INTERNATIONAL CONSTRUCTION CONSULTING, LLC

JOB No:
CLIENT: Frontier Energy / ACC
PROJECT: Alpha Crude Connector
SUBJECT: API 1102 Overburden Load Calculations - Regency Line at Truck Unloading

PREPRD.BY: FGL
CHECKD.BY:

DATE: 04-Feb-16
SHEET:

DATA INPUT:		For further details or explanations on the inputs below, refer to API 1102.
2	=	Type 1 for natural gas; Type 2 for liquids
60,000	S =	(psi) yield strength of pipe metallurgy (SMYS) (assumed)
1	Lap=	Lap weld pipe = 2 ; welded pipe =1
ERW		Type of Pipe
16.000	D =	(inch) outside diameter of pipe
0.250	tw =	(inch) wall thickness - allow for corrosion if it is non-oil pipeline (assumed)
0.016	tw/D=	wall thickness over diameter
0	P =	(psig) minimum internal pressure--(in event no internal pressure, can pipe withstand resulting stresses from overburden and earth loads)
1,000	p=	(psig) maximum operating pressure (assumed)
loose sand		Soil Type (text description, i.e. loose sand)
0.72	F=	Design Factor
1	E=	Longitudinal joint factor
120	den=	(#/ft3) density of overburden material [range from 85-125] (API 1102 recommends using 120 unless the value is known to be much higher)
0.069	y=	(#/in3) Unit Weight of Soil (Geotechnical Report or Soils Information)
5.00	H, depth=	(ft) road surface to top of pipe (or maximum depth of horizontal directional drill)
30,000,000	Es =	(psi) modulus of elasticity (from Pipe MTR's or QA report) (if preliminary design and unknown, use table A1 in table workbook)
1.25	Fs =	Factor of Safety (1.25 = 25% typical for d > 3'; 1.5 = 50% is used for d _< 3')
12	Ps=	(kips) Design Wheel Load from Single Axle (Recommended Value is 12: per API 1102)
10	Pt=	(kips) Design Wheel Load from Tandem Axles (Recommended Value is 10: per API 1102)
flexible		Pavement Type (text description, i.e. Rigid (concrete) or Flexible (asphalt)--Refer to API 1102)
85	T1=	(degrees F) Installation Temperature
50	T2=	Maximum or Minimum Operating Temperature
N/A (liquids)	T=	Temperature Derating Factor (See API 1102)
45	API=	(degrees) API gravity
0.0000065	$\alpha_{T=}$	(per degree F) coefficient of thermal expansion of steel (Recommended 6.5 X 10-6)
16.000	Bd=	(inches) Bored Diameter (Diameter of Horizontal Directional Drill, If unkown then this is typically D+2 inches)
0.31	H/Bd=	depth over bored diameter
1.00	Bd/D=	bored diameter over diameter of pipe
0.2	E'=	(ksi)Modulus of Soil Reaction (Recommended 0.5 ksi if unknown)
5	Er=	(ksi) Resilient Modulus (Refer to API 1102; use table A1in table workbook)
0.25	vs=	Poisson's Ratio of pipe material (from pipe MTR's or QA report) (if preliminary design and unknown, use .25)

STEP B: Barlow Stress versus Allowable
The Barlow Stress is the circumferential stress that results from internal pressure.
It is based on the following equation 8b (API 1102):

Barlow Stress

$S_{hi=}$ **p*D/2*tw** for natural gas and liquids

Allowable Barlow Stress (API 1102/ASME B31.4/3)

$S_{hi=}$ **F*e*T*SMYS** for natural gas

$S_{hi=}$ **F*E*SMYS** for liquids

Values as listed from above:

p=	1000
D=	16
tw=	0.25
F=	0.72
E=	1
T=	N/A (liquids)
SMYS=	60000

$S_{hi\ (calculated)=}$	**32,000**	**psig**
$S_{hi(allowable)=}$	**43,200**	**psig**

Result: **OK, Barlow stress meets code**

STEP C: Circumferential Stress due to Earth Load
The Circumferential Stress due to Earth Load is the stress the pipe feels from the soil above it.
It is based on the following equation 1 (API 1102):

Circumferential Stress from Earth Load

$S_{he=}$ $K_{He} \cdot B_e \cdot E_e \cdot y \cdot D$

Using the resulting values from the list below and the figure 3 from tables workbook, select and input Khe below:

Finding Stiffness Factor, Khe:

Values as listed from above:

tw/D=	0.016	
E'=	0.2	
K_{He}	=	2500

Finding Burial Factor, Be:
Using the resulting values from the list below and the figure 4 from tables workbook, select and input Be below:

Values as listed from above:

H/Bd=	0.313	
Soil Type=	loose sand	
Be	=	1.5

Finding Excavation Factor, Ee:
Using the resulting values from the list below and the figure 5 from tables workbook, select and input Be below:

Values as listed from above:

Bd/D=	1.000	
Ee	=	0.83

Circumferential Stress from Earth Load
Using the values listed below the stress is calculated:

	D=	16.000	inches
	y=	0.0694	#/in^3
$S_{he(calculated)}$=		**3458.33**	**psi**

STEP D: Impact Factor, Fi, and Applied Design Surface Pressure, w
Step D is finding the critical case for live loading over the roadway.

Finding Impact Factor, Fi:
Using the depth, H, as listed in the input section and Figure 7 from tables workbook, select and input the Impact Factor, Fi:

H=	5	ft
Fi=	1.50	

Finding Applied Design Surface Pressure, w:
Using Table 1 from API 1102 in tables workbook find the critical case of live loading (axles), select and input Critical Case, Pt and w below:
Refer to API 1102 Section 4.7.2.2.1 for more information.

Excerpt from Section 4.7.2.2.1:
The live, external rail load is the vehicular load, w, applied at the surface of the crossing. It is recommended that Cooper E-80 loading of w=13.9 psi be used, unless the loading is known to be greater. This is the load resulting from the uniform distribution of four 80 kip axles over an area 20 feet by 8 feet. If the load is known to be greater (highway), then the following recommended loading cases should be used. Use Table 1 and find the critical case. Knowing the critical case, the recommnended design loads (heavy trucks) are listed below:

Ps=	12	kips	(when critical case is single axle)
Pt=	10	kps	(when critical case is tandem axle)

The live, external highway load, w, is due to the wheel load, P, applied at the surface of the roadway. For design, only the load from one of the wheel sets needs to be considered. The design wheel load should either be the maximum wheel load from the truck's single axle, Ps, or the maximum wheel load from the truck's tandem axle set:

Pt. Flexible pavement refers to asphalt; rigid pavement refers to concrete.
Since w= P/Ap (API 1102 formula) **where P= design wheel load (lbs) and Ap=area of contact of which wheel load is applied--usually 144 in^2**
Thus

w=	83.3	psi for single axle loading
w=	69.4	psi for tandem axle loading

Critical Case	tandem	(tandem or single)
Pt=	10	kips
w=	69.40	psi

STEP E: Cyclic Stresses, Cyclic Circumferential Stress, ∆SHh, and Cyclic Longitudinal Stress, ∆SLh
The cyclic circumferential stress, ∆SHh, is the circumferential stress that results from the highway vehicular loading.
The formula (API 1102) is listed below:

∆SHh= $K_{Hh*}G_{Hh*}R*L_*F_{i*}w$ psi

The cyclic longitudinal stress, ∆SLh, is the longitudinal stress that results from the highway vehicular loading.

The formula (API 1102) is listed below:

ΔSLh= $K_{Lh*}GL_{h*}R*L_*F_{i*}w$ psi

Calculating ΔSHh

Finding Highway Stiffness Factor,KHh:

Using the values listed below and Figure 14 from tables workbook, select and input KHh below:

tw/D=	0.0156
Er=	5
KHh=	20

Finding Highway Geometry Factor, GHh:

Using the values listed below and Figure 15 from tables workbook, select and input GHh below:

D=	16.00	in
H=	5	ft
GHh=	1.4	

Finding R and L:

Using Table 2 with:

flexible	pavement	
tandem	axles	
H=	5	ft
D=	16	in
Fi=	1.5	
R=	1.1	
L=	1.10	

ΔSHh (calculated) = 3,527 psi

Calculating ΔSLh

Finding Highway Stiffness Factor,KLh:

Using the values listed below and Figure 16 from tables workbook, select and input KLh below:

tw/D=	0.0156
Er=	5
KLh=	12

Finding Highway Geometry Factor, GLh:

Using the values listed below and Figure 17 from tables workbook, select and input GLh below:

D=	16.0000	in
H=	5	ft
GLh=	2.2	

Finding R and L; Using Table 2 with:

flexible	pavement	
tandem	axles	
H=	5	ft
D=	16	in
Fi=	1.5	
R=	1.1	
L=	1.10	

ΔSLh (calculated) = 3,325 psi

STEP F: Circumferential Stress due to Internal Pressurization, Shi

The circumferential stress due to internal pressurization is the stress that acts on the pipe steel itself.

p=	1000	psi
D=	16	inches
tw=	0.25	inches

$S_{hi=}$ **p*(D-tw)/2*tw** for natural gas and liquids

Using the values listed below, the calculated stress is shown:

$S_{hi\ (calculated)=}$	**31,500**	**psi**

STEP G: Principal Stresses, S1,S2, and S3

The principal stresses are the stresses that act in the circumferential, longitudinal, and radial directions.

Circumferential Stress

S1= She+Shi+ΔSHh psi

Longitudinal Stress

S2= ΔSLh-Es αT (T2-T1)+vs(She+Shi) psi

Radial Stress

S3= -P or -MAOP or -MOP psi

Using the values listed below and equations from API 1102, the calculated principal stresses are:

Es=	30000000.00	psi
T1=	85	degree F
T2=	50	degree F
vs=	0.2500000	
$\alpha_{T=}$	0.0000065	per degree F
She=	3458.33	psi
Shi=	32000.00	psi
ΔSLh=	3325.37	psi
p=	1000.00	psi
ΔSHh=	3526.91	psi

Es*αT= 195
She+Shi= 35,458.33

S1 calculated=	38,985	psi
S2 calculated=	19,015	psi
S3calculated=	-1,000	psi

(S1-S2)^2 =(C259-C262)^2
(S2-S3)^2 =(C262-C265)^2
(S3-S1=)^2 =(C265-C259)^2

Effective Stress (Seff)

The effective stress is the vectoral effect of all of the stresses (radial, circumferential, and radial).

Seff= **{½ [(S1-S2)^2 + (S2-S3)^2 + (S3-S1)^2]}^ 1/2** psi

Seff (allowable)= **SMYS*F** psi

Seff (calculated)=	**0**	**psi**

Seff (allowable)=	**43200**	**psi**

Result: **OK, effective stress meet code**

STEP H: Check Fatigue (Welds)

This check is to check fatigue of the welds for both girth welds and longitudinal welds.

Using Table 3 (API 1102) from the tables workbook, select and input Sfg and Sfl below:

Stress of Girth Welds

Sfg= 12000 psi This is the fatigue endurance limit of girth weld per API 1102.

Stress of Longitudinal Welds

Sfl= 21000 psi This is the fatigue endurance limit of longitudinal welds from Table 3 (API 1102) found in the tables workbook.

Allowable Stress Check for Girth Welds

ΔSL <= Sfg x F=	**8640**	**psi**
ΔSL (calculated)=	**3325.3704**	**psi**

Result: **OK, girth weld stress meets code**

Allowable Stress Check for Longitudinal Welds

ΔSL <= Sfl x F=	**15120**	**psi**
ΔSL (calculated)=	**3325.3704**	**psi**

Result: **OK, longitudinal weld stress meets code**