Discussion on "The Telephone Wire Plant" at New York, April 26, 1907.

(Subject to final revision for the Transactions.)

John J. Carty: From the paper it is evident that the telephone wire plant consists of the conducting wires joining points distant from each other, and a large amount of auxiliary apparatus pertaining thereto. This distinguishes the telephone wire plant from that part of the plant which is composed of switchboards, telephones, transmitters, and the various classes of apparatus associated therewith.

The paper does well to call attention to the very great magnitude of the telephone wire plant as compared to the switchboard plant. The switchboard apparatus, all being assembled at the central office, can readily be viewed as a whole, and presents a commanding appearance. Very likely for this reason in the usual discussion of switchboards and switchboard apparatus those factors have been brought into undue prominence as compared with those parts of the plant which have been discussed to-night. The switchboard has too long held the center of the stage, and it is high time that attention has been directed to some of the numerous other features, aside from the switchboard, which are necessary for a complete telephone system.

The telephone wire plant of the city of New York and the suburban territory tributary to it consists in round numbers of one million miles of copper wire. Most of this copper wire is enclosed in lead-covered cables. The superficial area of the lead pipes covering a particular one of these cables amounts to 7.6 acres. The superficial area of the lead pipes covering all of the cables in this system of one million miles of wire amounts to 190 acres. All of this lead pipe is needed to protect from water and moisture the delicate paper-covered wires within, as a puncture in one, of these pipes no larger than a pinhole will admit moisture, which sooner or later causes a fault that produces an interruption of the service of one or of all the circuits within the cable. All of these 190 acres of lead pipe must therefore be maintained free from punctures even as small as that which would be produced by a pin, so that in the manufacture and laying and maintaining of this part of the telephone wire plant very important and serious problems are presented.

A few words concerning the development of this type of lead-covered cable may be of interest as bearing upon the subject under discussion. In the first telephone installations the wires, as a rule, were overhead and composed of iron, following the standard telegraph practice of the time. Soon it became necessary to extend telephone wires across rivers, and here for the first time telephone cables were used, the gutta percha or rubber-covered cables employed by the telegraph companies being imported into the telephone service for the purpose. As the number of wires increased, rubber-covered wires in cables were used to run upon poles and housetops.

Some use was also made of overhead cables composed of cotton saturated with beeswax and protected with rubber tape and braid. As might be expected in the light of our present knowledge, these cotton and beeswax cables failed. This failure, taken together with the bad experience obtained with paraffin-covered cotton office wires, led to the conclusion that cotton was a bad insulator and for some time, where cables were employed, rubber was the material used.

Owing to the high specific inductive capacity of rubber, the transmission obtained through rubber cables was extremely defective and the cross-talk was almost intolerable.

Experiments were also made with rubber-covered wires at an early date, laid in underground ducts. These wires were unprotected by lead pipe, and besides being open to the before-mentioned objections to the use of rubber cable, were especially subject to decay in many places underground.

All of these experiences led to a search for something better than rubber. Foremost among those who worked upon this problem was Mr. William R. Patterson, whose scientific investigations and remarkable practical skill brought forth a cable consisting of cotton and paraffin, in this respect resembling very much the cotton and beeswax cable which had been the cause of so much disastrous experience. It was difficult to convince anyone that cotton and wax could be a good insulator, but it was shown that perfectly dry cotton was an excellent insulator and that the former failures were due to the fact that, owing to its hygroscopic nature, cotton had absorbed moisture from the atmosphere and in the process of manufacture, and thus had its insulation destroyed. It was demonstrated that if the cotton core of the cable were throughly dried in an oven and then quickly hauled into a lead pipe and sealed up at the ends, that insulation as high as one thousand megohms or more per mile might be obtained, and that this high insulation would persist as long as moisture was kept from the core. The introduction of such a cable involved an entirely new state of the art and required that all those engaged in telephone construction should reform their ideas in the light of the new knowledge. After much agitation and discussion, and after a vigorous campaign of education, the superiority of the fibre cable, properly made and installed and maintained, was demonstrated. From that time the use of rubber cable began to decrease.

After much experience, it was found that the filling of wax might be omitted from the cable and yet the moisture could be kept out. This resulted in dry-core cotton cable, which had the advantage of much lower capacity than the filled cable and was not so much affected by heat as was the cable containing wax. The step from the use of dry cotton to the use of paper was a very important one and accomplished much in the way of economy.

The underground telephone cable of to-day is composed of copper wires covered with paper, all enclosed in a hermetically sealed lead pipe. This type of cable has persisted so long and seems to answer its purpose so well, that telephone engineers are fairly well content with it, and are no longer agitated by those serious questions which I have just discussed.

The tendency in cable construction and in telephone line construction generally has been to drive rubber insulation out of the field which it formerly dominated. Its use is now restricted to distributing wires, inside wiring, and certain special switchboard wiring. While the use of this rubber insulation has relatively decreased in the absolute amounts used, there has been a tremendous increase in the mileage employed. So important still is the use of this rubber wire that the question of its durability and cheapness is one of very great concern, and I am glad to see that in the paper just read there are some valuable data concerning the durability of rubber wire under certain conditions. Reliable data on this subject are much needed.

The open wires used in the first telephone lines were usually made of iron, and, as a rule, especially when employed in lines of any great length, they gave impaired service. The reasons for this are of course now well understood, but at the time of which I speak not much was known concerning the laws of transmission, nor of the electrical and magnetic properties of iron. There was a long period of groping in the dark. Where long-distance wires—at that time forty or fifty miles was long distance—were used, imperfect results were obtained, and in some cases it seemed that by using larger iron wires matters were made worse. During all of this period of fumbling and groping, there was one engineer with clear vision who perceived that if copper could be obtained with suitable mechanical qualities, it would be an excellent material for telephone lines. He directed his attention to this subject and produced hard-drawn copper wire in suitable form for telephone lines. I refer to Thomas B. Doolittle, who was the first one to use hard-drawn copper wire as the material for telephone lines. Hard-drawn copper wire was thus used by him at an early date at Ansonia, Conn. The results obtained were satisfactory, and, after a number of years had elapsed, a practical demonstration of the value of hard-drawn copper wire for long-distance lines was made by stringing a circuit extending from Boston to New York. The success of this circuit, using hard-drawn copper wire, demonstrated the feasibility of long-distance telephony. Here again the art of stringing wires had to be reformed. Linemen, foremen, engineers, and managers had to be taught how to handle the new material, the factories had to be instructed in its making, and even a new joint had to be perfected. The size of wire to be used had to be determined, and this was found out when the New York-Philadelphia long-distance line was established, upon which wires of various sizes were strung.

Those which were mechanically weak were eliminated and many valuable data were obtained. Since those times, hard-drawn copper wire has been found to be the only material suitable for long-distance lines. Compound wires of various sorts have been suggested from time to time, but invariably they have been found unsatisfactory for long-distance transmission. Whatever use they have must be for local lines and the precise function of this bimetallic wire in such lines is yet to be generally agreed upon.

While much has already been accomplished in the perfection of the telephone wire plant, much still remains to be done; and to make our record of future achievement as worthy as that which has already been accomplished we must constantly direct our efforts not only along broad and comprehensive lines, but we must also pay strict regard to each and every one of the thousands of small pieces of apparatus, many of which are dealt with in the paper, and all of which go to make up the sum total of the telephone wire plant.

Hammond V. Hayes: The methods of telephone plant development which Mr. Grace has described represent those which we are now employing and which have been employed by the Bell engineers for a number of years past. Practically every city and town in this country has been studied, and all new work is carried out on well-considered lines as formulated by development plans of this character.

The development plan is simply a forecast, what someone, I think Mr. Carty, has called a guess based on scientific or engineering principles, as to what may be expected for the future of the telephone business in each particular locality. So difficult is this forecast of the future, and so inadequate are any rules or formulas, that it has been our custom to employ for this work, as far as has been possible, a group of young men who have gained special training by the varied experience derived from the preparation of plans of this character for cities and towns scattered throughout the country. We find that in many parts of the country the optimism of local men is such as unduly to distort their judgment as to the future size and importance of their own towns; and, occasionally, although rarely, there is such insufficient appreciation of telephone possibilities that there is a tendency to create plants of insufficient size. Even engineers that are detailed for this work have methods of estimating and checking their work which cannot be definitely formulated. In fact, it is their judgment based on wide experience which prevails. I have no doubt that in very many cases as good or better estimates for the future can be made by men of good judgment and good sense without resorting wittingly to the elaborate method such as we describe; I say this but to emphasize the fact that in this as in every other engineering problem it is good judgment based on ample and proper premises which is of importance.

Mr. Grace has talked and spoken of an "all-cable" plant. I want to emphasize that the all-cable plant as described refers simply to the distribution of lines within a city. All the planning done in every city and town in the country is to arrange the plant so that the distribution of the wires to the sub-stations may be satisfactory and that it may be possible that each sub-station in each town will be capable of talking with every other sub-station in other towns. This placing of lines in cables cannot be applied to the wires used for long-distance circuits to any great extent, for the reasons that the cables tend to cut down the efficiency of service; what must be done is to keep the wire plant of the system not only the best possible for maintenance reasons, but to arrange it so that it is capable of rendering possible communication over the widest possible range of territory.

I am much interested in some of the mechanical features of the plans that Mr. Grace has shown us, and I hope that I may take the liberty of speaking of the cable-box. Mr. Grace has with great modesty said but little about it. This box is his own work; he designed it and perfected it, and I hope that t will be used very generally in the future throughout the United States.

I would like to say one word more about the question of steel and copper wire, following substantially the same thought that was in Mr. Carty's mind. Wire of this character was used some years ago in this country and has been on the market in Europe for many years. I am very glad indeed that the experiments with this wire are being carried out by Mr. Grace. I hope that he will continue the experiments, and will tell us at some later time what his success is and if such a wire offers an additional means of line distribution. I feel, however, that the wire plant is so important a feature of the telephone system that it would be well to go slowly and consider a material of this character as an experiment until such time as it has been more thoroughly tried out.

G. M. Yorke: The system described by Mr. Grace contains a minimum amount of open wire. As Mr. Hayes has said, this system is mainly used for connecting the subscribers' stations with the nearest central office. This portion of the plant has to be made compact and sightly. But a large percentage of its use is merely for communications between stations only a very few miles apart. Now, when we consider that other very important portion of the telephone plant, used for connecting central offices together many miles apart, hundreds of miles apart, we see that such an extensive use of cable is quite impossible. The reason for this is that cable circuits have always been very inefficient in transmitting speech. This inefficiency still exists in spite of the improvements in cable manufacture that have been touched upon and also in spite of other general improvements in the art. As an example of the inefficiency of cable circuits, take the type of circuit used for the longest distances in this country. These circuits are about fifty times as efficient as the form of cable circuit described by Mr. Grace, and used so largely for subscribers' lines. In other words, one of the regular lines from New York to Chicago talks as well in volume and in quality as a cable circuit only twenty miles long of the sort described by Mr. Grace. A further point is that if we connect only ten miles of such cable to this long open wire circuit, it is necessary, in order to keep the transmission efficiency at the same point of loudness and quality, practically to double the weight of copper in the long line circuit. Of course this is an extreme illustration. In view of this relative inefficiency of cable circuits, we are not going to speak right away of an all-cable long-distance plant. It is necessary to bring the open wires as near to the center of the terminal cities as is practicable and to keep all cable out of intermediate cities if we can. This becomes more and more necessary in view of the increasing amount of cable that it is necessary to use in subscribers' lines. I simply want to point out that the open wire is not to be abandoned just because it is unsightly. We are going to keep it if we are going to keep long-distance telephone service.

F. L. Gilman: As has been said several times, a material advance has been made in the art of cable manufacture, and the present paper-insulated cable has been used in its present form for a good while with satisfaction. One great effort in recent years has been in the direction of getting more wires into a given amount of space without increasing too much those electrical characteristics of the cable which are harmful to transmission, and without using sizes of wire that cannot be handled easily.

Mr. Grace has spoken of the braided rubber-covered wire used between the cable terminals and the subscribers' stations. Perhaps if I outline briefly the conditions which obtain, the problem of this rubber-covered wire will be realized more clearly. In telephone lines there is constantly a difference of potential existing between the two sides of the line and between one side of the line and ground; and throughout its entire length, in the kind of distribution of which Mr. Grace has been speaking, the line is composed of twisted wire. This is true of the rubber-covered wire as well as of the rest of line. The two wires are twisted together to keep outside disturbances from affecting the telephone transmission. Furthermore, the resistance of the part of the circuit including the rubber-covered wire has certain limitations. Then again, as can be seen from the pictures, this part of the plant runs anywhere and everywhere; it is on walls and fences; it is generally outdoors where it is exposed to sleet and rain; in the summer-time it is subjected to excessive heat, and in the winter-time to extreme cold. In other words, this wire is everywhere in the system and in nearly every telephone line in the large cities.

Now, if the wire is not in first class condition and has not first-class insulation there are a number of different troubles that exist. In the first place, there is a waste of current and the possibility of electrolysis. Then there is sensitive apparatus in the central office which will be affected. More important than these is the transmission which is also in jeopardy. If there is a leak on one wire of the pair, the line will be noisy; or if there is a leak between the two wires of a pair, reduced transmission will result because of the short-circuit. Another reason for first-class insulation is the fact that this braided rubber-covered wire is fairly expensive to start with, and the running of it is also expensive, so the life has to be long in order to make such construction economical. Furthermore, because of the moving of subscribers, this wire may have to stand taking down and putting up again.

What I want to bring out clearly is the fact that it is requisite that the wire used for this purpose shall be of first-class quality and maintain its insulation. Of course we are more or less familiar with braided rubber-covered wire, but perhaps we have not all realized just what the vital point is. The rubber compound itself will not last unless it is properly protected. The usual method of protecting the braid is a cotton braid, but that will not stand the heat and rain of summer unless it is properly protected, so the whole gist of the matter is the protection of the braid—some protection that will not run off in summer and will not crack in winter.

Kempster B. Miller: I wish that the Institute might have more telephone papers of this kind, wherein plants in different parts of the country are described not only in general terms but with a considerable amount of detail. Such description of practices in different parts of the country, and a frank discussion of them, are just as necessary and desirable in telephony as in any of the other arts, and I think perhaps more necessary, because they have been less common.

It is often interesting to watch the tendency of growth in the development of any art. From what has been said to-night, it is evident that there is a tendency to decrease gradually the use of bare wire in local telephone plants—I am speaking of the local plant as distinguished from the long-distance plant. There are some who contend that there should be absolutely no bare wire in a local telephone plant, and several plants of considerable magnitude have been constructed in which I understand there is not a foot of bare wire. The practice that Mr. Grace has outlined stops just short of this extreme, and it seems to me that it stops in just the right place. To say that there shall be absolutely no bare wire in the plant, simply for the purpose of being able to boast that there is none, is in the nature of riding a hobby rather than of good engineering.

Another tendency that has been brought out, not only by Mr. Grace but by Mr. Carty and others, is the diminishing use of rubber-insulated wire in telephone plants. Not long ago we did put a little rubber wire into almost every cable; that is, at the outer end of the cables. The practice that Mr. Grace describes does away with this in a large measure, certainly on all the small cables. He terminates the paper cable directly in a terminal sealed with an insulating compound so that there is no rubber-covered wire in that part of the plant. This means that the only rubber-covered wire is in the drop wires and in the house wires.

Perhaps after hearing of the beauties of the paper cable as outlined by Mr. Carty, people in other arts than telephony may be so impressed that they will adopt paper cable where it may be dangerous to do so. The paper cable is used in telephony because there is no other form of cable that we know of to take its place. Whatever may be said of paper cable, it is subject to one very serious drawback—any slight puncture of the sheath is liable to put all the wires out of business. While such troubles as these are readily repaired, yet they are very apt to occur. In other systems of communication where the high frequencies of telephony are not employed, it is feasible to use rubber or gutta percha insulated wires, and their reliability is infinitely greater than that of paper-covered wire. For this reason where the cable is difficult of access, as in submarine work, or where reliability is of paramount importance, as in the fire-alarm telegraph, the paper cable has little place.