STATE OF VERMONT
PUBLIC UTILITY COMMISSION

Case No. 17-3550-INV

Investigation pursuant to 30 V.S.A. §§ 30 and 209 regarding the alleged failure of Vermont Gas Systems, Inc. to comply with the certificate of public good in Docket 7970 by burying the pipeline at less than required depth in New Haven, Vermont	

Case No. 18-0395-PET

Notice of Probable Violations of Vermont Gas Systems, Inc. for certain aspects of the construction of the Addison natural gas pipeline	

REBUTTAL TESTIMONY OF CARLOS J. CHAVES ON BEHALF OF VERMONT GAS SYSTEMS, INC.

November 1, 2021

Summary of Testimony

Mr. Chaves responds to Mr. Liebert's retracted September 10, 2021 testimony and Mr. Liebert's October 4, 2021 testimony. Mr. Chaves explains how the HS20+15% loading standard is evaluated, including the various kinds of stress that are assessed in the surface loading calculation. Mr. Chaves also explains how Mr. Liebert misapplied the ASME B31.8 standard, leading to the faulty conclusion that the total allowable stress is 50% of the Specified Minimum Yield Strength rather than 90% of the Specified Minimum Yield Strength as set forth in Section 833 of B31.8.

EXHIBIT LIST

Exhibit VGS-CC-3 –	49 C.F.R. § 192.111
Exhibit VGS-CC-4 –	49 C.F.R. § 192.105
Exhibit VGS-CC-5 –	Development of a Pipeline Surface Loading Screening Process
Exhibit VGS-CC-6 –	Mr. Liebert's Loading Calculations from October 4, 2021
Exhibit VGS-CC-7 –	CEPA Surface Loading Calculator User Manual

REBUTTAL TESTIMONY OF
CARLOS J. CHAVES
ON BEHALF OF VERMONT GAS SYSTEMS, INC.

Q1. What is your name, occupation, and business address?

A1. My name is Carlos J. Chaves. I am a Principal Project Manager with Mott MacDonald, a professional engineering consulting firm. The Mott MacDonald office that I am based out of is located at 134 Capital Drive – Suite D, West Springfield, Massachusetts 01089.

Q2. Have you provided testimony in this case previously?

A2. Yes. I provided direct testimony dated September 10, 2021.

Q3. What is the purpose of your rebuttal testimony?

A3. I respond to Mr. Gregory Liebert's testimony, which claims that Mott MacDonald's loading calculations were not correct. At first, Mr. Liebert claimed there were a number of problems with our loading calculations, including problems with input values for (1) axle-weight, (2) bedding angle, and (3) soil strength. On October 4, 2021, Mr. Liebert submitted revised testimony, removing his testimony about these issues. Accordingly, it is my understanding that Mr. Liebert no longer disputes whether we have used the appropriate inputs for (1) axle-weight, (2) bedding angle, and (3) soil strength. As a result, I do not provide any rebuttal to his original testimony on those issues, however, I do provide some relevant background about those issues where I think it may be helpful.

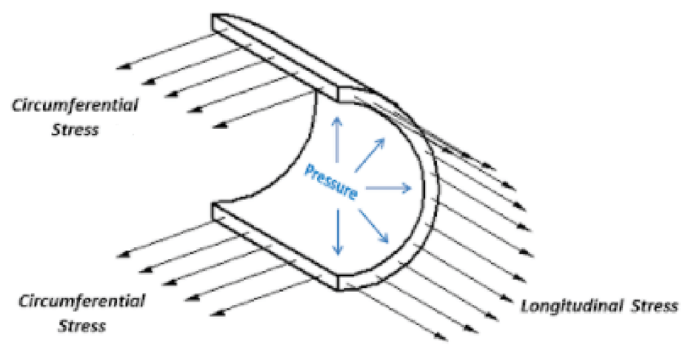
My testimony is focused on Mr. Liebert's sole remaining criticism of our loading calculations, which alleges that Mott MacDonald's calculations do not apply the appropriate

"Design Factor." In particular, Mr. Liebert's testimony about the Class 3 Design Factor demonstrates a misunderstanding about how the Class 3 Design Factor under 49 C.F.R. §§ 192.111, 192.105, and ASME B31.8 § 841 applies to surface loading calculations. Accordingly, my testimony first provides an explanation of the different kinds of stresses that are considered when calculating the impact of a HS20+15% loading standard. Second, I explain how the Design Factor requirements of 49 C.F.R. §§ 192.111, 192.105 and ASME B31.8 § 841 apply to these calculations. Finally, I explain how the overall pass/fail threshold is established for the loading standard based on applicable safety factors relating to longitudinal, circumferential, and combined allowable stress on a pipeline.

Q4. What are the different kinds of stress and stress limitations that are considered when performing a HS20+15% surface loading calculation?

A4. There are several kinds of stresses that are relevant to calculating whether a pipeline meets a HS20+15% loading standard. First, an overview of what it means to calculate surface loading under a HS20+15% loading standard may be helpful context. HS-20 loading is a design criteria of the American Association of State Highway Transportation Officials ("AASHTO") that assumes a 16,000-pound single wheel load and therefore a 32,000-pound axle load. The +15% represents an additional safety factor above the HS20 load, which is calculated by adding 15% to the applicable HS20 load, resulting in a 18,400-pound single wheel load and therefore a 36,800-pound axle load. Accordingly, the assessment of a HS20+15% loading standard involves evaluating whether the pipeline can withstand the stresses imposed by a vehicle with this weight.

Generally, there are two kinds of stresses imposed on the pipeline, (1) hoop stress, which is also referred to as circumferential stress, and (2) longitudinal stress, which is also referred to as axial stress. Hoop stress is the stress imposed on the circumference of the pipeline. This includes the stress imposed by the pressure of the natural gas inside the pipeline and the bending stresses due to the surface and earth loads. An example of hoop stress would be the stress imposed on a straw if you pinched it with two fingers. Longitudinal stress refers to the stress imposed along the length of the pipeline. This includes the stresses from internal pressure, surface and earth loads due to the Poisson Effect, axial deflection, and temperature differential. If you held a straw on both ends, a component of longitudinal stress would be the stress associated with bending the straw along its length. The following diagram illustrates these different kinds of stress.[1]



To calculate and evaluate the overall stresses acting on a pipeline, we account for the following forces:

1) Internal gas pressure inside the pipe;
2) Weight of the soil above the pipe;
3) Surface or live load acting on the pipe; and

[1] http://monghaihen.blogspot.com/2016/06/blog-post_14.html.

4) Temperature differential.

To evaluate whether a pipeline meets a HS20+15% loading standard, the stress resulting from the applied surface load of HS20+15% is determined and compared against the allowable stress levels in ASME B31.8. In other words, we are calculating the circumferential and longitudinal stress acting on the pipeline resulting from a surface load of an 18,400-pound single wheel load. The stresses imposed by this surface load are then combined with the stresses present under normal operating conditions to determine the total circumferential, total longitudinal, and total combined equivalent stress experienced by the pipeline. Finally, we look at whether these calculated stress values are lower than the maximum permitted values in ASME B31.8 Section 833. The maximum permitted values according to ASME B31.8 are detailed below:

- Total Longitudinal Stress: ASME B31.8 Section 833.3 (b) "The maximum permitted value of S_L is 0.9ST" or <u>90% of the </u>specified minimum yield strength<u> ("SMYS").</u>
- Total Circumferential Stress: ASME B31.8 Section 833.9 (b) "The maximum allowable sum of circumferential stress due to internal pressure and circumferential through-wall bending stress caused by a surface vehicle loads or other local loads is 0.9ST" or <u>90% of SMYS.</u>
- Total Combined Biaxial Stress: ASME B31.8 Section 833.4 "The maximum permitted value for the combined biaxial stress is kST" where k is defined as 0.90 for "loads of long duration" and 1.0 for "loads of short duration" or <u>90% of SMYS for long duration loads or 100% of SMYS for short duration loads.</u>

Q5. How is the internal hoop stress calculated?

A5. The internal hoop stress is one of the stress components that is present under normal operating conditions. It is the stress imposed by the pressure of the natural gas inside the pipe, expressed in pounds per square inch ("psi"). The internal hoop stress is calculated according to Barlow's Formula, which can be expressed as $S_H = PD/2t$, where S_H equals the internal hoop stress. The steel pipe input values for this internal hoop stress formula, specifically the nominal wall thickness ("t"), diameter ("D") and specified minimum yield strength ("S") are first computed by utilizing the "Design formula for steel pipe" in 49 C.F.R. § 192.105 or the "Steel Pipe Design Formula" from ASME B31.8 841.1.1, which are both expressed as $P = (2\ St/D) \times F \times E \times T$.[2] Based on this Design formula and the operator's preferred Design Pressure, the required minimum steel pipe design values are computed by applying the design factors for a Class 3 location (F = 0.5), the longitudinal joint factor (E = 1.0) and the temperature derating factor (T = 1.0) in accordance with the design formula. This calculation informs the operator of the minimum required steel pipe parameters (diameter, wall thickness, etc.) that are required for the Design Pressure. For the ANGP pipeline, a nominal wall thickness of 0.312", a diameter of 12.75", and a specified minimum yield strength (SMYS) of 65,000 psi were selected.

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[2]

P	=	Design pressure in pounds per square inch (kPa) gauge.
S	=	Yield strength in pounds per square inch (kPa) determined in accordance with § 192.107.
D	=	Nominal outside diameter of the pipe in inches (millimeters).
t	=	Nominal wall thickness of the pipe in inches (millimeters).
F	=	Design factor determined in accordance with § 192.111.
E	=	Longitudinal joint factor determined in accordance with § 192.113.
T	=	Temperature derating factor determined in accordance with § 192.115.

VGS has established a Maximum Operating Pressure ("MOP") of 1440 for ANGP, therefore; according to Barlow's Formula, when the ANGP operates at its MOP of 1440, the pressure of the gas produces an internal hoop stress (S_H) on the pipe of 29,423 psi.

$$S_H = PD/2t$$

$$S_H = 1440 \text{ x } 12.75\text{''} / 2 \text{ x } 0.312\text{''} = 29{,}423$$

Accordingly, in all of Mott MacDonald's loading calculations (as well as the calculations performed by Mr. Liebert), the internal hoop stress component of the calculations is 29,423 psi. This value is the same in all calculations because it is based on the same inputs for specified wall thickness, diameter, SMYS, and operating pressure of the ANGP. The internal hoop stress does not change with pipeline depth, surface load, or other factors.

Q6. What is the maximum allowable internal hoop stress on the ANGP?

A6. The Design Pressure and the resulting internal hoop stress produced by the Design Pressure is regulated under 49 C.F.R. § 192.105.[3] Section 192.105 establishes a Design Formula for natural gas pipelines. The Design Formula is the same Barlow's Formula used for calculating the internal hoop stress caused by the natural gas pressure discussed above, but it can also be used to determine maximum allowable design pressure. The Design Formula includes a Design Factor, represented by "F," which varies based on the Class Location of the pipeline as governed by 49 CFR 192.111.[4] Class Locations are determined by a pipeline's proximity to various dwellings, buildings, or places of public assembly.[5] The Design Formula calculates the Design

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[3] See **Exhibit VGS-CC-4** (49 C.F.R. § 192.105)
[4] See **Exhibit VGS-CC-3** (49 C.F.R. § 192.111)
[5] See 49 C.F.R. § 192.5.

Pressure for a pipeline, which is the maximum allowable operating pressure on the pipeline when substantiated with the appropriate strength tests under the PHMSA regulations.

In the case of the ANGP, the Design Formula incorporates a "Design Factor" (or "F") of 0.5 because the ANGP is designed to meet Class 3 Location standards regardless of whether it is actually a Class 3 location as defined by the regulations. Using a Design Factor of 0.5 for Class 3 and the same pipe specifications discussed above (nominal wall thickness, outside diameter, and SMYS), the Design Formula establishes a Design Pressure of 1590 for the ANGP:

$$P = (2\ St/D) \times F \times E \times T$$

$$1590 = (2 \times 65{,}000 \times 0.312''/12.75'') \times 0.5 \times 1.0 \times 1.0$$

At a Design Pressure of 1590, the maximum allowable internal hoop stress on the pipe is 32,500 psi:

$$S_H = PD/2t$$

$$32{,}500 = 1590 \times 12.75'' / 2 \times 0.312''$$

This means that under the Design Formula, the Design Pressure for the ANGP is 1590 and the corresponding internal hoop stress is 32,500 psi. In other words, a pipe of ANGP's specifications operating at the Design Pressure of 1590 may produce an internal hoop stress equal to one half of the 65,000 SMYS (32,500 psi) if it is located in a Class 3 location, because the Design Factor used in the Design Formula is one half or 0.5.

Further, as noted above the Design Pressure for ANGP may be no more than 1590 for a Class 3 location. This value is greater than the VGS-established Maximum Operating Pressure ("MOP") of 1440 for the ANGP which provides an added safety factor to the ANGP.

Q7. How are the other stresses on the pipe calculated?

A7. In addition to the internal hoop stress, additional stresses are assessed as part of the surface loading evaluation. These additional stresses are noted in Answer 4 above and include circumferential and longitudinal stresses associated with soil and surface load. To calculate these additional stresses, several parameters are required as inputs to the surface load calculation tools that we used, including the CEPA calculations (see Exhibit VGS-CC-2 at PDF page 32). The following is a screen shot of our CEPA calculations, which show the HS20+15% surface load, the weight of the soil, and the modulus of soil reaction highlighted in yellow. These inputs represent soils that impose an overburden load acting downward on the pipeline as well as representing a weak soil[6] that provides minimal support and resistance to the circumferential stresses acting on the pipeline from the surface loading conditions.

GENERAL INPUTS				VEHICLE INPUTS			LOCATION OF MAXIMUM LOAD
D =	12.75	inches	(Outside Diameter)	Axle or Track Separation 1 :	14	ft	The maximum pressure exerted on the surface of the pipe due to vehicle point load occurs:
t =	0.312	inches	(Wall Thickness)	Axle Separation 2 :	14	ft	
$P_{internal}$ =	1440	psig	(Maximum Operating Pressure)	Axle Width :	6	ft	
SMYS =	65000	psi	(Specified Minimum Yield Strength)	Track Length :	N/A	ft	
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	

In order to assess these additional stresses acting on the pipeline, including the live load of HS20+15% at the surface, we have to calculate and consider all of the stresses that are acting

[6] When we prepared our June 2021 memorandum, Mott MacDonald ran a sensitivity analysis to assess whether the ANGP would meet the HS20+15% loading standard with input values for soil strength that are lower than the 200 psi assumptions used in our 2016 and 2017 calculations. I consulted with our geotechnical team, which confirmed that a soil modulus of 100 psi is a conservative value, even for mucky, wet conditions in a wetland like the Clay Plains Swamp. We are confident that this sensitivity analysis is adequate for assessing conditions in the Clay Plains Swamp because we ran our calculations with even weaker soil conditions such as 50 psi and the ANGP still meets the HS20+15% loading standard under those more conservative conditions.

on the pipeline including those present under normal operating conditions. The evaluation to consider all of these stresses together results in the dynamic state known as the "combined biaxial stress state" or otherwise known as the "combined equivalent stress".

There are two equations that can be used for combining the various stresses acting on the pipeline to calculate the combined biaxial stress. The first is the Von Mises equation and the second is called the Tresca Equation. For these calculations, the Tresca Equation represents the more conservative approach because it always results in a higher combined biaxial stress than the Von Mises equation. For this reason, Mott MacDonald used the Tresca equation in our calculations using the CEPA method. The tool we used allows the user to select either Tresca or Von Mises. With the Tresca equation, the "combined biaxial stress" at the maximum operating pressure of 1440 (indicated as "@ MOP") is 47,563.[7]

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**

[7] This is a screen shot from our CEPA calculations set forth at PDF page 32 of 33 on Exhibit VGS-CC-2.

Q8. How do you determine if the overall stress on the pipeline is acceptable?

A8. The calculated stress values for total circumferential, total longitudinal, and combined equivalent stress are then compared against the maximum permitted values as previously noted in our response to Question 4 above. The calculated values must be lower than the maximum permitted values in order to be acceptable and in accordance with ASME B31.8. The references from ASME B31.8 833 that govern the maximum permitted values are listed below:

Total Longitudinal Stress (ASME B31.8 833.3):

833.3 Summation of Longitudinal Stress in Restrained Pipe

(a) The net longitudinal stresses in restrained pipe are

$$S_L = S_P + S_T + S_X + S_B$$

Note that S_B, S_L, S_T, or S_X can have negative values.

(b) The maximum permitted value of $|S_L|$ is $0.9ST$, where S is the specified minimum yield strength, psi (MPa), per para. 841.1.1(a), and T is the temperature derating factor per para. 841.1.8.

This section notes as follows: "(b) The maximum permitted value of S_L is 0.9ST, where S is the specified minimum yield strength, psi (MPa), per para. 841.1.1(a), and T is the temperature derating factor per para. 841.1.8." Based on this provision, the sum of the longitudinal stresses is limited to 0.9 of SMYS or in other words 58,500 psi (65,000SMYS x 0.9 = 58,500).

Total Circumferential Stress (ASME B31.8 833.9):

(b) The maximum allowable sum of circumferential stress due to internal pressure and circumferential through-wall bending stress caused by surface vehicle loads or other local loads is $0.9ST$, where S is the specified minimum yield strength, psi (MPa), per para. 841.1.1(a), and T is the temperature derating factor per para. 841.1.8.

This section notes as follows: "(b) The maximum allowable sum of circumferential stress due to internal pressure and circumferential through-wall bending stress caused by surface vehicle loads or other loads is 0.9ST, where S is the specified minimum yield strength, psi (MPa), per para. 841.1.1(a), and T is the temperature derating factor per para. 841.1.8." Based on this provision, the sum of the circumferential stresses is limited to 0.9 of SMYS or in other words 58,500 psi (65,000SMYS x 0.9 = 58,500).

Total Combined Biaxial Stress (ASME B31.8 833.4):

833.4 Combined Stress for Restrained Pipe

(a) The combined biaxial stress state of the pipeline in the operating mode is evaluated using the calculation in either (1) or (2) below:

(1) $|S_H - S_L|$ or

(2) $[S_L^2 - S_L S_H + S_H^2]^{1/2}$

The maximum permitted value for the combined biaxial stress is kST where S is the specified minimum yield strength, psi (MPa), per para. 841.1.1(a), T is the temperature derating factor per para. 841.1.8, and k is defined in paras. 833.4 (b) and (c).

(b) For loads of long duration, the value of k shall not exceed 0.90.

(c) For occasional nonperiodic loads of short duration, the value of k shall not exceed 1.0.

Under this provision of ASME B31.8, the "maximum permitted value of the combined biaxial stress is *k*ST." This means that the total combined stress calculated using either the Von Mises (shown in 833.4(a)(2)) or Tresca (shown in 833.4(a)(1)) equations cannot exceed the value of *k* x S x T. The value of k is determined under *(b)* or *(c)* depending on the duration of the load. For loads of long duration, the value of *k* cannot exceed 0.9 (0.9 x 65,000 x 1.0=58,500 psi). For loads of short duration, the value of *k* cannot exceed 1.0 (1.0 x 65,000 x 1.0 = 65,000). In our calculations, we used the more conservative value for *k* of 0.9 even though the ANGP is not subject to long duration loads in the Clay Plains Swamp. Based on these conservative assumptions, the total combined biaxial stress on the pipeline is limited to 58,500 psi.

To determine if the stress values are acceptable, the computed total longitudinal stress value must be less than 90% of SMYS, the total circumferential stress value must be less than 90% of SMYS, and the total combined biaxial stress must be less than either 90% or 100% of SMYS depending on the load duration. For all of our calculations, Mott MacDonald used a 90% of SMYS value as the limiting and maximum value for assessing the resulting stresses from an HS-20+15% surface load.

Q9. Does the ANGP meet the HS20+15% loading standard based on the requirements of ASME B31.8?

A9. Yes. The total longitudinal, total circumferential, and total combined equivalent stress values on the ANGP from a HS20+15% surface load are well below the maximum permitted value of 58,500 psi. Our calculations and Mr. Liebert's CEPA calculation #4 are based on similar input values and both indicate that the ANGP passes the surface load standard. The results from our calculations are summarized below:

Input Parameters:

D = 12.75 inches

t = 0.312 inches

$P_{internal}$ = 1440 psig

SMYS = 65,000 psi

$\Delta T = 0°F$

$\rho = 120$ lb/ft^3

H = 2 ft

ϴ = 30 degrees

E' = 100 psi

IF = 1.5

Soil Load Equation = Prism Load Equation

Equivalent Stress Equation = Tresca Equation

Results:

Total Longitudinal Stress = 23,632 @MOP < 58,500psi (Per 833.3 – OKAY)

Total Circumferential Stress = 41,585 @MOP < 58,500psi (Per 833.9 – OKAY)

Total Combined Equivalent Stress = 47,563 @MOP < 58,500psi (Per 833.4 – OKAY)

Similarly, Mr. Liebert's calculations (CEPA #4) for similar input parameters result in acceptable calculated values as well as noted below:

Total Longitudinal Stress = 23,052 @MOP < 58,500psi (Per 833.3 – OKAY)

Total Circumferential Stress = 43,302 @MOP < 58,500psi (Per 833.9 – OKAY)

Total Combined Equivalent Stress = 43,302 @MOP < 58,500psi (Per 833.4 – OKAY)

Notably, this calculation is also based on several conservative assumptions. First, the ANGP generally operates at a natural gas pressure of less than 600 psi rather than 1440 psi, so the internal hoop stress is actually lower—even though VGS's pipe design would permit a Design Pressure under the terms of 49 C.F.R. § 192.105 of 1590 psi. Second, this calculation assumes only 2 feet of cover even though there is no location on the ANGP where the cover is only 2 feet. Given the conservative assumptions that we incorporated into our calculations, the ANGP clearly meets an HS20+15% loading standard because all of the calculated stresses including total longitudinal, total circumferential, and total combined effective stress are below the maximum permitted value of 90% of SMYS (58,500 psi).

Q10. Mr. Liebert testifies that ASME B31.8 requires the total allowable stress to be no more than 50% of SMYS because the Class 3 location Design Factor is 0.5. Is this correct?

A10. No. Mr. Liebert is incorrect. His testimony confuses the Design Factor required in the Design Formula for determining the steel pipe design specifications with the requirements for calculating total longitudinal, total circumferential, and total combined biaxial stress on the pipeline from additional stresses on the pipeline, including weight of the soil above the pipe and surface or live load acting on the pipe as discussed above.

Q11. What is the basis for Mr. Liebert's confusion about how to determine total allowable stress?

A11. In discovery, Mr. Liebert explained his conclusion by stating, "When calculating combined stresses for a crossing in a Location Class 3, a Factor of Safety of 0.50 is applied to the SMYS based on *ASME B31.8 §841* and *Tables 841.1.6-1 and 841.1.6-2*, when checking for a pass or fail condition."[8] This statement identifies the source of Mr. Liebert's confusion. The part of ASME B31.8 that Mr. Liebert cites to is Section 841. Section 841, however, sets forth the same Design Formula (Barlow's Formula) established under 49 C.F.R. §192.105. This formula governs the Design Pressure and is used for establishing the steel pipe design specifications

[8] Intervenors Responses to VGS's First Set of Interrogatories, Request to Produce, and Request to Admit (emphasis added).

including the nominal wall thickness, pipe diameter, and grade. This same formula also requires that the internal hoop stress produced by the Design Pressure be limited by a 0.5 factor for a Class 3 location. Tables 841.1.6-1 and 841.1.6 of the ASME B31.8 code simply state the Design Factors for various Class Locations to be used in the Design Formula. These provisions have nothing to do with calculating the total longitudinal, total circumferential, or combined biaxial stress on the pipeline from additional stresses on the pipeline, because that is governed by Section 833.

Mr. Liebert is referring to Section 841.6, which requires the use of a Design Factor based on Class Location in the Design Formula set forth in Section 841:

> **841 STEEL PIPE**
>
> **841.1 Steel Piping Systems Design Requirements**
>
> **841.1.1 Steel Pipe Design Formula**
>
> *(a)* The design pressure for steel gas piping systems or the nominal wall thickness for a given design pressure shall be determined by the following formula (for limitations, see para. 841.1.3):
>
> *(U.S. Customary Units)*
>
> $$P = \frac{2St}{D} FET$$

As you can see, this is the same Barlow's Formula set forth in 49 C.F.R. § 192.105. Accordingly, when Mr. Liebert retracted his September 10, 2021 testimony and replaced his citation to 49 C.F.R. Part 192 with a citation to Section 841 of the ASME B31.8, it made no difference because Section 841 of ASME B31.8 is the same Design Formula.

As I testified above, the Design Formula is used to calculate the Design Pressure for the pipeline and to establish the pipe specifications including the nominal wall thickness, diameter and grade and is separate from assessing the resulting stress values from an applied surface load such as a HS-20+15%. The Design Formula requires the Design Pressure to be limited so that it imposes an internal hoop stress of no more than 50% of SMYS for a Class 3 location. This "Design Factor" applies solely to the internal hoop stress, which is only one component of the stress evaluation that is performed as a result of an applied surface load. In the case of the ANGP, this limit is 32,500 psi from internal pressure and corresponds to a Design Pressure of 1590 psi. In all of our calculations, the internal hoop stress is less than 32,500 psi, which complies with both 49 C.F.R. § 192.105 and Section 841 of ASME B31.8.

Q12. Could the Design Factor cited in Section 841 of ASME B31.8 apply to both internal hoop stress and total allowable stress as suggested by Mr. Liebert?

A12. No. Applying the Design Formula's Design Factor of 50% as a limitation on total longitudinal, total circumferential, or combined biaxial stress, rather than 90% under Section 833 as I explained above, does not make any sense for several reasons. First, it makes no practical sense because the Design Formula permits the Design Pressure in the pipeline to impose an internal hoop stress of up to 50% of SMYS from the natural gas pressure alone. If the same limitation of 50% of SMYS also applied to the resulting longitudinal, circumferential, or combined biaxial stress, the pipeline could not operate at Design Pressure and be buried without running afoul of Mr. Liebert's limitation. This is because the backfill itself would impose an additional earth load stress on the pipe. So, if you were operating a buried pipeline at the allowed Design Pressure under the Design Formula, you are always going to have a total circumferential and combined stress of more than 50% of SMYS.

Second, Mr. Liebert is ignoring the requirements for assessing total longitudinal, total circumferential, and combined biaxial stress under ASME B31.8, which, as I explained above, are set forth in Section 833 of ASME B31.8—not Section 841. When Mr. Liebert was questioned about Section 833 during discovery, he explained that the equations set forth in Section 833.4 strictly address "the conditions of internal pressure only and not total loads or subsequent stresses on the pipe."[9] This is entirely backwards because the Design Formula Mr. Liebert cites in Section 841 is limited to internal pressure, whereas Section 833.4 addresses "combined biaxial stress" from additional stresses. The additional stresses addressed in this section include vehicle loading as B31.8, Section 833.9 states, as I quoted above, "The maximum allowable sum of circumferential stress due to internal pressure and circumferential through-wall bending stress caused by **<u>surface vehicle loads or other local loads</u>** is 0.9*ST*." This means that the total circumferential stress caused by internal pressure, earth load, and vehicle live load must not exceed 90% of SMYS (0.9 x S x T).[10] In the case of the ANGP, that limitation is 90% of 65,000, which is 58,500 as noted above.

Third, Mr. Liebert is clearly misunderstanding how the total stresses are being calculated by the GPTC, CEPA, and other surface loading calculation tools. When he was asked in discovery about the CEPA Surface Loading Calculator User Manual, see **Exhibit VGS-CC-7**, Mr. Liebert testified that he had never reviewed that manual before performing CEPA calculations using that tool.[11] This helps explain why Mr. Liebert disregarded ASME B31.8, Section 833 because the CEPA User Manual explains that the equations being used to calculate the combined biaxial stress state or combined equivalent stress are the same general Tresca and Von Mises equations set forth in Section 833.4 of ASME B31.8. Finally, Mr. Liebert's claim that

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9 Deposition of Mr. Liebert, Volume 2 at 283.

10 As noted above, T = 1 for the ANGP because it is being operated at a temperature less than 250°F.

11 Deposition of Mr. Liebert, Volume 2 at 266.

Section 833.4 of the ASME B31.8 is not relevant to the total allowable stress on a pipeline is inconsistent with the leading research on this issue.[12]

Q13. In discovery, Mr. Liebert argued that ASME B31.8 Section 841 at paragraph 841.1.11(e) supports his claim that the combined effective stress is limited to 50% SMYS. Is this correct?

A13. No. Again, Mr. Liebert is mixing apples and oranges, so to speak. Section 841.1.11(e) addresses "Additional Underground Pipe Protection," and states that, "The pipe design factor, *F*, shall be in accordance with Table 841.1.6-2 for the crossing of roads and railroads." For context, some Class Locations, such as Class 1 or 2 locations, have a basic Design Factor of .8, .72 or .6. This means that those pipelines can operate at a Design Pressure that corresponds to an internal hoop stress of 80%, 72% or 60% of SMYS. For crossing of roads and railroads, the Design Factor is reduced for Class 1 or 2 pipe but is 0.5 for Class 3 pipe under all locations. Section 841.1.6, Table 841.1.6-2, and Section 841.1.11(e) are all referring to the Design Factor used in the Design Formula set forth at the beginning of Section 841. As explained above, this is the same Design Formula set forth in 49 C.F.R. § 192.105 and is not a limitation on the assessment of total longitudinal, total circumferential, or combined effective stress from additional stresses such as a HS20+15% vehicle load.

Additionally, Mr. Liebert's discovery responses assert that the Design Factor cited in Section 841.1.11(e) is referring to the total allowable stress because it is referring to the GPTC,

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[12] For example, See **Exhibit VGS-CC-5** (Development of a Pipeline Surface Loading Screening Process) at 9 (citing ASME B31.8 Section 833.4 and other related ASME provisions as a basis for establishing a screening tool with maximum combined effective stress of 90% of SMYS).

CEPA, and other surface loading calculators. Section 841.1.11(e) is not referring to surface loading calculation tools and does not apply the surface loading calculations at all. That paragraph refers to the guidance provided by API RP 1102 and a specific Appendix G-15 of the GPTC Guide Material. Those materials provide guidance about underground pipe protection. This section of the ASME B31.8 is simply stating that such guidance "may be considered." For example, API 1102 provides guidance about pipe bedding and other underground protection. Nothing in Section 841.1.11(e) governs the appropriate assessment of total longitudinal, total circumferential, or combined effective stress.

Q14. Do Mr. Liebert's surface loading calculations demonstrate that the ANGP meets a HS20+15% loading standard?

A14. Yes, they do. When Mr. Liebert submitted his September 10, 2021 testimony, he included an exhibit with calculations. After he changed that testimony on October 4, 2021, he also provided twelve additional calculations he had performed after he retracted his testimony about bedding angle, axle-weight, and soil inputs. Mr. Liebert's new calculations appear to have been calculated on October 3, 2021 and were not filed with the Commission, but I am including them as **Exhibit VGS-CC-6**. The following table summarizes the results of Mr. Liebert's calculations:

Liebert Calculation Title	Input Parameters		Combined Equivalent Stress Value	Combined Equivalent Stress Check (< 90% SMYS / 58,500 psi) Pass (Y/N)
	Depth of Cover	Soil Embedment		
CEPA 1	1.5 ft	30 degrees	53,128	Yes
CEPA 2	1.5 ft	0 degrees	58,802	No
CEPA 3	2 ft	30 degrees	43,302	Yes
CEPA 4	2 ft	0 degrees	46,624	Yes
GPTC 1	1.5 ft	30 degrees	54,526	Yes
GPTC 2	1.5 ft	0 degrees	60,533	No
GPTC 3	2 ft	30 degrees	44,949	Yes
GPTC 4	2 ft	0 degrees	48,663	Yes
GPTC 5	1.7 ft	0 degrees	54,450	Yes
WL 1	4 ft	NA	40,696	Yes
WL 2	3 ft	NA	39,987	Yes
WL 3	2 ft	NA	45,574	Yes

As noted in the table above, all of the calculations and computed combined biaxial stress values are lower than the allowable 58,500 psi—even the ones Mr. Liebert calculated at less than two feet of cover—except for two calculations that included only 1.5 feet of cover and a 0 degree bedding angle. Neither of those inputs models conditions in the Clay Plains Swamp because the depth of cover is greater than two feet and a zero-degree bedding angle is the equivalent of placing the pipe on a ledge or an immovable subsurface like concrete. Accordingly, the calculations that assume a normal bedding angle and a greater depth of cover are more representative. In summary, Mr. Liebert's calculations are consistent with Mott MacDonald's previous sensitivity analysis and calculations, which indicated that the ANGP pipeline is adequate to withstand surface loading of HS20+15% for depths of cover greater than two feet.[13]

Q15. Have you reviewed Mr. Palmer's September 10, 2012 testimony in this case?

A15. Yes.

Q16. Mr. Palmer refers to the testimony of Mr. Berger from August 14, 2013 and claims that the "Class 3 load-bearing standard of .5 is objective, verifiable and unambiguous." Do you agree with Mr. Palmer's testimony?

A16. No. Mr. Palmer does not appear to understand what Mr. Berger is saying, and like Mr. Liebert, confuses the application of a Class 3 Design Factor of .5 with a "load-bearing standard." I reviewed the Berger testimony cited by Mr. Palmer. In that testimony, Mr. Berger responds to the question, "What additional safety measures had VGS previously agreed to?" stating:

> The entire pipeline will be built and operated to Class 3 requirements which include heavier wall pipe, operation of the pipeline at no greater than 50% Specified Minimum Yield Strength (SMYS), hydrostatic pressure testing to 1.5 times the MAOP (maximum allowable operating pressure), and valve spacing at Class 3 intervals. Additionally, they will install remote operating valves with SCADA control at gate stations, and they will have two types of over pressure protection at all gate stations feeding the new distribution systems.

[13] Mr. Liebert's calculations included some using a Wheel Loading Analysis. That tool provides similar combined equivalent stress values at a depth of cover of 2 feet as compared to the CEPA and GPTC calculation tools (approximately 45,000 psi). This value is less than the allowable combined equivalent stress value of 58,500 psi allowed in 833.4. Mr. Liebert appears to argue those calculations demonstrate the ANGP does not meet the standard, but since the combined stress values are approximately the same, there is no basis for that conclusion. Moreover, Mr. Liebert argues that this tool establishes both "maximum allowable internal stress" and "maximum allowable combined stress" limits of 50% and 60% based on Class Location, but that is also not true. The 50% maximum for internal stress is consistent with the Design Formula, but the 60% value has no basis in any code or regulation. It appears to be a limitation specific to this calculation tool that is inconsistent with the total combined stress requirement of ASME B31.8, Section 833.4.

This paragraph is explaining the applicable “Class 3 requirements.” There is no Class 3 “load-bearing standard” as suggested by Mr. Palmer. As I have explained above, the Class 3 requirements include the use of a Design Factor of 0.5 in the Design Formula set forth in 49 C.F.R. 192.105, which governs the Design Pressure of a pipe with certain specifications. Mr. Berger is simply explaining that the Class 3 requirements instruct that the pipeline be operated at a Design Pressure that produces an internal hoop stress no greater than 50% of the SMYS. This is true on the ANGP, where the MOP of 1440 set by VGS is even lower than the allowed Design Pressure of 1590. There are no “Class 3 requirements” that establish a “load bearing standard,” as Mr. Palmer suggests. To the extent Mr. Palmer is referring to the maximum allowable biaxial stress from additional stress like surface loading, that standard is set forth in Section 833 of ASME B31.8 as I explained above.

Q17. Does this conclude your testimony?

A17. Yes.