Transcontinental Telephone Lines *

By J. J. PILLIOD

Late in 1937 a large construction project was completed which added 16 telephone circuits to the transcontinental layout, and the work was so planned that 48 additional circuits can be obtained by the addition of equipment but without stringing additional wire. A brief description of some features of this project and the general development of the transcontinental telephone routes since the first one was opened for service in 1915 is given in this article. Although most of the discussion relates to transcontinental lines, the methods described are generally applicable to other similar situations.

LESS than twenty-five years ago, it was impossible to talk by telephone from coast to coast across the United States. Furthermore, it was impossible to talk between points separated by any such distance anywhere in the world. By 1915, technological advancement had reached a point such that telephone service could be established across the country, and three telephone circuits had been built which connected San Francisco and the Pacific Coast with points in the East. Four telegraph circuits were also provided by the new wires. An improved loading system and especially the successful development of the vacuum-tube telephone repeater were outstanding factors which made telephone connections of such length possible for the first time in history.

Open-wire lines played the major role in the early transcontinental telephone circuits. The transmission losses caused by cable were so great that it was avoided whereever possible. The steady improvement of telephone repeaters, types of loading for use on cable circuits, and carrier telephone systems for use on open-wire lines made it possible to provide rapidly and economically more telephone circuits across the continent as use of the service grew. In the cross section

* This paper has been prepared from an address given before the Communications Group of the A. I. E. E., New York Section, March 22, 1938, and published in *Electrical Engineering* for October, 1938. Since the paper was written, three type J 12-channel carrier systems have been placed in service on the new line. Two of these systems operate between Oklahoma City and Whitewater, 1200 miles, and the third between Oklahoma City and Albuquerque, N. M. Twelve additional intermediate repeater stations have been constructed. Three of these are located at such remote distances from primary power that experiments are being made in generating by means of wind-mill power plants part of the power required. One such station is shown in Fig. 8. *Editor.*

just west of Denver there are today one hundred and forty through telephone circuits and about the same number of telegraph circuits carried by four open-wire routes, the last of which was completed during 1937. While open wire was used almost exclusively as a matter of necessity in the first transcontinental telephone lines, cable is now used for about half of the circuit mileage. This is a striking illustration of the large-scale changes which have taken place in the interest of more reliable toll telephone service.

Continued Importance of Open-Wire Lines

The open-wire line seems destined to continue to play an important part in long-distance telephone communication, particularly where distances are great and circuit requirements on any one route are relatively small. Improvements in the usage to which the wires may be put have made this increasingly so. The three circuits on the first transcontinental line were operated at voice frequencies and were obtained from two pairs of line conductors, the third circuit being derived by means of phantom circuit arrangement of these two pairs. The development of carrier telephone systems made it possible to ob-obtain three additional circuits on some pairs of wires, using frequencies above those required for existing voice-frequency circuits. Carrier telephone systems were first installed on a transcontinental route in 1926 and were quickly followed by others, so that today ninety-six of the one hundred and forty circuits mentioned earlier are obtained by means of these three-channel carrier telephone systems. Development work, however, has been continued, and it is now expected that it will be possible, by means of carrier telephone systems using still higher frequencies, to obtain as many as twelve more telephone circuits on some pairs of wires. It has been with a view toward using such systems and obtaining a total of sixteen telephone circuits on a pair of wires that the latest of the four transcontinental routes has been designed.

Construction of New Transcontinental Line

Early in 1937, it became clear from a study of loads carried on existing transcontinental routes that additional circuits would be required in the near future. Circuits in cable were available as far west as Omaha, Kansas City, Oklahoma City, and Dallas. After consideration of all the factors, it was decided to construct the new facilities west from Oklahoma City to Los Angeles on the route shown in Fig. 1. It was also decided to carry out the work in such a way that the route could be utilized for the future addition of a relatively

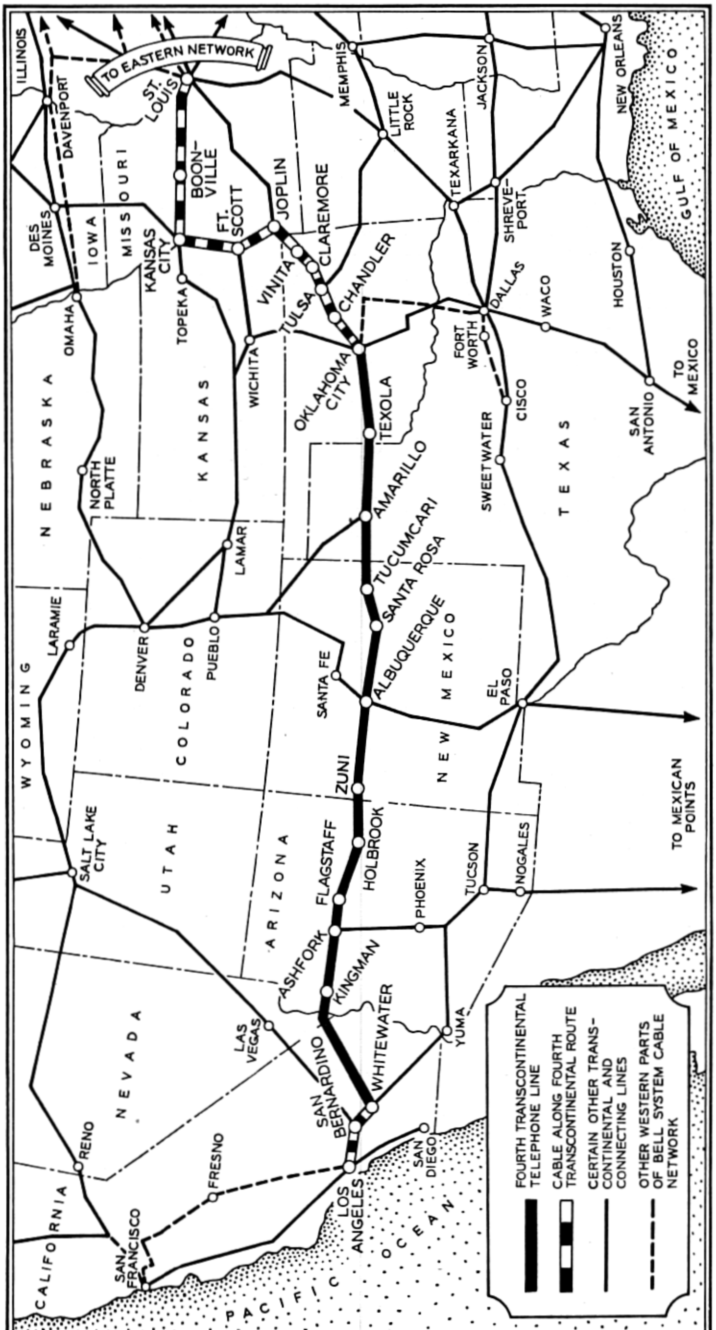

Fig. 1—Route of new transcontinental line across western states.

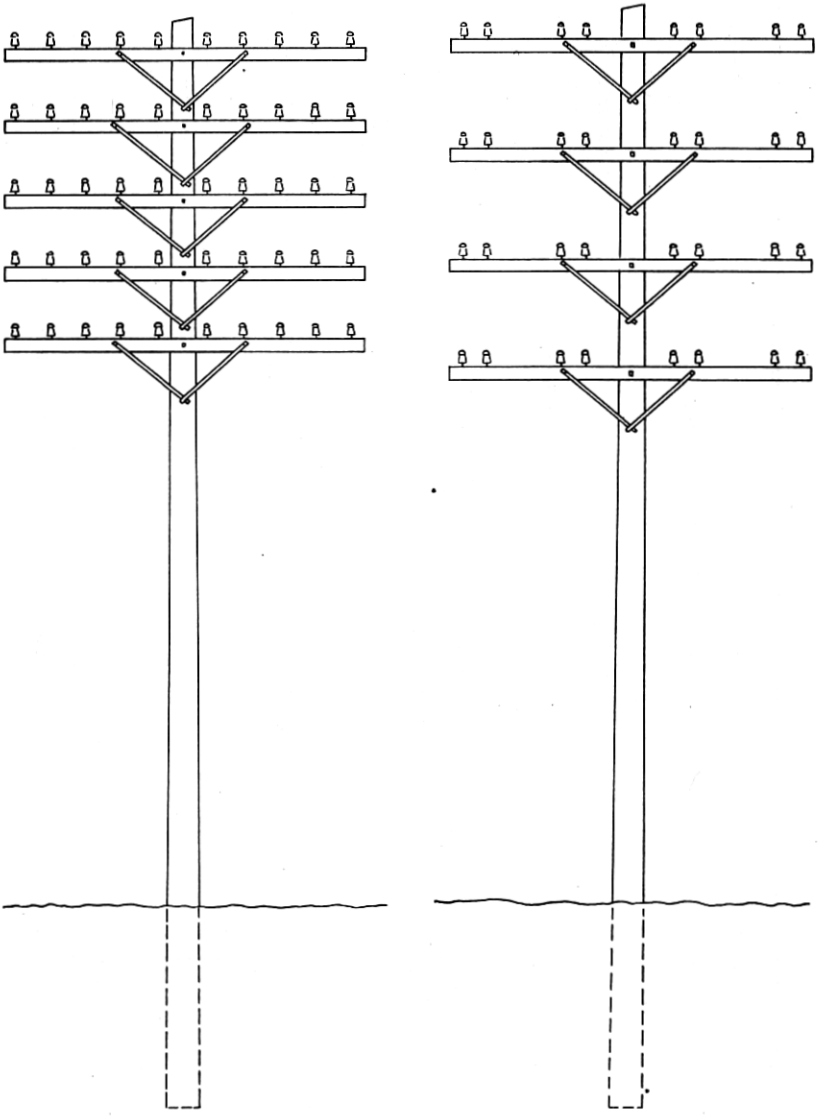

Fig. 2—Cross-arm arrangements. Left—50-wire phantomed line, capacity 77 telephone circuits. Right—32-wire non-phantomed line, capacity 256 telephone circuits.

large number of circuits through the application of the twelve-channel carrier-current telephone system then under development. Among the conditions favoring this particular route is freedom from winter storm hazards throughout most of the distance, which, looking ahead, is particularly important to the future application of twelve-channel carrier telephone systems. The work done in 1937 consisted of building a length of nearly three hundred miles of new pole line and stringing four pairs of wires throughout most of the section from Oklahoma City to Whitewater, California, a distance of 1,200 miles. Initially the voice channel and three-channel carrier telephone systems have been developed on these four pairs, providing a total of sixteen telephone circuits.

Wire Spacing and Transpositions

Open-wire telephone lines designed to carry frequencies up to 140 kilocycles per second, as used in the operation of the twelve-channel carrier telephone systems, have structural requirements substantially more stringent than those designed to carry only three-channel systems, which use frequencies up to 28 kilocycles. The usual type of open-wire toll telephone line has ten wires on each crossarm, spaced at about one-foot intervals, five on each side of the pole and with the crossarm spaced twenty-four inches apart. In the case of the line designed to conduct high carrier telephone frequencies, this configuration has been changed and is illustrated by Fig. 2. Eight wires are strung on each arm, grouped as four pairs, two on each side of the pole. The wires of the pair are spaced eight inches apart, and the nearest wires of the two pairs on each side of the pole are spaced twenty-six inches, while the spacing at the pole is thirty inches. Crossarms are spaced thirty-six inches apart.

These new wire spacings reduce the coupling between pairs on the same line or between pairs on this line and pairs on other lines which may parallel it. New transposition systems are used further to reduce this coupling. Transpositions are closer together and a transposition bracket of the type shown in Fig. 3 is used to turn the wires completely over at as nearly a given point as possible. Transpositions in one or more pairs are installed on every pole with an occasional exception, and certain pairs are transposed at every other pole. The wires of a pair must be adjusted to the same sag within close limits. These sag variations are held to a fraction of an inch, and a check of the completed work indicated that fifty per cent of the spans had been adjusted to within one-quarter inch. Telescopes are used to help obtain these close sag adjustments, and a final check is made by oscillating the wires in a span and observing the periods at which they oscillate.

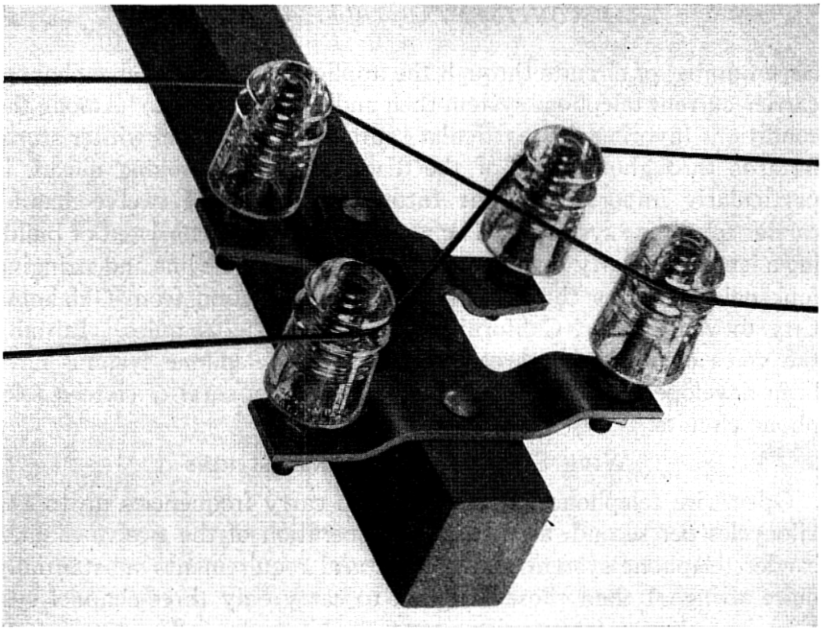

Fig. 3—Transposition bracket shown as installed. Tie wires are not used with this type bracket.

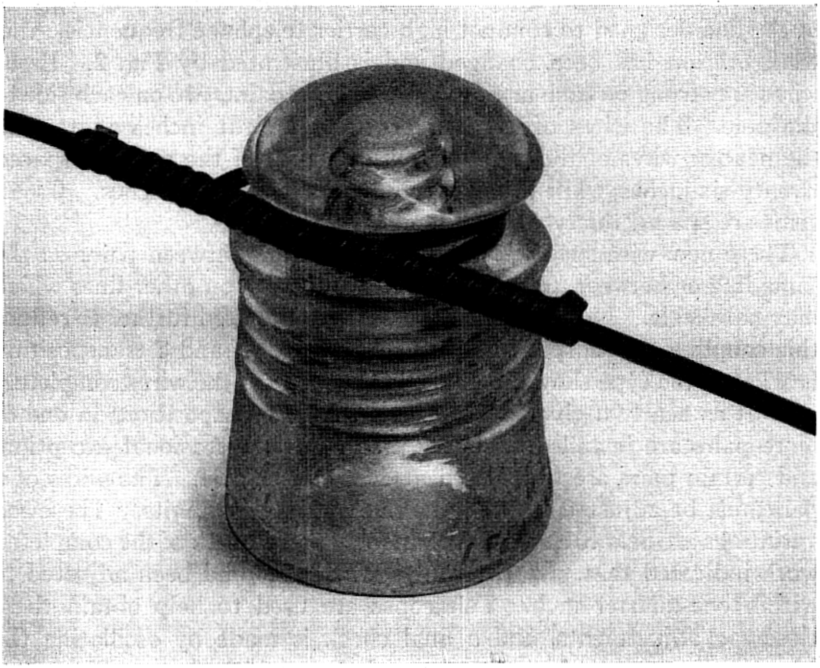

Fig. 4—Flat tie wire shown as installed.

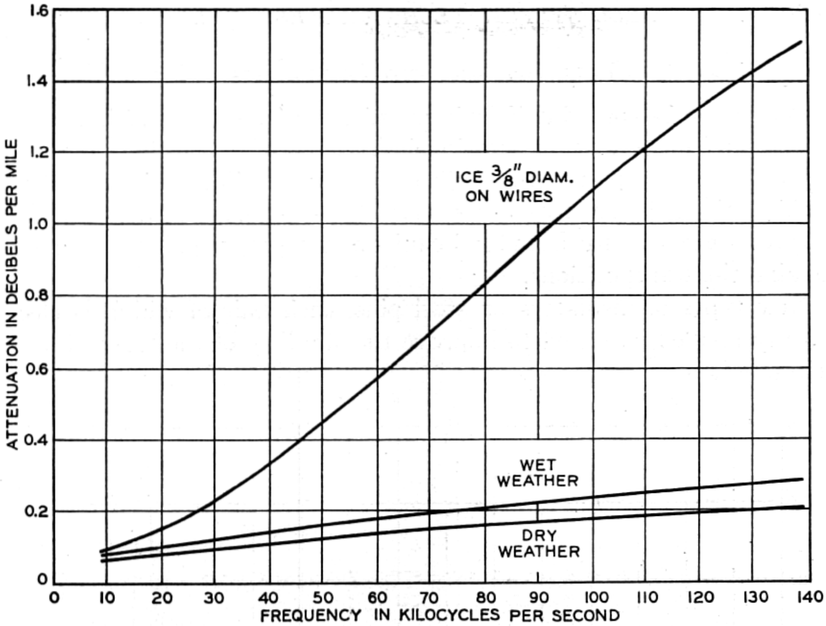

Fig. 5—Attenuation of open-wire pairs, 165-mil copper, 8-inch spacing, CS insulators.

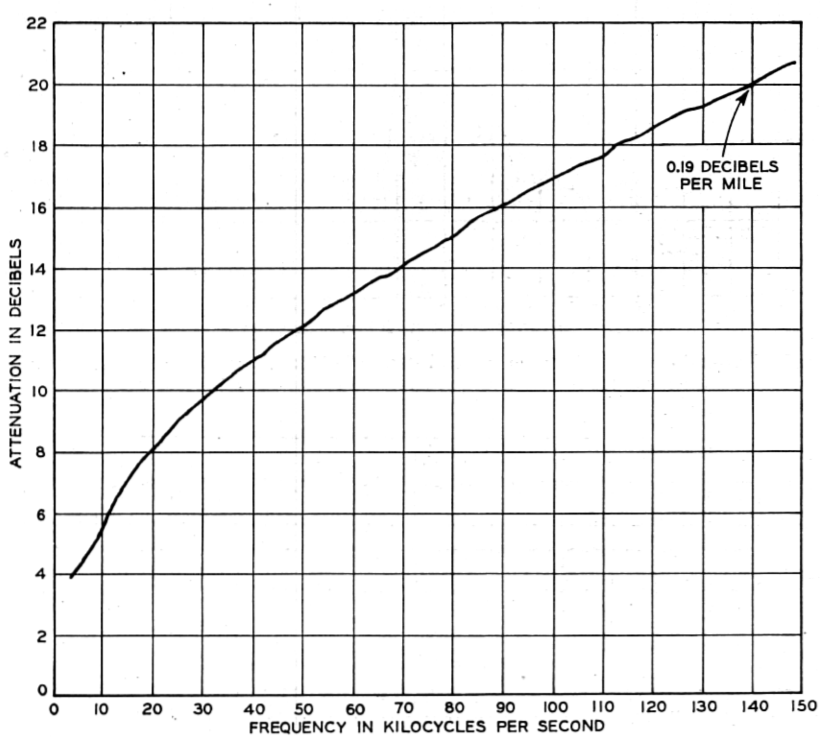

Fig. 6—Attenuation of 165-mil copper, 8-inch spaced pair of wires measured on a 105-mile section of the Amarillo-Albuquerque line in clear weather.

Pole Spacing and Insulators

Poles must be spaced uniformly in order that the transpositions may be most effective, and an occasional deviation of only thirty-five feet is the maximum permitted. Where it is impossible to locate poles within this limit, such as is the case at long-span crossings, special fixtures are suspended from steel cables at the proper points to permit making the transpositions.

New types of insulators on steel pins, each pair of which is electrically bonded, are used to improve the stability of the transmission characteristics.

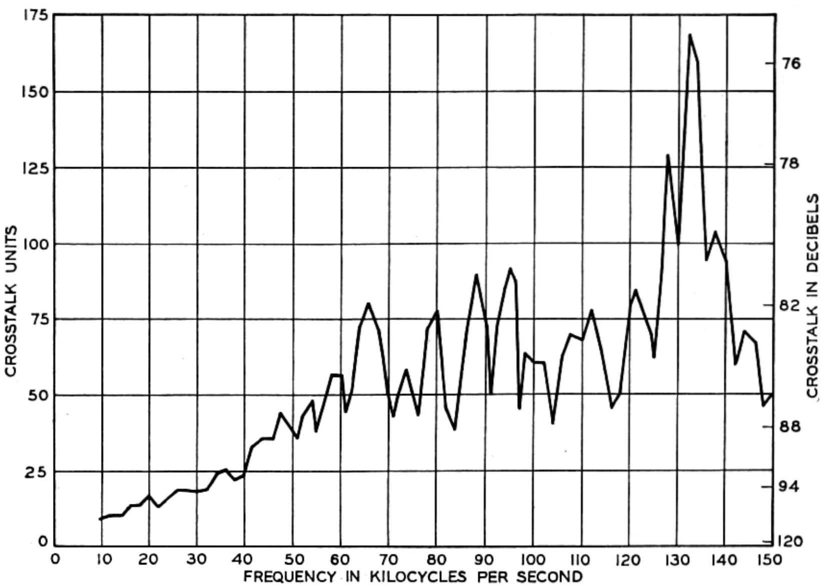

Fig. 7—Far-end crosstalk between wires 7–8 and 9–10 of Amarillo-Albuquerque line, measured from pole 1 to pole 4236, a distance of 105 miles.

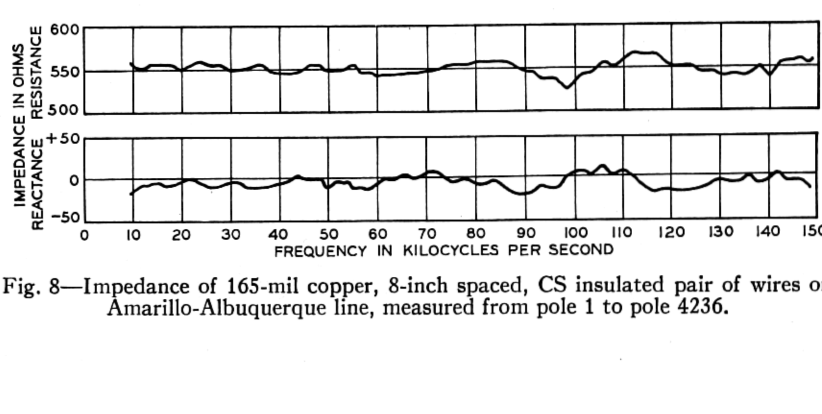

Fig. 8—Impedance of 165-mil copper, 8-inch spaced, CS insulated pair of wires on Amarillo-Albuquerque line, measured from pole 1 to pole 4236.

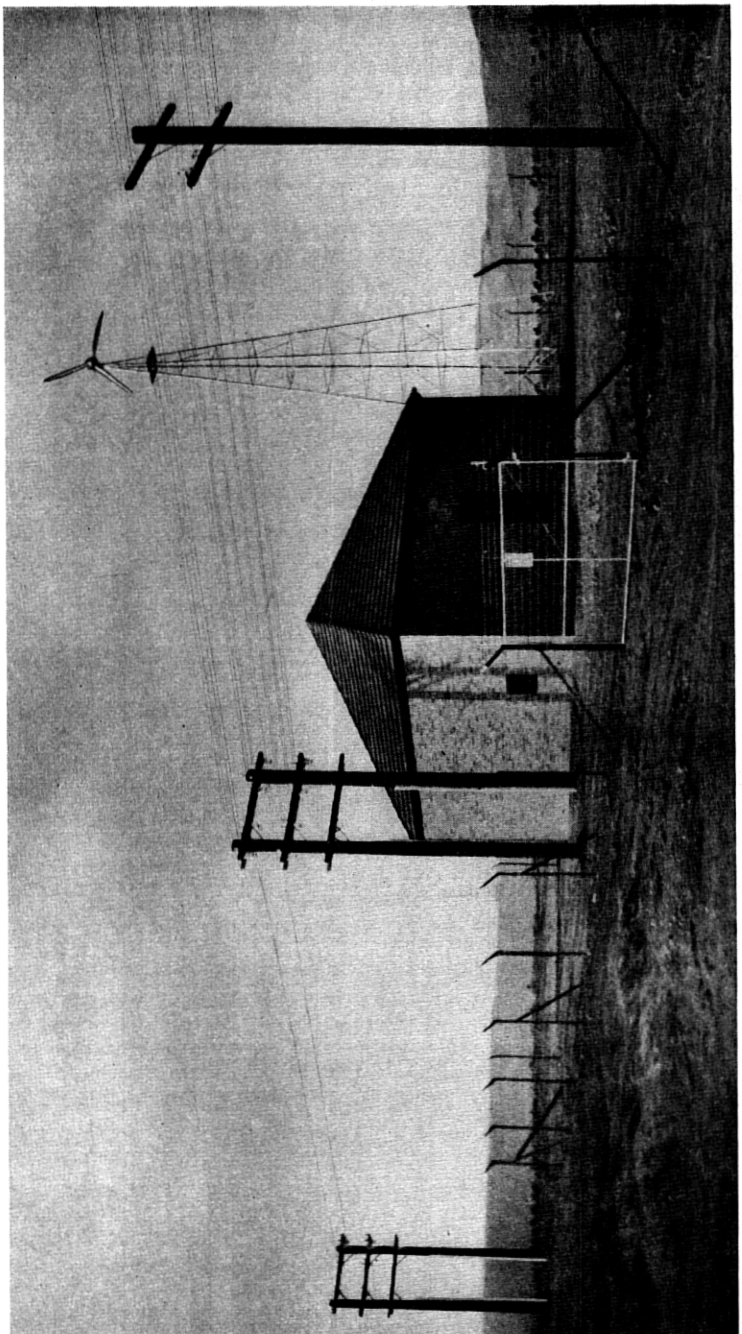

Fig. 9—Type J carrier repeater station at San Fidel, New Mexico (about sixty miles west of Albuquerque), showing wind mill power generating plant. This station is unattended.

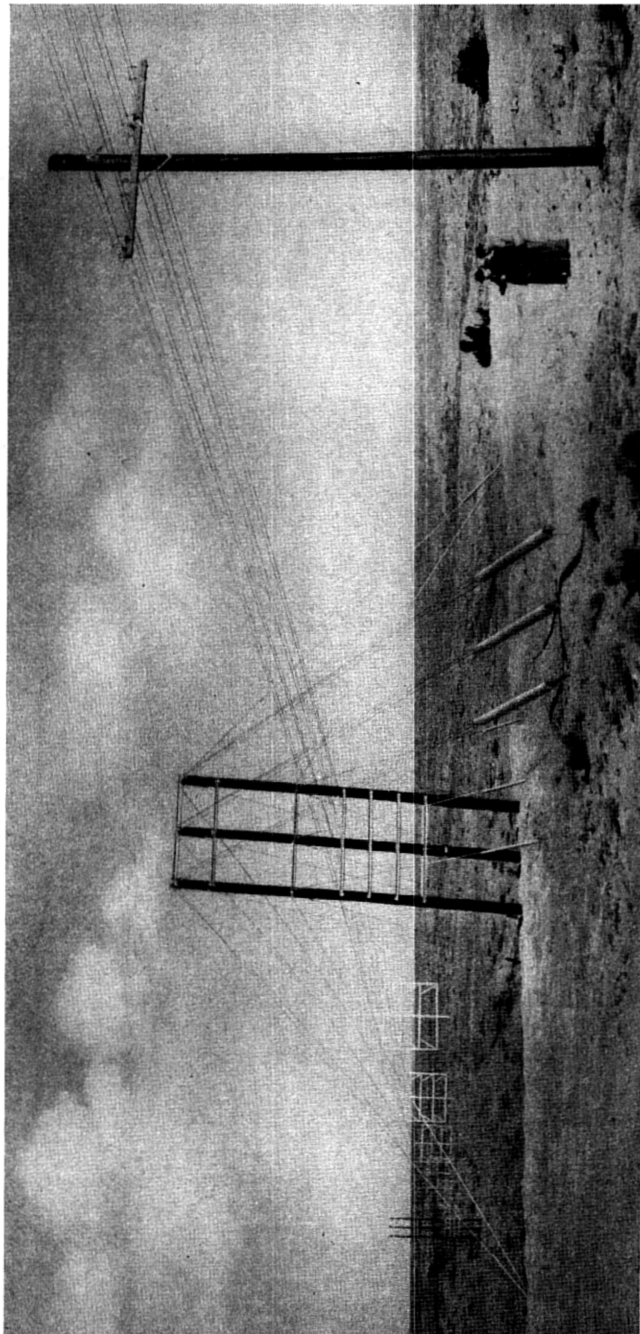

Fig. 10—Long span crossing at Tucumcari Creek, New Mexico. This span is 1080 feet between supporting towers. Normally, the creek carries very little water and the long span is to avoid damage at times of flood.

Wire 165 mils in diameter was used on this construction west of Oklahoma City because of its strength and resultant relative freedom from interruptions. Transmission losses were also a factor in this case. Rolled sleeve joints were used in splicing the wire because of their strength and good electrical characteristics. Flat tie wires, shown in Fig. 4, were used to reduce chafing of the line wire when the wires vibrate. Tie wires are not used at transposition points, as may be seen in Fig. 3.

Repeater Stations

The computed losses on open-wire pairs of this type at high-carrier frequencies and under different weather conditions are shown by Fig. 5. Field tests confirm these data. To offset the line losses it will be necessary to locate repeater stations at intervals of from fifty to one hundred miles, depending upon the weather conditions which may be expected. Between Oklahoma City and Whitewater, California, in order to operate the twelve-channel carrier telephone systems, it will be necessary to equip sixteen intermediate repeater stations. Most of these will be unattended and maintained from other offices.

It is not practicable, of course, to bring the open-wire pairs directly into all repeater stations and in some cases entrance cables several miles long must be used. Although ordinary non-loaded cable pairs may be used for this purpose, their usage involves transmission difficulties, and except where other factors dictate the use of this type of facility, it is planned to use low-loss cable conductors of a new design. These cable pairs have more favorable impedance characteristics as well as lower losses.

With the building and the further equipping of this latest open-wire line across the western states, open-wire facilities have played one more important part in the development of long-distance telephony. Although cable is being found more and more useful, there still remain many important links in the nation-wide telephone communication network where, for the present at least, the open-wire line can serve best and the development of it toward maximum usefulness is still being carried on.