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Wind Information:

Wind Velocity	33.000 M./sec.
Velocity Factor	0.37842
Wind Pressure	0.80031 KPa
Area Exposed to Wind	16.290 m.^2
Sect 5.9.7.1 Wind Moment on Tank	30351. N.m.
Wind Shear Force Acting on Tank	13037. N.
Wind Girder Height Reduction Factor	1.0000

Material Property Information:

The following material properties have been modified in accordance with API-650 (and API-653 where applicable).

Course Number	Material Name	Design Stress (Sd or Sts) (KPa)	Test Stress (St) (KPa)	App M Reduction
1	A-516,55	0.13789E+06	0.15513E+06	1.0000
2	A-516,55	0.13789E+06	0.15513E+06	1.0000

Shell Course Thickness Data - One Foot Method

Course #	Thickness Values for Three Cases Design (mm.)	Test (mm.)	User (mm.)	Min. Temp (deg C)	Status Pass/Fail
1	6.0000	6.0000	6.0000	-40.0	PASS
2	5.0000	5.0000	6.0000	-40.0	PASS

Note, "ANALYSIS" mode has been activated. From this point on, the user specified thicknesses will be used for all calculations. The above values for DESIGN and TEST thicknesses are for reference purposes only.

Shell Course Allowed Fluid Heights:

Course	Fluid Heights for Three Cases Design (m.)	Test (m.)	Required (m.)
1	32.036	54.566	4.1698
2	32.036	54.566	1.9198

Maximum Allowed Fluid Height of Entire Tank For:

Design Thickness Case	32.036 m.
Test Thickness Case	54.566 m.
Required fluid height	4.1698 m.

Base Plate Details - Shell Weight & Center of Gravity:

Required Annular Base Plate Thickness	6.0000 mm.
(from API-650 Table 5-1 plus corrosion)	

```
  Annular Baseplate thickness user specified .........         8.0000 mm.
  Annular Base Plate Width per 5.5.2 .................         791.50 mm.
   ( 2 + ThkCrs1 + max[ 24, (2tb * sqrt(Fy/2YHG))] )
```

Note:
The user specified baseplate thickness was used to compute the weight of the annular baseplate.

```
  Weight of Shell + Nozzles ..........................         22853. N.
  Total Weight of all Nozzles ........................        0.00000 N.
  Center of Gravity (Shell+Nozzles) ..................         2.2500 m.
```

Wind Overturning Stability Check:

```
 ---------------------------------------------------------------------------
  Corroded Shell Weight + %Roof - Uplift .............         427.24 N.
  Line Load ......................................[wa]         10.316 N./cm.
  Moment due to wind (hor+ver) press .............[Mw]         20710. N.m.
  Moment due to wind (hor) press ................[Mws]         11558. N.m.
  Moment due to internal pressure ...............[Mpi]    0.11786E+06 N.m.
  Moment due to tank liquid ......................[Mf]         19852. N.m.
  Moment due to shell & roof ....................[Mdl]         39995. N.m.
```

Wind Girder Information:

```
 ---------------------------------------------------------------------------
  For "open top" tanks ...
  Required Section Modulus, Top Girder ...............         1207.2 mm.^3
  Table 5-20 Detail, B value .........................     a     0.00 mm.
  Table 5-20 Shape name (if applicable)...............    2.5x2.5x.25

  Maximum Height of Unstiffened Shell ................         336.83 m.
```

Wind Girder - Transformed Section Method

```
  Number of Intermediate Girders Reqd ................              0
```

Weight Summary:

```
 ---------------------------------------------------------------------------
 Shell (Corroded) ...................................          22853. N.
 Shell (Non-Corroded) ...............................          22853. N.
 Annular Base Plate .................................           4303. N.
 Bottom Plate .......................................           4705. N.
 Nozzles ............................................              0. N.
 Roof Plates ........................................           4512. N.
 Roof Framing/Structure .............................              0. N.
 Shell Attachments ..................................              0. N.
 Shell + Roof Insulation ............................              0. N.
 Operating Fluid ....................................         528548. N.
 Water Weight .......................................         422915. N.

 Operating Weight (Non-Corroded) ....................         564922. N.
 Test Weight (Non-Corroded, Filled to Top)...........         459289. N.
 Empty Weight (Non-Corroded) ........................          36374. N.
```

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TANK - Roof Design/Analysis Data

```
 Corroded Roof Plate Thickness as given in input              5.99999 mm.
 New Roof Plate Thickness as given in input                   5.99999 mm.

 SELF-SUPPORTING CONE ROOF
 Roof thickness per  5.10.5, Cone Roof..............          5.0000 mm.

 Total weight of Roof Plates .......................          4512.3 N.
```
Based on user input thickness
```
 User Specified Design Roof Load ...................         0.46188 KPa
```
including user plate thickness
```
 Computed Design Roof Load .........................         0.46188 KPa
```
including user plate thickness

Roof Evaluations - Appendix F

```
 --------------------------------------------------------------------------------
 Uplift force due to internal pressure..............          67346. N.
 Total weight resisting uplift .....................          27366. N.

 Max Design Pressure,  roof/shell joint.............          31.795 in of H2O
 Max Design Pressure,  roof/shell joint.............          7.9157 KPa
   (According to F.4.1)

 Compression Ring Failure Pressure .................          49.740 in of H2O
 Compression Ring Failure Pressure .................          12.384 KPa
   (According to F.6)

 NOTE, this tank requires an Anchored Base !!!
 Per F.7, allowed pressure is: .....................          17.236 KPa

 Required Compression Areas, Roof/Shell Junction
 Area as per Section F.5  ..........................          438.51 mm.^2
 Area as per Section 5.10.5, Cone Roof..............          32.320 mm.^2

 Frangible Roof-to-Shell Junction Area Limit:
 Area as per Section 5.10.2.6 ......................          99.732 mm.^2

 Top Angle Requirement Per 5.1.5.9.e                        2x2x3/16
 (This is a minimum angle size based solely on the tank
  diameter.  Other criteria may require a larger section.)
```

API 650 Appendix F Calculations:

Nominal Tank Weight
```
  = Shell Weight + Roof Weight + Framing Weight + Attachment Weight
  = 5137.9 + 1014.4 + .0 + .0
  = 6152.4 lb.  [27365.7 N.]
```

Note: The uplift was greater than the total weight.

Appendix M Yield Stress reduction factor, M.3.6 [Mfact]:
```
  = Yield Reduction Factor * Fy / Fyamb
  = 1.000 * 30000.0/30000.0
  = 1.000 Must be less than or equal to 1.0
```

Note: Using the new roof weight in Appendix F calcs. There was no corrosion allowance specified on the roof plates.

Required Area of the Roof/Shell Junction per F.5.1 [A]:
```
  = D^2(Pi-0.245*DLR/D^2)/(0.962*Fy*Mfact(tan(theta)))
  = 11.5^2(28.117 -0.245*1014/11.5^2)/(0.962 *30000.0 *1.000 (tan(10.00 )))
  = .680 in.^2  [438.514 mm.^2]
```

Maximum Frangible Roof Area 5.10.2.6 [A]:
```
  = DLs/( 2 * pi * Fy * Mfact * tan(theta))
  = 5137.9/( 2 * pi * 30000.0 * 1.000 * tan(10.00 ))
  = .155 in.^2  [99.732 mm.^2]
```

Design Pressure per F.4.1 [P]:
```
  = (0.962 * A * Fy * Mfact * tan(theta))/(D^2) + 0.245 * DLR/D^2
  = (0.962*.775*30000.0*1.000*tan(10.00))/(11.5^2)+0.245*1014/11.5^2
  = 31.795 in. of water  [807.582 mm. of water]
  = 1.148 psi  [7.916 KPa]
```

Note: Design Pressure was less than maximum computed per F.4.1

Note: The tank is considered anchored since anchor bolts are specified, therefore the Appendix F.4.2 calculations are not required.

Calculated failure Pressure from F.6 [Pf]:
```
  = 1.6 * P - (0.147 * Dlr)/D^2
  = 1.6 * 31.795 - (0.147 * 1014 )/11.5^2
  = 49.740 in. of water  [1263.406 mm. of water]
```

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Anchor Bolt Results - Section 5.12

Load Case	Uplift (N.)	Allowable Bolt Stress (KPa)	Load/Bolt (N.)
Design Pressure	48716.7	103419.	3044
Test Pressure	39915.3	137892.	2494
Design Press + Wind Load	18365.0	137892.	1147

Anchor Bolt Results - Section 5.12

Load Case	Number of Bolts	Bolt Diameter (mm.)	Bolt Stress (KPa)
Design Pressure	16	31.750	7791
Test Pressure	16	31.750	6383
Design Press + Wind Load	16	31.750	2937

Final Anchor Bolt Spacing .... (m.) 0.69

Specified number of user bolts is sufficient.
Specified user bolt diameter is sufficient.

Bolt Load Calculations per API 650 Table 5.21b:

Compute weight per table 5.21b [W1]:
```
  = Corr. Shell Wght + Attachment Wght + ( Corr. Roof Wght + Ins. ) * %
  = 5137.9 + .0 + ( 1014.4 + .0 ) * 1.00
  = 6152.4 lb.  [27365.7 N.]
```

Compute weight per table 5.21b [W2]:
```
  = (Corr. Shell Wght + Ins. Wght)+Att. Wght+(Roof Wght + Fram Wght + Ins.)*%
  = ( 5137.9 ) + .0 + ( 1014.4 + .0 + .0 )*1.00
  = 6152.4 lb.  [27365.7 N.]
```

Compute weight per table 5.21b [W3]:
```
  = Nom. Shell Wght + Attachment Wght + (Nom. Roof Wght + Ins. Wght) * %
  = 5137.9 + .0 + (1014.4 + .0 ) * 1.00
  = 6152.4 lb.  [27365.7 N.]
```

Net Uplift due to Design Pressure:
```
  = [Pi * D^2 * 4.08 ] - W1
  = [31.795 * 11.5^2 * 4.08 ] - 6152.4
  = 10952.5 lb.  [48716.7 N.]
```

Net Uplift due to Test Pressure:
```
  = [Pt * D^2 * 4.08 ] - W3
  = [28.117 * 11.5^2 * 4.08 ] - 6152.4
  = 8973.8 lb.  [39915.3 N.]
```

Note that P and Pt above are in inches of water.

Net Uplift due to Wind Pressure:
```
  = PWR * D^2 * 4.08 + [4 * MWS/D] - W2
```

```
  = 2.183 * 11.5^2 * 4.08 + [4 * 8524/11.5 ] - 6152.4
  = -2008.4 lb.  [-8933.3 N.]
```

Net Uplift due to Design Pressure + Wind:

```
  = [Fp(P + PWR)D^2 * 4.08] + [4*MWS/D] - W1
  = [.40(31.795+2.18)11.5^2*4.08]+[4*8524/11.5]-6152.4
  = 4128.8 lb.  [18365.0 N.]
```

Note:
The Frangibility case was not analyzed because the design pressure was zero or the frangibilty requirements in API 650 paragraph 5.10.2.6 were not met.

Initial Bolt Design for each Load Case (mm., KPa & mm.^2):

Anchor Bolt Database: TEMA-Imperial

Case	Number	Diameter	Stress	Bolt Area
Design Pressure	16	31.750	7791.4	390.8018
Test Pressure	16	31.750	6383.7	390.8018
Design Press + Wind Load	16	31.750	2937.1	390.8018

Final Bolt Design for each Load Case (mm., KPa & mm.^2):

Case	Number	Diameter	Stress	Bolt Area
Design Pressure	16	31.750	7791.4	390.8018
Test Pressure	16	31.750	6383.7	390.8018
Design Press + Wind Load	16	31.750	2937.1	390.8018

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Nozzle Flexibilities & Loads - Appendix P:

Load Condition Nozzle: 1		Design	Test	User
Radial Stiffness	(N./cm.)	0.51254E+06	0.51254E+06	0.51254E+06
Long. Bending Stiff	(N.m./deg)	0.26069E+06	0.26069E+06	0.26069E+06
Circ. Bending Stiff	(N.m./deg)	0.23002E+06	0.23002E+06	0.23002E+06
Radial Deflection	(mm.)	0.66316E-01	0.66316E-01	0.66316E-01
Long. Rotation	(deg.)	0.11160E-02	0.11160E-02	0.11160E-02
Radial Force Multp	(1/N.)	0.71700E-04	0.71700E-04	0.71700E-04
Long. Moment Multp	(1/N.m.)	0.18209E-04	0.18209E-04	0.18209E-04
Circ. Moment Multp	(1/N.m.)	0.23899E-04	0.23899E-04	0.23899E-04
Radial Force Limit	(N.)	1394.7	1394.7	1394.7
+Long. Moment Limit	(N.m.)	5491.9	5491.9	5491.9
-Long. Moment Limit	(N.m.)	-5491.9	-5491.9	-5491.9
Circ. Moment Limit	(N.m.)	4184.3	4184.3	4184.3

Nozzle Stiffness Calculations:

Design Case for Nozzle, 1 per Appendix P:

Nozzle stiffness coefficients per P.2.4:

Outside radius of nozzle [a]:
```
  = D / 2
  = 23.6/2
  = 11.8 in.  [600.0 mm.]
```

Nominal tank radius [R]:
```
  = Nominal tank diameter / 2
  = 137.8/2
  = 68.9 in.  [3500.0 mm.]
```

L / 2a coefficient:
```
  = L / 2 * a
  = 23.622/2 * 11.811
  = 1.0
```

As L/2a <= 1.0, use first set of curves.

a / R coefficient:
```
  = a / R
  = 11.8/68.898
  = .171
```

R / t coefficient:
```
  = R / t
  = 68.898/.472
  = 145.8
```

From figure P-2A [KR/E(2a)]:
```
  =   0.420E-03
```

From figure P-2B [KL/E(2a)^3]:

```
  =   0.340E-03
```

From figure P-2C [KC/E(2a)^3]:
```
  =   0.300E-03
```

Stiffness coefficient for the radial thrust load per P.2.9.2.1 [KR]:
```
  = Coeff. from graph * E * 2 * a
  = 0.420E-03 * 29500000 * 2 * 11.811
  = 0.29268E+06 lbf./in.  [0.51254E+06 N./cm.]
```

Stiffness coefficient for the longitudinal moment per P.2.9.2.1 [KL]:
```
  = Coeff. from graph * E * ( 2.0 * a )^3
  = 0.340E-03 * 29500000 * ( 2.0 * 11.811 )^3
  = 0.23074E+07 in.lbf./deg  [0.31285E+07 N.m./deg]
```

Stiffness coefficient for the circumferential moment per P.2.9.2.1 [KC]:
```
  = Coeff. from graph * E * ( 2 * a )^3
  = 0.300E-03 * 29500000 * ( 2 * 11.811 )^3
  = 0.20360E+07 in.lbf./deg  [0.27604E+07 N.m./deg]
```

Characteristic parameter per P.2.3 [beta]:
```
  = 1.285 / (Rt)^0.5
  = 1.285/(68.898 * .472 )^0.5
  = 0.22523E+00 1/in.  [0.88674E-02 1/mm.]
```

Unrestrained radial growth of the shell per P.2.5.1 [W]:
```
  = (0.036*G*H*R^2)/Et
    * [1-(e^-(beta*L)) * cos(beta*L) - (L/H)]
    + alpha * R * delta[T]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [1-(e^-(.225 *23.622 )) * cos(.225 *23.622 ) - (23.622/164.17 )]
    + 0.000E+00 * 68.898 * .000
  = .00261 in.  [.06632 mm.]
```

Unrestrained shell rotation of the shell per P.2.5.2 [theta]:
```
  = (0.036*G*H*R^2)/E*t
    * [(1/H)-(beta*e^-(beta*L))
    * [cos(beta*L)+sin(beta*L)]]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [(1/164.167 )-(.225 *e^-(.225 *23.622 ))
    * [cos(.225 *23.622 )+sin(.225 *23.622 )]]
  =  0.11160E-02 deg
```

Value of lamda per P.2.3 [lamda]:
```
  = a/(Rt)^0.5
  = 11.811/(68.898 * .472 )^0.5
  = 2.070
```

Coefficient XA per P.2.3:
```
  = L + a
  = 23.622 + 11.811
  = 35.433 in.  [900.000 mm.]
```

Coefficient XB per P.2.3:
```
  = L - a
  = 23.622 - 11.811
  = 11.811 in.  [300.000 mm.]
```

Coefficient XC per P.2.3:
```
  = L
  = 23.622 in.  [600.000 mm.]
```

Coefficients YF and YL from figure P-4A based on lamda:
```
  YF = .960
  YL = 2.100
```

Coefficient YC from figure P-4B based on lamda:
```
  YC = 1.600
```

Pressure end load on the opening per P.2.3:
```
  = pi * a^2 * P
  = 3.1415 * 11.811^2 * 7.714
  = 3380.841 lbf.  [15037.979 N.]
```

Radial force nomogram limit values per figure P-3A:
```
  = max[(1 - 0.75)(XA / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(35.433/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Longitudinal nomogram limit values per figure P-3A:
```
  = max[(1 - 0.75)(XB / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(11.811/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Circumferential moment nomogram limit value per figure P-3B:
```
  = max[(1 - 0.75)(XC / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(23.622/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Radial force multiplier per figure P-3A:
```
  = lamda / (2 * YF * FP)
  = 2.070/(2 * .960 * 3380.841 )
  = 0.31892E-03 1/lbf.  [0.71700E-04 1/N.]
```

Longitudinal moment multiplier per figure P-3A:
```
  = lamda / (a / 12.0 * YL * FP)
  = 2.070/(11.811/12.0 * 2.100 * 3380.841 )
  = 0.29625E-03 1/ft.lb.  [0.18209E-04 1/N.m.]
```

Circumferential moment multiplier per figure P-3B:
```
  = lamda / (a * 12.0 * YC * FP)
  = 2.070/(11.811 * 12.0 * 1.600 * 3380.841 )
  = 0.38883E-03 1/ft.lb.  [0.23899E-04 1/N.m.]
```

Radial force limit [ML = 0 and MC = 0] per figure P-3A [FRmax]:
```
  = Radial force nomogram limit value / Radial force multp.
  = .100/0.319E-03
  = 0.31356E+03 lbf.  [0.13947E+04 N.]
```

Positive Long. moment limit [MC = 0 and FR = 0] per figure P-3A [MLmax]:
```
  = Long. moment nomogram limit value / Long. moment multiplier
  = .100/0.296E-03
  = 0.33755E+03 ft.lb.  [0.54919E+04 N.m.]
```

Negative Long. moment limit [ML = 0 and MC = 0] per figure P-3A [MLmin]:
```
  = - Radial Force nomogram limit value / Long. moment multiplier
  = -.100/0.296E-03
  = -.33755E+03 ft.lb.  [-0.54919E+04 N.m.]
```

Circ. moment limit [ML = 0 and FR = 0] per figure P-3B [MCmax]:
```
  = Circ. moment nomogram limit value / Circ. moment multiplier
  = .100/0.389E-03
  = 0.25718E+03 ft.lb.  [0.41843E+04 N.m.]
```

Test Case for Nozzle, 1 per Appendix P:

Nozzle stiffness coefficients per P.2.4:

Outside radius of nozzle [a]:
  = D / 2
  = 23.6/2
  = 11.8 in. [600.0 mm.]

Nominal tank radius [R]:
  = Nominal tank diameter / 2
  = 137.8/2
  = 68.9 in. [3500.0 mm.]

L / 2a coefficient:
  = L / 2 * a
  = 23.622/2 * 11.811
  = 1.0

As L/2a <= 1.0, use first set of curves.

a / R coefficient:
  = a / R
  = 11.8/68.898
  = .171

R / t coefficient:
  = R / t
  = 68.898/.472
  = 145.8

From figure P-2A [KR/E(2a)]:
  =   0.420E-03

From figure P-2B [KL/E(2a)^3]:
  =   0.340E-03

From figure P-2C [KC/E(2a)^3]:
  =   0.300E-03

Stiffness coefficient for the radial thrust load per P.2.9.2.1 [KR]:
  = Coeff. from graph * E * 2 * a
  = 0.420E-03 * 29500000 * 2 * 11.811
  = 0.29268E+06 lbf./in. [0.51254E+06 N./cm.]

Stiffness coefficient for the longitudinal moment per P.2.9.2.1 [KL]:
  = Coeff. from graph * E * (2.0 * a)^3
  = 0.340E-03 * 29500000 * (2.0 * 11.811)^3
  = 0.23074E+07 in.lbf./deg [0.31285E+07 N.m./deg]

Stiffness coefficient for the circumferential moment per P.2.9.2.1 [KC]:
  = Coeff. from graph * E * (2 * a)^3
  = 0.300E-03 * 29500000 * (2 * 11.811)^3
  = 0.20360E+07 in.lbf./deg [0.27604E+07 N.m./deg]

Characteristic parameter per P.2.3 [beta]:
  = 1.285 / (Rt)^0.5
  = 1.285/(68.898 * .472)^0.5
  = 0.22523E+00 1/in. [0.88674E-02 1/mm.]

Unrestrained radial growth of the shell per P.2.5.1 [W]:

```
  = (0.036*G*H*R^2)/Et
    * [1-(e^-(beta*L)) * cos(beta*L) - (L/H)]
    + alpha * R * delta[T]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [1-(e^-(.225 *23.622 )) * cos(.225 *23.622 ) - (23.622/164.17 )]
    + 0.000E+00 * 68.898 * .000
  = .00261 in.  [.06632 mm.]
```

Unrestrained shell rotation of the shell per P.2.5.2 [theta]:

```
  = (0.036*G*H*R^2)/E*t
    * [(1/H)-(beta*e^-(beta*L))
    * [cos(beta*L)+sin(beta*L)]]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [(1/164.167 )-(.225 *e^-(.225 *23.622 ))
    * [cos(.225 *23.622 )+sin(.225 *23.622 )]]
  =  0.11160E-02 deg
```

Value of lamda per P.2.3 [lamda]:

```
  = a/(Rt)^0.5
  = 11.811/(68.898 * .472 )^0.5
  = 2.070
```

Coefficient XA per P.2.3:

```
  = L + a
  = 23.622 + 11.811
  = 35.433 in.  [900.000 mm.]
```

Coefficient XB per P.2.3:

```
  = L - a
  = 23.622 - 11.811
  = 11.811 in.  [300.000 mm.]
```

Coefficient XC per P.2.3:

```
  = L
  = 23.622 in.  [600.000 mm.]
```

Coefficients YF and YL from figure P-4A based on lamda:

```
  YF = .960
  YL = 2.100
```

Coefficient YC from figure P-4B based on lamda:

```
  YC = 1.600
```

Pressure end load on the opening per P.2.3:

```
  = pi * a^2 * P
  = 3.1415 * 11.811^2 * 7.714
  = 3380.841 lbf.  [15037.979 N.]
```

Radial force nomogram limit values per figure P-3A:

```
  = max[(1 - 0.75)(XA / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(35.433/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Longitudinal nomogram limit values per figure P-3A:

```
  = max[(1 - 0.75)(XB / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(11.811/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Circumferential moment nomogram limit value per figure P-3B:

```
  = max[(1 - 0.75)(XC / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(23.622/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Radial force multiplier per figure P-3A:
```
  = lamda / (2 * YF * FP)
  = 2.070/(2 * .960 * 3380.841 )
  = 0.31892E-03 1/lbf.  [0.71700E-04 1/N.]
```

Longitudinal moment multiplier per figure P-3A:
```
  = lamda / (a / 12.0 * YL * FP)
  = 2.070/(11.811/12.0 * 2.100 * 3380.841 )
  = 0.29625E-03 1/ft.lb.  [0.18209E-04 1/N.m.]
```

Circumferential moment multiplier per figure P-3B:
```
  = lamda / (a * 12.0 * YC * FP)
  = 2.070/(11.811 * 12.0 * 1.600 * 3380.841 )
  = 0.38883E-03 1/ft.lb.  [0.23899E-04 1/N.m.]
```

Radial force limit [ML = 0 and MC = 0] per figure P-3A [FRmax]:
```
  = Radial force nomogram limit value / Radial force multp.
  = .100/0.319E-03
  = 0.31356E+03 lbf.  [0.13947E+04 N.]
```

Positive Long. moment limit [MC = 0 and FR = 0] per figure P-3A [MLmax]:
```
  = Long. moment nomogram limit value / Long. moment multiplier
  = .100/0.296E-03
  = 0.33755E+03 ft.lb.  [0.54919E+04 N.m.]
```

Negative Long. moment limit [ML = 0 and MC = 0] per figure P-3A [MLmin]:
```
  = - Radial Force nomogram limit value / Long. moment multiplier
  = -.100/0.296E-03
  = -.33755E+03 ft.lb.  [-0.54919E+04 N.m.]
```

Circ. moment limit [ML = 0 and FR = 0] per figure P-3B [MCmax]:
```
  = Circ. moment nomogram limit value / Circ. moment multiplier
  = .100/0.389E-03
  = 0.25718E+03 ft.lb.  [0.41843E+04 N.m.]
```

User Case for Nozzle, 1 per Appendix P:
```
 -----------------------------------------------------------------------------
```

Nozzle stiffness coefficients per P.2.4:

Outside radius of nozzle [a]:
```
  = D / 2
  = 23.6/2
  = 11.8 in.  [600.0 mm.]
```

Nominal tank radius [R]:
```
  = Nominal tank diameter / 2
  = 137.8/2
  = 68.9 in.  [3500.0 mm.]
```

L / 2a coefficient:
```
  = L / 2 * a
  = 23.622/2 * 11.811
  = 1.0
```

As L/2a <= 1.0, use first set of curves.

a / R coefficient:
```
  = a / R
  = 11.8/68.898
  = .171
```

R / t coefficient:
```
  = R / t
  = 68.898/.472
  = 145.8
```

From figure P-2A [KR/E(2a)]:
```
  =   0.420E-03
```

From figure P-2B [KL/E(2a)^3]:
```
  =   0.340E-03
```

From figure P-2C [KC/E(2a)^3]:
```
  =   0.300E-03
```

Stiffness coefficient for the radial thrust load per P.2.9.2.1 [KR]:
```
  = Coeff. from graph * E * 2 * a
  = 0.420E-03 * 29500000 * 2 * 11.811
  = 0.29268E+06 lbf./in.  [0.51254E+06 N./cm.]
```

Stiffness coefficient for the longitudinal moment per P.2.9.2.1 [KL]:
```
  = Coeff. from graph * E * ( 2.0 * a )^3
  = 0.340E-03 * 29500000 * ( 2.0 * 11.811 )^3
  = 0.23074E+07 in.lbf./deg  [0.31285E+07 N.m./deg]
```

Stiffness coefficient for the circumferential moment per P.2.9.2.1 [KC]:
```
  = Coeff. from graph * E * ( 2 * a )^3
  = 0.300E-03 * 29500000 * ( 2 * 11.811 )^3
  = 0.20360E+07 in.lbf./deg  [0.27604E+07 N.m./deg]
```

Characteristic parameter per P.2.3 [beta]:
```
  = 1.285 / (Rt)^0.5
  = 1.285/(68.898 * .472 )^0.5
  = 0.22523E+00 1/in.  [0.88674E-02 1/mm.]
```

Unrestrained radial growth of the shell per P.2.5.1 [W]:
```
  = (0.036*G*H*R^2)/Et
    * [1-(e^-(beta*L)) * cos(beta*L) - (L/H)]
    + alpha * R * delta[T]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [1-(e^-(.225 *23.622 )) * cos(.225 *23.622 ) - (23.622/164.17 )]
    + 0.000E+00 * 68.898 * .000
  = .00261 in.  [.06632 mm.]
```

Unrestrained shell rotation of the shell per P.2.5.2 [theta]:
```
  = (0.036*G*H*R^2)/E*t
    * [(1/H)-(beta*e^-(beta*L))
    * [cos(beta*L)+sin(beta*L)]]
  = (0.036*1.520 *164.167 *68.898^2)/29500000 *.472
    * [(1/164.167 )-(.225 *e^-(.225 *23.622 ))
    * [cos(.225 *23.622 )+sin(.225 *23.622 )]]
  =  0.11160E-02 deg
```

Value of lamda per P.2.3 [lamda]:
```
  = a/(Rt)^0.5
  = 11.811/(68.898 * .472 )^0.5
  = 2.070
```

Coefficient XA per P.2.3:
```
  = L + a
  = 23.622 + 11.811
  = 35.433 in.  [900.000 mm.]
```

Coefficient XB per P.2.3:
```
  = L - a
  = 23.622 - 11.811
  = 11.811 in.  [300.000 mm.]
```

Coefficient XC per P.2.3:
```
  = L
  = 23.622 in.  [600.000 mm.]
```

Coefficients YF and YL from figure P-4A based on lamda:
```
  YF = .960
  YL = 2.100
```

Coefficient YC from figure P-4B based on lamda:
```
  YC = 1.600
```

Pressure end load on the opening per P.2.3:
```
  = pi * a^2 * P
  = 3.1415 * 11.811^2 * 7.714
  = 3380.841 lbf.  [15037.979 N.]
```

Radial force nomogram limit values per figure P-3A:
```
  = max[(1 - 0.75)(XA / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(35.433/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Longitudinal nomogram limit values per figure P-3A:
```
  = max[(1 - 0.75)(XB / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(11.811/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Circumferential moment nomogram limit value per figure P-3B:
```
  = max[(1 - 0.75)(XC / (Rt)^0.5), 0.1]
  = max[(1 - 0.75)(23.622/(68.898 *.472 )^0.5), 0.1]
  = .100
```

Radial force multiplier per figure P-3A:
```
  = lamda / (2 * YF * FP)
  = 2.070/(2 * .960 * 3380.841 )
  = 0.31892E-03 1/lbf.  [0.71700E-04 1/N.]
```

Longitudinal moment multiplier per figure P-3A:
```
  = lamda / (a / 12.0 * YL * FP)
  = 2.070/(11.811/12.0 * 2.100 * 3380.841 )
  = 0.29625E-03 1/ft.lb.  [0.18209E-04 1/N.m.]
```

Circumferential moment multiplier per figure P-3B:
```
  = lamda / (a * 12.0 * YC * FP)
  = 2.070/(11.811 * 12.0 * 1.600 * 3380.841 )
  = 0.38883E-03 1/ft.lb.  [0.23899E-04 1/N.m.]
```

Radial force limit [ML = 0 and MC = 0] per figure P-3A [FRmax]:
```
  = Radial force nomogram limit value / Radial force multp.
  = .100/0.319E-03
  = 0.31356E+03 lbf.  [0.13947E+04 N.]
```

Positive Long. moment limit [MC = 0 and FR = 0] per figure P-3A [MLmax]:
```
  = Long. moment nomogram limit value / Long. moment multiplier
  = .100/0.296E-03
  = 0.33755E+03 ft.lb.  [0.54919E+04 N.m.]
```

Negative Long. moment limit [ML = 0 and MC = 0] per figure P-3A [MLmin]:
```
  = - Radial Force nomogram limit value / Long. moment multiplier
  = -.100/0.296E-03
  = -.33755E+03 ft.lb.  [-0.54919E+04 N.m.]
```

Circ. moment limit [ML = 0 and FR = 0] per figure P-3B [MCmax]:
```
  = Circ. moment nomogram limit value / Circ. moment multiplier
  = .100/0.389E-03
  = 0.25718E+03 ft.lb.  [0.41843E+04 N.m.]
```

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Anchor Chair Cap Input Values:

Thickness of Gusset Plates	j	13.000	mm.
Width of Gussets at Top Plate	twdt	120.000	mm.
Width of Gussets at Base Plate	bwdt	80.000	mm.
Height of Gussets	hg	150.000	mm.
Height of Gussets plus top Plate thickness	h	163.000	mm.
Distance between Gussets	g	120.000	mm.
Dist. from Bolt Center to Gusset (Rg/2)	cg	60.000	mm.
External Corrosion Allowance	Ca	0.0000	mm.
Top Plate allowable stress	S	250000.0	KPa
Number of Gussets per bolt	ng	2	
Bottom Shell Course Thickness		6.000	mm.
Shell Course Corrosion Allowance		0.0000	mm.
Thickness of Tank Baseplate	m	6.000	mm.
Thickness of Top Plate	c	13.000	mm.
Radial Width of the Top Plate	b	120.000	mm.
Circumferential Width of the Top Plate	a	220.000	mm.
Anchor Bolt Diameter	d	31.750	mm.

Anchor Chair Cap and Gusset Plate Analysis Results:

Required Thickness of Top Chair Cap Plate per AISI:

```
P          Bolt Load
e          Bolt eccentricity (center of bolt to shell OD)
Sb         Allowable Bending Stress ( 1.5 * S )
g          Distance between Gussets
d          Bolt Diameter
f          Distance from Edge of Hole to Tip of Top Plate
```

Top Chair Cap Plate Required Thickness per AISI [Tc]:

```
= ( P /( Sb * f ) * ( 0.375 * g - 0.22 * d ))½ + c
= (9134/(374999*107.125)*(0.375*120.00-0.22*31.750))½+.000
= 2.9401 mm.
```

Stress in the Top Plate at given Thickness [Stpl]:

```
= P( 0.375 * b - 0.22 * d ) / f / ( c - Ca )²
= 9134 (0.375*120.000 - 0.22*31.750 )/107.125/(13.000 -.000 )²
= 19180.9 KPa, must be less than 375000.0 KPa
```

Required Gusset Thickness per AISI:
Gusset Plate Thickness is the greater of(0.5 in (12mm), 0.04(hg))

```
= max( 12.700, 0.04( 150.000 ) ) + Ca
= 12.700 mm.
```

For gusset plates the following must also be true [English Units]:
Gusset Thickness * Average Gusset Width >= (P/1000)/25

```
= ( .512 - .000 ) * 3.937 > ( 2053.595/1000)/25 ) Passed
= 2.015 > .082 Passed
```

Local Stress at the Top Plate per AISI, including axial Stress [S]:

```
= P*e/t²[1.32*Z/(1.43*a*h²/(R*t)
  + (4(a)(h)²)·³³³ + 0.031 /(R*t)½
= 9134*-3.00/6.00²[1.32*.92/(1.43*220.00*(163.00)²/(1750.00*6.00)
  + (4*220.00 (163.00 )²)⁰·³³³ + 0.031/(1750.00 *6.00 )½
= -1082.5 KPa
```

Intermediate Value [Z]:

```
= 1/[(0.177*a*m/(R*t)½)*(m/t)² + 1]
= 1/[(0.177*220.000*6.000/(1750.000*6.000)½)*(6.000/6.000)²+1]
```

```
    = .918
```

Radial Distance [e]:

```
    = ( Dc - Ds ) / 2
    = ( 3494.000 - 3500.000 )/2
    = -3.000 mm.
```

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Determine Maximum allowed Fluid Heights:

For Course # 1, Operating Case

Allowed fluid height above this course based on the 1ft method
```
  = (Td - ca)Sd/(2.6 * D * G ) + X/12
  = (.2362 - .0000 )20000.00/(2.6 * 11.5 * 1.520 ) + 12.000/12
  = 105.106 ft.  [32.036 m.]
```

For Course # 1, Hydro Case, not corroded

Allowed fluid height above this course based on the 1ft method
```
  = (Td - ca)Sd/(2.6 * D * G ) + X/12
  = (.2362 - .0000 )22500.00/(2.6 * 11.5 * 1.000 ) + 12.000/12
  = 179.022 ft.  [54.566 m.]
```

For Course # 2, Operating Case

Allowed fluid height above this course based on the 1ft method
```
  = (Td - ca)Sd/(2.6 * D * G ) + X/12
  = (.2362 - .0000 )20000.00/(2.6 * 11.5 * 1.520 ) + 12.000/12
  = 105.106 ft.  [32.036 m.]
```

For Course # 2, Hydro Case, not corroded

Allowed fluid height above this course based on the 1ft method
```
  = (Td - ca)Sd/(2.6 * D * G ) + X/12
  = (.2362 - .0000 )22500.00/(2.6 * 11.5 * 1.000 ) + 12.000/12
  = 179.022 ft.  [54.566 m.]
```

Appendix M Yield Stress reduction factor, M.3.6 [Mfact]:
```
  = Yield Reduction Factor * Fy / Fyamb
  = 1.000 * 30000.0/30000.0
  = 1.000 Must be less than or equal to 1.0
```

Balanced Design Snow Load [Sb]:
```
  = 0.84 * S
  = 0.84 * .000
  = .000 psf
```

Unbalanced Design Snow Load [Su]:
```
  = Sb
  = .000
  = .000 psf
```

Total Design External Pressure Loading per 5.10.5.1 [Pr]:
```
  = max[ DL + (Lr or Sb) + Fpe*Pe, DL + Pe + 0.4(Lr or Sb) ]
  = max[ 9.647 + max[ .000, .000 ] + .400 * .000,
         9.647 + .000 + 0.4 * max[ .000, .000 ]]
  = max[ 9.647, 9.647 ]
  = 9.647 psf  [461.892 N/M2]
```

Wind Load Calculations:

Wind velocity factor 5.2.1 [Vfact]:
```
  = ( Wind Velocity / 120 )^2
  = ( 73.8/120 )^2
  = .378
```

Vertical projected wind area of tank [VArea]:
```
  = Tank Height * Insulated Tank Diameter
  = 14.76 * 11.48
  = 169.532 ft^2  [15.750 m.^2]
```

Velocity pressure per 5.9.7.1 [p]:
```
  = 0.00256 * Kz * Kzt * kd * V^2 * I * G + 5.0
  = 0.00256 * 1.040 * 1.000 * .950 * 73.819^2 * 1.000 * .850 + 5.0
  = 16.715 psf  [800.327 N/M2]
```

Wind moment on shell [Moment]:
```
  = Wind Pressure * Wind Area * Tank Height/2
  = 16.715 * 169.5 * 14.76/2
  = 0.20919E+05 ft.lb.  [0.28362E+05 N.m.]
```

Vertical projected wind area of Cone roof:
```
  = Roof Height * Roof triangular base
  = 1.01 * 5.74
  = 5.813 ft^2  [.540 m.^2]
```

Area Exposed to Wind:
```
  = Wind area of tank + Wind area of roof
  = 169.532 + 5.813
  = 175.344 ft.^2  [16.290 m.^2]
```

Wind moment at the base including the cone roof [Total Moment]:
```
  = Moment + ( Wind P * Roof Area( Tank Height + Roof Height/3))
  = 0.209E+05 + ( 16.715 * 5.8 ( 14.8 + 1.01/3))
  = 0.22386E+05 ft.lb.  [0.30351E+05 N.m.]
```

Wind shear force acting on the tank:
```
  = Wind Pressure * (tank area +  roof area)
  = 16.715 * 175.3
  = 0.29309E+04 lbf.  [0.13037E+05 N.]
```

Moment about shell-to-bottom joint [MDL]:
```
  = ( Shell Weight + Attachement Weight + Framing Weight * % )D/2
  = ( 5137.9 + .0 + .0 * 1.00 )11.5/2
  = 29499.1 ft.lb  [39995.5 N.m.]
```

Resisting Weight of Fluid [WL]:
```
  = min( 5.6 * tb * sqrt( Fby * H * min( 0.7, G )), 0.45 * H * D )
  = min(5.6*.2362*sqrt(38000.0*13.68*min(0.7,1.520)),0.45*13.7*11.48)
  = min( 798.0, 70.7 )
  = 70.7 lbf/ft  [1.0 N./mm.]
```

Moment from Fluid Weight [MF]:
```
  = WL * ( PI * D ) * ( D / 2 )
  = 70.7 * ( 3.1416 * 11.48 ) * ( 11.48/2 )
  = 14641.9 ft.lb  [19851.7 N.m.]
```

Moment from Design Internal Pressure [MPI]:
```
  = Design Pressure * pi( Diameter in inches / 2 )^2 * ( D / 2 )
  = 1.0153 * 3.1416 ( 137.80/2 )^2 * ( 11.48/2 )
```

```
  = 86930.2 ft.lb  [117861.6 N.m.]
```

Design Pressure per F.4.1 [P]:

```
  = (0.962 * A * Fy * Mfact * tan(theta))/(D^2) + 0.245 * DLR/D^2
  = (0.962*.775*30000.0*1.000*tan(10.00))/(11.5^2)+0.245*1014/11.5^2
  = 31.795 in. of water  [807.582 mm. of water]
  = 1.148 psi  [7.916 KPa]
```

Note: Design Pressure was less than maximum computed per F.4.1

Moment about shell-to-bottom joint [MWS]:

```
  = Pws * D * H^2/2
  = 18 * Vfact * (D + Insulation) * H^2/2
  = 18 * .3784 (11.5 + .0 ) * 14.8^2/2
  = 8524.4 ft.lb  [11557.5 N.m.]
```

Moment about shell-to-bottom joint [MW]:

```
  = MWS + Wind Uplift * VArea * D / 2
  = 8524.4 + .0788 * 14912.8 * 11.5/2
  = 15274.5 ft.lb  [20709.5 N.m.]
```

Moment about shell-to-bottom joint [MDLR]:

```
  = ( Roof Weight )D/2
  = ( 1014.4 )11.5/2
  = 5824.4 ft.lb  [7896.9 N.m.]
```

Warning: The following API 650 Section 5.11.2.1 criteria were not met:
1) 0.6MW + MPI < MDL/1.5 + MDLR
2) MW + FP(MPI) < (MDL + MF)/2 + MDLR
3) MWS + FP(MPI) < MDL/1.5 + MDLR

Note: Anchorage is required for this design.

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Determine required thickness per the selected Method:

Shell Course Thickness per the One Foot Method:

Required Thickness for Course # 1

Required thickness based on the 1ft method per 5.6.3.2, Operating [td]:
```
  = 2.6D( H - 1 )G/Sd
  = 2.6 * 11.483 ( 13.68 - 1 )1.520/20000.0
  = .029 in.  [.731 mm.]
```

Minimum thickness per 5.6.1.1 : = .236 in. [6.000 mm.]

Final Selected Thickness including corrosion and other allowances:
= .23622 in. [6.00000 mm.]

Required thickness per 5.6.3.2, Hydrotest [tt]:
```
  = 2.6D( H - 1 )/St
  = 2.6 * 11.483 ( 13.68 - 1 )/22500.0
  = .01683 in.  [.42738 mm.]
```

Minimum thickness per 5.6.1.1 : = .236 in. [6.000 mm.]

Final Selected Thickness including other Code allowances:
= .23622 in. [6.00000 mm.]

Required Thickness for Course # 2

Required thickness based on the 1ft method per 5.6.3.2, Operating [td]:
```
  = 2.6D( H - 1 )G/Sd
  = 2.6 * 11.483 ( 6.30 - 1 )1.520/20000.0
  = .012 in.  [.305 mm.]
```

Minimum thickness per 5.6.1.1 : = .197 in. [5.000 mm.]

Final Selected Thickness including corrosion and other allowances:
= .19685 in. [5.00000 mm.]

Required thickness per 5.6.3.2, Hydrotest [tt]:
```
  = 2.6D( H - 1 )/St
  = 2.6 * 11.483 ( 6.30 - 1 )/22500.0
  = .00703 in.  [.17859 mm.]
```

Minimum thickness per 5.6.1.1 : = .197 in. [5.000 mm.]

Final Selected Thickness including other Code allowances:
= .19685 in. [5.00000 mm.]

TANK 2017 SP1, API-650/653/620/579 Analysis
Licensee:
Job: CAUSTIC SODA **Date: May 28,2021** **Time: 1:38pm**

INPUT VALUES, Damage Description: Flaw#:[1 of 1] Shell Course : 1

Inside Diameter	Di	3500.000	mm.
Thickness	tnom	6.000	mm.
Design Fill Height	H	3.700	m.
Design Temperature	T	35	°C
Allowable Stress, Design	S	137892.000	KPa
Allowable Stress, Ambient	Sa	137892.000	KPa
Longitudinal Joint Efficiency	EL	0.85	
Circumferential Joint Efficiency	EC	0.85	
Specific Gravity	G	1.52	
Flaw Type		General Metal Loss (Part 4)	
Assessment Level		Level 1	
Future Corrosion Allowance	FCAml	0.000	mm.
Allowable Remaining Strength Factor	RSFa	0.90	
Measurement Method		Point Thickness Readings	
Number of Rows		2	
Layout Angle		0.00	deg.
Rlife MFH Approach included?		No	

WARNING: A minimum of 15 thickness readings should be used unless extensive nondestruction examination has been utilized.

ERROR: The minimum measured thickness is either zero or negative. Please check your thickness measurements for accuracy.

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