the height, but also upon the stresses which the tower has to withstand. These again will be dependent upon the size of the wires, the length of span, and the weather conditions. It is probable that, with an increase in height the cost increases less rapidly than the square of the overall length, but for approximate calculations it is convenient to assume the relation cost varies as H^2. Also, if the weight of a tower measuring 60 ft. overall is taken at 1,800 lb., and the price per pound of the finished (galvanized) tower at 5c.,* the cost per tower in dollars is

$$\frac{H^2}{40}. \qquad (2)$$

The cost of the flexible type of tower is appreciably less, being about seven-tenths of the cost of the rigid type with square base, or

$$\frac{H^2}{57}. \qquad (3)$$

It is, however, usual to provide rigid strain towers in place of the flexible type at, say, every mile, and as the cost of such structures is about double the cost of the flexible tower, the cost of supports per mile of line may be calculated by assuming $n + 1$ flexible structure per mile, when the actual spacing is n to the mile.

Duplicate Lines.—A point of great importance in connection with power transmission undertaking is the means adopted to guard against interruption of supply. If it is allowed that the least reliable part of a transmission system is the line itself, it is certainly advisable, when circumstances permit, to duplicate the lines; the two sets of conductors being connected in parallel under normal conditions. The best protection against interruption would be afforded by carrying the two sets of conductors on separate poles, preferably by different routes; but this would almost double the cost of the line, and it is usual to carry duplicate lines either on one set of poles, or on two sets of poles erected side by side on the same right-of-way. As an alternative to the duplication of the lines, the provision of reserve generating plant at the receiving end may be considered, and a comparison should be made between the relative advantages and costs of the various alternatives.

A good example of steam-driven auxiliary plant in connection with hydro-electric power stations, is the recently completed oil-burning steam-generating station of the Southern California Edison Co., situated 25 miles from the city of Los Angeles and capable of connecting in parallel with the 60,000-volt and 30,000-volt systems ordinarily supplied by the Kern River and other hydro-electric generating stations of this company.

Costs of Typical Transmission Lines.—It would be possible to give a large number of figures relating to material and labor costs of completed transmission lines; but the conditions of transport of materials and quality of labor differ widely, and without complete knowledge of these conditions, such figures are liable to be misleading. For this reason two ideal preliminary estimates, one referring to a wood pole line, and the other to a steel line, are here reproduced, in the hope that they may be useful as a basis on which somewhat similar estimates may be shaped.

Preliminary Estimate No. 1.—Wood pole transmission line, 20 miles long, carrying one three-phase line. Line pressure 22,000 volts. Span 130 ft. There is no grounded overhead guard wire; but two telephone wires are carried on the same set of poles. An allowance of 20 per cent. is made for extra insulators and fixtures to permit of doubling these on corner poles and in other selected positions.

*This cost may be anywhere between 3½ and 6c. per pound.

Preliminary Estimate No. 1.

Materials (Excluding Conductors)			
40 creosoted cedar poles, 35 ft. long, 8 in. diam. at top	$400.00		
48 cross-arms, 3½ by 4½ in. by 4 ft. long	14.50		
96 galvanized-iron braces, 1¼ by ¼ by 28 in. long	9.00		
32 galvanized bolts, ⅝ by 12½ in., with washers }			
8 galvanized bolts, ⅝ by 16 in., with washers }			
16 galvanized spacing rods, ¾ by 16 in., with nuts and washers }	7.50		
48 galvanized lag screws, ½ by 3½ in. }			
96 galvanized carriage bolts, ⅜ by 4½ in. }			
1500 ft. galvanized 7-strand 5/16 in. guy wire	12.00		
12 anchor rods with nuts and washers and necessary timber for	7.00		
anchor logs	3.00		
24 galvanized guy clamps with bolts			
8 galvanized sheet-iron bands to prevent cutting of poles by	0.50		
guy wire	0.40		
12 standard thimbles for guy wire	5.50		
20 galvanized-iron lightning conductors, with bolts	8.00		
20 ground plates or galvanized-iron pipes			
Staples and sundries, including allowance for breakages and	15.00		
contingencies }			
80 telephone wire insulators (glass) }	10.00		
80 side brackets for same (wood); 5-in. wire nails }			
144 H.T. porcelain insulators	36.00		
96 galvanized-iron insulator pins with porcelain bases	14.40		
48 special pole-top insulator pins, with bolts	19.20		
Total material cost per mile of line		$562.00	
Labor			
Clearing 50 ft. on each side of pole line @ $30 per acre	363.00		
Distributing poles and other materials along the line	30.00		
Trimming poles, cutting gains, drilling holes, setting cross-arms	30.00		
Digging holes and erecting poles, including the necessary guying	80.00		
Fixing insulators and stringing wires, including telephone line	90.00		
Supervision and sundry small labor items	30.00		
Loss and depreciation of tools	10.00		
Management and preliminary work	25.00		
Total cost per mile for charges other than materials		$658.00	
Total cost per mile, excluding cost of conductor material			$1220.00
Conductors			
16,000 ft. No. 1 copper conductors (hard-drawn); 700 ft. No. 4 copper for ties (soft); 10,800 ft. No. 10 copper for telephone circuit; 4550 lb. @ $15 per 100 lb.			682.50
Total cost of finished line			$1902.50

Preliminary Estimate No. 2.—"Flexible" type steel tower line, 60 miles long, with two sets of three-phase conductors. Line pressure = 80,000 volts. Average span, 480 ft. Spacing between wires, 8½ ft. A Siemens-Martin steel cable, acting as grounded guard wire, joins the tops of all towers. Insulators of the suspension type. No telephone wires. Minimum clearance between lowest H.T. conductor and ground = 40 ft. Cost of right-of-way not included in estimate.

Preliminary Estimate No. 2.

Materials (Excluding Conductors)			
10 flexible type, galvanized-steel, A-frame towers @ $85	$850.00		
1 galvanized-steel strain tower	170.00		
concrete foundations where necessary	80.00		
5600 ft. 7/16 in. galvanized Siemens-Martin steel-strand cable for guard wire and head guys on half-mile flexible towers	128.00		
4 anchor rods, complete with clamps and thimbles for guy wire	4.00		
90 sets of suspension-type insulators, including strain insulators and small allowance for breakages, complete with clamps	338.00		
Sundry small items or special material	50.00		
Total material cost per mile of line		$1620.00	
Labor			
Clearing 60 ft. on each side of line at average cost of $25 per acre	$363.00		
Distributing towers and other materials along the line	100.00		
Foundations for towers	75.00		
Assembly of parts and erection of towers	160.00		
Fixing insulators and stringing wires	170.00		
Supervision and sundry small labor items	50.00		
Allowance for loss and depreciation of tools	15.00		
Allowance for management and preliminary work	35.00		
Total charges other than materials per mile		968.00	
Total cost per mile not including conductor material			$2588.00
Conductors			
No. 00, hard-drawn, stranded-copper conductors; small amount of No. 2 soft copper for occasional ties; special clamps, shields, jointing materials, etc.; 13,350 lb. @ $15 per 100 lb.			2002.00
Total cost per mile of finished line, not including right-of-way			$4590.00

The cost of insulators increases rapidly with the rise of the working voltage. The curve of Fig. 1 gives approximate average prices of insulators complete with pins or suspension links for pressures up to 100,000 volts. The prices are per insulator or per series of insulator units. The suspension type of insulator consisting of a number of units in series is almost universally used for pressures exceeding 60,000 volts. One golden rule which applies to all overhead transmissions is that it is false economy to reduce first cost by putting in cheap and possibly unreliable insulators. The curves of Fig. 2 are intended to supplement the figures of the typical estimates. They give approximate costs of transmission poles or towers, with and without in