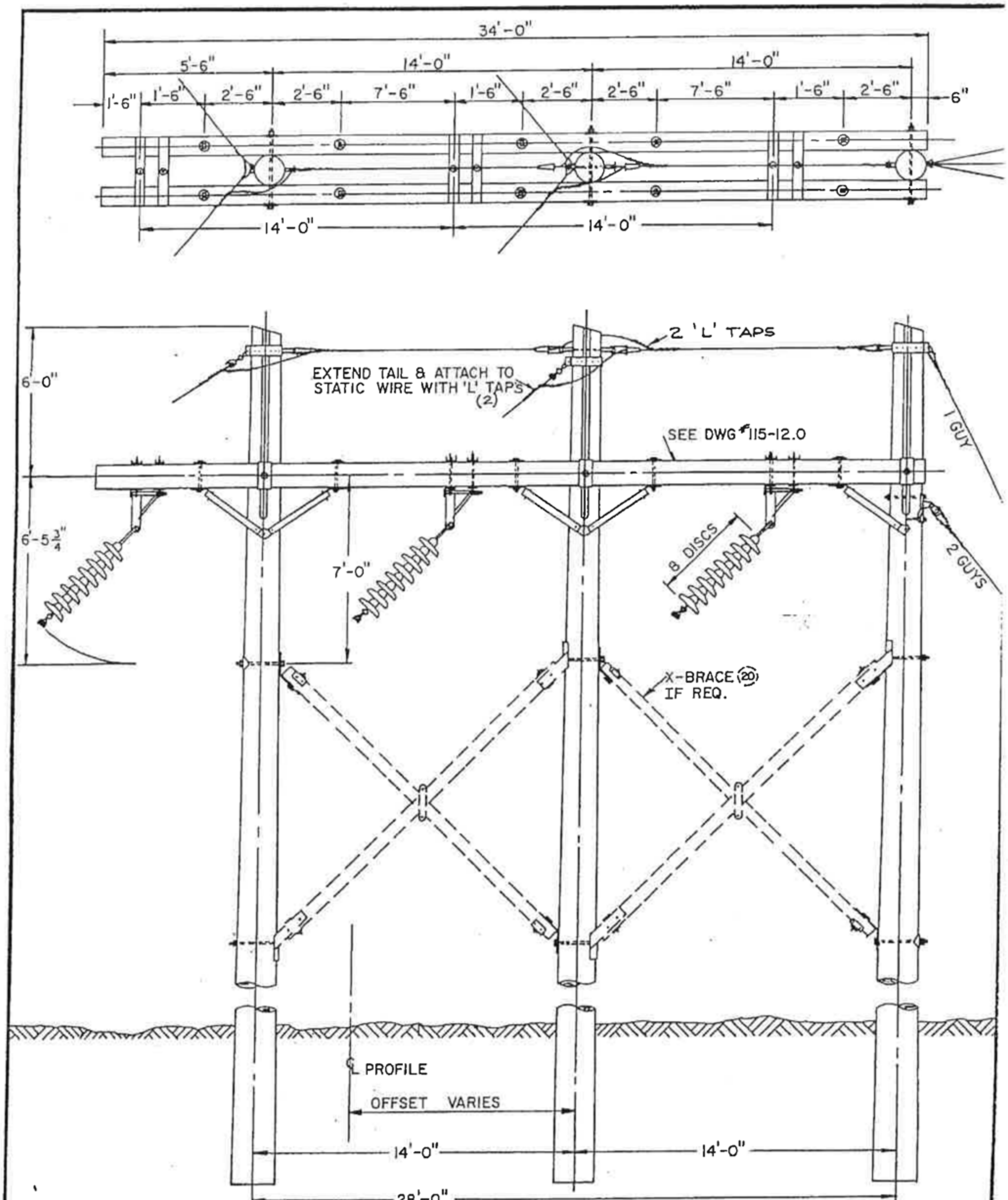
Rev 2/7

Rev. 2/74



NOTE:

1. POLE BANDS TO BE TIGHT & LAGGED WITH 2 LAGS, ROUND WASHERS & SPRING WASHERS.
2. CONE HEAD BOLTS NOT UNDER TENSION TO BE SECURED WITH LOCKNUTS.

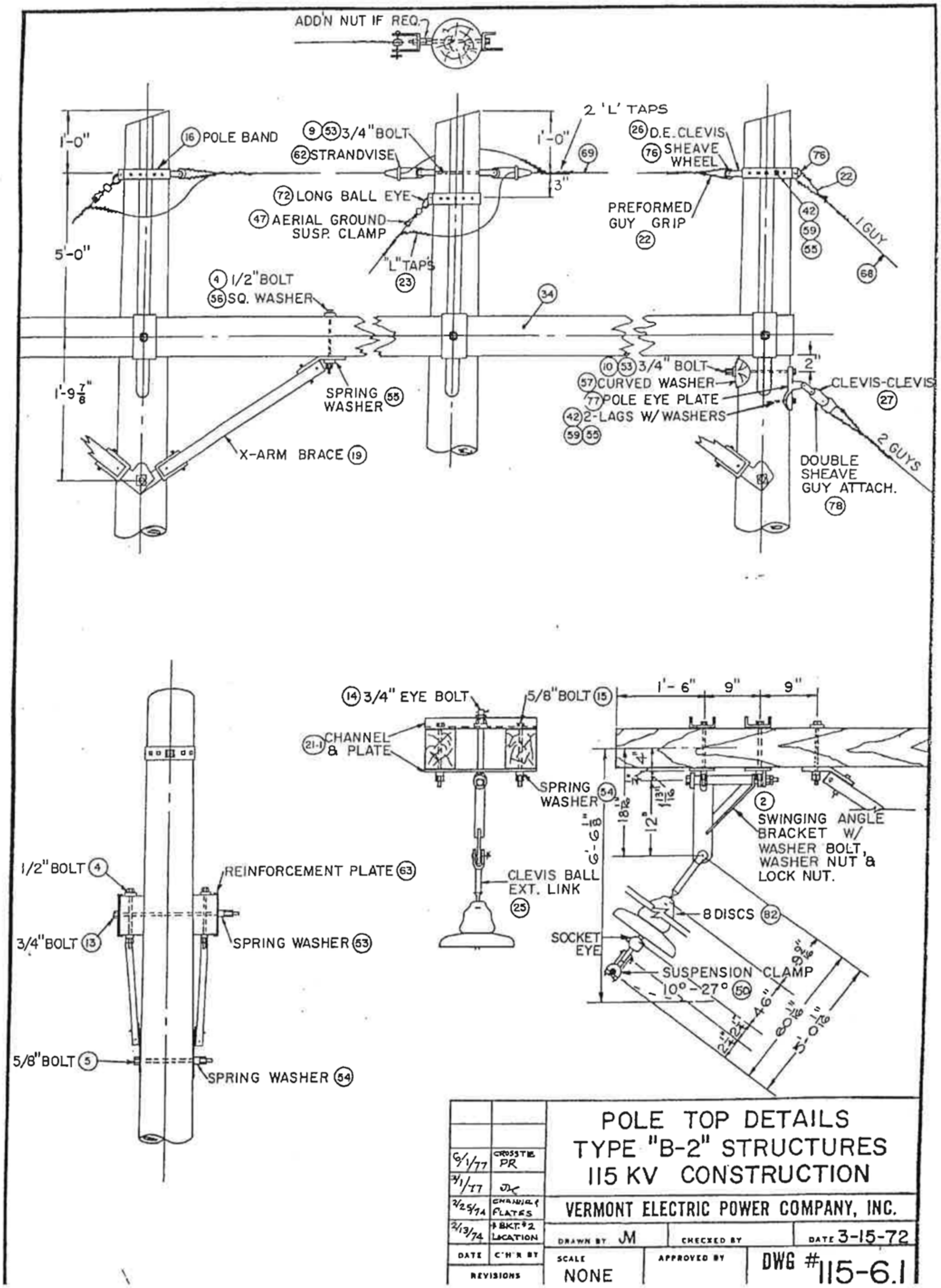
DATE	C'H'K BY
6/1/77	CROSSTIE PR
3/1/77	
2/13/74	# BKT. #2 LOCATION

REVISIONS

TYPE "B-2" STRUCTURE FOR ANGLES 10° – 27° 115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY JM	CHECKED BY	DATE 3/21/72
SCALE NONE	APPROVED BY	DWG # 115-6.0


ADD'N NUT IF REQ.
1'-0"
16 POLE BAND
9 53 3/4" BOLT
62 STRANDVISE
2 'L' TAPS
1'-0"
69
3"
26 D.E. CLEVIS
76 SHEAVE WHEEL
76
22
72 LONG BALL EYE
47 AERIAL GROUND SUSP. CLAMP
PREFORMED GUY GRIP
22
42
59
55
1 GUY
68
5'-0"
"L" TAPS
23
4 1/2" BOLT
56 SQ. WASHER
34
10 53 3/4" BOLT
57 CURVED WASHER
77 POLE EYE PLATE
42 2-LAGS W/ WASHERS
59 55
2"
CLEVIS-CLEVIS
27
1'-9 7/8"
SPRING WASHER 55
X-ARM BRACE 19
2 GUYS
DOUBLE SHEAVE GUY ATTACH.
78
14 3/4" EYE BOLT
5/8" BOLT 15
21-1 CHANNEL & PLATE
SPRING WASHER 54
CLEVIS BALL EXT. LINK
25
1'-6"
9"
9"
4"
1 13/16"
18 1/2"
12"
6'-6 1/8"
2
SWINGING ANGLE BRACKET W/ WASHER BOLT, WASHER NUT & LOCK NUT.
8 DISCS 82
SOCKET EYE
SUSPENSION CLAMP 10°-27° 50
9 9/16"
46"
60 1/16"
5'-0 1/16"
2"
2 3/4"
1/2" BOLT 4
REINFORCEMENT PLATE 63
3/4" BOLT 13
SPRING WASHER 53
5/8" BOLT 5
SPRING WASHER 54
POLE TOP DETAILS
TYPE "B-2" STRUCTURES
115 KV CONSTRUCTION
VERMONT ELECTRIC POWER COMPANY, INC.
6/1/77 CROSSTIE PR
3/1/77 JK
2/25/74 CHANNEL & PLATES
2/13/74 & BKT. #2 LOCATION
DATE C'H'R BY
REVISIONS
DRAWN BY JM
CHECKED BY
DATE 3-15-72
SCALE NONE
APPROVED BY
DWG # 115-6.1

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE C STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
6	12	Bolts, Cone head	Joslyn	J 6277
9	1	Bolt, 3/4" x 10" pole top	Joslyn	J 8910
11	3	Bolts, 3/4" x 16" crossarm	Joslyn	J 8916
16	3	Bands, pole - small	Joslyn	J 6280
17	3	Bands, pole - large	Joslyn	J 6270
18	3	Bands, pole extension	Joslyn	J 6272
22	12	Preformed deadend guy grips	Preformed	GDE 1107
23	6	Preformed "L" taps (for top guy to static)	Preformed	LC-MS-5963
26	4	Clevis - deadend	Joslyn	J 456
29	3	Twist clips for down guys	Joslyn	J 6282A
31	2	Anchor logs 4'	Koppers	
32	1	Anchor log 8'	Koppers	
35	1	Crossarm Type C		
40	5	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A		Rock anchors	Chance	R 360 R 384 R 372 R 396
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
42	12	Lags, screw 1/2" x 4"	Joslyn	8754P
43	1	Insulators, fiberglass strain	Anderson	GSI 3-54-1P
43A	4	Insulators, fiberglass strain	Anderson	GSI 3-78-1P
44	2	Clamps, ground rod connector	L M	DN14G1
45	2	Clamp, guy ground	Joslyn	J 1050
47	2	Clamps, suspension-static wire w/socket ftg	Lapp Bethea	N95750 FS-46-S
50	3	Clamps, suspension conductor- w/socket eye	Bethea	ACFS 114-26-30S
52	2	Chain Links	BTC	3082
53	4	Washers, coil spring 3/4"		
55	12	Washers, coil spring 1/2"		

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Rev 2/77

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Type C Str.

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE C STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
57	3	Washers, curved 4" x 4" x 1/4" 13/16" hole	Lapp MIF	804082 P 144
58	5	Washers, square 4" x 4" x 1/4" 7 / 8 hole	Joslyn	J 1082
59	12	Washers, round 1/2"		
61	5	Guy guards - metal	Oliver	808
62	2	Strandvise for span guys	Reliable	5152
63	3	Reinforcement plates	Joslyn	4047
66	20'	Cable, buried grd. 3/8" Galv. 3-strd	(common grade)	
68	300'	Cable, guying 3/8" EHS galv. steel		
69	35'	Cable, cross tie 3/8" galv. 3-strd. EHS		
70	3	Oval eye ball extension links	Lapp BTC	300024 3004HT
72	2	Ball eye - long	Lapp BTC	6422 3014
76	7	Roller eye	Joslyn	J 6288
78	1	Guy attachment double sheave	Joslyn	J 6274
82	27	Insulators, suspension 9" disc (9 per string)	Lapp GE	9000-70 155-409-
		When Required		ASA-70
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3 sets	Armor rods		
79		Pole roof, non-metalic (used if pole cut off in field)	Joslyn	J 2108

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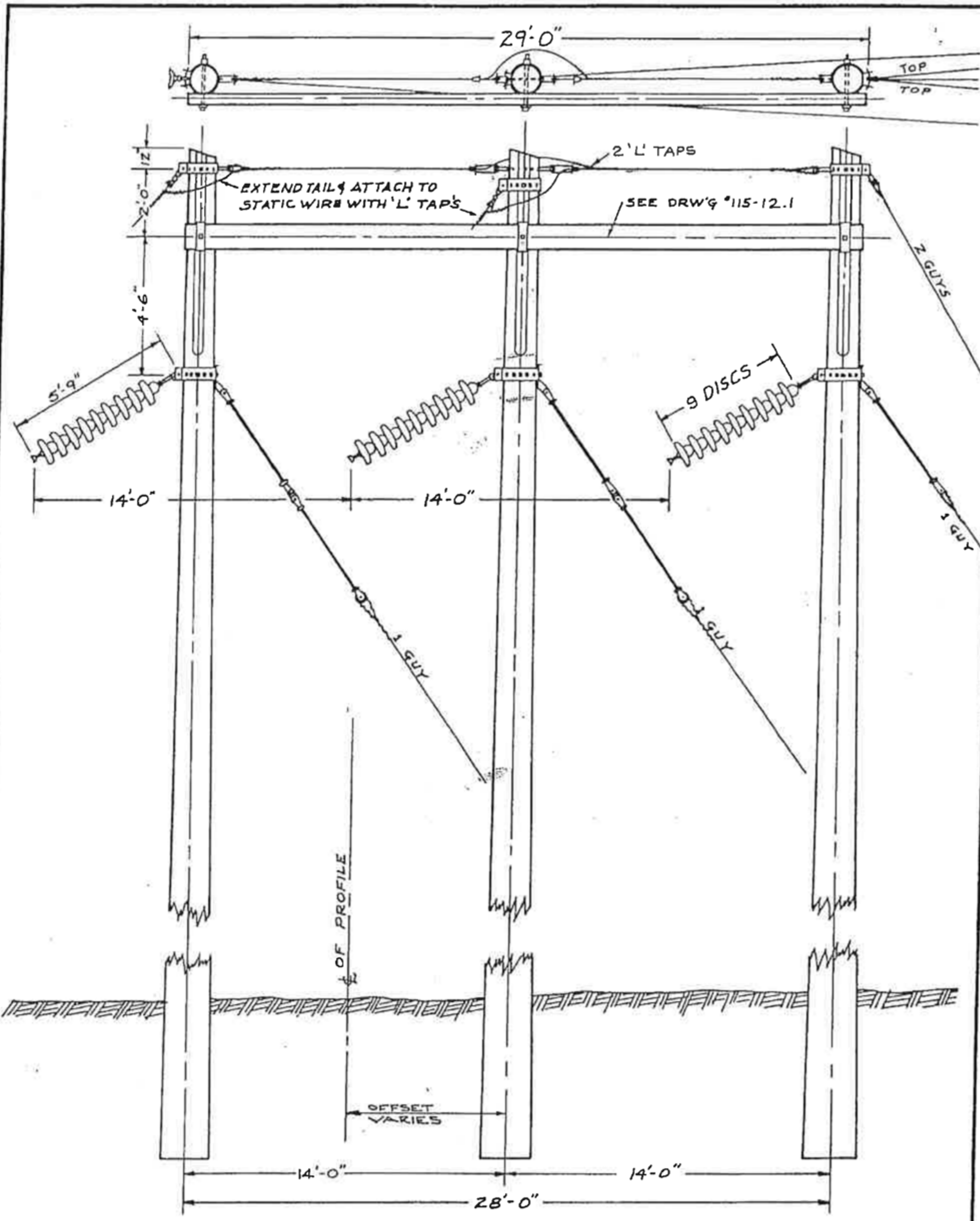
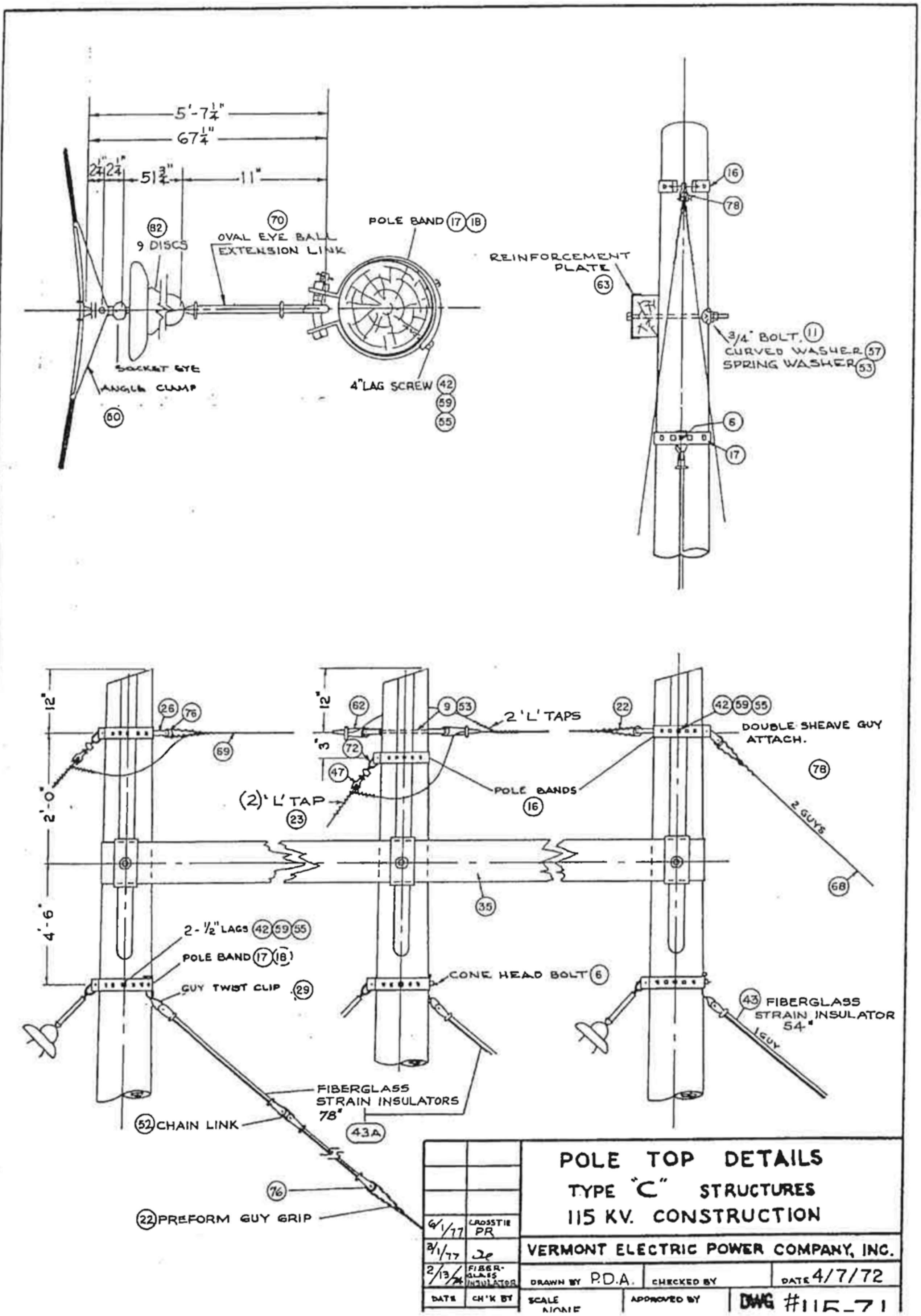
Rev 2/77
Rev. 2/74



NOTE:
1. POLE BANDS TO BE TIGHT AND LAGGED WITH 2 LAGS, ROUND WASHERS & SPRING WASHERS.
2. CONE HEAD BOLTS NOT UNDER TENSION TO BE SECURED WITH LOCKNUT.

8/1/77	CROSS TIE PR	**TYPE-C** STRUCTURE ANGLES 27° TO 50° 115 KV CONSTRUCTION
		VERMONT ELECTRIC POWER COMPANY, INC.
8/1/77	JLP	DRAWN BY JM — DATE 4/7/72
DATE	2/13/74	SCALE NONE — DWG # 115-7.0


5'-7 1/4"
67 1/4"
2 1/4" 2 1/4"
51 3/4"
11"
(82) 9 DISCS
(70) OVAL EYE BALL EXTENSION LINK
POLE BAND (17)(18)
SOCKET EYE
ANGLE CLAMP
(80)
4" LAG SCREW (42)(59)(55)
(16)
(78)
REINFORCEMENT PLATE (63)
3/4" BOLT (11)
CURVED WASHER (57)
SPRING WASHER (53)
(6)
(17)
12"
(26)(76)
(69)
2'-0"
(62)
(9)(53)
2 'L' TAPS
3"
(72)
(47)
(2)'L' TAP (23)
POLE BANDS (16)
(22)
(42)(59)(55)
DOUBLE SHEAVE GUY ATTACH.
(78)
2 GUYS
(68)
(35)
4'-6"
2 - 1/2" LAGS (42)(59)(55)
POLE BAND (17)(18)
GUY TWIST CLIP (29)
CONE HEAD BOLT (6)
(43) FIBERGLASS STRAIN INSULATOR 54"
1 GUY
FIBERGLASS STRAIN INSULATORS 78"
(43A)
(52) CHAIN LINK
(76)
(22) PREFORM GUY GRIP
POLE TOP DETAILS
TYPE "C" STRUCTURES
115 KV. CONSTRUCTION
VERMONT ELECTRIC POWER COMPANY, INC.
6/1/77 CROSSTIE PR
3/1/77
2/13/74 FIBER-GLASS INSULATOR
DATE
CH'K BY
DRAWN BY P.D.A.
CHECKED BY
DATE 4/7/72
SCALE NONE
APPROVED BY
DWG #115-71

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE D STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
1	2	Bayonets, complete w/plate, filler washer, w/bolts, nuts, washers (2" x 5/8" and 2½" x 5/8")	L M	DN 3B2
3	4	Bolts, machine 5/8" x 10" (12") for bayonet	Joslyn	J8810,8812
4	8	Bolts, brace 1/2" x 10"	Joslyn	J 8710
5	2	Bolts, machine 5/8" x 12" for cross brace	Joslyn	J 8812
13	2	Bolts, machine 3/4" x 24" (26") (28")	Joslyn	J8924,8926 J8928
14	3	Bolts, eye 3/4" x 10" -forged shoulder w/ cotter pin or dbl. nut and lock washer	Joslyn	J 2180
15	6	Bolts, 5/8" x 10" for plate & channel	L M	DF 3B10
19	4 pr	Brace wood xarms	Hughes	2000CC
20	1	Xbrace w/mounting hardware	Hughes	1042X
21	3	Channel & Plate	L M	66D901M1 DP23A3
22	2	Preformed guy grips - deadend	Preformed	GDE 1107
23	4	Preformed "L" taps	Preformed	LC-MS-5963
26	2	Clevis - deadend	Joslyn	J 456
28	6	Clevis - ball	~~Lapp~~ OB	~~6227~~ 70689
30	6	Plates - yoke 18"	Chance	C904-0329
36	2	Crossarms Type D		
39A	6	Socket clevis	~~Lapp~~ BTC	~~6228~~ 3040
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
44	2	Clamps, ground rod 3/4"	L M	DN 14G1
46	2	Clamps, suspension for s/w	Lapp Bethea	N95750 FS-46
48	3	Clamps, suspension w/clevis for cond.	Bethea	ACFS 114-19 -25C
53	2	Washers, coil spring 3/4"		
54	12	Washers, coil spring 5/8"		
55	8	Washers, coil spring 1/2"		

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VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE D STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
56	8	Washers, 2" x 2" x 1/8" - 9/16" hole square	Joslyn	J 1073
63	4	Reinforcement plate for Xarms	Joslyn	J 4047
64	75	Staples 3/8" x 1-3/4"	Joslyn	J 173
67	120'	Down lead 3/8" galv. 3-strd - common grade		
69	14'	Static wire 3/8" galv. cross tie		Common Grade
75	3	Shackle - anchor	BTC	3023
76	2	Sheave wheel (roller eye)	Joslyn	J 6288
82	48	Insulators, Discs 9" (8 per string)	Lapp GE	9000-70 155-409- ASA-70
		When Required		
73	3	150# Weights	Bethea	ASM 389-150 M-H
74	3 sets	Armor rods		
79		Pole Roof, non-metalic(used if pole cut in field)	Joslyn	J 2108
		Line Guys - When Required		
10	2	Bolts, thru 3/4" x 12"	Joslyn	J 8912
10A	2	Bolts, thru 3/4" x 14"	Joslyn	J 8914
22	8	Preformed Guy grips - deadend	Preformed	GDE 1107
24	4	Thimble Clevis	Lapp MIF	304056 PA 271
31	4	Anchor logs 4 ft.	Koppers	
40A		Rock anchors	Chance	R360, 372 R384 396
45	4	Clamp, ground guy	Joslyn	J 1050
53	4	Washers, coil spring 3/4"		
58	4	Washers, 4" x 4" x 1/4" w/ 7/8 " hole Flat	Joslyn	J1082
40	4	Rods, anchor 3/4" x 8'	Joslyn	J 7328

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Rev. 2/74

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE D STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
61	4	Guy guards - metal	Oliver	808
66	230'	Cable, 3/8" galv. 3-strd.(common grade)		
68	275'	Cable, guying 3/8" EHS Galv. Steel		
77	4	Pole eye plate	Lapp MIF	304021 PX 88
		Side Guys - When Required Refer to Side Guy Materials for Type "A"		

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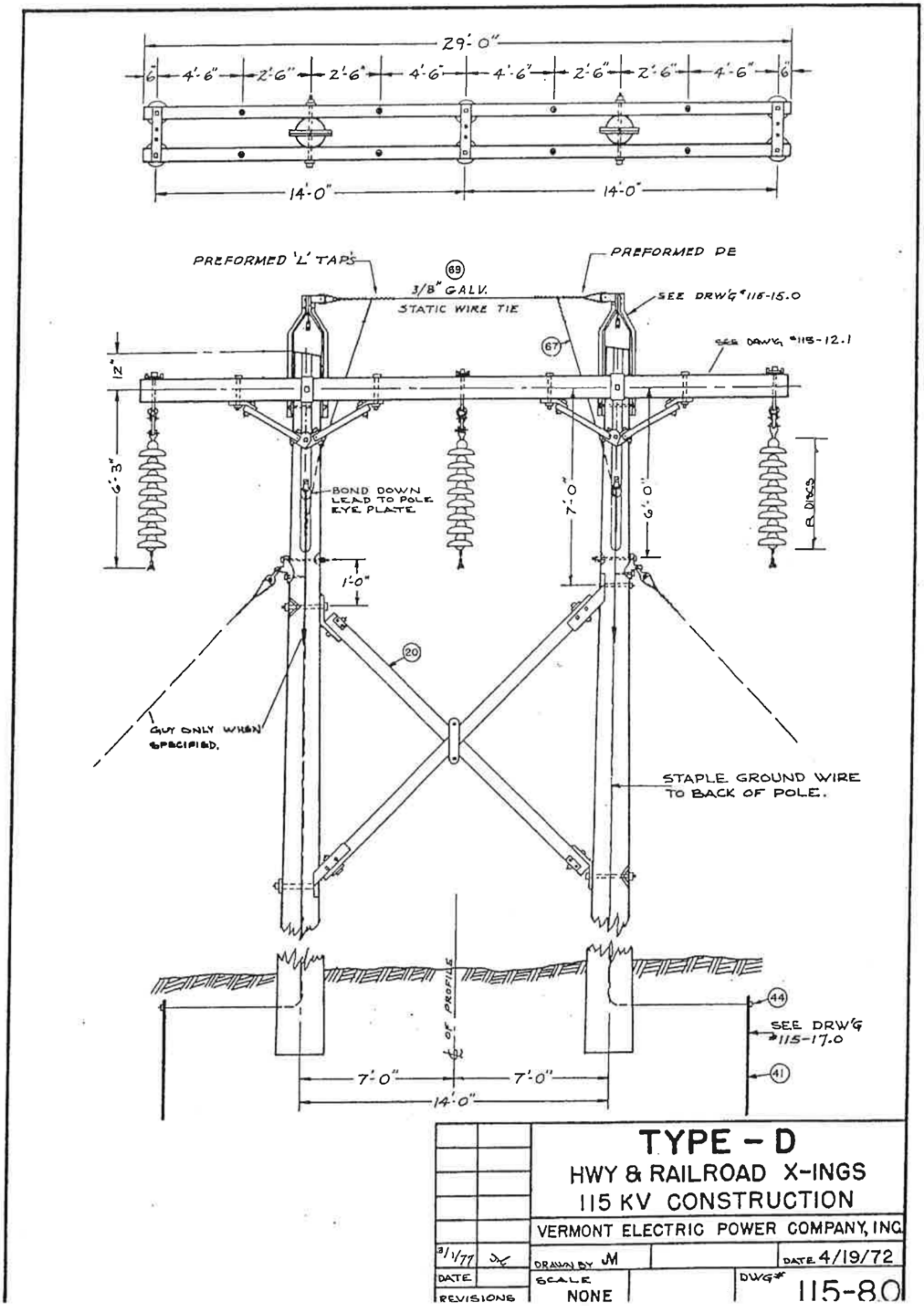
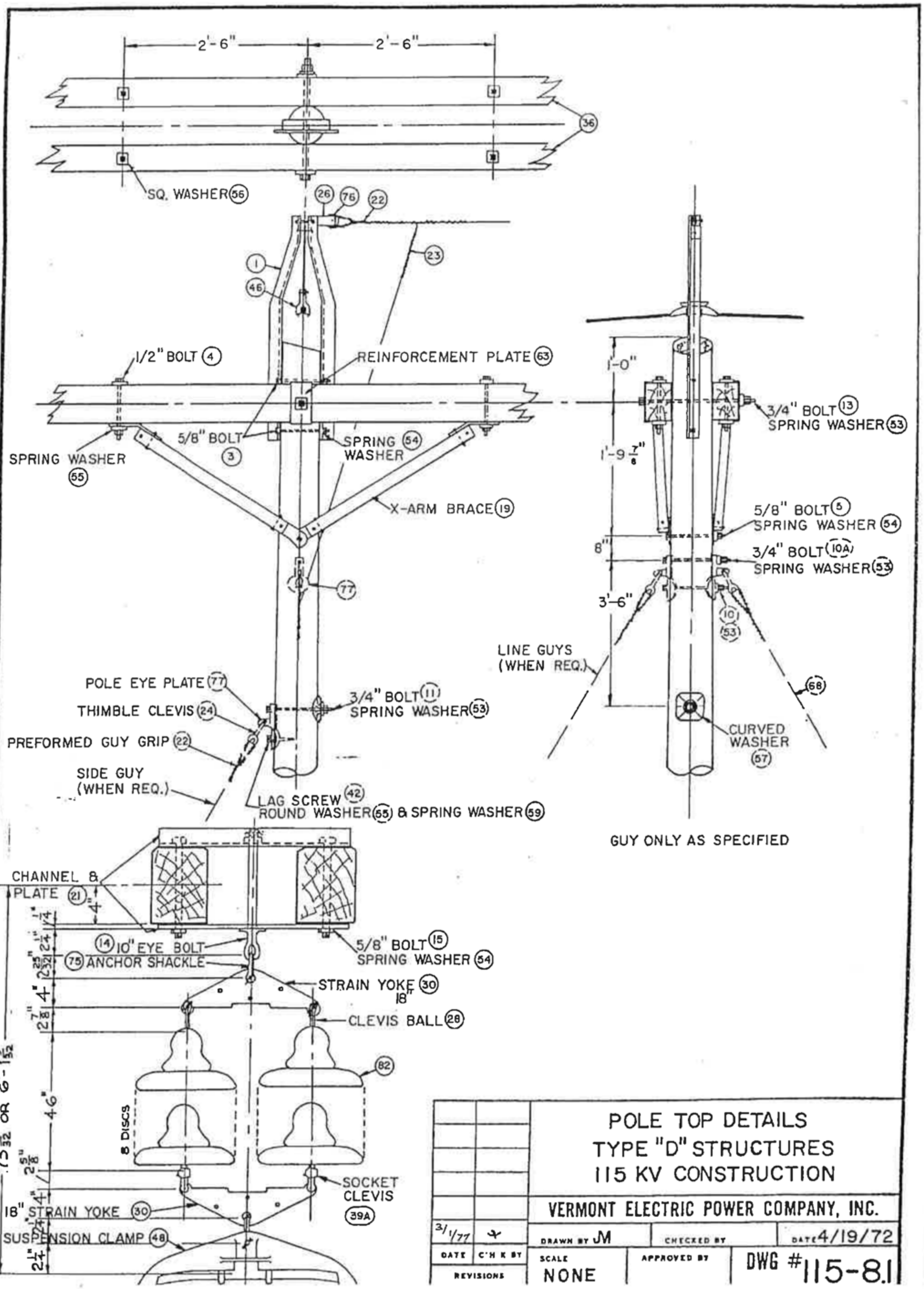
4/72


29'-0"
6" 4'-6" 2'-6" 2'-6" 4'-6" 4'-6" 2'-6" 2'-6" 4'-6" 6"
14'-0" 14'-0"
PREFORMED 'L' TAPS
PREFORMED DE
69
3/8" GALV.
STATIC WIRE TIE
SEE DRW'G #115-15.0
67
SEE DRW'G #115-12.1
12"
6'-3"
7'-0"
6'-0"
8 DISCS
BOND DOWN LEAD TO POLE EYE PLATE
1'-0"
20
GUY ONLY WHEN SPECIFIED.
STAPLE GROUND WIRE TO BACK OF POLE.
℄ OF PROFILE
44
SEE DRW'G 115-17.0
41
7'-0" 7'-0"
14'-0"
TYPE – D
HWY & RAILROAD X-INGS
115 KV CONSTRUCTION
VERMONT ELECTRIC POWER COMPANY, INC.
DRAWN BY JM
DATE 4/19/72
SCALE NONE
DWG # 115-80
DATE
REVISIONS


2'-6"
2'-6"
36
SQ. WASHER 56
26
76
22
23
1
46
1/2" BOLT 4
REINFORCEMENT PLATE 63
5/8" BOLT 3
SPRING WASHER 54
SPRING WASHER 55
X-ARM BRACE 19
77
POLE EYE PLATE 77
THIMBLE CLEVIS 24
PREFORMED GUY GRIP 22
SIDE GUY (WHEN REQ.)
3/4" BOLT 11
SPRING WASHER 53
LAG SCREW 42
ROUND WASHER 55 & SPRING WASHER 59
1'-0"
3/4" BOLT 13
SPRING WASHER 53
1'-9 7/8"
5/8" BOLT 5
SPRING WASHER 54
8"
3/4" BOLT 10A
SPRING WASHER 53
3'-6"
10
53
LINE GUYS (WHEN REQ.)
68
CURVED WASHER 57
GUY ONLY AS SPECIFIED
CHANNEL & PLATE 21
4"
1 1/4"
2 1/4"
2 25/32"
4"
2 7/8"
4'6"
2 5/8"
4"
2 1/4"
2 1/4"
73 9/32" OR 6'-1 9/32"
14 10" EYE BOLT
75 ANCHOR SHACKLE
5/8" BOLT 15
SPRING WASHER 54
STRAIN YOKE 30
18"
CLEVIS BALL 28
82
8 DISCS
SOCKET CLEVIS 39A
18" STRAIN YOKE 30
SUSPENSION CLAMP 48
POLE TOP DETAILS
TYPE "D" STRUCTURES
115 KV CONSTRUCTION
VERMONT ELECTRIC POWER COMPANY, INC.
3/1/77
DATE
C'H K BY
REVISIONS
DRAWN BY JM
CHECKED BY
DATE 4/19/72
SCALE
NONE
APPROVED BY
DWG # 115-8.1

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE DA STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
6	18	Bolts, cone head	Joslyn	J 6277
7	3	Bolts, Xarm clamp 3/4"	Joslyn	J 8908
9	1	Bolt, thru 3/4" x 10"	Joslyn	J 8910
11	3	Bolts, thru 3/4" x 16"	Joslyn	J 8916
16	3	Bands, pole - small	Joslyn	J 6280
17	6	Bands, pole - large	Joslyn	J 6270
18	6	Bands, extensions pole	Joslyn	J 6272
20	2	Xbrace w/mounting hardware	Hughes	1042X
22	22	Preformed Guy grips-deadend	Preformed	GDE 1107
23	8	Preformed "L" taps	Preformed	LC MS 5963
24	3	Thimble clevis	Lapp MIF	304056 PA 271
26	4	Clevis - deadend	Joslyn	J 456
29	10	Clips- twist type for guys	Joslyn	J6282A
31	6	Anchor logs -4 ft.	Koppers	
32	1	Anchor logs -8 ft.	Koppers	
37	1	Crossarm-Type DA		
38	2	Adjustable Compression DE-static wire	Alcoa	4620-12
39	6	Adjustable Compression DE- conductor	Alcoa	AC-9300 7534-122HV 5134-122HV
40	7	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A		Rock anchors	Chance	R360,372 R384,396
41	2	Rods, ground 3/4" x 8'	Joslyn	J5338
42	18	Lags, screw 1/2" x 4"		8754-P
43	7	Fiberglass strain insulators	Anderson	GSI-3-54-1P
44	2	Clamp, ground rod 3/4"	L M	DN 14G1
45	3	Clamp, guy ground	Joslyn	J 1050
47	1	Clamp, suspension w/socket for S.W.	Bethea	FS 46-S

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VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE DA STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
49	3	Clamp, suspension w/socket for conductor	Bethea	ACFS-114-19-25S
51	3	Clamp, crossarm	Joslyn	J 1820
52	2	Chain Link	BTC	3082
53	7	Washers, coil spring 3/4"		
55	18	Washers, coil spring 1/2"		
57	3	Washers, 4" x 4" x 1/4" 13/16" curved	Lapp MIF	304082 P 144
58	7	Washers, 4" x 4" x 1/4" 7/8 " flat	Joslyn	J 1082
59	18	Washers, round 9/16"		
61	7	Guards, guy- metal	Oliver	808
62	2	Strandvise for span guys	Reliable	5152
63	3	Reinforcement plate for xarms	Joslyn	4047
66	100'	Cable, 3/8" galv. 3-strd. (common grade)		
68	550'	Cable, guying 3/8" EHS galv. steel		
69	35'	Static wire - cross tie 3/8" galv. EHS		
70	6	Oval eye ball extension link	Lapp BTC	300024 3004-HT
71	6	Socket eye extension link	Lapp BTC	93161B 4314B
72	4	Ball eye - long	Lapp BTC	6422 3014
73	3	150# Weights	Bethea	ASM 389-150-M-H
76	11	Sheave wheel	Joslyn	J 6288
82	78	Insulators Discs 9" 3 strings of 8 (Idler) 6 strings of 9	GE Lapp	155-409-ASA-70 9000-70
		When Required		
79		Pole roof, non-metalic (used if pole cut in field)	Joslyn	J 2108
		S.W. DE guys under 50°		
40	2	Rods, anchor 3/4" x 8'	Joslyn	J7328
31	2	Logs, anchor 4'	Koppers	
58	2	Washers 4" x 4" x 1/4" 13/16" flat	Hughes	SW-4-70

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Rev 2/77
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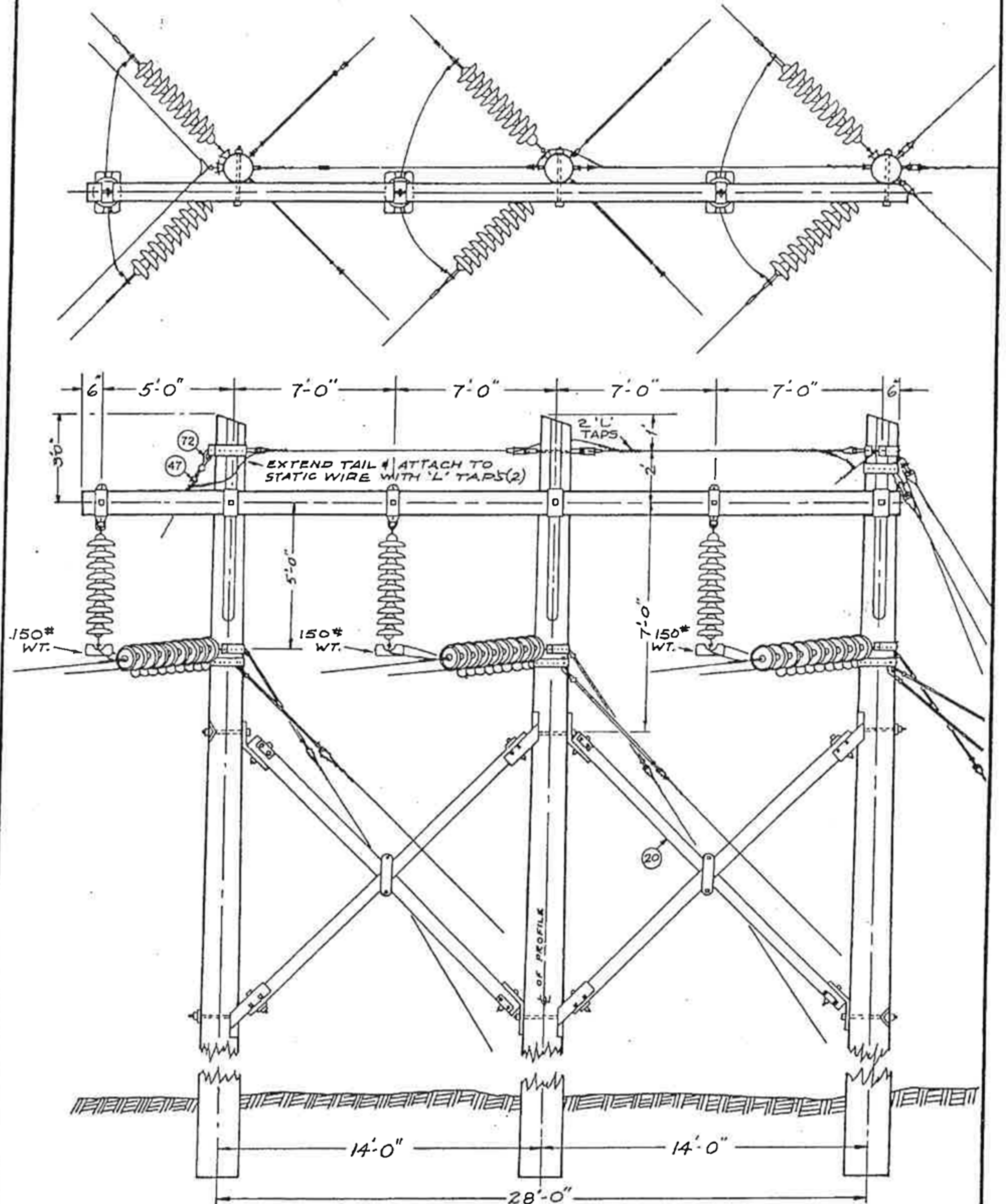


NOTE:

1. POLE BANDS TO BE TIGHT & LAGGED WITH 2 LAGS, ROUND WASHERS & SPRING WASHERS.
2. CONE HEAD BOLTS NOT UNDER TENSION TO BE SECURED WITH LOCKNUTS.
3. FOR ANGLES LESS THAN 50° SEE DRAWING #115-18.2

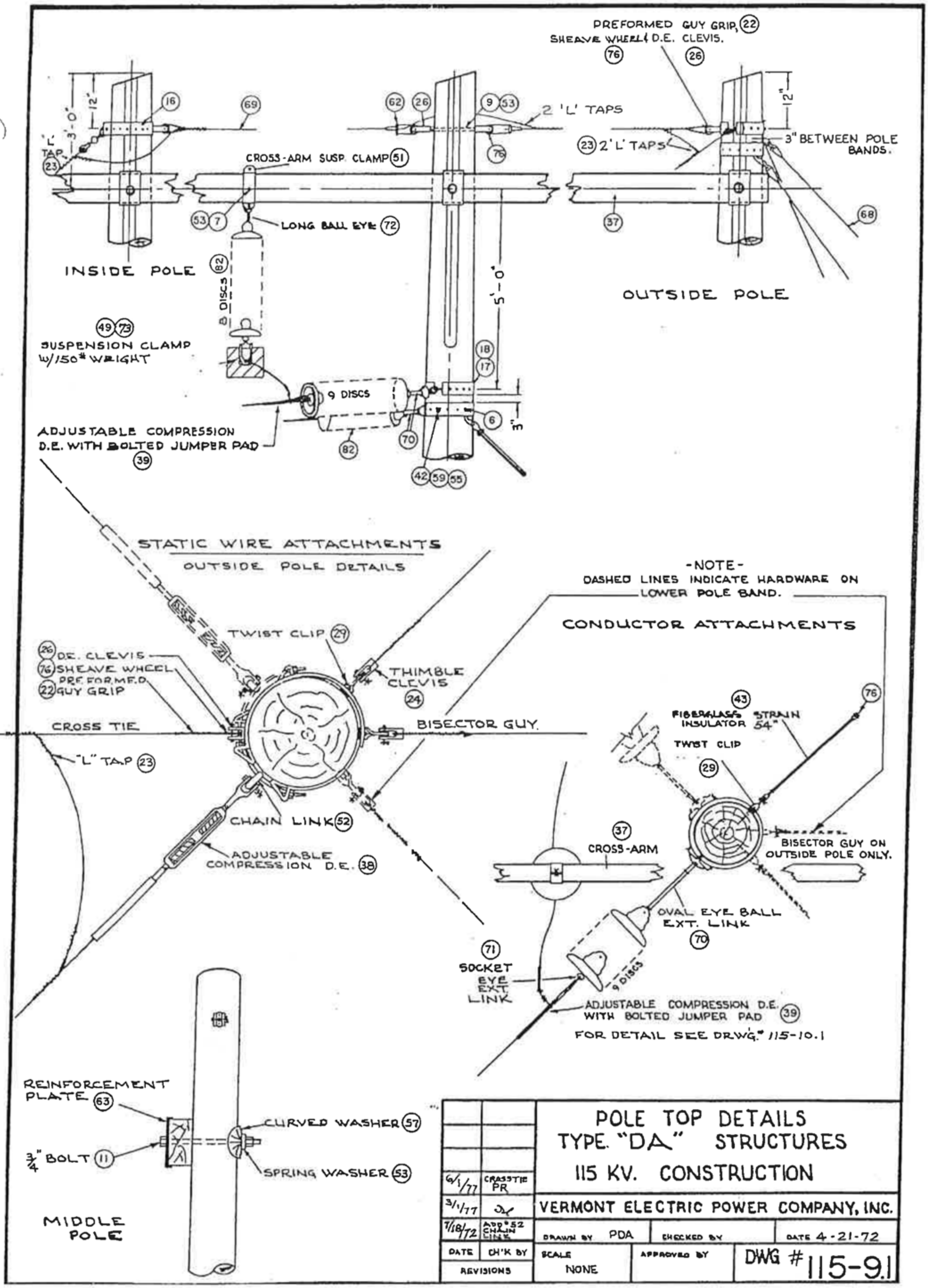
9/1/77	CROSSTIE PR	
3/1/77		
DATE	CHK'D BY	
REVISIONS		

TYPE DA STRUCTURE FOR ANGLES OVER 50°
115 KV. CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY	CHECKED BY	DATE
JM		4/20/72

SCALE	APPROVED BY	DWG #
NONE		115-9.0


PREFORMED GUY GRIP (22)
SHEAVE WHEEL & D.E. CLEVIS.
(76) (26)
12"
3'-0"
(16) (69)
'L' TAP
(23)
(62) (26) (9) (53) 2 'L' TAPS
(76)
(23) 2 'L' TAPS
3" BETWEEN POLE BANDS.
CROSS-ARM SUSP. CLAMP (51)
(53) (7)
LONG BALL EYE (72)
(37)
(68)
INSIDE POLE
OUTSIDE POLE
(82)
8 DISCS
5'-0"
(49) (73)
SUSPENSION CLAMP W/150# WEIGHT
(18)
(17)
9 DISCS
(6)
3"
ADJUSTABLE COMPRESSION D.E. WITH BOLTED JUMPER PAD (39)
(70)
(82)
(42) (59) (55)
STATIC WIRE ATTACHMENTS
OUTSIDE POLE DETAILS
TWIST CLIP (29)
(26) DE. CLEVIS
(76) SHEAVE WHEEL
PREFORMED
(22) GUY GRIP
THIMBLE CLEVIS (24)
CROSS TIE
BISECTOR GUY
"L" TAP (23)
CHAIN LINK (52)
ADJUSTABLE COMPRESSION D.E. (38)
-NOTE-
DASHED LINES INDICATE HARDWARE ON LOWER POLE BAND.
CONDUCTOR ATTACHMENTS
(43)
FIBERGLASS STRAIN INSULATOR 54"
(76)
TWIST CLIP
(29)
(37)
CROSS-ARM
BISECTOR GUY ON OUTSIDE POLE ONLY.
OVAL EYE BALL EXT. LINK
(70)
(71)
SOCKET EYE EXT. LINK
9 DISCS
ADJUSTABLE COMPRESSION D.E. WITH BOLTED JUMPER PAD (39)
FOR DETAIL SEE DRWG.# 115-10.1
REINFORCEMENT PLATE (63)
CURVED WASHER (57)
3/4" BOLT (11)
SPRING WASHER (53)
MIDDLE POLE
POLE TOP DETAILS
TYPE "DA" STRUCTURES
115 KV. CONSTRUCTION
6/1/77 CROSSTIE PR
3/1/77
7/18/72 ADD #52 CHAIN LINK
DATE CH'K BY
REVISIONS
VERMONT ELECTRIC POWER COMPANY, INC.
DRAWN BY PDA
CHECKED BY
DATE 4-21-72
SCALE NONE
APPROVED BY
DWG # 115-9.1

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE E STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
4	8	Bolts, brace 1/2" x 10'	Joslyn	J 8710
5	2	Bolts, machine 5/8" x 12"	Joslyn	J 8812
8	3	Bolts, DA 3/4" x 24" (26") (28")	Joslyn	J 8894,8896 J 8897
9	2	Bolts, thru 3/4" x 10"	Joslyn	J 8910
10	4	Bolts, thru 3/4" x 12"	Joslyn	J 8912
10A	4	Bolts, thru 3/4" x 14"	Joslyn	J 8914
13	2	Bolts, thru 3/4" x 24" (26") (28")	Joslyn	J8924,8926 J8928
19	4pr	Brace wood xarm 60"	Hughes	2000CC
20	1	X-brace w/mounting hardware	Hughes	1042X
22	8	Preformed Guy grips - deadend	Preformed	GDE 1107
23	20	Preformed "L" taps	Preformed	LC MS-5963
24	4	Thimble clevis	Lapp MIF	304056 PA 271
26	6	Clevis - deadend	Joslyn	J 456
31	4	Anchor logs 4 ft.	Koppers	
33	2	Crossarms - Type A		
38	4	Adjustable Compression DE-static wire	Alcoa	4620-12
39	6	Adjustable Compression DE-conductor	Alcoa	AC 9300 7534-122HV 5134-122HV
40A		Rock anchors	Chance	R360,372 R384,396
40	4	Rods, anchor 3/4" x 8'	Joslyn	J 7328
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
44	4	Clamp, ground rod 3/4"	L M	DN 14G1
45	4	Clamp, guy ground	Joslyn	J 1050
51	6	Clamp, crossarm	Joslyn	J 1820
53	16	Washers, coil spring 3/4"		

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VERMONT ELECTRIC POWER COMPANY, INC.
MATERIAL FOR TYPE E STRUCTURE
115 KV

Mark	Quant	Description	Manuf.	Cat. No.
54	2	Washers, coil spring 5/8		
55	8	Washers, coil spring 1/2"		
56	8	Washers, 2" x 2" x 1/8" w/9/16" hole square	Joslyn	J 1073
58	4	Washers, 4" x 4" x 1/4" w/ 7/8 " hole flat	Joslyn	J 1082
61	4	Guards - guy metal	Oliver	808
63	4	Reinforcement plate for xarms	Joslyn	J 4047
64	75	Staples, 3/8" x 1-3/4"	Joslyn	J 173
66	230'	Cable, 3/8" galv. 3-strd (common grade)		
67	120'	Down lead 3/8" galv. 3 strd. (common grade)		
68	275'	Cable, guying 3/8" EHS. Galv. Steel		
69	14'	Static wire - cross tie 3/8" galv.		Common Grade
70	6	Oval eye ball extension link	Lapp BTC	300024 3004HT
71	6	Socket eye extension link	Lapp BTC	93161B 4314B
77	8	Pole eye plate	Lapp MIF	304021 PX 88
82	54	Insulators, discs 9" (9 per string)	Lapp GE	9000-70 155-409- ASA-70
		<u>When Required</u>		
79		Pole roof, non-metalic (used if pole cut in field)	Joslyn	J 2108
		<u>Side Guys - When Required</u> Refer to Side Guy Material for Type "A"		

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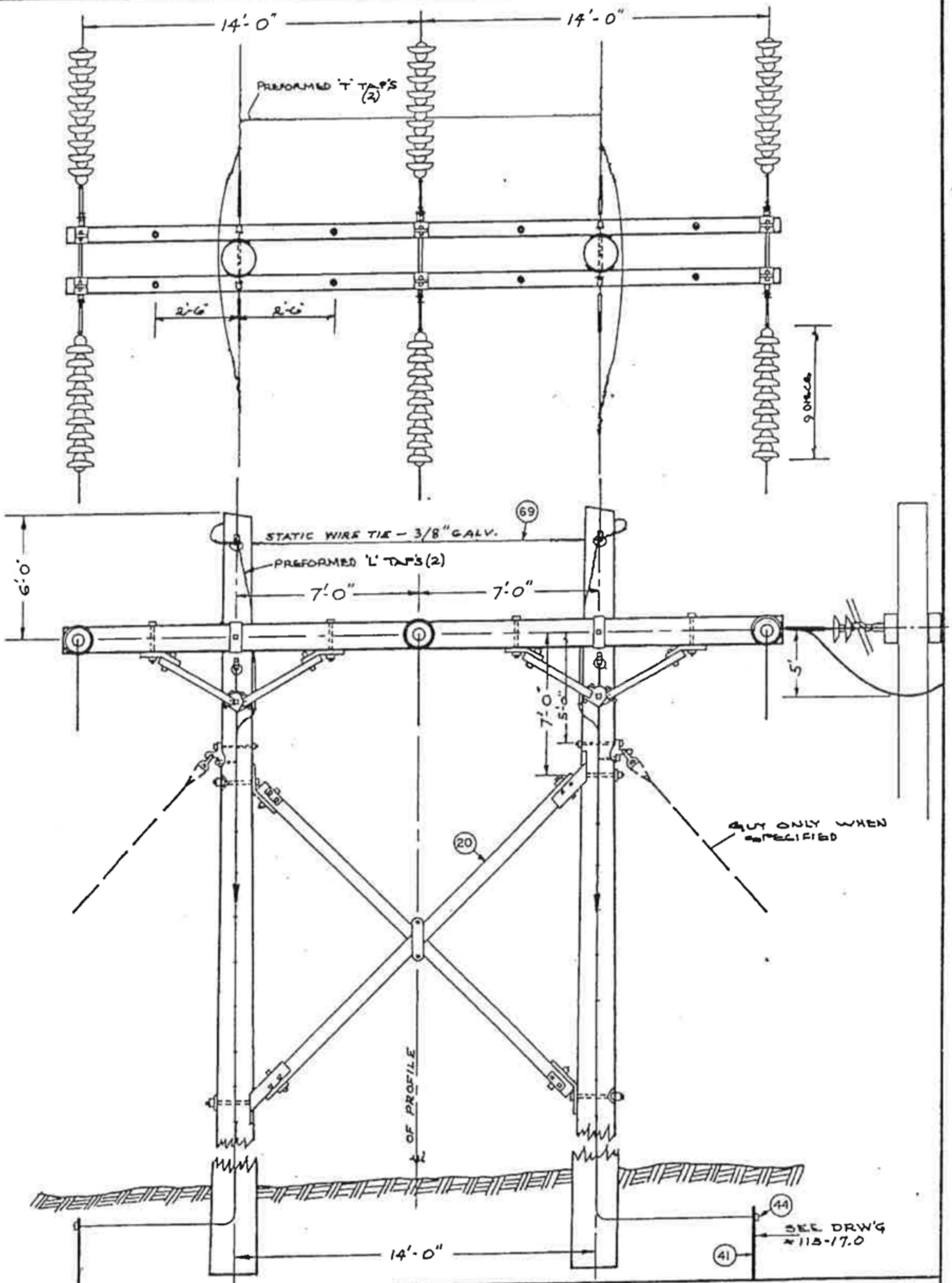
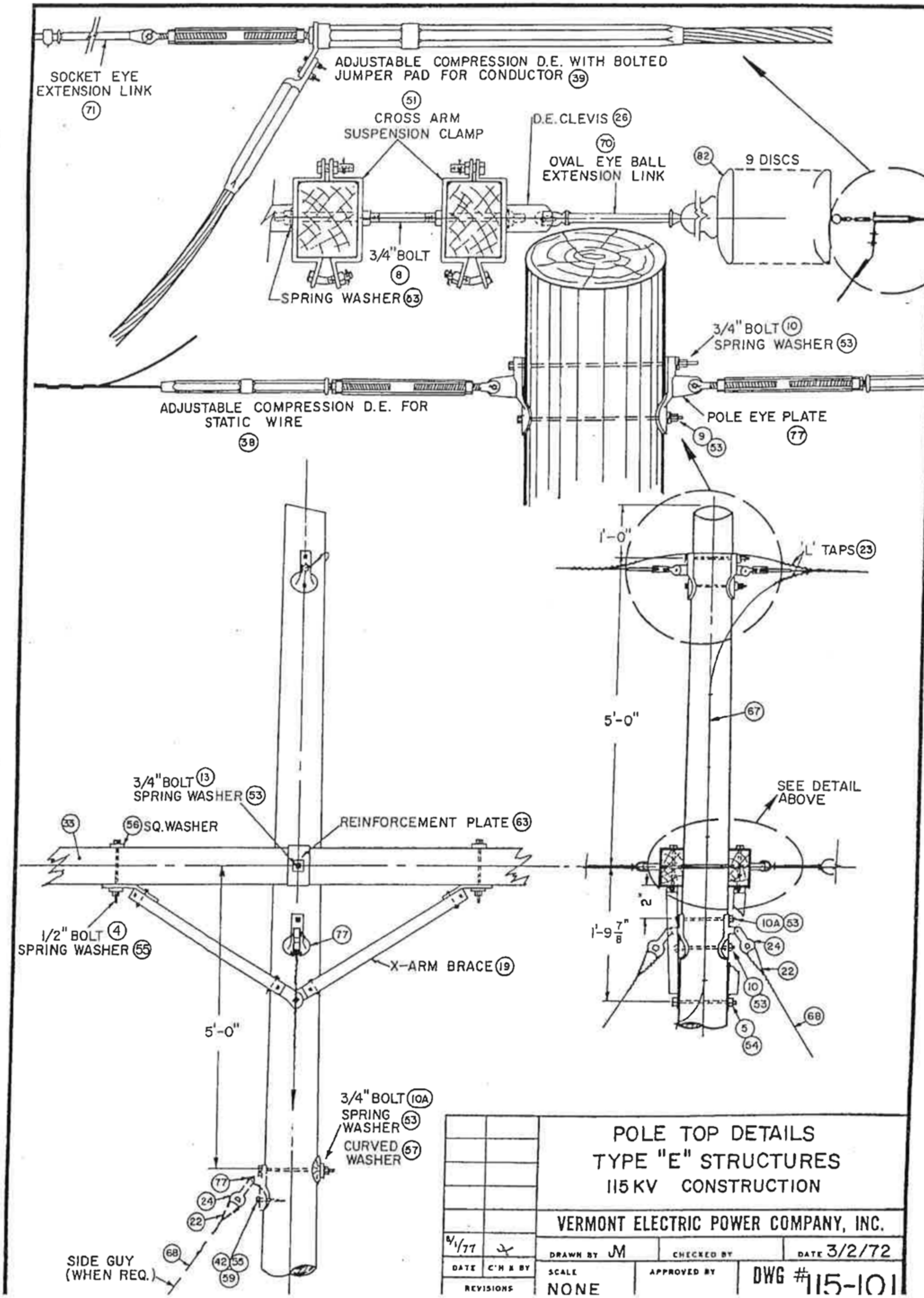
Rev 2/77

Rev. 2/74



NOTE:
1. WHEN USED FOR ANGLES ATTACH GUY 6" BELOW X-ARM.
2. WHEN STRINGING CONDUCTOR USE ADDITIONAL TEMPORARY GUYS TO HOLD X-ARM FROM BENDING.

		TYPE – E STRUCTURE DEAD – END 115 KV CONSTRUCTION
		VERMONT ELECTRIC POWER COMPANY, INC.
3/1/77		DRAWN BY JM — CHECKED BY — DATE 3/3/72
DATE		SCALE NONE — APPROVED BY — DWG # 115-10.0
REVISIONS		



POLE TOP DETAILS
TYPE "E" STRUCTURES
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DATE	C'H & BY	DRAWN BY	CHECKED BY	DATE
8/1/77	[illegible]	JM		3/2/72

REVISIONS

SCALE NONE | APPROVED BY | DWG # 115-101

VERMONT ELECTRIC POWER COMPANY, INC.
MATERIALS FOR TYPE DA-T
115 Kv

7	3	Bolts, Xarm clamp 3/4"	Joslyn	J 6277
11	3	Bolts, thru 3/4" x 16"	Joslyn	J 8916
13A	6	Bolts, thru 7/8" x 16" 14" 12"	Joslyn	J 9064
14A	2	Static wire support	Hughes	2854
20	2	Xbrace w/mounting hardware	Hughes	1042X
22A	12	Preformed guy grips deadend 1/2"	Preformed	BG 2-115
23	4	Preformed 'L' tap	Preformed	LC-MS-596[illegible]
28A	6	'Y' Clevis ball extension link	BTC	3091
31	6	Anchor logs 4'	Koppers	
37	1	Crossarm Type DA-T		
39	6	Adjustable Compression DE -conductor	Alcoa	AC-9300 7534-122HV 5134-122HV
40	6	Rods, anchor 3/4" x 8'	Joslyn	J 7328
40A	6	Rock Anchors	Chance	R360,372 R384,396
41	2	Rods, ground 3/4" x 8'	Joslyn	J 5338
43	12	Fiberglass Strain Insulators	Anderson	GSI-3-54-1[illegible]
44	2	Ground rod clamps	LM	DN 14G1
47	2	Clamp, suspension w/clevis for s w	Bethea	FS-46C
49	3	Clamp, suspension w/socket for conductor	Bethea	ACFS-108-19-25S
51	3	Clamp, crossarm	Joslyn	J1820
52	6	Chain link	BTC	3082
53	6	Washers, coil spring 3/4"	Eaton	
53A	8	Washers, coil spring 7/8"	Eaton	
56A	2	Washer, curved 4" x 4" x 1/4" w/15/16"hole	MIF	P144-B
57	3	Washer, curved 4" x 4" x 1/4" w/13/16" hole	MIF	P144
58	6	Washer, flat 4" x 4" x 1/4" w/7/8" hole for anchor	Joslyn	J. 1082
61	6	Guy Guards	Oliver	808

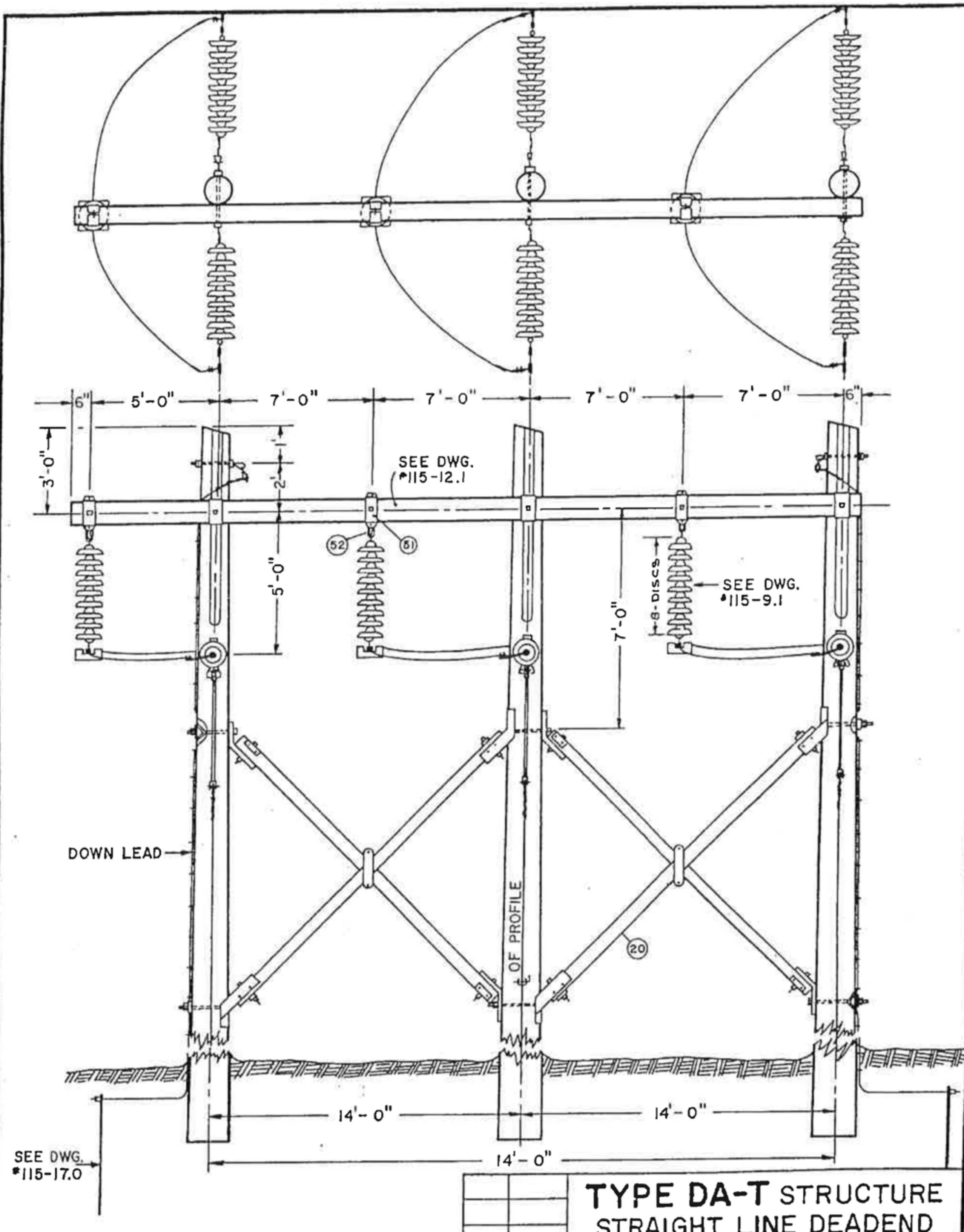
Rev 1/7

Type DA-T

VERMONT ELECTRIC POWER COMPANY, INC.

MATERIALS FOR TYPE DA-T
115 KV

Item	Quant		Manuf.	Cat. No.
63	3	Reinforcement plate for Xarm	Joslyn	4047
67	120'	Cable, 3/8" galv. 3-strd (common grade)		
68A	400'	Cable, guying 1/2" EHS galv steel		
71	3	Socket eye extension link	BTC	4314B
72	3	Ball eye-long	BTC	3014
73	3	Weights - 150#	Bethea	ASM 389-150-E-H
75	6	Anchor shackle	BTC	3023
76	6	Sheave wheel	Joslyn	J 6288
77A	6	Deadend Tee	MIF	PX 41
82	78	Insulator disc 9" (3 strings of 8 -idler) (6 strings of 9)	GE	155-409 ASA-70
		When Required		
79		Pole Roof - non-metalic (used if pole cut in field)	Joslyn	J 2108

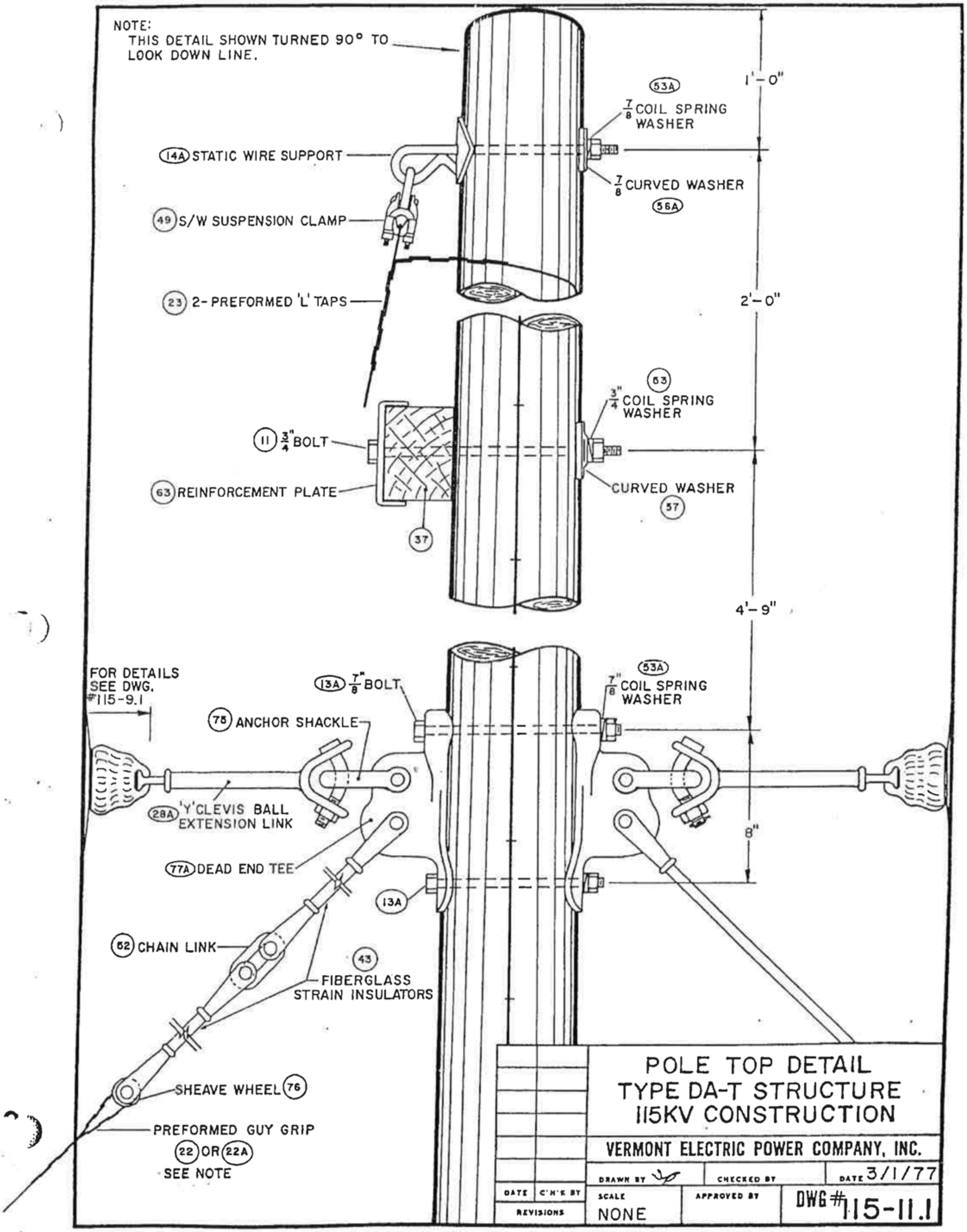


TYPE DA-T STRUCTURE
STRAIGHT LINE DEADEND
115KV CONSTRUCTION

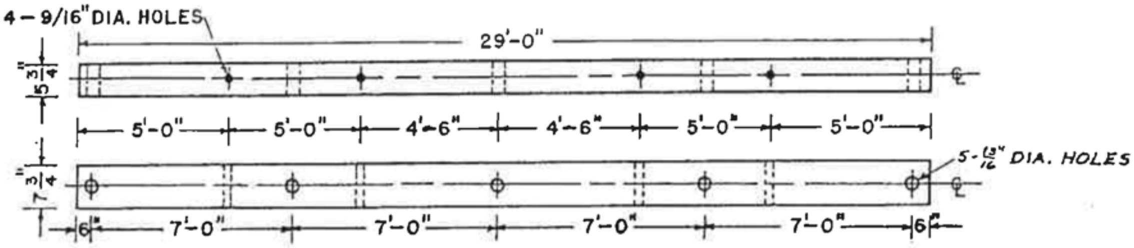
VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY	CHECKED BY		DATE 3/1/77
SCALE NONE	APPROVED BY		DWG #115-11.0

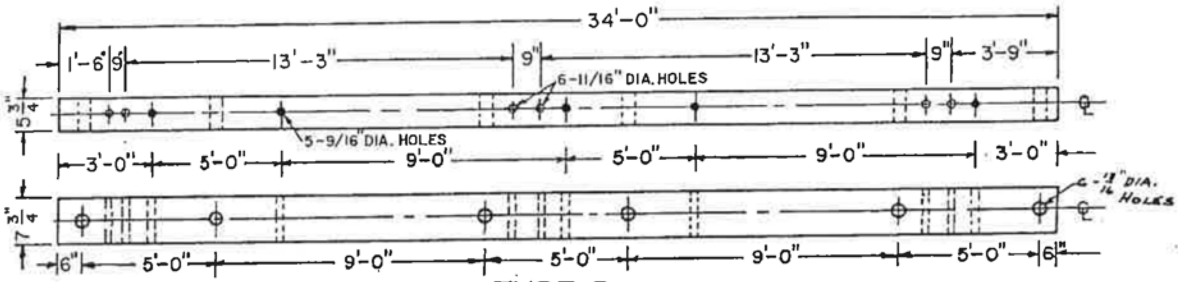
DATE | C'H'K BY
REVISIONS



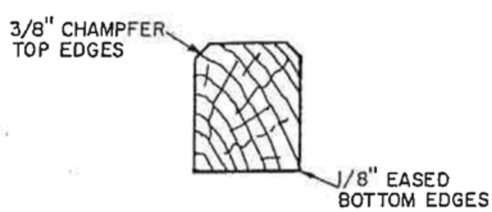
Boston Blue Print Co.-100-8-57-8½x 11



TYPE A (A & E STRUCTURE)
(33)



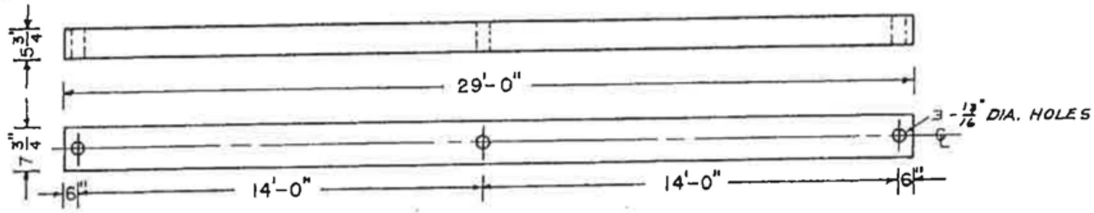
TYPE B (B & B-2 STRUCTURE)
(34)



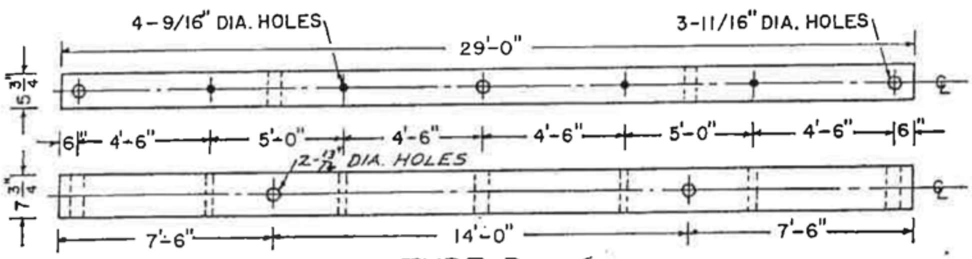
DETAIL OF CROSSARMS A & B

VERMONT ELECTRIC POWER COMPANY, INC.

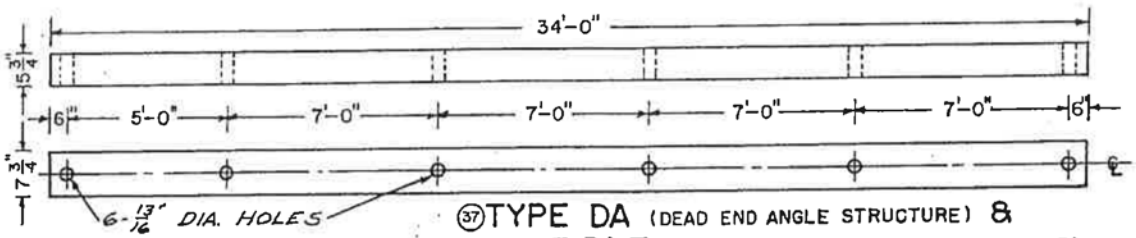
7/15/74	TYPE "B-2"	DRAWN BY JM	CHECKED BY
DATE	CH'K BY	SCALE NONE	APPROVED BY
REVISIONS		DATE 4/19/72	DWG #115-12.0



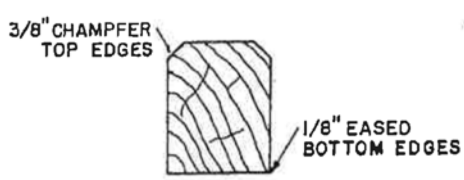
TYPE C (C & F STRUCTURE)
(35)



TYPE D (D STRUCTURE)
(36) A2 & D STR.



(37) TYPE DA (DEAD END ANGLE STRUCTURE) &
TYPE DA-T (DEAD END STRAIGHT LINE STRUCTURE)



3/1/77	JK	DRAWN BY JM
DATE	C'H K BY	SCALE NONE
REVISIONS		

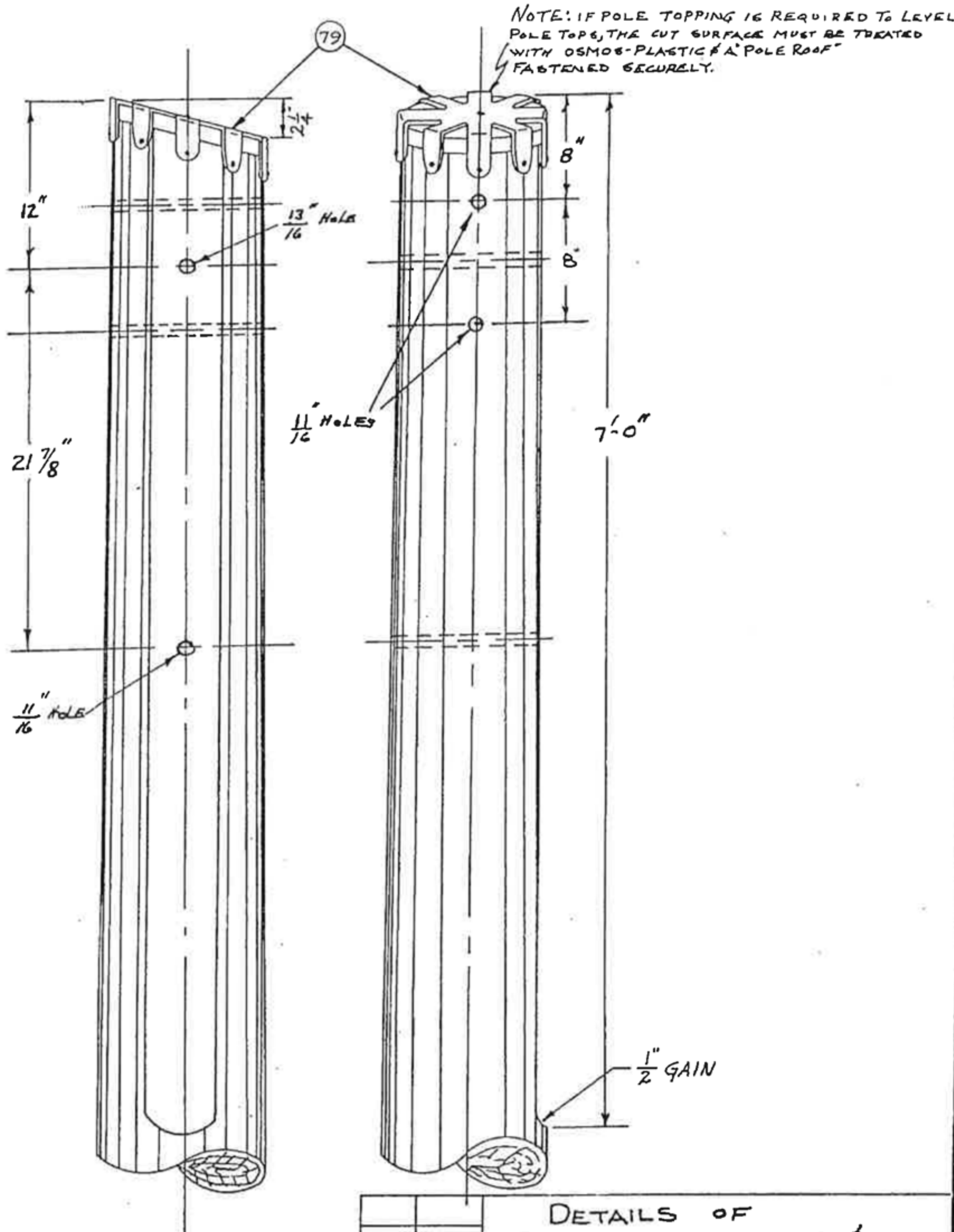
DETAIL OF CROSSARMS C, D, DA

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY JM — CHECKED BY — DATE 4/18/72

SCALE NONE — APPROVED BY — DWG # 115-12.1

FORM CV 100



		DETAILS OF BORING, GAINING & POLE ROOF
		VERMONT ELECTRIC POWER COMPANY, INC.
		DRAWN BY R.G. / CHECKED BY / DATE 4-6-72
DATE	C'H'K BY	SCALE None / APPROVED BY / DWG #115-13.0
REVISIONS		

BOSTON BLUE PRINT CO. 814C - 200 - 3-83

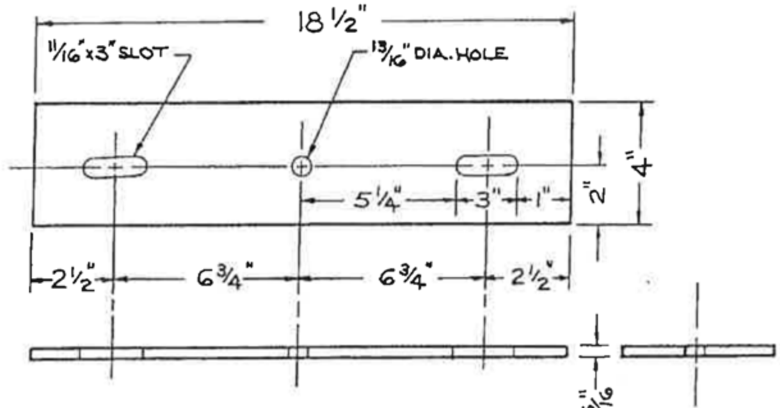
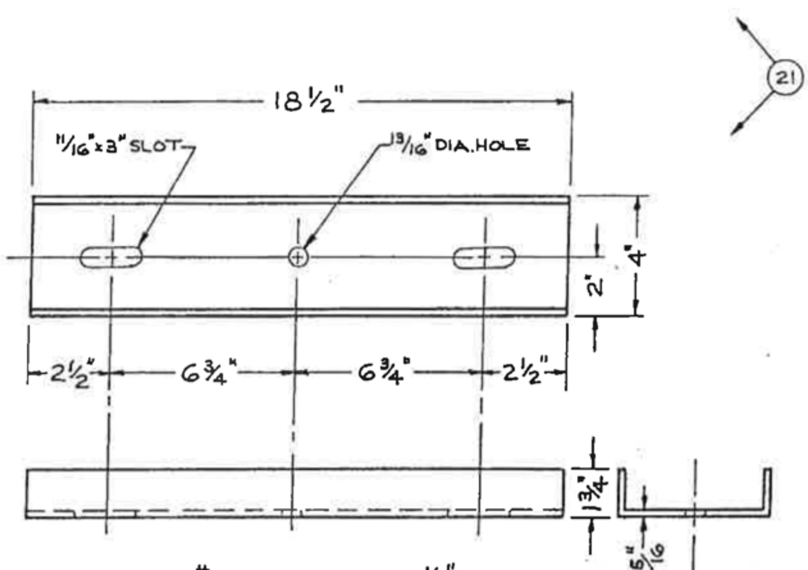


PLATE 18 1/2" x 4" x 5/16"



4" – 7.25# CHANNEL 18 1/2" LG.

- NOTE -
PLATE & CHANNEL
HOT DIP GALVANIZED

PLATE & CHANNEL DETAIL
115 KV CONSTRUCTION

VERMONT ELECTRIC POWER COMPANY, INC.

DRAWN BY DC	CHECKED BY	DATE 3-1-77
SCALE None	APPROVED BY	DWG #115-14.0

DATE | C'H'K BY
REVISIONS

Boston Blue Print Co.-100-8-57-8½ x 11

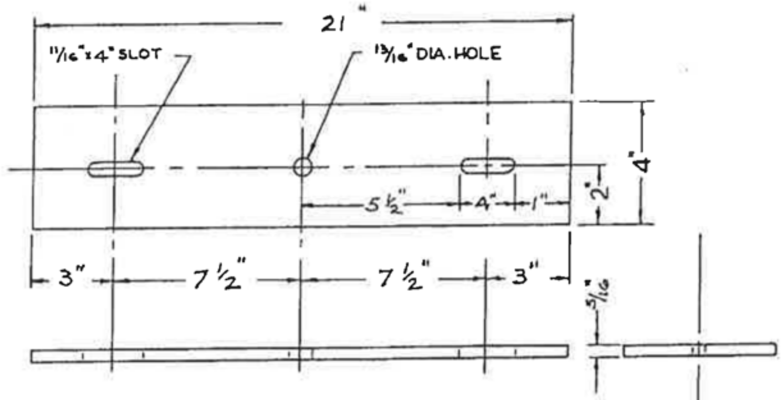
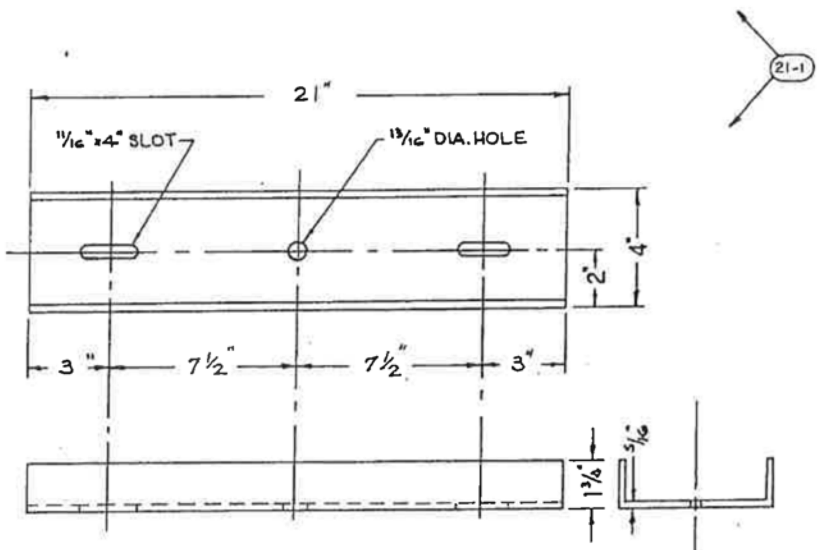


PLATE 21" x 4" x 5/16"



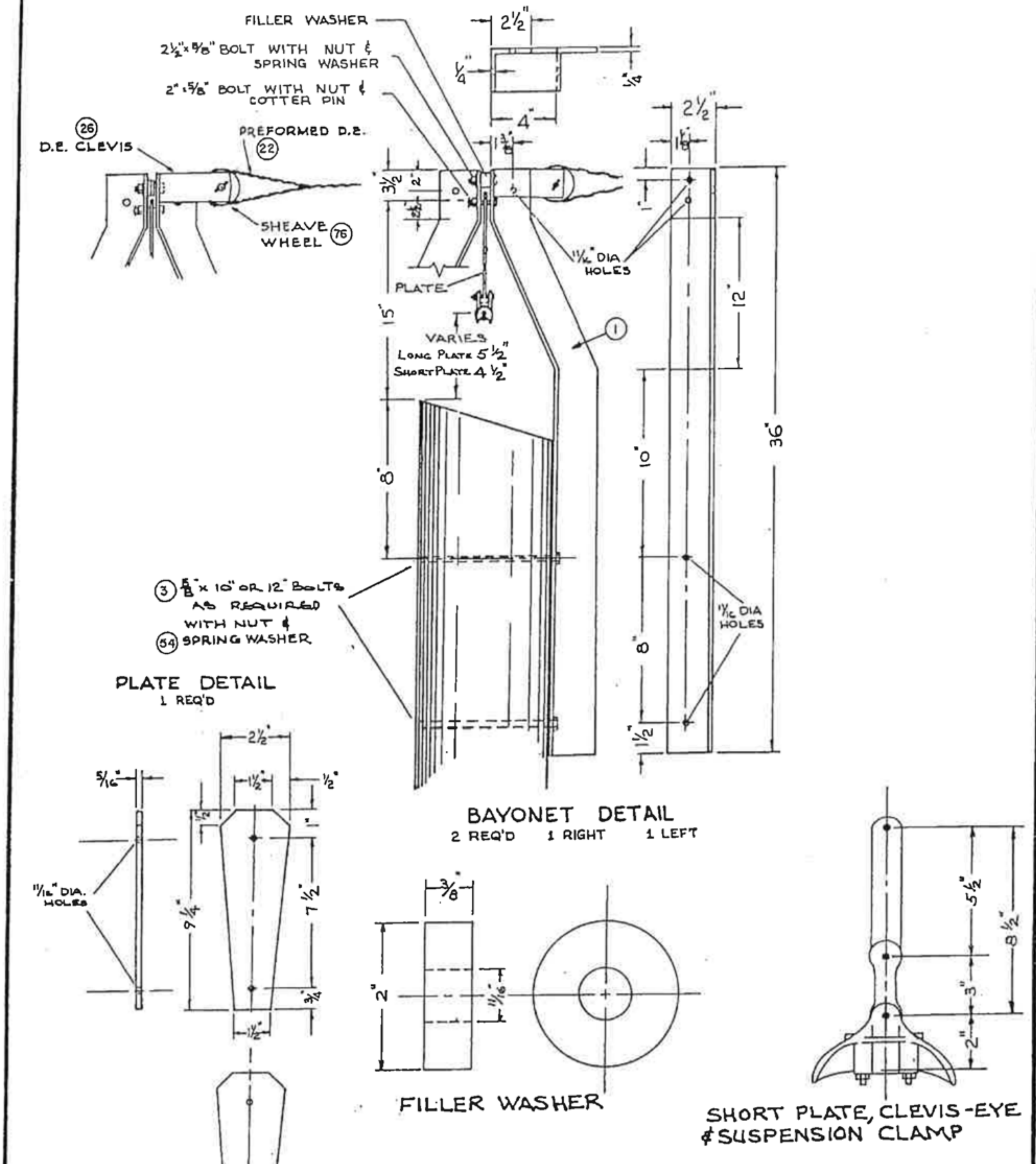
4" – 7.25# CHANNEL 21" LG.

- NOTE -
PLATE & CHANNEL
HOT DIP GALVANIZED

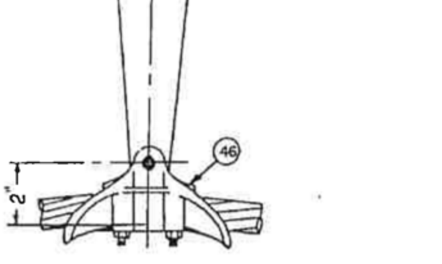
PLATE & CHANNEL DETAIL 115 KV. CONSTRUCTION		
VERMONT ELECTRIC POWER COMPANY, INC.		
DRAWN BY P.D.A.	CHECKED BY	DATE 4-25-74
SCALE	APPROVED BY	DWG #115-141

DATE	CH'K BY

FORM CV 100



NOTE
ALL HARDWARE GALVANIZED



LONG PLATE & SUSPENSION CLAMP ASSEMBLY

		BAYONET DETAIL
		115 KV. CONSTRUCTION
		VERMONT ELECTRIC POWER COMPANY, INC.
3/1/77	JC	DRAWN BY PDA · CHECKED BY · DATE 4-7-72
DATE	CH'K BY	SCALE NONE · APPROVED BY · DWG #115-15.0
REVISIONS		

VERMONT ELECTRIC POWER COMPANY, INC.
Material for Special Type A Structure
w/Shield Wire Deadended

Mark	Quant.	Description	Manuf.	Cat. No.
4	4	Bolts, brace 1/2" x 10"	Joslyn	J8710
5	2	Bolts, 5/8" x 12" (xarm brace)	Joslyn	J8812
7	3	Bolts, Xarm Clamps 3/4" x 8"	Joslyn	J8908
11	2	Bolts, machine 3/4" x 16"(Xarm)	Joslyn	J8916
13A	4	Bolts, thru 7/8" x 12" 14" 16" (345 Kv material)	Joslyn	
19	2 prs	Brace wood - 60" Xarm	Hughes	2000cc
22	8	Preformed guy grips DE	Preformed	GDE 1107
23	12	Preformed "L" taps	Preformed	LC-MS 5963
31	4	Anchor logs 4'	Kopper	
33	1	Crossarm Type A	Haley	
38	4	Adjustable Compression DE for Static Wire	Alcoa	4620-12
40	4	Rods, anchor 3/4" x 8'	Joslyn	J7328
40A		Rock anchors	Chance	R360, R384 R372, R396
43	4	Fiberglass Strain Insulators	Anderson	GSI 3-54-1P
44	2	Clamps, ground rod	LM	DN14G1
49	3	Clamps, suspension conductor w/socket fitting	Bethea	ACFS 114-19 25S
51	3	Clamps, crossarm	Joslyn	J1820
53	5	Washer, coil spring 3/4"	Eaton	
53A	4	Washer, coil spring 7/8"	Eaton	
54	6	Washer, coil spring 5/8"	Eaton	
55	4	Washers, coil spring 1/2"	Eaton	
56	4	Washer 2" x 2" x 1/8" w/9/16" hole square	Joslyn	J1073
57	2	Washer 4" x 4" x 1/4" w/3/16" hole curved	Lapp MIF	304082 P144

VERMONT ELECTRIC POWER COMPANY, INC.
Material for Special Type A Structure
w/Shield Wire Deadended

Mark	Quant.	Description	Manuf.	Cat. No.
58	4	Washers, 4" x 4" x 1/4" w/ 7/8" hole square	Joslyn	J 1002
60	2	Washers, 3" x 3" x 3/16" w/11/16"hole curved	Lapp MIF	304078 P143
61	4	Guy guards, metal	Oliver	808
63	2	Plate, reinforcement for Xarms	Joslyn	J4047
64	75	Staples 3/8" x 1-3/4" (down lead)	Joslyn	J173
67	120'	Down Lead 3/8" galv. 3-strd-common		
68	275'	Cable, guying 3/8" EHS galv steel		
72	3	Ball eye - long	BTC Lapp	3014 6422
77A	4	Deadend Tee - (345Kv material)	MIF	PX41
76	4	Sheave wheel	Joslyn	J6288
41	2	Rods, ground 3/4" x 8'	Joslyn	J5338
82	21	Insulators 9" disc	Lapp GE	9000-70 155409- ASA-70
		<u>When Required</u>		
20	1	Xbrace w/mounting hardware	Hughes	1042X
73	3	150# Weights	Bethea	ASM 389-150 M-H
79		Pole Roof, non-metalic (used if pole cut in fld)	Joslyn	J 2108

6/77
REv 1/78