REVIEWED
By Russ Van Oudenaren at 9:47 am, Oct 05, 2012

FDH Engineering, Inc., 6521 Meridien Drive Raleigh, NC 27616, Ph. 919.755.1012

Structural Analysis for T-Mobile Towers

105' Monopole Tower

T-Mobile Towers Site Name: Winston Nature Garden
T-Mobile Towers Site ID: 6FB1251A

FDH Project Number 12-06376E S2

Analysis Results

Tower Components	81.9%	Sufficient
Foundation	92.1%	Sufficient

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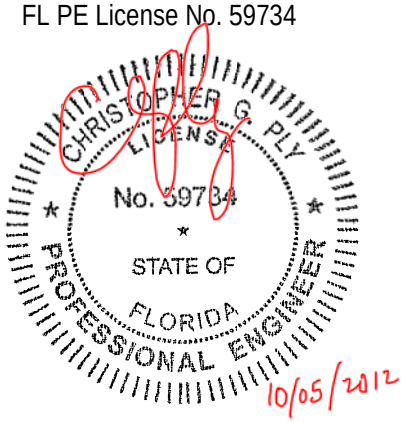

October 5, 2012

Prepared pursuant to ANSI/TIA-222-G Structural Standard for Antenna Supporting Structures and Antennas and the 2010 Florida Building Code

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EXECUTIVE SUMMARY

At the request of T-Mobile Towers, FDH Engineering, Inc. performed a structural analysis of the monopole located in Coconut Creek, FL to determine whether the tower is structurally adequate to support both the existing and proposed loads pursuant to the *Structural Standard for Antenna Supporting Structures and Antennas, ANSI/TIA-222-G* and the *2010 Florida Building Code (FBC)*. Information pertaining to the existing/proposed antenna loading, current tower geometry, geotechnical data, and member sizes was obtained from:

- Paul J. Ford & Company (Job No. 61107-0291) original design drawings dated March 6, 2008
- Florida Engineering & Testing, Inc. (Job No. 07-4071) Subsoil Investigation dated October 10, 2007
- T-Mobile Towers

The *basic design wind speed* per the *ANSI/TIA-222-G* standard and the *2010 FBC* is 170 mph without ice. Furthermore, this structure was analyzed as a Class II structure in Exposure Category C with a topographical factor of 1.

Conclusions

With the existing and proposed antennas from T-Mobile in place at 100 ft, the tower meets the requirements of the *ANSI/TIA-222-G* standard and the *2010 FBC* provided the Recommendation listed below is satisfied. Furthermore, provided the foundation was designed and constructed to support the original design reactions (see PFJ Job No. 61107-0291), the foundation should have the necessary capacity to support both the proposed and existing loading. For a more detailed description of the analysis of the tower, see the Results section of this report.

Our structural analysis has been performed assuming all information provided to FDH Engineering, Inc. is accurate (i.e., the steel data, tower layout, existing antenna loading, and proposed antenna loading) and that the tower has been properly erected and maintained per the original design drawings.

Recommendation

To ensure the requirements of the *ANSI/TIA-222-G* standard and the *2010 FBC* are met with the existing and proposed loading in place, we have the following recommendation:

1. The proposed coax should be installed inside the pole's shaft.

APPURTENANCE LISTING

The proposed and existing antennas with their corresponding cables/coax lines are shown in Table 1. *If the actual layout determined in the field deviates from the layout, FDH Engineering, Inc. should be contacted to perform a revised analysis.*

Table 1 - Appurtenance Loading

Existing Loading:

Antenna Elevation (ft)	Description	Coax and Lines [1]	Carrier	Mount Elevation (ft)	Mount Type
100	Existing Antennas	Existing Coax	T-Mobile	100	(3) 12' T-Arm Mounts

[1] Existing coax is installed inside the pole's shaft unless otherwise noted.

Final Loading:

Antenna Elevation (ft)	Description	Coax and Lines	Carrier	Mount Elevation (ft)	Mount Type
100	(6) RFS APX17DWV-17DWVS-A20 (3) RFS APXV18-206517S-A20 (6) RFS Twin AWS TMAs	(12) 1-5/8" (1) 1-5/8" Hybrid	T-Mobile	100	(3) 12' T-Arm Mounts
	(3) FRIG RRU Units (2) FXFB RRU Units (1) COVP				Quad Collar Mount
90	(9) Andrew ADFD1820-6565C-XDM	(12) 1-5/8"	---	90	(3) 12' T-Arm Mounts
80	(9) Andrew ADFD1820-6565C-XDM	(12) 1-5/8"		80	(3) 12' T-Arm Mounts
70	(9) Andrew ADFD1820-6565C-XDM	(12) 1-5/8"		70	(3) 12' T-Arm Mounts

RESULTS

The following yield strength of steel for individual members was used for analysis:

Table 2 - Material Strength

Member Type	Yield Strength
Tower Shaft Sections	65 ksi
Base Plate	50 ksi
Anchor Bolts	75 ksi

Table 3 displays the summary of the ratio (as a percentage) of force in the member to their capacities. Values greater than 100% indicate locations where the maximum force in the member exceeds its capacity. *Note: Capacities up to 105% are considered acceptable.* Table 4 displays the maximum foundation reactions.

If the assumptions outlined in this report differ from actual field conditions, FDH Engineering, Inc. should be contacted to perform a revised analysis. Furthermore, as no information pertaining to the allowable twist and sway requirements for the existing or proposed appurtenances was provided, deflection and rotation were not taken into consideration when performing this analysis.

See the Appendix for detailed modeling information

Table 3 - Summary of Working Percentage of Structural Components

Section No.	Elevation ft	Component Type	Size	% Capacity	Pass Fail
L1	105 - 71.25	Pole	TP36.51x20x0.25	42.2	Pass
L2	71.25 - 38	Pole	TP48.558x33.6864x0.4375	54.9	Pass
L3	38 - 0	Pole	TP58.25x45.3348x0.5	71.9	Pass
---	0	Anchor Bolts	(20) 2.25" ø on a 65.25" B.C.	81.9	Pass
---	0	Base Plate	PL 71.25" ø x 2.75" thick	58.5	Pass

Table 4 - Maximum Base Reactions

Base Reactions	Current Analysis *(ANSI/TIA-222-G)*	Original Design *(ANSI/TIA-222-G)*
Axial *	45 k	40 k
Shear	75 k	80 k
Moment	5,525 k-ft	6,000 k-ft

* Per our experience with foundations of similar type, the axial loading should not control the foundation analysis.

GENERAL COMMENTS

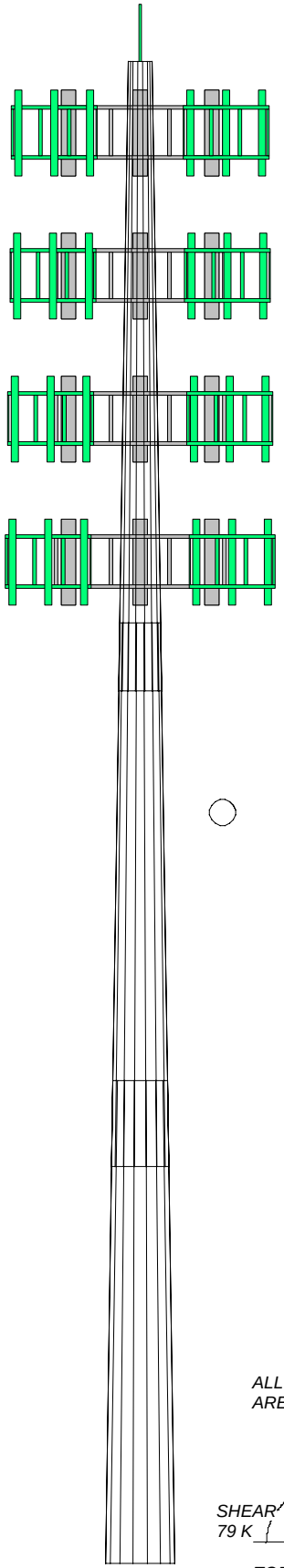
This engineering analysis is based upon the theoretical capacity of the structure. It is not a condition assessment of the tower and its foundation. It is the responsibility of T-Mobile Towers to verify that the tower modeled and analyzed is the correct structure (with accurate antenna loading information) modeled. If there are substantial modifications to be made or the assumptions made in this analysis are not accurate, FDH Engineering, Inc. should be notified immediately to perform a revised analysis.

LIMITATIONS

All opinions and conclusions are considered accurate to a reasonable degree of engineering certainty based upon the evidence available at the time of this report. All opinions and conclusions are subject to revision based upon receipt of new or additional/updated information. All services are provided exercising a level of care and diligence equivalent to the standard and care of our profession. No other warranty or guarantee, expressed or implied, is offered. Our services are confidential in nature and we will not release this report to any other party without the client's consent. The use of this engineering work is limited to the express purpose for which it was commissioned and it may not be reused, copied, or distributed for any other purpose without the written consent of FDH Engineering, Inc.

APPENDIX

Section	Length (ft)	Number of Sides	Thickness (in)	Socket Length (ft)	Top Dia (in)	Bot Dia (in)	Grade	Weight (K)
1	44.00	18	0.2500	4.75	20.0000	36.5100	A572-65	3.3
2	38.00	18	0.4375	6.00	34.2277	48.5580		7.4
3	33.75	18	0.5000		45.4203	58.2500		9.4
								20.0



DESIGNED APPURTENANCE LOADING

TYPE	ELEVATION	TYPE	ELEVATION
Lightning Rod	105	(3) ADFD1820-6565C-XDM w/ Mount Pipe	90
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	90
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	100	12' T-Arm Mount MNT	80
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	80
APXV18-206517S-A20 w/Mount Pipe	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	80
APXV18-206517S-A20 w/Mount Pipe	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	80
APXV18-206517S-A20 w/Mount Pipe	100	(11) 6' Branches	77
(2) RFS Twin AWS TMA	100	(11) 6' Branches	77
(2) RFS Twin AWS TMA	100	(11) 6' Branches	77
(2) RFS Twin AWS TMA	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	70
12' T-Arm Mount MNT	100	12' T-Arm Mount MNT	70
FRIG RRU Units	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	70
FRIG RRU Units	100	(3) ADFD1820-6565C-XDM w/ Mount Pipe	70
FRIG RRU Units	100	(7) 8' Branches	65
FXFB RRU Units	100	(7) 8' Branches	65
FXFB RRU Units	100	(8) 8' Branches	65
COVP	100	(16) 10' Branches	65 - 55
Quad Collar Mount MNT	100		
(13) 4' Branches	95		
(13) 4' Branches	95		
(13) 4' Branches	95		
12' T-Arm Mount MNT	90		
(3) ADFD1820-6565C-XDM w/ Mount Pipe	90		

MATERIAL STRENGTH

GRADE	Fy	Fu	GRADE	Fy	Fu
A572-65	65 ksi	80 ksi			

TOWER DESIGN NOTES

1. Tower is located in Broward County, Florida.
2. Tower designed for Exposure C to the TIA-222-G Standard.
3. Tower designed for a 134 mph basic wind in accordance with the TIA-222-G Standard.
4. Deflections are based upon a 60 mph wind.
5. Tower Structure Class II.
6. Topographic Category 1 with Crest Height of 0.00 ft
7. TOWER RATING: 80.3%

ALL REACTIONS ARE FACTORED

AXIAL 43 K

SHEAR 79 K

MOMENT 5813 kip-ft

TORQUE 0 kip-ft

REACTIONS - 134 mph WIND

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Tower Analysis

Job: *Winston Nature Garden - 6FB1251A*			
Project: *12-06376E S2*			
Client: T-Mobile Towers	Drawn by: Christopher Stryffeler		App'd:
Code: TIA-222-G	Date: 10/04/12		Scale: NTS
Path:			Dwg No. E-1

Stiffened or Unstiffened, Ungrouted, Circular Base Plate - Any Rod Material

TIA Rev G Assumption: Clear space between bottom of leveling nut and top of concrete **not** exceeding (1)*(Rod Diameter)

Site Data

Site ID:	*6FB1251A*
Site Name:	*Winston Nature Garden*
Project No.:	*12-06376E S2*
Pole Manufacturer:	*Other*

Reactions		
Mu:	5813.2	ft-kips
Axial, Pu:	43.2	kips
Shear, Vu:	75.3	kips
Eta Factor, η	0.5	TIA G (Fig. 4-4)

If No stiffeners, Criteria: AISC LRFD <-Only Applcable to Unstiffened Cases

Anchor Rod Data		
Qty:	20	
Diam:	2.25	in
Rod Material:	A615-J	
Strength (Fu):	100	ksi
Yield (Fy):	75	ksi
Bolt Circle:	65.25	in

Anchor Rod Results

Max Rod (Cu+ Vu/ή):	223.5	Kips
Allowable Axial, Φ*Fu*Anet:	260.0	Kips
Anchor Rod Stress Ratio:	86.0%	**Pass**

Rigid
AISC LRFD
φ*Tn

Plate Data		
Diam:	71.25	in
Thick:	2.75	in
Grade:	50	ksi
Single-Rod B-eff:	9.24	in

Base Plate Results Flexural Check

Base Plate Stress:	27.7	ksi
Allowable Plate Stress:	45.0	ksi
Base Plate Stress Ratio:	61.5%	**Pass**

Rigid
AISC LRFD
φ*Fy
Y.L. Length: 29.40

Stiffener Data (Welding at both sides)		
Config:	0	*
Weld Type:		
Groove Depth:		in **
Groove Angle:		degrees
Fillet H. Weld:		<-- Disregard
Fillet V. Weld:		in
Width:		in
Height:		in
Thick:		in
Notch:		in
Grade:		ksi
Weld str.:		ksi

n/a

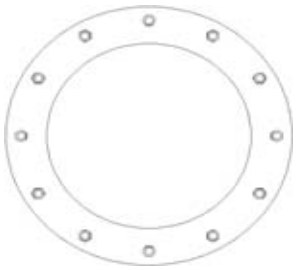
Stiffener Results

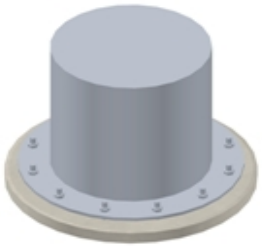
Horizontal Weld :	n/a
Vertical Weld:	n/a
Plate Flex+Shear, fb/Fb+(fv/Fv)^2:	n/a
Plate Tension+Shear, ft/Ft+(fv/Fv)^2:	n/a
Plate Comp. (AISC Bracket):	n/a

Pole Results

Pole Punching Shear Check: n/a

Pole Data		
Diam:	58.25	in
Thick:	0.5	in
Grade:	65	ksi
# of Sides:	18	"0" IF Round
Fu	80	ksi
Reinf. Fillet Weld	0	"0" if None





* 0 = none, 1 = every bolt, 2 = every 2 bolts, 3 = 2 per bolt

** Note: for complete joint penetration groove welds the groove depth must be exactly 1/2 the stiffener thickness for calculation purposes

Analysis Date: 10/4/2012

FOUNDATION REACTION COMPARISON

REACTIONS PER ANCHOR	DESIGN REACTIONS	CURRENT REACTION	% CAPACITY
AXIAL (kips)	40	43.2	108.0%
SHEAR (kips)	80	75.3	94.1%
MOMENT (kip-ft)	6000	5813.2	96.9%

Design loads from: PFJ Project No. 61107-0291 dated 03/06/2008

Although the axial capacity is at 108.0%, the moment reaction is the governing criteria for a monopole drilled shaft foundation. Therefore, the overall capacity for this foundation is 96.9%.

Tower Input Data

There is a pole section.
This tower is designed using the TIA-222-G standard.
The following design criteria apply:

Tower is located in Broward County, Florida.
Basic wind speed of 134 mph.
Structure Class II.
Exposure Category C.
Topographic Category 1.
Crest Height 0.00 ft.
Deflections calculated using a wind speed of 60 mph.
A non-linear (P-delta) analysis was used.
Pressures are calculated at each section.
Stress ratio used in pole design is 1.
Local bending stresses due to climbing loads, feedline supports, and appurtenance mounts are not considered.

Tapered Pole Section Geometry

Section	Elevation ft	Section Length ft	Splice Length ft	Number of Sides	Top Diameter in	Bottom Diameter in	Wall Thickness in	Bend Radius in	Pole Grade
L1	105.00-61.00	44.00	4.75	18	20.0000	36.5100	0.2500	1.0000	A572-65 (65 ksi)
L2	61.00-27.75	38.00	6.00	18	34.2277	48.5580	0.4375	1.7500	A572-65 (65 ksi)
L3	27.75-0.00	33.75		18	45.4203	58.2500	0.5000	2.0000	A572-65 (65 ksi)

Tapered Pole Properties

Section	Tip Dia. in	Area in^2	I in^4	r in	C in	I/C in^3	J in^4	It/Q in^2	w in	w/t
L1	20.3085	15.6716	772.2994	7.0112	10.1600	76.0137	1545.6150	7.8373	3.0800	12.32
	37.0732	28.7723	4779.3384	12.8723	18.5471	257.6868	9564.9656	14.3889	5.9858	23.943
L2	36.5746	46.9219	6768.5178	11.9955	17.3877	389.2714	13545.9419	23.4654	5.2541	12.009
	49.3071	66.8213	19548.4723	17.0828	24.6675	792.4800	39122.6670	33.4170	7.7762	17.774
L3	48.4370	71.2885	18173.6766	15.9467	23.0735	787.6421	36371.2667	35.6510	7.1140	14.228
	59.1486	91.6492	38616.2718	20.5012	29.5910	1305.0006	77283.3559	45.8333	9.3720	18.744

Tower Elevation ft	Gusset Area (per face) ft^2	Gusset Thickness in	Gusset Grade	Adjust. Factor A_f	Adjust. Factor A_r	Weight Mult.	Double Angle Stitch Bolt Spacing Diagonals in	Double Angle Stitch Bolt Spacing Horizontals in
L1 105.00-61.00				1	1	1		
L2 61.00-27.75				1	1	1		
L3 27.75-0.00				1	1	1		

Feed Line/Linear Appurtenances - Entered As Round Or Flat

Description	Face or Leg	Allow Shield	Component Type	Placement ft	Total Number	Number Per Row	Clear Spacing in	Width or Diameter in	Perimeter in	Weight plf
***										

Feed Line/Linear Appurtenances - Entered As Area

Description	Face or Leg	Allow Shield	Component Type	Placement ft	Total Number		C_AA_A ft^2/ft	Weight plf
1-5/8"	C	No	Inside Pole	100.00 - 0.00	12	No Ice	0.00	1.04
1-5/8" Hybrid	C	No	Inside Pole	100.00 - 0.00	1	No Ice	0.00	1.04
***								
1-5/8"	C	No	Inside Pole	90.00 - 0.00	12	No Ice	0.00	1.04
***								
1-5/8"	C	No	Inside Pole	80.00 - 0.00	12	No Ice	0.00	1.04
***								
1-5/8"	C	No	Inside Pole	70.00 - 0.00	12	No Ice	0.00	1.04
***								

Feed Line/Linear Appurtenances Section Areas

Tower Section	Tower Elevation ft	Face	A_R ft^2	A_F ft^2	C_AA_A In Face ft^2	C_AA_A Out Face ft^2	Weight K
L1	105.00-61.00	A	0.000	0.000	0.000	0.000	0.00
		B	0.000	0.000	0.000	0.000	0.00
		C	0.000	0.000	0.000	0.000	1.24
L2	61.00-27.75	A	0.000	0.000	0.000	0.000	0.00
		B	0.000	0.000	0.000	0.000	0.00
		C	0.000	0.000	0.000	0.000	1.69
L3	27.75-0.00	A	0.000	0.000	0.000	0.000	0.00
		B	0.000	0.000	0.000	0.000	0.00
		C	0.000	0.000	0.000	0.000	1.41

Feed Line Center of Pressure

Section	Elevation ft	CP_X in	CP_Z in	CP_X Ice in	CP_Z Ice in
L1	105.00-61.00	0.0000	0.0000	0.0000	0.0000
L2	61.00-27.75	0.0000	0.0000	0.0000	0.0000
L3	27.75-0.00	0.0000	0.0000	0.0000	0.0000

FDH Engineering, Inc.
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Shielding Factor Ka

Tower Section	Feed Line Record No.	Description	Feed Line Segment Elev.	K_a No Ice	K_a Ice

Discrete Tower Loads

Description	Face or Leg	Offset Type	Offsets: Horz Lateral Vert ft ft ft	Azimuth Adjustment °	Placement ft		C_AA_A Front ft^2	C_AA_A Side ft^2	Weight K
Lightning Rod	C	From Face	0.00 0.00 2.00	0.0000	105.00	No Ice	0.25	0.25	0.03
***									
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	A	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	9.44	4.76	0.08
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	B	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	9.44	4.76	0.08
(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	C	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	9.44	4.76	0.08
APXV18-206517S-A20 w/Mount Pipe	A	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	5.40	4.70	0.05
APXV18-206517S-A20 w/Mount Pipe	B	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	5.40	4.70	0.05
APXV18-206517S-A20 w/Mount Pipe	C	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	5.40	4.70	0.05
(2) RFS Twin AWS TMA	A	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	0.18	0.47	0.01
(2) RFS Twin AWS TMA	B	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	0.18	0.47	0.01
(2) RFS Twin AWS TMA	C	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	0.18	0.47	0.01
12' T-Arm Mount MNT	C	None		0.0000	100.00	No Ice	11.59	11.59	0.77
***									
FRIG RRU Units	A	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	2.79	1.10	0.06
FRIG RRU Units	B	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	2.79	1.10	0.06
FRIG RRU Units	C	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	2.79	1.10	0.06
FXFB RRU Units	A	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	3.85	1.07	0.06
FXFB RRU Units	B	From Leg	4.00 0.00	0.0000	100.00	No Ice	3.85	1.07	0.06

Description	Face or Leg	Offset Type	Offsets: Horz Lateral ft Vert ft ft	Azimuth Adjustment °	Placement ft		C_AA_A Front ft^2	C_AA_A Side ft^2	Weight K
			0.00						
COVP	C	From Leg	4.00 0.00 0.00	0.0000	100.00	No Ice	1.58	0.99	0.01
Quad Collar Mount MNT ***	C	None		0.0000	100.00	No Ice	3.00	3.00	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	A	From Leg	4.00 0.00 0.00	0.0000	90.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	B	From Leg	4.00 0.00 0.00	0.0000	90.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	C	From Leg	4.00 0.00 0.00	0.0000	90.00	No Ice	8.06	6.30	0.08
12' T-Arm Mount MNT ***	C	None		0.0000	90.00	No Ice	11.59	11.59	0.77
(3) ADFD1820-6565C-XDM w/ Mount Pipe	A	From Leg	4.00 0.00 0.00	0.0000	80.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	B	From Leg	4.00 0.00 0.00	0.0000	80.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	C	From Leg	4.00 0.00 0.00	0.0000	80.00	No Ice	8.06	6.30	0.08
12' T-Arm Mount MNT ***	C	None		0.0000	80.00	No Ice	11.59	11.59	0.77
(3) ADFD1820-6565C-XDM w/ Mount Pipe	A	From Leg	4.00 0.00 0.00	0.0000	70.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	B	From Leg	4.00 0.00 0.00	0.0000	70.00	No Ice	8.06	6.30	0.08
(3) ADFD1820-6565C-XDM w/ Mount Pipe	C	From Leg	4.00 0.00 0.00	0.0000	70.00	No Ice	8.06	6.30	0.08
12' T-Arm Mount MNT ***	C	None		0.0000	70.00	No Ice	11.59	11.59	0.77
(13) 4' Branches	A	None		0.0000	95.00	No Ice	2.70	2.70	0.01
(13) 4' Branches	B	None		0.0000	95.00	No Ice	2.70	2.70	0.01
(13) 4' Branches ***	C	None		0.0000	95.00	No Ice	2.70	2.70	0.01
(11) 6' Branches	A	None		0.0000	77.00	No Ice	3.51	3.51	0.04
(11) 6' Branches	B	None		0.0000	77.00	No Ice	3.51	3.51	0.04
(11) 6' Branches ***	C	None		0.0000	77.00	No Ice	3.51	3.51	0.04
(7) 8' Branches	A	None		0.0000	65.00	No Ice	3.62	3.62	0.07
(7) 8' Branches	B	None		0.0000	65.00	No Ice	3.62	3.62	0.07
(8) 8' Branches ***	C	None		0.0000	65.00	No Ice	3.62	3.62	0.07
(16) 10' Branches ***	A	None		0.0000	65.00 - 55.00	No Ice	4.13	4.13	0.09
********** **********									

Load Combinations

Comb. No.	Description
1	Dead Only
2	1.2 Dead+1.6 Wind 0 deg - No Ice
3	0.9 Dead+1.6 Wind 0 deg - No Ice
4	1.2 Dead+1.6 Wind 30 deg - No Ice
5	0.9 Dead+1.6 Wind 30 deg - No Ice
6	1.2 Dead+1.6 Wind 60 deg - No Ice
7	0.9 Dead+1.6 Wind 60 deg - No Ice
8	1.2 Dead+1.6 Wind 90 deg - No Ice
9	0.9 Dead+1.6 Wind 90 deg - No Ice
10	1.2 Dead+1.6 Wind 120 deg - No Ice
11	0.9 Dead+1.6 Wind 120 deg - No Ice
12	1.2 Dead+1.6 Wind 150 deg - No Ice
13	0.9 Dead+1.6 Wind 150 deg - No Ice
14	1.2 Dead+1.6 Wind 180 deg - No Ice
15	0.9 Dead+1.6 Wind 180 deg - No Ice
16	1.2 Dead+1.6 Wind 210 deg - No Ice
17	0.9 Dead+1.6 Wind 210 deg - No Ice
18	1.2 Dead+1.6 Wind 240 deg - No Ice
19	0.9 Dead+1.6 Wind 240 deg - No Ice
20	1.2 Dead+1.6 Wind 270 deg - No Ice
21	0.9 Dead+1.6 Wind 270 deg - No Ice
22	1.2 Dead+1.6 Wind 300 deg - No Ice
23	0.9 Dead+1.6 Wind 300 deg - No Ice
24	1.2 Dead+1.6 Wind 330 deg - No Ice
25	0.9 Dead+1.6 Wind 330 deg - No Ice
26	Dead+Wind 0 deg - Service
27	Dead+Wind 30 deg - Service
28	Dead+Wind 60 deg - Service
29	Dead+Wind 90 deg - Service
30	Dead+Wind 120 deg - Service
31	Dead+Wind 150 deg - Service
32	Dead+Wind 180 deg - Service
33	Dead+Wind 210 deg - Service
34	Dead+Wind 240 deg - Service
35	Dead+Wind 270 deg - Service
36	Dead+Wind 300 deg - Service
37	Dead+Wind 330 deg - Service

Maximum Member Forces

Section No.	Elevation ft	Component Type	Condition	Gov. Load Comb.	Axial K	Major Axis Moment kip-ft	Minor Axis Moment kip-ft
L1	105 - 61	Pole	Max Tension	2	0.00	-0.00	-0.00
			Max. Compression	1	-12.06	-0.21	0.10
			Max. Mx	8	-11.68	-1031.52	-2.45
			Max. My	2	-11.67	2.32	1034.34
			Max. Vy	8	51.91	-1031.52	-2.45
			Max. Vx	2	-52.00	2.32	1034.34
			Max. Torque	20			0.02
L2	61 - 27.75	Pole	Max Tension	1	0.00	0.00	0.00
			Max. Compression	18	-26.45	2796.78	-1614.75

Section No.	Elevation ft	Component Type	Condition	Gov. Load Comb.	Axial K	Major Axis Moment kip-ft	Minor Axis Moment kip-ft
			Max. Mx	8	-26.45	-3232.78	-4.87
			Max. My	2	-26.45	4.73	3238.39
			Max. Vy	8	73.12	-3232.78	-4.87
			Max. Vx	2	-73.20	4.73	3238.39
			Max. Torque	5			-0.02
L3	27.75 - 0	Pole	Max Tension	1	0.00	0.00	0.00
			Max. Compression	18	-43.18	5019.09	-2897.80
			Max. Mx	8	-43.18	-5800.27	-7.40
			Max. My	2	-43.18	7.26	5808.80
			Max. Vy	8	78.97	-5800.27	-7.40
			Max. Vx	2	-79.06	7.26	5808.80
			Max. Torque	5			-0.02

Maximum Reactions

Location	Condition	Gov. Load Comb.	Vertical K	Horizontal, X K	Horizontal, Z K
Pole	Max. Vert	18	43.22	68.33	-39.45
	Max. H_x	21	32.42	78.95	0.07
	Max. H_z	3	32.42	0.07	79.03
	Max. M_x	2	5808.80	0.07	79.03
	Max. M_z	8	5800.27	-78.95	-0.07
	Max. Torsion	17	0.02	39.41	-68.41
	Min. Vert	3	32.42	0.07	79.03
	Min. H_x	9	32.42	-78.95	-0.07
	Min. H_z	15	32.42	-0.07	-79.03
	Min. M_x	14	-5808.56	-0.07	-79.03
	Min. M_z	20	-5799.75	78.95	0.07
	Min. Torsion	5	-0.02	-39.41	68.41

Tower Mast Reaction Summary

Load Combination	Vertical K	$Shear_x$ K	$Shear_z$ K	Overturning Moment, M_x kip-ft	Overturning Moment, M_z kip-ft	Torque kip-ft
Dead Only	36.02	0.00	0.00	-0.10	-0.21	0.00
1.2 Dead+1.6 Wind 0 deg - No Ice	43.22	-0.07	-79.03	-5808.80	7.26	0.02
0.9 Dead+1.6 Wind 0 deg - No Ice	32.42	-0.07	-79.03	-5793.27	7.30	0.02
1.2 Dead+1.6 Wind 30 deg - No Ice	43.22	39.41	-68.41	-5026.98	-2893.83	0.02
0.9 Dead+1.6 Wind 30 deg - No Ice	32.42	39.41	-68.41	-5013.50	-2886.03	0.02
1.2 Dead+1.6 Wind 60 deg - No Ice	43.22	68.33	-39.45	-2898.04	-5019.60	0.02
0.9 Dead+1.6 Wind 60 deg - No Ice	32.42	68.33	-39.45	-2890.26	-5006.12	0.02
1.2 Dead+1.6 Wind 90 deg - No Ice	43.22	78.95	0.07	7.40	-5800.27	0.01
0.9 Dead+1.6 Wind 90 deg - No Ice	32.42	78.95	0.07	7.41	-5784.74	0.01

Load Combination	Vertical K	$Shear_x$ K	$Shear_z$ K	Overturning Moment, M_x kip-ft	Overturning Moment, M_z kip-ft	Torque kip-ft
1.2 Dead+1.6 Wind 120 deg - No Ice	43.22	68.41	39.58	2910.81	-5027.10	0.00
0.9 Dead+1.6 Wind 120 deg - No Ice	32.42	68.41	39.58	2903.05	-5013.59	0.00
1.2 Dead+1.6 Wind 150 deg - No Ice	43.22	39.54	68.48	5034.23	-2906.85	-0.01
0.9 Dead+1.6 Wind 150 deg - No Ice	32.42	39.54	68.48	5020.79	-2899.00	-0.01
1.2 Dead+1.6 Wind 180 deg - No Ice	43.22	0.07	79.03	5808.56	-7.78	-0.02
0.9 Dead+1.6 Wind 180 deg - No Ice	32.42	0.07	79.03	5793.09	-7.69	-0.02
1.2 Dead+1.6 Wind 210 deg - No Ice	43.22	-39.41	68.41	5026.74	2893.32	-0.02
0.9 Dead+1.6 Wind 210 deg - No Ice	32.42	-39.41	68.41	5013.32	2885.65	-0.02
1.2 Dead+1.6 Wind 240 deg - No Ice	43.22	-68.33	39.45	2897.80	5019.09	-0.02
0.9 Dead+1.6 Wind 240 deg - No Ice	32.42	-68.33	39.45	2890.08	5005.73	-0.02
1.2 Dead+1.6 Wind 270 deg - No Ice	43.22	-78.95	-0.07	-7.64	5799.75	-0.01
0.9 Dead+1.6 Wind 270 deg - No Ice	32.42	-78.95	-0.07	-7.58	5784.35	-0.01
1.2 Dead+1.6 Wind 300 deg - No Ice	43.22	-68.41	-39.58	-2911.05	5026.58	-0.00
0.9 Dead+1.6 Wind 300 deg - No Ice	32.42	-68.41	-39.58	-2903.23	5013.20	-0.00
1.2 Dead+1.6 Wind 330 deg - No Ice	43.22	-39.54	-68.48	-5034.47	2906.33	0.01
0.9 Dead+1.6 Wind 330 deg - No Ice	32.42	-39.54	-68.48	-5020.97	2898.61	0.01
Dead+Wind 0 deg - Service	36.02	-0.01	-8.81	-646.72	0.62	0.00
Dead+Wind 30 deg - Service	36.02	4.39	-7.62	-559.67	-322.32	0.00
Dead+Wind 60 deg - Service	36.02	7.61	-4.40	-322.68	-558.95	0.00
Dead+Wind 90 deg - Service	36.02	8.80	0.01	0.74	-645.87	0.00
Dead+Wind 120 deg - Service	36.02	7.62	4.41	323.93	-559.78	0.00
Dead+Wind 150 deg - Service	36.02	4.41	7.63	560.30	-323.77	-0.00
Dead+Wind 180 deg - Service	36.02	0.01	8.81	646.52	-1.05	-0.00
Dead+Wind 210 deg - Service	36.02	-4.39	7.62	559.47	321.88	-0.00
Dead+Wind 240 deg - Service	36.02	-7.61	4.40	322.48	558.51	-0.00
Dead+Wind 270 deg - Service	36.02	-8.80	-0.01	-0.94	645.43	-0.00
Dead+Wind 300 deg - Service	36.02	-7.62	-4.41	-324.13	559.35	-0.00
Dead+Wind 330 deg - Service	36.02	-4.41	-7.63	-560.50	323.33	0.00

Solution Summary

	Sum of Applied Forces			Sum of Reactions			
Load Comb.	PX K	PY K	PZ K	PX K	PY K	PZ K	% Error
1	0.00	-36.02	0.00	0.00	36.02	0.00	0.000%
2	-0.07	-43.22	-79.03	0.07	43.22	79.03	0.002%
3	-0.07	-32.42	-79.03	0.07	32.42	79.03	0.002%
4	39.41	-43.22	-68.41	-39.41	43.22	68.41	0.000%
5	39.41	-32.42	-68.41	-39.41	32.42	68.41	0.000%
6	68.33	-43.22	-39.45	-68.33	43.22	39.45	0.000%
7	68.33	-32.42	-39.45	-68.33	32.42	39.45	0.000%
8	78.95	-43.22	0.07	-78.95	43.22	-0.07	0.002%

	Sum of Applied Forces			Sum of Reactions			
Load Comb.	PX K	PY K	PZ K	PX K	PY K	PZ K	% Error
9	78.95	-32.42	0.07	-78.95	32.42	-0.07	0.002%
10	68.41	-43.22	39.58	-68.41	43.22	-39.58	0.000%
11	68.41	-32.42	39.58	-68.41	32.42	-39.58	0.000%
12	39.54	-43.22	68.48	-39.54	43.22	-68.48	0.000%
13	39.54	-32.42	68.48	-39.54	32.42	-68.48	0.000%
14	0.07	-43.22	79.03	-0.07	43.22	-79.03	0.002%
15	0.07	-32.42	79.03	-0.07	32.42	-79.03	0.002%
16	-39.41	-43.22	68.41	39.41	43.22	-68.41	0.000%
17	-39.41	-32.42	68.41	39.41	32.42	-68.41	0.000%
18	-68.33	-43.22	39.45	68.33	43.22	-39.45	0.000%
19	-68.33	-32.42	39.45	68.33	32.42	-39.45	0.000%
20	-78.95	-43.22	-0.07	78.95	43.22	0.07	0.002%
21	-78.95	-32.42	-0.07	78.95	32.42	0.07	0.002%
22	-68.41	-43.22	-39.58	68.41	43.22	39.58	0.000%
23	-68.41	-32.42	-39.58	68.41	32.42	39.58	0.000%
24	-39.54	-43.22	-68.48	39.54	43.22	68.48	0.000%
25	-39.54	-32.42	-68.48	39.54	32.42	68.48	0.000%
26	-0.01	-36.02	-8.81	0.01	36.02	8.81	0.003%
27	4.39	-36.02	-7.62	-4.39	36.02	7.62	0.003%
28	7.62	-36.02	-4.40	-7.61	36.02	4.40	0.003%
29	8.80	-36.02	0.01	-8.80	36.02	-0.01	0.003%
30	7.62	-36.02	4.41	-7.62	36.02	-4.41	0.003%
31	4.41	-36.02	7.63	-4.41	36.02	-7.63	0.003%
32	0.01	-36.02	8.81	-0.01	36.02	-8.81	0.003%
33	-4.39	-36.02	7.62	4.39	36.02	-7.62	0.003%
34	-7.62	-36.02	4.40	7.61	36.02	-4.40	0.003%
35	-8.80	-36.02	-0.01	8.80	36.02	0.01	0.003%
36	-7.62	-36.02	-4.41	7.62	36.02	4.41	0.003%
37	-4.41	-36.02	-7.63	4.41	36.02	7.63	0.003%

Non-Linear Convergence Results

Load Combination	Converged?	Number of Cycles	Displacement Tolerance	Force Tolerance
1	Yes	6	0.00000001	0.00000001
2	Yes	8	0.00000001	0.00009640
3	Yes	8	0.00000001	0.00007791
4	Yes	10	0.00000001	0.00006299
5	Yes	10	0.00000001	0.00004541
6	Yes	10	0.00000001	0.00006292
7	Yes	10	0.00000001	0.00004536
8	Yes	8	0.00000001	0.00009640
9	Yes	8	0.00000001	0.00007791
10	Yes	10	0.00000001	0.00006342
11	Yes	10	0.00000001	0.00004570
12	Yes	10	0.00000001	0.00006346
13	Yes	10	0.00000001	0.00004573
14	Yes	8	0.00000001	0.00009648
15	Yes	8	0.00000001	0.00007797
16	Yes	10	0.00000001	0.00006292
17	Yes	10	0.00000001	0.00004536
18	Yes	10	0.00000001	0.00006292
19	Yes	10	0.00000001	0.00004536
20	Yes	8	0.00000001	0.00009634
21	Yes	8	0.00000001	0.00007788
22	Yes	10	0.00000001	0.00006340

23	Yes	10	0.00000001	0.00004569
24	Yes	10	0.00000001	0.00006343
25	Yes	10	0.00000001	0.00004571
26	Yes	7	0.00000001	0.00013501
27	Yes	7	0.00000001	0.00012670
28	Yes	7	0.00000001	0.00012659
29	Yes	7	0.00000001	0.00013482
30	Yes	7	0.00000001	0.00012683
31	Yes	7	0.00000001	0.00012688
32	Yes	7	0.00000001	0.00013489
33	Yes	7	0.00000001	0.00012652
34	Yes	7	0.00000001	0.00012636
35	Yes	7	0.00000001	0.00013458
36	Yes	7	0.00000001	0.00012667
37	Yes	7	0.00000001	0.00012689

Maximum Tower Deflections - Service Wind

Section No.	Elevation ft	Horz. Deflection in	Gov. Load Comb.	Tilt °	Twist °
L1	105 - 61	5.941	31	0.4858	0.0000
L2	65.75 - 27.75	2.313	31	0.3372	0.0000
L3	33.75 - 0	0.598	31	0.1607	0.0000

Critical Deflections and Radius of Curvature - Service Wind

Elevation ft	Appurtenance	Gov. Load Comb.	Deflection in	Tilt °	Twist °	Radius of Curvature ft
105.00	Lightning Rod	31	5.941	0.4858	0.0000	70306
100.00	(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	31	5.435	0.4696	0.0000	70306
95.00	(13) 4' Branches	31	4.934	0.4531	0.0000	35153
90.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	31	4.442	0.4361	0.0000	23435
80.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	31	3.500	0.3994	0.0000	14061
77.00	(11) 6' Branches	31	3.232	0.3874	0.0000	12554
70.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	31	2.643	0.3573	0.0000	10044
65.00	(7) 8' Branches	31	2.257	0.3335	0.0000	9082
60.00	(16) 10' Branches	31	1.904	0.3077	0.0000	8990
55.00	(16) 10' Branches	31	1.585	0.2805	0.0000	9020

Maximum Tower Deflections - Design Wind

Section No.	Elevation ft	Horz. Deflection in	Gov. Load Comb.	Tilt °	Twist °
L1	105 - 61	53.300	12	4.3615	0.0003

Section No.	Elevation ft	Horz. Deflection in	Gov. Load Comb.	Tilt °	Twist °
L2	65.75 - 27.75	20.769	12	3.0286	0.0001
L3	33.75 - 0	5.367	12	1.4439	0.0000

Critical Deflections and Radius of Curvature - Design Wind

Elevation ft	Appurtenance	Gov. Load Comb.	Deflection in	Tilt °	Twist °	Radius of Curvature ft
105.00	Lightning Rod	12	53.300	4.3615	0.0004	7926
100.00	(2) APX17DWV-17DWVS-A20 w/ Mount Pipe	12	48.771	4.2163	0.0003	7926
95.00	(13) 4' Branches	12	44.279	4.0688	0.0003	3962
90.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	12	39.864	3.9163	0.0002	2640
80.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	12	31.415	3.5870	0.0001	1583
77.00	(11) 6' Branches	12	29.015	3.4796	0.0001	1412
70.00	(3) ADFD1820-6565C-XDM w/ Mount Pipe	12	23.729	3.2089	0.0001	1129
65.00	(7) 8' Branches	12	20.268	2.9954	0.0001	1020
60.00	(16) 10' Branches	12	17.103	2.7643	0.0000	1008
55.00	(16) 10' Branches	12	14.236	2.5197	0.0000	1010

Compression Checks

Pole Design Data

Section No.	Elevation ft	Size	L ft	L_u ft	Kl/r	A in^2	P_u K	ϕP_n K	Ratio $\frac{P_u}{\phi P_n}$
L1	105 - 61 (1)	TP36.51x20x0.25	44.00	0.00	0.0	27.3580	-11.67	1839.66	0.006
L2	61 - 27.75 (2)	TP48.558x34.2277x0.4375	38.00	0.00	0.0	63.6793	-26.44	4674.63	0.006
L3	27.75 - 0 (3)	TP58.25x45.4203x0.5	33.75	0.00	0.0	91.6492	-43.18	6545.49	0.007

Pole Bending Design Data

Section No.	Elevation ft	Size	M_{ux} kip-ft	ϕM_{nx} kip-ft	Ratio $\frac{M_{ux}}{\phi M_{nx}}$	M_{uy} kip-ft	ϕM_{ny} kip-ft	Ratio $\frac{M_{uy}}{\phi M_{ny}}$
L1	105 - 61 (1)	TP36.51x20x0.25	1035.77	1305.06	0.794	0.00	1305.06	0.000
L2	61 - 27.75 (2)	TP48.558x34.2277x0.4375	3241.26	4400.78	0.737	0.00	4400.78	0.000
L3	27.75 - 0 (3)	TP58.25x45.4203x0.5	5813.20	7766.81	0.748	0.00	7766.81	0.000

Pole Shear Design Data

Section No.	Elevation ft	Size	Actual V_u K	ϕV_n K	Ratio $\frac{V_u}{\phi V_n}$	Actual T_u kip-ft	ϕT_n kip-ft	Ratio $\frac{T_u}{\phi T_n}$
L1	105 - 61 (1)	TP36.51x20x0.25	52.05	919.83	0.057	0.01	2613.31	0.000
L2	61 - 27.75 (2)	TP48.558x34.2277x0.4375	73.25	2337.32	0.031	0.01	8812.33	0.000
L3	27.75 - 0 (3)	TP58.25x45.4203x0.5	79.10	3272.74	0.024	0.01	15552.58	0.000

Pole Interaction Design Data

Section No.	Elevation ft	Ratio $\frac{P_u}{\phi P_n}$	Ratio $\frac{M_{ux}}{\phi M_{nx}}$	Ratio $\frac{M_{uy}}{\phi M_{ny}}$	Ratio $\frac{V_u}{\phi V_n}$	Ratio $\frac{T_u}{\phi T_n}$	Comb. Stress Ratio	Allow. Stress Ratio	Criteria
L1	105 - 61 (1)	0.006	0.794	0.000	0.057	0.000	0.803 ✔	1.000	4.8.2 ✔
L2	61 - 27.75 (2)	0.006	0.737	0.000	0.031	0.000	0.743 ✔	1.000	4.8.2 ✔
L3	27.75 - 0 (3)	0.007	0.748	0.000	0.024	0.000	0.756 ✔	1.000	4.8.2 ✔

Section Capacity Table

Section No.	Elevation ft	Component Type	Size	Critical Element	P K	ϕP_{allow} K	% Capacity	Pass Fail
L1	105 - 61	Pole	TP36.51x20x0.25	1	-11.67	1839.66	80.3	Pass
L2	61 - 27.75	Pole	TP48.558x34.2277x0.4375	2	-26.44	4674.63	74.3	Pass
L3	27.75 - 0	Pole	TP58.25x45.4203x0.5	3	-43.18	6545.49	75.6	Pass
							Summary	
						Pole (L1)	80.3	Pass
						RATING =	**80.3**	**Pass**