

Exhibit VGS-AG-057

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		
<u>Note:</u>			
1. Calculated girth weld and longitudinal weld stress values were less than the allowable (Girth: 6,000 psi & Long. Welds: 11,500 psi).			



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	Kerry Kim	5/25/16	J. Wujcik	JL	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
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Distribution: Original to project file

Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	16.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	31,239
Cyclic Circumferential Stress [psi]	4,271	Girth Welds	3,229
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Long. Welds	4,271
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		Allowable
Cyclic Longitudinal Stress [psi]	3,229		PASS/FAIL

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
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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	34,529
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,306
Stiffness Factor for Earth Load Circumferential Stress	2,196	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.97	Total Effective Stress [psi]	31,437
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,555		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	16.60	Allowable	PASS/FAIL
Highway Geometry Factor for Cyclic Circumferential	1.22	Hoop	29,423
Cyclic Circumferential Stress [psi]	4,271	Effective	31,437
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Girth Welds	3,229
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16	Long. Welds	4,271
Cyclic Longitudinal Stress [psi]	3,229		11,500

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

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

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Location Burlington, VT		

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
Installation Temperature [°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]	34,285
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,136
Stiffness Factor for Earth Load Circumferential Stress	2,196	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	1.08	Total Effective Stress [psi]	31,234
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,732		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	16.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.10	Effective	31,234
Cyclic Circumferential Stress [psi]	3,850	Girth Welds	3,006
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Long. Welds	11,500
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08		
Cyclic Longitudinal Stress [psi]	3,006		

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

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

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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
Installation Temperature [°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	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	16.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	31,180
Cyclic Circumferential Stress [psi]	4,271	Girth Welds	3,229
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Long. Welds	4,271
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		Allowable
Cyclic Longitudinal Stress [psi]	3,229		PASS/FAIL

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

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

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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
Installation Temperature [°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	Stress [psi]	Calculated	Allowable	PASS/FAIL
Highway Stiffness Factor for Cyclic Circumferential	16.60	Hoop	29,423	32,500	PASS
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	31,370	32,500	PASS
Cyclic Circumferential Stress [psi]	4,271	Girth Welds	3,229	6,000	PASS
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Long. Welds	4,271	11,500	PASS
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16				
Cyclic Longitudinal Stress [psi]	3,229				

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

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

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Location Burlington, VT	Date 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	
Installation Temperature [°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]	34,200
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	12,111
Stiffness Factor for Earth Load Circumferential Stress	2,088	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	1.08	Total Effective Stress [psi]	31,159
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,647		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	16.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.10	Effective	31,159
Cyclic Circumferential Stress [psi]	3,850	Girth Welds	3,006
Highway Stiffness Factor for Cyclic Longitudinal Stress	13.20	Long. Welds	11,500
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08		
Cyclic Longitudinal Stress [psi]	3,006		

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	11,500		

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

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

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	33,209
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,265
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]	30,360
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	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	30,360
Cyclic Circumferential Stress [psi]	3,241	Girth Welds	2,275
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	3,241
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		11,500
Cyclic Longitudinal Stress [psi]	2,275		PASS/FAIL

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

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	33,423
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,330
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]	30,550
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	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Allowable	PASS/FAIL
Highway Geometry Factor for Cyclic Circumferential	1.22	Hoop	29,423
Cyclic Circumferential Stress [psi]	3,241	Effective	30,550
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Girth Welds	2,275
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16	Long. Welds	3,241
Cyclic Longitudinal Stress [psi]	2,275		6,000
			11,500

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

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

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	33,273
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,223
Stiffness Factor for Earth Load Circumferential Stress	2,088	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	1.08	Total Effective Stress [psi]	30,427
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,647		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Calculated	Allowable
Highway Geometry Factor for Cyclic Circumferential	1.10		PASS
Cyclic Circumferential Stress [psi]	2,923	Girth Welds	2,118
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	2,923
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08		6,000
Cyclic Longitudinal Stress [psi]	2,118		11,500

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

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

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

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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]	3
Bored Diameter [in]	12.75
Installation Temperature [°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]	33,046
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,216
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.78	Total Effective Stress [psi]	30,216
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,102		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	30,216
Cyclic Circumferential Stress [psi]	3,241	Girth Welds	2,275
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	3,241
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		11,500
Cyclic Longitudinal Stress [psi]	2,275		PASS/FAIL

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

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

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	30,366
Cyclic Circumferential Stress [psi]	3,241	Girth Welds	2,275
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	3,241
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		6,000
Cyclic Longitudinal Stress [psi]	2,275		11,500

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"

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	33,010
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,144
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.98	Total Effective Stress [psi]	30,193
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,384		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Calculated	Allowable
Highway Geometry Factor for Cyclic Circumferential	1.10		PASS/FAIL
Cyclic Circumferential Stress [psi]	2,923	Hoop	29,423
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Effective	32,500
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08	Girth Welds	2,118
Cyclic Longitudinal Stress [psi]	2,118	Long. Welds	6,000

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

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

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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
Installation Temperature [°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]	33,116
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,238
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.83	Total Effective Stress [psi]	30,278
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,172		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Calculated	Allowable
Highway Geometry Factor for Cyclic Circumferential	1.22		PASS/FAIL
Cyclic Circumferential Stress [psi]	3,241	Hoop	29,423
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Effective	32,500
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16	Girth Welds	6,000
Cyclic Longitudinal Stress [psi]	2,275	Long. Welds	11,500

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

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

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Project Vermont Gas Systems		
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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
Installation Temperature [°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]	33,314
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,297
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.97	Total Effective Stress [psi]	30,453
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,370		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	12.60	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	30,453
Cyclic Circumferential Stress [psi]	3,241	Girth Welds	2,275
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	3,241
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		11,500
Cyclic Longitudinal Stress [psi]	2,275		PASS/FAIL

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

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

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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
Installation Temperature [°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]	33,151		
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	11,186		
Stiffness Factor for Earth Load Circumferential Stress	1,934	Maximum Radial Stress [psi]	-1,440		
Burial Factor for Earth Load Circumferential Stress	1.08	Total Effective Stress [psi]	30,318		
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500		
Circumferential Stress from Earth Load [psi]	1,525				
Impact Factor	1.50	Stress [psi]	Calculated	Allowable	PASS/FAIL
Highway Stiffness Factor for Cyclic Circumferential	12.60	Hoop	29,423	32,500	PASS
Highway Geometry Factor for Cyclic Circumferential	1.10	Effective	30,318	32,500	PASS
Cyclic Circumferential Stress [psi]	2,923	Girth Welds	2,118	6,000	PASS
Highway Stiffness Factor for Cyclic Longitudinal Stress	9.30	Long. Welds	2,923	11,500	PASS
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08				
Cyclic Longitudinal Stress [psi]	2,118				

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

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

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Project Vermont Gas Systems		Date 5/24/2016
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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
Installation Temperature [°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]	32,060
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	10,417
Stiffness Factor for Earth Load Circumferential Stress	1,693	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.78	Total Effective Stress [psi]	29,422
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	964		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	9.30	Calculated	Allowable
Highway Geometry Factor for Cyclic Circumferential	1.22		PASS
Cyclic Circumferential Stress [psi]	2,393	Girth Welds	6,000
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20	Long. Welds	11,500
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		PASS
Cyclic Longitudinal Stress [psi]	1,517		

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

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

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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
Installation Temperature [°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]	32,209
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	10,462
Stiffness Factor for Earth Load Circumferential Stress	1,693	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.90	Total Effective Stress [psi]	29,554
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,113		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	9.30	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.22	Effective	29,554
Cyclic Circumferential Stress [psi]	2,393	Girth Welds	1,517
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20	Long. Welds	2,393
Highway Geometry Factor for Cyclic Longitudinal Stress	1.16		11,500
Cyclic Longitudinal Stress [psi]	1,517		PASS/FAIL

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

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

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Project Vermont Gas Systems		
Location Burlington, VT	Date 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
Installation Temperature [°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]	32,071
Allowable Hoop Stress [psi]	32,500	Maximum Longitudinal Stress [psi]	10,386
Stiffness Factor for Earth Load Circumferential Stress	1,693	Maximum Radial Stress [psi]	-1,440
Burial Factor for Earth Load Circumferential Stress	0.98	Total Effective Stress [psi]	29,437
Excavation Factor for Earth Load Circumferential Stress	0.83	Allowable Effective Stress [psi]	32,500
Circumferential Stress from Earth Load [psi]	1,211		
Impact Factor	1.50	Stress [psi]	Calculated
Highway Stiffness Factor for Cyclic Circumferential	9.30	Hoop	29,423
Highway Geometry Factor for Cyclic Circumferential	1.10	Effective	29,437
Cyclic Circumferential Stress [psi]	2,157	Girth Welds	1,412
Highway Stiffness Factor for Cyclic Longitudinal Stress	6.20	Long. Welds	2,157
Highway Geometry Factor for Cyclic Longitudinal Stress	1.08		6,000
Cyclic Longitudinal Stress [psi]	1,412		11,500

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"

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