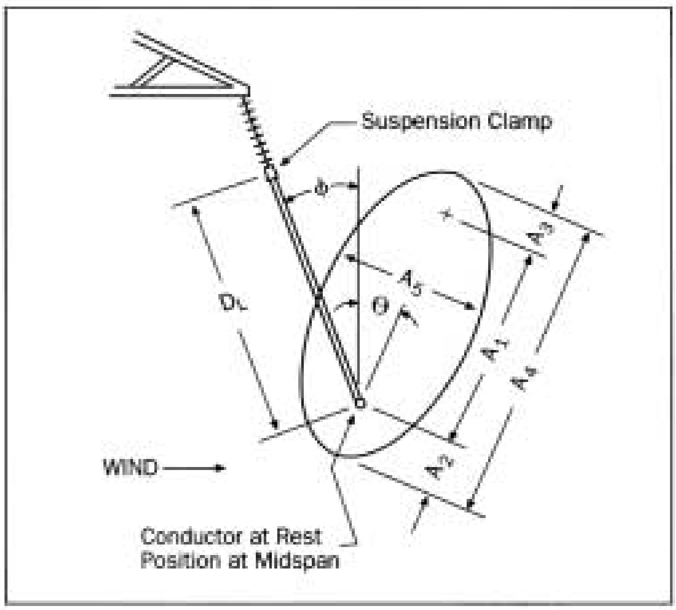
Dealing with Ice Galloping

Ice galloping occurs for transmission and distribution lines in many areas of the world. It occurs as the combined result of ice on the conductors and strong winds. While the resulting conductor motions are of relatively large amplitude, the main result of such motions is electrical not mechanical failure. Once ice forms on the conductor it usually adheres for the duration of the galloping motions until the wind eventually stops or the air temperature rises.

Various techniques have been suggested including the use of drag devices, reduction in sag, and inter-phase spacing insulators.

Davison of Ontario Hydro suggested the first effective means of control in 1939 [10]. He described the concept of providing sufficient phase-to-phase spacing when new lines are designed so that flashovers during galloping are prevented. Calculation of minimum required phase-to-phase spacing is done in terms of "galloping ellipses" based on observation of ice galloping occurrences.

Figure 1 - Ice Galloping Ellipse for Phase Spacing Calculations [3]



$A_1 = D_L$, the loaded sag

$A_2 = A_1/4$

$A_3 = 0.3$ m (1 foot)

$A_5 = 0.4\,A_4$

$\theta = \phi/2$

$\phi = \tan^{-1}\left(\frac{F_H}{w_c}\right)$

w_c = conductor weight, lb/ft

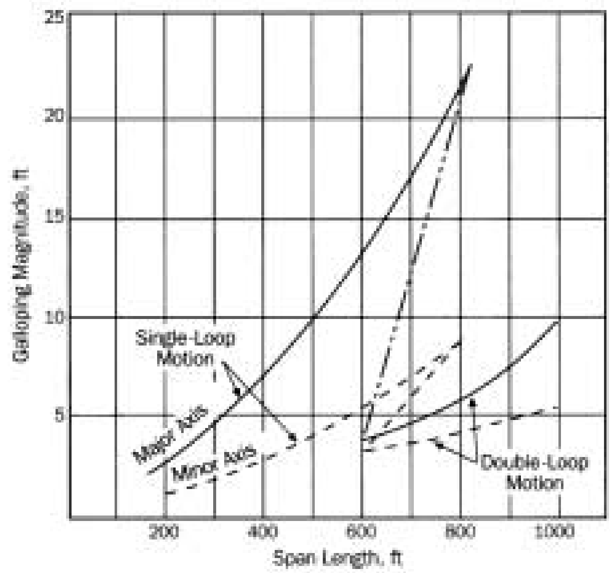
F_H = horizontal wind force, lb/ft

Courtesy Alcoa Conductor Products Company.

Other methods were developed in later years. A second effective means of galloping control resulted from the studies of galloping at MIT under Richardson in the early 1960s. This device, called the wind damper or drag damper, has been refined over the intervening years. A third effective means of control — the detuning pendulum — was developed at Ontario Hydro in the 1970s and became the object of an extensive field investigation by EPRI in the early 1980s. The effectiveness of this device is supported by a thorough statistical analysis of the field data. A fourth method of galloping control by means of either spoilers or VR conductor has also become available in recent years.

Ice galloping motions occur at one of the fundamental vertical string modes of the catenary — usually the first, second, or third mode. The amplitude of motion associated with the single loop mode is of primary concern, because the maximum amplitude of such motion can approach or even exceed the sag of the catenary. As the span length increases, the degree of rotation under ice load increases and the probability of lower order galloping motions increases. Thus, short spans (less than 600 ft) are more prone to single loop galloping than are long spans of the same conductor.

Figure 2 - Effect of Span Length on Ice Galloping Magnitude [12]



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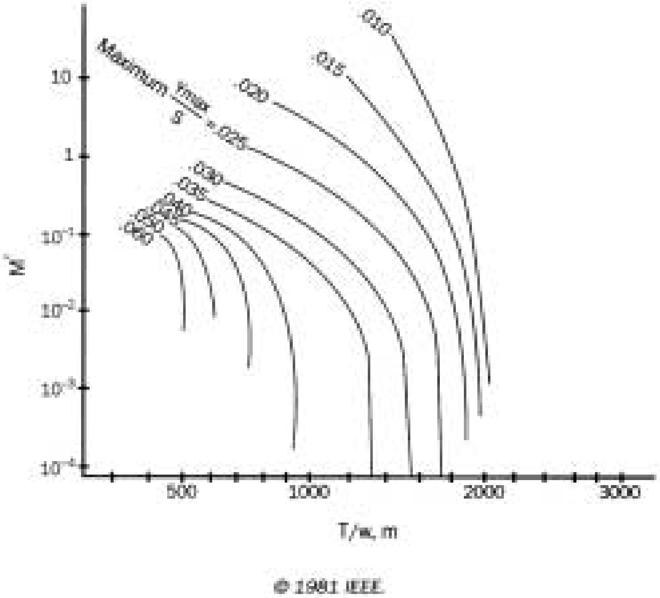
Field Observations of Galloping. There are several sources of field data, some formal and semi-quantitative, others informal and qualitative. Field data are available both for lines untreated by control devices and for lines treated with various control devices. The most comprehensive analysis of field data for untreated spans by Rawlins [13] concludes that the best parameters to determine whether lines will gallop or not and the amplitude of galloping, if it does occur, are *T/w* (conductor tension over conductor weight per unit length) and *M'* (a catenary parameter related to the type of span, suspension or strain, and to the unloaded conductor elastic strain). Rawlins studied galloping reports taken from a number of sources. All the field data dealt with untreated spans; i.e., none of the cases involved lines having anti-galloping devices or conductor. His purpose was to identify any parameters that could be used to identify spans prone to galloping.

- The maximum allowable *T/w* ratios, according to the NESC Code limits, to prevent Aeolian vibration fatigue are on the order of 2000 m (6000 ft).

Figure 3 - Ice Galloping Amplitude as a function of T/w and M’.



Line Design to Avoid Galloping Flashovers

No ice galloping control device is 100% effective under all conceivable weather conditions. Therefore it is more desirable to make changes in standard line design practices, if possible, to prevent ice galloping rather than trying to control it after the line is built.

From the analysis of Rawlins, it is apparent that the use of higher conductor unloaded tensions and the use of more rigid insulating attachments might be expected to reduce the amplitude of galloping. Unfortunately, either of these changes will increase static loading on any angle structures and thus increase their cost.

As an alternative to the use of higher conductor tensions, one might consider the use of vibration resistant T2 or SDC conductor. The use of VR conductor would increase the wind and ice loads about 10% above those of a standard conductor having the same total cross-sectional area. The VR conductor is at least as effective in preventing galloping as standard conductor with air-flow spoilers and there would be no problems with deterioration of PVC or with spoiler droop under high conductor operation.

Operation Procedures to Prevent Galloping

If, under icing conditions, the conductors were kept warm enough to prevent the formation of ice on the conductor, then galloping could not ensue. Alternatively, if galloping occurs, line loadings could be increased to melt the already- formed ice. This approach presents certain hazards and difficulties. Beside the dubious advisability of increasing the power flow on a line, which is likely to trip out, the high wind speeds typical of ice galloping make heating the conductor much above air temperature difficult. Operational solutions (other than taking the line out of service until the ice galloping stops) do not appear practical in most situations.