MOTT MACDONALD

Memorandum

Subject	**Surface/Earth Load Evaluation**
To	Vermont Gas Systems, Inc.
From	Mott MacDonald, LLC
Our reference	507105094
Office	West Springfield, MA
Date	June 15, 2021

1 Introduction

Vermont Gas Systems, Inc. (VGS) has requested that Mott MacDonald provide additional information regarding Mott MacDonald's prior analysis of whether the construction of the Addison Natural Gas Pipeline (ANGP) meets a HS-20+15% loading standard. Our prior analysis of the ANGP loading included two different assessments of the ANGP under the HS-20+15% loading standard. The first analysis in 2016 involved calculation of the loading on the ANGP using a generic loading calculation tool, the API RP 1102 tool, which is frequently used for general assessments of loading for highway and railway crossings. We used this tool to assess the loading on the ANGP assuming "no compaction[1]" at a variety of depths and soil types that could be present along the ANGP. The second analysis utilized a more case-specific loading calculation, ANSI GPTC Z380.1, 2018 edition (GPTC), which is based on the same underlying loading research as the API 1102 tool and is also consistent with ASME/ANSI B31.8. In this 2017 loading analysis, we assessed representative input parameters that included depths of cover greater than or equal to two feet with soil types that exhibited low strength soil properties and the results demonstrated that the ANGP meets the HS-20+15% loading standard under such conditions.

VGS has asked Mott MacDonald to provide additional information about the assumptions used in those analyses in light of questions raised by the Vermont Public Utility Commission (Commission). We have reviewed our prior loading calculations as well as the Commission's January and April 2021 orders in Case No. 17-3550 questioning whether Mott MacDonald's calculations were based on "flawed assumptions about: (1) the diameter of the pipeline (12 inches versus 15 inches); (2) the method of burial (sink-in-the-swamp versus horizontal directional drilling); and (3) the density of the soil surrounding the pipeline." As explained in more detail below, the prior loading calculations utilized appropriate inputs regarding (1) pipe diameter, (2) burial method, and (3) soil density. In our professional opinion, the 2016 loading calculations accurately assessed a HS-20+15% loading standard and the 2017 loading calculations demonstrate the ANGP meets the HS-20+15% loading standard with depths of cover of 2 feet or greater.

In addition, we have performed a variety of sensitivity analyses using different methods (provided in Attachment B) for calculating the loading on the ANGP. These analyses, as well as our prior calculations, demonstrate that the ANGP meets the HS-20+15% loading standard with as little as 2 feet of cover even when assuming low soil strength properties that represent weak soils and/or an absence of soil compaction. In our professional judgment, after analyzing the loading calculations based on a variety of sensitivity assessments, the ANGP meets the HS-20+15% loading standard in areas where it is buried at least two feet.

[1] Our reference to "no compaction" adopts an assumption that mechanical means were not used to compact backfill soil materials. However, as discussed in section 2.3 varying modulus of soil reaction values were used to assess this condition.

2 Additional Information Regarding the 2016 and 2017 Calculations

The following responds to the Commission's specific questions regarding the (1) pipe diameter, (2) burial method, and (3) soil density and explains why the values used in our 2016 and 2017 calculations were appropriate for assessing whether the ANGP meets the HS-20+15% loading standard.

2.1 Diameter of pipeline

Our assessment of the loading on the ANGP assumed a pipe diameter of 12.75" (See Attachment A). The diameter that was utilized in these loading calculations was based on the outside diameter of the steel pipeline. Utilizing the steel pipeline outside diameter (12.75") is industry practice and is required for performing the loading evaluation using any of the standard loading calculation tools used in the industry, including API RP1102, ANSI GPTC Z380.1, 2018 edition (GPTC) and the Canadian Energy Pipeline Association Surface Loading Calculator (CEPA).

The Commission has questioned whether the diameter input should include the extra width of concrete coating on the pipe. The concrete coating is not taken into account in the diameter input because the concrete coating does not provide significant structural value to the steel pipeline itself. The concrete coating applied to the exterior of the ANGP pipeline is not a material factor when assessing the ability of the 12.75" diameter steel pipeline to withstand surface loads. Instead, concrete coating is used to provide negative buoyancy and protect the pipeline against external damage during installation. The industry standard surface and earth loading calculation tools for natural gas pipelines do not recommend changing the pipe diameter input based on a concrete coating layer. The 12.75" input for pipe diameter was therefore appropriate for the surface loading calculations even for those locations where the pipeline was coated with concrete.

2.2 Method of burial

Our assessment of the loading on the ANGP assumed installation of the ANGP was performed using an open trench installation rather than a bore or horizontal directional drill (HDD) installation. The Commission has questioned whether our loading calculations mistakenly assumed the ANGP was installed using HDD. The Commission's January 29, 2021 Order states that the assessment should have assumed an "open-cut trench with a pipeline diameter of 15.75" rather than a "data assessment tool applicable to an HDD installation that assumes a bore width of 12.75 inches." The Order appears to be referring to an input for "bored diameter" on the API RP 1102 calculation sheet, implying that because there was a value used for that input, we had treated the pipeline as though it was installed by bore.

Our use of the API RP 1102 tool for assessing the loading on a pipeline that is installed by open-cut trench was appropriate based on the guidance provided in API RP 1102. In particular, the guidance for that calculation method states in Section 4.7.2.1 that bored diameter (B_d = D) should be assumed when analyzing a trenched construction. In other words, the guidance instructs us to input the pipe diameter value for the bored diameter parameter when applying the calculation to an open trench construction. Our loading calculations followed this instruction by inputting the pipeline diameter (D = 12.75") for the bored diameter value (B_d). We were fully aware that the pipeline was being installed by open-cut trench and therefore our calculations were consistent with this understanding and the API RP 1102 guidance.

2.3 Density of soil surrounding the pipeline

The Commission has also questioned whether our prior loading calculations included appropriate assumptions about the density of soil. The purpose of our 2016 loading assessment was to evaluate the "pipeline's integrity under loading without compaction of backfill." The density of the soil surrounding the pipeline is a factor when calculating the loading on the pipeline because different soil types and varying levels of compaction exert and transfer the pressure differently. The relevant parameter in the loading calculation that captures for these

variables is the modulus of soil reaction. Section 6.2 of the API RP 1102 provides general recommendations for trench installation including recommendations for compaction of backfill. The API RP 1102 loading calculation tool does not include an input parameter based on Section 6.2 compaction levels. Instead, the API RP1102 loading tool accounts for soil strength and compaction properties by allowing the user to input relevant modulus of soil reaction values that are consistent with various soil types and levels of compaction.

Accordingly, our 2016 loading evaluation using the API 1102 tool employed sensitivity analysis to evaluate various soil parameters that represented a wide range of modulus of soil reaction values, which is inputted using values ranging from 200 psi (representing very weak soils) to 2,000 psi (representing stronger soils). This modulus of soil reaction range represented soil types exhibiting “soft to medium clays and silts with high plasticities” (200 psi) to “dense to very dense sands and gravels” (2000 psi). The range in modulus of soil reaction values can also be understood as a range of soil compaction, with lower modulus of soil reaction representing backfill with low strength soil properties and no compaction. Accordingly, our 2016 calculations provided an assessment of the “pipeline’s integrity under loading without compaction of backfill” under a variety of circumstances including low soil strengths.

Likewise, our 2017 calculation modeled a low strength soil density (fully saturated clay), which is the equivalent of assessing loading with low or no compaction. Under all the soil densities we assessed, including the 2017 GPTC calculation, we concluded that the ANGP achieved the HS-20+15% loading criteria in locations where it is buried a minimum of two feet. We have also confirmed this conclusion by performing a variety of additional calculations as discussed below.

3 Additional Loading Calculation Validation

As part of our review of Mott MacDonald’s prior loading calculations for ANGP, we performed several additional calculations utilizing the same GPTC method used in 2017, as well as a CEPA loading calculation tool, which also adheres to the ASME/ANSI B31.8[2] standard regarding combined equivalent stresses on a steel pipeline. These calculation tools are similar to the API RP 1102 tool used in 2016, are based on the same underlying principles, and are consistent with the combined stress formula found in ASME/ANSI B31.8 paragraph 833.4. Our verification calculations are provided as Attachment B and demonstrate that – like our prior loading calculations – the ANGP meets the HS-20+15% loading standard for a variety of scenarios. For example, one such scenario modeled the loading on the ANGP based on a low strength soil simply “dumped” (100 psi) into the trench with no subsequent compaction. The results show that the total effective stress from a HS-20+15% load is 47,563 psi, which is well below the total effective stress that can be safely handled by the ANGP.

Based on our review of the prior calculations, as well as our calculations verifying similar results under a variety of scenarios, Mott MacDonald is of the opinion that the loading analysis that has been performed utilized appropriate assumptions and input data for the ANGP construction, and the ANGP meets the HS-20+15% loading standard even where it is assumed there is only 2 feet of cover backfill with low strength soils.

[2] ASME has been defining piping safety since 1922. ASME B31.8 covers gas transmission and distribution piping systems, including gas pipelines, gas compressor stations, gas metering and regulation stations, gas mains, and service lines up to the outlet of the customer’s meter set assembly.

Attachment A – 2016 & 2017 Calculations

Project Name: Vermont Gas Systems 5/25/2016

Location: Burlington, VT Rev. 1

Prepared for: Vermont Gas Systems

Prepared by: Mott MacDonald

Purpose:

Mott MacDonald has prepared the stress calculations included herein for Vermont Gas Systems, to ensure the pipeline's integrity under loading without compaction of backfill. The stress calculations were performed per API 1102, using various combinations of soil type and depth of cover to confirm that 90% compaction will not be necessary.

Knowns:

- Class 3 Location, Design Factor of 0.5
- 12.75 inch OD
- 0.312 inch WT
- API-5L Electric Resistance Welded
- Grade X-65
- MAOP of 1440 psi
- Design Wheel Load HS-20 + 15%

Results:

A summary table has been provided below. The stress calculations show that under all soil types, paired with 3', 4', and 5' of cover, the pipeline passes all stress checks (Hoop, Effective, Girth Weld, and Longitudinal Weld). In conclusion, Mott MacDonald recommends a minimum depth of cover of 4 feet. Although 3 feet of cover is sufficient under the given loading, a one foot buffer would help ensure that even if settlement were to occur, the pipeline would remain safe and operational.

API 1102 STRESS CALCULATION RESULTS			
	Calculated Effective Stress (psi)		
Soil type	3' Cover	4' Cover	5' Cover
Soft to medium clays and silts with high plasticities	31,239	31,437	31,234
Soft to medium clays and silts with low/medium plasticities	31,180	31,370	31,159
Loose sands and gravels	30,360	30,550	30,427
Stiff to very stiff clays and silts	30,216	30,366	30,193
Medium dense sands and gravels	30,278	30,453	30,318
Dense to very dense sands and gravels	29,422	29,554	29,437
ALLOWABLE EFFECTIVE STRESS (psi)	**32,500**		
Note: 1. Calculated girth weld and longitudinal weld stress values were less than the allowable (Girth: 6,000 psi & Long. Welds: 11,500 psi).			

Mott MacDonald

Calculation cover sheet

Project Title:	VERMONT GAS SYSTEMS	**Project No:**	351481KK01
File No:		**No. of Sheets:**	18
Section:		**Subject:**	
Calc No:			
Project Manager:		**Designer:**	
Design Phase:	**A** - Concept or preliminary	**C** - Design verification	
	B - Analysis and detailed design	**D** - Other (specify)	

Computer Applications Used:	
Title:	Version Date:
PIPELINE TOOLBOX	2013

Scopes for Checking Manual and Computer Generated Calculations:

> Back check project information
> Back check individual calculations to verify results

Sheets Checked: *	**Calculations by:**			**Checked By:**		
	Name:	Signature:	Date:	Name:	Signature:	Date:
18/18	K. KIBBE	Kelsey Kibbe	5/25/16	J. WOJNAS	JW	5/25/16

**If an Excel spreadsheet or other computer file has been checked and has not been attached, enter the name, date and full file path or PiMS location of the file that was checked. (PiMS nickname or short link from Properties – General could also be useful.)*

a) Basic Design Information or Source and Reference:

> Design Info. per Mike Reagan's discussions with client
> API 1102 for design factors and procedure

b) Identify documents/technical records where output will be used:

> calculations summary provided to client

Approved by Project Manager:	**Signature:** ..... **Print name:** Joseph WOJNAS	**Date:** 5/25/16

Distribution: Original to project file

Step

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with high plasticities
E' - Modulus of Soil Reaction [ksi]	0.2
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423	Maximum Circumferential Stress [psi]	34,305
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,239
Stiffness Factor for Earth Load Circumferential Stress	2,196	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.83	Total Effective Stress [psi]	31,239
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,331		
Impact Factor	1.50		
Highway Stiffness Factor for Cyclic Circumferential	16.60		
Highway Geometry Factor for Cyclic Circumferential	1.22		
Cyclic Circumferential Stress [psi]	4,271		
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20		
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		
Cyclic Longitudinal Stress [psi]	3,229		

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,239	32,500	PASS
Girth Welds	3,229	6,000	PASS
Long. Welds	4,271	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with high plasticities
E' - Modulus of Soil Reaction [ksi]	0.2
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,196
Burial Factor for Earth Load Circumferential Stress	0.97
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,555
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	16.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	4,271
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	3,229

Maximum Circumferential Stress [psi]	34,529
Maximum Longitudinal Stress [psi]	12,306
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	31,437
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,437	32,500	PASS
Girth Welds	3,229	6,000	PASS
Long. Welds	4,271	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with high plasticities
E' - Modulus of Soil Reaction [ksi]	0.2
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,196
Burial Factor for Earth Load Circumferential Stress	1.08
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,732
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	16.60
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	3,850
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	3,006

Maximum Circumferential Stress [psi]	34,285
Maximum Longitudinal Stress [psi]	12,136
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	31,234
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,234	32,500	PASS
Girth Welds	3,006	6,000	PASS
Long. Welds	3,850	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with low/medium plasticities
E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423	Maximum Circumferential Stress [psi]	34,239
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,219
Stiffness Factor for Earth Load Circumferential Stress	2,088	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.83	Total Effective Stress [psi]	31,180
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,265		
Impact Factor	1.50		
Highway Stiffness Factor for Cyclic Circumferential	16.60		
Highway Geometry Factor for Cyclic Circumferential	1.22		
Cyclic Circumferential Stress [psi]	4,271		
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20		
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		
Cyclic Longitudinal Stress [psi]	3,229		

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,180	32,500	PASS
Girth Welds	3,229	6,000	PASS
Long. Welds	4,271	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with low/medium plasticities
E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423	Maximum Circumferential Stress [psi]	34,453
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,284
Stiffness Factor for Earth Load Circumferential Stress	2,088	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.97	Total Effective Stress [psi]	31,370
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,479		
Impact Factor	1.50		
Highway Stiffness Factor for Cyclic Circumferential	16.60		
Highway Geometry Factor for Cyclic Circumferential	1.22		
Cyclic Circumferential Stress [psi]	4,271		
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20		
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		
Cyclic Longitudinal Stress [psi]	3,229		

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,370	32,500	PASS
Girth Welds	3,229	6,000	PASS
Long. Welds	4,271	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type:	Soft to medium clays and silts with low/medium plasticities
E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	5.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,088
Burial Factor for Earth Load Circumferential Stress	1.08
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,647
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	16.60
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	3,850
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	3,006

Maximum Circumferential Stress [psi]	34,200
Maximum Longitudinal Stress [psi]	12,111
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	31,159
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	31,159	32,500	PASS
Girth Welds	3,006	6,000	PASS
Long. Welds	3,850	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Loose sands and gravels

E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,088
Burial Factor for Earth Load Circumferential Stress	0.83
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,265
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	3,241
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	2,275

Maximum Circumferential Stress [psi]	33,209
Maximum Longitudinal Stress [psi]	11,265
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,360
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,360	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Loose sands and gravels

E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,088
Burial Factor for Earth Load Circumferential Stress	0.97
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,479
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	3,241
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	2,275

Maximum Circumferential Stress [psi]	33,423
Maximum Longitudinal Stress [psi]	11,330
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,550
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,550	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Loose sands and gravels

E' - Modulus of Soil Reaction [ksi]	0.5
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	2,088
Burial Factor for Earth Load Circumferential Stress	1.08
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,647
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	2,923
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	2,118

Maximum Circumferential Stress [psi]	33,273
Maximum Longitudinal Stress [psi]	11,223
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,427
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,427	32,500	PASS
Girth Welds	2,118	6,000	PASS
Long. Welds	2,923	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factqr	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Stiff to very stiff clays and silts

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,934
Burial Factor for Earth Load Circumferential Stress	0.78
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,102
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	3,241
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	2,275

Maximum Circumferential Stress [psi]	33,046
Maximum Longitudinal Stress [psi]	11,216
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,216
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,216	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Stiff to very stiff clays and silts

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423	Maximum Circumferential Stress [psi]	33,215
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,267
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.90	Total Effective Stress [psi]	30,366
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,271		
Impact Factor	1.50		
Highway Stiffness Factor for Cyclic Circumferential	12.60		
Highway Geometry Factor for Cyclic Circumferential	1.22		
Cyclic Circumferential Stress [psi]	3,241		
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30		
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		
Cyclic Longitudinal Stress [psi]	2,275		

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,366	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Stiff to very stiff clays and silts

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,934
Burial Factor for Earth Load Circumferential Stress	0.98
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,384
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	2,923
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	2,118

Maximum Circumferential Stress [psi]	33,010
Maximum Longitudinal Stress [psi]	11,144
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,193
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,193	32,500	PASS
Girth Welds	2,118	6,000	PASS
Long. Welds	2,923	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Medium dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,934
Burial Factor for Earth Load Circumferential Stress	0.83
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,172
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	3,241
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	2,275

Maximum Circumferential Stress [psi]	33,116
Maximum Longitudinal Stress [psi]	11,238
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,278
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,278	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Medium dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,934
Burial Factor for Earth Load Circumferential Stress	0.97
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,370
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	3,241
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	2,275

Maximum Circumferential Stress [psi]	33,314
Maximum Longitudinal Stress [psi]	11,297
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,453
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,453	32,500	PASS
Girth Welds	2,275	6,000	PASS
Long. Welds	3,241	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Medium dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	1.0
Er - Resilient Modulus [ksi]	10.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,934
Burial Factor for Earth Load Circumferential Stress	1.08
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,525
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	12.60
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	2,923
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	2,118

Maximum Circumferential Stress [psi]	33,151
Maximum Longitudinal Stress [psi]	11,186
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	30,318
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	30,318	32,500	PASS
Girth Welds	2,118	6,000	PASS
Long. Welds	2,923	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Dense to very dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	2.0
Er - Resilient Modulus [ksi]	20.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	3
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,693
Burial Factor for Earth Load Circumferential Stress	0.78
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	964
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	9.30
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	2,393
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	1,517

Maximum Circumferential Stress [psi]	32,060
Maximum Longitudinal Stress [psi]	10,417
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	29,422
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	29,422	32,500	PASS
Girth Welds	1,517	6,000	PASS
Long. Welds	2,393	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
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Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Dense to very dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	2.0
Er - Resilient Modulus [ksi]	20.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	4
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,693
Burial Factor for Earth Load Circumferential Stress	0.90
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,113
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	9.30
Highway Geometry Factor for Cyclic Circumferential	1.22
Cyclic Circumferential Stress [psi]	2,393
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16
Cyclic Longitudinal Stress [psi]	1,517

Maximum Circumferential Stress [psi]	32,209
Maximum Longitudinal Stress [psi]	10,462
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	29,554
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	29,554	32,500	PASS
Girth Welds	1,517	6,000	PASS
Long. Welds	2,393	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

Project	
Vermont Gas Systems	
Location	Date
Burlington, VT	5/24/2016

API 1102 - Gas Pipeline Crossing Highway

PIPE AND OPERATIONAL DATA:

Operating Pressure [psi]	1440
Location Class:	3
Operating Temperature [°F]	60.0
Pipe Outside Diameter [in]	12.75
Pipe Wall Thickness [in]	0.312
Pipe Grade: X65	
Specified Minimum Yield Stress	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Pipe Class: API 5L Electric Resistance Welded	
Young's Modulus for Steel [ksi]	30,000
Poisson's Ratio for Steel	0.30
Coefficient of Thermal Expansion [per°F]	0.0000065

SITE AND INSTALLATION DATA:

Soil Type: Dense to very dense sands and gravels

E' - Modulus of Soil Reaction [ksi]	2.0
Er - Resilient Modulus [ksi]	20.0
Average Unit Weight of Soil [lb/ft³]	120.00
Pipe Depth [ft]	5
Bored Diameter [in]	12.75
InstallationTemperature [°F]	60.0
Design Wheel Load from Single Axle [kips]	18.4
Design Wheel Load from Tandem Axles [kips]	18.4

Pavement Type: None

Impact Factor Method: ASCE - Highway

Safety Factor Applied: API 1102 Procedure

RESULTS

Hoop Stress [psi]	29,423
Allowable Hoop Stress [psi]	32,500
Stiffness Factor for Earth Load Circumferential Stress	1,693
Burial Factor for Earth Load Circumferential Stress	0.98
Excavation Factor for Earth Load Circumferential Stress	0.83
Circumferential Stress from Earth Load [psi]	1,211
Impact Factor	1.50
Highway Stiffness Factor for Cyclic Circumferential	9.30
Highway Geometry Factor for Cyclic Circumferential	1.10
Cyclic Circumferential Stress [psi]	2,157
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08
Cyclic Longitudinal Stress [psi]	1,412

Maximum Circumferential Stress [psi]	32,071
Maximum Longitudinal Stress [psi]	10,386
Maximum Radial Stress [psi]	-1,440
Total Effective Stress [psi]	29,437
Allowable Effective Stress [psi]	32,500

Stress [psi]	Calculated	Allowable	PASS/FAIL
Hoop	29,423	32,500	PASS
Effective	29,437	32,500	PASS
Girth Welds	1,412	6,000	PASS
Long. Welds	2,157	11,500	PASS

Notes: Open cut construction, calculations run using HS-20 loading + 15%

Reference: API RP 1102 "Steel Pipelines Crossing Railroads and Highways"

Prepared By Kelsey Kibbe	Approved By	Revision: 13.0.1

From: Hartman, Daniel J <Daniel.Hartman@mottmac.com>
Sent: Tuesday, June 20, 2017 4:46 PM
To: John St.Hilaire
Cc: Wojnas, Joseph E; Wolf, Brian D; Kibbe, Kelsey E; Guthrie, Karen M
Subject: RE: Vermont Gas Systems - GPTC Calculations

The calculation was run using assuming a fully saturated clay. It would have an effect on the hoop stress from the applied load.

Daniel J. Hartman PE | Project Engineer

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Daniel.Hartman@mottmac.com

From: John St.Hilaire [mailto:jsthilaire@vermontgas.com]
Sent: Tuesday, June 20, 2017 4:41 PM
To: Hartman, Daniel J <Daniel.Hartman@mottmac.com>
Cc: Wojnas, Joseph E <Joseph.Wojnas@mottmac.com>; Wolf, Brian D <Brian.Wolf@mottmac.com>; Kibbe, Kelsey E <Kelsey.Kibbe@mottmac.com>; Guthrie, Karen M <Karen.Guthrie@mottmac.com>
Subject: Re: Vermont Gas Systems - GPTC Calculations

Sorry one las qu strong. We found some documentation that the soil type is "LK" meaning Livingston clay - flooded. Which category of the original analysis does LK fit into?

Sent from my iPad

On Jun 20, 2017, at 9:11 AM, Hartman, Daniel J <Daniel.Hartman@mottmac.com> wrote:

> Hey John,
>
> The previous calculations we ran were using the 2' depth of cover and produced effective stresses less than allowable.
>
> I just ran a scenario where we would have 1' of cover with the 25 kip load (the calculation will not allow a trench depth/width ratio less than .5 so I changed the trench width from 3' to 2' now that the cover is down to 1'). The results produced a hoop stress of 71,752 psi from external loading alone and a total hoop stress of 101,175 psi which exceeds the allowable by a large margin without even adding in the S2 and S3 principal stresses. Long story short the calculations pass for up to a depth of 2' but that is the cutoff. I reduced the load from 25kips down to 10 kips and it still fails at the 1' of cover.
>
> Hopefully this answers your question. Feel free to reach back out should you need any further clarification or evaluation.
>
> Kind Regards,
>
> -Danny
>
> **Daniel J. Hartman PE** | Project Engineer

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From: John St.Hilaire [mailto:jsthilaire@vermontgas.com]
Sent: Monday, June 19, 2017 7:14 AM
To: Hartman, Daniel J <Daniel.Hartman@mottmac.com>; Wojnas, Joseph E <Joseph.Wojnas@mottmac.com>
Cc: Wolf, Brian D <Brian.Wolf@mottmac.com>; Kibbe, Kelsey E <Kelsey.Kibbe@mottmac.com>; Guthrie, Karen M <Karen.Guthrie@mottmac.com>
Subject: RE: Vermont Gas Systems - GPTC Calculations

Hi Daniel

Quick follow –up. I am being asked if we are good at 5', 4', 3', and now 2', what is the level where this calculation would show we exceed the total stress? At what depth would the calc exceed 58,500?

Is this something easy to do?

Thanks,
John

From: Hartman, Daniel J [mailto:Daniel.Hartman@mottmac.com]
Sent: Wednesday, May 10, 2017 4:54 PM
To: John St.Hilaire; Wojnas, Joseph E
Cc: Wolf, Brian D; Kibbe, Kelsey E; Guthrie, Karen M
Subject: RE: Vermont Gas Systems - GPTC Calculations

Hey John,

Please see below for the calculation of the total effective stress that results from the wheel load applied using the GPTC method. Feel free to reach out with any questions.

From the GPTC calc we get the combined total stress for the principal plane S1 (hoop stress from internal pressure + hoop stress from applied load)

S1 = 29,423 + 20,206 = 49,629 psi

S1 = 49,629 psi

From the below calculation we get the longitudinal stress which represents the principal stress S2

Design Temperature – T_d =	60	^{o}F
Installation Temperature – T_i =	80	^{o}F
Poisson's Ratio – v =	0.30	
Thermal Coefficient of Steel – α =	6.7×10^{-6}	1 / ^{o}F

Young's Modulus – E = 29×10^6 psi

SL=(vSH-Eα(Td-Ti)) from ASME B31.8 Clause 833.3
*SL=(.3*49,629 -29*10^6*6.7*10^-6(60-80))*
SL= 18,774.7 psi

S2 = 18,774.7 psi

The maximum radial stress results from the negative of the MAOP and represents the principal stress S3

S3 = -1440

The simplified Von Mises equation for principal stresses is used to translate the three principal stresses into the equivalent tensile stress (total effective stress). *Design factor F from ASME B31.8 Clause 833.4b*

Seff=12[S1-S22+S2-S32+S3-S12]

Seff=12[49,629 -18,774.7 2+18,774.7 --14402+-1440-49,629 2]

Seff=44,545.85

Seff≤SMYS×F

44,545.85≤65,000×(.9)

44,545.85≤58,500 OK

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From: John St.Hilaire [mailto:jsthilaire@vermontgas.com]
Sent: Wednesday, May 10, 2017 8:12 AM
To: Wojnas, Joseph E <Joseph.Wojnas@mottmac.com>
Cc: Wolf, Brian D <Brian.Wolf@mottmac.com>; Hartman, Daniel J <Daniel.Hartman@mottmac.com>; Kibbe, Kelsey E <Kelsey.Kibbe@mottmac.com>; Guthrie, Karen M <Karen.Guthrie@mottmac.com>
Subject: RE: Vermont Gas Systems - GPTC Calculations

Hi Joe

Quick question. In the original analysis the result table pulled in "total effective stress". In the additional analysis I do not find this number. How would I correlate the two analysis?

Thanks,
John

From: Wojnas, Joseph E [mailto:Joseph.Wojnas@mottmac.com]
Sent: Monday, May 01, 2017 11:56 AM
To: John St.Hilaire
Cc: Wolf, Brian D; Hartman, Daniel J; Kibbe, Kelsey E; Guthrie, Karen M
Subject: FW: Vermont Gas Systems - GPTC Calculations

John,

Please see the summary below. Kelsey performed the work under the direction of one of our professional engineers. In summary, the pipe looks good.

In talking with the staff the total effort appears to take less than 4 hours. Timesheets are developed at the end of the week where the exact time is collected. With your permission I was going to honor the rates from the Addison Natural Gas Project contract dated January 9, 2015.

Please do not hesitate to contact us with any other questions and/or comments you may have.

Thank you

Joe

From: Kibbe, Kelsey E
Sent: Monday, May 1, 2017 9:48 AM
To: Wojnas, Joseph E <Joseph.Wojnas@mottmac.com>
Cc: Hartman, Daniel J <Daniel.Hartman@mottmac.com>
Subject: Vermont Gas Systems - GPTC Calculations

Hi Joe –

As requested, I've attached two calculations using 2' depth of cover and the weakest soil type. One calculation was run using 1440 psig internal pressure, the other was run using no internal pressure. **Both scenarios pass, the total calculated combined stress for each is less than 90% SMYS.**

Note: the calculations were performed using the GPTC Guide, as 2' depth of cover is out of scope for the API 1102 (method used for previous calculations). A more conservative design wheel load of 25 kips was used.

Let me know if you need anything further.

Thanks,

Kelsey E. Kibbe
Engineer II, EIT

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kelsey.kibbe@mottmac.com

<image020.png>

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<VTGas_GPTC Calc_1ftcover.pdf>

Attachment B – Additional CEPA & GPTC Calculations

Results for Surface Loading Calculation

PIPELINE INFORMATION:	Vermont Gas
PIPELINE LOCATION:	Burlington, VT
VEHICLE INFORMATION:	HS20+15%
VEHICLE TYPE:	Wheel: 3-Axles, 6-Wheels
DATE:	6/14/2021 17:16

GENERAL INPUTS				VEHICLE INPUTS			LOCATION OF MAXIMUM LOAD
D =	12.75	inches	(Outside Diameter)	Axle or Track Separation 1 :	14	ft	The maximum pressure
t =	0.312	inches	(Wall Thickness)	Axle Separation 2 :	14	ft	exerted on the surface of
$P_{internal}$ =	1440	psig	(Maximum Operating Pressure)	Axle Width :	6	ft	the pipe due to vehicle
SMYS =	65000	psi	(Specified Minimum Yield Strength)	Track Length :	N/A	ft	point load occurs:
ΔT =	0	°F	(Temperature Differential)	Axle 1 or Track Vehicle Load :	9200	lbs	
ρ =	120	lb/ft^3	(Density)	Contact Width 1 :	20	inches	**Under the middle tires.**
H =	2	ft	(Depth of Cover)	Tire Pressure 1 :	100	psi	
θ =	30	degrees	(Bedding Angle)	Axle Load 2 :	36800	lbs	
E' =	500	psi	(Modulus of Soil Reaction)	Contact Width 2 :	20	inches	
IF =	1.50		(Impact Factor)	Tire Pressure 2 :	100	psi	
Soil Load Equation:	Prism Load Equation			Axle Load 3 :	36800	lbs	
ϕ =	N/A	degrees		Contact Width 3 :	20	inches	
Equivalent Stress Equation:	Tresca Equation			Tire Pressure 3 :	100	psi	
				Measurement Point X-coord :	N/A	inches	
				Measurement Point Y-coord :	N/A	inches	

CALCULATED STRESS DATA			Variable Description	Pipeline Regulatory Code	Pass / Fail
Hoop Stress (σ_H):					
$\sigma_{H\_Internal\_MOP}$ =	29423	psi	<----- Internal Pressure @ MOP		
$\sigma_{H\_Live\_Zero}$ =	21158	psi	<----- Live Load @ Zero pressure		
$\sigma_{H\_Live\_MOP}$ =	10788	psi	<----- Live Load @ MOP		
$\sigma_{H\_Total\_Zero}$ =	22935	psi	<----- Total Hoop Stress @ Zero pressure		
$\sigma_{H\_Total\_MOP}$ =	41117	psi	<----- Total Hoop Stress @ MOP		
$\sigma_{H\_\%SMYS\_Zero}$ =	35.3%		<----- Hoop Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{H\_\%SMYS\_MOP}$ =	63.3%		<----- Hoop Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**
Longitudinal Stress (σ_L):					
$\sigma_{L\_Live\_Zero}$ =	13741	psi	<----- Live Load @ Zero pressure		
$\sigma_{L\_Live\_MOP}$ =	10380	psi	<----- Live Load @ MOP		
$\sigma_{L\_Total\_Zero}$ =	14274	psi	<----- Total Longitudinal Stress @ Zero pressure		
$\sigma_{L\_Total\_MOP}$ =	19479	psi	<----- Total Longitudinal Stress @ MOP		
$\sigma_{L\_\%SMYS\_Zero}$ =	22.0%		<----- Longitudinal Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{L\_\%SMYS\_MOP}$ =	30.0%		<----- Longitudinal Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**
Equivalent Stress (σ_E):					
σ_{E_Zero} =	37210	psi	<----- Equivalent Stress @ Zero pressure		
σ_{E_MOP} =	42942	psi	<----- Equivalent Stress @ MOP		
$\sigma_{E\_\%SMYS\_Zero}$ =	57.2%		<----- Equivalent Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{E\_\%SMYS\_MOP}$ =	66.1%		<----- Equivalent Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**

GENERAL NOTES:

- Refer to "Table 3-Fatigue Endurance Limits, S_{FG} and S_{FL}, for Various Steel Grades" on page 18 of API Recommended Practice 1102 when performing fatigue check calculations. This table has also been reproduced courtesy of the American Petroleum Institute on the "API RP 1102 Fatigue Table" tab to provide the user with a quick reference.

Results for Surface Loading Calculation

PIPELINE INFORMATION:	Vermont Gas
PIPELINE LOCATION:	Burlington, VT
VEHICLE INFORMATION:	HS20+15%
VEHICLE TYPE:	Wheel: 3-Axles, 6-Wheels
DATE:	6/14/2021 8:31

GENERAL INPUTS				VEHICLE INPUTS			LOCATION OF MAXIMUM LOAD
D =	12.75	inches	(Outside Diameter)	Axle or Track Separation 1 :	14	ft	The maximum pressure
t =	0.312	inches	(Wall Thickness)	Axle Separation 2 :	14	ft	exerted on the surface of
$P_{internal}$ =	1440	psig	(Maximum Operating Pressure)	Axle Width :	6	ft	the pipe due to vehicle
SMYS =	65000	psi	(Specified Minimum Yield Strength)	Track Length :	N/A	ft	point load occurs:
ΔT =	0	°F	(Temperature Differential)	Axle 1 or Track Vehicle Load :	9200	lbs	
ρ =	120	lb/ft^3	(Density)	Contact Width 1 :	20	inches	**Under the middle tires.**
H =	2	ft	(Depth of Cover)	Tire Pressure 1 :	100	psi	
θ =	30	degrees	(Bedding Angle)	Axle Load 2 :	36800	lbs	
E' =	100	psi	(Modulus of Soil Reaction)	Contact Width 2 :	20	inches	
IF =	1.50		(Impact Factor)	Tire Pressure 2 :	100	psi	
Soil Load Equation:	Prism Load Equation			Axle Load 3 :	36800	lbs	
ϕ =	N/A	degrees		Contact Width 3 :	20	inches	
Equivalent Stress Equation:	Tresca Equation			Tire Pressure 3 :	100	psi	
				Measurement Point X-coord :	N/A	inches	
				Measurement Point Y-coord :	N/A	inches	

CALCULATED STRESS DATA			Variable Description	Pipeline Regulatory Code	Pass / Fail
Hoop Stress (σ_H):					
$\sigma_{H\_Internal\_MOP}$ =	29423	psi	<----- Internal Pressure @ MOP		
$\sigma_{H\_Live\_Zero}$ =	22884	psi	<----- Live Load @ Zero pressure		
$\sigma_{H\_Live\_MOP}$ =	11219	psi	<----- Live Load @ MOP		
$\sigma_{H\_Total\_Zero}$ =	24806	psi	<----- Total Hoop Stress @ Zero pressure		
$\sigma_{H\_Total\_MOP}$ =	41585	psi	<----- Total Hoop Stress @ MOP		
$\sigma_{H\_\%SMYS\_Zero}$ =	38.2%		<----- Hoop Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{H\_\%SMYS\_MOP}$ =	64.0%		<----- Hoop Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**
Longitudinal Stress (σ_L):					
$\sigma_{L\_Live\_Zero}$ =	18303	psi	<----- Live Load @ Zero pressure		
$\sigma_{L\_Live\_MOP}$ =	14522	psi	<----- Live Load @ MOP		
$\sigma_{L\_Total\_Zero}$ =	18879	psi	<----- Total Longitudinal Stress @ Zero pressure		
$\sigma_{L\_Total\_MOP}$ =	23632	psi	<----- Total Longitudinal Stress @ MOP		
$\sigma_{L\_\%SMYS\_Zero}$ =	29.0%		<----- Longitudinal Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{L\_\%SMYS\_MOP}$ =	36.4%		<----- Longitudinal Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**
Equivalent Stress (σ_E):					
σ_{E_Zero} =	43685	psi	<----- Equivalent Stress @ Zero pressure		
σ_{E_MOP} =	47563	psi	<----- Equivalent Stress @ MOP		
$\sigma_{E\_\%SMYS\_Zero}$ =	67.2%		<----- Equivalent Stress %SMYS @ Zero pressure	ASME B31.8-2010	**PASS**
$\sigma_{E\_\%SMYS\_MOP}$ =	73.2%		<----- Equivalent Stress %SMYS @ MOP	ASME B31.8-2010	**PASS**

GENERAL NOTES:

- Refer to "Table 3-Fatigue Endurance Limits, S_{FG} and S_{FL}, for Various Steel Grades" on page 18 of API Recommended Practice 1102 when performing fatigue check calculations. This table has also been reproduced courtesy of the American Petroleum Institute on the "API RP 1102 Fatigue Table" tab to provide the user with a quick reference.

Project	
VGS	
Location	Date
Burlington, VT	6/1/2021

Design of Uncased Pipeline Crossings - GPTC Appendix G-192-15

PIPE AND CROSSING DATA:

Nominal Pipe Size	12 3/4
Nominal Outside Diameter [in.]	12.75
Nominal Wall Thickness [in.]	0.312
Grade	X65
Specified Minimum Yield Strength [psi]	65,000
Design Factor	0.50
Longitudinal Joint Factor	1.0
Temperature Derating Factor	1.000
Modulus of Elasticity for Steel [psi]	30,000,000
Unit Weight of Soil [lbs/ft³]	120
Deflection Parameter	0.108
Bending Parameter	0.235
Impact Factor	1.5
Pipeline Internal Pressure [psig]	1440
Wheel Load [lbs]	18400
Width of Pipe Trench or Diameter of Bore [ft.]	4
Height of Soil over Pipe [ft.]	2

RESULTS OF CALCULATION:

Load Coefficient	0.474
Total External Load [lbs/lineal inch of pipe]	367.0
Hoop Stress due to Internal Pressure [psi]	29,423
Hoop Stress due to External Loading [psi]	16,442
Total Calculated Combined Stress [psi]	45,865

Note: The total calculated combined stress should not exceed 100% of SMYS.

Uniform Support Under Pipe [°] and Crossing Conditions: 30° - Open Trench

Soil Type: Extreme maximum for clay (completly saturated).

Notes:

Reference: GPTC - Guide for Gas Transmission and Distribution Systems, Appendix G-192-15, A.G.A.

Prepared By	John Smith	Approved By	Revision: 10.0.0