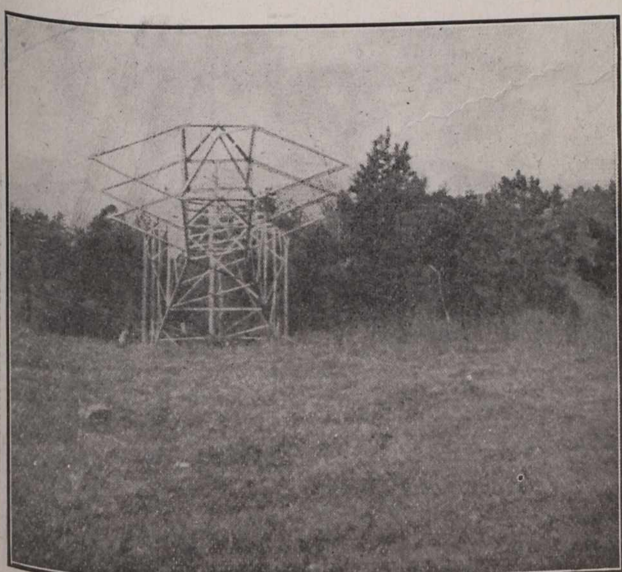
As transmission lines extend for hundreds of miles and are composed of thousands of towers, the question of the amount of strength to put into these towers is a most important consideration. It is necessary to make them strong enough to guarantee continuous service, at the same time care should be taken to avoid extravagance. As before stated, intermediate towers are essentially supporting towers, having the wires led to them and passing on to the next towers, exerting no force except vertical dead weight, ice, etc., in addition to the transverse wind. The longitudinal pull of the wires on one side of the tower is equalized by the longitudinal pull of the wires on the other side, and thus equilibrium will be maintained until a wire breaks. When this occurs that particular wire in the one span falls, but in the next adjoining span the wire is still being held up by the tower, owing to its connection to the insulator. This latter wire still exerts its longitudinal pull, and, as the broken span is unable to exert its equal and opposite pull, the tower is called upon to do it, consequently exerting a definite longitudinal pull thereon.

Although wires for high tension lines are carefully strung, being kept well within their elastic limit and with substantial connection to the towers, a break is apt to occur at any time, but to have two or more wires breaking simultaneously in the same location is a very remote possibility.



Erecting Towers.

Engineers have not fully agreed upon the number of wires to allow for breaking in the same span, but the minimum amount of strength in an intermediate tower should be with all wires covered with ice, the highest velocity of wind, and provision for any one wire breaking.

Terminal towers are different from intermediate towers in that they are called upon to do much heavier work. They are designed for wind and ice and the combined pull of all wires, simultaneously or separately, without any relief of the adjoining span. These are used at the end of the transmission lines, at points where branch lines are taken off, and very often are placed along the line at certain intervals; that is, about every mile is inserted a terminal tower instead of an intermediate tower.

Angle towers are again different from either of the foregoing. Transmission lines are run straight as much as possible, or run with easy curves, but at some points sharp bends are unavoidable. At these bends or angles, special towers are used of sufficient strength to resist the continuous pull of the resultant forces of the converging lines, and in addition must be provided with longer arms to maintain the proper spacing of the wires, and sometimes with auxiliary arms to properly support the wires as they make the turn.

Transposition towers are used at certain intervals for transposing the relative position of the wires. This transposition is done by twisting or turning the entire group after they leave the intermediate tower and leading the wires to the arms of the transposition tower, so named, in that it has specially long arms, in order to spread the wires and avoid the danger of conflicting with each other in the turn or twist of the group.

Other features in tower equipment are extensions for use on steep, sloping ground, guard-arms for supporting protecting wires over highways, telephone wire supports, etc. Then, again, there are especially narrow towers, or rather poles, where they go through city or town streets, and also high towers for river crossings.

Character, Number and Position of Wires.

The character and number of conductors are determined by the electrical engineer; whether he is to use copper or aluminum, and the size of same. He is to determine whether the line will be of three-phase single circuit or three-phase double circuit. In the first case three wires are required, in the second six wires. He also is to determine whether a ground wire is required, and whether the insulators are to be of the pin or hung type. The tower engineer usually has the liberty of deciding on the position or location of the insulators to best suit his particular design.

Forces.—Height and Design.

The forces on a tower are divided into two classes: those acting directly on the tower and those acting indirectly by means of the wires. The direct forces can very easily be obtained, in that they comprise the wind pressure on the tower and the dead weight of the tower itself, sometimes covered with ice. The indirect forces are the weight of the wires and insulators, the ice or sleet coating, the wind pressure on the wires and the longitudinal pull of one or more wires. Ice will vary from almost nothing to 1 in. thick and the wind pressure from 20 to 50 pounds per square foot, all depending on locality. The longitudinal pull cannot exceed the amount that the wire is good for working up to the elastic limit. All of these forces must be taken into consideration, acting separately or simultaneously. The direct forces will not exert any eccentric or torsional action on the tower, but the indirect forces are very liable to.

The height at the tower of the lowest wire is determined by three conditions: the size and material of the wire, the span between the tower and the minimum clearance distance from the ground to the lowest position of the wire. Assuming a certain span, the wires must be so strung and given such a sag that in the coldest weather, when the wires reach their minimum sag, the tension stress will be within the elastic limit of the wires. The sag will fall and rise, due to the linear expansion or contraction from temperature changes. As above stated, the sag will be smallest in cold weather, and as the temperature increases the sag increases, but this increase is largely retarded by the property of the wires shrinking as the tension stresses decrease. In other words, the minimum sag will put the greatest tension stress in the wires, and this stress must be kept within the elastic limit. From this is figured the maximum sag made to correspond with the maximum change of temperature, corrected by the shrinkage from reduction of stress. The minimum clearance from the ground to the lowest point of the lowest wire is determined very often by law or other requirements, but it usually runs from 20 to 30 feet. This distance, added to the maximum calculated sag, will give the height at the tower.