ARCHITECTURAL METAL PRODUCTS

AMERICAN NATIONAL STANDARD

ANSI/NAAMM FP 1001-07

METAL FLAGPOLES

ANSI/NAAMM FP 1001-07
October 5, 2007

GUIDE SPECIFICATIONS FOR DESIGN OF METAL FLAGPOLES

ANSI/NAAMM FP 1001-07
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METAL FLAGPOLES

THE NATIONAL ASSOCIATION OF ARCHITECTURAL METAL MANUFACTURERS

A Division of
NAAMM
NATIONAL ASSOCIATION OF ARCHITECTURAL METAL MANUFACTURERS

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This standard was developed by representative members of the Architectural Metal Products Division (AMP) of the National Association of Architectural Metal Manufacturers (NAAMM) to provide their opinion and guidance on the specification and use of metal flagpoles. This standard contains advisory information only and is published as a public service by NAAMM and its AMP Division. NAAMM and its AMP Division disclaim all liability of any kind for the use, application, or adaptation of material published in this standard.

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INTRODUCTION

The design of safe flagpoles requires knowledge of the loads to which they will be subjected. The principal loads acting on flagpoles are the wind loads, and it is these loads which must be most carefully determined. Maximum wind speeds to which flagpoles are exposed depend on the geographical location, whether or not it is in the center of a large city, the outskirts of a small town, the seashore at ground level or on the roof of a high rise building. Wind speeds are generally higher along coastal areas than inland. They are also higher in open country than in the center of cities, and wind speed increases with height above ground.

ASCE 7-05, page 300, third paragraph states "It is not the intent of this standard to exclude the use of other recognized literature for the design of special structures,….. For the design of flagpoles, see ANSI/NAAMM FP1001-97, 4th Ed., Guide Specifications for Design of Metal Flagpoles." This 5th Edition of the Guide follows the same design procedure as the 4th Edition.

The wind will exert a force on the pole itself as well as on the flag, and these two forces must be taken into consideration to determine the total load. Different size flags are flown from different poles, and it is important that flagpoles be selected which are capable of supporting the largest size flag intended to be flown under the highest speed wind to which it will be subjected. Loads on the flagpole are resisted by the mounting and the foundation or building structure (roof or wall) to which it is secured. The procedures used to determine wind loads on flagpoles are those set forth in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. There is sufficient similarity between flagpoles and the poles used for signs, lights and signals to justify this approach. Furthermore, there has been a vast amount of knowledge and data accumulated by AASHTO on the requirements for pole design because of experience with many types of poles installed all across the country which are subjected to the wind conditions occurring in these varied geographical locations. NAAMM believes that the procedures developed by AASHTO over the years provide a sound basis for the determination of flagpole loadings without the flag flying

However, a flagpole's function is to fly flags, and hence this standard presents procedures for determining the loads applied to poles as a result of the wind loads on flags. The original procedures set forth in the first edition of this standard in 1983 were developed by NAAMM as a result of a laboratory test program conducted in the fall of 1979 in which flags attached to a flagpole were subjected to winds generated by an aircraft engine and propeller. There were limitations to flag sizes and wind speeds in this program. Recognizing the limitations of the laboratory test program, NAAMM initiated a program of actual flight testing of flags in sizes ranging from 5 ft x 8 ft (1.5 m x 2.4 m) through 20 ft x 30 ft (6.1 m x 9.1 m) and at air speeds from 60 mph (27 m/s) up to 110 mph (49 m/s). This flight test program, completed in the fall of 1984, yielded the most complete and reliable data obtained to date on the loading of flags under high speed wind conditions. The results of this test program provided the basis for the development of the flag drag formulas given in the later editions of these guide specifications.

In the determination of the pole design, the inclusion of the wind load on the flag with the wind load on the pole, provides an added degree of safety for the flagless pole. Flags are not always lowered when a high speed wind occurs. Under such a circumstance the flag can be ripped off of the pole. Some flags are made of materials such as nylon which are very strong and resist the tendency to rip away as flags in years past were prone to do. NAAMM recommends that flagpole designers consider both pole and flag loads when selecting a flagpole design. Building codes that do not take into account the load caused by the flag drag do not require a design as safe as that required by this standard. Nevertheless, the designer shall check to be certain that his design meets or exceeds the requirements of the governing building code.

This 5th edition of the standard has replaced the basic wind speed map found in the previous editions with the new wind speed map in ASCE 7-05 which is based on 3-second gust speeds.

GUIDE SPECIFICATIONS

1. SCOPE

1.1 These specifications set forth the procedures for determining the design loads for metal flagpoles of hollow circular cross section.

1.2 The method for determining the wind speed and resulting wind load on the pole is part of these specifications.

1.3 The method for determining the wind load on the flag and the resulting load imposed on the pole is part of these specifications also.

1.4 Methods of analysis are given with sample calculations for a typical flagpole.

1.5 Minimum properties of materials typically used in the design of flagpoles are included.

2. APPLICABLE DOCUMENTS

The publications listed in this section form a part of this specification to the extent referenced. The publications are referenced in the text by basic designation only. When a more recent standard is available, the specifier should verify its applicability to this Guide prior to its inclusion.

2.1 *Aluminum Design Manual, 8th Edition, 2005*
The Aluminum Association
1525 Wilson Boulevard, Suite 600
Arlington, Virginia 22209
www.aluminum.org

2.2 *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 4th Edition 2001, Interim Revisions 2002, 2003 and 2006*
American Association of State Highway and Transportation Officials
444 North Capitol Street, NW, Suite 249
Washington, DC 20001

2.3 ASCE/SEI 7-05. *Minimum Design Loads for Buildings and Other Structures*
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4400
www.asce.org

2.4 ASTM Standards
ASTM International
100 Barr Harbor Drive
West Conshohocken, Pennsylvania 19428
www.astm.org

3. FLAGPOLE LOADS

3.1 Dead Load. The dead load shall consist of the weight of the flagpole plus the fittings, accessories and flag.

3.2 Wind Load. The wind load shall be the pressure of the wind on the flagpole and the load created by the wind drag on the flag. For nautical flagpoles, the pressure of the wind on the yardarms and gaffs plus the load created by the wind drag of the flags flying from these members shall be included to obtain the total wind load. Equations with a suffix of "M" indicate a metric formula.

3.2.1 Wind Pressure. Wind pressure shall be computed by the following formula:

$$P = 0.00256 \times V^2 \times C_d \times C_h \times G \qquad \text{Equation 1}$$

$$(0.613 \times V^2 \times C_d \times C_h \times G) \qquad \text{Equation 1 M}$$

Where:

P = Wind pressure in pounds per square foot (Newtons per square meter)
V = 3-sec gust wind speed in miles per hour (meters per second) Figure 3.2.2
C_d = Drag Coefficient (Table 3.2.4)
C_h = Coefficient for height above ground for wind pressure (Table 3.2.3A)
G = Gust Effect Factor. Use minimum value of 1.14.
z = Height above grade.

3.2.2 Wind Speed. Wind speeds based on a 50-year mean recurrence interval shall be used for the design of flagpoles. Figure 3.2.2 shows the 3-second gust speed at 33 ft (10 m) above the ground associated with an annual probability of 0.02 of being equaled or exceeded (50-year mean recurrence level). Select the appropriate wind speed for the geographical area in which the flagpole will be located. Use this value in Equation 1 (1M) to compute the wind pressure.

3.2.3 Coefficient of Height. The coefficient of height, C_h, to be used in computing the wind pressure on an area a given height above grade can be determined using the following forrmulae:

C_h = 2.01 (z/900) ^ (2/9.5)	for 16.4 ft < z <= 900 ft	Equation 2
C_h = 2.01 (z/274) ^ (2/9.5)	for 5 m < z <= 274m	Equation 2M
For z <= 16.4 (5m)	C_h = 0.86	

The coefficients of height to be used in calculating wind pressure for a given height above ground are shown in Table 3.2.3 A.

3.2.4 Wind Force. The wind force is calculated from the wind pressure at increasing heights above ground. To find the wind force, W_p, on the segment multiply the design wind pressure, P, by the projected area, A, of the segment and by the drag coefficient C_d, as specified in Section 5.1.1, using Equation 3.

$W_p = P \times A \times C_d$ Equation 3

Where:
A is in square feet (square meters)

For heights up to 300 ft (91.4m) and wind speeds from 85 mph (38m/s) to 150 mph (67m/s), wind pressures given in Table 3.2.3B (3.2.3B[M]) have been computed from Equation 1 (1M) using the coefficients of height from Table 3.2.3A, a drag coefficient (C_d = 1), and a gust effect factor of 1.14. To compute the design wind pressure for any segment of the flagpole, find the wind pressure from Table 3.2.3B (3.2.3B[M]) corresponding to the height of the segment and the wind speed, and multiply this value by the appropriate drag coefficient from Table 3.2.4.

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Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-05
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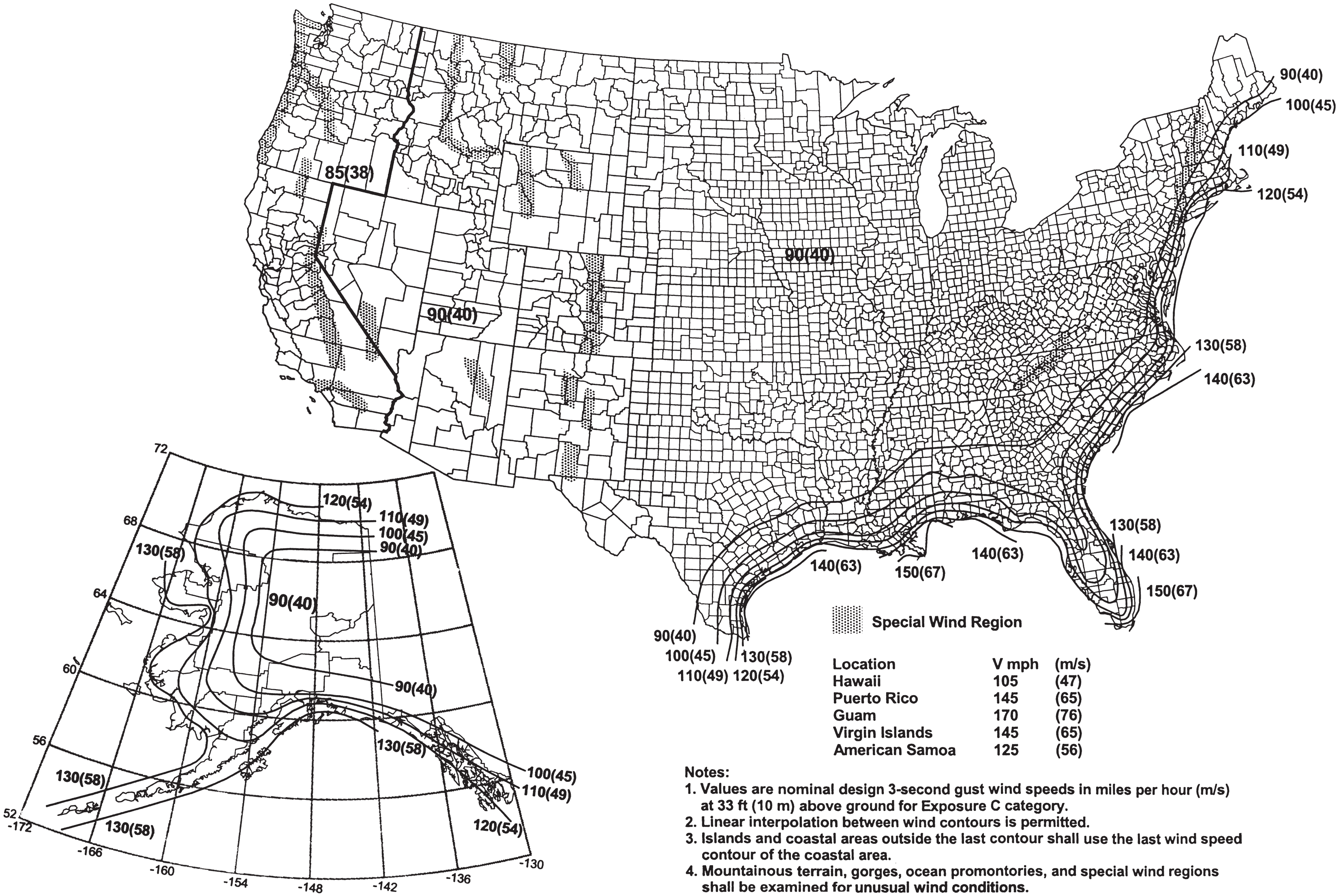


Location	V mph	(m/s)
Hawaii	105	(47)
Puerto Rico	145	(65)
Guam	170	(76)
Virgin Islands	145	(65)
American Samoa	125	(56)

Notes:
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

Figure 3.2.2
Basic Wind Speed

TABLE 3.2.3A

Height Above Ground Level, z ft	(m)	Coefficient of Height, C_h for Wind Pressure
0-16.4	(0-5)	0.86
20	(6.1)	0.90
25	(7.6)	0.94
30	(9.1)	0.98
40	(12.2)	1.04
50	(15.2)	1.09
60	(18.3)	1.14
70	(21.3)	1.17
80	(24.4)	1.21
90	(27.4)	1.24
100	(30.5)	1.27
120	(36.6)	1.32
140	(42.7)	1.36
160	(48.8)	1.39
180	(54.9)	1.43
200	(61.0)	1.46
250	(76.2)	1.53
300	(91.4)	1.59

Note: Linear interpolation for intermediate values of height z is acceptable.

TABLE 3.2.3B

WIND PRESSURE ON FLAGPOLES (for C_d = 1 and G = 1.14)								
Height Above Ground Level, z, ft	Pressure, psf, for indicated wind speed, mph							
	85	90	100	110	120	130	140	150
0-16.4	18	20	25	31	36	43	49	57
20	19	21	26	32	38	44	52	59
25	20	22	28	33	40	47	54	62
30	21	23	29	35	41	48	56	64
40	22	25	30	37	44	51	60	69
50	23	26	32	39	46	54	63	72
60	24	27	33	40	48	56	65	75
70	25	28	34	41	49	58	67	77
80	25	29	35	43	51	60	69	79
90	26	29	36	44	52	61	71	81
100	27	30	37	45	53	62	72	83
120	28	31	38	46	55	65	75	86
140	29	32	40	48	57	67	78	89
160	29	33	41	49	59	69	80	92
180	30	34	42	51	60	71	82	94
200	31	35	43	52	62	72	84	96
250	32	36	45	54	65	76	88	101
300	34	38	47	58	67	79	91	105

Note: Linear interpolation for intermediate values of height z is acceptable.

TABLE 3.2.3B(M)

WIND PRESSURE ON FLAGPOLES (for C_d = 1 and G = 1.14)								
Height Above Ground Level, z, m	**Pressure, N/m^2, for indicated wind speed, m/s**							
	38	**40**	**45**	**49**	**54**	**58**	**63**	**67**
0-5	873	967	1224	1452	1763	2034	2400	2714
6.1	910	1009	1277	1514	1839	2121	2502	2830
7.6	954	1057	1337	1586	1926	2221	2621	2964
9.1	990	1097	1389	1647	2000	2307	2722	3079
12.2	1053	1167	1477	1752	2127	2454	2896	3275
15.2	1103	1223	1547	1835	2228	2570	3033	3430
18.3	1147	1271	1609	1908	2317	2673	3154	3567
21.3	1185	1313	1661	1970	2392	2760	3256	3683
24.4	1219	1351	1709	2027	2462	2840	3351	3790
27.4	1249	1384	1752	2077	2522	2910	3433	3883
30.5	1278	1416	1792	2124	2580	2976	3512	3972
36.6	1328	1471	1862	2207	2681	3093	3649	4127
42.7	1371	1520	1923	2280	2769	3195	3769	4263
48.8	1411	1563	1978	2345	2848	3286	3877	4385
54.9	1446	1602	2028	2404	2920	3368	3974	4495
61.0	1478	1638	2073	2458	2985	3444	4063	4596
76.2	1549	1717	2173	2576	3129	3609	4258	4816
91.4	1610	1784	2257	2677	3251	3750	4424	5004

Note: Linear interpolation for intermediate values of height z is acceptable.

TABLE 3.2.4

Wind Speed x Diameter	**Drag Coefficient, C_d**
$V\,d \leq 39$ (5.33)	1.10
39 (5.33) < V d < 78 (10.66)	$129 / [V\,d]^{1.3}$ ($9.69 / [V\,d]^{1.3}$)
$V\,d \geq 78$ (10.66)	0.45
V = wind speed in mph (m/s)	
d = diameter of cylindrical pole or segment or average diameter of tapered pole or segment in feet (meters)	

4. FLAG LOAD

4.1 Wind. The load acting on the pole as a result of the wind acting on the flag shall be computed by the following formulas:

for nylon and cotton flags,

$$W_F = 0.0010 \times V^2 \times \sqrt{A_F} \times C_h \times G \qquad \text{Equation 4}$$
$$W_F = 0.0730 \times V^2 \times \sqrt{A_F} \times C_h \times G \qquad \text{Equation 4M}$$

for polyester flags,

$$W_F = 0.0014 \times V^2 \times \sqrt{A_F} \times C_h \times G \qquad \text{Equation 5}$$
$$W_F = 0.1022 \times V^2 \times \sqrt{A_F} \times C_h \times G \qquad \text{Equation 5M}$$

Where

- W_F = flag load on pole in pounds (Newtons), including height correction
- V = 3-second gust wind speed in miles per hour (meters per second) Figure 3.2.2
- A_F = area of flag in square feet (square meters)
- C_h = coefficient of height for wind pressure from Table 3.2.3A, calculated at top of flag.
- G = Gust effect factor, use minimum value of 1.14

Note: Equations 4 and 5 are empirical formulas based on data obtained from actual flight testing of nylon rectangular flags 5 ft x 8 ft (40 sq ft), 8 ft x 12 ft (96 sq ft), 12 ft x 18 ft (216 sq ft), 15 ft x 25 ft (375 sq ft), and 20 ft x 30 ft (600 sq ft). In addition to the five nylon flags, one 15 ft x 25 ft polyester flag was tested. The tow line for the flags was connected through a load cell to the airplane so that continuous readings of the drag on the flag were taken. Wind load data was recorded for air speeds of 60, 70, 80, 90, 100, and 110 miles per hour. The formulas provide values which reasonably match the values obtained in testing. The flight test data represents a significant advance over the previous laboratory test data which was used as a basis for the original guide specifications. The flight testing has provided NAAMM with what is believed to be the best data currently available. Although no flight testing was done with cotton flags, such flags were given comparative laboratory wind load tests with nylon flags and found to have equivalent drag. (Use 1 ft = 0.3048 m, 1 sq ft = 0.0929 m^2, 1 mph = 0.447 m/s to obtain metric equivalents)

5. BENDING MOMENTS, SHEAR FORCES AND TORSIONAL MOMENTS ON POLE

5.1 Bending Moments

5.1.1 Bending Moment due to Wind Pressure on Pole. To determine this bending moment, M, divide the pole into segments not exceeding 15 feet (4.6 m). The cylindrical section of the pole is divided in increments beginning at the base up to the transition to the tapered section. The tapered section is divided in increments beginning at the transition from the cylindrical section up to the top of the pole. Refer to Figure A 1 in Appendix A for an example.

5.1.1.1 Calculate the projected areas, A, of the segments in square feet (square meters) using the average diameters of the tapered sections and the diameters of the cylindrical sections of the pole.

5.1.1.2 Locate the centroid of each segment at the intersection of the mid length of the segment and the centerline of the flagpole.

Note: This simplification makes an insignificant difference when compared to the results obtained by calculating the moments using tapered segments of the pole. Entasis poles are simplified in the same manner.

5.1.1.3 Determine the coefficient of drag, C_d, for each segment of the pole from Table 3.2.4 using the basic wind speed, V, the average diameter of each tapered segment and the diameter of each cylindrical segment.

5.1.1.4 Calculate the bending moment, M, for each segment of the pole by multiplying the wind force, W_p, by the distance, L, from the ground surface to the assumed centroid of the segment. The wind force, W_p, is determined using Equation 3 in Section 3.2.3.

$$M = W_p L \qquad \text{Equation 6}$$

5.1.1.5 Calculate the total bending moment due to wind pressure on the pole, M_p, as the sum of the bending moments of all the segments.

$$M_p = M_1 + M_2 + M_3 + ... + M_n \qquad \text{Equation 7}$$

5.1.2 Bending Moment due to Wind Pressure on the Yardarm. For nautical flagpoles, calculate the bending moment, M_y, due to wind pressure on the yardarm by multiplying the wind force on the yardarm, W_y, by the distance, L, from the ground surface to the centerline of the yardarm. The wind force, W_y, is determined using the procedure stipulated in Section 5.1.1 to calculate the wind pressure on the pole.

$$M_y = W_y L \qquad \text{Equation 8}$$

5.1.3 Bending Moment due to Flag Wind Load.

5.1.3.1 For regular flagpoles, calculate the bending moment, M_F, due to the flag load, W_F, by adding the product of one-half of W_F and the height of the pole, L, to the product of one-half of W_F, and the height of the pole minus the width of the flag, b.

$$M_F = 0.5 W_F L + 0.5 W_F (L - b) = W_F (L - b/2) \qquad \text{Equation 9}$$

Note: An analysis of loads applied by flags flown from halyards indicates that this simplified method of calculation provides conservative values for flag storing poles as well as poles to which the halyards are secured to cleats near the base. The values calculated by the simplified method will be not greater than 10% more conservative when compared to the theoretically correct values.

5.1.3.2 For nautical flagpoles with yardarms only, determine the bending moment, M_{FY}, caused by wind load on flags flying from the yardarm by multiplying 95% of the flag force, W_F, by the distance, L, from the ground surface to the centerline of the yardarm. Assuming two flags of equal size and the same material the moment will be

$$M_{FY} = 2 \times 0.95 W_F L = 1.9 W_F L \qquad \text{Equation 10}$$

Note: The total bending moment caused by the wind load on flags flying from the yardarm is conservatively taken into account by considering that 95% of the flag force acts through the sheave at the end of the yardarm. The remainder of the force acts through the halyard down to the cleat.

5.1.3.3 For nautical flagpoles with yardarm and gaff, determine the bending moment, M_{FG}, caused by the wind load on flags flying from the gaff by multiplying 95% of the flag force, W_F, by the distance, L, from the ground surface to the point of attachment of the gaff to the pole,

$$M_{FG} = 0.95 W_F L \qquad \text{Equation 11}$$

5.1.4 Total Bending Moment. The total bending moment, M_T, is the sum of the bending moments due to wind pressure and the bending moments due to flag forces.

5.1.4.1 For the regular flagpole,

$$M_T = M_P + M_F \qquad \text{Equation 12}$$

5.1.4.2 For the nautical flagpole with yardarm only,

$$M_T = M_P + M_Y + M_F + M_{FY} \qquad \text{Equation 13}$$

5.1.4.3 For the nautical flagpole with yardarm and gaff,

$$M_T = M_P + M_Y + M_F + M_{FY} + M_{FG} \qquad \text{Equation 14}$$

5.2 Shear Force

5.2.1 Shear Force due to Wind Pressure on Pole. Add the wind forces (Equation 3, section 3.2.4) on all segments of the pole to get the shear force, W_P.

5.2.2 Shear Force due to Wind Pressure on Yardarm. Add the wind forces on the yardarm to get the shear force, W_Y.

5.2.3 Shear Force due to Flag Load. The shear forces, W_F(pole), W_F(yardarm), and W_F(gaff), due to flag load are the forces exerted by flags as found in Section 4.1.

5.2.4 Total Shear Force. The total shear force, W_T, on the flagpole is the sum of the shear forces due to the wind pressure and the shear forces exerted by the flag.

5.2.4.1 For the regular flagpole,

$$W_T = W_P + W_{F(pole)} \quad \text{Equation 15}$$

5.2.4.2 For the nautical flagpole with yardarm only,

$$W_T = W_P + W_{F(Pole)} + W_Y + 2\ W_{F(yardarm)} \quad \text{Equation 16}$$

5.2.4.3 For the nautical flagpole with yardarm and gaff,

$$W_T = W_P + W_{F(Pole)} + W_Y + 2\ W_{F(yardarm)} + W_{F(gaff)} \quad \text{Equation 17}$$

5.3 Torsional Moment

5.3.1 Torsional Moment due to Wind Pressure on Gaff of Nautical flagpole.

5.3.1.1 Determine the coefficient of drag, C_d, for the gaff from Table 3.2.4, using the basic wind speed and the diameter of the gaff. Calculate the wind force, W_P, using Equation 3.

5.3.1.2 Calculate the torsional moment, M_{ZP}, by multiplying W_P by the horizontal distance, L_G, from the center of the pole to the centroid of the gaff.

$$M_{ZP} = W_P \times L_G \quad \text{Equation 18}$$

5.3.2 Torsional Moment due to Flag Load on Gaff of Nautical Flagpole. Calculate the torsional moment, M_{ZF}, by multiplying 95% of the flag force, W_F, as determined from Section 4.1, by the horizontal distance, L_F, from the center of the pole to the point of attachment of the flag to the gaff.

$$M_{ZF} = 0.95 \times W_F \times L_F \quad \text{Equation 19}$$

5.3.3 Total Torsional Moment. The total torsional moment on the flagpole, M_{ZT}, is the sum of the torsional moment due to the wind pressure, M_{ZP}, and the torsional moment due to the flag load, M_{ZF}.

$$M_{ZT} = M_{ZP}\ X\ M_{ZF} \quad \text{Equation 20}$$

6. STRESS ANALYSIS

Axial compression, bending, and shear stresses shall be calculated for all flagpoles. In addition, torsional stress shall be calculated for the nautical flagpole with gaff.

Note: Where the stress analysis is based on the pole with the flag flying, the bending moments, shear forces and torsional moments resulting from the flag loads are added to those resulting from wind pressure to obtain the total loads to which the flagpole is subjected. Stresses due to shear forces and torsional moments are generally small compared to the stresses caused by bending moments. Flagpole design is primarily determined by the bending moments to which the pole is subjected. However, a check of the combined stress ratio shall always be made using Equation 25 to be sure the ratio is within the limit.

6.1 Compressive Stress. The compressive stress, f_a, is the axial dead load, D_P, caused by the weight of the pole plus accessories and flags, divided by the cross sectional area, A, of the pole at the base.

$$f_a = D_P / A \quad \text{Equation 21}$$

Where A is in square inches (square millimeters).

6.2 Bending Stress. The stress in bending, f_b, is the total bending moment, MT' divided by the section modulus, S, of the pole at the base.

$$f_b = M_T / S \quad \text{Equation 22}$$

6.3 Shear Stress. The shear stress, f_v, is the total shear force, W_T, multiplied by 2 and divided by the cross section area, A, of the pole at the base.

$$f_v = 2\ W_T / A \quad \text{Equation 23}$$

Where A is in square inches (square millimeters).

6.4 Torsional Shear Stress (For nautical flagpole with gaff). The shear stress, f_s, due to torsional moment, M_{ZT}, for flagpoles of circular cross section with wall thickness, t, and outside radius to midthickness of wall, R, is found from the approximate equation for torsional shear stress.

$$f_s = M_{ZT} / 6.28 R^2 t \quad \text{Equation 24}$$

6.5 Stresses. Stresses shall not exceed allowable values for the metal of which the pole is fabricated. (Sections 6.7, 6.8, 6.9, 6.10, 6.11)

6.6 The Combined Stress Ratio, CSR. Actual stresses shall be compared to allowable stresses in axial compression, bending, and shear. Equation 25 gives the relationship which shall exist for a satisfactory pole design. Include torsional shear if gaff is present.

$$CSR = f_a / 0.6 F_y + f_b / C_A F_b + (f_v / F_v)^2 \leq 1.0 \quad \text{Equation 25}$$

In the combined stress ratio, C_A is a coefficient of amplification that accounts for secondary bending moment caused by an axial load. For flagpoles, this is not a major consideration since, except for flags and light accessories, flagpoles do not usually support concentrated axial loads at their top. For flagpoles:

$$C_A = 1 - (0.38 D_P L^2 / 2.46 E I_B) / 0.52 \quad \text{Equation 26}$$

For the unusual case in which a concentrated axial load is supported at the top of the pole, Equation 26a, which is valid for $F_a \leq 0.26 F_y$, shall be used to calculate the coefficient of amplification.

$$C_A = 1 - ((0.38 D_P + P_T \sqrt[3]{I_B/I_T}) L^2 / 2.46 E I_B) / 0.52 \quad \text{Equation 26a}$$

6.7 Allowable Stresses. Except for the axial compressive stress, F_a, the mechanical properties and allowable stresses for metal flagpoles are given in Sections 6.8, 6.9, 6.10, and 6.11. In determining the allowable axial compressive stress, flagpoles shall be considered as cantilevered columns. Equation 27 is used to calculate the stress for such columns.

$$F_a = \pi^2 E / 1.95 (2 L / r)^2 \quad \text{Equation 27}$$

For tapered poles and poles with straight and tapered sections, the average radius of gyration, r, shall be used (see Section 6.12 for equations for r).

Note: In Equation 27 the factor of safety used is 1.95 which is based on the ultimate stress of the metal. This factor of safety is used only for axial compression. Bending due to wind loads causes the critical stress in flagpoles. Axial compression and shear stresses will generally be found to be well within allowable limits. Since bending and shear stresses are caused by wind and dead loads combined, the allowable stresses for bending and shear are increased 33% over the allowable stresses for dead loads. Tables 6.8.2, 6.8.3, 6.9.2, 6.10.2, and 6.11.2, show the dead load allowable, the 33% increase allowed for the wind loads in accordance with the AASHTO standard, and the allowable wind load stress.

6.8 Allowable Stresses for Aluminum. The mechanical properties and allowable stresses for extruded aluminum pipe and tube, alloy 6063-T6 are given in Tables 6.8.1, 6.8.2, and 6.8.3.

6.8.1 Yield stresses and modulus of elasticity for aluminum alloy 6063-T6

TABLE 6.8.1

	Yield Stress		Shear Yield Stress		Modulus of Elasticity	
non-welded	Yield Stress, F_y		Shear Yield Stress, F_{sy}		Modulus of Elasticity, E	
	psi	(MPa)	psi	(MPa)	psi	(MPa)
	25,000	(172)	14,000	(97)	10,000,000	(68,900)
welded with no	Yield Stress, F_{yw}		Shear Yield Stress, F_{sw}		Modulus of Elasticity, E	
postweld heat	psi	(MPa)	psi	(MPa)	psi	(MPa)
treatment	8,000	55	4,600	(32)	10,000,000	(68,900)

6.8.2 Allowable stresses in non-welded members of aluminum alloy 6063-T6

TABLE 6.8.2

	Dead Load		33% Increase allowed for Wind Load		Allowable Wind Load Stress	
	psi	(MPa)	psi	(MPa)	psi	(MPa)
F_b	18,000	(124)	6,000	(41)	24,000	(165)
F_s	8,500	(59)	2830	(20)	11,330	(79)

The allowable bending stress, as shown in Table 6.8.2, for non-welded, round, aluminum flagpoles is valid for slenderness ratios not exceeding R/t = 33. For slenderness ratios exceeding 33, but not more than 102, the allowable dead load stress shall be calculated using Equation 28 (28M). Most aluminum flagpoles are within the slenderness ratio of 33. For slenderness ratios exceeding 102, refer to the Aluminum Design Manual. For non-welded members and for welded members at locations farther than 1 in.(25mm) from a weld use

$F_b = (27.7 - 1.70 \sqrt{R/t})\ 1000\ \text{psi}$ Equation 28

$F_b = (190.6 - 11.67 \sqrt{R/t})\ \text{MPa}$ Equation 28M

6.8.3 Allowable stresses in welded members within 1.0 in. (25 mm) of weld of 6063-T6

TABLE 6.8.3

	Dead Load		33% Increase allowed for Wind Load		Wind Load	
	psi	(MPa)	psi	(MPa)	psi	(MPa)
F_b	8,000	(55)	2,640	(18.2)	10 642	(73.2)
F_s	3,900	(27)	1,287	(8.91)	5 187	(35.91)

The allowable bending stress, as shown in Table 6.8.3, for welded, round, aluminum flagpoles is valid for slenderness ratios not exceeding R/t = 62. For slenderness ratios exceeding 62, but not more than 206, the allowable dead load stress shall be calculated using Equation 29 [29M]. For slenderness ratios exceeding 206 refer to the Aluminum Design Manual.

$F_b = 12.8 – 0.61\ \sqrt{R/t}\ \ 1000\ \text{psi}$ Equation 29

$F_b = 88.3 - 4.21\ \sqrt{R/t}\ \ \text{Mpa}$ Equation 29M

Note: When heat treated and artificially aged aluminum is welded, the properties at the weld and in the heat affected zone will be reduced. This in turn will reduce the allowable stress. For welded poles, the yield stresses and the allowable stresses within 1.0 in. (25 mm) of the weld are shown in Tables 6.8.1 and 6.8.3 respectively. These are the stresses which provide a structurally safe design at the weld joint. However, there are exceptions to this. For alloy 6063 flagpole assemblies, up through 0.375 in. (10 mm) thick, which are welded in the -T4 temper with filler alloy 4043 and precipitation heat treated (artificially aged) to the - T6 temper, by an approved method after welding, the allowable stresses within 1.0 in. (25 mm) of the weld shall be 85% of the values for nonwelded alloy 6063-T6. Additional information on welded aluminum construction in general and, in particular, for information on allowable stresses in fillet welds joining round members subject to bending and transverse loading, can be found in The Aluminum Association’s Aluminum Design Manual.

6.9 Allowable Stresses for Steel. The mechanical properties and allowable stresses for carbon steel seamless pipe, ASTM A 53, Type S, Grade B, and cold-formed welded and seamless carbon steel structural tubing, ASTM A 500, Grades B and C, and ASTM A 501, are given in Tables 6.9.1 and 6.9.2.

6.9.1 Yield stresses and modulus of elasticity for carbon steel

TABLE 6.9.1

	Yield Stress, F_y psi	(MPa)	Modulus of Elasticity, E psi	(MPa)
ASTM A 53, Type S, Grade B	35,000	(240)	29,000,000	(200,000)
ASTM A 500, Grade B	42,000	(290)	29,000,000	(200,000)
ASTM A 500, Grade C	46,000	(317)	29,000,000	(200,000)
ASTM A 501	36,000	(250)	29,000,000	(200,000)

6.9.2 Allowable bending stresses for carbon steel

TABLE 6.9.2

$F_b = 0.66\ F_y$ $F_v = 0.33\ F_y$

		Dead Load		33% Increase allowed for Wind Load		Wind Load	
		psi	(MPa)	psi	(MPa)	psi	(MPa)
ASTM A 53	F_b	23,000	(159)	7,700	(53)	30,700	(212)
Type S, Gr B	F_v	11,500	(79)	3,800	(26)	14,800	(105—)
ASTM A 500	F_b	28,000	(193)	9,300	(64)	37,300	(257)
Grade B	F_v	14,000	(96)	4,700	(32-)	19,600	(128)
ASTM A 500	F_b	30,000	(207)	10,000	(69)	40,000	(276)
Grade C	F_v	15,000	(103)	5,000	(34)	20,000	(137)
ASTM A 501	F_b	24,000	(165)	8,000	(55)	32,000	(220)
	F_v	12,000	(82)	4,000	(27)	16,000	(109)

6.10 Allowable Stresses for Stainless Steel. The mechanical properties and allowable stresses for stainless steel annealed pipe, ASTM A 312, and tubing, ASTM A 554, Type S30400, are given in Tables 6.10.1 and 6.10.2.

6.10.1 Yield stress and modulus of elasticity for stainless steel

TABLE 6.10.1

	Yield Stress, F_y psi	(MPa)	Modulus of Elasticity, E psi	(MPa)
ASTM A 312 and A 554 S30400, Annealed	30,000	(207)	28,000,000	(193,000)

6.10.2 Allowable bending stresses for stainless steel

TABLE 6.10.2

$Fb = 0.66\ F_y$ $\quad F_v = 0.33\ F_y$

		Dead Load		33% Increase allowed for Wind Load		Wind Load	
		psi	**(MPa)**	**psi**	**(MPa)**	**psi**	**(MPa)**
ASTM A 312, A 554	F_b	20,000	(138)	6,700	(46)	26,700	(184)
S30400, Annealed	F_v	10,000	(69)	3,300	(23)	13,300	(92)

6.11 Allowable Stresses for Copper Alloys (Bronze). The mechanical properties and allowable stresses for copper alloys are given in Tables 6.11.1 and 6.11.2.

6.11.1 Yield stresses and modulus of elasticity for copper seamless pipe, alloy C23000

TABLE 6.11.1

	Yield Stress, F_y		Modulus of Elasticity, E	
	psi	**(MPa)**	**psi**	**(MPa)**
ASTM B 43 Temper 061, Annealed	12,000	(83)	17,000,000	(117,000)
ASTM B 43 Temper H58, Drawn	18,000	(124)	17,000,000	(117,000)

6.11.2 Allowable bending stresses for copper alloys.

TABLE 6.11.2

$F_b = 0.66\ F_y$ $\quad F_v = 0.33\ F_y$

		Dead Load		33% Increase allowed for Wind Load		Wind Load	
		psi	**(MPa)**	**psi**	**(MPa)**	**psi**	**(MPa)**
ASTM B 43	F_b	8,000	(55)	2,700	(18)	10,700	(73)
Temper 061, Annealed	F_v	4,000	(28)	1,300	(9)	5,300	(37)
ASTM B 43	F_b	12,000	(83)	4,000	(28)	16,000	(111)
Temper H58, Drawn	F_v	6,000	(41)	2,000	(14)	8,000	(55)

6.12 Properties of the Hollow Circle

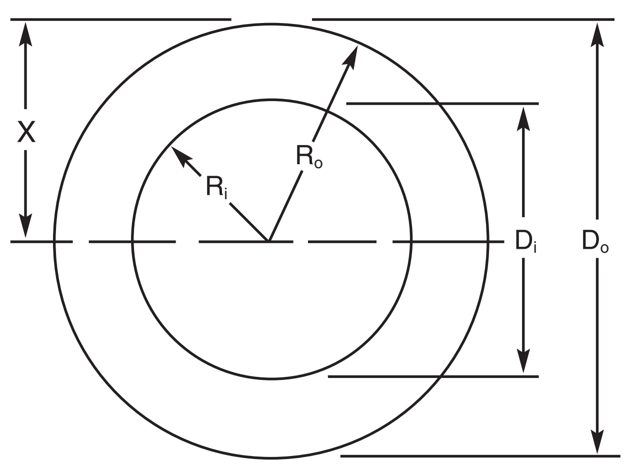
$A = \Pi\ (R_0^2 - R_i^2) = \Pi\ (D_o^2 - D_i^2)/4$

$x = R_o = D_o/2$

$I = \Pi\ (R_o^4 - R_i^4)/4 = \Pi\ (D_o^4 - D_i^4)/64$

$S = \Pi\ (R_o^4 - R_i^4)/4\ R_o = \Pi\ (D_o^4 - D_i^4)/32\ D_o$

$r = \sqrt{R_o^2 + R_i^2)/4} = \sqrt{(D_o^2 + D_i^2)/16}$



7. CALCULATION PROCEDURE

Note: The procedure outlined here and the sample calculations shown in Appendix A are for conventional ground set flagpoles. The principles employed, however, are applicable to other types of mountings and flagpoles. Procedures for nautical flagpoles are not included here.

7.1 Select a flagpole of aluminum, steel, stainless steel, or bronze from the Construction Details and Data Section of the NAAMM Metal Flagpole Manual. Alternatively, make a selection from a manufacturer's catalogue.

7.2 Note the configuration of the pole and its dimensions.

7.3 Note the maximum size flag, or flags, which are to be flown from the pole.

7.4 Divide the flagpole into segments as described in Section 5.1.1 and illustrated in Figure A 1 in Appendix A. Calculate the area of each segment and determine the distance above ground of the centroid of the segment as called for in Sections 5.1.1.1 and 5.1.1.2.

7.5 Refer to Figure 3.2.2 to find the wind speed to be used for the geographical location of the flagpole. Confirm the value of wind speed with the local building official.

7.6 From Table 3.2.3B or 3.2.3B(M) find the wind pressure for the wind speed found in Calculation Procedure Step 7.5 for the heights to the centroids of the flagpole segments. Follow the procedure of Section 5.1.1.2 to locate the centroids of the areas of the segments.

7.7 To facilitate calculations prepare a table similar to Table A1 in Appendix A to include the following items:

1. segment numbers (refer to Section 5.1.1)
2. distances to centroids (refer to Section 5.1.1.2)
3. wind pressures (refer to Table 3.2.3B or 3.2.3B[M])
4. areas of segments (refer to Section 5.1.1.1)
5. drag coefficients (refer to Table 3.2.4)
6. wind forces on segments (refer to Section 3.2.4)
7. bending moments (refer to Section 5.1.1.4)

7.8 Multiply the wind pressure on the segment by the drag coefficient and the area of the segment to find the wind force on the segment as per Table 3.2.3. Use Equation 3 of Section 3.2.4.

7.9 Multiply the wind force of the segment found in Calculation Procedure Step 7.8 by the distance from the ground to the centroid of the segment to find the bending moment caused by the segment. Use Equation 6 of Section 5.1.1.4.

7.10 Total the wind force on all of the segments to find the total shear force due to the wind pressure on the pole.

7.11 Total the bending moments on all of the segments to find the total bending moment due to the wind pressure on the pole. Use Equation 7 of Section 5.1.1.5.

7.12 Follow Section 4.1 to find the wind load acting on the pole due to wind load on the flag. Use Equation 4, 4M, 5, or 5M.

7.13 Add the total force of the flag to the total force on the pole due to wind pressure to obtain the total shear force on the pole. Use Equation 15 of Section 5.1.4.1.

7.14 Follow procedure in Section 5.1.3 to find the bending moment due to the flag. Equation 9.

7.15 Add the bending moment for the flag found in Section 7.14 to the bending moment for wind pressure found in Section 7.11 to obtain the total bending moment for the pole. Use Equation 12 of Section 5.1.4.1.

7.16 Add the weight of the pole, accessories, and flag to obtain the axial load.

7.17 Make a stress analysis to ascertain whether or not axial compressive, bending, and shear stresses are within allowable limits.

7.18 Calculate axial compressive stress from Equation 21 in Section 6.1.

7.19 Calculate bending stress from Equation 22 in Section 6.2.

7.20 Calculate shear stress from Equation 23 in Section 6.3.

7.21 Check calculated stresses against allowable stresses.

7.22 Calculate allowable stress for axial compression using Equation 27 in Section 6.7.

7.23 Check combined stress ratio using Equation 25 in Section 6.6.

Note: For a nautical flagpole with yardarm, the concentrated load caused by the wind acting on the yardarm and its flags is added to the pole at the point of attachment of the yardarm. If the pole also has a gaff, the wind load on the gaff and its flag is also included in the load on the main pole. In addition, the torsional load on the pole is determined as per Section 5.3, and the shear stress from torsion is checked by Equations 24 and 25.

8. TERMINOLOGY

A	=	area, sq in. (mm^2) or sq ft (m^2) , as designated
b	=	width of flag, ft (m)
C	=	distance from neutral axis to extreme fiber, in. (mm)
C_A	=	coefficient of amplification
C_d	=	drag coefficient
C_h	=	coefficient of height above ground for wind pressure
CSR	=	combined stress ratio
d	=	diameter of pole, ft (m)
D_i	=	inside diameter of pole, in. (mm)
Do	=	outside diameter of pole, in. (mm)
D_P	=	weight of pole plus accessories and flag(s),lbf (N)
E	=	modulus of elasticity, psi (MPa)
F_a	=	calculated axial compressive stress, psi (MPa)
F_b	=	calculated bending stress, psi (MPa)
f_s, f_v	=	calculated stress due to shear or torsion, psi (MPa)
F_a	=	allowable axial compressive stress, psi (MPa)
F_b	=	allowable bending stress, psi (MPa)
F_S, F_v	=	allowable shear stress, psi (MPa)
F_{sy}	=	yield stress, shear, psi (MPa)
F_y	=	yield stress, psi (MPa)
G	=	gust effect factor
I_B	=	moment of inertia at base, in^4(mm^4)
I_T	=	moment of inertia at top, in .^{4}(mm^4)
L	=	distance from base of pole to centroid of pole segment, or to top of pole, or to centerline of yardarm, ft (m). Horizontal distance from center of pole to center of gaff, or to point of attachment of flag, for nautical flagpoles, ft (m).

M = bending moment, lbf ft (Nm)

M_F = bending moment exerted by flag, lbf ft (Nm)

M_{FG} = bending moment due to flag load on gaff, Ibf ft (N m)

M_{FY} = bending moment due to flag load on yardarm,lbf ft (Nm)

M_P = bending moment due to wind pressure on pole, lbf ft (Nm)

M_T = total bending moment on pole, lbf ft (Nm)

M_Y = bending moment due to wind pressure on yardarm, lbf ft (Nm)

M_{ZF} = torsional moment exerted by flag on gaff, lbf ft (Nm)

M_{ZG} = torsional moment due to wind pressure on gaff, lbf ft (Nm)

M_{ZT} = total torsional moment on pole, lbf ft (Nm)

P = wind pressure, psf (N/m2)

P_T = top load, lbf (N)

r = radius of gyration, in. (mm)

R = radius to midthickness of wall, in. (mm)

R_i = inside radius, in. (mm)

R_o = outside radius, in. (mm)

S = section modulus, in. ^{3} (mm^3)

t = wall thickness, in. (mm)

V = wind speed, mph (m/s) from Figure 3.2.2

V_{max} = specified wind speed, which includes gust factor, height coefficient and other factors, mph (m/s)

W_F = force exerted by wind drag on flag, lbf (N)

W_G = force due to wind pressure on gaff, lbf (N)

W_P = force due to wind pressure on pole, lbf (N)

W_T = total shear force due to wind loading, lbf (N)

W_Y = force due to wind pressure on yardarm, lbf (N)

APPENDIX A

SAMPLE CALCULATIONS

Cone tapered aluminum pole - alloy 6063-T6
Exposed length, L = 60’, taper = 44’, butt dia = 12”, top dia = 4”
Wall thickness, straight 0.250”, taper 0.188”, taper in/ft = 0.182
Ground set, conventional pole. Flag 8’ x 12’ = 96 sq ft
Values of Vd and Cd, are for 90 mph wind speed.

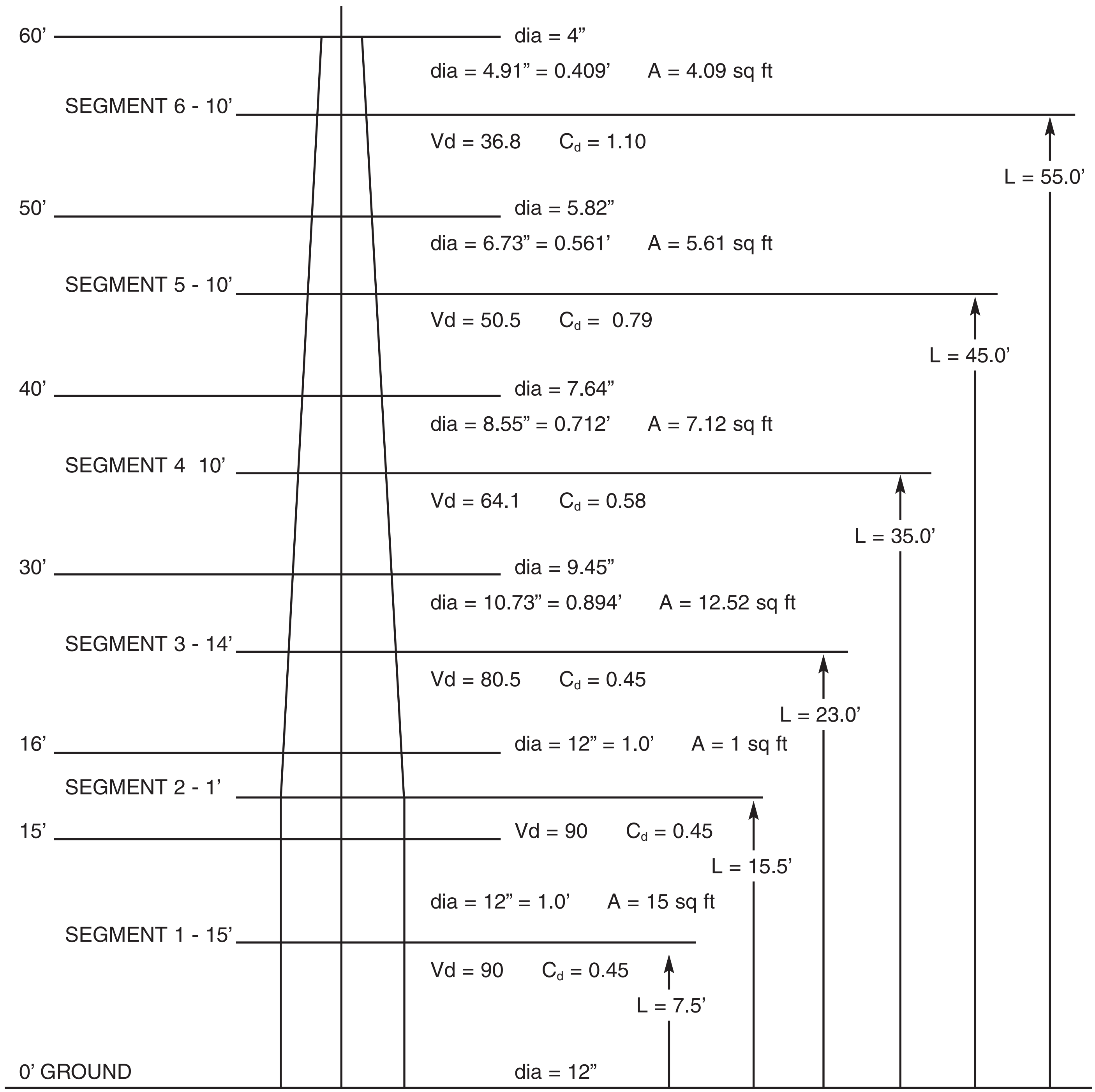


FIGURE A 1

SAMPLE CALCULATIONS

Location: Columbus, Ohio
Wind Speed: from Figure 3.2.2 - 90 mph

CALCULATIONS FOR BENDING MOMENT DUE TO WIND PRESSURE ON POLE

Wind Pressures: from Table 3.2.38.

TABLE A 1

1 Segment	2 Distance to Centroid L-ft	3 Wind Pressure P - psf	4 Length of Segment feet	5 Average Pole Diameter d-ft	6 Area of Segment A-sqft	7 Drag Coef Cd	8 Wind Force on Segments Wp - lbf	9 Bending Moments Mp- lbf ft
1	7.5	20.0	15.0	1.000	15.00	0.45	135.0	1,012.5
2	15.5	20.0	1.0	1.000	1.00	0.45	9.0	139.5
3	23.0	21.6	14.0	0.894	12.52	0.45	121.7	2,799.1
4	35.0	24.0	10.0	0.712	7.12	0.58	99.1	3,468.5
5	45.0	25.5	10.0	0.561	5.61	0.79	113.0	5.085.0
6	55.0	26.5	10.0	0.409	4.09	1.10	119.2	6,556.0
							Total W_p 597.0	Total M_p 19,060.6

Typical drag coefficient calculations: from Table 3.2.4

Segment 1: Vd = 90 x 1 = 90   90 > 78.0 $C_d = 0.45$
Segment 4: Vd = 90 x 0.712 = 64.1   39.0 < Vd < 78.0 $C_d = 129/(64.1)^{1.3}$ $C_d = 0.58$
Segment 6: Vd = 90 x 0.409 = 36.8   36.8 < 39.0 C_d = 1-10

Typical bending moment calculations: from Equations 3 and 6

Segment 4: $M_p = W_p\ L = P\ A\ C_d\ L$ = 24.0 x 7.12 x 0.58 x 35 = 3,468.5 lbf ft

CALCULATIONS FOR BENDING MOMENT DUE TO FORCE EXERTED BY FLAG ON POLE

Flag load caused by wind: from Equation 4

$W_F = 0.0010\ V^2 \sqrt{A}\ C_h \times G = 0.0010 \times 90^2 \times \sqrt{96} \times 1.14 \times 1.14$ = 103.1 lbf

C_h = 1.14 is found from Table 3.2.3A for the height at which the top of the flag is flying.

G = 1.14 minimum.

Bending moment due to flag: from Equation 9

$M_F = W_F\ (L - b/2)$ = 103.1 (60 - 8/2) = 5,774 lbf ft

CALCULATIONS FOR TOTAL BENDING MOMENT ON POLE

Total bending moment on pole: from Equation 12

$M_T = M_P + M_F$ = 19,061 + 5,774 24,835 lbf ft

CALCULATIONS FOR AXIAL LOAD

Axial load, D_p, equals the dead weight of the pole plus accessories and flag(s). Pole weight, based on density of aluminum = 0.1 lb/cu in.

Cylindrical section:	$16 \times 12 \times \Pi\ (6^2 - 5.75^2)\ \times 0.1$	=	177 lbf
Conical section:	$44 \times 12 \times \Pi\ (4^2 - 3.812^2) \times 0.1$	=	244 lbf
Total pole weight			421 lbf
Accessories plus flag (estimated 10% pole weight)			42 lbf
Total D_P		=	463 lbf

CALCULATIONS FOR SHEAR FORCE

Total shear force on pole: from Equation 15

$W_T = W_P + W_F = 597.0 + 103.1 = 701.1$ lbf

W_P is found by totaling column 8 in Table 1 bending moment calculation table.

STRESS ANALYSIS

Area of pole base, $A = \pi(R_o^2 - R_i^2) = \Pi(6^2 - 5.75^2) = 9.23\ in^2$

Moment of inertia at base, I_B, $= \Pi(D_o^4 - D_i^4) / 64 = \Pi(12^4 - 11.5^4) / 64 = 159.3\ in^4$

Section modulus at base, $S = I/c = 159.3 / 6 = 26.56\ in^3$

Compressive stress: from Equation 21

$f_a = D_P / A = 463 / 9.23 = 50$ psi

Tensile stress from bending: from Equation 22

$f_b = M_T / S = 24{,}786 \times 12 / 26.56 = 11{,}198$ psi

Shear stress: from Equation 23

$f_s = 2\ W_T / A = 2 \times 701.1 / 9.23 = 151.9$ psi

The allowable stresses for aluminum are found in Sections 6.7 and 6.8.

Allowable axial compressive stress, $\Pi^2\ E\ (r/2L)^2 / 1.95$ where $r = \sqrt{(D_o^2 + D_i^2)/16}$

Average r for 44 ft tapered length = $\sqrt{(8^2 + 7.625^2)/16} = 2.763$ in.

Average r for 16 ft straight length = $\sqrt{(12^2 + 11.5^2)/16} = 4.155$ in.

Average r for pole = $[(2.763 \times 44) + (4.155 \times 16)] / 60 = 3.134$ in.

$F_a = \Pi^2 \times 10 \times 10^6 \times [3.134 / (2 \times 60 \times 12)]^2\ 1.95 = 240$ psi

Allowable bending stress, $F_b = 23{,}940$ psi

Allowable shear stress, $F_S = 11{,}305$ psi

The calculated stresses are well within the limits allowed.

A limitation on the combined stress ratio, CSR, is shown in Equation 25

$CSR = f_a/0.6\ F_y\ (1.33) + f_b, /C_A\ F_b + (f_s/F_s)^2 \leq 1.0$

C_A is calculated from Equation 26

$C_A = 1 - (0.38\ D_P, L^2 / 2.46\ E\ I_B) / 0.52 = 1 -[(0.38 \times 463 \times 60^2 \times 12^2)/(2.46 \times 10^7 \times 159.3)] / 0.52 = 0.955$

$CSR = 50/ (0.6 \times 25{,}000 \times 1.33) + 11{,}198 / (0.955 \times 23{,}940) + (151.9 / 11{,}305)^2 = 0.49 < 1.0$

This meets the requirement for CSR.

Check the same flagpole with 8' x 12' flag flying for the 130 mph requirement for certain Gulf Coast and Atlantic Coast areas.

Follow the same calculation procedures used for the 90 mph wind speed.

CALCULATIONS FOR SENDING MOMENT DUE TO WIND PRESSURE ON POLE

TABLE A2

1 Segment	2 Distance to Centroid L - ft	3 Wind Pressure P - psf	4 Length of Segment feet	5 Average Pole Diameter D - ft	6 Area of Segment A - sq ft	7 Drag Coef C_d	8 Wind Force on Segments W_p - lbf	9 Bending Moments M_p - lbf ft
1	7.5	43.0	15.0	1.000	15.00	0.45	290.3	2,177.3
2	15.5	43.0	1.0	1.000	1.00	0.45	19.4	300.7
3	23.0	45.8	14.0	0.894	12.52	0.45	258.0	5,934.0
4	35.0	49.5	10.0	0.712	7.12	0.45	158.6	5,551.0
5	45.0	52.5	10.0	0.561	5.61	0.49	144.3	6,493.5
6	55.0	55.0	10.0	0.409	4.09	0.74	166.5	9,157.5
							Total W_p	Total M_p
							1,037.1	29,614.0

Axial load, D, = 463 lbf

Bending moment, $M_T = M_P + M_F$ = 29,614.0 + 12,051.2 = 41,665.2 lbf ft

Shear force, $W_T = W_P + W_F$ = 1,037.1 + 215.2 = 1,252.3 lbf

Compressive stress, f_a = 50 psi

Tensile stress from bending, f_b = 41,665.2 x 12 / 26.56 = 18,824.6 psi

Shear stress, f_s = 2 x 1,252.3 / 9.23 = 271.4 psi

These stresses are well within the limits allowed.

$$CSR = 50/(0.6 \times 25{,}000 \times 1.33) + 18{,}824.6/(0.955 \times 23{,}940) + (271.4 / 11{,}305)^2 = 0.83 < 1.0$$

This meets the requirement for CSR.

APPENDIX B - FLAG SIZES

Ground Set Flagpoles

Pole Height	Flag Size
15’	3’ x 5’
20’	4’ x 6’
25’	5’ x 8’
30’	6’ x 10’
35’	6’ x 10’
40’	8’ x 12’
45’	8’ x 12’
50’	10’ x 15’
60’	12’ x 18’
70’	12’ x 18’
80’	15’ x 25’

Roof-Mounted

Pole Height	Flag Size
15’	4’x 6’
20’	5’ x 8’
25’	6’ x 10’
30’	6’ x 10’
35’	8’ x 12’
40’	8’ x 12’
45’	10’ x 15’
50’	12’ x 18’
60’	12’ x 18’
70’	15’ x 25’
80’	15’ x 25’

Wall-Mounted Flagpoles

Pole Height	Flag Size
12’ to 15’	4’ x 6’
20’ to 25’	5’ x 8’
30’ to 35’	6’ x 10’
40’ to 45’	8’ x 12’

Outrigger Flagpoles

Pole Height	Flag Size
8’	3’ x 5’
10’ to12’	4’ x 6’
13’ to 16’	5’ x 8’
17’ to 23’	6’ x 10’