SK ENGINEERING

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Aermotor Windmill Corporation
4277 DAN BANKS LANE
San Angelo, Texas 76903

Subject: Certification of Aermotor Windmill wind load design strengths.

AERMOTOR:

At your request, the 6', 8', 10', 12', 14', and 16' diameter mills and their respective towers up to 47' in height have been evaluated for their wind resistance capability.

The evaluation indicates that all heights of the tower for the 10', 12', 14', and 16' mills; the 21' and 27' towers of the 8' mill and the 21', 27', and 33' tower of the 6' mill are designed to withstand wind loads equivalent to 130 mph. The 6' mill on the 40' tower can withstand windloads equivalent to 110 mph, on the 47' tower the equivalent speed is 105 mph. The 8' mill on the 33' tower can withstand an equivalent speed of 112 mph, on the 40' tower the equivalent speed is 100 mph, and on the 47' tower the equivalent speed is 100 mph. The detailed calculations supporting these findings is attached to this report.

The equivalent wind speeds indicated above are for the Aermotor standard tower. The foundation design for withstanding these wind forces must be accomplished on a case by case basis, considering all local soil conditions and requirements.

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STATE OF TEXAS
JAMES G. KIMREY
23560
REGISTERED PROFESSIONAL ENGINEER

STRUCTURAL EVALUATION

OF

AERMOTOR WINDMILL TOWERS

REQUIREMENT: AERMOTOR HAS REQUESTED THAT THE TOWERS FOR THEIR 6 SIZES OF WINDMILL BE CERTIFIED BY A REGISTERED PROFESSIONAL ENGINEER IN THE STATE OF TEXAS.

NOTES:

1. WINDMILLS TO BE EVALUATED ARE THE 8', 10', 12', 14' AND 16' DIAMETER MILLS. THE 6' MILL WILL BE EVALUATED USING THE SAME TOWER AS THE 8' MILL WITHOUT RECALCULATING THE FORCES.
2. THE MILL IS ASSUMED TO BE SOLID AND PERPENDICULAR TO THE WIND. THE ACTUAL SITUATION IS THE MILL IS PARALLEL TO THE WIND THEREBY PRESENTING A SMALLER SURFACE AREA.
3. THE SHAPE FACTORS USED FOR THE FORCE CALCULATIONS ARE FROM THE STANDARD BUILDING CODE, 1985.
4. ONE-FOURTH THE WEIGHT OF THE MILL AND TOWER TO BE ADDED TO EACH CORNER POST STRESS.
5. THE WIND FORCES WILL BE MULTIPLIED BY A FACTOR OF 1.41 TO ALLOW FOR WIND AT A 45° OBLIQUE TO THE SIDE.
6. ALLOWABLE STRESS FROM AMERICAN INSTITUTE OF STEEL CONSTRUCTION "MANUAL OF STEEL CONSTRUCTION" SEVENTH EDITION, PAGE 1-56, 1-57, 5-16, 5-17.
7. THE MAXWELL DIAGRAM AND WIND FORCES WILL BE PREPARED FOR THE 47' TOWER ONLY. THE MAXIMUM ALLOWABLE WIND FORCE WILL BE CALCULATED FOR ALL TOWER HEIGHTS.
8. A_m = NET AREA OF MEMBERS, A = GROSS AREA OF MEMBERS, φ = RATIO OF NET AREA TO GROSS AREA.

6' OR 8' WINDMILL ON 47' TOWER

q_8 = MAXIMUM ALLOWABLE WIND FORCE ON A 47' TOWER WITH AN 8' MILL

SEE FIGURE 1 FOR MEMBER SIZE, FORCES AND MAX WELL DIAGRAM.

ALLOWABLE STRESS

$$F_a = \frac{12\pi^2 E}{23(kl/r)^2} = \frac{P}{A}$$

WHERE $E = 29,000$ KSI
$k = 1.0$
$r = .394$ FOR 2"x2"x3/16" ANGLE
$A = .715\ in^2$

7' MEMBER $F_a = \frac{12\pi^2(29,000\ KSI)}{23(7\times12/.394)^2} = 3,285$ PSI

$P_a = F_a \times A = (3,285\ PSI)(.715\ in^2) = 2,348\#$

6.75' MEMBER $F_a = \frac{12\pi^2(29,000\ KSI)}{23(6.75'\times12/.394_{in})^2} = 3,533$ PSI

$P_a = (3,533\ PSI)(.715\ in^2) = 2,526\#$

6.25' MEMBER $F_a = \frac{12\pi^2(29,000\ KSI)}{23(6.25'\times12/.394_{in^2})} = 4,121$ PSI

$P_a = (4,121\ PSI)(.715\ in^2) = 2,946\#$

WIND LOAD CALCULATIONS

W_ϕ

$$W_\phi = q_8 A$$
$$= q_8(\pi)(4')^2$$
$$= 12.57 q_8$$

W_A

$$\varphi = \frac{A_m}{A}$$

$A_m = 2(2")(7')/12 + \frac{1}{2}(1.5")(1.4')/12 = 2.42\ ft^2$
$A = \frac{1}{2}(1.4')(7') = 4.90\ ft^2$

8' MILL

W_A (CONT)

$$\varphi = \frac{2.42\ ft^2}{4.9\phi\ ft^2} = .49 \quad \therefore \quad C = \phi.89$$

$$W_A = C q_8 A = \phi.89\, q_8\, (4.9\phi\ ft^2) = 4.36\, q_8$$

W_B

$$A_m = 2(2")(6.75')/12 + \tfrac{1}{2}(1.5")(1.4' + 2.7')/12 + 2(\tfrac{3}{8}")(7')/12$$
$$= 2.94\ ft^2$$
$$A = \tfrac{1}{2}(1.4' + 2.7')(6.75') = 13.84\ ft^2$$
$$\varphi = \frac{2.94\ ft^2}{13.84\ ft^2} = .21 \quad \therefore \quad C = \phi.56$$

$$W_B = C q_8 A = \phi.56\, q_8\, (13.84\ ft^2) = 7.75\, q_8$$

W_C

$$A_m = 2(2")(6.25')/12 + \tfrac{1}{2}(1.5")(2.7' + 4.1')/12 + 2(\tfrac{3}{8}")(7.1')/12 = 2.95\ ft^2$$
$$A = \tfrac{1}{2}(2.7' + 4.1')(6.25') = 21.25\ ft^2$$

$$\varphi = \frac{2.95\ ft^2}{21.25\ ft^2} = .14 \quad \therefore \quad C = \phi.43$$

$$W_C = C q_8 A = \phi.43\, q_8\, (21.25\ ft^2) = 9.14\, q_8$$

W_D

$$A_m = 2(2")(6.75')/12 + \tfrac{1}{2}(1.5")(4.1')/12 + \tfrac{1}{2}(2")(5.5')/12 + 2(\tfrac{3}{8}")(8.3')/12$$
$$= 3.48\ ft^2$$
$$A = \tfrac{1}{2}(4.1' + 5.5')(6.75') = 32.4\phi\ ft^2$$

$$\varphi = \frac{3.48\ ft^2}{32.4\phi\ ft^2} = .11 \quad \therefore \quad C = \phi.37$$

$$W_D = C q_8 A = \phi.37\, q_8\, (32.4\phi\ ft^2) = 11.99\, q_8$$

W_E

$$A_m = 2(2")(6.25')/12 + \tfrac{1}{2}(2")(5.5' + 6.8')/12 + 2(\tfrac{3}{8}")(8.8')/12 = 3.66\ ft^2$$
$$A = \tfrac{1}{2}(5.5' + 6.8')(6.25') = 38.44\ ft^2$$

$$\varphi = \frac{3.66\ ft^2}{38.44\ ft^2} = .1\phi \quad \therefore \quad C = \phi.35$$

$$W_E = C q_8 A = \phi.35\, q_8\, (38.44\ ft^2) = 13.45\, q_8$$

8' MILL

W_F

$A_m = 2(2")(6.75')/12 + \frac{1}{2}(2")(6.8'+8.2')/12 + \frac{1}{2}(2)(1.25")(15.7')/12 = 5.14 ft^2$

$A = \frac{1}{2}(6.8'+8.2')(6.75') = 50.63\ ft^2$

$\varphi = \frac{5.14\ ft^2}{50.63\ ft^2} = .10$ $\therefore$ $C = .35$

$W_F = C q_8 A = .35\, q_8 (50.63\ ft^2) = 17.72\, q_8$

W_G

$A_m = 2(2")(6.25')/12 + \frac{1}{2}(2")(8.2')/12 + \frac{1}{2}(2)(1.25")(15.7')/12 = 4.40\ ft^2$

$A = \frac{1}{2}(8.2' + 9.5')(6.25') = 55.31\ ft^2$

$\varphi = \frac{4.40\ ft^2}{55.31\ ft^2} = .08$ $\therefore$ $C = .35$

$W_G = C q_8 A = .35 q_8 (55.31\ ft^2) = 19.36\, q_8$

FORCE CALCULATIONS

$F_1 = \left(\frac{W_\phi}{4} + \frac{W_A}{4}\right) 1.41 = 1.41\left(\frac{12.57 q_8}{4} + \frac{4.36 q_8}{4}\right) = 5.97\, q_8$

$F_2 = 1.41\left(\frac{W_A}{4} + \frac{W_B}{4}\right) = 1.41\left(\frac{4.36 q_8}{4} + \frac{7.75 q_8}{4}\right) = 4.27\, q_8$

$F_3 = 1.41\left(\frac{W_B}{4} + \frac{W_C}{4}\right) = 1.41\left(\frac{7.75 q_8}{4} + \frac{9.14 q_8}{4}\right) = 5.95\, q_8$

$F_4 = 1.41\left(\frac{W_C}{4} + \frac{W_D}{4}\right) = 1.41\left(\frac{9.14 q_8}{4} + \frac{11.99 q_8}{4}\right) = 7.45\, q_8$

$F_5 = 1.41\left(\frac{W_D}{4} + \frac{W_E}{4}\right) = 1.41\left(\frac{11.99 q_8}{4} + \frac{13.45 q_8}{4}\right) = 8.97\, q_8$

$F_6 = 1.41\left(\frac{W_E}{4} + \frac{W_F}{4}\right) = 1.41\left(\frac{13.45 q_8}{4} + \frac{17.72 q_8}{4}\right) = 10.99\, q_8$

$F_7 = 1.41\left(\frac{W_F}{4} + \frac{W_G}{4}\right) = 1.41\left(\frac{17.72 q_8}{4} + \frac{19.36 q_8}{4}\right) = 13.07\, q_8$

SEE FIGURE 1 FOR MAXWELL DIAGRAM

8' MILL

MAXIMUM WIND LOAD

47' TOWER

MEMBER 2-21 (6.25' LONG)

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$294\text{6}^{\#} = 124.7\phi q_8 + 121\phi^{\#}/4$

$q_8 = 21.2\phi$ psf

MEMBER 2-12 (6.75' LONG)

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2526^{\#} = 102.25 q_8 + 106\phi^{\#}/4$

$q_8 = 22.1\phi$ psf

MEMBER 2-21 GOVERNS $\therefore q_8 = 21.2\phi$ psf OR 100 MPH

40' TOWER

MEMBER 2-12 GOVERNS $\therefore q_8 = 22.1\phi$ psf OR 100 MPH

33' TOWER

MEMBER 2-10 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$294\text{6}^{\#} = 81.8\phi q_8 + 96\phi^{\#}/4$

$q_8 = 33.08$ psf OR 112 MPH

27' TOWER

MEMBER 2-8 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2526^{\#} = 64.\phi q_8 + 86\phi/4$

$q_8 = 36.11$ psf OR $130+$ MPH

8' MILL

21' TOWER

MEMBER 2-6 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2946^{\#} = 49.55 q_8 + 76\phi/4$

$q_8 = 55.62$ psf OR $13\phi^{+}$ MPH

6' MILL

NOTE: FORCE F_1 (W_ϕ) AND THE WEIGHT CHANGE; ALL OTHER FORCES, AREAS AND CALCULATIONS REMAIN THE SAME AS FOR THE 8' MILL. SEE FIGURE 2 FOR MEMBER SIZES, FORCES AND MAXWELL DIAGRAM.

ALLOWABLE STRESS

SAME AS FOR 8' MILL

7' MEMBER $P_A = 2348^{\#}$

6.75' MEMBER $P_A = 2526^{\#}$

6.25' MEMBER $P_A = 2946^{\#}$

WIND LOAD CALCULATIONS

W_ϕ

$W_\phi = q_6 A$
$= q_6 (\pi)(3')^2$
$= 7.07 q_6$

$W_A = 4.36 q_6$ $W_D = 11.99 q_6$ $W_G = 19.36 q_6$

$W_B = 7.75 q_6$ $W_E = 13.45 q_6$

$W_C = 9.14 q_6$ $W_F = 17.72 q_6$

6' MILL

FORCE CALCULATIONS

$$F_1 = \left(\frac{W_\Phi}{4} + \frac{W_A}{4}\right) 1.41 = 1.41\left(\frac{7.\Phi 7 q_L}{4} + \frac{4.36 q_L}{4}\right) = 4.\Phi 3\, q_L$$

$F_2 = 4.27\, q_L$ $\quad F_4 = 7.45\, q_L$ $\quad F_6 = 1\Phi.99\, q_L$

$F_3 = 5.95\, q_L$ $\quad F_5 = 8.97\, q_L$ $\quad F_7 = 13.\Phi 7\, q_L$

SEE FIGURE 2 FOR MAXWELL DIAGRAM

MAXIMUM WIND LOAD

47' TOWER

MEMBER 2-14 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2946^{\#} = 117.75\, q_L + 1\Phi 55^{\#}/4$

$q_L = 22.78$ psf OR 1Φ5 mph

4Φ' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2526^{\#} = 95.3\Phi\, q_L + 91\Phi^{\#}/4$

$q_L = 24.12$ psf OR 11Φ mph

33' TOWER

MEMBER 2-1Φ GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2946^{\#} = 74.\Phi q_L + 8\Phi 5^{\#}/4$

$q_L = 37.\Phi 9$ psf OR 13Φ+ mph

6' MILL

27' TOWER

MEMBER 2-8 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2526^{\#} = 56.3\Phi q_6 + 7\Phi 5^{\#}/4$

$q_6 = 41.74$ psf OR $13\Phi^{+}$ MPH

21' TOWER

MEMBER 2-6 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$2946^{\#} = 41.25 q_6 + 6\Phi 5^{\#}/4$

$q_6 = 67.75$ psf OR $13\Phi^{+}$ MPH

1Φ' MILL

$q_{1\Phi}$ = MAXIMUM ALLOWABLE WIND FORCE ON A TOWER WITH A 1Φ' MILL.

SEE FIGURE 3 FOR MEMBER SIZE AND FORCES.

NOTE: THE 1Φ' TOWER HAS THE SAME GROSS AREA AS THE 8' TOWER, SO THE PREVIOUS VALUES WILL BE USED.

ALLOWABLE STRESS

$$F_a = \frac{12\pi^2 E}{23(kl/r)^2} = \frac{P}{A}$$

WHERE $E = 29,\Phi\Phi\Phi$ KSI
$K = 1.\Phi$
$r = .495"$
$A = .9\Phi 2$ $_{IN}{}^2$ FOR A $2\frac{1}{2}" \times 2\frac{1}{2}" \times \frac{3}{16}"$ ANGLE

10' MILL

7' MEMBER $F_a = \frac{12\pi^2(29,000\ ksi)}{23(7'\times 12/.495")^2} = 5,185\ psi$

$P_{allow} = F_a \times A = (5,185\ psi)(.902\ in^2) = 4,677\ \#$

6.75' MEMBER $F_a = \frac{12\pi^2(29,000\ ksi)}{23(8.75'\times 12/.495")^2} = 5,576\ psi$

$P_{allow} = F_a \times A = (5,576\ psi)(.902\ in^2) = 5,030\ \#$

6.25' MEMBER $F_a = \frac{12\pi^2(29,000\ ksi)}{23(6.25'\times 12/.495")^2} = 6,504\ psi$

$P_{allow} = (6,504\ psi)(.902\ in^2) = 5,867\ \#$

WIND LOAD CALCULATIONS

W_ϕ

$W_\phi = q_{z\phi} A$
$= q_{1\phi}(\pi)(5)^2$
$= 19.63 q_{1\phi}$

W_A

$\varphi = \frac{A_m}{A}$

$A_m = 2(2.5")(7')/12 + \frac{1}{2}(1.5")(1.4')/12 = 3.00\ ft^2$
$A = 4.90\ ft^2$

$\varphi = \frac{3.00\ ft^2}{4.90\ ft^2} = .61 \quad \therefore \quad C = 1.01$

$W_A = C q_{1\phi} A = 1.01 q_{1\phi}(4.90\ ft^2) = 4.95 q_{1\phi}$

W_B

$A_m = 2(2.5")(6.75')/12 + \frac{1}{2}(1.5")(1.4' + 2.7')/12 + 2(\frac{3}{8}")(7')/12 = 3.51\ ft^2$

$\varphi = \frac{3.51\ ft^2}{13.84\ ft^2} = 0.25 \quad \therefore \quad C = 0.61$

$W_B = 0.61 q_{1\phi}(13.84\ ft^2) = 8.44 q_{1\phi}$

10' MILL

W_C

$A_M = 2(2.5")(6.25')/12 + \frac{1}{2}(1.5")(2.7'+4.1')/12 + 2(\frac{3}{8}")(7.1')/12 = 3.47 ft^2$

$\varphi = \frac{3.47 ft^2}{21.25 ft^2} = .16 \quad \therefore C = \Phi.47$

$W_C = \Phi.47 q_{1\Phi} (21.25 ft^2) = 9.99 q_{1\Phi}$

W_D

$A_M = 2(2.5")(6.75')/12 + \frac{1}{2}(1.5")(4.1')/12 + \frac{1}{2}(2")(5.5')/12 + 2(\frac{3}{8}")(8.3')/12$
$= 4.\Phi4 ft^2$

$\varphi = \frac{4.\Phi4 ft^2}{32.4\Phi ft^2} = .12 \quad \therefore C = \Phi.39$

$W_D = \Phi.39 q_{1\Phi} (32.4\Phi ft^2) = 12.64 q_{1\Phi}$

W_E

$A_M = 2(2.5")(6.25')/12 + \frac{1}{2}(2")(5.5'+6.8')/12 + 2(\frac{3}{8}")(8.8')/12 = 4.18 ft^2$

$\varphi = \frac{4.18 ft^2}{38.44 ft^2} = .11 \quad \therefore C = \Phi.37$

$W_E = \Phi.37 q_{1\Phi} (38.44 ft^2) = 14.22 q_{1\Phi}$

W_F

$A_M = 2(2.5")(6.75')/12 + \frac{1}{2}(2")(6.8'+8.2')/12 + \frac{1}{2}(2)(1.25")(15.7')/12 = 5.7\Phi ft^2$

$\varphi = \frac{5.7\Phi ft^2}{5\Phi.63 ft^2} = .11 \quad \therefore C = \Phi.37$

$W_F = \Phi.37 q_{1\Phi} (5\Phi.63 ft^2) = 18.73 q_{1\Phi}$

W_G

$A_M = 2(2.5")(6.25')/12 + \frac{1}{2}(2")(8.2')/12 + \frac{1}{2}(2)(1.25")(15.7')/12 = 4.92 ft^2$

$\varphi = \frac{4.92 ft^2}{55.31 ft^2} = .\Phi9 \quad \therefore C = \Phi.35$

$W_G = \Phi.35 q_{1\Phi} (55.31 ft^2) = 19.36 q_{1\Phi}$

10' MILL

FORCE CALCULATIONS

$$F_1 = 1.41\left(\frac{W_\Phi}{4} + \frac{W_A}{4}\right) = 1.41\left(\frac{19.63 q_{10\Phi}}{4} + \frac{4.95 q_{10\Phi}}{4}\right) = 8.66 q_{10\Phi}$$

$$F_2 = 1.41\left(\frac{W_A}{4} + \frac{W_B}{4}\right) = 1.41\left(\frac{4.95 q_{10\Phi}}{4} + \frac{8.44 q_{10\Phi}}{4}\right) = 4.72 q_{10\Phi}$$

$$F_3 = 1.41\left(\frac{W_B}{4} + \frac{W_C}{4}\right) = 1.41\left(\frac{8.44 q_{10\Phi}}{4} + \frac{9.99 q_{10\Phi}}{4}\right) = 6.5\Phi q_{10\Phi}$$

$$F_4 = 1.41\left(\frac{W_C}{4} + \frac{W_D}{4}\right) = 1.41\left(\frac{9.99 q_{10\Phi}}{4} + \frac{12.64 q_{10\Phi}}{4}\right) = 7.98 q_{10\Phi}$$

$$F_5 = 1.41\left(\frac{W_D}{4} + \frac{W_E}{4}\right) = 1.41\left(\frac{12.64 q_{10\Phi}}{4} + \frac{14.22 q_{10\Phi}}{4}\right) = 9.47 q_{10\Phi}$$

$$F_6 = 1.41\left(\frac{W_E}{4} + \frac{W_F}{4}\right) = 1.41\left(\frac{14.22 q_{10\Phi}}{4} + \frac{18.73 q_{10\Phi}}{4}\right) = 11.61 q_{10\Phi}$$

$$F_7 = 1.41\left(\frac{W_F}{4} + \frac{W_G}{4}\right) = 1.41\left(\frac{18.73 q_{10\Phi}}{4} + \frac{19.36 q_{10\Phi}}{4}\right) = 13.43 q_{10\Phi}$$

SEE FIGURE 3 FOR MAXWELL DIAGRAM

MAXIMUM WIND LOAD

47' TOWER

MEMBER 2-14 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5867^{\#} = 147.9\Phi q_{10\Phi} + 174\Phi^{\#}/4$

$q_{10\Phi} = 36.73$ psf OR $13\Phi^{+}$ MPH

1Ø' MILL

4Ø' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5\phi3\phi^{\#} = 124.2\phi\, q_{1\phi} + 1577^{\#}/4$

$q_{1\phi} = 37.32$ psf OR $13\phi^{+}$ MPH

33' TOWER

MEMBER 2-1Ø GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5867^{\#} = 1\phi2.15\, q_{1\phi} + 1433^{\#}/4$

$q_{1\phi} = 53.93$ psf OR $13\phi^{+}$ MPH

27' TOWER

MEMBER 2-8 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5\phi3\phi^{\#} = 83.25\, q_{1\phi} + 13\phi4^{\#}/4$

$q_{1\phi} = 56.5\phi$ psf OR $13\phi^{+}$ MPH

21' TOWER

MEMBER 2-6 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5867^{\#} = 66.95\, q_{1\phi} + 1174^{\#}/4$

$q_{1\phi} = 83.25$ psf OR $13\phi^{+}$ MPH

12' MILL

q_{12} = MAXIMUM ALLOWABLE WIND FORCE ON A TOWER WITH A 12' MILL.

SEE FIGURE 4 FOR MEMBER SIZE AND FORCES.

NOTE: THE 12' TOWER HAS SAME SIZE CORNER POSTS AS THE 10' TOWER, SO THE P_{ALLOW} REMAINS THE SAME.

ALLOWABLE STRESS

7' MEMBER	$F_a = 5,185$ PSI	$P_{ALLOW} = 4,677$ #
6.75' MEMBER	$F_a = 5,576$ PSI	$P_{ALLOW} = 5,030$ #
6.25' MEMBER	$F_a = 6,504$ PSI	$P_{ALLOW} = 5,867$ #

WIND LOAD CALCULATIONS

W_Φ

$$W_\Phi = q_{12} A$$
$$= q_{12} (\pi)(6')^2$$
$$\therefore 28.27\, q_{12}$$

W_A

$$\varphi = \frac{A_m}{A}$$

$$A_m = 2(2.5")(17')/12 + \tfrac{1}{2}(1.5")(1.3')/12 \therefore 3.00\ ft^2$$
$$A = \tfrac{1}{2}(1.3')(7') = 4.55\ ft^2$$

$$\varphi = \frac{3.00\ ft^2}{4.55\ ft^2} = .66 \quad \therefore \quad C = 1.06$$

$$W_A = C q_{12} A = 1.06\, q_{12} (4.55\ ft^2) = 4.82\, q_{12}$$

W_B

$$A_m = 2(2.5")(6.75')/12 + \tfrac{1}{2}(1.5")(1.3'+3.25')/12 + 2(\tfrac{3}{8}")(7.25')/12 = 3.55\ ft^2$$
$$A = \tfrac{1}{2}(1.3'+3.25')(6.75') = 15.36\ ft^2$$

$$\varphi = \frac{3.55\ ft^2}{15.36\ ft^2} = .23 \quad \therefore \quad C = .59$$

$$W_B = .59\, q_{12} (15.36\ ft^2) = 9.06\, q_{12}$$

12' MILL

W_C

$A_m = 2(2.5")(6.25')/12 + \frac{1}{2}(1.5")(3.25' + 4.8')/12 + 2(\frac{3}{8}")(8')/12 = 3.61\ ft^2$

$A = \frac{1}{2}(3.25' + 4.8')(6.25') = 25.16\ ft^2$

$\varphi = \frac{3.61\ ft^2}{25.16\ ft^2} = .14 \quad \therefore \quad C = \phi.43$

$W_C = \phi.43\ q_{12}(25.16\ ft^2) = 10.82\ q_{12}$

W_D

$A_m = 2(2.5")(6.75')/12 + \frac{1}{2}(1.5")(4.8')/12 + \frac{1}{2}(2")(6.67')/12 + 2(\frac{3}{8}")(8.9')/12$
$= 4.22\ ft^2$

$A = \frac{1}{2}(4.8' + 6.67')(6.75') = 38.71\ ft^2$

$\varphi = \frac{4.22\ ft^2}{38.71\ ft^2} = .11 \quad \therefore \quad C = \phi.37$

$W_D = \phi.37\ q_{12}(38.71\ ft^2) = 14.32\ q_{12}$

W_E

$A_m = 2(2.5")(6.25')/12 + \frac{1}{2}(2")(6.67' + 8.33')/12 + 2(\frac{3}{8}")(9.8')/12 = 4.47\ ft^2$

$A = \frac{1}{2}(6.67' + 8.33')(6.25') = 46.88\ ft^2$

$\varphi = \frac{4.47\ ft^2}{46.88\ ft^2} = .1\phi \quad \therefore \quad C = \phi.35$

$W_E = \phi.35\ q_{12}(46.88\ ft^2) = 16.41\ q_{12}$

12' MILL

W_6

$$\varphi = \frac{5.26\,ft^2}{67.72\,ft^2} = .08 \quad \therefore \quad C = .35$$

$$W_6 = .35\,q_{12}\,(67.72\,ft^2) = 23.7\,q_{12}$$

FORCE CALCULATIONS

$$F_1 = 1.41\left(\frac{W_\phi}{4} + \frac{W_A}{4}\right) = 1.41\left(\frac{28.27}{4}q_{12} + \frac{4.82}{4}q_{12}\right) = 11.66\,q_{12}$$

$$F_2 = 1.41\left(\frac{W_A}{4} + \frac{W_B}{4}\right) = 1.41\left(\frac{4.82}{4}q_{12} + \frac{9.06}{4}q_{12}\right) = 4.89\,q_{12}$$

$$F_3 = 1.41\left(\frac{W_B}{4} + \frac{W_C}{4}\right) = 1.41\left(\frac{9.06}{4}q_{12} + \frac{10.82}{4}q_{12}\right) = 7.01\,q_{12}$$

$$F_4 = 1.41\left(\frac{W_C}{4} + \frac{W_D}{4}\right) = 1.41\left(\frac{10.82}{4}q_{12} + \frac{14.32}{4}q_{12}\right) = 8.86\,q_{12}$$

$$F_5 = 1.41\left(\frac{W_D}{4} + \frac{W_E}{4}\right) = 1.41\left(\frac{14.32}{4}q_{12} + \frac{16.41}{4}q_{12}\right) = 10.83\,q_{12}$$

$$F_6 = 1.41\left(\frac{W_E}{4} + \frac{W_F}{4}\right) = 1.41\left(\frac{16.41}{4}q_{12} + \frac{21.65}{4}q_{12}\right) = 13.42\,q_{12}$$

12' MILL

4Φ' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5Φ3Φ^{\#} = 122.88\ q_{12} + 227Φ^{\#}/4$

$q_{12} = 36.32$ psf OR 13Φ+ MPH

33' TOWER

MEMBER 2-1Φ GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5867^{\#} = 1Φ1.13\ q_{12} + 2Φ93^{\#}/4$

$q_{12} = 52.84$ psf OR 13Φ+ MPH

27' TOWER

MEMBER 2-8 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$5Φ3Φ^{\#} = 84.13\ q_{12} + 191Φ^{\#}/4$

$q_{12} = 54.12$ psf OR 13Φ+ MPH

14' MILL

q_{14} = MAXIMUM ALLOWABLE WIND FORCE ON A TOWER WITH A 14' MILL.

SEE FIGURE 5 FOR MEMBER SIZE AND FORCES.

NOTE: THE 14' TOWER HAS THE SAME GROSS AREA AS THE 12' TOWER, SO THE AREA CALCULATIONS WILL REMAIN THE SAME.

ALLOWABLE STRESS

$$F_a = \frac{12\pi^2 E}{23(kl/r)^2} = \frac{P}{A} \quad \text{FOR } \frac{kl}{r} > C_c$$

WHERE: $E = 29{,}000$ KSI $\quad C_c = 126.1$
$k = 1.0$
$r = .596$ IN FOR 3" x 3" x 3/16" ANGLE
$A = 1.09$ IN^2

7' MEMBER $\quad F_a = \frac{12\pi^2(29{,}000\ \text{KSI})}{23(7\times12/.596)^2} = 7{,}517$ PSI

$P_{ALLOW} = F_a \times A = (7{,}517\text{PSI})(1.09\ \text{IN}^2) = 8{,}194$ #

6.75' MEMBER $\quad F_a = \frac{12\pi^2(29{,}000\text{KSI})}{23(6.75'\times12/.596)^2} = 8{,}084$ PSI

$P_{ALLOW} = (8{,}084\ \text{PSI})(1.09\ \text{IN}^2) = 8{,}812$ #

6.25' MEMBER $\quad F_a = \dfrac{\left[1 - \frac{(kl/r)^2}{2C_c^2}\right] F_y}{\frac{5}{3} + \frac{3(kl/r)}{8C_c} - \frac{(kl/r)^3}{8C_c^3}}$

$$= \frac{\left[1 - \frac{(6.25'\times12'/.596)^2}{2(126.1)^2}\right] 36\ \text{KSI}}{\frac{5}{3} + \frac{3(6.25'\times12/.596)}{8(126.1)} - \frac{(6.25\times12/.596)}{8(126.1)^3}} = 9{,}415\ \text{PSI}$$

$P_{ALLOW} = (9415\ \text{PSI})(1.09\ \text{IN}^2) = 10{,}262$ #

14' MILL

WIND LOAD CALCULATIONS

W_Φ

$$W_\Phi = q_{14} A$$
$$= q_{14} (\pi)(7')^2$$
$$= 38.48\, q_{14}$$

W_A

$$\varphi = \frac{A_m}{A}$$

$$A_m = 2(3")(7')/12 + \tfrac{1}{2}(1.5")(1.3')/12 = 3.58\ ft^2$$
$$A = 4.55\ ft^2$$

$$\varphi = \frac{3.58\ ft^2}{4.55\ ft^2} = .79 \quad \therefore \quad C = 1.19$$

$$W_A = C\, q_{14} A = 1.19\, q_{14} (4.55\ ft^2) = 5.41\, q_{14}$$

W_B

$$A_m = 2(3")(6.25)/12 + \tfrac{1}{2}(1.5")(1.3' + 3.25')/12 + 2(\tfrac{3}{8}")(7.25')/12 = 4.11\ ft^2$$

$$\varphi = \frac{4.11\ ft^2}{15.36\ ft^2} = .27 \quad \therefore \quad C = \Phi.64$$

$$W_B = \Phi.64\, q_{14} (15.36\ ft^2) = 9.83\, q_{14}$$

W_C

$$A_m = 2(3")(6.25')/12 + \tfrac{1}{2}(1.5")(3.25' + 4.8')/12 + 2(\tfrac{3}{8}")(8')/12 = 4.13\ ft^2$$

$$\varphi = \frac{4.13\ ft^2}{25.16\ ft^2} = .16 \quad \therefore \quad C = \Phi.47$$

$$W_C = \Phi.47\, q_{14} (25.16\ ft^2) = 11.83\, q_{14}$$

W_D

$$A_m = 2(3")(6.75')/12 + \tfrac{1}{2}(1.5")(4.8')/12 + \tfrac{1}{2}(2")(6.67')/12 + 2(\tfrac{3}{8}")(8.9')/12$$
$$= 4.78\ ft^2$$

$$\varphi = \frac{4.78\ ft^2}{38.71\ ft^2} = .12 \quad \therefore \quad C = \Phi.39$$

$$W_D = \Phi.39\, q_{14} (38.71\ ft^2) = 15.1\Phi\, q_{14}$$

14' MILL

W_E

$A_m = 2(3")(6.25')/12 + \frac{1}{2}(2")(6.67' + 8.33')/12 + 2(\frac{3}{8}")(9.8')/12 = 4.99\ ft^2$

$\varphi = \frac{4.99\ ft^2}{46.88\ ft^2} = .11 \quad \therefore \quad C = \Phi.37$

$W_E = \Phi.37 q_{14}(46.88\ ft^2) = 17.35\ q_{14}$

W_F

$A_m = 2(3")(6.75')/12 + \frac{1}{2}(2")(8.33' + 1\Phi')/12 + \frac{1}{2}(2)(1.25")(17.5')/12 = 6.72\ ft^2$

$\varphi = \frac{6.72\ ft^2}{61.86\ ft^2} = .11 \quad \therefore \quad C = \Phi.37$

$W_F = \Phi.37 q_{14}(61.86\ ft^2) = 22.89\ q_{14}$

W_G

$A_m = 2(3")(6.25')/12 + \frac{1}{2}(2")(1\Phi')/12 + \frac{1}{2}(2)(1.25")(17.5')/12 = 5.78\ ft^2$

$\varphi = \frac{5.78\ ft^2}{67.72\ ft^2} = .09 \quad \therefore \quad C = \Phi.35$

$W_G = \Phi.35 q_{14}(67.72\ ft^2) = 23.7\Phi\ q_{14}$

FORCE CALCULATIONS

$F_1 = 1.41\left(\frac{W_\Phi}{4} + \frac{W_A}{4}\right) = 1.41\left(\frac{38.48 q_{14}}{4} + \frac{5.41 q_{14}}{4}\right) = 15.47 q_{14}$

$F_2 = 1.41\left(\frac{W_A}{4} + \frac{W_B}{4}\right) = 1.41\left(\frac{5.41 q_{14}}{4} + \frac{9.83 q_{14}}{4}\right) = 5.37 q_{14}$

$F_3 = 1.41\left(\frac{W_B}{4} + \frac{W_C}{4}\right) = 1.41\left(\frac{9.83 q_{14}}{4} + \frac{11.83 q_{14}}{4}\right) = 7.64 q_{14}$

$F_4 = 1.41\left(\frac{W_C}{4} + \frac{W_D}{4}\right) = 1.41\left(\frac{11.83 q_{14}}{4} + \frac{15.1\Phi q_{14}}{4}\right) = 9.49 q_{14}$

$F_5 = 1.41\left(\frac{W_D}{4} + \frac{W_E}{4}\right) = 1.41\left(\frac{15.1\Phi q_{14}}{4} + \frac{17.35 q_{14}}{4}\right) = 11.44 q_{14}$

$F_6 = 1.41\left(\frac{W_E}{4} + \frac{W_F}{4}\right) = 1.41\left(\frac{17.35 q_{14}}{4} + \frac{22.89 q_{14}}{4}\right) = 14.18 q_{14}$

14' MILL

27' TOWER

MEMBER 2-8 GOVERNS

$$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$$

$$8{,}812^{\#} = 1\Phi 2.63\, q_{14} + 2681^{\#}/4$$

$$q_{14} = 79.33 \text{ psf} \quad \text{OR} \quad 13\Phi^{+} \text{ MPH}$$

16' MILL

q_{16} = MAXIMUM ALLOWABLE WIND FORCE ON A TOWER WITH A 16' MILL

SEE FIGURE 6 FOR MEMBER SIZE AND FORCES.

NOTE: FORCE F_1 (W_Φ), F_a (P_{ALLOW}) AND THE WEIGHTS CHANGE, ALL OTHER FORCES, AREAS AND CALCULATIONS REMAIN THE SAME.

ALLOWABLE STRESS

$$F_a = \frac{12\pi^2 E}{23(kl/r)^2} = \frac{P}{A}$$

WHERE $E = 29{,}\Phi\Phi\Phi$ KSI
$k = 1.\Phi$
$r = .592$ IN FOR 3" x 3" x 1/4" ANGLE
$A = 1.44$ IN^2

7' MEMBER $\quad F_a = \dfrac{12\pi^2 (29{,}\Phi\Phi\Phi \text{ KSI})}{23(.7' \times 12/.592)^2} = 7417 \text{ PSI}$

$$P_{ALLOW} = F_a \times A = (7417 \text{PSI})(1.44_{IN^2}) = 1\Phi{,}68\Phi^{\#}$$

14' MILL

$$F_7 = 1.41\left(\frac{W_F}{4} + \frac{W_G}{4}\right) = 1.41\left(\frac{22.89 q_{14}}{4} + \frac{23.7\Phi q_{14}}{4}\right) = 16.42 q_{14}$$

SEE FIGURE 5 FOR MAXWELL DIAGRAM

MAXIMUM WIND LOAD

47' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$18{,}812^{\#} = 143.75\, q_{14} + 3\Phi 81^{\#}/4$

$q_{14} = 55.94$ PSF OR $13\Phi^{+}$ MPH

4Φ' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$8{,}812^{\#} = 143.75\, q_{14} + 3\Phi 81^{\#}/4$

$q_{14} = 55.94$ OR $13\Phi^{+}$ MPH

33' TOWER

MEMBER 2-1Φ GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$1\Phi{,}262^{\#} = 121.\Phi\Phi\, q_{14} + 287 1^{\#}/4$

$q_{14} = 78.88$ PSF OR $13\Phi^{+}$ MPH

16' MILL

6.75' MEMBER $F_a = \frac{12\pi^2(29,000\ KSI)}{23(6.75' \times 12/.592)^2} = 7976\ PSI$

$P_{ALLOW} = (7976\ PSI)(1.44\ IN^2) = 11,486^{\#}$

6.25' MEMBER $F_a = \frac{12\pi^2(29,000\ KSI)}{23(6.25' \times 12/.592)^2} = 9304\ PSI$

$P_{ALLOW} = (9304\ PSI)(1.44\ IN^2) = 13,397^{\#}$

WIND LOAD CALCULATIONS

W_ϕ

$W_\phi = q_{16} A$
$= q_{16}(\pi)(8')^2$
$= 50.27\, q_{16}$

$W_A = 5.41\, q_{16}$ $W_C = 11.83\, q_{16}$ $W_E = 17.35\, q_{16}$ $W_G = 23.70\, q_{16}$

$W_B = 9.83\, q_{16}$ $W_D = 15.10\, q_{16}$ $W_F = 22.89\, q_{16}$

FORCE CALCULATIONS

$F_1 = 1.41\left(\frac{W_\phi}{4} + \frac{W_A}{4}\right) = 1.41\left(\frac{50.27 q_{16}}{4} + \frac{5.41 q_{16}}{4}\right) = 19.63\, q_{16}$

$F_2 = 5.37\, q_{16}$ $F_4 = 9.49\, q_{16}$ $F_6 = 14.18\, q_{16}$

$F_3 = 7.64\, q_{16}$ $F_5 = 11.44\, q_{16}$ $F_7 = 16.42\, q_{16}$

SEE FIGURE 6 FOR MAXWELL DIAGRAM

MAXIMUM WIND LOAD

47' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

16' MILL

$11,486^{\#} = 159.89\ q_{16} + 4423^{\#}/4$

$q_{16} = 64.92$ PSF OR $13\Phi^{+}$ MPH

4Φ' TOWER

MEMBER 2-12 GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$11,486^{\#} = 159.89\ q_{16} + 4423^{\#}/4$

$q_{16} = 64.92$ psf OR $13\Phi^{+}$ MPH

33' TOWER

MEMBER 2-1Φ GOVERNS

$P_{ALLOW} = P_{WIND} + P_{WEIGHT}$

$13,397^{\#} = 137.39 + 4,108^{\#}/4$

$q_{16} = 9\Phi.\Phi4$ PSF OR $13\Phi^{+}$ MPH

RECAPITULATION OF RESULTS

HEIGHT \ MILL	6'	8'	1Φ'	12'	14'	16'
21'	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	—	—	—
27'	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	—
33'	$13\Phi^{+}$	112	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$
4Φ'	11Φ	1ΦΦ	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$
47'	1Φ5	1ΦΦ	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$	$13\Phi^{+}$

ALL FIGURES IN MPH.