LINES AND CABLES

Practically every road in Ohio carries its high-tension lines on the poles supporting the trolley wires and direct-current feeders. In other words, there are few separate transmission lines except in several instances cross-country lines have been built to provide short cuts from power stations to sub-stations. In the case of the Toledo Urban & Interurban, which was equipped with high-tension transmission several years after its original road was built, on some sections separate poles have been erected for the high tension. Poles are uniformly 35 ft. or 40 ft., except in a number of instances where poles of 50 ft. and 60 ft. were employed to carry the high-tension wires over the tops of trees. Roads following highways and passing through villages in Ohio have been greatly troubled by the presence of trees, which, as a rule, owners were unwilling to have trimmed. There are a number of instances where pole lines were carried to the rear of lots in order to avoid trees, and nearly every road has one or two places in which it was obliged to carry its transmission lines to the rear of towns in order to avoid the trees and accommodate the ideas of village authorities.

Methods of arranging and attaching high-tension wires to poles have furnished another subject for wide discussion among engineers, but it may be stated that notions which were prevalent a few years ago are now being dispelled and the various roads are coming nearer to a standard on their transmission lines. This, of course, is largely the result of combinations of interest and the necessity for putting various lines together.

For example, one prominent engineer provided in his specifications that there should be no iron of any kind at the tops of the poles, all pins, bolts and braces being of hardwood. In later construction on this same road this idea has been modified, as it was found that such precautions were unnecessary, and that the line was not as strong as where metal was used more freely. Up to two or three years ago the majority of engineers held firmly to the belief that three-phase transmission lines should be arranged in an equilateral triangle and that they should be transposed at regular intervals. The majority of Ohio operating men now believe that these two ideas were the result of too much theory and not enough practice. The latest transmission lines are attached to cross-arms, according to the arrangement which is most convenient, and there is no transposition of wires. While the triangular arrangement is still used, it is largely the result of the desirability of using two sets of transmission lines, and two cross-arms are employed, one, shorter than the other, carrying two insulators on its ends, and the other carrying four insulators. On some of the roads the longer arm is placed above, while in others the opposite arrangement is followed.

On the matter of spacing circuits, however, one point is becoming impressed on roads using the higher voltages, and that is that there should be ample space between the wires to avoid short circuits and jumping across in case of overloads. The Western Ohio, for example, formerly had 32 ins. between wires for 33,000 volts transmission. It is now spreading these, and, at the same time, strengthening its construction, using 10-ft. arms for four pins and 8-ft. arms for two pins and providing for a minimum distance between wires of 36 ins. Pins are 15 ins. long instead of 10 ins., as formerly used. The Fort Wayne, Van Wert & Lima and the Toledo & Lima follow this practice quite closely in their new work. The Cleveland Construction Company, which is building several new lines, is providing for a spacing of 42 ins. between wires, and it uses 16-in. pins boiled in carbo-linium. It might be stated here that wood pins are almost universally used.

The idea of placing one pin on the top of the pole and the other two on a cross-arm below it where but a single transmission line is provided for, is losing favor among some of the best engineers. The pin and insulator on the top of the pole almost invariably gives more trouble than the other two. There are, of course, several methods of attaching this pin. The Toledo, Port Clinton & Lakeside uses a metal ridge pin with four heavy lag screws, which is undoubtedly a strong form of construction. On the Cincinnati, Milford & Loveland and several other roads a wood block is attached to the side of the pole and the pin is batted to this. On a number of roads the top of the pole is drilled and the pin set in. The objection found to this is that moisture gathers in the hole and the pole rots in the center. On several roads this has been partially overcome by boring "weep" holes for the moisture to drain out and by placing porcelain plates around the top of the pole, but after trying these various devices there are a number of prominent engineers who believe it is best to get the insulator off from the top of the pole and place all these wires on a single cross-arm. This has been done on recent construction work on the Western Ohio and the Toledo & Indiana, using one insulator on one side of the pole and two on the other. The Cleveland & Southwestern on some recent work used two short cross-arms with an insulator on the end of each, the fourth insulator being for a spare wire which is used in case of breakage to any of the other three. Tell-tale devices in the sub-stations tell which wires are dead, and the spare wire can be thrown instantly into service in case of accident. This device has saved a tie-up on several occasions. A variation from usual forms of cross-arm braces was used in this work, a triangular shaped block of wood soaked in carbolineum to prevent cracking, being used instead of metal braces, which had given trouble.

Copper lines are used by the great majority of roads, although considerable aluminum has been used during the past two or three years. During the past twelve months, however, builders of roads have been unable to secure proposals from manufacturers of aluminum wire because they are too busy with other work, hence it is not being used on roads under construction. One of the chief advantages found for aluminum is that sleet does not stick to it, in spite of the larger area of surface, and aluminum lines have gone through the most severe sleet storms without interruption, where copper lines have broken down in many places. The lower fusing point of aluminum, as compared with copper, and its liability to break when coming in contact with electric light or telephone wires, are, of course, disadvantages which perhaps more than compensate for the advantage mentioned. At times when copper has been high in price aluminum has been considerably lower for the same carrying capacity, and, as a rule, it is always a trifle lower in price, the price being based upon the price of copper. On long spans, aluminum has been known to stretch considerably when first erected, but one of the advantages frequently pointed out for aluminum is that the manufacturers have always insisted upon inspecting all erection work, requiring that the feeders be strung at the proper tension and in the most substantial manner possible.

The Scioto Valley Traction Company uses seven-strand aluminum of No. 2 capacity for its lines, and has had excellent results. The Western Ohio, Lake Shore Electric and Cleveland & Southwestern have secured very satisfactory results from aluminum.

Lines of No. 4 capacity are used by the majority of roads of medium length, while the roads with heavier equipment, longer transmission and higher voltages use a larger conductor.

The Canton-Akron Company's system is about equally divided between No. 2, No. 4 and No. 6, starting out of the house with the larger conductor and tapering down to the smaller at the ends. The Western Ohio uses No. 2 and No. 4, with the same arrangements. The Lake Shore Electric has all No. 2, in order to render it possible to run all the sub-stations from one power house if necessary, necessitating a transmission of about 100 miles. The Fort Wayne, Van Wert & Lima has No. 2 throughout, and there seems to be a tendency among other roads to adopt this on extensions and new lines, in order to secure ample capacity to handle the road from some other station in case the usual base of supply is interrupted.

Glass insulators are being used by several roads with the medium voltages of from 12,000 to 16,500, but the roads using the higher voltages of from 20,000 to 33,000 seem to prefer porcelain insulators, the usual size being 7 ins. The Lake Shore Electric, with 16,500, uses 7-in. glass with most satisfactory results, while the Cleveland & Southwestern has a num-

TABLE VII.—SUMMARY OF PRACTICE IN HIGH TENSION TRANSMISSION LINES ON ROADS TREATED.

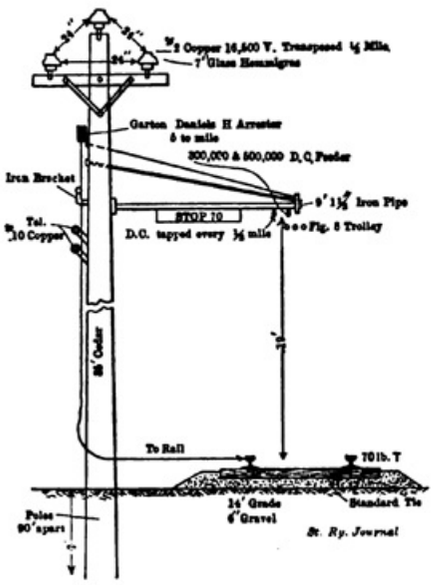
NAMES OF COMPANIES.	Voltage on Transmission Line.	Number of Circuits.	Material of Line.	Size of Conductors.	Length of Transmission Poles in Ft.	Distance Apart of Transmission Poles in Ft.	Diameter Transmission Poles at Top in Ins.	Arrangement of Circuits.
NORTHERN OHIO GROUP.								
Cleveland & Southwestern	24,000	3	Copper and aluminum	No. 4	35	100	8	Triangle.
Lake Shore Electric	16,500	2	Copper and aluminum	No. 2	35	90	7	Triangle.
Eastern Ohio	13,000	1	Copper	No. 4	35	100	7	Flat.
Toledo & Indiana	13,500	1	Copper	No. 4	35	100	7	Flat.
Toledo & Western	13,500	1	Copper	No. 4	35	100	6	Triangle.
Toledo, Pt. Clinton & Lakeside	20,000	2	Copper	No. 4	35	100	7	Triangle.
Stark Electric	22,000	2	Copper	No. 4	35	100	6	Triangle.
Canton-Akron	13,200	3	Aluminum and copper	Nos. 2, 4, 6	35	100	9	Triangle.
CENTRAL AND SOUTHERN OHIO GROUP								
Western Ohio	33,000	3	Aluminum and copper	Nos. 2, 4	40	100	7	Flat.
Ft. Wayne, Van Wert & Lima	33,000	1	Copper	No. 2	40	100	7	Flat.
Dayton & Troy	.....	..	.....	.....	..	...	..	
Dayton, Covington & Piqua	.....	..	.....	.....	..	...	..	
Scioto Valley	27,000	2	Stranded aluminum	No. 2	40	100	8	Triangle.
Cincinnati & Columbus	33,000	1	Copper	No. 4	40	100	8	Triangle.
Cincinnati, Milford & Loveland	16,500	2	Copper	No. 4	35	100	6	Triangle.
Interurban Ry. & T. Cincinnati	10,000	2	Copper	No. 4	40	100	8	Triangle.
Cincinnati, Georgetown & Portsmouth	15,000	2	Insulated copper	No. 4	35	100	7	Triangle.
INDIANA GROUP.								
*Indiana Union	15,000 and 30,000	6	Copper	Nos. 3, 5	40	100	7	2 triangular, 1 flat.
Indianapolis & Northwestern	30,000	3	Phosphor bronze	No. 4	36	100	6	Triangular.
Indianapolis & Cincinnati	33,000	5	Copper	No. 4	35	100 and 120	8	Two-phase flat.
Indianapolis, Columbus & Southern	15,000	1	Aluminum	No. 0, copper equivalent	35	100	8	Triangular.
Terre Haute Tr. & Lgt	11,000 and 22,000	2	Aluminum and copper	No. 4	40	100	..	Triangular.
Kokomo, Marion & Western	11,000	1	Aluminum	No. 2	40	100	6	Triangular.
Ft. Wayne & Wabash Valley	16,500 and 13,200	3	Copper	No. 2	40	100	7	Triangular.
MICHIGAN GROUP.								
Rapid Railway System, Detroit	16,500	2	Copper	No. 1	40 to 60	...	7	Triangular.
Detroit, Ypsilanti, A. A. & J	22,000	3	Copper	Nos. 3, 4	40	...	8 to 10	Triangular.

* Union Traction Company of Indiana and Indianapolis Northern Traction Company only considered.

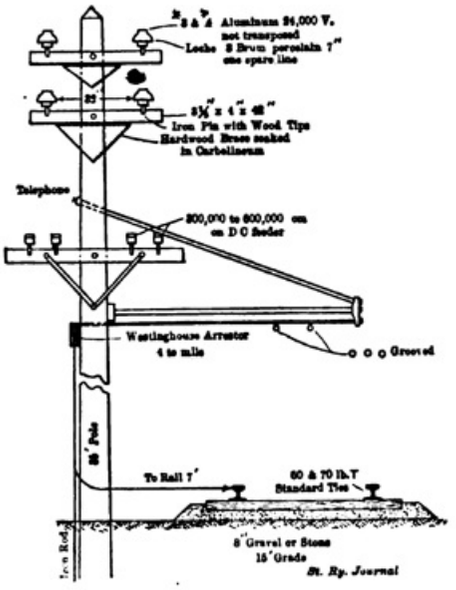
TABLE VII.—SUMMARY OF PRACTICE IN HIGH TENSION TRANSMISSION LINES ON ROADS TREATED.—*Concluded.*

NAMES OF COMPANIES.	Distance Between Wires of Circuit in Ins.	How Often Are Wires Transposed.	Type of High-tension Insulators.	How Are Insulators Attached to Cross Arms.	How is High-tension Line Protected Against Lightning.
NORTHERN OHIO GROUP.					
Cleveland & Southwestern	32	Not transposed	7-in. porcelain, 8-in. glass	Wood pins	Arresters.
Lake Shore Electric	24	Every mile	7-in. glass	Wood pins	Arresters.
Eastern Ohio	24	.....	7-in. porcelain	Wood pins	Arresters.
Toledo & Indiana	18	Not transposed	7-in. glass	Wood pins	Arresters.
Toledo & Western	24	Twice on road	5-in. white porcelain, 7-in. glass	Wood pins	Arresters.
Toledo, Pt. Clinton & Lakeside	28 and 30	Every 3d mile	7-in. porcelain	Wood pins	Arresters.
Stark Electric	24	.....	6-in. porcelain	Wood pins	Arresters.
Canton-Akron	26	.....	6-in. glass	Wood pins	Arresters.
CENTRAL AND SOUTHERN OHIO GROUP					
Western Ohio	36	Not transposed	7-in. porcelain	Wood pins	Arresters.
Ft. Wayne, Van Wert & Lima	36	Not transposed	8-in. porcelain	Wood pins	Arresters.
Dayton & Troy	..	.....	.....	.....	
Dayton, Covington & Piqua	..	.....	.....	.....	
Scioto Valley	30	2 miles	8-in. porcelain	Wood pins	Arresters.
Cincinnati & Columbus	..	.....	8-in. porcelain	Wood pins	Arresters.
Cincinnati, Milford & Loveland	24	3½ miles	7-in. porcelain	Wood pins	Arresters.
Interurban Ry. & T. Cincinnati	28	.....	7-in. porcelain	Iron pins	Arresters.
Cincinnati, Georgetown & Portsmouth	28	.....	7-in. porcelain	Iron pins	Arresters.
INDIANA GROUP.					
*Indiana Union	35	Every mile	7½-in., 9-in. glass	11½-in. locust pins	Arresters.
Indianapolis & Northwestern	36	Not transposed	Brown porcelain	.....	Arresters.
Indianapolis & Cincinnati	36	Not transposed	Brown porcelain	Iron pins and stud bolts	Arresters.
Indianapolis, Columbus & Southern	19 and 30	Not transposed	Glass insulators	Wood pins	Arresters.
Terre Haute Tr. & Lgt	..	Every 90 poles	Porcelain	Wood pins	Arresters.
Kokomo, Marion & Western	40	.....	5-in. porcelain	11½-in. locust pins	Arresters.
Ft. Wayne & Wabash Valley	30	Every mile	Porcelain	Locust pins	Arresters.
MICHIGAN GROUP.					
Rapid Railway System, Detroit	31	Not transposed	Porcelain	Iron pins	Fuse arresters in power house, sub-stations and other points where there is competent attendance.
Detroit, Ypsilanti, A. A. & J	18	Not transposed	Replacing glass with porcelain	Wood pins	Arresters.

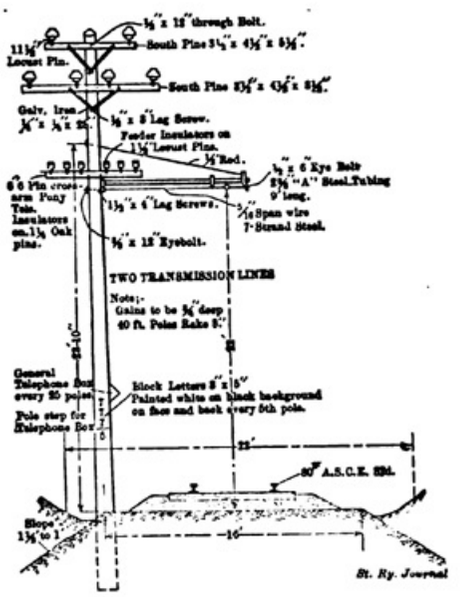
* Union Traction Company of Indiana and Indianapolis Northern Traction Company only considered.



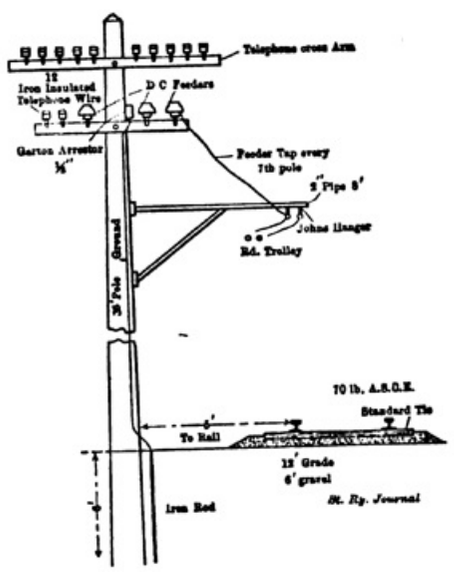
Lake Shore Electric



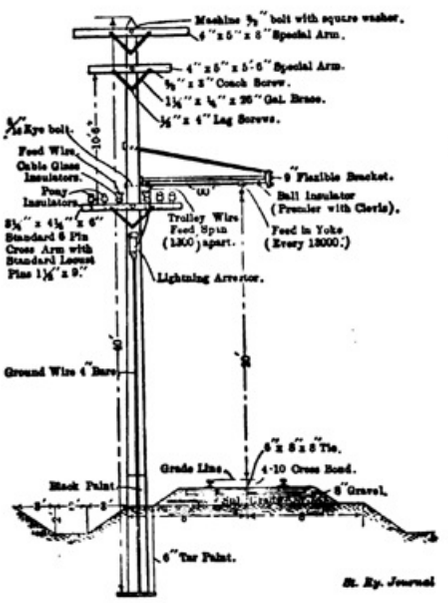
Cleveland & Southwestern



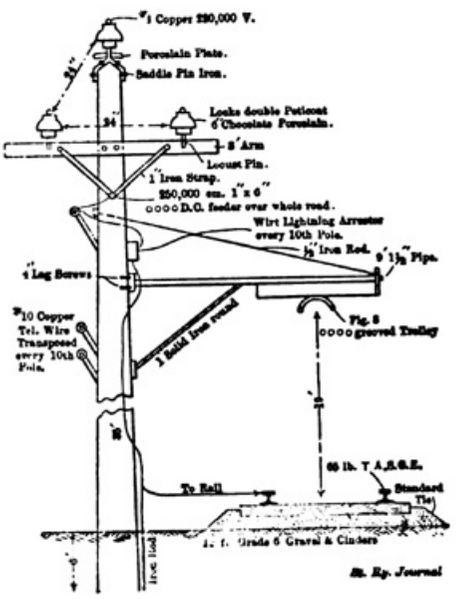
Indianapolis Northern Traction



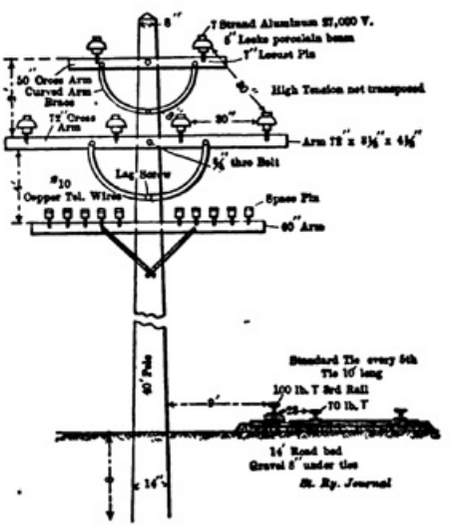
Dayton, Covington & Piqua



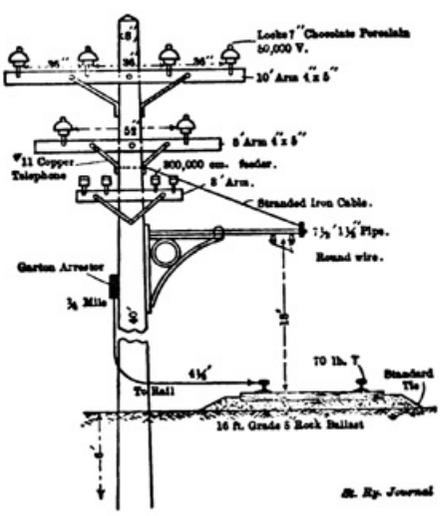
Fort Wayne & Wabash Valley



Stark Electric



Scioto Valley



Western Ohio

TYPES OF STANDARD OVERHEAD AND TRACK CONSTRUCTION

ber of stretches of 8-in. glass insulators, which are giving excellent service. The Toledo Urban & Interurban and the Cincinnati & Columbus, with their 33,000-volt transmission lines, use 8-in. x 8-in. porcelain insulators designed for 90,000 volts, and the tendency is in this direction.

Considerable interest is being displayed in high-tension lightning arresters placed on poles, but as yet they have not been adopted by any of the roads in the district. The Detroit, Monroe & Toledo and Toledo Urban & Interurban string a galvanized iron barbed wire at the top of the pole and ground it at every tenth pole, which is said to be an excellent protection against lightning. Other engineers who have considered this scheme say that while it may be some protection, the comparatively short life of galvanized iron wire, as compared with copper wire, is likely to cause a great deal of trouble when the barbed wire commences to rust through and break, falling on the high-tension lines.

The majority of roads are now taking unusual precautions to protect their wires against telegraph wires at railroad crossings. In a number of places cradles have been erected below the transmission wires so that they cannot fall onto the telegraph wires. At one undergrade crossing, the Toledo & Western has insulated its high-tension lines and carries them under the crossing. The Dayton & Muncie in one place has erected 100-ft. lattice iron poles to carry the high tension over telegraph wires. At Lorain, crossing a navigable stream where vessels with tall masts frequently pass, the Lake Shore Electric has erected two 350-ft. towers and passes the wires over with a thousand-foot span, stranded aluminum wire being used.

In the other States visited copper is used for high-tension conductors in the majority of cases. Aluminum conductors are used by three systems, and in one instance the conductors are of phosphor-bronze. High-tension conductors vary in size from 1-0 copper equivalent to No. 5. The smallest size is used on the older portion of the Indiana Union Traction Company. On this system the two sub-stations between Anderson and Indianapolis are fed by one line, consisting of No. 5 copper conductors. Each of the sub-stations contain two 250-kw rotaries, and one is 13 miles and the other 24½ miles distant from the power station. On practically all of the new work of this system the high-tension wires are of No. 3 copper. On all the systems visited, with the exception of the Indianapolis & Cincinnati Traction Company, the high-tension circuits are carried on the trolley poles. On this system, however, a second and separate pole line, placed on the opposite side of track from the trolley poles, is used. The majority of the systems use transmission poles 40 ft. long. The size, however, varies greatly, as poles with tops varying from 6 ins. to 10 ins. are used. On all of the systems visited the poles are placed 100 ft. apart.

Disposition of the high-tension wires in the form of a triangle was found in every instance, with the exception of the single circuits on the Indiana Union Traction system. The wires of these single circuits are all on one cross-arm, two being on one side of the pole. Wide differences were found in the distance between the separate wires of high-tension circuits. The distances range from 18 ins. to 40 ins., and, moreover, the greatest width was found on that system having the lowest transmission voltage. On the systems carrying the highest voltage distances of 35 ins. and 36 ins. between wires are usually employed.

The practice of transposing high-tension wires is adhered to by some companies and is not followed by others. Three systems were found having high-tension wires transposed. In two instances the transpositions are made every mile and in another they occur every 9000 ft.

Porcelain high-tension insulators are used on all but two systems visited. On one system on which glass insulators are used it was stated that no trouble whatever is being experienced with them except their occasional breakage by boys, but on another system glass insulators are being replaced by porcelain whenever breakage occurred. On the Rapid Railway division of the Detroit United Railways, and also on the Indianapolis & Cincinnati system, the high-tension insulators are carried on iron pins secured to the cross-arm by stud bolts. On all the other systems visited wood pins, usually locust, are used.

Several recent installations throughout the country have ground wires on the cross-arms carrying the high-tension wires as a protection against lightning. This practice was not found on any of the systems visited.

OVERHEAD CONSTRUCTION

Grooved, or Fig. 8, wire is used for trolley by the majority of Ohio roads. There is a growing tendency to equip with double trolley wire and reduce the size of the d. c. feeders. On the Toledo & Indiana, Cincinnati & Columbus and several other roads where the sub-stations are ample and fairly close together, the use of d. c. feeders was dispensed with, the trolley wires being used exclusively for carrying the direct current. The Canton-Akron Railway Company uses a special trolley wire, known as the Myers special, which is a modification of the Fig. 8, except that it is flat on top. It is believed that it gives the ear a better gripping surface, but, as it is unique, there is some difficulty in getting new ears and repair parts.

As with high-tension lines, aluminum has been used by a number of roads for d. c. feeders, and the same conditions apply as with the high-tension wires. The majority of the roads using a. c. transmission and having No. 000 single trolley use a 300,000 c. m. d. c. feeder. The Cleveland & Southwestern uses a 300,000 c. m. feeder where it has double trolley and 500,000 c. m. to 600,000 c. m. with much of its single trolley. A portion of this system has direct-current transmission, and on these sections it uses 60,000 c. m. The Dayton & Troy, with d. c. transmission, has No. 00 trolley and 1,000,000 c. m. feeders.

Practically all the work done in Ohio in the past two years has been bracket construction for single track. The older portions of the Lake Shore Electric, Eastern Ohio Traction, Cincinnati, Georgetown & Portsmouth and Toledo, Port Clinton & Lakeside are cross suspension, but later extensions were built with bracket construction, which has been found cheaper to build and to maintain. Span construction is used on practically all of the double track in the State, there being but very little center pole construction. The height of trolley above rail varies from 16 ft. on the Cincinnati & Columbus to 21 ft. on the Dayton & Troy, the usual practice being 18 ft. This is a point which ought to be adjusted, in view of the growing tendency to run cars over other lines. Soldered and clinch ears are about in equal favor, with possibly a growing sentiment in favor of the former. There is an increasing tendency to use longer and heavier ears, many 15-in. and 16-in. ears now being used.

Line voltages vary from 550 to 650, with a growing tendency toward the higher voltage. In figuring feeders, the usual rule is to allow for a maximum voltage drop of about 25 per cent, although several roads estimate copper upon a drop of only 100 volts.

Pole lightning arresters are used by all the roads. Arresters are placed from 1 to 6 to the mile, and it might be stated that there is a growing tendency to use more arresters and to see that they are maintained in order. Six out of seventeen roads visited ground the arresters to the rail exclusively, three ground to an iron rod driven into the ground, two ground to a copper plate and six use a combination of these methods, grounding both to rail and earth.

Bracket trolley construction is followed in practically all of

TABLE VIII.—SUMMARY OF OVERHEAD CONSTRUCTION ON ROADS TREATED (See also Following Page).

NAMES OF COMPANIES.	Shape and Size of Trolley Wire.	Number of Poles to the Mile.	Length of Poles in Ft.	Diameter of Poles at Top in Ins.	Material of Poles.	Bracket or Span Suspension.	Height of Trolley Wire Above Rail in Ft.	Single or Double Trolley.	Type of Hanger.	Type of Ear.
NORTHERN OHIO GROUP.										
Cleveland & Southwestern	No. 00, grooved and round	53	35	8	Cedar and chestnut	B	18	Both	O. B	Clinch and clamp.
Lake Shore Electric	No. 000, Fig. 8	53 and 58	35	7 and 8	Cedar and chestnut	Both	19	D	O. B	Clinch.
Eastern Ohio	No. 0000, Fig. 8	52	35	7 and 8	Cedar.	B	18	D	O. B	Soldered and clinch.
Toledo & Indiana	No. 000, grooved	60	35	6½ and 7	Chestnut	B	17	D	Boston West End O. B.	4 screw.
Toledo & Western	No. 000, Fig. 8	52	35	6½ and 7	Cypress	B	17½	S	....	Clinch.
Toledo, Pt. Clinton & Lakeside	No. 000, Fig. 8	52	35	7	Chestnut	Both	19	S	O. B	Screw.
Stark Electric	No. 000, Fig. 8	52	35	7	Chestnut	Both	19	D	O. B	
Canton-Akron	No. 0000, Myers T	52	35	7	Chestnut	B	18	S	O. B	15-in. clinch.
CENTRAL AND SOUTHERN OHIO GROUP.										
Western Ohio	No. 00, round	52	40	7	Cypress	B	18	D	O. B	12-in. solder.
Ft. Wayne, Van Wert & Lima	No. 000, round	52	40	7	Idaho cedar	B	18	S	Type M	15-in. clinch.
Dayton & Troy	No. 00, Fig. 8	48	35	7	Cedar	Both	21	D	O. B	12-in. clinch.
Dayton, Covington & Piqua	No. 00 round	52	35	7	Chestnut	B	18	D	Johns	Soldered.
Scioto Valley	3d rail	52	40	8	Chestnut	3d rail	18	S	....	
Cincinnati & Columbus	No. 0000, grooved	52	35	7	Chestnut	B	16	S	....	
Cincinnati, Milford & Loveland	No. 0000, round	52	35	7	Chestnut	Both	18	D	Craighead solid	Clamp.
Interurban Ry. & T. Cincinnati	No. 00, round	55	35	7	Cedar	Both	20	D	Craighead cap and cone	Soldered.
Cincinnati, Georgetown & Portsmouth	No. 000, round	52	35	6	Chestnut and cedar.	B	18	D	4-screw	Soldered.
INDIANA GROUP.										
Indiana Union	No. 000	52	30	7	Cedar	Both	20	S	....	Clinch.
Indianapolis & Northwestern	No. 000, grooved	52	36 and 32	6	Cedar	B	18	S	....	Clinch.
Indianapolis & Cincinnati	No. 000, grooved	Old work 52, new work 44	40	7	White cedar	B	18	S	Special	Special.
Indianapolis, Columbus & Southern	Old work 2—0, round; new work 4—0, round	52	35	8	Cedar	B	18	D	O. B	Clinch.
Terre Haute Tr. & Lgt	No. 00, round	52	40	..	Cedar	B	19	S	....	Clinch.
Kokomo, Marion & Western	No. 000, round	52	40	..	Cedar	B	19	D	O. B	12-in. clinch.
Ft. Wayne & Wabash Valley	No. 000, round	52	40	7	....	B	20	S new work, D old work	....	Clinch.
MICHIGAN GROUP.										
Rapid Railway System, Detroit	No. 00 and No. 000, round, and Fig. 8	48	40	..	....	B	19	Mostly D	....	15-in. clinch.
Detroit, Ypsilanti, A. A. & J.	No. 00, Fig. 8	52	40	..	Cedar	B	19 to 20	D	....	

the new work in Indiana and Michigan. Both round and Fig. 8 trolley is employed, but there is a tendency towards the abandonment of the Fig. 8 section. Three sizes of wire, No. 00, No. 000 and No. 0000 trolley, are used, the smaller sizes being employed when a double trolley is employed.

Opinion varies in this section as to the advantages and disadvantages of single and double trolley wire. The Fort Wayne & Wabash Valley Traction Company is building all new work with single trolley, although the old lines are of double trolley construction. On the Detroit United Railways system, upon which most of the construction is with double trolley, this construction is preferred.

On the several roads visited the height of the trolley above the rail ranges from 18 ft. to 20 ft. There is a tendency to place the trolley a little higher than is absolutely necessary, with a view to accommodating higher cars should these be adopted at any time in the future. It would seem that neither difference in the height of cars nor operating features would warrant the wide variation found in the height of the trolley. On the Terre Haute Traction & Light Company system, which uses the car of least height, the trolley is 19 ft. high, while on the Indianapolis & Northwestern system the trolley is 1 ft. lower and the cars are about 9 ins. higher. Other similar examples lead to the belief that one standard height of trolley could be adopted by practically all systems.

Where 500 or 525 volts was the pressure formerly carried on the trolley, 600 to 625 volts pressure is now found. Of the systems visited in Indiana the lowest voltage is carried by the Terre Haute Traction & Light Company and is 550 volts. Several d. c. systems carry 650 volts.

Practice differs greatly in Indiana as to the number of lightning arresters necessary for proper protection to the line. From two to five per mile are used. Various methods of grounding arresters are in use. On the Indianapolis & Cincinnati Traction system the arresters are grounded to a galvanized iron pipe driven 10 ft. into the ground. None of them is grounded to the rails. On the Indianapolis, Columbus & Southern Traction system every fifth arrester is grounded to the rail. Arresters on the Kokomo, Marion & Western Traction system are all grounded to ⅝-in. rods driven into the ground. In addition to this, the ground wire from each arrester is connected alternately to one rail and to the other. Ground plates are used by the Fort Wayne & Wabash Valley Traction Company. On the Detroit, Ypsilanti, Ann Arbor & Jackson Railway some of the arresters are grounded to the rail and some to ground plates. The grounding wires consist of wire from old motor field coils.

The Detroit United Railway system grounds each arrester to both rails and to ground rods. In addition to gap arresters, this company places fuse arresters in the power houses, sub-stations and at other points where there is competent attendance. These arresters consist of several No. 22 cotton-covered wires connected in multiple between the trolley and ground terminals in such a manner that the insulation of the wire prevents the passage of the current. A lightning discharge, however, jumps across this insulation. Fusing of the wire breaks the current after a discharge.

Direct-current feeders of about 500,000 c. m. are usually employed. On the Detroit United Railway system No. 0000 feeders are preferred, several being placed in multiple when necessary. The great advantage of a feeder system consisting of this size of feeders is its flexibility. Whenever conditions of load change some of the feeders may be taken down and replaced on other portions of the line where the load demands.

The frequency of feeder taps varies on the different systems. On the Indianapolis, Columbus & Southern Traction system within five miles of substations two taps per mile are made. At greater distances there are five taps per mile. The spacing of feeder taps on the Detroit United Railway system is governed by the demands for load. In level country the taps are 1320 ft. apart. On curves, or where the service is extremely heavy, they are from 700 ft. to 800 ft. apart.

The collection of drawings on page 657 forcibly illustrates the lack of uniformity in pole and overhead construction. There seems to be no standard rule whatever for number or dimensions of cross-arms, methods of attaching the arms to the poles, and arrangement of high-tension wires, d. c. feeders and telephone wires.

In reference to telephone wires, it may be stated that the trouble with telephone circuits carried on the same poles with high-tension circuits, which was freely predicted when high-tension work was first suggested, has not been serious. It is now quite the common practice to carry the company's own telephone wires on the railway pole line, and no serious difficulty due to the high-voltage circuits is encountered, even when, as is now common practice, the power circuits are not transposed. Some companies as an extra precaution against noisy telephone lines transpose the telephone wires at frequent intervals. On a number of roads the telephone wires are carried on pins let into the pole instead of on cross-arms, and in cities where span construction is used it is common practice to carry the telephone wires on the span wires.

Of the roads treated eleven use chestnut poles, cedar coming next in favor. Diameters of poles at the top range from 6½ ins. to 8 ins., with 7 ins. predominating. Lengths range from 25 ft. to 40 ft. and spacing of poles varies from 48 to the mile to 60 to the mile with 52 a good average.

The Cincinnati, Georgetown & Portsmouth has had an excellent opportunity of testing the theory that the escaping gases from steam locomotives is injurious to the feed and trolley wires of the overhead electric railway system. This road handles part of its freight business with steam locomotives, and it has watched this point with some anxiety; but after three years of constant and frequent freight train service, it has been unable to discover that there is any unusual deterioration of insulation, or breaking off of soldered connections due to this cause. The only effect noticed is a heavy coating of soot on the entire overhead and feeder system.

In Tables VII. and VIII. are given the details of high-tension transmission lines and overhead construction on the twenty-six roads investigated in Ohio, Indiana and Michigan. These tables are worthy of study as setting forth the latest ideas and practices in designing transmission lines and overhead construction for interurban roads.

TABLE VIII.—SUMMARY OF OVERHEAD CONSTRUCTION ON ROADS TREATED.—*Concluded.*

NAMES OF COMPANIES.	Voltage on Trolley Wire at the Station.	Number of Arresters Per Mile.	How are Arresters Grounded.	Material of D. C. Feeders.	Standard Sizes of Feeders Used.	Feeder Taps to Mile.	How is Tap Made.	Maximum Voltage Drop for Which Feeders are Calculated.
Northern Ohio Group.								
Cleveland & Southwestern	600	4	To earth and rail	Copper and aluminum	300,000 to 600,000 c.m.	4	Soldered	150
Lake Shore Electric	650	5	To rail	Copper and aluminum	300,000 to 500,000 c.m	4	Soldered	25%
Eastern Ohio	650	6	To rail	Copper and aluminum	No. 0000	3 and 4	Soldered	25%
Toledo & Indiana	650	2	To rail	None				200
Toledo & Western	650	5	To iron rod	Copper	300,000 circ. mil	4	Soldered	150
Toledo, Pt. Clinton & Lakeside	650	5	To copper plate	Copper	No. 0000	4	Bronze feeder tap ear	200
Stark Electric	600	5	To iron rod and to rail	Copper	250,000 circ. mil	Every 20 poles	Soldered	150
Canton-Akron	650	5	To ground, to copper plate	Aluminum	500,000 circ. mil	5	Clamp soldered	100
Central and Southern Ohio Group.								
Western Ohio	650	5	To rail	Copper	500,000 circ. mil	2	Soldered	220
Ft. Wayne, Van Wert & Lima	600	6	To rail	Copper	No. 0000	2	Soldered	220
Dayton & Troy	650	5	To copper plate and rail	Aluminum	1,000,000 circ. mil	4	Soldered	125
Dayton, Covington & Piqua	610	1	To iron rod	Copper	3 No. 0000	7	Solder and screw	210
Scioto Valley	650	-						
Cincinnati & Columbus	650	-		Copper	No. 0000	5	Special lug soldered	200
Cincinnati, Milford & Loveland	650	-		Copper	300,000 circ. mil	4	Special ear soldered	145
Interurban Ry. & T. Cincinnati	575	5	To rail	Copper		5	Soldered	137
Cincinnati, Georgetown & Portsmouth	550	3	To iron rod					
Indiana Group.								
Indiana Union	650	2	To rail and ground plate	Copper	550,000 circ. mil	2	Feed in ear and hanger	
Indianapolis & Northwestern	650	8	To rail and a pipe driven into ground	Aluminum and copper	400,000 circ. mil	5	Special feed in car	
Indianapolis & Cincinnati	3,300	8	To galv. iron pipe driven 10 ft. in ground	No feeders	None			
Indianapolis, Columbus & Southern	625	5	On ground rods and every 8th arrester to the rail	Copper	300,000 circ. mil	2 per mile near sub-station, 5 per mile 5 miles from sub-station	Special feed in ear	
Terre Haute Tr. & Lt.	550	4	On iron pipe driven 16 ft. into the ground		500,000 circ. mil	5	Special feed in ear	
Kokomo, Marion & Western	600	4	To ground rod and to rail	14 miles aluminum, 300,000 circ. mil; copper equivalent	500,000 circ. mil	4	Special feed in ear, soldered to copper feeder & clamped to aluminum feeders	150
Ft. Wayne & Wabash Valley	600	3	To a ground plate	Copper		4	Special feed in ear	
Michigan Group.								
Rapid Railway System, Detroit	625–650	2	Through ground rods and bonded to both rails		400,000 circ. mil	In level country 1,320 ft.; on curves and hills 700 to 800 ft.	Special feed in hanger of own type	
Detroit, Ypsilanti, A. A. & J.	650	3	To rail and ground	Copper	400,000 circ. mil. to No.8			