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ON

TECHNICAL PROGRESS IN COMMUNICATION WIRES AND CABLES

INSULATED PARALLEL CIRCUIT WITH AIR DIELECTRIC FOR RURAL TELEPHONE SERVICE

BY

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The need for open wire circuits in rural areas will prevail for the foreseeable future. The use of bare wire for such circuits has many disadvantages which can be offset by using individually insulated wires. In addition, insulated wires would permit changes in design with substantial additional benefits. Field trial data with the insulated wire and new types of support are encouraging to date. Field trials on an increasing scale are progressing.

Net increases in first cost because of the present costs of insulating the wires is an obstacle to widespread use of this type of construction in spite of the tangible and intangible benefits in operation and maintenance.

While first costs comparisons are not favorable, it is expected that there will be many situations where elimination of hits, improvement in the leakage characteristics, resistance to corrosion and freedom from effects of foliage will easily prove it in over bare wire. Experience in these situations will permit determination of specific information on savings in operation and maintenance.

It is clear that the differences in cost are sufficiently close that only minor savings in costs of operations and maintenance are needed for insulated wire to be more economical than bare wire on an annual cost basis.

I. The Need for Circuits with Air Dielectric

There have been many papers presented at this and other symposiums describing the use of plastic insulating materials in telephone plant items such as plastic cable, multi-pair distribution wire, (Bell System B Rural) etc. These are important developments and have been major contributions to the telephone industry. These items are in use at many places on systems of REA borrowers. However, as shown in Table I in a breakdown of Outside Plant Construction of REA borrowers, the opportunities to provide a multiplicity of circuits initially are distinctly limited, the primary need being for mechanically and electrically improved facilities for smaller leads.

TABLE I

Breakdown of Outside Plant Construction
of REA Borrowers

Total Pole Line Miles Makeup		Open Wire Pole Line Miles Makeup	
Open wire - Separate Poles	- 66%	One Circuit	- 68%
Open wire - Joint Poles	- 26%	Two Circuits	- 13%
Cable	- 5%	Three Circuits	- 7%
Other	- 3%	Four Circuits	- 4%
	100%	Five and more Circuits	- 8%

It can be seen that the primary requirements are for open wire lines, 23,000 miles out of 25,000 during 1955 and, of these, almost 16,000 miles were for one circuit. The predominance of open wire is the result of the nature of the areas served. The average borrower serves a large area with low subscriber density. This calls for small numbers of circuits over relatively long distances. Open wire is the best available plant today for such conditions if economic and transmission objectives are to be met. Open wire circuits, because of their wide spacing and air dielectric, have relatively low attenuation at voice and carrier frequencies.

In the past few years, developments in subscriber carrier equipment have been promising and rapid. Carrier systems with 3 to 10 channels per pair are now available. This forces increased attention to carrier frequency characteristics of telephone plant. With this in mind, REA has recommended that on each multi-circuit open wire lead, at least one circuit be copperweld. By making this provision for carrier initially at very minor expense, the ability to employ carrier to expand facilities is obtained.

From the present trend in carrier development with transistors destined to replace vacuum tubes, it now seems highly probable that carrier channels can be justified over much shorter distances, say in the order of 5 to 6 miles. As many of you know the reason for this is that all present day evidence points to the fact that transistor life can be expected to be anywhere from 10 to 20 times that of current day vacuum tubes. The cost of replacing vacuum tubes, in which the cost of time of travel transcends the tube cost itself, plus the greatly reduced cost of power, both pinpoint the urgent need for carrier equipment manufacturers to concentrate on transistorized carrier systems.

Out of this comes a corollary requirement to improve the reliability of the open wire plant in every practicable way, since open wire has inherently low attenuation at carrier frequencies - as a result of the air dielectric.

Table II presents estimated attenuation in db per mile at voice and carrier frequencies for open wire, both bare and insulated conductors, as well as for cables and parallel and twisted pairs of wires. The close spaced insulated open wire is not as good for carrier transmission as the bare wire, due to the reduced spacing between wires and to the assumed losses in the extraneous foreign deposit on the insulation, but the degradation is nominal. The variation between dry and wet weather conditions is relatively small. The effect of the absence or near absence of the air dielectric on the twisted pair cables and parallel extruded pairs is pronounced, even at 1 kc, and becomes quite overwhelming at the higher carrier frequencies.

II. Experience with Insulated Open Wire Plant

In a paper presented at this Symposium in 1954, by REA authors, the case for insulating the wires of rural open wire plant was discussed in detail. The advantages can be summarized as follows:

a. Shorts and crosses due to mid-span hits are eliminated.
b. Resagging requirements after storm loading becomes a problem of crosstalk and noise control rather than of hits.
c. DC insulation resistance is expected to be high, with less variation with weather.
d. Wires will be less subject to corrosion and the deleterious effects of salt spray.
e. Insulated wires will permit close spacing, with consequent reduction in length of crossarm. The close spaced insulated wires have higher attenuation than 12" spaced bare wires, but the attenuation swing between wet and dry weather conditions is lower with the insulated wire. Also, the increased spacing between pairs relative to the spacing of a pair gives more efficient control of noise and crosstalk.
f. New and less expensive means for fastening wires at crossarms may prove satisfactory as a substitute for glass insulators and conventional ties.

Since 1954, field trials of insulated pairs have been made in various parts of the country. These trials included several types of support and utilized both 109 - 135 steel conductors and 080 - 30 percent copperweld. Some 20 miles of all insulated plant have been installed in Minnesota, North Dakota, Indiana and Louisiana. In Indiana, Minnesota and North Dakota, the trials of supports included two types (a) assemblies of bare armor rods as shown on Figure 1 and (b) insulated "grasshopper" splints in underarm construction as shown in Figure 2. Span lengths averaged about 350 feet. Separations were 4 inches in Minnesota and North Dakota and 12 inches in Indiana and Louisiana. In Louisiana, Grade A Galvanized 109 - 135 steel and 080 - 30 copperweld were used. The circuits were installed on pole lines that were severely exposed to salt fog from the Gulf of Mexico. Normal plant used in the area was 104 hard drawn copper because of severe corrosion experienced. With the short pole spans, the matter of support fixtures was not particularly important, the trial being primarily a test of the corrosion preventative characteristics of polyethylene coatings. Splices were taped and all conductor surfaces protected.

The results of the trials have been encouraging in all respects. Except for an initial difficulty with the armor rods of Figure 1 which was cured by using one additional rod to provide a full circle of covering, no difficulties with the supports have been experienced. The efficiency and economy associated with the insulated "grasshopper" splints demonstrated in the underarm trials of March 1955 have spurred the use of insulated splints for supporting other types of plastic insulated line wire. While experience with the wire and supports has only extended over a period of 18 months, the lack of any difficulties over this period provides sufficient confidence to warrant more extensive trials so that additional experience can be obtained on an accelerated basis. Additional trials are being made in Kansas of pairs with one wire insulated and also of pairs with both wires insulated. In the trial with both wires insulated, standard 6 foot crossarms will be used for 4-circuit leads, with insulated splints pre-tied to glass insulators as shown in Figure 3. The wires of each circuit are 4" apart at one pole and 1-1/8" apart at the next pole for pinch-in or transposition. By staggering the pinch-in or transposition points for the two circuits on the same side of the pole and locating the points in the outer pin locations, a maximum separation between these circuits is obtained in a minimum of crossarm space. Climbing space is adequate for joint use poles. For separate pole line construction, a crossarm 16" shorter could be used.

It is expected that further trials will be made in areas where line hits, low dc insulation resistance or corrosion from salt spray are serious problems for bare open wire. Additional types of construction to be used are shown in Figures 4 and 5. Figure 4 is quite similar to Figure 3 for 4 circuits, for use where span lengths do not exceed 350 feet. Instead of using glass insulators to support the line wires, insulated "grasshopper" splints will be used with overarm construction.

For separate pole construction not requiring more than 2 physical circuits, or joint use for one physical circuit, the arrangements of Figure 5 can be used where span lengths do not exceed 350 feet. Short L brackets are shown with 1-bolt clamps holding the insulated pre-formed splints. This arrangement should also be attractive for carrier applications in cable overbuilds.

III. Economic Considerations

The economics of insulated open wire plant is of course a major consideration in its ultimate field of use. The limited experience available on this type of plant does not permit realistic estimates of relative maintenance costs as compared with bare open wire. Based on experience with other types of insulated plant, it is reasonable to assume a substantial reduction in maintenance costs.

We have set up in Table III a few tentative cost comparisons based on insulating .080 - 30 copperweld with 15 mils of polyethylene. This is based on allowing $60.00 per circuit mile for the insulation, which is a compromise of several bids received. These bids are based on the wire being drawn and coiled in one factory, transported to another factory, uncoiled, insulated and recoiled for shipment to a job. Obviously, considerable savings could be obtained through more direct insulating methods.

It can be seen from Table III that the insulated open wire pair is more costly than bare open wire in both single and multi-circuit leads. It is noted that "B" rural wire is also cheaper than a 4 circuit lead. This is not important since "B" rural is used primarily for local distribution where its higher voice frequency attenuation is no problem. Where carrier is desired it would be necessary to provide an open wire overbuild if more than an entrance length of "B" rural were involved.

The single pair with air dielectric is slightly less in cost than the parallel extruded 14 gauge copperweld pair. Again, this is of minor interest since the parallel extruded type is not an adequate transmission medium as line wire for the REA systems of interest.

The cost comparisons indicate that where there are factors involved in particular situations, (i.e. heavy foliage, salt spray, high winds), etc., where the advantages of the insulated pair are particularly important, the use of the insulated type of plant can be justified. As more widespread use of this type of plant takes place, specific information on maintenance and operation will be obtainable. This information will permit firm analysis of the ultimate field of use of this type of plant from first cost, annual costs and operational standpoints. Only minor savings in annual costs are needed to prove in the design even with present costs of insulating the wire.

TABLE I[illegible]

DC LOOP RESISTANCE IN OHMS AND ESTIMATED ATTENUATION IN DB PER MILE

			FREQUENCY IN KILOCYCLES											
	Wire	DC Loop Res. Ohms	1		50		100		150		200		400	
Open Wire (R-1 Type Transpositions)	Diam. Mat'l.	@ 68° F.	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
(1) Bare, Copperweld, 12" Spaced (Point transposed)	.080-30% CW	54.5	.26	.26	.41	.44	.43	.48	.44	.51	.45	.55	.53	.70
(2) [illegible] lated Copperweld, Close Spaced* ([illegible] em transposed)	.080-30% CW	54.5	.36	.36	.63	.64	.65	.67	.67	.70	.69	.72	.79	.87
(3) [illegible] ated Steel, A Galvanized [illegible] Spaced* (Tandem transposed)	.109-135 Steel	76.5	.40	.40	3.88	3.89	5.05	5.07	5.83	5.86	6.60	6.63	7.68	7.76
Twisted Pair Wires and Cables														
(4) Multipair Distribution Wire** (B Rural Type, .064 Cap. when dry)	.036 Copper	85.0	1.1	1.5	3.2	5.0	4.1	7.0	5.0	9.0	6.0	11.0	8.5	18.0
(5) 19 Ga. Paper Type CNB (.084 Cap. dry core)	.036 Copper	85.0	1.3	-	5.0	-	6.5	-	7.8	-	9.0	-	12.9	-
Parallel Extruded Pairs														
(6) Copperweld 14 Gauge	.064-30% CW	87.0	1.1	1.5	4.0	7.6	4.3	8.9	4.4	9.9	-	-	-	-
(7) Steel - A Galvanized	.083-135 Steel	119.0	1.3	1.8	-	-	20.6	-	27.1	32.3	-	-	-	-

NOTES

* Spacing is 4" at one end of span and 1" at other end. Insulation is 15 mil polyethylene.

** Data from "Transmission Characteristics of Rural Distribution Wire at Audio and Carrier Frequencies" by John A. Brazee, Signal Corps Symposium, Asbury Park, New Jersey, December 1955.

TABLE III

ESTIMATED FIRST COST PER MILE FOR POLES, SUPPORT FIXTURES AND WIRE

	Wire Diam.Mat'l.	Poles/ Mile	First Cost	Remarks
Four Circuit Lead				
(1) Bare, Copperweld, 12" Spaced, 10' Arms (Regular Point Brackets)	.080-30% CW	19.5	$1,165	Basic cost for 4 circuit lead suitable for carrier application (for comparison with other plans).
([illegible]) Insulated, Copperweld, Close Spaced, 6' Arms (Using "Grasshopper" Splints)	.080-30% CW	19.5	1,288	Cost of insulation estimated at $60/pair mile. In order that the cost of insulated wire construction [illegible]e comparable with bare open wire construction, a reduction in insta[illegible]led cost of approximately $30/pair mile must be effected.
(4) 4 Pair 19 Gauge Multi-pair Distribution Wire (B Rural Type)	.036 Copper	18.9	1,012	An excellent tool for local distribution where higher attenuation, even at voice frequency is no problem. Cost would have to be burdened with over-build costs for carrier, i[illegible] more than an entrance cable length of B rural type wire were involved.
([illegible]) 26 Pair 19 Gauge Paper	.036 Copper	[illegible]0.0	3,600	Same comments as for B rural type wire. The 26 pair size is shown to provide equivalent channels to those obtained with 20 carrier channels and 4 (3 or 2) physical O.W. circuits.
Single Circuit Lead				
(1) Bare, Copperweld, 12" Spaced, 2 Pir Arm	.080-30% CW	19.5	476	Basic cost for single circuit lead for comparison with other plans.
([illegible]) Insulated, Copperweld, Close Spaced, L Bracket with Clamped Splints	.080-30% CW	19.5	530	Cost of 15 mil PE insulation estimated at $60/pair mile. To make total cost equal to that of bare wire, a further saving of $24/pair mile is required, in addition to the $30/pair mile previously referred to. Some savings in fixture and splint costs are a possibility.
(3) Insulated Steel, A Galvanized, Close Spaced, L Bracket with Clamped Splints	.109-135 Steel	19.5	509	Slightly lower in cost than .080 insulated copperweld. Attractive for salt fog and corrosive atmospheres, also in windy and shade tree areas, where higher DC resistance and attenuation at carrier frequencies are no problem.
([illegible]) Parallel Pair, Copperweld, 14 Gauge	.064-30% CW	18.9	545	Estimated greater cost of this wire to REA borrowers, together with its unsuitability for carrier and its signaling limitations, does not make it attractive for general use as line wire in REA rural areas.
(7) Parallel Pair, Steel A Galvanized	.083-135 Steel	16.8	478	While lower in cost than individually insulated wires, the carrier and DC resistance objections against 14 gauge copperweld apply with greater force to the use of this wire.

Note: Numbers (1), ([illegible]) etc. refer to corresponding items on Table II "DC Loop Resistance in Ohms and Estimated Attenuation in db per Mile."

REA TEL. ENGR. DIV

INSULATED LINE WIRE CONSTRUCTION
ARMOR RODS AND ONE BOLT CLAMPS AT SUPPORT POINTS

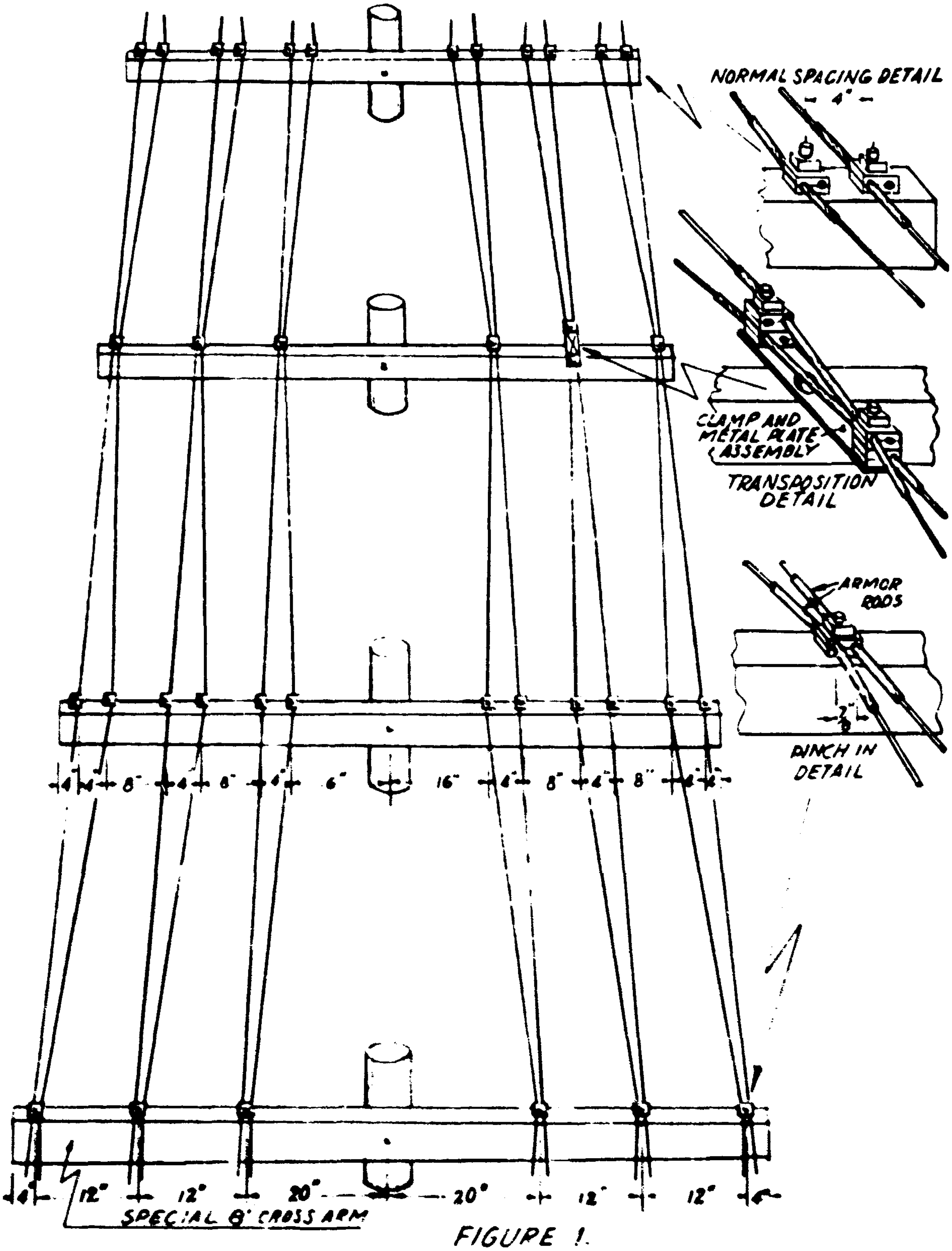

FIGURE 1.

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INSULATED LINE WIRE CONSTRUCTION
INSULATED "GRASS HOPPER" SPLINTS - UNDER ARM CONSTRUCTION

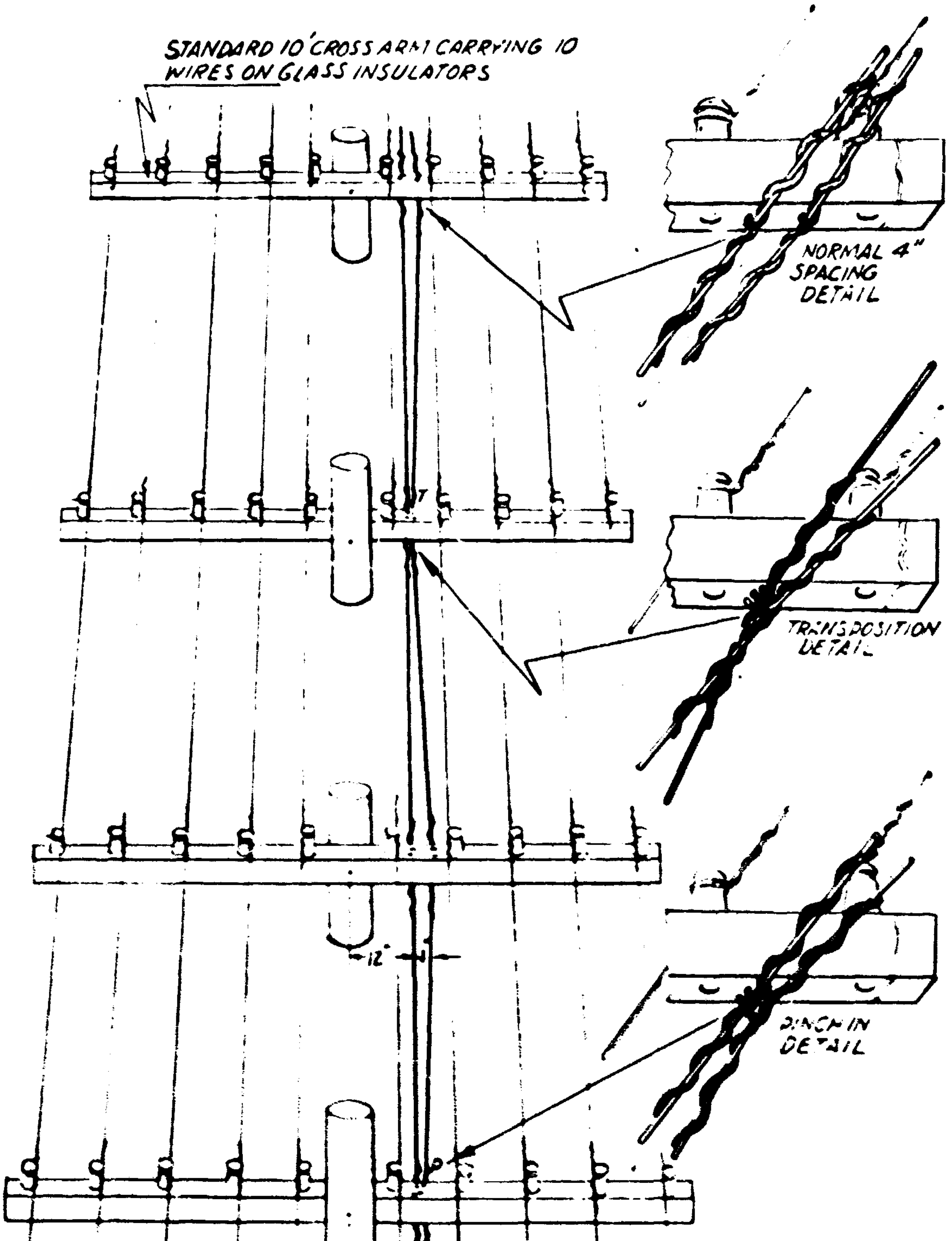

FIGURE 2.

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INSULATED LINE WIRE CONSTRUCTION
INSULATED PRE TIED SPLINTS ON GLASS INSULATORS

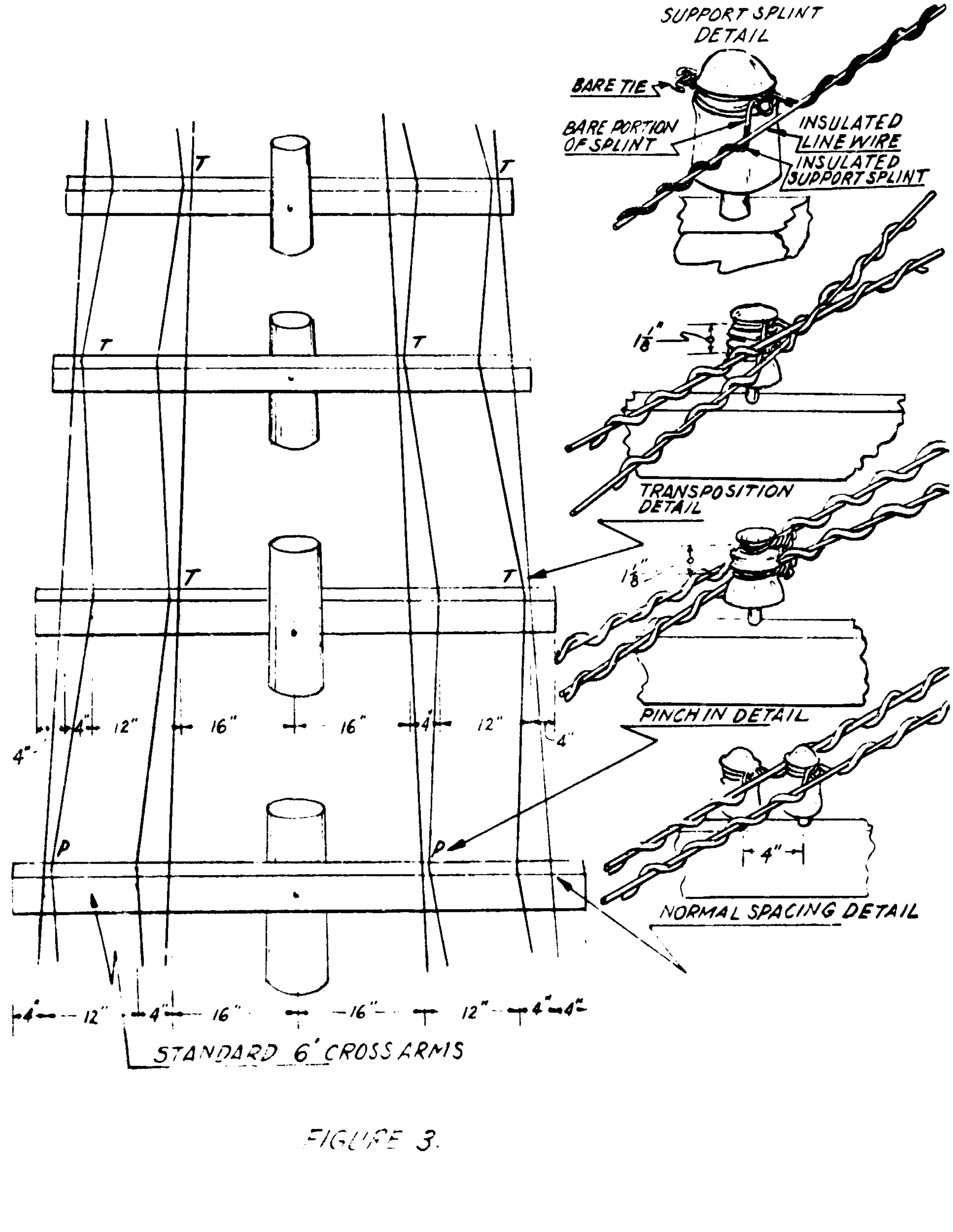

FIGURE 3.

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INSULATED LINE WIRE CONSTRUCTION

INSULATED "GRASSHOPPER" SPLINTS - OVER ARM CONSTRUCTION

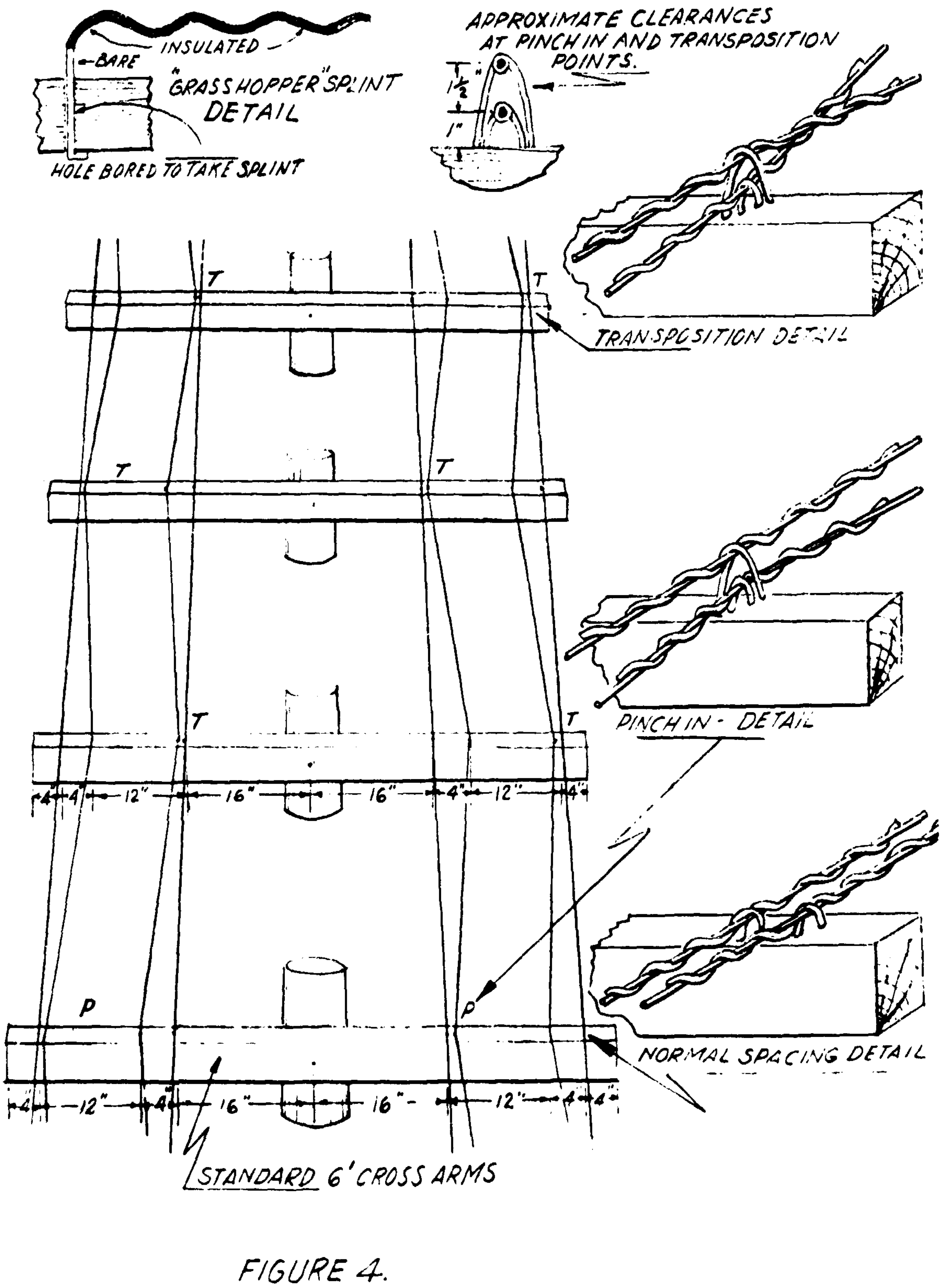

FIGURE 4.

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INSULATED LINE WIRE CONSTRUCTION
INSULATED SPLINTS - CLAMP AND "ELL" BRACKET ASSEMBLY

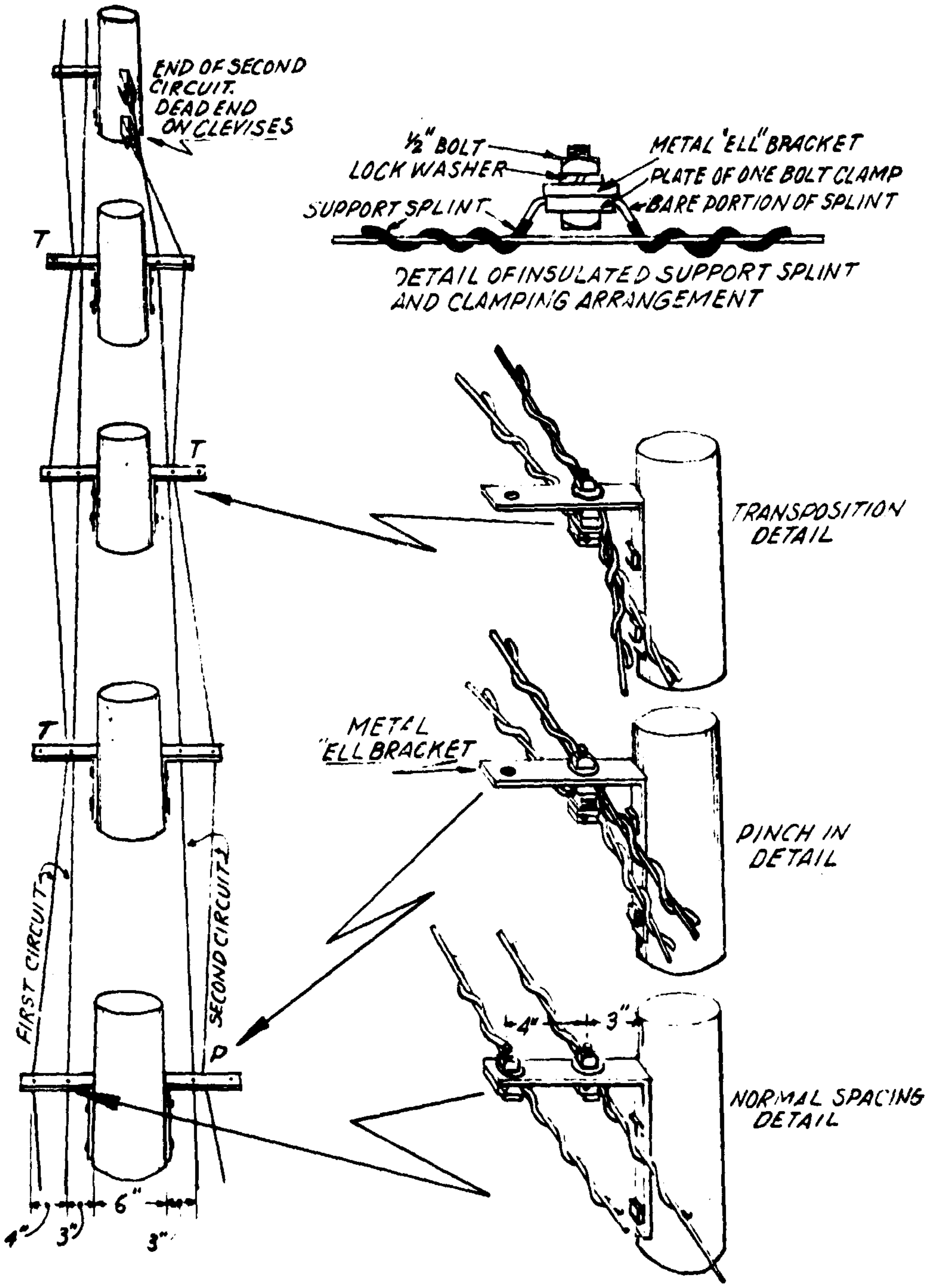

FIGURE 5.