Conductor Loads

$W_i = 1.24(d + I_z)I_z = 1.24(1.165 + 0.25)0.25 = 0.439$ lbs/ft (Eq. 2-16)

$d_i = 2(0.25) + 1.165 = 1.665$ in.

$V_l = 1{,}800(1.075 + 0.439)(1.5) + 200(1.5) = 4{,}388$ lbs = 4.4 kips

$T = 4(1.665/12)(1{,}500)(2.5) + 8{,}800 \sin(5/2)(2)(1.65) = 3{,}348$ lbs = 3.3 kips

Wind on Structure

Transverse Wind Loads

Wind pressure = 4(2.5) = 10 psf

Areas are provided in the *Wind* loading case.

The NESC force coefficient is 3.2.

$W_1 = 10(3.2)(34) = 1{,}088$ lbs = 1.1 kips

$W_2 = 10(3.2)(33) = 1{,}056$ lbs = 1.1 kips

$W_3 = 10(3.2)(62) = 1{,}984$ lbs = 2.0 kips

Construction and Maintenance, Chapter 3, Section 3.1

Wind on Wires

Wind pressure = 3 psf

Ground-Wire Loads

The pulling slope is 3 horizontal to 1 vertical.

$V_l = 1.5(1{,}751)(1/3) + 0.262(1{,}800)(1.5)/2 + 50(1.5)$
$= 1{,}304$ lbs = 1.3 kips (Alt. A controls)

$V_l = 0.262(1{,}800)(2) + 50(2) = 1{,}043$ lbs = 1.1 kips (Alt. B controls)

$T = 3(0.385/12)(1{,}500)1.5 + 1751 \sin(5/2)(2)1.5 = 446$ lbs = 0.5 kips

Conductor Loads

$V_l = 1.5(5{,}961)(1/3) + 1.075(1{,}800)(1.5)/2 + 200(1.5)$
$= 4{,}732$ lbs = 4.7 kips (Alt. A controls)

$V_l = 1.075(1{,}800)2 + 200(2) = 4{,}270$ lbs = 4.3 kips (Alt. B controls)

$T = 3(1.165/12)(1{,}500)1.5 + 5{,}961 \sin(5/2)(2)1.5 = 1{,}435$ lbs = 1.4 kips

Wind on Structure

Transverse Wind Loads

Wind pressure = 3(1.5) = 4.5 psf

Force coefficients and areas are provided in the *Wind* loading case.

$W_1 = 4.5(1.8)(34) = 275$ lbs = 0.3 kips

$W_2 = 4.5(3.22)(33) = 478$ lbs = 0.5 kips

$W_3 = 4.5(3.32)(62) = 926$ lbs = 0.9 kips

Failure Containment, Chapter 3, Section 3.3.2

This loading case is based on the residual static load of a broken conductor or ground wire (0 psf wind and 0 in. of radial ice at 30°F).

Ground-Wire Loads
The RSL load factor for a broken ground wire is 1.0.

Broken Wire
V_l = 0.262(1,800)/2 + 50 = 286 lbs = 0.3 kips
T = 1,623 sin(5/2)(1.0) = 71 lbs = 0.1 kips
L = 1,623 cos(5/2)(1.0) = 1,621 lbs = 1.6 kips

Intact Wire
V_l = 0.262(1,800) + 50 = 522 lbs = 0.5 kips
T = 1,623 sin(5/2)(2) = 142 lbs = 0.1 kips
L = 0.0 kips

Conductor Loads
Ratio of the span to insulator length = 1,250/6 = 208
Ratio of the span to sag = 1,250/31.6 = 40
From Fig. 3-2 in Chapter 3, the RSL load factor is 0.7. Refer to Table 5-2.

Broken Wire
V_l = 1.075(1,800)/2 + 200 = 1,168 lbs = 1.2 kips
T = 5,615 sin(5/2)(0.7) = 171 lbs = 0.2 kips
L = 5,615 cos(5/2)(0.7) = 3,927 lbs = 3.9 kips

Intact Wire
V_l = 1.075(1,800) + 200 = 2,135 lbs = 2.2 kips
T = 5,615 sin(5/2)(2) = 490 lbs = 0.5 kips
L = 0.0 kips

5.1 WEIGHT SPAN CHANGE WITH BLOW-OUT ON INCLINED SPANS

This example compares weight spans with and without wind for the center tower shown in Fig. 5-2. The equations are shown in Section 4.5.1.1 of Chapter 4. Wire data is from Section 5.0 above.

Ground Wire
No Wind
$C_v = H/w_v$ = 1,546/0.262 = 5,901 ft Eq. 4-7)
$X_1 = S/2 - C_v \sinh^{-1}[(B/2)/C_v \sinh(S/2C_v)]$
$= 1{,}250/2 - 5{,}901 \sinh^{-1}[(50/2)/5{,}901 \sinh(1{,}250/2(5{,}901))]$
= 390 ft (Eq. 4-5)
Weight span = 2(1,250 − 390) = 1,720 ft

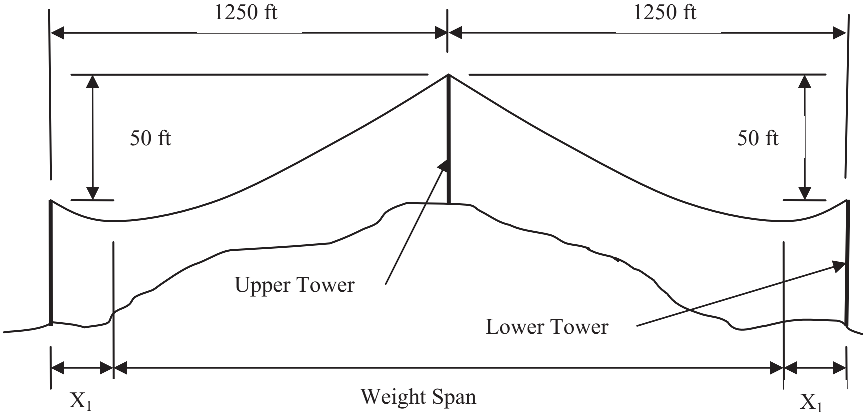

Figure 5-2. Weight span for center tower with inclined spans.

16.3-psf Wind

$C_v = 2{,}939/0.262 = 11{,}218$ ft (Eq. 4-7)

$X_1 = 1{,}250/2 - 1{,}1218 \sinh^{-1}[(50/2)/11{,}218 \sinh(1{,}250/2(11{,}218))]$

$= 177$ ft (Eq. 4-5)

Weight span = 2(1,250 – 177) = 2,146 ft (*25% increase*)

Conductor

No Wind

$C_v = 5{,}302/1.075 = 4{,}932$ ft

$X_1 = 1{,}250/2 - 4{,}932 \sinh^{-1}[(50/2)/4{,}932 \sinh(1{,}250/2(4{,}932))] = 428$ ft

Weight span = 2(1,250 – 428) = 1,644 ft

16.3-psf Wind

$C_v = 8{,}598/1.075 = 7{,}998$ ft

$X_1 = 1{,}250/2 - 7{,}998 \sinh^{-1}[(50/2)/7{,}998 \sinh(1{,}250/2(7{,}998))] = 306$ ft

Weight span = 2(1,250 – 306) = 1,888 ft (*15% increase*)

5.2 TRADITIONAL CATENARY CONSTANT

This example compares weight spans to those in Section 5.1 using the traditional catenary constant. The traditional catenary constant is based on the resultant unit weight (w_r). The catenary constant in Section 5.1 is based on the vertical unit weight (w_v). Figure 5-2 shows the upper and lower towers and spans.

Ground Wire

16.3-psf Wind

$w_v = 0.262$ lbs/ft

$w_t = 16.3(0.385/12) = 0.523$ lbs/ft

$w_r = (0.262^2 + 0.523^2)^{1/2} = 0.585$ lbs/ft

$C_r = H/w_r = 2{,}939/0.585 = 5{,}025$ ft (Eq. 4-6)

$X_1 = S/2 - C_r \sinh^{-1}[(B/2)/C_r \sinh(S/2C_r)]$

$= 1{,}250/2 - 5{,}025 \sinh^{-1}[(50/2)/5{,}025 \sinh(1{,}250/2(5{,}025))]$

$= 425$ ft (Eq. 4-5)

Weight span = 2(1,250 – 425) = 1,650 ft

Conductor

Refer to Table 5-3.

16.3-psf Wind

$w_v = 1.075$ lbs/ft

$w_t = 16.3(1.165/12) = 1.582$ lbs/ft

$w_r = (1.075^2 + 1.582^2)^{1/2} = 1.913$ lbs/ft

$C_r = 8{,}598/1.913 = 4{,}494$ ft (Eq. 4-6)

$X_1 = 1{,}250/2 - 4{,}494 \sinh^{-1}[(50/2)/4{,}494 \sinh(1{,}250/2(4{,}494))]$

$= 446$ ft (Eq. 4-5)

Weight span = 2(1,250 – 446) = 1,608 ft

The traditional catenary constant underestimates the vertical load on the upper tower and overestimates the vertical load on the lower tower.

APPENDIX A

DEFINITIONS, NOTATIONS, AND SI CONVERSION FACTORS

A.1 DEFINITION OF STRUCTURE TYPES

Tangent Structure: Minimum line deflection angle. Usually suspension or some type of post insulators (line post, braced line post, horizontal V) used to support the conductors and transfer wind and weight loads to the structure. In practice, structures with very small line angles, such as 2 degrees or less, are often referred to as tangent structures.

Angle Structure (change in direction in plan view):

a. May be similar to tangent structure, using suspension or post insulators to support the conductors and transfer wind, weight, and line angle loads to the structure.
b. May be similar to strain or dead-end structures, using insulators in series with the conductors to bring wind, weight, and line angle loads directly into the structure.

Strain Structure (usually has line angle, also): Similar to dead-end structure, using insulators in series with the conductors to bring wind, weight, and line angle loads directly into the structure. Also capable of resisting some unbalanced tensions in one direction of one or all wires on one face of the structure, but not capable of resisting the full unbalanced tensions of all wires removed on one face of the structure (i.e., with all ahead span or back span wires removed).

Dead-End Structure (usually has line angle, also): Uses insulators in series with the conductors to bring wind, weight, and line angle loads directly into the structure. Also (generally) capable of resisting the full unbalanced tensions of all wires removed on one face of the structure (i.e., with ahead span or back span wires removed).

A.2 DEFINITIONS OF SPAN

Span. The distance, generally measured horizontally, between two points. Unless otherwise stated, span usually refers to the distance between two adjacent structures. See Fig. A-1.

Span Length. The horizontal distance between two adjacent structures.

Back Span. The span length in the span behind (generally in the direction of decreasing stationing) the structure in question. In Fig. B-1, span 1 is the back span of structure B.

Ahead Span. The span length in the span ahead (generally in the direction of increasing stationing) of the structure in question. In Fig. B-1, span 2 is the fore span (ahead span) of structure B.

Sag. The relative vertical distance of the straight line made by two adjacent supports to a point along a conductor.

Slack. The amount of conductor length difference between a straight line made by two adjacent supports and a sagging conductor.

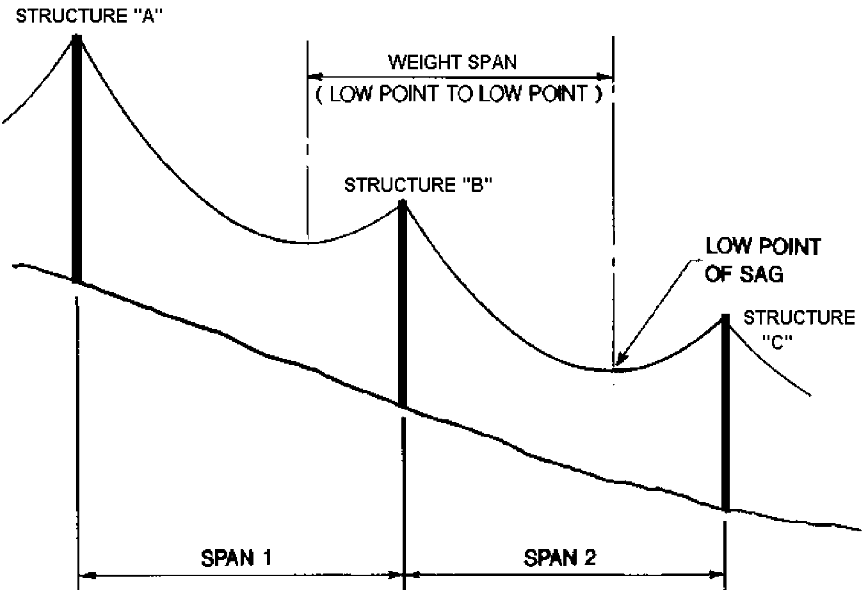

Figure A-1. Span usually refers to the distance between two adjacent structures.

Weight Span. The horizontal distance between the low point of sag in back span and the low point of sag in the ahead span. It is used in calculating the vertical load that the conductor imposes on the supporting structure.

Wind Span. The mathematical average of the back span and the fore span. It is used in calculating the wind load that the conductor imposes on the supporting structure. This may also be referred to as the horizontal span.

Vertical Span. The vertical span is the same as the weight span.

A.3 NOTATION

The following notation is used in this manual:

A	solid tributary area of surfaces projected normal to the wind, in square feet
A_{i}	cross-sectional area of ice accretion on a wire, in inches
A_{m}	the area of all members in the windward face of a structure, in square feet
A_{ml}	the area of all members in the face of the structure that, in a tangent structure, is parallel to the line, in square feet
A_{mt}	the area of all members in the face of the structure that, in a tangent structure, is perpendicular to the line, in square feet
A_{o}	the area of the outline of the windward face of a structure, in square feet
B	difference in elevation of supports, in feet
B_{t}	dimensionless response term corresponding to the quasi-static background wind loading on the structure
B_{w}	dimensionless response term corresponding to the quasi-static background wind loading on the wire (conductor or ground wire)
BWL	broken wire load
c	correction factor for aspect ratio
C	catenary constant or parameter of the catenary curve
C_{f}	force coefficient
C_{fl}	the force coefficient associated with faces of the structure that, in a tangent structure, are parallel to the line
C_{ft}	the force coefficient associated with faces of the structure that, in a tangent structure, are perpendicular to the line
C&M	construction and maintenance loads
$\mathrm{COV_R}$	coefficient of variation of component strength
d	diameter of wire (conductor or ground wire), in inches
D	straight-line distance between the supports, in feet

DL	dead loads from weights of components
e	exclusion limit of component strength, in percentage
E	exposure factor evaluated at the effective height of the wire or structure
f	structure/member natural frequency, in cycles/second
f_t	fundamental frequency of the free-standing structure in the transverse direction, in Hertz
f_w	fundamental frequency for horizontal sway of the conductor or ground wire, in Hertz
F	wind force, in pounds or kips (1,000 pounds)
F_l	wind force in the longitudinal direction, in pounds or kips
F_t	wind force in the transverse direction, in pounds or kips
FC	failure containment loads
FPP	Fujita-Pearson tornado scale
G	gust response factor
g_s	statistical peak factor for gust response of a component
G_t	gust response factor for the structure
G_w	gust response factor for the wire (conductor or ground wire)
H	height of hill or escarpment relative to the upwind terrain, in feet
HA	horizontal line angle, in degrees
I_{RP}	ice thickness having an RP-year return period, in inches
I_{50}	ice thickness having a 50-year return period, in inches
I_Z	design ice thickness, in inches
K_1	factor to account for shape of topographic feature and maximum speed-up effect
K_2	factor to account for reduction in speed-up with distance upwind of downwind effect
K_3	factor to account for reduction in speed-up with height above local terrain
K_v	ratio of the 3-sec wind speed to the 10-min average wind speed in open country (Exposure C) at 33-ft (10-m) reference height
K_Z	velocity pressure exposure coefficient
K_{zt}	topographic factor
LEL	lower exclusion limit
LL	legislated loads
L_h	distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in feet
L_m	length of member, in feet
L_s	transverse integral scale of turbulence, in feet
L_T	transverse structure load, in pounds or kips
L_V	vertical structure load, in pounds or kips
m_i	mass of typical ice sample
PDF	probability density function of a random variable

P_f	component annual probability of failure
Q	the numerical constant determined by air density
Q_D	design load effect in each component of a structure
Q_{RP}	weather-related load with an RP-year return period
Q_{50}	weather-related load with a 50-year return period
R	Reynolds number
R_n	nominal value of component strength
R_t	dimensionless resonant response term of the structure
R_w	dimensionless resonant response term of the wire
RP	return period of weather-related event, load, or load effect
RRF	relative reliability factor
RSL	residual static load for the broken wire loading condition
RTS	rated tension strength
s	member diameter or width normal to the wind, in feet
S	span length of the wires (conductor and ground wire), in feet
Str	Strouhal number
t	time
T_H	horizontal component of tension, in pounds or kips
UH	horizontal component of unit wire load for a certain tension, in pounds or kips
UR	resultant unit wire load for a certain tension, in pounds or kips
UV	vertical component of unit wire load for a certain tension, in pounds or kips
V	design wind speed (3-sec) at standard height of 33 ft (10 m) in open country (Exposure C), in miles per hour (mph)
V_{50}	wind speed at a 50-year return period (basic wind speed), 3-sec gust, in mph
V_{cr}	critical vortex-induced wind speed, in feet per second
V_l	vertical structure load, in pounds or kips
V_o	10-min average wind speed at the effective height of the wires and structure, in ft/sec
V_{RP}	wind velocity having an RP-year return period, 3-sec gust, in mph
VA	vertical line angle, in degrees
w	wire weight per unit length, in pounds per foot
Wi	weight of glaze ice, in pounds per foot
X_1	distance from the low point of sag to lower support, in feet
z	height above ground, in feet
z_g	gradient height, in feet
z_h	effective height above ground of the wire (conductor or ground wire) or structure, in feet
α	power-law coefficient for terrain factor equation
α_{FM}	power-law coefficient for sustained wind
γ	load factor applied to weather-related loads Q_{50}

γ_{CM} load factor applied to construction and maintenance loads
γ_i load factor applied to ice load
γ_w load factor applied to wind load
ε approximate coefficient for separation of the wire and structure response terms in the general gust response factor equations
κ surface drag coefficient
ρ mass density of air
ρ_i ice density
Φ the solidity ratio (A_m/A_o)
ϕ_{LL} strength factor specified with legislated loads
ζ_t structure damping to critical damping ratio
ζ_w wire aerodynamic damping to critical damping ratio
Ψ angle of yaw, in degrees

A.4 SI CONVERSION FACTORS

1 ft = 0.305 meter (m)
1 in. = 25.4 millimeters (mm)
1 pound (lb) force = 4.45 newtons (N)
1 lb/ft = 14.6 N/m
1 lb/ft^2 (psf) = 47.8 pascals (Pa) (N/m^2)
1 lb mass/ft^3 (pcf) = 0.016 gram/cubic centimeter (g/c^3)
1 mile per hour (mph) = 0.45 meter/second (m/s)
To convert temperature, θ, from °F to °C, θ (°C) = 5/9 [θ (°F) – 32°F]