CYLINDER FOUNDATION FOR LARAMIE COUNTY COMMUNITY COLLEGE

NORDTANK 15M ROTOR WIND TURBINE

DIRECT EMBED PIER

LARAMIE, WY

74' TUBE TOWER

DATE: 11-1-05

JOB NO. 05-066

Steel / Concrete / Bolts

Design Wind Velocity 100 MPH (BASE WIND SPEED)

Turbine : Nordtank 15M Rotor

Tower: 74 Feet

CMP Inside Diameter (Di) =	0	FT.
Tube Outside Diameter (Do) =	8.00	FT.
Inside Bolt Diameter (Bi) =	0	FT.
Outside Bolt Diameter (Bo) =	6.2927	FT.
Insde. Bse. Flng. Diameter (Id) =	6.03	FT.
Outside Bse. Flng. Diam. (Od) =	6.69	FT.
Diam. of Tower Wall (Dwall) =	6.69	
Base Shear (Fx) =	18,078	LBS.
Dead Load (Fz) =	14,900	LBS.
Maximum Moment (M) =	1,284,000	FT.-LBS.
Length of Foundation (L) =	18.0	FT.
Area of Long Bolts (abl) =	0.606	IN.^2
Embedment Plate Width (Pw) =	0.000	FT.
Tnsl. Strngth. Twr. Bs. Plt. (fyb) =	36,000	PSI.
Concrete Cmprsv. Strngth (f'c) =	4,000	PSI.
Density of Concrete (λc) =	150	Lbs./Ft.^3
Cncrt. Modulus of Elstcty. (Ec) =	3,604,997	PSI.
Steel Modulus of Elasticity (Es) =	29,000,000	PSI.
Width of Bs. Flng. on Twr. (lbf) =	4.0	IN.
Inside Width (lbfi) =	5.535	IN.
Diam. of Long Bolts (dbl) =	1.00	IN.
Ultm. Strs. of Long Blts. (ful) =	120,000	PSI.
Ultm. Strgth. of Long Blts. (Ful) =	72,720	LBf.
Number of Long Bolts (nbl) =	30	
Post Tnsn. of Long Bolts (Pbl) =	30,000	LBS.
Base Flange Thickness (Bft) =	2.0	IN.
π =	3.141592654	
Tower Tube Thickness(tt)=	0.375	IN.

CMP 14 Gauge (3 x 1 Helical)

Refer to Table 2.6 Sectional Properties of CMP,
Handbook of Steel Drainage & Highway Construction
Products by American Iron and Steel Institute 5th Edition, 1994

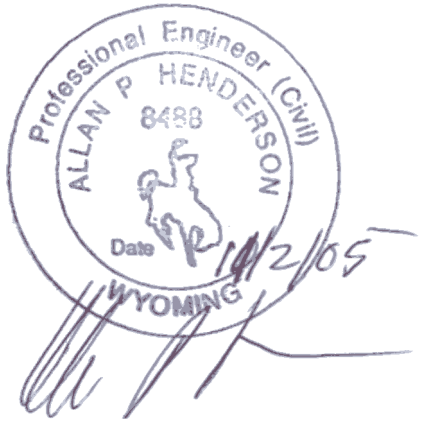
Uncoated Thickness (t) =	0.046	IN.
Developed Width Factor (b) =	1,243	
Outside CMP Diameter (Do) =	8	FT.
Inside CMP Diameter (Di) =	0	FT.

Geotechnical Data

Friction Factor (μg) =	0.50	(Granular)
Friction Factor (μc) =	1.0	(Clay)
Upper Soil Conditions (Us) =	8	FT.
Lower Soil Conditions (Ls) = L - Us =	10	FT.
Direct Shear Angle Above Us (ϕs) =	30	Degrees
Direct Shear Angle for Ls (ϕL) =	32	Degrees
Soil Density Above Us (λs) =	105	Lbs./cu.ft.
Soil Density for Ls (λL) =	110	Lbs./cu.ft.
Cohesion Above Us (Cs) =	150	Lbs./sq.ft.
Cohesion for Ls (CL) =	150	Lbs./sq.ft.
Density of Soil Backfill (λb) =	100	Lbs./cu.ft.

V = Concrete Volume =	34.44	CY.
Safety Factor (SF) =	3.60	

Dimnsions of Sq. Excvatin Uppr Soils (Deu) =	10.00 Ft.
Dimension orf Sq. Excvatin Lower Soils (Del)=	9.00 Ft.
Average Density of Backfill (λa) =	150 Lbs/cu.ft.
Dimnsions of Sq. Excvatin Mid Soils (Dem) =	9.00 Ft.
Height Upper Slurry (Hsu) =	18 Ft.
Height Mid Soil (Hms) =	9 Ft.



IMPORTANT NOTE :

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LATERAL EARTH PRESSURE ANALYSIS / FOUNDATION RESISTANCE TO OVERTURNING

A. Equivalent Fluid Pressures (pcf)

$\lambda's = \lambda s[(1 + \sin\phi s)/(1 - \sin\phi s)]$

$\lambda's =$ 315

$\lambda'L = \lambda L[(1 + \sin\phi L)/(1 - \sin\phi L)]$

$\lambda'L =$ 358

B. Passive Resistance Soil Pressures (psf)

1. $f1 = 2Cs$

   $f1 =$

2. $f'1 = f1 + \lambda's\ Us$

   $f'1 =$ 2,820.00

3. $f2 = 2CL + \lambda's\ Us$

   $f2 =$ 2,820.00

4. $f'2 = f2 + \lambda'L\ (z - Us)$

   $f'2 =$ 358.00 -44.04

5. $f3 = f'2 + \lambda'L\ (L - z)$

   $f3 =$ 6,400.05

C. Lateral Forces (LBf)

1. $Su = [(f1 + f'1)/2]\ [(Hsu)(Deu) + (Hms)(Dem)$

   $Su =$ 407,160.00

2. $SL = (f2 + f'2)/2\ (z - Us)\ De$

   $SL =$ 1,790.02 z^2 + -440.38 z 111,038.49

3. $R = (f'2 + f3)/2\ (L - z)\ Del$

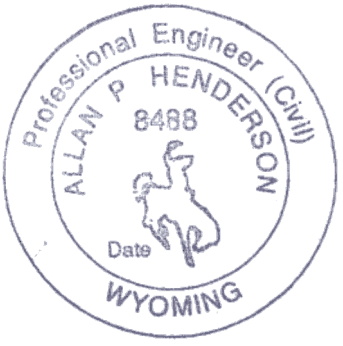
   $R =$ -1,611.02 z^2 396.34 z 514,836.76

4. $Ff = mc\ \{Fz + (Del^2 - PI/4\ Do^2)\ L\ \lambda a + PI/4(Do^2 - Di^2)L\ \lambda c + (PI/4\ Di^2\ lbL)]$

   $Ff =$ 233,600.00

5. Fx = Base Shear

   $Fx =$ 18,078



D. Sum of Lateral Forces = 0

1. $Su + SL - R - Ff - Fx = 0$

   3,401.04 z^2 -836.72 470,393.26

   1.00 z^2 -0.25 138.31

   $z =$ 11.8841

2. Check Sum of Lateral Forces

   407,160 136,537 -737,655

   233,600 18,078 -445,636

E. Sum of Moments About Point of Rotation "A" (FT-LBf)

1. $a1 = z - [(Us/3)((2f'1 + f1)/(f1 + f'1))]$

   $a1 =$ 6.8072

2. $a2 = (z - Us)[(1 - ((2f'2 + f2)/(3(f2 + f'2))]$

   $a2 =$ 1.8140

3. $a3 = ((L - z)/3)((2f3 + f'2)/(f'2 + f3))$

   $a3 =$ 3.2683

4. Resisting Moment to Overturn = Mrt = $a1\ Su + a2\ SL + a3\ R + (L-z)\ Ff$

   $Mrt =$ 5,402,367

5. Overturning Moment at Point of Rotation "A" = $Mo = Fx((M/Fx) + z)$

   $Mo =$ 1,498,841

6. Safety Factor to Overturn = SF = Mrt/Mo

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SF = 3.60

II. STEEL / CONCRETE ANALYSIS

External Load Including 360° Basis (LBf)

Fext = (((4M))/(Dwall)) - Fz

Fext = 752,813 LBf.

B. Stiffness Constants (LBf./ft.)

1. Long Bolts

Cbl = ((nbl) (Es) (abl))/L

Cbl = 29,290,000

2. Lower Concrete

Ccl = ((π/4)(Do^2 - Di^2)(Ec)/(L)

Ccl = 1,449,655,120

3. Outer Steel Pipe

Cpo = (Es)(p)(Do)(b)(t))/L

Cpo = 27,782,770,974

4. Inner Steel Pipe

Cpi = (Es)(π)(Di)(b)(t))/L

Cpi = 0

C. Elongation of Foundation (Ft.)

Fext = (Cbl + Ccl + Cpo + Cpi)Δuf

Δuf = 0.0000 Ft. (Elongation of Foundation)

D. Tensile Forces in Each Element of Foundation (LBf.)

1. Fbl = Force in Long Bolts = Δuf Cbl

Fbl = 754

2. Fpo = Force in Outer Steel Pipe = Δuf Cpo

Fpo = 714,764

3. Fpi = Force in Inner Steel Pipe = Δuf Cpi

Fpi = 0

4. Fcl = Force in Lower Concrete = Δuclf Ccl

Fcl = 37,295

Total = 752,813 = Fext total TRUE

5. F'bl = Force in Each Long Bolt = Fbl/nbl

F'bl = 25 LBf.

E. Set Compressive Forces in Concrete to Counter Tensile Forces (LBf.)

1. Set Post Tension in Bolts

a. Long Bolts (Pbl)

Fcl = 37,295

Pblm ³ Fcl/nbl (min. post tension)

Pblm ³ 1,243

Set Pbl = 30,000 ³ Pblm TRUE

P'bl = Pbl + F'bl

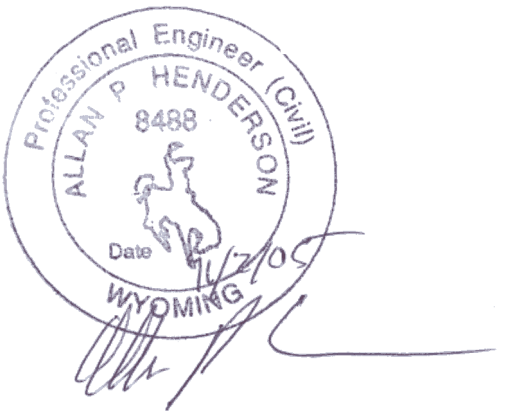
P'bl = 30,025

Fybl = (0.9)*(0.8*(Ful) = Max. Allowable Tensile Load

Fybl = 52,358

P'bl < Fybl = TRUE

III. RESISTANCE TO BASE SHEAR (LBf.)



Allowable Shear = Fv = (0.17(ful)(abl))(nbl)

Fv =	370,872
Fx =	18,078
Fv >> Fx =	TRUE

IV. CONCRETE COMPRESSION / PULLOUT (PSi.)

A. Base Flange of Tower

Pbf = Total Load on Base Flange = P'bl nbl

Pbf =	900,754	LBf.

Abf = Area of Base Flange = (π/4)(Od^2 - Id^2)

Abf =	949	In.^2

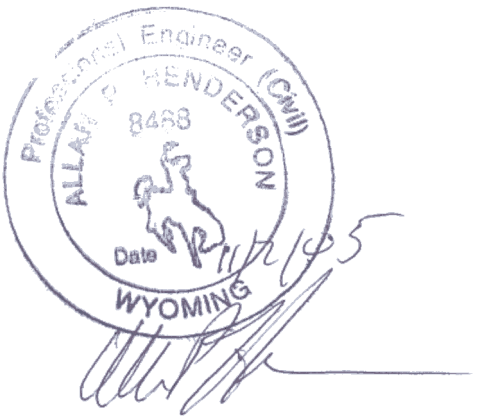
Aab = Area of Anchor Bolts = (abl)(nbl)

Aab =	18.18	In.^2

fcbf = Concrete Compression at Base Flange = Pbf/(Abf - Aab)

fcbf =	967	PSi.
fcbf < f'c =	TRUE	

B. Bearing Plates - None Required



V. REQUIRED THICKNESS OF BASE FLANGE (In.)

tb = Required Thickness = lbfi(SQRT(3)(fcbf)/(fyb*0.75)

tb =	1.81	In.

Bft = Base Flange Thickness Design by Others

Bft =	2.00
Bft > tb =	TRUE

FOUNDATION SUMMARY

Length =		18	
Outside Diameter =		8	
Inside Diameter =		0	
18	LF -	8	FT. Diameter CMP
18	LF -	0	FT. Diameter CMP
34.44	CY 6 Sack Concrete		
23.94624919	CY 2 Sack Slurry		

IMPORTANT NOTE :