APPENDIX G
SUPPLEMENTAL INFORMATION ON FORCE COEFFICIENTS

G.1 CONDUCTOR AND SHIELD WIRE FORCE COEFFICIENTS

Wind tunnel test data, such as those shown in Figure G-1, indicate that measured force coefficients for stranded wires show a wide range of variation depending on Reynolds number and the type of stranding. For this reason, there is also a wide variation in values recommended by various design codes and guides as illustrated in Figure G-2.

A force coefficient of 1.0 is recommended in Chapter 2, Section 2.1.6.2 for all conductors and shield wires. This is the same value recommended in NESC (2012). The data in Figure G-1 indicate that the force coefficient can be significantly greater than 1.0, particularly for Reynolds numbers less than 3×10^4 (small wires under nominal wind speed). For Reynolds numbers above this value, the force coefficients are reduced to a value of 1.0 or less. The expression for Reynolds number is given in Equation (2-9).

For a 0.5 inch diameter wire or larger, the Reynolds number will exceed 3×10^4 for the range of design wind speeds given in Chapter 2, Figure 2-1. For this reason, a value of 1.0 has been chosen for all conductors and shield wires. However, force coefficients larger than 1.0 are often appropriate, especially on wires having a small diameter (< 0.5 inch) and wires having accreted ice.

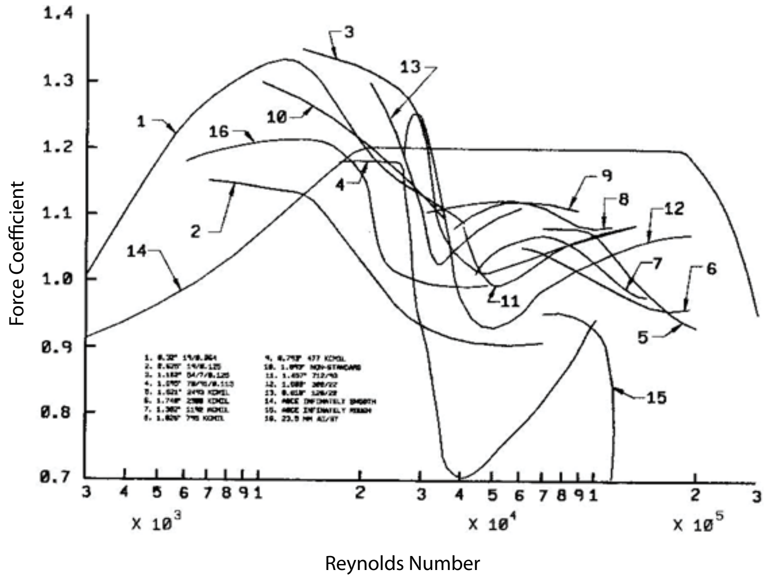


Figure G-1. Force coefficients for conductors based on wind tunnel tests.
Source: Data from ASCE (1961), Birjulin et al. (1960), Castanheta (1970), Engleman and Marihugh (1970), Richards (1965), and Watson (1955).

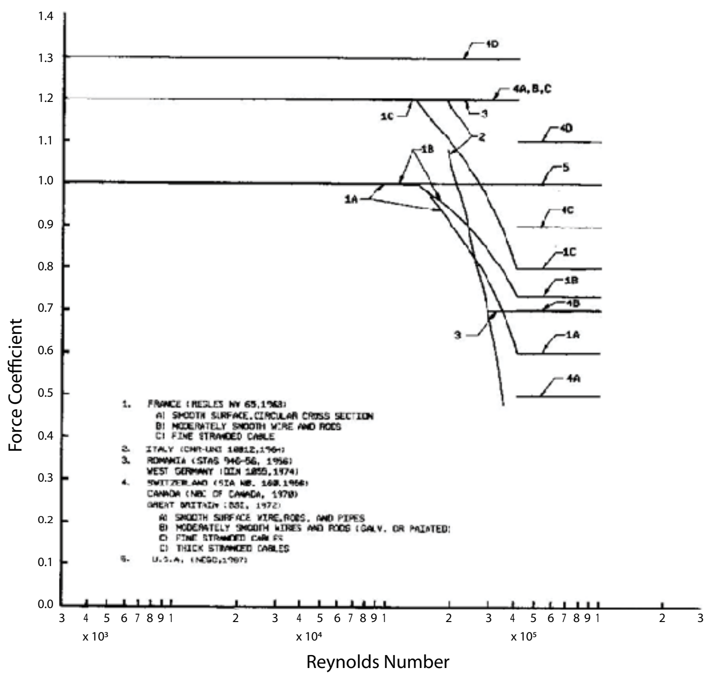


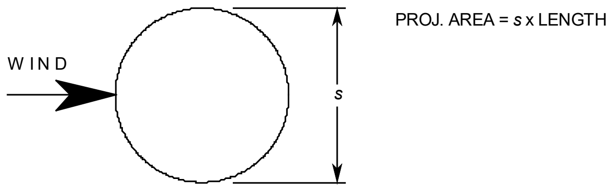
Figure G-2. Force coefficients for conductors based on code values.

G.2 MEMBER FORCE COEFFICIENTS

Table 2-5 lists recommended force coefficients for some common structural shapes used in transmission structures. Table G-1 lists force coefficients from various sources for these members and for additional shapes not listed in Table 2-5. For some shapes, values are given for variations in surface roughness, Reynolds number, corner radius ratio, yaw angle, or test conditions.

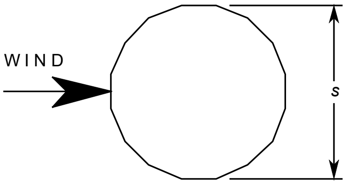
The force coefficients of asymmetrical shapes are dependent on the orientation of the wind with respect to the cross section of the member. No general equation exists for this condition; however, values have been determined through wind tunnel testing. These instances are indicated in Table G-1.

Table G-1. Member Force Coefficients.



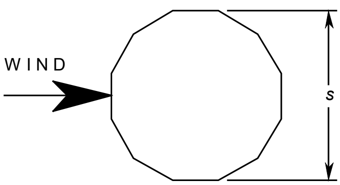
Circle

Surface	Reynolds number	Force coefficient	Reference
Any	$< 3.5 \times 10^5$	1.2	Scruton and Newberry (1963)
Any	$< 4.1 \times 1^{05}$	1.2	MacDonald (1975)
Smooth	—	0.7	ASCE (1990a)
Smooth	$< 10^5$	1.0	Sachs (1978)
Smooth	$< 3.0 \times 10^5$	1.1	AASHTO (1975)
Smooth	$> 3.5 \times 10^5$	0.7	Scruton and Newberry (1963)
Smooth	$> 4.1 \times 10^5$	0.6	MacDonald (1975)
Smooth	$3 \times 10^5 < Re < 6 \times 10^5$	$14.5 \times 10^6 / Re1.3$	AASHTO (1975)
Smooth	$> 6.0 \times 10^5$	0.45	AASHTO (1975)
Rough	$> 4.1 \times 10^5$	1.2	MacDonald (1975)
Rough	—	0.9	ASCE (1990a)
Very rough	$> 3.5 \times 10^5$	1.0	Scruton and Newberry (1963)
Very rough	—	1.2	ASCE (1990a)



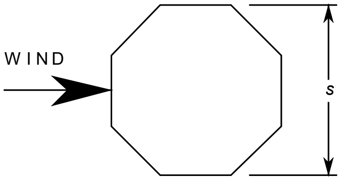
16-sided polygon

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
< 0.26	$> 6.0 \times 10^5$	$0.83–1.08(r/R)$	James (1976)
> 0.26	$> 6.0 \times 10^5$	0.55	James (1976)



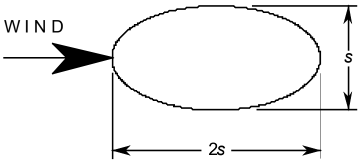
12-sided polygon

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
0	$< 3.5 \times 10^5$	1.3	Scruton and Newberry (1963)
0	$< 8.2 \times 10^5$	1.3	MacDonald (1975)
0	$> 3.5 \times 10^5$	1.0	Scruton and Newberry (1963)
0	$> 8.2 \times 10^5$	1.1	MacDonald (1975)
$0.09 < r/R < 0.34$	$> 10^6$	$0.936–1.087(r/R)$	James (1976)
> 0.125	$< 3.0 \times 10^5$	1.2	AASHTO (1975)
> 0.125	$3.0 \times 10^5 < Re < 6.0 \times 10^5$	$2{,}322/Re^{0.6}$	AASHTO (1975)
> 0.125	$> 6.0 \times 10^5$	0.79	AASHTO (1975)
> 0.34	$> 10^6$	0.57	James (1976)



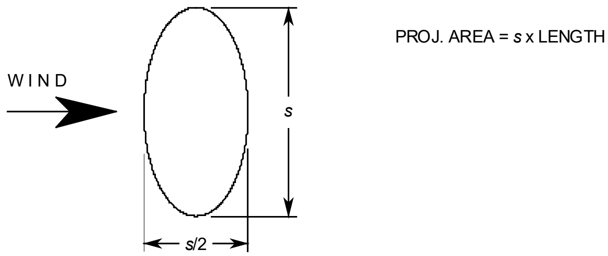
8-sided polygon

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
0	—	1.2	AASHTO (1975)
0	—	1.4	ASCE (1990a), MacDonald (1975)
$0.09 < r/R < 0.59$	$> 10^6$	$1.422–1.368(r/R)$	James (1976)
> 0.59	$> 10^6$	$0.744–0.194(r/R)$	James (1976)



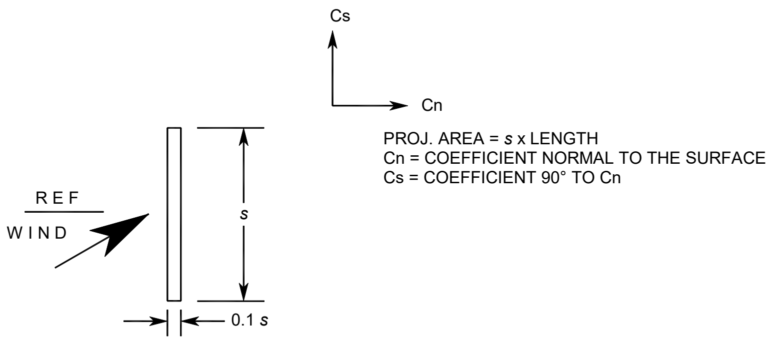
Ellipse, wind on narrow side

Sides	Reynolds number	Force coefficient	Reference
Smooth	$< 6.9 \times 10^5$	0.7	MacDonald (1975)
Smooth	$> 6.9 \times 10^5$	0.2	MacDonald (1975)
Multi-sided	—	$(C/3)(4 - D/d)$	AASHTO (1975)
where	D = Major diameter d = Minor diameter $D/d = 2.0$ C = Force coefficient of cylindrical shape with diameter equal to D		



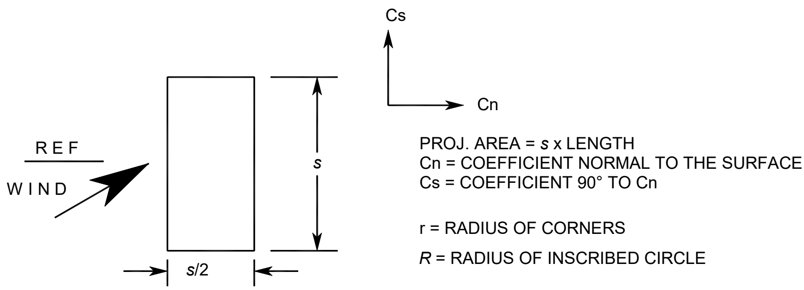
Ellipse, wind on broad side

Sides	Reynolds number	Force coefficient	Reference
Smooth	$< 5.5 \times 10^5$	1.7	MacDonald (1975)
Smooth	$> 5.5 \times 10^5$	1.5	MacDonald (1975)
Multisided	—	$1.7(D/d - 1) + C(2 - D/d)$	AASHTO (1975)



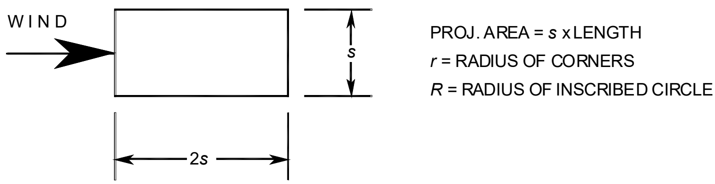
Flat plate

Angle	C_n	C_s	Reference
0°	2.0	0.0	Scruton and Newberry (1963), Sachs (1978)
45°	1.8	0.1	Sachs (1978)
90°	0.0	0.1	Sachs (1978)



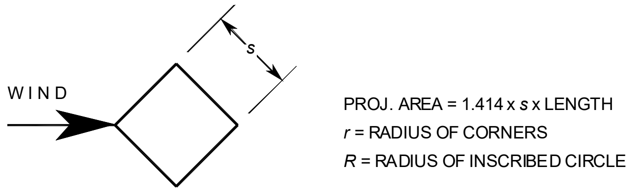
Rectangle

Corner radius (r/R)	Angle	C_n	C_s	Reference
0	0°	2.2	0.0	Scruton and Newberry (1963)
0	0°	2.1	0.0	Sachs (1978)
0	45°	1.4	0.7	Sachs (1978)
0	90°	0.0	0.75	Sachs (1978)
0.08	0°	1.9	0.0	MacDonald (1975)
0.25	0°	1.6	0.0	Scruton and Newberry (1963)



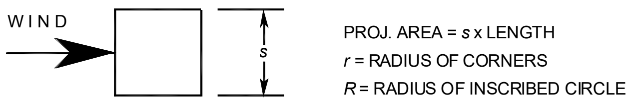
Rectangle

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
0.0	—	1.4	Scruton and Newberry (1963)
0.167	—	0.7	MacDonald (1975)
0.5	—	0.4	Sachs (1978)



Square, wind at apex (cornering)

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
0.0	—	1.5	ASCE (1990b), Scruton and Newberry (1963)
0.33	$< 6.86 \times 10^5$	1.5	MacDonald (1975)
0.33	$> 6.86 \times 10^5$	0.6	MacDonald (1975)



Square, wind at side

Corner radius (r/R)	Reynolds number	Force coefficient	Reference
0.0	—	2.0	ASCE (1990b), Scruton and Newberry (1963)
0.167	$< 6.86 \times 10^5$	1.3	MacDonald (1975)
0.167	$> 6.86 \times 10^5$	0.6	MacDonald (1975)
0.33	$< 2.7 \times 10^5$	1.0	MacDonald (1975)
0.33	$> 2.7 \times 10^5$	0.5	MacDonald (1975)