Design & Wind Stability Analysis Of Horizontal Vee Assemblies

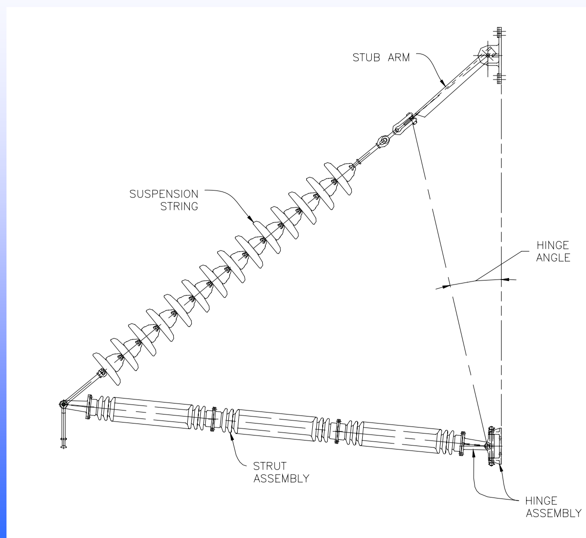
Panel Session PN23

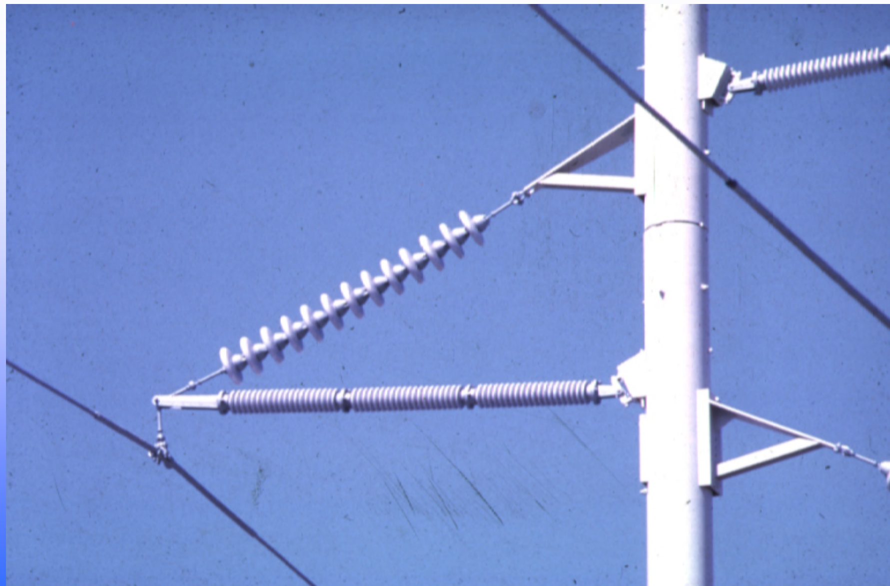
Thursday April 24 8-12 am

2008 IEEE Transmission & Distribution Exposition & Conference

April 2008 Chicago, IL

Horizontal Vee Design

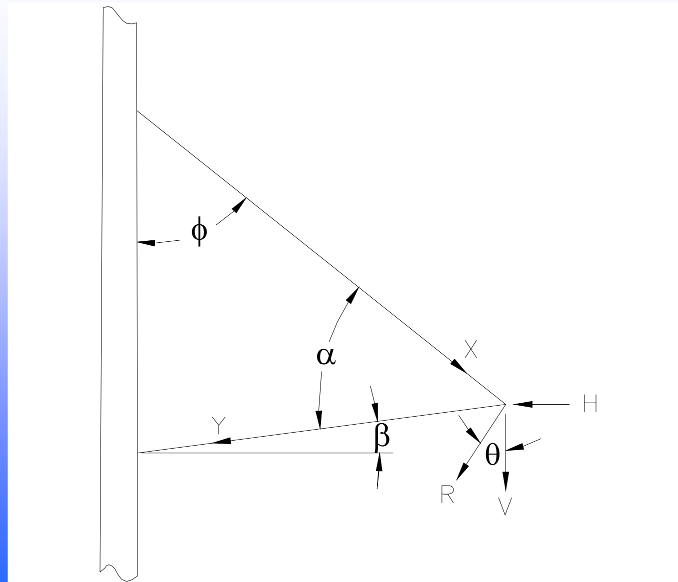




Typical 230 kV (Thirteen Bell) Horizontal Vee Assembly.

500 kV Horizontal Vee Assembly.

Horizontal Vee Loading



Horizontal Vee Loading

Swing Angle = θ

$$\theta = \text{Tan}^{-1} \frac{H}{V}$$

Horizontal Vee Loading

Critical Buckling Load Of Strut = Pcr = $\frac{\Pi^2 \times E \times I}{L^2}$

E = Youngs Modulus lbs/in^2

I = Moment of Inertia in^4

L = Strut Length ins.

HORIZONTAL VEE LOADING.

Case No 1: Transverse Load "H" Due to Wind and or Line Angle Acting Towards Structure.

Load in Strut = "Y"

$$Y = -\frac{V \times \cos(\acute{\alpha} - \beta)}{\sin \acute{\alpha}} + -\frac{H \times \sin(\acute{\alpha} - \beta)}{\sin \acute{\alpha}}$$

Load in Suspension = "X"

$$X = +\frac{V \cos \beta}{\sin \alpha} - \frac{H \sin \beta}{\sin \alpha}$$

HORIZONTAL VEE LOADING.

Case No 2: Transverse Load "H" Due to Wind and or Line Angle Acting Away From Structure.

Load in Strut = "Y"

$$Y = -\frac{V \times \cos(ά - β)}{\sin ά} + \frac{H \times \sin(ά - β)}{\sin ά}$$

Load in Suspension = "X"

$$X = +\frac{V \cos β}{\sin α} + \frac{H \sin β}{\sin α}$$

Combined Loading Curve.

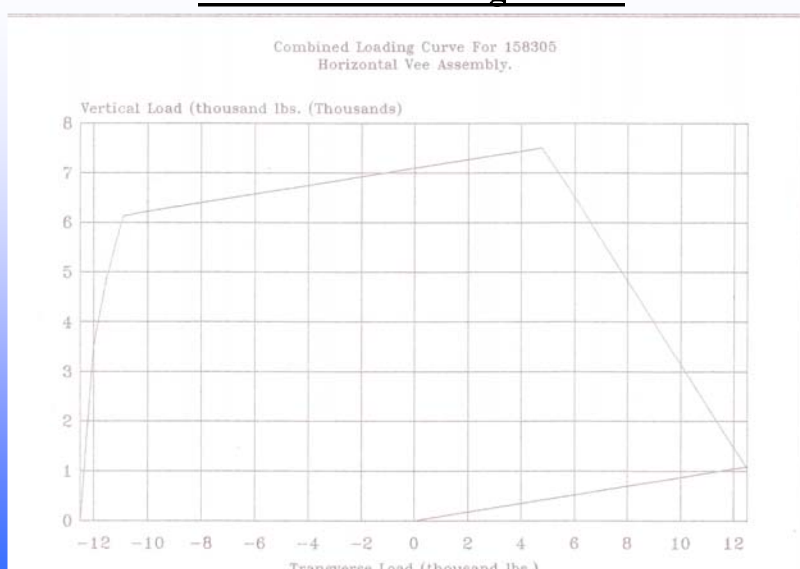
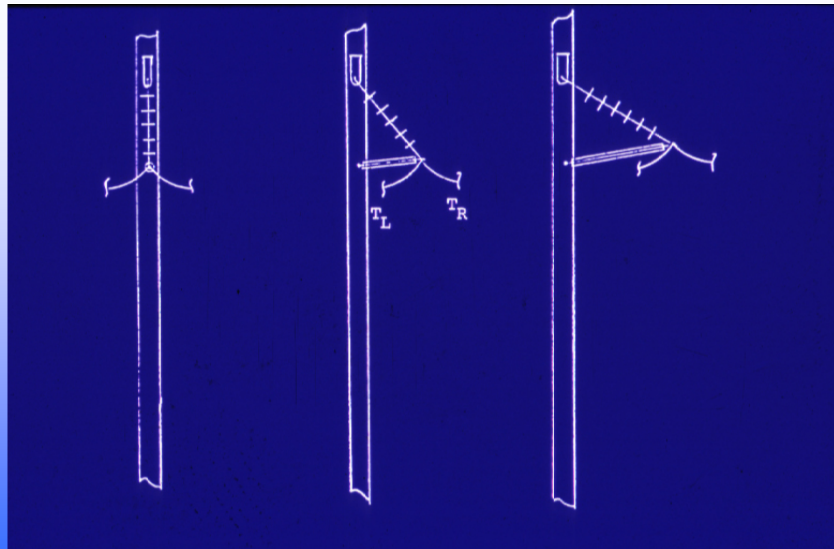


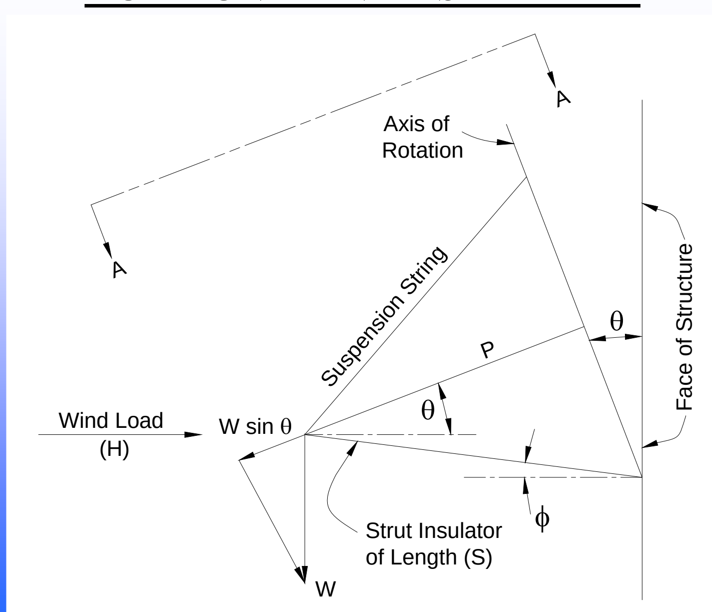
Figure No.2 Negative Load Acts Away From Structure.



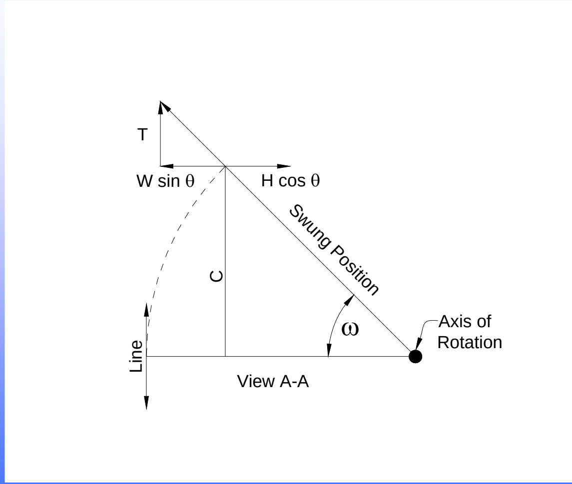
Horizontal Vee in normal position

Horizontal Vee under broken conductor condition.

HORIZONTAL VEE STABILITY



HORIZONTAL VEE STABILITY



$T = (W \sin\theta + H \cos\theta) \tan \omega$

HORIZONTAL VEE STABILITY

$T = (W \sin\theta + H \cos\theta) \tan \omega$

If $(W \sin\theta + H \cos\theta) > 0$ Assembly & System Are Stable.

If $(W \sin\theta + H \cos\theta) < 0$ System Stability is Dependent On Line Parameters.

Horizontal Vee Wind Stability Analysis.

Computer program developed to evaluate system parameters.

Original program developed under EPRI Project No. 561. for determining longitudinal loads imposed on transmission line systems under broken conductor and/or unequal ice loading. (BRODI 1)

BRODI 1 program was modified to consider longitudinal loads caused by transverse wind loading on transmission line systems supported by Horizontal Vee insulator assemblies.

INPUT DATA.

Line Parameters	Horizontal Vee Ass'y Parameters	Wind Load Input
*Conductor =	Effective Length =	*Base Wind
Weight =	Weight =	Magnitude
Diameter =	Hinge angle =	Direction (15 Degrees)
Area =	Projected Area =	*Gust Wind (Not Used)
Modulus of Elasticity =		Magnitude
Coefficient of Expansion =		Direction
Number Of Conductors =		
Line Tension =		
*Span Lengths		
Number Of Spans =		
Angle effects		

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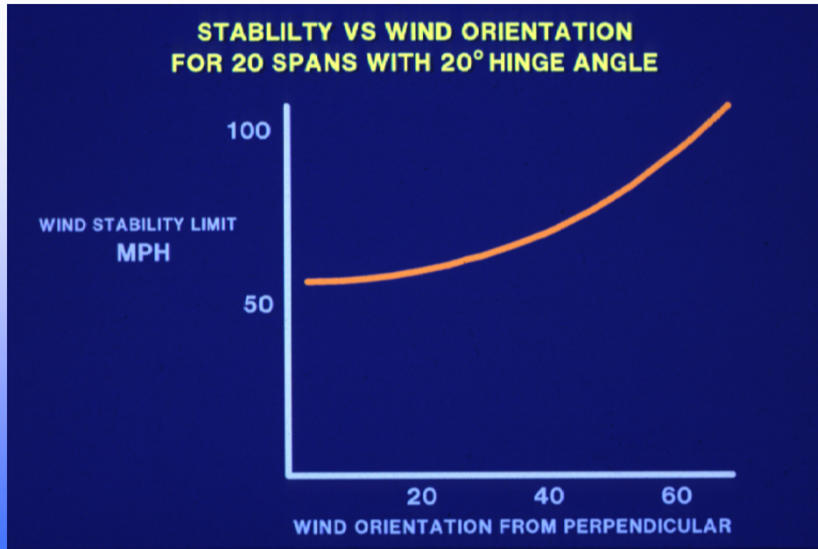
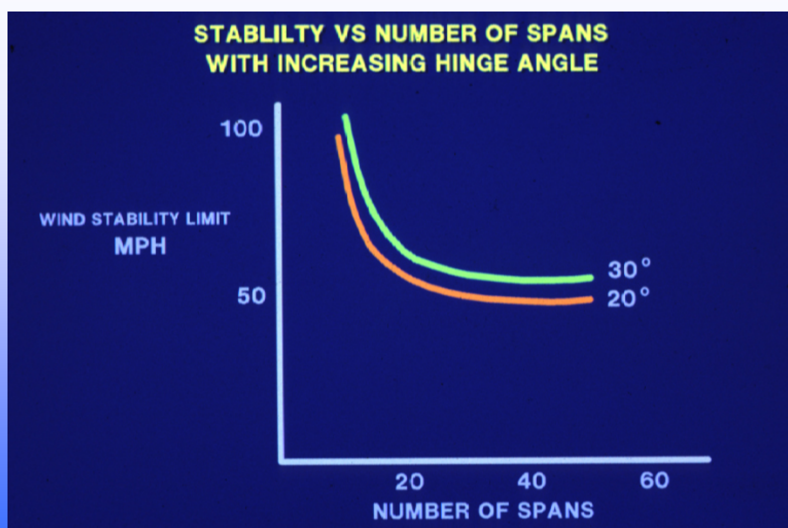
Horizontal Vee Wind Stability

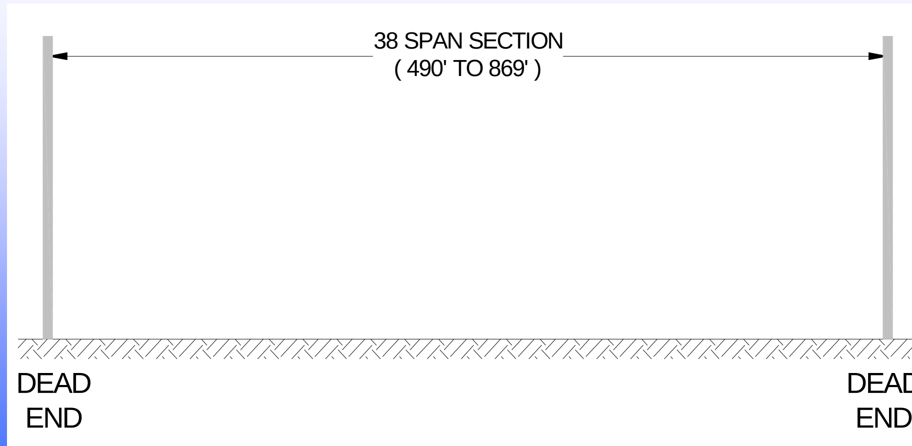


Wind orientation 15° From Perpendicular Worst Case.

Horizontal Vee Wind Stability



Wind Stability Analysis (1).



Required To Be Stable At 100 MPH.

Input File

```
DATA FILE A:OG2.dat CONTAINS THE FOLLOWING:

Title: Moultrie - N.Tifton 230/115 kV Line Sect2

Number of towers: 37                      Number of spans: 38
Area of conductor = 1.196 sq. in.         Weight of conductor = 1.737 lb./ft
Effective modulus = 1.02E+07 psi          Diameter of conductor = 1.424 in.
Coeffecient of linear expansion = .0000108 in./in./deg. F
Initial tension = 9800 lbs.at temperature = 90 deg. F
Effective insulator length = 8.092 ft.    Insulator weight = 350 lbs.
Effective insulator area = 296.64 sq. in. Hinge angle = 25 deg.
```

Tower #	Span #	Span length	Wind angle	Tower angle
DE	-	-	-	-
	1	702	15	-
1	-	-	-	0
	2	780	15	-
2	-	-	-	0
	3	620	15	-
3	-	-	-	0
	4	780	15	-
4	-	-	-	0
	5	720	15	-
5	-	-	-	0
	6	600	15	-
6	-	-	-	0
	7	730	15	-
7	-	-	-	0
	8	730	15	-
8	-	-	-	0
	9	670	15	-
9	-	-	-	0
	10	750	15	-
10	-	-	-	0

Output File 74 MPH

Moultrie - N.Tifton 230/115 kV Line Sect2

FINAL DISPLACEMENTS AND LOADS FOR BASE WIND OF 74 MPH

WIRE	TENSION	L. WIND	T. WIND	L. FORCE	WEIGHT	INSULATOR	DEGREES
1	11.718	0.003	1.042	0.000	0.618	1	-0.04
2	11.716	0.003	0.985	0.002	0.588	2	-0.31
3	11.714	0.003	0.985	0.001	0.588	3	-0.19
4	11.714	0.003	1.055	0.003	0.625	4	-0.47
5	11.714	0.003	0.928	0.004	0.559	5	-0.56
6	11.713	0.003	0.935	0.003	0.562	6	-0.41
7	11.714	0.003	1.027	0.004	0.610	7	-0.53
8	11.715	0.003	0.985	0.005	0.588	8	-0.66
9	11.716	0.003	0.999	0.004	0.596	9	-0.63
10	11.716	0.003	1.055	0.006	0.625	10	-0.81
11	11.719	0.003	0.950	0.006	0.570	11	-0.98
12	11.722	0.003	0.928	0.005	0.559	12	-0.82
13	11.725	0.003	1.090	0.007	0.643	13	-0.91
14	11.729	0.004	1.217	0.012	0.710	14	-1.33
15	11.738	0.004	0.976	0.014	0.584	15	-2.03

Output File 75 MPH

Moultrie - N.Tifton 230/115 kV Line Sect2

FINAL DISPLACEMENTS AND LOADS FOR BASE WIND OF 75 MPH

WIRE	TENSION	L. WIND	T. WIND	L. FORCE	WEIGHT	INSULATOR	DEGREES
1	11.197	0.003	1.071	0.006	0.618	1	-0.75
2	11.207	0.004	1.011	0.014	0.588	2	-1.91
3	11.197	0.003	1.011	0.017	0.588	3	-2.31
4	11.228	0.004	1.084	0.028	0.625	4	-3.44
5	11.243	0.003	0.954	0.029	0.559	5	-4.22
6	11.252	0.003	0.961	0.031	0.562	6	-4.51
7	11.292	0.003	1.055	0.041	0.610	7	-5.28
8	11.326	0.003	1.011	0.044	0.588	8	-6.00
9	11.358	0.003	1.026	0.049	0.596	9	-6.43
10	11.405	0.003	1.084	0.058	0.625	10	-7.15
11	11.453	0.003	0.975	0.056	0.570	11	-7.80
12	11.493	0.003	0.954	0.055	0.559	12	-7.89
13	11.547	0.003	1.120	0.069	0.643	13	-8.29
14	11.614	0.004	1.250	0.086	0.710	14	-9.08
15	11.692	0.004	1.002	0.074	0.584	15	-10.09

Output File 75.2 MPH

```
Moultrie - N.Tifton 230/115 kV Line Sect2

FINAL DISPLACEMENTS AND LOADS FOR BASE WIND OF 75.2 MPH
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WIRE   TENSION  L. WIND  T. WIND  L. FORCE  WEIGHT  INSULATOR  DEGREES
----------------------------------------------------------------------

INSULATOR 4 HAS REACHED INSTABILITY
TRY A LOWER WIND VELOCITY
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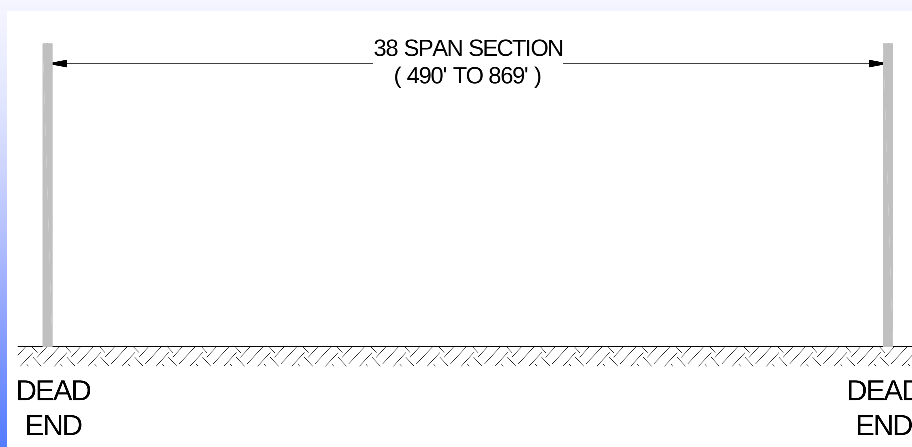
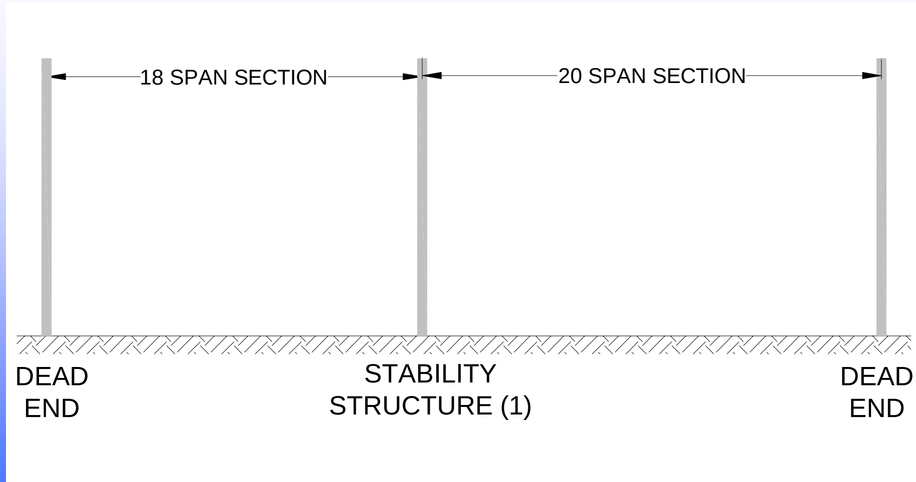
Wind Stability Analysis (1)

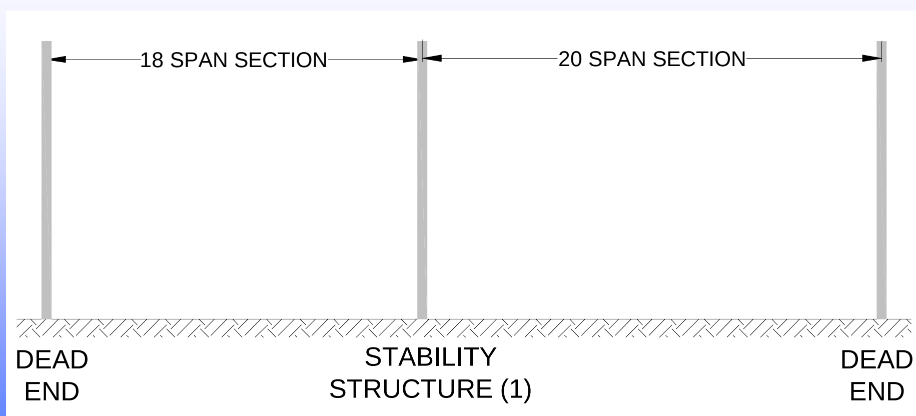


38 Span Section Stable At 74 MPH.

Wind Stability Analysis (2)

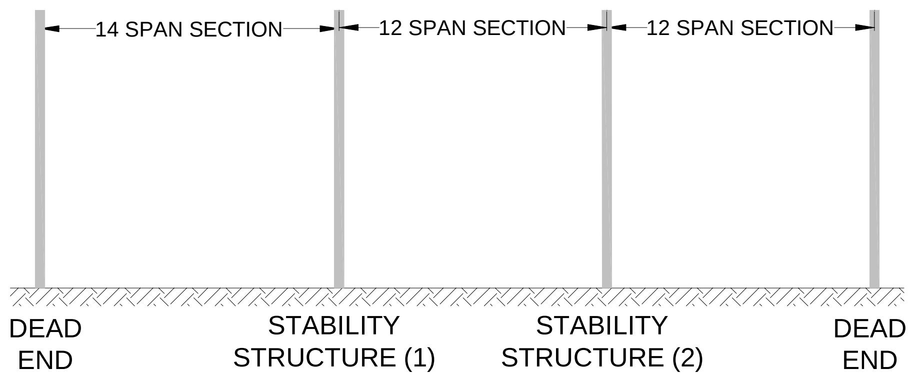


Wind Stability Analysis (2)

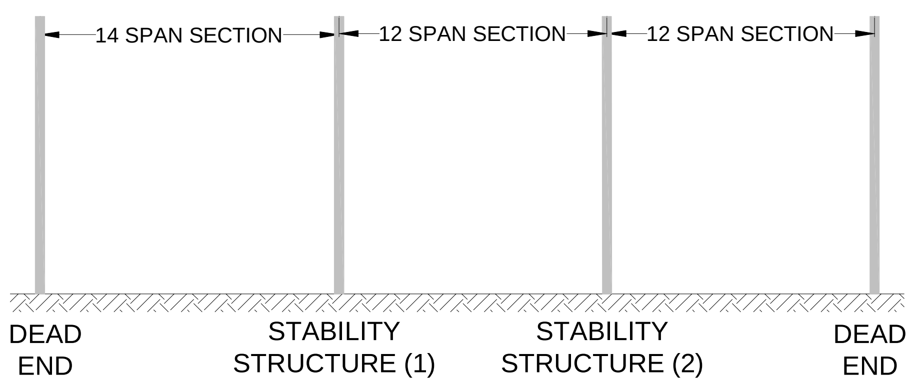


Eighteen Span Section Unstable At 107 MPH - Stable At 102 MPH ($\Delta \leq 5°$)
Twenty Span Unstable At 105 MPH - Stable At 95 MPH ($\Delta \leq 5°$)

Wind Stability Analysis (3).



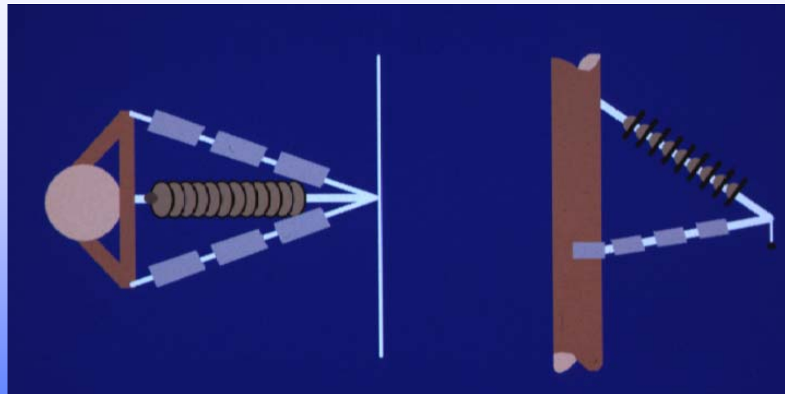
Wind Stability Analysis (3)



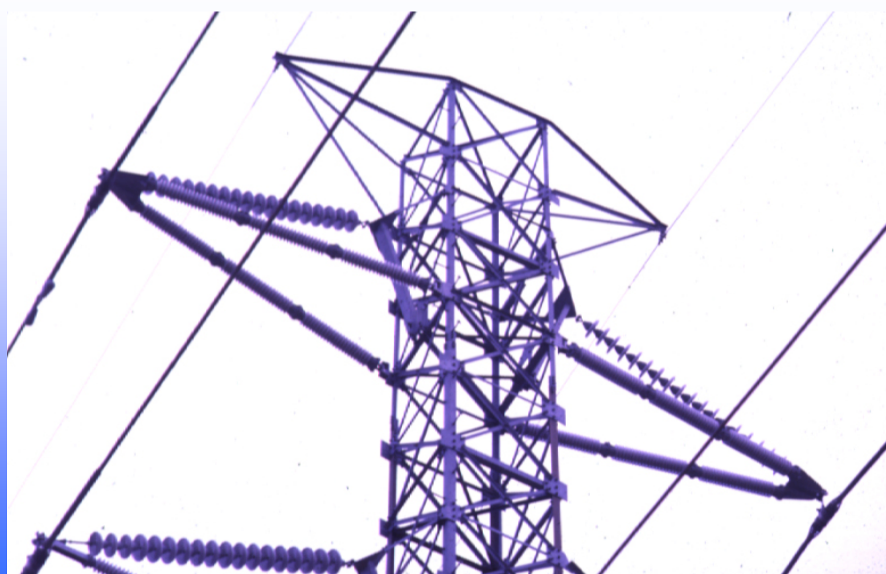
Fourteen Span Section Unstable At 125 MPH Stable At 110 MPH ($\Delta \leq 5°$)
Twelve Span Section Unstable At 145 MPH Stable At > 110 MPH ($\Delta \leq 5°$)
Twelve Span Section Unstable At 160 MPH Stable At > 110 MPH ($\Delta \leq 5°$)

Differential Tension At 100MPH at Structure 1 = 14,947lbs – 14,658 lbs = 289 lbs.
Differential Tension At 100MPH at Structure 2 = 14,817lbs – 14,521 lbs = 296 lbs.

Tripod Assembly



Top View Side View



345 kV (Eighteen Bell) Tripod Assembly.

Horizontal Vee Stability Analysis.

For further information on this subject refer to IEEE paper 81 TD 711-1 presented at IEEE PES 1981 Transmission and Distribution Conference and Exposition, Minneapolis, Minnesota, September 20 – 25, 1981.