HIGH-TENSION TRANSMISSION LINES AND STEEL TOWERS

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(Continued from last week's issue.)

Unit Stresses.—Working stresses for the towers of a transmission line are to be used with loads that may actually occur at not infrequent intervals; there being no impact whatever. On the other hand, their maximum values are capable of being actually determined. Hence it is a little difficult to relate them intelligently to bridge stresses. Certain engineers feel that conservative unit stresses for towers are somewhat in the nature of an insurance or guarantee and that for lines not so important as trunk lines, higher stresses may justifiably be used. In this connection R. Fleming divides proposed towers into three classes, A, B and C, and allots unit stresses for each class, depending on their importance thus:—

Class A.—Towers for a line whose purchaser insists upon uninterrupted service, with heavy penalty clauses. Cases where failure of tower would mean probable loss of life, as in thickly populated regions.

Class B.—Towers for a line where certain interruptions are not inadmissible. Towers for a line through sparsely settled country.

Class C.—Towers that must be put up as cheaply as possible, independent of all other considerations.

He then gives the following unit stresses for open-hearth structural steel: Class A, 22,500 lbs. per square inch; Class B, 27,000 lbs. per square inch; Class C, no definite figure given, but the inference is that certain engineers assume that wind and ice-covered cables are not considered as occurring simultaneously, and the resulting loads are figured at 30,000 lbs. per square inch. He condemns this high figure as being too near the elastic limit, and does not commit himself as to the assumption.

Before this question of the unit stresses to be used can be finally settled, their relation to the test safety factor must be discussed briefly. It was noted in the preceding paragraph that many purchasers insist on test loads of double the actual calculated loads. If, for example, the tower under test belonged to Class B of Mr. Fleming's list, and the material were closely designed, the resulting stress in certain of the members would be 54,000 lbs. per square inch. This is much beyond the elastic limit and the tower would probably fail. If, however, instead of an arbitrary test factor of two, the purchaser would insist upon a test safety factor having for its magnitude the ratio between extreme elastic limit and unit stress desired (which should be conservative), and would at the same time stipulate that the maximum combination of loads must be used, the resulting towers would be in no danger of being weak or badly detailed, and rigid tests to elastic limit would be not only possible but would be welcomed by the manufacturer.

Adopting in the meantime Mr. Fleming's very reasonable classification of towers, the writer would recommend that the following unit stresses be used with the clear understanding that in each case the maximum for any combination of loads A, B and C be used:—

Class A, 20,000 lbs. per square inch; Class B, 25,000 lbs. per square inch; Class C, 30,000 lbs. per square inch.

The foregoing stresses are for tension, and the following formulæ, similar to the formulæ of D. G. Span, 1908, are recommended for use with struts in compression:

$$\text{Class A, } f = \frac{16{,}000}{1 + \frac{1}{24{,}000}\left(\frac{l}{r}\right)^2}$$

$$\text{Class B, } f = \frac{20{,}000}{1 + \frac{1}{24{,}000}\left(\frac{l}{r}\right)^2}$$

$$\text{Class C, } f = \frac{25{,}000}{1 + \frac{1}{24{,}000}\left(\frac{l}{r}\right)^2}$$

These formulæ are for rigid end connections. When one bolt (or pin) per end is employed use factor $\frac{1}{18{,}000}$.

Where f is unit stress to be used in lbs. per square inch.

The following ratios for $\frac{l}{r}$ are also recommended:—

Class A—For main member $\frac{l}{r}$ not more than 125; for bracing, carrying live load, $\frac{l}{r}$ not more than 175; for struts without load $\frac{l}{r}$ not more than 200.

Class B—For main members $\frac{l}{r}$ not more than 150.

Class C—for bracing $\frac{l}{r}$ not more than 200.

The foregoing recommendations enable the purchasers to have the following test safety factors. At first sight they seem small but they are thoroughly rational and in consequence of the relation between unit stresses and assumed elastic limit, these factors may be applied rigidly, and with full confidence:—

Class A, 1.80; Class B, 1.44; Class C, 1.20.

NOTE:—These safety factors should be applied to the maximum combination of all possible loads.

Conductors and Wires.—(*a*) Conductors are in general of three different kinds—(1) copper, (2) aluminium, (3) steel reinforced aluminium. The latter two are the ones frequently used in transmission lines to-day owing to the high price of copper. A cable often used by the Montreal Light, Heat & Power Co. for high-tension service consists of a steel stranded core of 78,500 c.m. and a stranded aluminium sheath of 336,420 c.m., with a total diameter of about 0.74. As mentioned above, this paper does not intend to do more than touch upon those purely electrical features that may need, however, to be mentioned in passing.

(*b*) *Ground Wires*: These wires may be of either stranded or solid steel and are about ½ in. in diameter. Those engineers who place reliance in the capacity of these ground cables to save the line from lightning, usually assume that they protect all conductors underneath and within 45° lines. It may be interesting in regard to their serviceability to read "Lightning Rods and Grounded Cables as Means of Protecting Transmission Lines Against Lightning," by Norman Row,* and the subsequent discussion. Ground cables should be grounded thoroughly at each tower.

(*c*) *Stresses and Sags*: The stresses and sags in any of these conductors may be found from the well-known equations which are presented in very clear form in an article entitled "Mechanical Stresses in Transmission Lines," by A. Guell, Bulletin 54, University of Illinois, Eng. Exp. Station.

A very simple group of sag and tension equations is given by Kenneth Wilkinson in a paper entitled "Sag in Overhead Conductors," which appeared in the "Electrical World" for February 6th, 1915.

*Trans. Am. Inst. E.E., vol. XXVI., Pt. 2, p. 1239.