ANTENNA TOWERS AND SIGNS

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1.0 SCOPE

This data sheet provides recommendations and guidelines for design loads, inspection, and maintenance for large advertising signs; and for antenna towers used for radio, television, and cellular telephony and microwave transmissions. In general, these recommendations and guidelines are intended for new construction or when changes occur to original designs or operational loading criteria.

1.1 Changes

July 2011. The following changes were done for this revision:

- Added provisions to determine wind loads on trussed (latticed) and monopole towers
- Added wind pressure tables for trussed (latticed) and monopole towers
- Added guidance for radial ice thickness variations with tower height
- Added guidance for wind load effects on roof-mounted towers and signs
- Added guidance for velocity pressure exposure coefficient (K_z)
- Added guidance for topographic wind effects (K_{zt}) for towers and signs located on hills, ridges, or escarpments
- Added guidance for using several tower standards (TIA-222-G, TIA/EIA-222-F, CSA S37-01, and AS/NZS 1170.2); and several national standards for structural loads (ASCE 7, NBCC, Eurocode) for wind loads on towers and signs.
- Updated provisions to determine wind loads on signs.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Antenna Towers

2.1.1 Construction and Location

2.1.1.1 Use of Other Codes and Standards

See Section 2.1.1.7 for the use of other tower codes and standards.

2.1.1.2 Natural Hazards

If using allowable stress or working stress design procedures, do not use increases in allowable stresses for structural members or connections for any wind or earthquake load combinations.

2.1.1.2.1 Wind

2.1.1.2.1.1 Design Wind Forces

Design and construct towers, tower appurtenances, tower foundations, and tower foundation anchorages to adequately resist design wind forces. Determine the design wind forces exerted against signs in the following manner:

Use the following procedures to determine wind forces (wind loads) on the tower:

1. Use the Basic Wind Speed (V) from FM Global Data Sheet 1-28, *Wind Design*.

2. Determine if the location is in Ground Roughness (Terrain Roughness or Exposure) B, C, or D in accordance with FM Global Data Sheet 1-28, *Wind Design*, and if the tower is located on a hill, ridge or escarpment as defined in Section 2.1.1.2.1.4.

3. Determine the projected areas of the flat and round tower members (A_f and A_r) in each latticed tower section. Calculate the projected areas of the flat and round members separately since the wind pressures differ for each. For monopole towers, determine the projected area of the monopole (A_p). The projected area of round tower members and monopole towers is the diameter multiplied by the unit length. The projected area of flat tower members is the member width multiplied by the unit length. Round members are generally

pipes and rods. Flat members are generally angles, channels, plates, and square or rectangular tubes. See Section 3.3.1.1 for additional detail.

For example, the projected area of a 6 ft (1.83 m) long x 8.625-in. (219 mm) outside diameter pipe leg:
A_r = (6 ft)x(8.625-in.)/(12-in./ft) = 4.31 ft^2 (0.401 m^2)

4. Determine the solidity ratio (e) for latticed (trussed) tower sections. The solidity ratio (e) is the ratio of the projected area of solid members (both flat and round) to the gross area of the tower face ($0 \le e \le 1.0$).

5. Determine the wind pressures and wind forces (loads) on the tower.

a) Refer to Table 1 for monopole towers, or Tables 2, 3, 4 and 5 for latticed (trussed) towers, for wind pressures associated with a 3-second gust Basic Wind Speed of 90 mph (40 m/s) . Note that these tables are applicable for Exposure C (Ground Roughness C), and include a wind load Importance Factor (I_w) of 1.15. Refer to the table notes for additional details.

For example, on a square-legged lattices tower, normal wind direction, 90 mph (40 m/s) basic wind speed (V), 20% solid (e = 0.20), at a height of 100 ft [30 m], the wind pressures are 76 psf (3.7 kPa) on a flat member and 45 psf (2.2 kPa) on a round member, according to Tables 2 or 3. To determine the wind forces, multiply the wind pressures by the projected areas of the respective members.

Refer to the job aid in Appendix C for an example of how to determine solidity ratio, calculate wind pressures and loads of flat and round members for the full tower height, and calculate the resulting base shear and overturning moment for a square (4-legged) latticed tower for both normal and 45-degree wind directions.

Refer to Section 3.3.1.1 for background and details on how wind pressures and loads are determined, including the differenced between super-critical and sub-critical flow conditions.

b) Adjust the wind pressures from Tables 1, 2, 3, 4 and 5 for Basic Wind Speeds (V) other than 90 mph (40 m/s), as described in the table notes.

c) Adjust wind pressures for Ground Roughness (Exposure) B or D.

If the site is in Ground Roughness B or D, adjust the wind pressure values from Tables 1, 2, 3, 4, and 5 based on the K_z values from Table 7. For example, for Ground Roughness D, and for tower members at 200 ft [61 m] above ground:

From Table 7, at 200 ft (61 m), K_z = 1.46 for Exposure C, and K_z = 1.61 for Exposure D.

Therefore, use a multiplier of 1.10 applied to the wind pressures from Tables 1, 2, 3, 4, and 5 (since 1.61/1.46 = 1.10).

d) Determine the wind forces (loads) by multiplying the projected areas of the tower members by the wind pressures from Tables 1, 2, 3, 4, and 5, adjusted for Ground Roughness and Basic Wind Speed (V) as necessary.

Note that, in Tables 2, 3, 4 and 5: % Solid of Projected Area = 100 x solidity ratio (e).

6. Determine wind forces (loads) acting on guy wires. Add these forces to the other wind forces acting on the tower and tower appurtenances.

Refer to Table 6 for wind pressure on guy wires associated with a 3-second gust Basic Wind Speed of 90 mph (40 m/s) . Note that this table is applicable for Exposure C (Ground Roughness C), and includes a wind load Importance Factor (I_w) of 1.15. Refer to the table notes for additional details.

a) Adjust the wind pressures from Table 6 for Basic Wind Speeds (V) other than 90 mph (40 m/s), as described in the table notes.

b) Adjust wind pressures for Ground Roughness (Exposure) B or D.

If the site is in Ground Roughness B or D, adjust the wind pressure values from Table 6 based on the K_z values from Table 7.

For example, for Ground Roughness D, and a guy wire with its mid-height at 200 ft (61 m) above ground:

From Table 7, at 200 ft (61 m), K_z = 1.46 for Exposure C, and K_z = 1.61 for Exposure D. Therefore, use a multiplier of 1.10 applied to the wind pressures from Table 6 (since 1.61/1.46 = 1.10).

c) Determine the wind loads by multiplying the projected areas of the guy wires (guy diameter x length) by the wind pressures from Table 6, adjusted for Ground Roughness and Basic Wind Speed (V) as necessary.

7. Determine the wind forces on tower appurtenances. Appurtenances can include antennas, antenna mounts, transmission cable and conduit, lighting equipment, ladders, platforms, ice/hail shields, and signage.

a) Due to the many different sizes and shapes of available antennas, a simple method of determining drag and associated wind forces may not be practicable. Refer to reputable antennas tower standards or antennas manufacturer's data for additional guidance; when using these resources, ensure that the wind pressures and forces are representative of - or properly adjusted to account for - the proper wind speed, wind speed time duration (e.g., 3-second gust), wind direction, height above ground, exposure (ground roughness) and topography. Refer to Table 8 to adjust Basic Wind Speed based on height above grade by applying the Wind Speed Exposure Coefficient (K_v).

For example, for a location in Ground Roughness C with a Basic Wind Speed (V) of 90 mph (40 m/s) per FM Global Data Sheet 1-28, and an antenna attached to the tower at 200 ft (61 m) above grade. From Table 8, K_v = 1.21; therefore, the minimum 3-second gust design wind speed for the antenna and its mounting hardware is 1.21 x 90 mph (40 m/s) = 109 mph (49 m/s).

b) If a tower standard or manufacturer's specification provides wind forces on an appurtenance for a given wind speed, adjust the wind forces as necessary for differing wind speeds based on the ratio of the square of the wind speeds. For example, if the design wind speed at the height of the antenna is determined to be 109 mph (49 m/s), but the manufacturer's listed antenna wind forces are based on an allowable wind speed of 125 mph (55.9 m/s), then the design antenna wind forces can be reduced to 76% of the manufacturer's listed antenna wind forces ($[109/123]^2$ = 0.76).

c) For clustered appurtenances (e.g., bundled transmission cable or conduit), evaluate the wind force on each individual appurtenance in the cluster to determine the total wind force; however, the total wind force need not be larger than the wind force on an equivalent single appurtenance that circumscribes the individual appurtenances in the cluster. Use C_a of 1.2 for round and elliptical appurtenances or clusters, or C_a of 1.5 for rectangular appurtenances or clusters. Refer to Section 3.3.1.1 for additional detail.

8. Consider Wind Shielding (Wind Shadow)

Shielding applies to both parallel and intersecting tower members. Where the horizontal distance, parallel to the wind direction, between two members at the same elevation is less than or equal to twice (2x) the width of the windward (upwind) member, the leeward (downwind) member can be considered ″shielded″ from the wind <u>if</u> its width in no greater than the width of the windward member. For a ″shielded″ leeward element or member, the wind force will be negligible.

When considering a round member shielding flat member (e.g., a pipe shielding an angle), assume that the shielding round member is a flat member with the same projected area for the purpose of determining wind pressures. This technique need not be applied when a round member shield a round member, or when a flat member shields a round member.

Wind shielding does not apply to antennas.

2.1.1.2.1.2 Design Wind Directions

Ensure that the tower has been designed to properly resist wind forces (loads) for all typical design wind directions based on the most demanding load conditions.

Although the each latticed tower face will typically have the same effective wind area based only on the tower's structural elements, the location and size of antennas and other appurtenances attached to the tower will generally result in substantial differences in the total effective wind area for different tower faces; therefore, critical wind loading conditions will depend not only on wind direction relative to the tower orientation, but also on the antennas configuration and location of appurtenances on a specific tower.

See Figure 1 for typical wind directions used for tower analysis and design. For a square tower, the normal wind and 45-degree wind directions must be examined on each face and corner in order to determine the most demanding wind load conditions. For the triangular tower, the normal, 60-degree, and 90-degree wind directions must be examined on each face and corner in order to determine the most demanding wind load conditions. For the triangular tower, and when considering only the tower structure (excluding antennas and appurtenances), the wind forces for the 60-degree wind direction are very similar to those for the 90-degree wind direction; therefore the 90-degree wind direction forces (and pressures) can be used for the 60-degree wind direction.

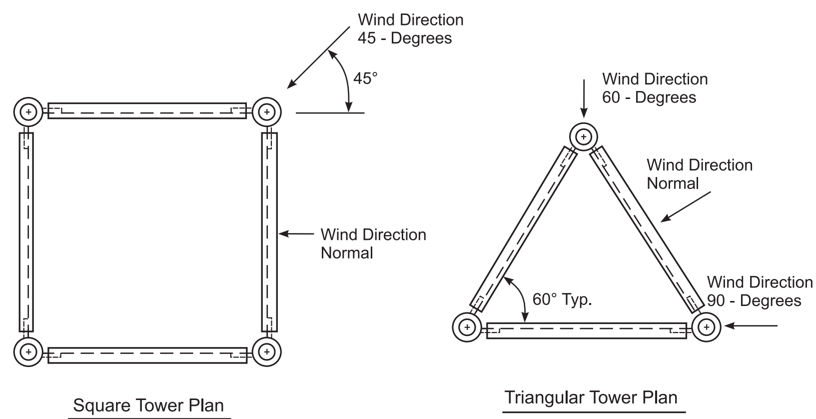


Fig. 1. Typical design wind directions

2.1.1.2.1.3 Towers Mounted on Building Roofs

For towers mounted on buildings roofs, calculate the wind pressure based on the elevation above ground, but increase the wind pressure by 30% in the ″wind speed-up zone″ as shown in Figure 2. H_a is defined as the lesser of either the height or width of the windward face of the building. Use the edge of the building closest to the tower to determine the largest wind speed-up zone.

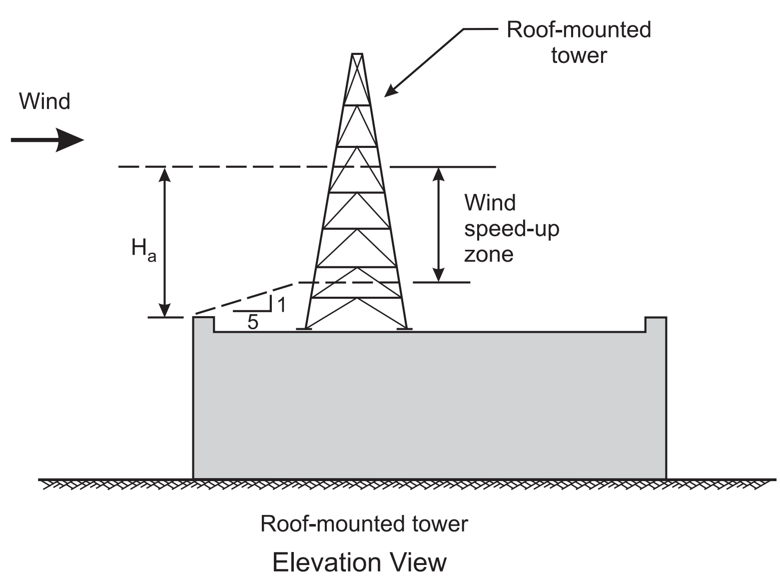


Fig. 2. Wind speed-up zone for roof-mounted towers

For example, for a building with plan dimensions 200 ft x 80 ft (61 m x 24 m), and a height of 60 ft (18 m) to the parapet, a roof mounted tower is setback 30 ft (9 m) from the closest roof edge, which is the 80 ft (24 m) side of the building. Therefore, H_a = 60 ft (18 m), and 1/5 x 30 ft (9 m) = 6 ft (2 m). So the 30% increase in wind load is applied to a wind speed-up zone from 6 ft (2 m) to 60 ft (18 m) on the tower.

2.1.1.2.1.4 Towers Located on Hills, Ridges, or Escarpments (Cliffs)

1. For towers located on hills, ridges, or escarpments, use the topographic wind factor (K_{zt}), applied to wind pressure, or to wind load, to account for the wind speed-up effect of the local topography. To be classified as an escarpment, the upper plateau of the escarpment must have an average slope not greater than 5% (3-degrees) for a horizontal distance downwind of the crest of at least twice the height (H) of the escarpment.

K_{zt} need only be used where all of the following are applicable:

a) The average slope of the hill, ridge, or escarpment – from the base to crest - is 10% (6-degrees) or greater.

b) The height (H) of the hill, ridge or escarpment is at least 60 ft (18.3 m) for Exposure B, or at least 15 ft (4.6 m) for Exposure C and Exposure D.

c) The structure is located on the upper half of the hill, ridge, or escarpment slope (i.e., mid-height or higher); or located on the escarpment plateau within a horizontal distance 2L from the crest of the escarpment.

d) The hill, ridge, or escarpment is isolated and unobstructed – that is, the hill, ridge, or escarpment is at least twice (2x) the height of upwind topographic features within a radius of 2 miles or 100 x H, whichever is less, in any wind direction quadrant.

2. When evaluating overall tower strength and stability (e.g., base reactions such as shear load and overturning moment) under wind loading, K_{zt} may be disregarded (i.e., use K_{zt} = 1.0) when ratio of the tower height to the height (H) of the hill, ridge, or escarpment is greater than 7.0 ; however, when evaluating wind loading on tower appurtenances, such as antennas and antennas supports, K_{zt} may not be disregarded.

3. The use of a topographic wind factor from a nationally recognized consensus standard or code, such as ASCE 7, NBCC, Eurocode, or Australian/New Zealand Standard, is also acceptable.

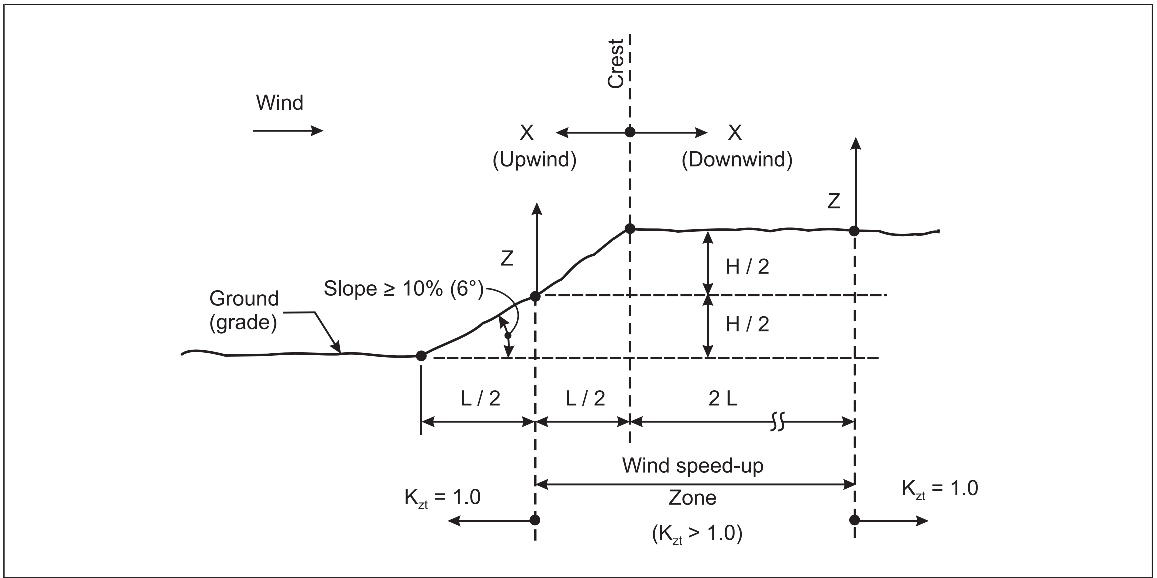


Fig. 3. Topographic Wind Factor (K_{zt}) Zone (Note: An escarpment is shown, but the upwind portion of the diagram is also applicable to hills and ridges).

2.1.1.2.1.5 Guy Dampers

Provide appropriate vibration dampers where low and high frequency guy oscillations can be expected.

Table 1. Wind Pressure on Tubular Pole (Monopole) Towers

MONOPOLE (TUBULAR POLE) STRUCTURES					
WIND PRESSURE in pounds per ft^2 (psf) 90 MPH (40 m/s) WIND SPEED					
Height (ft)	ROUND	18-SIDED	16-SIDED	12-SIDED	8-SIDED
0 to 30	16	17	20	26	31
50	18	19	22	30	35
70	20	21	25	33	39
90	21	23	27	35	42
110	22	24	28	37	44
130	23	25	29	39	47
150	24	26	31	40	49
170	25	27	32	42	50
190	26	28	33	43	52
210	27	29	34	45	53
230	27	30	35	46	55
WIND PRESSURE in kiloPascals (kPa) 40 m/s (90 MPH) WIND SPEED					
Height (m)	ROUND	18-SIDED	16-SIDED	12-SIDED	8-SIDED
0 to 10	1.2	1.2	1.5	1.9	2.3
20	1.4	1.5	1.8	2.3	2.8
30	1.6	1.7	2.0	2.6	3.2
40	1.7	1.9	2.2	2.9	3.4
50	1.8	2.0	2.3	3.0	3.7
60	1.9	2.1	2.4	3.2	3.9
70	2.0	2.2	2.5	3.4	4.0

TABLE NOTES:

(1) Wind speed noted is the Basic Wind Speed, 3-second gust, at 33 ft (10 m) above grade.
(2) Table is based on Ground Roughness **C** and includes an Importance Factor **I_w = 1.15**, and a directionality factor **K_d = 1.0**.
(3) Apply a factor of 0.8 or 1.13 to the table wind pressures for Ground Roughness B or D, respectively.
(4) Wind pressures shown are based on a gust factor **G = 1.10**.
(5) Pressures are unfactored (characteristic); therefore, apply a load factor or partial safety factor for use in ultimate limit states or strength (LRFD) design.
(6) Table is based on relatively flat topography (i.e., not applicable to structures located on hills, ridges, or escarpments; therefore **K_{zt} = 1.0**)
(7) Table is applicable to pole structures mounted at grade, not to poles mounted on building roofs.
(8) Linear interpolation may be used for HEIGHT.
(9) To obtain pressures for wind speeds other than 90 mph (40 m/s), apply a factor based on the square of the ratio of the velocities. For example, to obtain pressures that represent a wind speed of 110 mph (49 m/s), apply a factor of 1.49 to the pressure values in the table [$(110/90)^2$ = 1.49].
(10) Values are based on **supercritical flow**, and generally should only be used for members with widths or diameters greater than 12 inches (305 mm) at 90 mph (40 m/s) wind speed.
(11) For **subcritical flow**, use 8-Sided wind pressures for all monopole shapes.
(12) To determine wind force, multiply the wind pressure values in the table by the projected area of the pole (A_p).

Table 2. Wind Pressure (psf) on Square (4-Legged) Trussed Tower for 90 mph Basic Wind Speed.

SQUARE (4-LEGGED) TRUSSED TOWER — 90 MPH (40 m/s) WIND SPEED — DESIGN WIND PRESSURE in pounds per ft² (psf)																							
WIND DIRECTION NORMAL																							
Height (ft)	% Solid of Projected Area																						Height (ft)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 30	80	45	69	40	59	35	52	32	45	30	41	28	38	29	36	30	37	33	38	38	42	42	0 to 30
50	89	51	76	44	66	39	57	35	51	33	45	32	42	32	41	33	41	37	43	42	47	47	50
70	95	54	82	47	71	42	62	38	54	35	49	34	45	34	44	36	44	39	46	45	50	50	70
100	103	58	89	51	76	45	66	41	58	38	53	37	49	37	47	38	47	42	50	49	54	54	100
150	112	64	96	55	83	49	72	45	64	42	57	40	53	40	51	42	51	46	54	53	59	59	150
200	119	68	102	59	88	52	77	47	68	44	61	42	56	43	54	45	55	49	57	56	62	62	200
250	124	71	107	62	93	55	81	50	71	46	64	44	59	45	57	47	57	51	60	59	65	65	250
300	129	74	112	64	96	57	84	52	74	48	66	46	61	46	59	49	59	53	62	61	68	68	300
400	137	78	118	68	102	60	89	55	78	51	70	49	65	49	63	52	63	57	66	65	72	72	400
500	144	82	124	71	107	63	93	57	82	53	74	51	68	52	66	54	66	59	69	68	76	76	500
600	150	85	129	74	111	66	97	60	85	56	77	53	71	54	68	56	69	62	72	71	79	79	600
700	155	88	133	77	115	68	100	62	88	57	79	55	73	55	71	58	71	64	75	73	81	81	700
800	159	91	137	79	118	70	103	63	91	59	81	57	76	57	73	60	73	66	77	75	83	83	800
1000	167	95	144	83	124	73	108	66	95	62	85	60	79	60	76	63	77	69	80	79	87	87	1000
1200	173	99	149	86	129	76	112	69	99	64	89	62	82	62	79	65	80	71	84	82	91	91	1200
1400	179	102	154	89	133	79	116	71	102	66	92	64	85	64	82	67	82	74	86	85	94	94	1400
1600	184	105	159	91	137	81	119	73	105	68	94	66	87	66	84	69	85	76	89	87	97	97	1600
1800	189	107	163	94	140	83	122	75	107	70	97	67	90	68	86	71	87	78	91	89	99	99	1800
2000	193	110	166	96	144	85	125	77	110	72	99	69	92	69	88	72	89	79	93	91	101	101	2000
WIND DIRECTION 45-DEGREES																							
Height (m)	% Solid of Projected Area																						Height (m)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 30	80	45	74	42	68	40	62	38	54	35	49	34	45	34	44	36	44	39	46	45	50	50	0 to 30
50	89	51	82	47	76	45	69	42	61	40	55	38	51	38	49	40	49	44	51	51	56	56	50
70	95	54	88	51	82	48	74	46	65	42	59	41	54	41	52	43	53	47	55	54	60	60	70
100	103	58	95	55	88	52	80	49	70	46	63	44	58	44	56	46	57	51	60	58	65	65	100
150	112	64	104	60	96	57	87	53	76	50	69	48	64	48	61	50	62	55	65	64	70	70	150
200	119	68	110	63	102	60	92	57	81	53	73	51	68	51	65	53	66	59	69	68	75	75	200
250	124	71	115	66	107	63	97	60	85	55	77	53	71	53	68	56	69	62	72	71	78	78	250
300	129	74	120	69	111	65	100	62	88	58	80	55	74	56	71	58	71	64	75	74	81	81	300
400	137	78	127	73	118	69	107	66	94	61	84	59	78	59	75	62	76	68	80	78	87	87	400
500	144	82	134	77	123	73	112	69	98	64	89	62	82	62	79	65	79	71	84	82	91	91	500
600	150	85	139	80	128	76	116	72	102	67	92	64	85	64	82	67	83	74	87	85	94	94	600
700	155	88	143	82	132	78	120	74	106	69	95	66	88	66	85	70	85	76	90	88	97	97	700
800	159	91	147	85	136	80	124	76	109	71	98	68	91	68	87	72	88	79	92	91	100	100	800
1000	167	95	154	89	143	84	129	80	114	74	102	71	95	72	91	75	92	82	97	95	105	105	1000
1200	173	99	161	92	148	88	135	83	118	77	106	74	99	74	95	78	96	86	100	99	109	109	1200
1400	179	102	166	95	153	90	139	86	122	80	110	77	102	77	98	81	99	88	104	102	113	113	1400
1600	184	105	171	98	158	93	143	88	126	82	113	79	105	79	101	83	102	91	107	105	116	116	1600
1800	189	107	175	101	162	95	147	90	129	84	116	81	107	81	104	85	104	93	109	107	119	119	1800
2000	193	110	179	103	165	98	150	92	132	86	119	83	110	83	106	87	106	95	112	110	121	121	2000

TABLE NOTES: (1) Wind speed noted is the Basic Wind Speed, **3-second gust** at 33 ft (10 m) above grade.

(2) Wind pressures shown are based on Ground Roughness C and include an Importance Factor **I_W = 1.15**, and a directionality factor **K_d = 0.85.**

(3) Wind pressures shown are based on a gust factor **G = 1.0**.

(4) Wind pressures shown are unfactored (charteristic) — that is, they include an embedded default Load Factor (Partial Safety Factor) of 1.0.

(5) Wind direction is measured from a line normal (perpendicular) to the face of the tower.

(6) Wind pressures shown are based on relatively flat topography (i.e., not applicable to structures located on hills, ridges, or escarpments): **K_{zt} = 1.0**.

(7) FLAT designates structural members with flat profiles (e.g., angle, channel).

(8) ROUND designates structural members with rounded profiles (e.g., pipe, rod).

(9) SOLID OF PROJECTED AREA = (ratio of projected solid area to gross area of one tower face) x 100 = **e** x 100

(10) Linear interpolation may be used for SOLID OF PROJECTED AREA and HEIGHT.

(11) To obtain pressures for wind speeds other than 90 mph (40 m/s), apply a factor based on the square of the ratio of the speeds.
For example, to obtain pressures that represent a wind speed of 110 mph, apply a factor of 1.49 to the pressure values in the table [$(110/90)^2$ = 1.49].

(12) To obtain wind loads, multiply the wind pressure values in the table by the projected areas of the tower members (A_{fr}).

Table 3. Wind Pressure (kPa) on Square (4-Legged) Trussed Tower for 40 m/s Basic Wind Speed.

SQUARE (4-LEGGED) TRUSSED TOWER — 40 m/s (90 mph) WIND SPEED — WIND PRESSURE in kiloPascals (kPa)

WIND DIRECTION NORMAL

Height (m)	% SOLID OF PROJECTED AREA 0		10		20		30		40		50		60		70		80		90		100		Height (m)
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 9	3.8	2.2	3.3	1.9	2.8	1.7	2.5	1.5	2.2	1.4	2.0	1.4	1.8	1.4	1.7	1.4	1.8	1.6	1.8	1.8	2.0	2.0	0 to 9
15	4.2	2.4	3.7	2.1	3.2	1.9	2.8	1.7	2.4	1.6	2.2	1.5	2.0	1.5	1.9	1.6	2.0	1.8	2.0	2.0	2.2	2.2	15
21	4.6	2.6	3.9	2.3	3.4	2.0	3.0	1.8	2.6	1.7	2.3	1.6	2.2	1.6	2.1	1.7	2.1	1.9	2.2	2.2	2.4	2.4	21
30	4.9	2.8	4.2	2.4	3.7	2.2	3.2	2.0	2.8	1.8	2.5	1.8	2.3	1.8	2.2	1.8	2.3	2.0	2.4	2.3	2.6	2.6	30
46	5.4	3.1	4.6	2.7	4.0	2.4	3.5	2.1	3.1	2.0	2.7	1.9	2.5	1.9	2.4	2.0	2.5	2.2	2.6	2.5	2.8	2.8	46
61	5.7	3.2	4.9	2.8	4.2	2.5	3.7	2.3	3.2	2.1	2.9	2.0	2.7	2.0	2.6	2.1	2.6	2.3	2.7	2.7	3.0	3.0	61
76	6.0	3.4	5.1	3.0	4.4	2.6	3.9	2.4	3.4	2.2	3.1	2.1	2.8	2.1	2.7	2.2	2.7	2.5	2.9	2.8	3.1	3.1	76
91	6.2	3.5	5.3	3.1	4.6	2.7	4.0	2.5	3.5	2.3	3.2	2.2	2.9	2.2	2.8	2.3	2.8	2.6	3.0	2.9	3.3	3.3	91
122	6.6	3.8	5.7	3.3	4.9	2.9	4.3	2.6	3.8	2.4	3.4	2.4	3.1	2.4	3.0	2.5	3.0	2.7	3.2	3.1	3.5	3.5	122
152	6.9	3.9	5.9	3.4	5.1	3.0	4.5	2.8	3.9	2.6	3.5	2.5	3.3	2.5	3.2	2.6	3.2	2.8	3.3	3.3	3.6	3.6	152
183	7.2	4.1	6.2	3.6	5.3	3.2	4.6	2.9	4.1	2.7	3.7	2.6	3.4	2.6	3.3	2.7	3.3	3.0	3.5	3.4	3.8	3.8	183
213	7.4	4.2	6.4	3.7	5.5	3.3	4.8	3.0	4.2	2.7	3.8	2.6	3.5	2.6	3.4	2.8	3.4	3.1	3.6	3.5	3.9	3.9	213
244	7.6	4.3	6.6	3.8	5.7	3.3	4.9	3.0	4.3	2.8	3.9	2.7	3.6	2.7	3.5	2.9	3.5	3.1	3.7	3.6	4.0	4.0	244
305	8.0	4.5	6.9	4.0	5.9	3.5	5.2	3.2	4.5	3.0	4.1	2.9	3.8	2.9	3.7	3.0	3.7	3.3	3.9	3.8	4.2	4.2	305
366	8.3	4.7	7.2	4.1	6.2	3.6	5.4	3.3	4.7	3.1	4.2	3.0	3.9	3.0	3.8	3.1	3.8	3.4	4.0	3.9	4.4	4.4	366
427	8.6	4.9	7.4	4.2	6.4	3.8	5.5	3.4	4.9	3.2	4.4	3.1	4.1	3.1	3.9	3.2	3.9	3.5	4.1	4.1	4.5	4.5	427
488	8.8	5.0	7.6	4.4	6.6	3.9	5.7	3.5	5.0	3.3	4.5	3.1	4.2	3.2	4.0	3.3	4.1	3.6	4.3	4.2	4.6	4.6	488
549	9.0	5.1	7.8	4.5	6.7	4.0	5.8	3.6	5.1	3.4	4.6	3.2	4.3	3.2	4.1	3.4	4.2	3.7	4.4	4.3	4.7	4.7	549
610	9.2	5.3	8.0	4.6	6.9	4.1	6.0	3.7	5.3	3.4	4.7	3.3	4.4	3.3	4.2	3.5	4.2	3.8	4.5	4.4	4.8	4.8	610

WIND DIRECTION 45-DEGREES

Height (m)	% SOLID OF PROJECTED AREA 0		10		20		30		40		50		60		70		80		90		100		Height (m)
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 9	3.8	2.2	3.5	2.0	3.3	1.9	3.0	1.8	2.6	1.7	2.3	1.6	2.2	1.6	2.1	1.7	2.1	1.9	2.2	2.2	2.4	2.4	0 to 9
15	4.2	2.4	3.9	2.3	3.6	2.1	3.3	2.0	2.9	1.9	2.6	1.8	2.4	1.8	2.3	1.9	2.3	2.1	2.5	2.4	2.7	2.7	15
21	4.6	2.6	4.2	2.4	3.9	2.3	3.5	2.2	3.1	2.0	2.8	2.0	2.6	2.0	2.5	2.1	2.5	2.3	2.6	2.6	2.9	2.9	21
30	4.9	2.8	4.6	2.6	4.2	2.5	3.8	2.4	3.4	2.2	3.0	2.1	2.8	2.1	2.7	2.2	2.7	2.4	2.9	2.8	3.1	3.1	30
46	5.4	3.1	5.0	2.9	4.6	2.7	4.2	2.6	3.7	2.4	3.3	2.3	3.1	2.3	2.9	2.4	3.0	2.6	3.1	3.1	3.4	3.4	46
61	5.7	3.2	5.3	3.0	4.9	2.9	4.4	2.7	3.9	2.5	3.5	2.4	3.2	2.4	3.1	2.6	3.1	2.8	3.3	3.2	3.6	3.6	61
76	6.0	3.4	5.5	3.2	5.1	3.0	4.6	2.9	4.1	2.7	3.7	2.6	3.4	2.6	3.3	2.7	3.3	2.9	3.5	3.4	3.8	3.8	76
91	6.2	3.5	5.7	3.3	5.3	3.1	4.8	3.0	4.2	2.8	3.8	2.7	3.5	2.7	3.4	2.8	3.4	3.1	3.6	3.5	3.9	3.9	91
122	6.6	3.8	6.1	3.5	5.6	3.3	5.1	3.1	4.5	2.9	4.0	2.8	3.8	2.8	3.6	3.0	3.6	3.3	3.8	3.8	4.1	4.1	122
152	6.9	3.9	6.4	3.7	5.9	3.5	5.4	3.3	4.7	3.1	4.2	3.0	3.9	3.0	3.8	3.1	3.8	3.4	4.0	3.9	4.3	4.3	152
183	7.2	4.1	6.6	3.8	6.1	3.6	5.6	3.4	4.9	3.2	4.4	3.1	4.1	3.1	3.9	3.2	4.0	3.5	4.2	4.1	4.5	4.5	183
213	7.4	4.2	6.9	3.9	6.3	3.7	5.8	3.5	5.1	3.3	4.6	3.2	4.2	3.2	4.1	3.3	4.1	3.7	4.3	4.2	4.7	4.7	213
244	7.6	4.3	7.1	4.1	6.5	3.9	5.9	3.6	5.2	3.4	4.7	3.3	4.3	3.3	4.2	3.4	4.2	3.8	4.4	4.3	4.8	4.8	244
305	8.0	4.5	7.4	4.3	6.8	4.0	6.2	3.8	5.5	3.6	4.9	3.4	4.5	3.4	4.4	3.6	4.4	3.9	4.6	4.5	5.0	5.0	305
366	8.3	4.7	7.7	4.4	7.1	4.2	6.4	4.0	5.7	3.7	5.1	3.6	4.7	3.6	4.6	3.7	4.6	4.1	4.8	4.7	5.2	5.2	366
427	8.6	4.9	7.9	4.6	7.3	4.3	6.7	4.1	5.9	3.8	5.3	3.7	4.9	3.7	4.7	3.9	4.7	4.2	5.0	4.9	5.4	5.4	427
488	8.8	5.0	8.2	4.7	7.5	4.5	6.8	4.2	6.0	3.9	5.4	3.8	5.0	3.8	4.8	4.0	4.9	4.4	5.1	5.0	5.6	5.6	488
549	9.0	5.1	8.4	4.8	7.7	4.6	7.0	4.3	6.2	4.0	5.6	3.9	5.1	3.9	5.0	4.1	5.0	4.5	5.2	5.1	5.7	5.7	549
610	9.2	5.3	8.6	4.9	7.9	4.7	7.2	4.4	6.3	4.1	5.7	4.0	5.3	4.0	5.1	4.2	5.1	4.6	5.4	5.3	5.8	5.8	610

TABLE NOTES: (1) Wind speed noted is the Basic Wind Speed, **3-second gust** at 10 m (33 ft) above grade.

(2)Wind pressures shown are based on Ground Roughness C and include an Importance Factor $\mathbf{I_w = 1.15}$, and a directionality factor $\mathbf{K_d = 0.85}$.

(3) Wind pressures shown are based on a gust factor **G = 1.0**.

(4)Wind pressures shown are unfactored (charteristic) — that is, they include an embedded default Load Factor (Partial Safety Factor) of 1.0.

(5)Wind direction is measured from a line normal (perpendicular) to the face of the tower.

(6)Wind pressures shown are based on relatively flat topography (i.e., not applicable to structures located on hills, ridges, or escarpments): $\mathbf{K_{zt} = 1.0}$.

(7) FLAT designates structural members with flat profiles (e.g., angle, channel).

(8) ROUND designates structural members with rounded profiles (e.g., pipe, rod).

(9) SOLID OF PROJECTED AREA = (ratio of projected solid area to gross area of one tower face) x 100 = **e** x 100

(10) Linear interpolation may be used for SOLID OF PROJECTED AREA and HEIGHT.

(11) To obtain pressures for wind speeds other than 40 m/s (90 mph), apply a factor based on the square of the ratio of the speeds.
For example, to obtain pressures that represent a wind speed of 49 m/s, apply a factor of 1.50 to the pressure values in the table [$(49/40)^2$ = 1.50].

(12) To obtain wind loads, multiply the wind pressure values in the table by the projected areas of the tower members ($\mathbf{A_f}$ or $\mathbf{A_r}$).

Table 4. Wind Pressure (psf) on Triangular (3-Legged) Trussed Tower for 90 mph Basic Wind Speed.

TRIANGULAR (3-LEGGED) TRUSSED TOWER — 90 mph (40 m/s) WIND SPEED — DESIGN WIND PRESSURE in pounds per ft^2																							
WIND DIRECTION NORMAL																							
Height (m)	% SOLID OF PROJECTED AREA																						Height (m)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 30	68	39	59	34	52	31	46	28	41	27	38	26	36	27	35	29	36	32	38	38	42	42	0 to 30
50	75	43	66	38	58	34	51	31	46	30	42	29	40	30	39	32	40	36	43	42	47	47	50
70	81	46	71	41	62	36	55	34	49	32	45	32	43	32	42	35	43	39	46	45	50	50	70
100	87	50	76	44	67	39	59	36	53	35	49	34	46	35	46	37	47	42	49	49	54	54	100
150	95	54	83	48	73	43	64	40	58	38	53	37	50	38	50	41	51	45	54	53	59	59	150
200	101	58	88	51	77	45	68	42	61	40	56	39	54	40	53	43	54	48	57	56	62	62	200
250	106	60	92	53	81	48	71	44	64	42	59	41	56	42	55	45	56	51	60	59	65	65	250
300	110	63	96	55	84	50	74	46	67	43	61	43	58	44	57	47	59	53	62	61	68	68	300
400	117	67	102	59	89	53	79	49	71	46	65	46	62	47	61	50	62	56	66	65	72	72	400
500	122	70	107	61	93	55	83	51	74	48	68	48	65	49	64	52	65	59	69	68	76	76	500
600	127	73	111	64	97	57	86	53	77	50	71	50	67	51	66	54	68	61	72	71	79	79	600
700	131	75	115	66	100	59	89	55	80	52	73	51	70	53	69	56	70	63	74	73	81	81	700
800	135	77	118	68	103	61	91	56	82	53	76	53	72	54	71	58	72	65	76	75	83	83	800
1000	142	81	123	71	108	64	96	59	86	56	79	55	75	57	74	61	76	68	80	79	87	87	1000
1200	147	84	128	74	112	66	99	61	89	58	82	57	78	59	77	63	79	70	83	82	91	91	1200
1400	152	87	133	76	116	69	103	63	92	60	85	59	81	61	79	65	81	73	86	85	94	94	1400
1600	156	89	136	78	119	70	106	65	95	62	87	61	83	63	82	67	84	75	88	87	97	97	1600
1800	160	91	140	80	122	72	108	67	97	63	90	62	85	64	84	69	86	77	91	89	99	99	1800
2000	164	94	143	82	125	74	111	68	99	65	92	64	87	66	86	70	88	78	93	91	101	101	2000
WIND DIRECTION 90-DEGREES																							
Height (m)	% SOLID OF PROJECTED AREA																						Height (m)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 30	58	39	50	34	44	31	39	28	35	27	32	26	31	27	30	29	31	32	33	38	36	42	0 to 30
50	64	43	56	38	49	34	43	31	39	30	36	29	34	30	33	32	34	36	36	42	40	47	50
70	69	46	60	41	53	36	46	34	42	32	38	32	36	32	36	35	37	39	39	45	42	50	70
100	74	50	65	44	57	39	50	36	45	35	41	34	39	35	39	37	40	42	42	49	46	54	100
150	81	54	70	48	62	43	55	40	49	38	45	37	43	38	42	41	43	45	46	53	50	59	150
200	86	58	75	51	66	45	58	42	52	40	48	39	46	40	45	43	46	48	49	56	53	62	200
250	90	60	78	53	69	48	61	44	55	42	50	41	48	42	47	45	48	51	51	59	56	65	250
300	93	63	81	55	71	50	63	46	57	43	52	43	50	44	49	47	50	53	53	61	58	68	300
400	99	67	87	59	76	53	67	49	60	46	55	46	53	47	52	50	53	56	56	65	61	72	400
500	104	70	91	61	79	55	70	51	63	48	58	48	55	49	54	52	56	59	59	68	64	76	500
600	108	73	94	64	83	57	73	53	66	50	60	50	57	51	56	54	58	61	61	71	67	79	600
700	112	75	97	66	85	59	75	55	68	52	62	51	59	53	58	56	60	63	63	73	69	81	700
800	115	77	100	68	88	61	78	56	70	53	64	53	61	54	60	58	61	65	65	75	71	83	800
1000	120	81	105	71	92	64	81	59	73	56	67	55	64	57	63	61	64	68	68	79	74	87	1000
1200	125	84	109	74	96	66	84	61	76	58	70	57	66	59	65	63	67	70	71	82	77	91	1200
1400	129	87	113	76	99	69	87	63	78	60	72	59	69	61	67	65	69	73	73	85	80	94	1400
1600	133	89	116	78	101	70	90	65	81	62	74	61	71	63	69	67	71	75	75	87	82	97	1600
1800	136	91	119	80	104	72	92	67	83	63	76	62	72	64	71	69	73	77	77	89	84	99	1800
2000	139	94	121	82	106	74	94	68	85	65	78	64	74	66	73	70	74	78	79	91	86	101	2000

TABLE NOTES:

(1)Wind speed noted is the Basic Wind Speed, **3-second gust** at 33 ft (10 m) above grade.

(2)Wind pressures shown are based on Ground Roughness C and include an Importance Factor $\mathbf{I_W = 1.15}$, and a directionality factor $\mathbf{K_d = 0.85}$.

(3)Wind pressures shown are based on a gust factor **G = 1.0**.

(4)Wind pressures shown are unfactored (charteristic) — that is, they include an embedded default Load Factor (Partial Safety Factor) of 1.0.

(5)Wind direction is measured from a line normal (perpendicular) to the face of the tower.

(6)Wind pressures shown are based on relatively flat topography (i.e., not applicable to structures located on hills, ridges, or escarpments): $\mathbf{K_{zt} = 1.0}$.

(7)FLAT designates structural members with flat profiles (e.g., angle, channel).

(8)ROUND designates structural members with rounded profiles (e.g., pipe, rod).

(9) SOLID OF PROJECTED AREA = (ratio of projected solid area to gross area of one tower face) x 100 = **e** x 100

(10)Linear interpolation may be used for SOLID OF PROJECTED AREA and HEIGHT.

(11)To obtain pressures for wind speeds other than 90 mph (40 m/s), apply a factor based on the square of the ratio of the speeds.

For example, to obtain pressures that represent a wind speed of 110 mph, apply a factor of 1.49 to the pressure values in the table [$(110/90)^2 = 1.49$].

(12)To obtain wind loads, multiply the wind pressure values in the table by the projected areas of the tower members ($\mathbf{A_f}$ or $\mathbf{A_r}$).

Table 5. Wind Pressure (kPa) on Triangular (3-Legged) Trussed Tower for 40 m/s Basic Wind Speed.

TRIANGULAR (3-LEGGED) TRUSSED TOWER — 40 m/s (90 mph) WIND SPEED — WIND PRESSURE in kiloPascals (kPa)																							
WIND DIRECTION NORMAL																							
Height (m)	% SOLID OF PROJECTED AREA																						Height (m)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 9	3.2	1.8	2.8	1.6	2.5	1.5	2.2	1.3	2.0	1.3	1.8	1.3	1.7	1.3	1.7	1.4	1.7	1.6	1.8	1.8	2.0	2.0	0 to 9
15	3.6	2.1	3.1	1.8	2.8	1.6	2.4	1.5	2.2	1.4	2.0	1.4	1.9	1.4	1.9	1.5	1.9	1.7	2.0	2.0	2.2	2.2	15
21	3.9	2.2	3.4	1.9	3.0	1.7	2.6	1.6	2.4	1.5	2.2	1.5	2.1	1.5	2.0	1.7	2.1	1.9	2.2	2.2	2.4	2.4	21
30	4.2	2.4	3.6	2.1	3.2	1.9	2.8	1.7	2.5	1.7	2.3	1.6	2.2	1.7	2.2	1.8	2.2	2.0	2.4	2.3	2.6	2.6	30
46	4.5	2.6	4.0	2.3	3.5	2.1	3.1	1.9	2.8	1.8	2.5	1.8	2.4	1.8	2.4	1.9	2.4	2.2	2.6	2.5	2.8	2.8	46
61	4.8	2.8	4.2	2.4	3.7	2.2	3.3	2.0	2.9	1.9	2.7	1.9	2.6	1.9	2.5	2.1	2.6	2.3	2.7	2.7	3.0	3.0	61
76	5.1	2.9	4.4	2.5	3.9	2.3	3.4	2.1	3.1	2.0	2.8	2.0	2.7	2.0	2.6	2.2	2.7	2.4	2.9	2.8	3.1	3.1	76
91	5.3	3.0	4.6	2.6	4.0	2.4	3.6	2.2	3.2	2.1	2.9	2.1	2.8	2.1	2.7	2.3	2.8	2.5	3.0	2.9	3.3	3.3	91
122	5.6	3.2	4.9	2.8	4.3	2.5	3.8	2.3	3.4	2.2	3.1	2.2	3.0	2.2	2.9	2.4	3.0	2.7	3.2	3.1	3.5	3.5	122
152	5.9	3.3	5.1	2.9	4.5	2.6	4.0	2.4	3.6	2.3	3.3	2.3	3.1	2.3	3.1	2.5	3.1	2.8	3.3	3.3	3.6	3.6	152
183	6.1	3.5	5.3	3.1	4.7	2.7	4.1	2.5	3.7	2.4	3.4	2.4	3.2	2.4	3.2	2.6	3.3	2.9	3.4	3.4	3.8	3.8	183
213	6.3	3.6	5.5	3.2	4.8	2.8	4.2	2.6	3.8	2.5	3.5	2.5	3.3	2.5	3.3	2.7	3.4	3.0	3.6	3.5	3.9	3.9	213
244	6.5	3.7	5.6	3.2	4.9	2.9	4.4	2.7	3.9	2.6	3.6	2.5	3.4	2.6	3.4	2.8	3.5	3.1	3.7	3.6	4.0	4.0	244
305	6.8	3.9	5.9	3.4	5.2	3.1	4.6	2.8	4.1	2.7	3.8	2.6	3.6	2.7	3.5	2.9	3.6	3.2	3.8	3.8	4.2	4.2	305
366	7.0	4.0	6.1	3.5	5.4	3.2	4.8	2.9	4.3	2.8	3.9	2.7	3.7	2.8	3.7	3.0	3.8	3.4	4.0	3.9	4.4	4.4	366
427	7.3	4.2	6.3	3.7	5.6	3.3	4.9	3.0	4.4	2.9	4.1	2.8	3.9	2.9	3.8	3.1	3.9	3.5	4.1	4.1	4.5	4.5	427
488	7.5	4.3	6.5	3.8	5.7	3.4	5.1	3.1	4.5	3.0	4.2	2.9	4.0	3.0	3.9	3.2	4.0	3.6	4.2	4.2	4.6	4.6	488
549	7.7	4.4	6.7	3.8	5.9	3.5	5.2	3.2	4.7	3.0	4.3	3.0	4.1	3.1	4.0	3.3	4.1	3.7	4.3	4.3	4.7	4.7	549
610	7.8	4.5	6.8	3.9	6.0	3.5	5.3	3.3	4.8	3.1	4.4	3.1	4.2	3.1	4.1	3.4	4.2	3.8	4.4	4.4	4.8	4.8	610
WIND DIRECTION 45-DEGREES																							
Height (m)	% SOLID OF PROJECTED AREA																						Height (m)
	0		10		20		30		40		50		60		70		80		90		100		
	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	FLAT	ROUND	
0 to 9	2.8	1.8	2.4	1.6	2.1	1.5	1.9	1.3	1.7	1.3	1.5	1.3	1.5	1.3	1.4	1.4	1.5	1.6	1.6	1.8	1.7	2.0	0 to 9
15	3.1	2.1	2.7	1.8	2.3	1.6	2.1	1.5	1.9	1.4	1.7	1.4	1.6	1.4	1.6	1.5	1.6	1.7	1.7	2.0	1.9	2.2	15
21	3.3	2.2	2.9	1.9	2.5	1.7	2.2	1.6	2.0	1.5	1.8	1.5	1.7	1.5	1.7	1.7	1.8	1.9	1.9	2.2	2.0	2.4	21
30	3.6	2.4	3.1	2.1	2.7	1.9	2.4	1.7	2.2	1.7	2.0	1.6	1.9	1.7	1.9	1.8	1.9	2.0	2.0	2.3	2.2	2.6	30
46	3.9	2.6	3.4	2.3	3.0	2.1	2.6	1.9	2.3	1.8	2.2	1.8	2.1	1.8	2.0	1.9	2.1	2.2	2.2	2.5	2.4	2.8	46
61	4.1	2.8	3.6	2.4	3.1	2.2	2.8	2.0	2.5	1.9	2.3	1.9	2.2	1.9	2.1	2.1	2.2	2.3	2.3	2.7	2.5	3.0	61
76	4.3	2.9	3.8	2.5	3.3	2.3	2.9	2.1	2.6	2.0	2.4	2.0	2.3	2.0	2.2	2.2	2.3	2.4	2.4	2.8	2.7	3.1	76
91	4.5	3.0	3.9	2.6	3.4	2.4	3.0	2.2	2.7	2.1	2.5	2.1	2.4	2.1	2.3	2.3	2.4	2.5	2.5	2.9	2.8	3.3	91
122	4.8	3.2	4.1	2.8	3.6	2.5	3.2	2.3	2.9	2.2	2.7	2.2	2.5	2.2	2.5	2.4	2.5	2.7	2.7	3.1	2.9	3.5	122
152	5.0	3.3	4.3	2.9	3.8	2.6	3.4	2.4	3.0	2.3	2.8	2.3	2.6	2.3	2.6	2.5	2.7	2.8	2.8	3.3	3.1	3.6	152
183	5.2	3.5	4.5	3.1	4.0	2.7	3.5	2.5	3.1	2.4	2.9	2.4	2.7	2.4	2.7	2.6	2.8	2.9	2.9	3.4	3.2	3.8	183
213	5.3	3.6	4.7	3.2	4.1	2.8	3.6	2.6	3.2	2.5	3.0	2.5	2.8	2.5	2.8	2.7	2.9	3.0	3.0	3.5	3.3	3.9	213
244	5.5	3.7	4.8	3.2	4.2	2.9	3.7	2.7	3.3	2.6	3.1	2.5	2.9	2.6	2.9	2.8	2.9	3.1	3.1	3.6	3.4	4.0	244
305	5.8	3.9	5.0	3.4	4.4	3.1	3.9	2.8	3.5	2.7	3.2	2.6	3.1	2.7	3.0	2.9	3.1	3.2	3.3	3.8	3.6	4.2	305
366	6.0	4.0	5.2	3.5	4.6	3.2	4.0	2.9	3.6	2.8	3.3	2.7	3.2	2.8	3.1	3.0	3.2	3.4	3.4	3.9	3.7	4.4	366
427	6.2	4.2	5.4	3.7	4.7	3.3	4.2	3.0	3.8	2.9	3.5	2.8	3.3	2.9	3.2	3.1	3.3	3.5	3.5	4.1	3.8	4.5	427
488	6.4	4.3	5.5	3.8	4.9	3.4	4.3	3.1	3.9	3.0	3.6	2.9	3.4	3.0	3.3	3.2	3.4	3.6	3.6	4.2	3.9	4.6	488
549	6.5	4.4	5.7	3.8	5.0	3.5	4.4	3.2	4.0	3.0	3.6	3.0	3.5	3.1	3.4	3.3	3.5	3.7	3.7	4.3	4.0	4.7	549
610	6.7	4.5	5.8	3.9	5.1	3.5	4.5	3.3	4.0	3.1	3.7	3.1	3.5	3.1	3.5	3.4	3.6	3.8	3.8	4.4	4.1	4.8	610

TABLE NOTES:

(1)Wind speed noted is the Basic Wind Speed, **3-second gust** at 10 m (33 ft) above grade.

(2)Wind pressures shown are based on Ground Roughness C and include an Importance Factor **I_W = 1.15**, and a directionality factor **K_d = 0.85.**

(3)Wind pressures shown are based on a gust factor **G = 1.0**.

(4)Wind pressures shown are unfactored (charteristic) — that is, they include an embedded default Load Factor (Partial Safety Factor) of 1.0.

(5)Wind direction is measured from a line normal (perpendicular) to the face of the tower.

(6)Wind pressures shown are based on relatively flat topography (i.e., not applicable to structures located on hills, ridges, or escarpments): **K_{zt} = 1.0**.

(7)FLAT designates structural members with flat profiles (e.g., angle, channel).

(8)ROUND designates structural members with rounded profiles (e.g., pipe, rod).

(9) SOLID OF PROJECTED AREA = (ratio of projected solid area to gross area of one tower face) x 100 = **e** x 100

(10)Linear interpolation may be used for SOLID OF PROJECTED AREA and HEIGHT.

(11)To obtain pressures for wind speeds other than 40 m/s (90 mph), apply a factor based on the square of the ratio of the speeds.

For example, to obtain pressures that represent a wind speed of 49 m/s, apply a factor of 1.50 to the pressure values in the table [$(49/40)^2$ = 1.50].

(12)To obtain wind loads, multiply the wind pressure values in the table by the projected areas of the tower members (**A_f** or **A_r**).

Table 6. Wind Pressure on Guy Wires

Wind Pressure in pounds per ft² (psf) on Guy Wire for 90 mph Wind Speed									
Height (ft)	Incident Angle (degrees)								
	10	20	30	40	50	60	70	80	90
33	0.6	2.4	5.2	8.6	12.2	15.5	18.3	20.1	20.7
50	0.7	2.6	5.7	9.3	13.3	17.0	20.0	21.9	22.6
100	0.8	3.1	6.5	10.8	15.4	19.6	23.1	25.4	26.2
200	0.9	3.5	7.6	12.5	17.8	22.7	26.7	29.4	30.3
300	1.0	3.9	8.2	13.6	19.4	24.7	29.1	32.0	33.0
400	1.1	4.1	8.8	14.5	20.6	26.3	30.9	34.0	35.0
500	1.1	4.3	9.2	15.2	21.5	27.5	32.4	35.6	36.7
600	1.2	4.5	9.5	15.8	22.4	28.6	33.7	37.0	38.2
800	1.2	4.7	10.1	16.7	23.8	30.4	35.8	39.3	40.5
1000	1.3	5.0	10.6	17.6	24.9	31.9	37.5	41.2	42.5
1200	1.3	5.2	11.0	18.2	25.9	33.1	39.0	42.8	44.2
1400	1.4	5.3	11.4	18.8	26.8	34.2	40.3	44.2	45.6
1600	1.4	5.5	11.7	19.4	27.5	35.2	41.4	45.5	46.9
2000	1.5	5.8	12.3	20.3	28.9	36.9	43.4	47.7	49.2
Wind Pressure in kilo-Pascals (kPa) on Guy Wire for 40 m/s Wind Speed									
Height (m)	Incident Angle (degrees)								
	10	20	30	40	50	60	70	80	90
10	0.03	0.12	0.25	0.41	0.58	0.74	0.88	0.96	0.99
15	0.03	0.13	0.27	0.45	0.64	0.81	0.96	1.05	1.08
30	0.04	0.15	0.31	0.52	0.74	0.94	1.11	1.22	1.25
61	0.04	0.17	0.36	0.60	0.85	1.09	1.28	1.41	1.45
91	0.05	0.18	0.39	0.65	0.93	1.18	1.39	1.53	1.58
122	0.05	0.20	0.42	0.69	0.98	1.26	1.48	1.63	1.68
152	0.05	0.21	0.44	0.73	1.03	1.32	1.55	1.71	1.76
183	0.06	0.21	0.46	0.75	1.07	1.37	1.61	1.77	1.83
244	0.06	0.23	0.49	0.80	1.14	1.46	1.71	1.88	1.94
305	0.06	0.24	0.51	0.84	1.19	1.53	1.80	1.97	2.03
366	0.06	0.25	0.53	0.87	1.24	1.59	1.87	2.05	2.11
427	0.07	0.26	0.55	0.90	1.28	1.64	1.93	2.12	2.18
488	0.07	0.26	0.56	0.93	1.32	1.68	1.98	2.18	2.25
610	0.07	0.28	0.59	0.97	1.38	1.77	2.08	2.28	2.35

Table Notes:

Wind speed is the Basic Wind Speed, 3-second gust, at 33 ft (10 m) above grade.

Table is based on **Ground Roughness C**

Table is based on the following Importance, Directionality, and Gust factors: I_W **= 1.15**, K_d **= 0.85, G = 0.85.**

(4) Table is based on a wind force coefficient **(Cf)** of **1.2**.

(5) Wind pressures are unfactored (characteristic); therefore, apply a load factor or partial safety factor for use in ultimate limit states or strength (LRFD) design.

(6) Table is based on relatively flat topography, with an assumed K_{zt} **= 1.0**.

(7) Height is the mid-height of the guy wire above grade.

(8) Indicent angle is the angle between the guy wire and the horizontal wind vector, in the plane containing the wind vector and the guy wire.

(9) Linear interpolation may be used for Height and Incident Angle.

(10) To obtain wind forces, multiply the wind pressure by the guy wire diameter and length. The resultant wind force will act normal (perpendicular) to the guy wire, in the plane containing the wind vector and the guy wire.

(11)To obtain wind pressure for wind speeds other than 90 mph (40 m/s), apply a factor based on the square of the wind speeds. For example, for a wind speed of 110 mph (49 m/s), apply a factor of 1.49 to the pressure values in this table [$(110/90)^2$ = 1.49].

(12)The wind pressures in this table are based on **subcritical** flow.

Table 7. Wind Pressure Exposure Coefficient (K_z)

Height above Ground (z)		*Exposure (Ground or Terrain Roughness)*		
feet	meters	B	C	D
≤ 33	≤ 10	0.72	1.00	1.18
50	15	0.81	1.09	1.27
70	21	0.89	1.17	1.35
100	30	0.99	1.27	1.43
150	46	1.11	1.38	1.54
200	61	1.20	1.46	1.62
250	76	1.28	1.53	1.68
300	91	1.35	1.59	1.73
400	121	1.47	1.69	1.82
500	152	1.57	1.78	1.90
600	183	1.65	1.85	1.96
700	213	1.72	1.91	2.01
800	244	1.79	1.96	2.06
1000	305	1.91	2.06	2.14
1200	366	2.01	2.14	2.21
1400	427	2.10	2.21	2.27
1600	488	2.18	2.27	2.32
1800	549	2.26	2.33	2.37
2000	610	2.33	2.38	2.41

Notes:
1) Linear interpolation is appropriate for reasonable approximations.
2) K_z is a factor to be applied to wind pressure, where wind pressures are based on 3-second gust basic wind speeds.

Table 8. Wind Speed Exposure Coefficient (K_v)

Height above Ground (z)		*Exposure (Ground or Terrain Roughness)*		
feet	meters	B	C	D
≤ 33	≤ 10	0.85	1.00	1.09
50	15	0.90	1.05	1.13
70	21	0.94	1.08	1.16
100	30	0.99	1.12	1.20
150	46	1.05	1.17	1.24
200	61	1.11	1.21	1.27
250	76	1.13	1.24	1.30
300	91	1.16	1.26	1.32
400	121	1.21	1.30	1.35
500	152	1.25	1.33	1.38
600	183	1.28	1.36	1.40
700	213	1.31	1.38	1.42
800	244	1.34	1.40	1.43
1000	305	1.38	1.43	1.46
1200	366	1.42	1.46	1.49
1400	427	1.45	1.49	1.51
1600	488	1.48	1.51	1.52
1800	549	1.50	1.53	1.54
2000	610	1.53	1.54	1.55

Notes:
1) Linear interpolation is appropriate for reasonable approximations.
2) K_v is a factor to be applied to 3-second gust wind speeds.

Table 9. Topographic Wind Factor (K_{zt})

Topographic Wind Speed-Up Factor (K_{zt})													
z/H	**Hill** Located at Crest (x = 0)						**Hill** Located at Mid-Height (x = L/2, Upwind of Crest)						z/H
	Slope ≥ 25% (14°)			Slope = 10% (6°)			Slope ≥ 25% (14°)			Slope = 10% (6°)			
	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	
0.00	2.17	2.32	2.48	1.42	1.46	1.51	1.34	1.38	1.42	1.13	1.14	1.16	0.00
0.02	2.12	2.26	2.41	1.40	1.44	1.49	1.33	1.36	1.40	1.13	1.14	1.15	0.02
0.06	2.02	2.15	2.28	1.37	1.41	1.45	1.30	1.33	1.37	1.12	1.13	1.14	0.06
0.10	1.93	2.04	2.16	1.34	1.37	1.41	1.28	1.31	1.34	1.11	1.12	1.13	0.10
0.20	1.74	1.83	1.92	1.27	1.30	1.33	1.22	1.25	1.27	1.09	1.10	1.11	0.20
0.40	1.47	1.53	1.58	1.18	1.20	1.22	1.15	1.16	1.18	1.06	1.06	1.07	0.40
0.60	1.31	1.34	1.38	1.12	1.13	1.14	1.10	1.11	1.12	1.04	1.04	1.05	0.60
0.80	1.20	1.22	1.25	1.08	1.09	1.10	1.06	1.07	1.08	1.03	1.03	1.03	0.80
1.00	1.13	1.15	1.16	1.05	1.06	1.06	1.04	1.05	1.05	1.02	1.02	1.02	1.00
1.25	1.08	1.09	1.10	1.03	1.03	1.04	1.03	1.03	1.03	1.01	1.01	1.01	1.25
1.50	1.05	1.05	1.06	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.50
2.00	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	2.00
≥ 3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	≥ 3
z/H	**Ridge or Escarpment** Located at Crest (x = 0)						**Ridge or Escarpment** Located Mid-Height (x = L/2, Upwind of Crest)						z/H
	Slope ≥ 25% (14°)			Slope = 10% (6°)			Slope ≥ 25% (14°)			Slope = 10% (6)			
	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	
0.00	2.72	2.97	3.15	1.59	1.66	1.71	1.48	1.54	1.58	1.18	1.20	1.22	0.00
0.02	2.66	2.90	3.07	1.57	1.64	1.69	1.46	1.52	1.56	1.18	1.20	1.21	0.02
0.06	2.54	2.76	2.92	1.53	1.60	1.65	1.44	1.49	1.53	1.16	1.18	1.20	0.06
0.10	2.43	2.64	2.78	1.50	1.56	1.60	1.41	1.46	1.49	1.15	1.17	1.19	0.10
0.20	2.19	2.36	2.48	1.42	1.48	1.51	1.35	1.39	1.42	1.13	1.15	1.16	0.20
0.40	1.84	1.95	2.03	1.31	1.34	1.37	1.25	1.28	1.30	1.10	1.11	1.12	0.40
0.60	1.60	1.68	1.73	1.22	1.25	1.27	1.18	1.21	1.22	1.07	1.08	1.09	0.60
0.80	1.43	1.48	1.52	1.16	1.18	1.20	1.13	1.15	1.16	1.05	1.06	1.06	0.80
1.00	1.31	1.35	1.38	1.12	1.13	1.14	1.10	1.11	1.12	1.04	1.04	1.05	1.00
1.25	1.21	1.23	1.25	1.08	1.09	1.10	1.07	1.08	1.08	1.03	1.03	1.03	1.25
1.50	1.14	1.16	1.17	1.06	1.06	1.07	1.05	1.05	1.06	1.02	1.02	1.02	1.50
2.00	1.07	1.07	1.08	1.03	1.03	1.03	1.02	1.02	1.03	1.01	1.01	1.01	2.00
≥ 3	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	≥ 3
z/H	**Escarpment** Downwind of Crest: x = L/2						**Escarpment** Downwind of Crest: x = L						z/H
	Slope ≥ 25% (14°)			Slope = 10% (6°)			Slope ≥ 25% (14°)			Slope = 10% (6°)			
	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	Exp B	Exp C	Exp D	
0.00	1.64	1.74	1.84	1.24	1.27	1.30	1.41	1.47	1.53	1.16	1.18	1.20	0.00
0.02	1.62	1.72	1.82	1.23	1.26	1.30	1.40	1.46	1.52	1.15	1.17	1.19	0.02
0.06	1.59	1.68	1.77	1.22	1.25	1.28	1.38	1.43	1.49	1.14	1.16	1.18	0.06
0.10	1.56	1.64	1.73	1.21	1.24	1.27	1.36	1.41	1.46	1.14	1.16	1.17	0.10
0.20	1.49	1.56	1.63	1.18	1.21	1.23	1.31	1.36	1.40	1.12	1.14	1.15	0.20
0.40	1.37	1.42	1.48	1.14	1.16	1.18	1.24	1.27	1.31	1.09	1.11	1.12	0.40
0.60	1.28	1.32	1.36	1.11	1.12	1.14	1.18	1.21	1.24	1.07	1.08	1.09	0.60
0.80	1.22	1.25	1.28	1.08	1.10	1.11	1.14	1.16	1.18	1.06	1.06	1.07	0.80
1.00	1.17	1.19	1.21	1.07	1.07	1.08	1.11	1.13	1.14	1.04	1.05	1.06	1.00
1.25	1.12	1.14	1.15	1.05	1.05	1.06	1.08	1.09	1.10	1.03	1.04	1.04	1.25
1.50	1.09	1.10	1.11	1.03	1.04	1.04	1.06	1.07	1.07	1.02	1.03	1.03	1.50
2.00	1.05	1.05	1.06	1.02	1.02	1.02	1.03	1.04	1.04	1.01	1.01	1.02	2.00
≥ 3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	≥ 3

Notes:

1. K_{zt} = 1.0 when x > L/2 for Hills, Ridges, and upwind (windward) of Escarpments.
2. K_{zt} = 1.0 when x ≥ 2L downwind (leeward) of Escarpment crest.
3. K_{zt} = 1.0 when ground slope <10% (6°)
4. H = height of hill, ridge, or escarpment; z = height above ground; x = horizontal distance from crest
5. In order to obtain reasonably accurate estimates, linear interpolation for slope (between 10% and 25%), z/H, and x (x/L from 0 to 0.5 for Hills, Ridges, and upwind of Escarpment crest; and x/L from 0 to 0.5, 0.5 to 1.0, and 1.0 to 2.0 downwind Escarpment crest) are appropriate.
6. K_{zt} is to be applied to wind pressure (or wind load) values, not wind velocity. In order to find equivalent topographic speed-up factors for wind velocity, use the square root of the K_{zt} values in this table.

2.1.1.2.2 Ice Accretion

Ice accretion is the accumulation of solid glaze ice or rime ice on exposed surfaces of the tower structure, guy wires, connections, and appurtenances. Ice accretion is generally the result of freezing rain, except in mountainous regions where in-cloud icing can also occur.

1. Provide appropriate de-icing equipment for antennas and other tower appurtenances subject to ice accretion.

2. Provide ice shields to protect tower antennas from falling ice impact where towers are subject to ice accretion.

3. Design and construct tower support buildings and facilities (e.g., control buildings, exposed horizontal runs of transmission lines and cables), to withstand the impact of falling ice where towers are subject to ice accretion.

4. For design loads from wind on ice-encrusted members, and for design ice weight (ice dead load), apply the Radial Ice Thickness Height Factor (See Table 10) to the basic radial ice thickness (33 ft above grade) obtained from the appropriate ice map, or other reliable sources for the location, if the mapped ice thickness is intended for or normalized for the standard height of 33 ft (10 m) above grade.

Table 10. Radial Ice Thickness Height Factor

Height above Ground		*Radial Ice Thickness Factor*
(ft)	(m)	
≤ 33	≤ 10	1.00
50	15	1.05
100	30	1.12
200	60	1.20
400	125	1.28
700	215	1.36
≥ 1000	≥ 305	1.40

5. For wind loads due to wind acting on ice-encrusted towers and appurtenances, apply the recommendations for Section 2.1.1.2.1 (Wind without ice accretion), but with the following changes:

a) Use 65% of the Basic Wind Speed from FM Global Data Sheet 1-28.

b) Use a wind load Importance Factor of 1.15.

c) When calculating solidity ratio (e) for latticed (trussed) towers, account for the effects of ice accretion. The projected area, and solidity ratio (e), with ice accretion may be significantly higher that without ice accretion.

2.1.1.2.3 Hail

1. Provide appropriate hail shields or radomes/shrouds to protect tower antennas from hail impact damage where towers have ″severe″ exposure to hailstorm.

2. Refer to FM Global Data Sheet 1-34, *Hail Damage,* for locations in the US subject to severe hailstorm - and guidance regarding hailstone size, velocity and impact energy.

3. For locations outside the continental US, consult local authorities, codes, or standards to determine hail-prone areas and the appropriate size of hailstones.

2.1.1.2.4 Earthquake

1. Design and construct towers, tower foundations, and tower foundation anchorages to be adequately earthquake resistant if they are to be located in active FM Global Earthquake Zones (50-, 100-, 250-, or 500-year earthquake zones). Refer to Data Sheet 1-2, *Earthquakes*.

2. Use an earthquake Importance Factor of 1.5 for towers located in active FM Global Earthquake Zones. For towers located outside active FM Global Earthquake Zones, use an earthquake Importance Factor of at least 1.0.

2.1.1.2.5 Flood and Surface Water

Locate towers outside of known flood zones. If this is not possible, then ensure that adequate measures have been provided to protect the tower foundation, tower, equipment, and associated utilities. Refer to FM Global Data Sheet 1-40, *Flood*, for additional guidance, and pay particular attention to the effects of surface water on geotechnical/foundation properties, including reduced soil bearing capacity; buoyant effects; foundation undermining, scour, and settlement; and loss of credited soil overburden.

2.1.1.2.6 Wildland Fire/Bushfire

For locations susceptible to wildfire or bushfire, ensure that combustible materials on, or attached to, the tower are adequately protected by following the setback/clearance recommendations in Data Sheet 9-19, *Wildland Fire*.

Combustible materials on a tower can include plastic or rubber cable (feed line) sheathing, or fabric/membrane antenna radome covers, and these materials could be ignited or damaged a brushfire.

2.1.1.3 Lightning

Provide primary grounding for all towers, including guy cables and anchors, to safeguard against lightning damage. The total resistance of the primary grounds as referenced to remote earth shall not exceed 10 ohms, as determined in accordance with IEEE Standard 142-2007.

Provide secondary grounding/bonding for all antennas and electrically active equipment and appurtenances attached or connected to the tower.

Refer to FM Global Data Sheet 5-11, *Lightning and Surge Protection*, for additional recommendations regarding protection of associated electrical equipment and systems.

2.1.1.4 Site Security

Provide security and security fences as appropriate to safeguard towers, guy anchors, and support facilities from unintended access, tampering, or vandalism.

2.1.1.5 Analysis of Existing Towers

Retain an independent consultant, with specific expertise and experience in tower design and analysis, when planning to modify existing towers to assess appropriate tower design criteria and specifications and to review the manufacturer's proposals and construction documents.

Structural analysis of existing towers should be performed by qualified professional engineers, licensed in the project location, using the recommendations set forth in this data sheet when:

a) There is a change in quantity, size, location, orientation, or type of antennas, transmission lines, and/or appurtenances.

b) There is a change in operational requirements that necessitates more restrictive deflection (twist and sway) limits.

c) An increase wind or ice loading is necessary.

2.1.1.6 Structural Stability of Foundations

The overturning moments due to wind or earthquake design loads should not exceed 67% of the stabilizing moment at the supports due to the counteracting dead load (self-weight of structure and foundations) acting together with the capacity of support anchorage.

The lateral (horizontal) design loads at the support base due to wind or earthquake should not exceed 67% of the total resisting force due to friction for prevention of sliding, unless the support base is anchored to withstand the excess sliding force without exceeding the allowable stresses for the foundation and bearing materials.

Anchors provided to resist overturning moment may also be considered as providing resistance to sliding, if not exceeding the allowable combination of stresses for the materials used.

2.1.1.7 Use of Other Codes and/or Standards

The use of the following nationally recognized consensus codes or standards for tower design and analysis is acceptable, with the changes or exceptions as noted.

1. Locations in the United States

a) When using TIA/EIA-222-F:

- Do not use any increases in allowable stresses for structural members, components, or connections in any load combinations.
- Refer to and implement all the recommendations in Section 2.1 *Loss Prevention Recommendations,* except those in Section 2.1.1.2.1.1 *Design Wind Forces*, Section 2.1.1.2.1.2 *Design Wind Directions*, and Section 2.1.1.3 *Lightning*.

b) When using TIA-222-G (with addenda through 2009):

- Classify all towers and appurtenances as ″Structure Class III″ and use the appropriate Importance Factors specified in TIA-222-G for this classification, except that an earthquake load Importance Factor of 1.0 may be used for towers located outside active FM Global Earthquake Zones; that is, towers not located in 50-, 100-, 250-, or 500-year earthquake zones as defined in FM Global Data Sheet 1-2, *Earthquakes*.
- Refer to and implement the recommendations in the following sections of this data sheet: Section 2.1.1.2.1.3 *Towers Mounted on Building Roofs*, Section 2.1.1.2.2.1 *Ice Loading and Impact*, Section 2.1.1.2.3 *Hail*, Section 2.1.1.2.5 *Flood and Surface Water*, Section 2.1.1.2.6 *Wildfire/Brushfire*, 2.1.1.4 *Security*, 2.1.1.5 *Analysis of Existing Towers*, 2.1.2 *Operation and Maintenance*, and 2.1.3 *Contingency Planning*.

2. Locations in Canada

When using Canadian Standards Association CSA S37-01 *Antennas, Towers, and Antenna-Supporting Structures* with updates through 2006:

a) Use Basic Wind Speeds (V) from FM Global Data Sheet 1-28.

b) Use a wind load Importance Factor (I_w) of 1.15

c) For wind acting on ice-encrusted members (wind with ice accretion), use a wind load Importance Factor of 1.0.

Note that the Basic Wind Speeds in FM Global DS 1-28 are based on 3-second gusts; however CSA S37-01 uses wind velocity pressures based on mean hourly wind speeds. Therefore, when using CSA S37-01, convert the 3-second gust Basic Wind Speeds from FM Global DS 1-28 into approximate mean hourly wind speeds by dividing by 1.5 (3-second gust/1.5 = mean hourly wind speed). Then determine the reference wind velocity pressure: wind velocity pressure (Pascal) = (0.5)(1.29 kg/m^3)(V^2) with V in m/s.

For example, if the Basic Wind Speed from FM Global DS 1-28 is 40.3 m/s (90 mph), then use 26.8 m/s (60 mph) as the reference wind speed in CSA C37-01. Therefore, the reference wind velocity pressure = (0.5)(1.29 kg/m^3)(26.8 m/s)^2 = 463 Pa (9.7 psf).

c) For towers located on hills, ridges, or escarpments, ensure that topographic wind effects are accounted for according to the NBCC (National Building Code of Canada) or Section 2.1.1.2.1.4 *Towers Located on Hills, Ridges, or Escarpments* of this data sheet.

d) Refer to and implement the recommendations in the following sections of this data sheet: Section 2.1.1.2.2.1 *Ice Loading and Impact*, Section 2.1.1.2.3 *Hail*, Section 2.1.1.2.4 *Earthquake*, Section 2.1.1.2.5 *Flood and Surface Water*, Section 2.1.1.2.6 *Wildland Fire/Brushfire*, 2.1.1.4 *Security*, 2.1.1.5 *Analysis of Existing Towers*, 2.1.2 *Operation and Maintenance*, and 2.1.3 *Contingency Planning*.

3. Locations in Australia and New Zealand

When using AS/NZS 1170.2, 2002 edition:

a) Use Basic Wind Speeds (V) from FM Global DS 1-28.

b) Use a wind load Importance Factor (I_w) of 1.15, or its equivalent. For example, rather than using I_w = 1.15 as a factor for wind load or wind pressure, a factor of 1.07 may be applied to the Basic Wind Speed (V).

c) For wind acting on ice-encrusted members (wind with ice accretion), use a wind load Importance Factor of 1.0.

d) Refer to and implement all the recommendations in Section 2.1 Loss Prevention Recommendations except those in Section 2.1.1.2.1.1 *Design Wind Forces*, Section 2.1.1.2.1.2 *Design Wind Directions*, and Section 2.1.1.2.1.4 *Towers Located on Hills, Ridges, or Escarpments (Cliffs)*.

2.1.2 Operation and Maintenance

Perform periodic inspections and maintenance as follows:

1. Visual annual inspections by properly trained staff or a tower consultant, to examine tower foundations, structures, guys, and connections from the ground for evidence of settlement or lateral movement; soil erosion; condition of paint or galvanizing; rust or corrosion; loose or missing bolts; loose or corroded lightning protection connectors; tower plumbness; significant variation in guy sags (i.e., guy tension); and guy dampers.

2. Inspections after severe wind and/or ice storms.

3. Major inspections at the end of one year of service and at 3-year intervals thereafter by a firm of specialists in accordance with the ″Tower Maintenance and Inspection Procedures″, in Annex E of the standard, TIA/EIA-222-F, ″Maintenance and Condition Assessment″ in Annex J of TIA-222-G, ″Recommendations for Maintenance″ in Appendix D of CSA-S37, or the maintenance and inspection provisions from a nationally recognized consensus tower standard or code.

4. Schedule and perform maintenance in accordance with a sound preventive maintenance program and as recommended by periodic inspection reports.

5. Ensure that inspection reports, or the results of inspections, are available at or near the site for review.

2.1.3 Contingency Planning

Establish a comprehensive emergency response plan - including, as appropriate, having a tower manufacturer and erector/contractor on retainer for emergencies; spare tower sections and parts and standby equipment available; and contingency agreements for antenna space rental on other towers.

2.2 Large Advertising Signs

2.2.1 Construction and Locations

2.2.1.1 Use of other Codes and Standards

See Section 2.2.1.4 for the use of other codes and standards.

2.2.1.2 Natural Hazards

2.2.1.2.1 Wind

Design and construct signs, sign foundations, and sign foundation anchorages to adequately resist design wind forces. Determine the design wind forces exerted against signs in the following manner:

1. Use the Basic Wind Speeds (V) from FM Global Data Sheet 1-28.

2. Determine if the site is in Ground Roughness (Exposure) B, C or D in accordance with FM Global Data Sheet 1-28.

3. Determine the gust factor (G): Use G = 1.35 for all signs unless it is proven by rational analysis that the fundamental natural period (T) is less than 1.0 second. When T is less than 1.0 second, G may be determined by rational analysis but shall not be less than 1.0.

4. Determine the appropriate pressure coefficients (C_s or C_o) in accordance with Tables 11 and 12 herein for solid and open signs, respectively.

5. Use a wind load Importance Factor (I_w) of 1.15.

6. For signs located on hills, ridges or escarpments, an additional topographic wind factor (K_{zt}) applied to the force equation (F) may be appropriate. Use the same recommendations regarding K_{zt} used for towers in Section 2.1.1.2.1.4, except that K_{zt} may be disregarded (i.e., use K_{zt} = 1.0) when the ratio of the height of the bottom of the sign to the height (H) of the hill, ridge, or escarpment is greater than 7.0 ([Bottom of Sign Height]/H > 7.0).

7. See Table 7 for K_z values; note that these K_z values are intended to be used with 3-second gust wind speeds and vary based on height above ground and ground roughness.

8. Determine the wind velocity pressure (Ph), and resultant wind force (F) acting normal to the sign by computing the expressions:

$P_h = (UCF)(K_z)(K_{zt})(K_d)(V^2)(I_w)$ = psf or Pascal

and

$F_s = (P_h)(G)(C_s \text{ or } C_o)(A_s \text{ or } A_o)$ = Lbs or Newtons

Where:
UCF (unit conversion factor) = 0.00256 for English units (mph, ft^2, Lbs, psf),
or
UCF = 0.613 for SI units (m/s, m^2, Newtons, Pascal)
K_z = velocity pressure exposure coefficient for ground roughness (B, C, or D) at the top of the sign
K_d = 0.85 (wind direction probability factor)
K_{zt} = topographic speed-up factor at the bottom of the sign
V = 3-second gust basic wind speed in miles per hour (mph), or meters per second (m/s)
G = gust factor
C_s = force coefficient for solid signs
C_o = force coefficient for open signs
A_s = the gross area of the sign for solid signs
A_o = the effective (solid) area of the sign for open signs
I_w = 1.15 (wind load importance factor)

9. For the purposes wind load determination, classify all signs as either ″open″ or ″solid″. Classify signs with openings not less than 30% of the gross area as ″open″; classify all other signs as ″solid″.

10. For ″open″ signs located in areas exposed to ice accretion from freezing rain or in-cloud icing, examine wind forces on the sign for both the ″open″ condition and where ice build up has caused an effective ″closed″ condition; also account for the weight of the accumulated ice.

11. Account for wind loading on sign appurtenances and support structures separately by using the appropriate methodology from Section 2.2.1.2.1 for towers and appurtenances.

12. Assume that wind can act in any direction. To allow for winds oblique to the surfaces of solid signs, the resultant wind force should be applied in accordance with Note 3 of Table 11.

13. For signs mounted to rooftops, calculate the wind loads based on the sign elevation above grade, but increase the wind pressure by **30%** on the entire sign.

Table 11. Force Coefficients for Solid(1) Signs, C_s.

	At Ground Level(2)	*Above Ground Level(2)*
Width/Height	C_s	C_s
≤0.05	1.85	1.95
0.25	1.7	1.85
0.5	1.6	1.85
1	1.55	1.8
2	1.5	1.8
4	1.45	1.85
≥10	1.4	1.85

NOTES:
(1) Signs with openings comprising less than 30% of the gross area (e < 0.3) shall be considered as solid signs.
(2) Signs for which the distance from the ground to the top edge not more than 10% greater than the vertical sign dimension shall be considered to be at ground level.
(3) To allow for both normal and oblique wind directions, two cases shall be considered.
(a) resultant force acts normal to sign at geometric center; and
(b) resultant force acts normal to sign at level of geometric center and at a distance from windward edge of 0.3 times the horizontal dimension.

Table 12. Force Coefficients (C_o) for Open Signs and Latticed Support Frameworks

	C_o		
	Flat-Sided Members	Rounded Members	
		$D\sqrt{P_h} \le 2.5$ (US units)	$D\sqrt{P_h} > 2.5$(US units)
E		$D\sqrt{P_h} \le 5.3$ (SI units)	$D\sqrt{P_h} > 5.3$(SI units)
> 0.1	2.0	1.2	0.8
0.1 to 0.29	1.8	1.3	0.9
0.3 to 0.7	1.6	1.5	1.1

NOTES:
(1) Signs with openings comprising 30% or more of the gross area (e ≥0.3) are classified as open signs.
(2) The calculation of the design wind forces shall be based on the area of all exposed members and elements projected on a plane normal to the wind direction. Forces shall be assumed to act parallel to the wind direction.
(3) The area A_o consistent with these force coefficients is the solid area projected normal to the wind direction.
(4) Notation:
e = ratio of solid area to gross area
D = diameter of a typical round member (ft [m])
P_h = wind velocity pressure (psf [Pascal])

2.2.1.2.2 Earthquake

1. Design and construct signs, sign foundations, and sign foundation anchorages to be adequately earthquake resistant if they are to be located in active FM Global Earthquake Zones (50-, 100-, 250-, or 500-year earthquake zones). Refer to Data Sheet 1-2, *Earthquakes*.

2. Use an earthquake Importance Factor of 1.25 for signs located in active FM Global earthquake zones. For signs located outside active FM Global earthquake zones, use an earthquake importance factor of at least 1.0.

2.2.1.2.3 Flood and Surface Water

Locate signs outside of known flood zones. If this is not possible, then ensure that adequate measures have been provided to protect the supporting foundation and associated utilities. Refer to FM Global Data Sheet 1-40, *Flood*, for additional guidance, and pay particular attention to the effects of surface water on geotechnical/foundation properties, including reduced soil bearing capacity; buoyant effects; foundation undermining, scour, and settlement; and loss of credited soil overburden.

2.2.1.2.4 Wildland Fire/Bushfire

For locations susceptible to wildfire or brushfire, ensure that combustible materials on, or attached to, the sign are adequately protected by following the setback/clearance recommendations in Data Sheet 9-19, *Wildland Fire*.

Combustible materials associated with a large sign can include wood support structure, wood-backed display panels, and plastic display panels, and these materials could be ignited or damaged in a bushfire.

2.2.1.3 Structural Stability of Foundations

The overturning moments due to wind or earthquake design loads should not exceed 67% of the stabilizing moment of the support (structure and foundations) due to the dead load only, unless the support is anchored.

The lateral (horizontal) design loads at the support base due to wind or earthquake should not exceed 67% of the total resisting force due to friction for preventing sliding, unless the support base is anchored to withstand the excess sliding force without exceeding the allowable stresses for the materials used.

Anchors provided to resist overturning moment may also be considered as providing resistance to sliding, if not exceeding the allowable combination of stresses for the materials used.

2.2.1.4 Use of Other Codes and/or Standards

2.2.1.4.1 Note that the recommendations in Section 2.2.2 *Operation and Maintenance* still apply when using a code or standard as described in Section 2.2.1.4.2.

2.2.1.4.2 The use of a nationally recognized consensus code or standard for design and analysis – such as ASCE 7-02 or 7-05 (United States locations), NBCC 2005 (Canada locations), Eurocode with appropriate National Annex (locations in CEN member European nations), and AS/NZS 1170.2 (for Australia and New Zealand location) – are acceptable provided that the following recommendations are followed:

1. Use Basic Wind Speeds (V) from FM Global Data Sheet 1-28.

2. Use a Wind Load Importance Factor (I_w) of 1.15 applied to all wind pressures or wind loads. Alternatively, rather than using I_w = 1.15 as a factor for wind load or wind pressure, a factor of 1.07 may be applied to the Basic Wind Speed (V).

3. Ensure that ground roughness (exposure or terrain roughness) has been accounted for in the determination of wind speed (or wind pressure) increases with height above ground.

4. For signs located on the upper half of a hill, ridge, or escarpment slope (i.e., mid-height or higher); or located on the escarpment plateau within a horizontal distance 2L from the crest of the escarpment (See Figure 3, Topographic Wind Factor [K_{zt}], of this data sheet); ensure that topographic effects that increase wind speed or wind pressure have been considered in the design wind loads.

5. For signs located on building roofs, ensure that the design wind loads account for wind speed-up effects. If this is not addresses in the local code or standard, then use a wind pressure (or wind load) factor of at least 1.3 for the entire sign area.

6. For areas where ice accretion and snow are know to occur, account for the effects of ice and/or snow on the gravity loading and wind loading, including ice accretion clogging ″open″ signs and causing them to be effectively ″solid″ for when calculating wind pressures.

7. Ensure that the dynamic characteristics of the sign support structure have been considered when determining wind loads and/or gust factors. If this is not addresses in the local code or standard, then use a gust factor (G) of at least 1.35 applied to wind pressure of wind load.

8. Use earthquake load parameters from a nationally recognized consensus code or standard, appropriate for location and site (soil) conditions, with earthquake design loads based on a return period of at least 475-years. Refer to FM Global DS 1-2, *Earthquakes* if local earthquake load parameters are not available.

2.2.2 Operation and Maintenance

2.2.2.1 Establish a periodic inspection schedule by qualified personnel for signs located on insured property to ensure proper maintenance.

2.2.2.2 Determine the following as part of the inspection:

1. All bolted connections are tight and no bolts are missing.

2. Steel members are free of substantial rust and corrosion and receive periodic zinc-rich priming and painting.

3. Wood members are free of rot and insect damage, and receive painting when necessary.

4. Guy cables/wires are intact and tight.

5. Concrete foundations are free from substantial spalling or cracking, and anchor bolts are in good condition.

6. Display letters are bolted tightly to their frames.

7. Electrical wiring and grounding is in good condition.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

3.1.1 Antenna Towers

Since 1932, there have been over 500 recorded instances of partial or total collapse of commercial radio and television broadcasting towers. Windstorm (with and without ice accretion) and Hail are the greatest perils to antenna towers, accounting for over 60% of the total losses. Lightning, airplane and vehicle impacts, floods, tornados, earthquakes, insulator breakage, structural deficiencies, and vandalism collectively accounted for the remainder.

3.2 Illustrative Losses

3.2.1 Loss Example 1

High winds result in total collapse of a commercial radio transmitting tower. The 650 ft (198 m) high tower was a 4-legged square latticed steel tower of uniform square cross section (except for tapered base) with a single set of four guy cables at the 394 ft (120 m) elevation. The guy cables extended radially 400 ft (120 m) from the tower to concrete anchor blocks. With the exception of two 6 ft (1.8 m) diameter microwave dishes positioned at the 240 ft (75 m) level, the antenna configuration was accounted for in the original 1939 design.

The likely cause of the tower collapse was high winds, with peak gusts of 49 mph (22 m/s) recorded at the nearest National Weather Service location, combined with corrosion and degradation of some structural members and connections. Given the age of the tower, metal fatigue may have also played a role.

The radio station was back on the air within one day on reduced power, and broadcast intermittently for approximately one week, utilizing various temporary transmitting towers.

3.3 Additional Information

3.3.1 Antenna Towers

As of early 2009, television broadcasters in the United States are required to broadcast in digital signals (as opposed to analog signals), although many broadcasters have been broadcasting digitals for some time prior to 2009. The change to digital antennas could affect antenna tower requirements since many digital antennas have a greater effective projected area (i.e., greater ″sail area″) than analog antennas and therefore can impart more wind load on the supporting towers than their analog predecessors.

3.3.1.1 Calculating Wind Forces (Wind Loads)

Refer to Tables 2, 3, 4, and 5 for wind pressures on 4-legged and 3-legged latticed (trussed) towers. These tables provide wind pressures for various tower heights and % solid (e x 100) of trussed tower face area. To obtain wind loads, wind pressures from the tables are multiplied by the projected areas (A_f or A_r) of the tower members on a single face of the trussed tower. The wind pressures in these tables are based on the assumption that subcritical flow is acting on the round members of the latticed (trussed) tower. Unless supercritical flow can be proven by rational analysis, it is assumed that subcritical flow is appropriate.

Refer to Table 1 for wind pressure on monopole (tubular pole) towers. The wind pressures for all but the 8-sided monopole are based on the assumption that supercritical flow is acting. To obtain wind loads, wind pressures from the table are multiplied by the projected area (A_p) of the monopole.

See additional explanation of subcritical and supercritical flow conditions under the Wind Flow Factor (W_f) and Reduction Factor for Rounded Members (R_r) section below.

Wind forces are determined by the following equations:

1. Wind Force (F_t) on Latticed or Monopole Tower
   $F_t = (UCF)(K_z)(K_{zt})(K_d)(V^2)(G)(I_w)(EPA)$= Lbs or Newtons

For factors and variables, see below.

F_t is applicable for latticed (trussed) towers and monopole (tubular pole) towers.

2. Wind Force on Tower Appurtenances (F_a)
   $F_a = (UCF)(K_z)(K_{zt})(K_d)(V^2)(I_w)(G)(EPA)$ = Lbs or Newtons

For other factors and variables, see below.

3. Wind Force (F_g)of Guy Wires (Guys)
   $F_g = (UCF)(K_{zg})(K_{zt})(K_d)(V_2)(I_w)(G)(d_g)(l_g)(1.2)(\sin^2\Phi)$ = Lbs or Newtons

   Where:
   K_{zg} = Wind Pressure Exposure Coefficient (Kz) at mid-height of the guy
   d_g = guy diameter (ft or m)
   l_g = guy length (ft or m)
   Φ = incident angle between guy chord and wind vector

   For other factors and variables, see below.

   F_g is the force normal to the guy and in the plane containing the guy chord and the wind vector

4. Wind Force Equation Factors and Variables

   a) Basic Wind Speed (V)
   V is the 3-second gust basic wind speed, at 33 ft (10 m) above grade, in miles per hour (mph), or meters per second (m/s).

   Refer to FM Global Data Sheet 1-28 to determine V.

   b) Unit Conversion Factor (UCF)

   UCF = 0.00256 for English units (mph, ft^2, Lbs)
   UCF = 0.613 for SI units (m/s,m^2, Newtons)

   UCF is simply a unit conversion factor used to convert wind velocity into velocity pressure based on the mass density of air of 0.0024 slug per cubic ft .

   c) Wind Load Importance Factor (I_w)
   $I_w = 1.15$

   d) Wind Force Coefficients – Towers (C_f)
   $C_f = 4.0e^2 – 5.9e + 4.0$ (square latticed tower)
   $C_f = 3.4e^2 – 4.7e + 3.4$ (triangular latticed tower)

   Refer to Figure 4 for a graphical representation of C_f versus e for latticed towers.

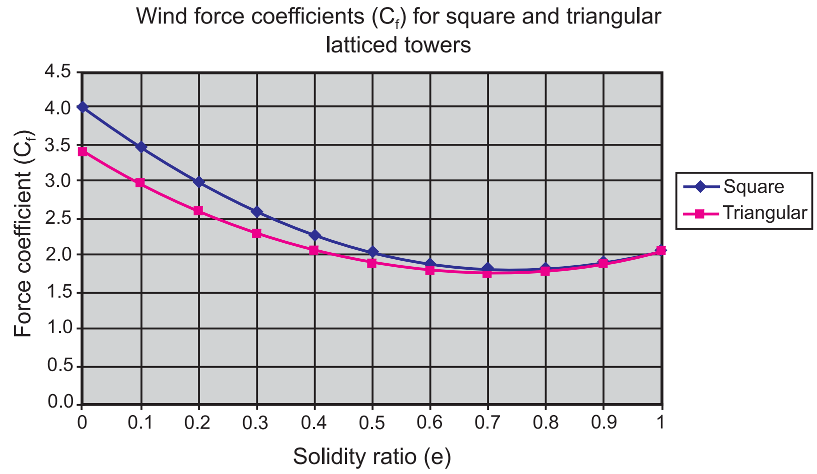


Fig. 4. Wind force coefficient (C_f) versus solidity ratio (e) for latticed towers

For monopoles (supercritical to subcritical flow, respectively):
C_f = 0.6 to 1.2 (round and 18-sided monopoles)
C_f = 0.75 to 1.2 (16-sided monopole)
C_f = 1.0 to 1.2 (12-sided monopole)
C_f = 1.2 (8-sided monopole)

Supercritical or subcritical flow is determined by the Wind Flow Factor (W_f).

e) Wind Force Coefficients - Appurtenances (C_a)

Flat-sided members:
C_a = 2.0 (length/width ≥ 25)
C_a = 1.4 (length/width = 7)
C_a = 1.2 (length/width ≤ 2.5)

Round members (supercritical to subcritical flow, respectively):
C_a = 0.6 to 1.2 (length/width ≥ 25)
C_a = 0.6 to 0.8 (length/width = 7)
C_a = 0.5 to 0.7 (length/width ≤ 2.5)
Use linear interpolation for other length/width ratios.

Super-critical or sub-critical flow is determined by the Wind Flow Factor (W_f).

f) Wind Flow Factor (W_f)

W_f is used to determine if wind flow is supercritical, subcritical, or somewhere in between (transitional), when selecting the proper wind force coefficients (C_a or C_f).

$W_f = (K_z^{0.5})(V)(\text{Width})$

Where:
V = 3-second gust wind speed (mph)
K_z = Velocity Pressure Exposure Coefficient
Width = projected width of appurtenance (ft [m])

When:
$W_f > 64$ (English units) supercritical flow
$W_f < 32$ (English units) subcritical flow
$W_f > 8.7$ (SI units) supercritical flow
$W_f < 4.4$ (SI units) subcritical flow

For W_f transitional values (between supercritical and subcritical flow), base approximate C_a or C_f values on linear interpolation of W_f.

g) Wind Direction Factors (D)
D = 1.0 (square latticed tower, normal wind)
$D = 1.0 + 0.75e \leq 1.2$ (square latticed tower, 45-degree wind, flat and round members)
D = 1.0 (triangular latticed tower, all wind directions, round members)
D = 0.85 (triangular latticed tower, 90-degree wind, flat members)
D = 0.80 (triangular latticed tower, 60-degree wind, flat members)

Refer to Figure 1 for wind direction relative to the tower.

h) Reduction Factor for Rounded Members (R_r)
$R_r = 0.51e^2 + 0.57 \leq 1.0$

The above equation for R_r is based on subcritical flow conditions.

Sub-critical flow for round members of latticed towers and round appurtenances is generally assumed unless supercritical flow is proven by a rigorous rational analysis.

Since supercritical flow only applies to smooth surfaced rounded members, subcritical flow conditions is generally assumed for any ice-encrusted rounded members.

i) Wind Directionality Factors (K_d)
K_d = 0.85 (square latticed and triangular latticed towers)
K_d = 0.85 (guys)
K_d = 1.00 (monopoles, and miscellaneous towers and appurtenances)

j) Wind Pressure Exposure Coefficient (K_z)
K_z accounts for the effects of vertical wind shear (the increase in wind pressure with height above ground) for various ground roughness or exposure (Exposure B, C or D), as indicated in Table 7 and Section 2.1.1.2.1.1.

k) Topographic Wind Factor for Wind Pressure (K_{zt})
K_{zt} accounts for the effects that local topography (hill, ridge, or escarpment) has on wind pressure, as indicated on Table 9 and Section 2.1.1.2.1.4. K_{zt} – sometimes known as an orography factor – varies over the height on the tower (z), and may range from roughly 1.0 to 3.0 depending on the slope and height (H) of the hill, ridge, or escarpment; the Exposure (terrain or ground roughness); and the distance of the tower to the crest.

l) Gust Factors (G) used with 3-second gust wind speeds
G = 1.0 for latticed tower; unless a lesser value is justified by rational analysis, but shall not less than 0.85
G = 1.1 for latticed tower, mounted on another tower or structure
G = 1.1 for monopole
G = 1.35 for monopole mounted on another tower or structure
G = 0.85 for guy (guy wire)

m) Effective Projected Area (EPA)

(i) For latticed (trussed) towers:
$EPA = C_f ([D \times A_f] + [D \times A_r \times R_r])$

Where:
A_f = projected area of flat members (ft^2 or m^2)
A_r = projected area of round members (ft^2 or m^2)
D = wind direction factor

Note: The additional projected area of a member due to ice accretion can be assumed to be rounded and therefore the reduction factor for round members (Rr) may be applied to the additional projected area due to ice on a flat member.

(ii) For monopole (tubular pole) towers:
$EPA = (C_f)(A_p)$

Where:
Ap = projected area of monopole (ft^2 or m^2)

(iii) For tower appurtenances:
EPA = (C_a)(A_a)

Where:
A_a = the projected effective area of the appurtenance (ft^2)

The projected area (A_f, A_r, A_p or A_a) of a tower member, monopole, or appurtenance is simply the width or diameter of the member multiplied by the unit length. For example, the projected area for a 1 ft (0.30 m) length of 8.625inch diameter pipe is (8.625/12)x(1 ft) = 0.72 ft^2 (0.066 m^2).

3.3.2 Large Advertising Signs

Billboards and similar large advertising signs are generally either mounted to a building or free standing. Building-mounted signs have a metal framework supported by the building roof structure, or are sometimes mounted to a building wall. Free-standing signs have a metal framework supported on multiple steel posts, or on a single conical or tubular steel tower. Support posts or towers are generally supported on shallow concrete foundations, or sometimes on deep foundations.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-2, *Earthquakes*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-34, *Hail Damage*
Data Sheet 1-40, *Flood*
Data Sheet 5-11, *Lightning and Surge Protection*

4.2 Other

Australian/New Zealand Standard AS/NZS 1170.2:2002. *Structural Design Actions, Part 2: Wind Actions*.

Canadian Standards Association (CSA), CAN/CSA-S37-01 with 2004 and 2006 Updates. *Antennas, Towers and Antenna Supporting Structures*.

IEEE Standard 142-2007. *Grounding of Industrial and Commercial Power Systems*.

National Building Code of Canada (NBCC) 2005.

Structural Engineering Institute of the American Society of Civil Engineers, ASCE/SEI Standard 7-05 (or 7-02). *Minimum Design Loads for Buildings and Other Structures*.

Telecommunications Industry Association/Electronic Industry Association. *Structural Standard for Steel Antenna Towers and Antenna Supporting Structures*, TIA/EIA-222-F-1996

Telecommunications Industry Association. *Structural Standard for Steel Antenna Towers and Antenna Supporting Structures*, ANSI/TIA-222-G-2005 with 2007(TIA-222-G-1) and 2009(TIA-222-G-2) Addenda.

APPENDIX A GLOSSARY OF TERMS

Appurtenance: all items attached to, but not part of, the structural system of the tower; includes antennas, antenna support brackets, antenna ice or hail shields, cable and conduit, ladders, and signage or call letters.

Glaze Ice: Glaze ice is clear and without substantial entrapped air, and the density is generally considered to be 56 Lb/ft^3 (8.8 kN/m^3). Freezing rain typically forms glaze ice.

Guys (guy wires): A series of steel cables or heavy steel wires used to provide lateral stability to tall antenna towers.

Hurricane-Prone, Typhoon-Prone, and Tropical Cyclone-Prone Areas: Refer to FM Global DS 1-28, *Wind Design*.

MRI (Mean Recurrence Interval): The ″return period″ of the event. For example the 50-year MRI wind speed has a ″return period″ of 50-years, indicating that the annual probability of exceedance is approximately 0.02 (or 2%).

Rime Ice: Rime ice is opaque due to entrapped air, and the density is generally considered to be 30 Lb/ft^3 (4.7 kN/m^3) to 40 Lb/ft^3 (6.3 kN/m^3). In-cloud icing typically forms rime ice.

APPENDIX B DOCUMENT REVISION HISTORY

July 2011:

- Added provisions to determine wind loads on trussed (latticed) and monopole towers
- Added wind pressure tables for trussed (latticed) and monopole towers
- Added guidance for radial ice thickness variations with tower height
- Added guidance for wind load effects on roof-mounted towers and signs
- Added guidance for velocity pressure exposure coefficient (K_z)
- Added guidance for topographic wind effects (K_{zt}) for towers and signs located on hills, ridges, or escarpments
- Added guidance for using several tower standards (TIA-222-G, TIA/EIA-222-F, CSA S37-01, and AS/NZS 1170.2); and several national standards for structural loads (ASCE 7, NBCC, Eurocode) for wind loads on towers and signs.
- Updated provisions to determine wind loads on signs.

January 2000. This revision of the document has been reorganized to provide a consistent format.

January 1991. The following changes were made:

1. The title of this data sheet has been changed, substituting the word antenna for transmission so it would not be confused with transmission (power) line towers.

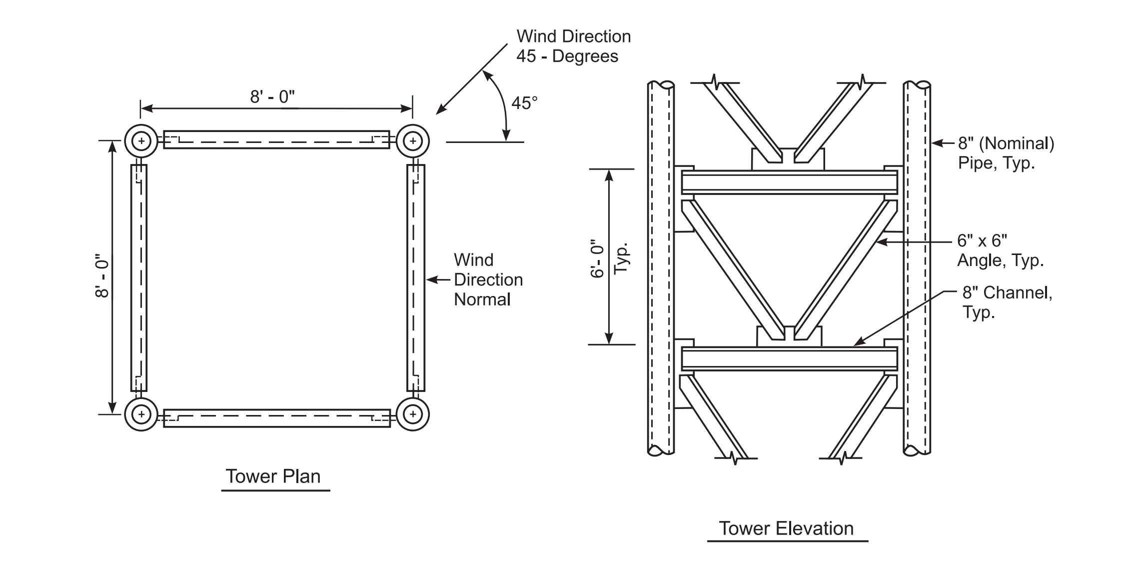
APPENDIX C JOB AIDS

EXAMPLE PROBLEM #1 – WIND FORCES ON ANTENNA TOWER

Given:

- 120 ft (36.6 m) high square self-supporting trussed (latticed) tower
- 90 mph (40 m/s) Basic Wind Speed (3-second gust), Groud Roughness D, Importance Factor 1.15
- Gust Factor G = 1.0
- Topographic Wind Factor K_{zt} = 1.0 (not located on hill, ridge or escarpment)
- Tower Structure
  Vertical Legs: 8 in. nominal pipe (8.625 in. [219 mm] outside diameter)
  Horizontal Brace: 8 in. wide channel, spaced at 8.0 ft (2.44 m)
  Diagonal Brace: 6 in. (152 mm) x 6 in. (152 mm) x 7.21 ft (2.20 m) long angle
- Plan, elevation and section sketches shown below (Square [4-legged], 8.0 ft [2.44 m] wide to centerline of legs).

Determine:
The base reactions (shear and overturning moment) due to wind forces for Normal wind direction and 45-degree wind direction.



Notes:

1. For the purpose of simplification for this example, wind loads on antennas and appurtenances (e.g., conduit, ladders, etc.) have been omitted.

2. Assume no ice accretion.

PART A: PROPERTIES OF TYPICAL 6 FT (1.83 m) TOWER SECTION
Projected area of channel = (8 in.)(1 ft/12 in.)(8 ft) = 5.33 ft^2
Projected area of angle = (6 in.)(1 ft/12 in.)(7.21 ft)(2) = 7.21 ft^2
Projected area pipe leg = (8.625 in.)(1 ft/12 in.)(6 ft)(2) = 8.63 ft^2

Total projected solid area = 5.33 + 7.21 + 8.63 = 21.17 ft^2 (1.97 m^2)

Gross area (out to out) = (8.0 ft + [(8.625 in.) (1 ft/12 in.)] (6 ft) = 52.31 ft^2 (4.86 m^2)

% Solid of Projected Area = [(Total Projected Solid Area)/(Gross Area)] x 100 = ((21.17/52.31)x(100) = 40.4% (e = 0.404)
Say **40% SOLID***

*When the % solid is less than roughly 70%, it is conservative to round <u>down</u> the % solid to determine the appropriate wind pressure.

Equivalent solid area of <u>flats</u> (angle and channel) per ft (m) of height:
(5.33 ft^2 + 7.21 ft^2)/6 ft = 2.09 ft^2/ft (0.64 m^2/m)

Equivalent solid area of <u>rounds</u> (pipe legs) per ft (m) of height:
8.63 ft^2/6 ft = 1.44 ft^2/ft (0.44 m^2/m)

PART B: WIND DIRECTION NORMAL
From Table 2 for 40% SOLID and WIND DIRECTION NORMAL (US units):

Height (ft)	*Pressure on Flats(psf)*	*Pressure on Rounds(psf)*
0 to 30	45	30
120*	60	40
*interpolated		

<u>Load/ft on flats + Load/ft on rounds = Total Load/ft</u>
0-30 ft:(2.09 ft^2/ft)(45 psf)+(1.44 ft^2/ft)(30 psf) = 94+43 = 137 Lb/ft
120 ft: (2.09 ft^2/ft)(60 psf)+(1.44 ft^2/ft)(40 psf) = 125+58 = 183 Lb/ft

From Table 3 for 40% SOLID and WIND DIRECTION NORMAL (SI units):

Height (m)	*Pressure on Flats(kPa)*	*Pressure on Rounds(kPa)*
0 to 9	2.2	1.4
37*	2.9	1.9
*interpolated		

Load/m on flats + Load/m on rounds = Total Load/m
0-9 m:($0.64m^2$/m)(2.2 kPa)+($0.44m^2$/m)(1.4 kPa)=1.41+0.62 = 2.03 kN/m
37 m:($0.64m^2$/m)(2.9 kPa)+($0.44m^2$/m)(1.9 kPa)=1.86+0.84 = 2.70 kN/m

An approximate method using an assumed linear pressure distribution (as shown in the figure below) will generally produce acceptable results (within roughly 5% of a more rigorous incremental non-linear method) for small towers (tower height < 250 ft [76 m]).

At base: W_1 = 137 Lb/ft (2.03 kN/m)
At top: W_t = 183 Lb/ft (2.70 kN/m)

h = 120 ft (36.6 m)

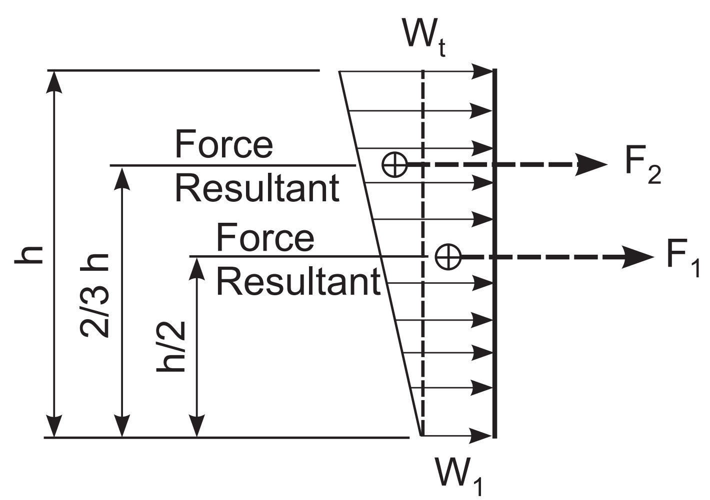
F_1 = 137 Lb/ft (2.03 kN/m) x 120 ft (36.6 m) = 16,440 Lb (73.1 kN)
F_2 = (183 Lb/ft [2.70 kN/m] – 137 Lb/ft [2.03 kN/m])x 120 ft (36.6 m) x 0.5 = 2,760 Lb (12.3 kN)

Total Base Wind Shear:

F_{total} = F_1 + F_2 = 16,440 Lb (73.1 kN) + 2,760 Lb (12.3 kN) = **19,200 Lb (85.4 kN)**

Total Base Wind OTM:

OTM = (16,440 Lb [73.1 kN] x 60 ft [18.3 m])+(2,760 Lb [12.3 kN] x 80 ft [24.4 m])= 986,400 Lb-ft (1337 kN-m) + 220,800 Lb-ft (299 kN-m) = **1,207,200 Lb-ft (1636 kN-m)**



PART C: WIND DIRECTION 45-DEGREES

Using the approximate method with an assumed linear pressure distribution as shown in the figure:

From Table 2 for 40% SOLID and WIND DIRECTION 45-DEGREES (US units)

Height (ft)	*Pressure on Flats(psf)*	*Pressure on Rounds(psf)*
0 to 30	54	35
120*	72	48

*interpolated

Load/ft on flats + Load/ft on rounds = Total Load/ft
0-20 ft:(2.09 ft^2/ft)(54 psf)+(1.44 ft^2/ft)(35 psf) = 113+50 = 163 Lb/ft
120 ft: (2.09 ft^2/ft)(72 psf)+(1.44 ft^2/ft)(48 psf) = 150+69 = 219 Lb/ft

From Table 3 for 40% SOLID and WIND DIRECTION 45-DEGREES (SI units)

Height (ft)	*Pressure on Flats(kPa)*	*Pressure on Rounds(kPa)*
0 to 9	2.6	1.7
37*	3.5	2.3

*interpolated

Load/m on flats + Load/m on rounds = Total Load/m
0-9 m:(0.64m^2/m)(2.6 kPa)+(0.44m^2/m)(1.7 kPa) = 1.66+0.75 = 2.41 kN/m
37 m:(0.64m^2/m)(3.5 kPa)+(0.44m^2/m)(2.3 kPa) = 2.24+1.01 = 3.25 kN/m

At base: W1 = 163 Lb/ft (2.41 kN/m)
At top: Wt = 219 Lb/ft (3.25 kN/m)

F_1 = 163 Lb/ft (2.41 kN/m) x 120 ft (36.6 m) = 19,560 Lb (89.2 kN)
F_2 = (219 Lb/ft [3.25 kN/m] – 163 Lb/ft [2.41 kN/m]) x 120 ft (36.6 m) x 0.5 = 3,360 Lb (15.5 kN)

Total Base Wind Shear:

F_{total} = F_1 + F_2 = 19,560 Lb (89.2 kN) + 3,360 Lb (11.5 kN) = **22,920 Lb (104.7 kN)**

Total Base Wind OTM:
OTM = (19,560 Lb [89.2 kN] x 60 ft [18.3 kN]) + (3,360 Lb [15.5 kN] x 80 ft [24.4 m]) = 1,173,600 Lb/ft (1591 kN/m) + 268,800 Lb/ft (420 kN/m) = **1,442,400 Lb/ft (2011 kN/m)**

Note that the wind pressures used in this example (from the referenced table above) includes an embedded wind directionality constant (K_d) of 0.85, a gust factor (G) of 1.0, and an Importance Factor (I_w) of 1.15.

Wind loads are intended to be used in conjunction with other loads (e.g., dead load due to the self-weight of the tower) in typical load combinations for structural analysis. When determining the net resultant base reactions (e.g., base shear and OTM), the effects of dead load acting concurrently with the wind load must be examined.