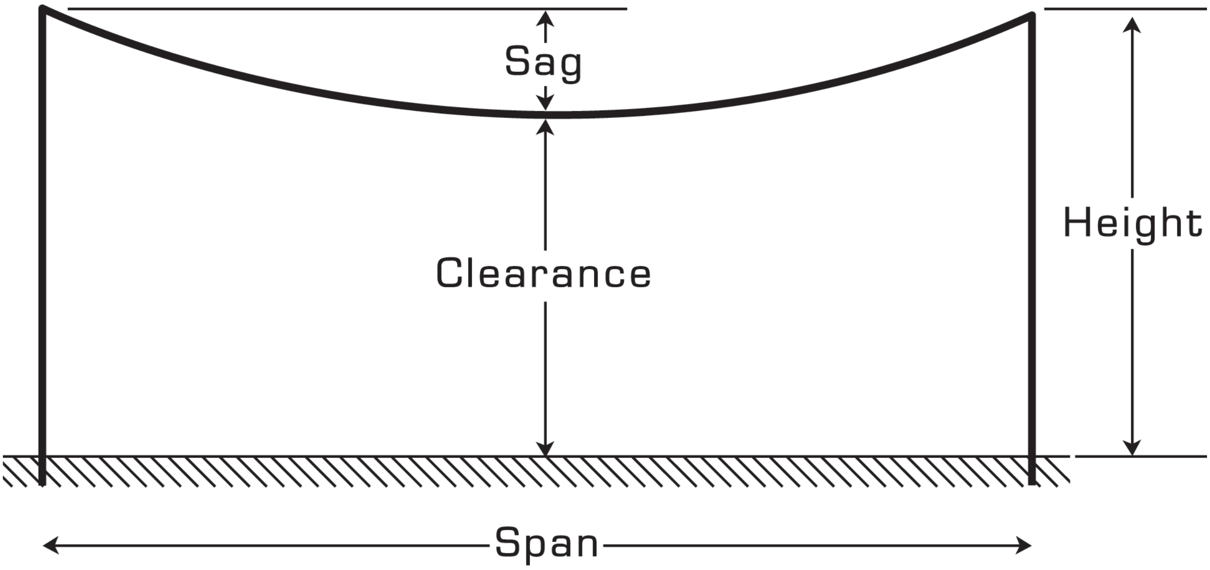
TECHNICAL DATA & GENERAL INFORMATION

An overhead conductor span is, mechanically speaking, a long flexible tension member supported at two points, and, being uniform in weight, it occupies a catenary curve (from the Latin "catenarius," meaning a chain). Such a span has some simple linear dimensions as shown below.

Figure A. Basic span Dimensions



Preliminary design is usually a matter of assigning values to the dimensions shown in Figure A.

The dimension usually established first is clearance, commonly controlled by code regulations or company standards.There remain three other dimensions, span, sag and height, which are determined by an economic consideration of optimum conductor size and material, maximum loading conditions and supporting structures. In such a study the conductor sags are calculated for a sufficient number of span lengths to secure a smooth curve, so that sags for any intermediate span length may be easily obtained. This accomplished, the unknow dimensions are quickly established since the choice of average span and sag and height are all interrelated. The Graphic Method for Sag-Tension Calculations is a system employing a series of correlated graphs to determine the sag and tension characteristics of an overhead conductor.

The first unique feature of this method consists of determining in a tensile testing machine, the change in length of a conductor and its components corresponding to a definite change in stress and from these data preparing a stress-strain curve. This procedure immediately removes all uncertainty regarding the correct value for the Modulus of Elasticity, which for stranded or composite conductors is always a variable and often a misunderstood quantity.

The second point of originality consists in representing graphically the effect of temperature change upon the Stress-Strain Curve of the conductor and then superimposing that curve upon another which gives the variations in sag and tension of a catenary span corresponding to the same changes of arc length as those given in the Stress-Strain Curve.

An adequate knowledge of some of the basic mechanical properties of metals is essential for a comprehensive understanding of the graphic method.

Most of the mechanical properties used for sag and tension calculations are determined by tensile testing. Tension test specimens vary with the form to be tested. For example, wires as used in the manufacture of transmission conductors are tested in full section. The loads determined in a tension test are reported as unit stresses based on the area of the original section.

$$\text{Stress} = \frac{\text{load}}{\text{area}}$$

Elongation is measured as increase in length of a gage-marked length. The elongation is then determined as

$$\frac{\text{final length - original length}}{\text{original length}}$$

Stress-Strain curves are prepared from the data obtained from these tests. From such a curve one can determine the Modulus of Elasticity, Proportional Limit, Yield Strength and Ultimate Tensile Strength.

Modulus of Elasticity. A typical initial stress-strain curve for wire has a straight line portion which in the deformation is proportional to the applied load.

$$\text{Then the unit stress } \frac{\text{load}}{\text{original area}} \text{ is proportional}$$

$$\text{to the unit strain } \frac{\text{deformation}}{\text{original gage length}}$$

The numerical value of this ratio (stress/strain), usually expressed in pounds per square inch, is known as **Modulus of Elasticity.** If a wire, as it comes from the mill, is subjected to any tension up to the working limit and if that load is than reduced, the stress-strain curve, upon the reduction of stress, will be a straight line parallel to the tangent to the original stress-strain curve at the origin. If the load is again applied, the elongation curve will lie exactly upon the previous curve obtained by decreasing the stress. If the application of load be carried beyond the maximum stress previously reached and then reduced, a new straight line will result parallel to the first, but displaced along the axis of elongation. This process can be repeated indefinitely up to the working limit.

From the above discussion, it becomes apparent that any wire which has once been stressed to a point within its working limit possesses a constant modulus of elasticity, provided the previous maximum stress is not exceeded.

In the foregoing statements, the discussion pertains only to single wires. The results are the same if a bundle of wires is used, provided the wires are all of the same length when the load is first applied and provided they do not slip with reference to each other as the test proceeds.

Because it is not practical to used a bundle of parallel wires in overhead lines, the wires are usually arranged in several helical layers. The wires of the outer layers are longer than the inner ones, but this difference in length is so small that difference in elongation of each wire from that of the conductor as a whole is negligible. This effect is kept within proper limits by making the lay of the conductor as long as possible.

In other methods of sag-tension calculations, it is customary to assume a certain fixed modulus of elasticity and a certain definite coefficient of expansion for the material under consideration.

Sags and tensions are then determined as resulting from an assumed change in temperature with or without a change in load per unit of length produced by ice or snow and wind.

Proportional Limit. The stress value at which the de-formation ceases to be proportional to the applied load is the **Proportional Limit.**

Elastic Limit. The maximum stress which can be applied without causing permanent deformation upon release of the load is the **Elastic Limit.**

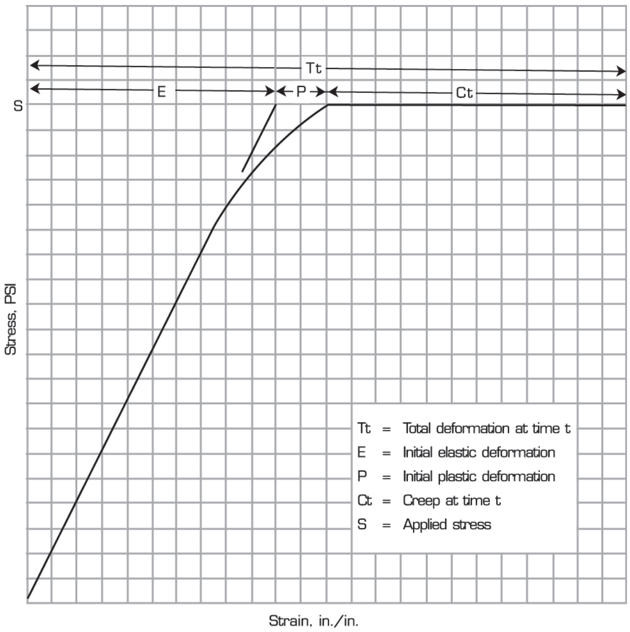
NOTE : Usually there is little difference between the proportional limit and the elastic limit. The values obtained for both are dependent on the sensitivity of the measuring devices and details of the testing methods.

Yield Strength. The stress at which the deformation ceases to be proportional to the applied load by a specified per cent elongation (usually 0.2 per cent) is the **Yield Strength.**

Ultimate Tensile Strength is the maximum tensile stress which a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross-sectional area of the specimen.

Creep. The flow or plastic deformation of material which occurs with time under load, and after the initial deformation which results from application of load is known as **Creep.** The initial deformation, in addition to including the elastic deformation, may include some initial plastic deformation depending upon the magnitude of the stress. This is illustrated in the stress-strain graph, ***Figure B***

Figure B



Working Limit. All metals have lower ultimate strength value when subjected to a fluctuating stress. The actual ultimate strength of all metals, when subjected to fluctuating stress, will be lower than that determined in regular tensile tests. The amount of decrease will depend upon the range of the fluctuating stress and the number of repetitions. As the limits of the fluctuating stress are reduced, the ratio of the breaking stress to the ultimate strength will be increased. This ratio will continue to increase as the fluctuation limits are narrowed. Research on this subject and years of experience in the design of transmission lines indicate that if the limits of variation in tensile stress are approximately ten per cent, the maximum value of the fluctuating stress necessary to produce fracture will be approximately 70 per cent of the ultimate strength This stress will be referred to in the following discussion as the **Working Limit.**

TEMPERATURE COEFFICIENT OF EXPANSION

The Aluminum Association Stress-Strain-Creep Curves, the.following values for temperature coefficients of expansion may be used for normal sag-tension computations. For ACSR conductors, the temperature coefficients of expansion listed computations. For ACSR conductors, the temperature coefficients of expansion listed apply only so long as the stress is borne by both the steel and aluminum strands.

Conductor	Stranding	Temperature Coefficient of Expansion			
		Initial/°F	Final/°F	Initial/°C	Final/°C
EC Aluminum	All	$12.8 \cdot 10^{-6}$	$12.8 \cdot 10^{-6}$	$23.0 \cdot 10^{-6}$	$23.0 \cdot 10^{-6}$
Steel	All	$6.4 \cdot 10^{-6}$	$6.4 \cdot 10^{-6}$	$11.5 \cdot 10^{-6}$	$11.5 \cdot 10^{-6}$
ACSR	6/1	$10.2 \cdot 10^{-6}$	$10.5 \cdot 10^{-6}$	$18.3 \cdot 10^{-6}$	$18.9 \cdot 10^{-6}$
ACSR	7/1	$9.5 \cdot 10^{-6}$	$9.8 \cdot 10^{-6}$	$17.1 \cdot 10^{-6}$	$17.7 \cdot 10^{-6}$
ACSR	18/1	$11.6 \cdot 10^{-6}$	$11.7 \cdot 10^{-6}$	$20.8 \cdot 10^{-6}$	$21.1 \cdot 10^{-6}$
ACSR	24/7	$10.5 \cdot 10^{-6}$	$10.8 \cdot 10^{-6}$	$18.9 \cdot 10^{-6}$	$19.5 \cdot 10^{-6}$
ACSR	26/7	$9.9 \cdot 10^{-6}$	$10.5 \cdot 10^{-6}$	$17.8 \cdot 10^{-6}$	$18.9 \cdot 10^{-6}$
ACSR	30/7	$9.5 \cdot 10^{-6}$	$9.9 \cdot 10^{-6}$	$17.0 \cdot 10^{-6}$	$17.8 \cdot 10^{-6}$
ACSR	45/7	$11.2 \cdot 10^{-6}$	$11.5 \cdot 10^{-6}$	$20.2 \cdot 10^{-6}$	$20.7 \cdot 10^{-6}$
ACSR	54/7	$10.2 \cdot 10^{-6}$	$10.7 \cdot 10^{-6}$	$18.3 \cdot 10^{-6}$	$19.3 \cdot 10^{-6}$
ACSR	54/19	$10.4 \cdot 10^{-6}$	$10.8 \cdot 10^{-6}$	$18.8 \cdot 10^{-6}$	$19.5 \cdot 10^{-6}$
ACSR	84/19	$11.2 \cdot 10^{-6}$	$11.5 \cdot 10^{-6}$	$20.1 \cdot 10^{-6}$	$20.6 \cdot 10^{-6}$