

DISCUSSION ON "REPORT BY THE JOINT COMMITTEE ON INDUCTIVE INTERFERENCE," SAN FRANCISCO, CAL., SEPT. 17, 1915.

PROGRESS OF THE INVESTIGATION OF INDUCTIVE INTERFERENCE BY THE JOINT COMMITTEE ON INDUCTIVE INTERFERENCE

Since the presentation of our report at the Spokane convention a year ago, the principal experimental work has been conducted at San Fernando, about twenty miles north of Los Angeles. Here the committee had completely at its disposal, for several months, a thirty-seven mile power circuit and private telephone circuit of the Pacific Light and Power Corporation, also several banks of transformers, loaned by the same corporation. These facilities, in addition to the regular equipment of instrument transformers and portable field laboratory, made it possible to conduct extensive tests along various lines. The chief points investigated will be briefly mentioned.

The unbalances to ground of a power circuit isolated from ground. This study was undertaken with reference to the residual voltage caused by such unbalances and the effectiveness of transpositions as a means of balancing the system. The conductors of the circuit used for the experiments are spaced five feet apart in a vertical plane. Tests were made under three conditions of the power circuit as regards transpositions; first, no transpositions; second, two transpositions dividing the line into three equal sections, or one barrel; and third, five transpositions dividing the line into six equal sections, or two barrels. Under each condition, tests were made consisting, in part, of residual voltage measurements with the line energized at approximately 28 kv. between wires, by a bank of transformers isolated from ground; and, in part, of measurements of capacitance and conductance unbalances to ground of pairs of conductors at frequencies ranging up to about 1000 cycles per sec. The influences of connected apparatus and of leakage under wet weather conditions were considered. As might be expected, the results of the residual voltage measurements at the fundamental frequency (50 cycles) showed no difference in the effectiveness of two over one barrel for this length of line. In the absence of a source of three-phase energy for frequencies ranging from 200 to 1200 cycles it was necessary to resort to an indirect means of determining the residual voltage at these frequencies. Measurements of the unbalances between pairs of conductors, supplemented by measurements of the total admittance to ground of different combinations of conductors, afford means of computing the residual voltage. The results of these tests at high frequencies showed a marked difference in the effectiveness of the one and two barrel systems; two barrels being, of course, better than one with the advantage increasing at the higher frequencies. It is interesting to note in this connection that the non-transposed condition of the line gave better balance at the highest fre-

quencies than at the lowest. A point was reached when the gradual decrease of the unbalance with no transpositions and the rapid increase of unbalance with a single barrel resulted in a worse unbalance for the single barrel than for no transpositions. The question naturally arises in the minds of some, as to the reason for tests at such high frequencies where the fundamental operating frequency is only 50 or 60 cycles per sec. It has been repeatedly stated and shown that the harmonics rather than the fundamental frequency components are the basic cause of disturbances in parallel telephone circuits. The practical goal of all this work is the determination of reasonable requirements of transpositions in power circuits isolated from ground as a means of obtaining effective electrostatic balance and thereby preventing harmful residual voltage.

Parallel with the experimental work, a theoretical study of the unbalances characteristic of different circuit configurations was carried out. Consideration was also given to the equivalent unbalances of a line at high frequencies.

The relationship of triple harmonic residuals to the magnetic density in grounded star connected transformers. This study included tests with both delta-star and star-star connected transformers. Since the reaction of the line is a factor in determining the residuals introduced by a given bank of transformers the investigation included tests of the influence of different line conditions.

The magnitude of triple harmonic residuals as affected by transformer connections. The comparisons were made at approximately constant magnetic density. The connections considered included star-star, delta-star, delta-interconnected-star, star-interconnected-star, and the effect of an auxiliary bank of delta-star or delta-interconnected-star transformers so connected as to act as a shunt to the line for the triple harmonic residuals introduced by the main transformers.

Induction between the power and telephone circuits. The close and uniform association of the two circuits, the two being carried on the same poles, afforded an unusual opportunity for an experimental determination of the coefficients of induction and a comparison with computed results, and for testing the effectiveness of transpositions in both the power and telephone circuits as means of reducing inductive interference.

Tests of induction at the fundamental operating frequency of the system were made by energizing the power circuit through transformers under conditions favoring in turn the predominant effect of: (a) balanced voltages, (b) balanced currents, (c) residual voltages, and (d) residual currents. The corresponding induction in the telephone circuit was measured simultaneously with the current and voltages of the power circuit. As the induction from the balanced components of voltage and current is dependent upon the transpositions in the power circuit, these tests were carried out under the three previously mentioned conditions of power circuit as regards transpositions.

The effectiveness of transpositions in the telephone circuit as a means of reducing induction arising from the several components of power circuit voltages and currents, was tested on a short section of the line which contained no power circuit transpositions.

In a short section of the "parallel," with both power and telephone circuits non-transposed, an extensive series of measurements of induction was made using many combinations of conductors and methods of energizing the power conductors. The effects of shielding were studied to a limited extent.

With a single-phase source of energy at high frequencies (Vreeland sine wave oscillator) measurements were made of the coefficients of induction corresponding to harmonic residuals of high frequencies, and the effect of telephone transpositions, as a means of minimizing induction from such sources, was studied. The lack of a three-phase source of energy at high frequencies prevented the doing of any experimental work to determine the effectiveness of power circuit barrels of different lengths on the induction from the higher harmonics of balanced currents and voltages.

The computed coefficients of induction were in very close agreement with those experimentally determined. As a basis for the computations of induction from residual current it was necessary to determine experimentally the depth of the equivalent locus of earth currents. In general, the study of induction and of the effectiveness of power and telephone circuit transpositions, while not being as complete as might be desired, owing to the lack of some apparatus and the fact that only one telephone circuit was considered, has given results of considerable value.

The effect of a ground on one phase of a normally isolated system in producing abnormal residual voltages and currents was studied both experimentally and theoretically with close agreement in the results. Under the abnormal conditions of a ground on a power circuit it is, of course, the resulting residual currents and voltages which cause the greatest damage to parallel communication circuits.

Observations of the residuals of the 15-kv. network (Pacific Light and Power Corporation) which supplied the committee's temporary substation and field laboratory, were studied under two conditions of operation of the power system.

In addition to the San Fernando work there has been some work done on a study of the residuals under operating conditions at several points on grounded neutral networks. The object of these tests was to obtain information as to the magnitude of residuals to be expected under different typical conditions of operation so as to afford a basis for future recommendations as to the limitations of residuals of this type of system.

During the past year a considerable amount of work has been done on several problems by the telephone companies at the

request of the joint committee. The American Telephone and Telegraph Company has conducted extensive tests to determine the detrimental effect, on the intelligibility of conversation, of extraneous currents of different frequencies in a telephone receiver. A report of the results obtained for single frequencies has been submitted to the committee and work is now under way with reference to the effect of multiple-frequency currents of different combinations. The important bearing of this work was indicated in the discussion submitted by this committee, at the Deer Park convention, on the subject of irregular wave-forms.

Subsequent to the issuance of our report last year, the matter of the redesign of its standard telephone transposition system was undertaken by the American Telephone and Telegraph Company, in order to facilitate compliance with the committee's recommendations in regard to transpositions within the limits of parallels. The present standard system of telephone transpositions affords very limited opportunities for coordination with power circuit barrels of different lengths, to make the power and telephone circuits mutually non-inductive. For this reason, the redesign of the telephone transposition system to permit of more flexible arrangements in combination with power circuit barrels was made necessary. This modification of the telephone transposition system applies both to the standard sections and to the short length sections. A large amount of work is involved which has not as yet been entirely completed.

At the request of the joint committee, the Pacific Telephone and Telegraph Company has submitted a report dealing with the development of balance of telephone circuits. This report is the result of an investigation of the methods and measures employed by the telephone companies to obtain good electrical balance of their circuits and to protect them against inductive interference from other telephone circuits (cross-talk) and from foreign sources. The report considers the subject from the conditions presented by the earliest experience of the telephone companies to those of the present day. This report was desired as a basis for the consideration of the subject by the committee.

The committee has recently been giving careful attention to the matter of future work. There appears to be no good reason for deviation at this time from the general program as laid down in the committee's report published last year. It is expected, therefore, that the future work will continue, as has the work during the past year, along the general lines suggested by that program. The detailed plans for the conduct of this work have, however, been the subject of much discussion. The facility with which the work at San Fernando could be carried out with both power and telephone lines completely at the disposal of the committee at all times, suggested the possibility of test lines constructed primarily for experimental purposes. Were necessary funds available, tests of great value could be of course carried out under such conditions. After carefully weighing all ques-

tions involved, it was decided that the information desired could be obtained most advantageously by a study carried out under practical conditions. In any event the committee could not, in justice to itself, properly call its work complete without actually applying in several cases the remedial measures which it proposes and noting the difficulties and limitations imposed by practical conditions.

The problem offered by any case of parallelism between power and communication circuits is capable of subdivision into two main parts. These are, first, the matters of line configuration and coordinated transposition systems to render the power and communication circuits as nearly as practicable mutually non-inductive, and second, the control of residuals and their restriction to frequencies and magnitudes which do not cause material interference either to grounded telegraph circuits or to properly transposed and balanced metallic telephone circuits. Normal operating conditions on the power system are assumed.

With reference to the first subdivision, the problem is identical for both the isolated and the grounded neutral types of power system. The second, control of residuals, differs entirely with respect to the two types of systems. For the isolated system the principle is relatively simple. Transposition of the circuit involved in the parallel, throughout its entire length, so as to obtain good electrostatic balance offers the most practical way of accomplishing the result desired. Assuming a uniform configuration throughout the line, the transpositions for this purpose must be so located that each conductor of the circuit occupies all of the conductor positions for equal distances. In other words, they must be equally "exposed" to the earth. In addition, the transpositions must be frequent enough so that their balancing effect is not rendered ineffective by the attenuation and phase changes which occur along the circuit at frequencies producing harmful interference to the communication circuits. With reference to grounded neutral systems, the control of residuals presents a more complex problem, especially on existing systems. Its solution has engaged the attention of the committees in large measure from the outset of the investigation and will undoubtedly continue to do so in the future, as this seems one of the main outstanding problems. The residuals of grounded neutral systems characteristically contain the third harmonic and its odd multiples, together with some fundamental and other harmonic components due to unbalanced load conditions. The solution of this problem, therefore, involves a very careful study of transformer connections, magnetic density, the reaction of lines upon the triple harmonics introduced by transformers, and the interaction of the different banks of grounded star-connected transformers throughout a system. The practical solution of a question of this kind requires tests of typical grounded neutral systems under actual operating conditions. Tests such as were conducted at San Fernando, under the relatively simple condi-

tions where the residuals introduced by a single bank of transformers were studied, afford, however, a good foundation for the study of the more complicated cases to be encountered in practice.

To carry out the plans just discussed, a tentative program, now under consideration, includes the investigation of one parallel involving the isolated type of power system and several parallels involving the grounded neutral type of power system. It is felt that the study of an isolated power circuit, as conducted at San Fernando, supplemented by one other investigation involving this type of power system, will afford the committee all the information necessary for it to establish, on a firm basis of scientific fact, the requirements for transpositions to give good electrostatic balance on power circuits isolated from ground, thereby preventing residuals of harmful magnitude. The complex conditions encountered on grounded neutral systems make it inadvisable that general conclusions be drawn from an investigation of a single case.

It was said above that a theoretical study has been made of the effect of power-circuit configuration on the electrostatic balance of the circuit. It is proposed also to study the effect of circuit configuration on the induction between power and communication circuits. Some work along this line has already been done, especially with reference to possible alterations in configuration of telephone phantom circuits. In general, if it is possible to make power and telephone circuits mutually non-inductive, to a satisfactory degree, by a reasonable number of transpositions installed for this purpose, it is not expected that the question of configuration for either class of circuit will become of controlling importance. Configuration of both classes of circuits will be considerably influenced by other reasons; economical methods of construction for both lines. Other things being equal, it is very desirable that circuit configurations be such that the coefficients of induction between non-transposed sections of lines shall be as small as possible.

A study of the variation with frequency of the effectiveness of transpositions in both power and telephone circuits has been suggested. Under practical conditions there are, however, many other factors, such as length of parallel, large number of telephone circuits involved and points of discontinuity within the limits of the parallel, which enter into the problem of determining the proper number of transpositions in both types of circuits. These factors are such as to enforce arbitrary and somewhat inflexible limits, so that this matter of frequency is not the determining factor in setting a limit for the number of transpositions required to obtain mutually non-inductive conditions. The effectiveness of transpositions at high frequencies was one of the chief questions proposed for experimental investigation on test lines. Such an investigation would be of undoubted scientific interest, but the practical bearing of the

subject does not seem to warrant the expense involved, especially as it is expected that the results can be obtained more economically by theoretical study.

Upon completion of the work which has just been discussed, the committee expects to draft a supplementary report to be presented to the Railroad Commission of the State of California, giving in detail the conclusions derived from its investigation from the date of its first report, and such recommendations as it feels necessary, to make the rules recommended in the former report more complete and explicit than was possible at the time the earlier report was rendered.

During the past year \$7200.00 have been raised by contributions of the power and communication interests. Previous to this, \$9400.00 had been raised by a similar contribution made shortly after the formation of the committee. It should be noted in this connection that this amount of money represents only a small portion of the total expended on the investigation. Both the power and communication interests have in addition to the above, contributed heavily in the time of their employees and in apparatus placed at the disposal of the committee. This has been true particularly of the telephone companies. The Railroad Commission of California has also contributed financially, and the railroads of the state have contributed through the provision of free transportation for all committee members, employees, and freight. From the outset, the investigation has had the support of communication interests with more than statewide affiliations. On the other hand, upon the power interests of California has fallen almost the entire burden of meeting the power interests' share of the expense. Of late there has been considerable discussion among the California power interests with reference to obtaining the financial support of the similar interests throughout the country. This subject is undoubtedly of far more than local importance and it is to the interest of all parties that the investigation thus begun be brought to a state of reasonable completeness. The organization and equipment of the committee and the unrivaled field for investigation offered by the conditions in California render it desirable that the work be prosecuted to a conclusion in this State. It is the hope of the Joint Committee on Inductive Interference to bring its study, which involves the mutual relationship of the two largest subdivisions of electrical industry, abreast of the present state of development in each of the two arts involved, electrical energy supply and electrical communication. Beyond this point we can not reasonably go; further progress will occur naturally with the evolution of the two arts. We believe that this result can be realized in such a manner as to leave both unfettered in their development. This, as we undoubtedly all agree, broad-minded public policy will demand.

A. J. Bowie, Jr.: I am very much interested in the effect of high-frequency oscillation on telephone lines. It is a well known fact that the higher the frequency the worse would be the inductive effect upon the lines, and it is highly desirable that any effort it is possible to make should be made to keep away from the effect of high frequency, no matter what it comes from. There appeared some time ago in the *Electrotechnische Zeitschrift* some articles by Doctor W. Linke, these were in the issues of July 2nd and July 9th, 1914. He discussed transient phenomena. He had made a general study of these phenomena from many points of view with different phases, kinds of circuits, conditions and kinds of switch apparatus; and the result of this is published in the two issues referred to. In particular he discusses the effect of different types of switches, and arcs found in the different types of switches, and the voltage varia-

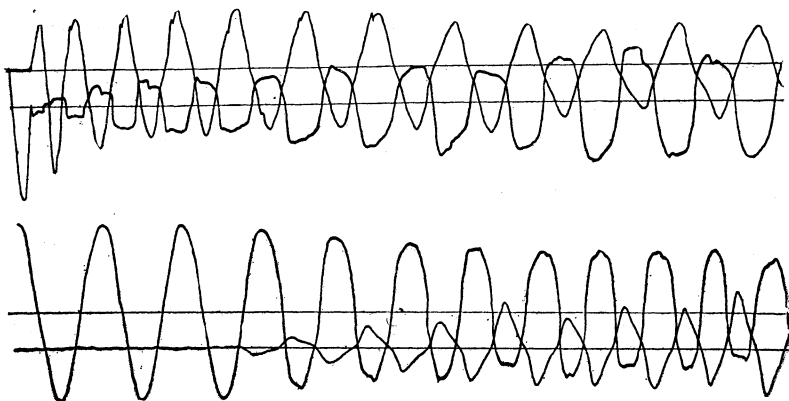


FIG. 1

tion, particularly with reference to the creation of harmonics in their own circuits. He has made tests of both oil switches, air switches without horns, and air switches with horns. His conclusions are that the oil switch causes the most serious harmonics, but the air switch without horns was gentler in its action, and that the air switch with horns was ideal in its action in suppressing the harmonic and gradually reducing the current before the point of final break.

Among others he made a test on a 10,000-kw. generator, which was short-circuited by a horn-break air switch. The generator was brought up to normal voltage before short-circuiting. The phenomenon of opening is shown by the oscillograms. The voltage curve does not show a single sharp peak or quick rise, even with the rising of the arc on the horn, and likewise with the gradual increase of resistance the voltage rises from the moment of short-circuiting slowing to the normal height, while the current changes to zero. This is shown in

Fig. 1. Fig. 2 shows the corresponding test made with the oil-break switch.

There has been a certain amount of misunderstanding of the action of arcs in air, which I think is being gradually straightened out as further experiments throw more light on the subject. At first it was supposed that the arcs which occurred in air caused destructive rises of voltages on their own circuits. It has been pretty well disclosed by many tests which have been made, among them some made by W. P. Hammond, which appeared about a year ago in the *General Electric Review*, and showed definitely, that the rise of voltage which occurred from opening the horn type of switch was less than that which occurred in opening the air type of switch. Having disproven any material rise of voltage occurred on their own circuit, they were finally confronted with the fact that the arc may affect the neighboring circuit.

There are only three cases in which a rise of voltage can

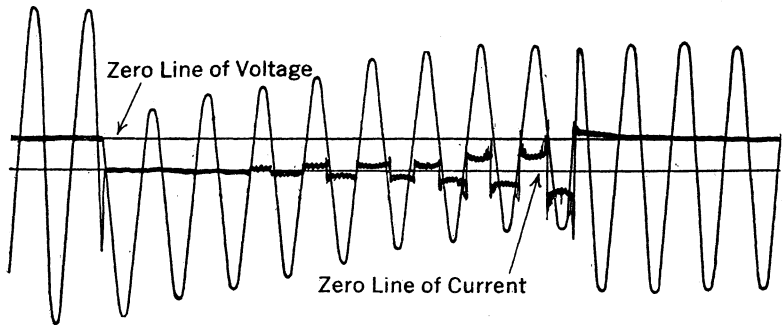


FIG. 2

occur on the power circuit which will affect the telephone circuit. The one is from a natural rise, from the opening of the switch; the second is from harmonics; and the third is from the unbalanced condition which will result from one phase opening in advance of the other phases. We cannot say definitely, either with an oil switch or an air switch, that all three phases open at the same time, in fact, it is doubtful whether they do; but no definite data have been brought forward on this subject one way or another. It is a matter which should be investigated further before any rules or regulations are passed on the subject.

John B. Fiskens: There are some rules that are a little hard on the power company, possibly because they are not understood. I have been for about a year trying to find out what is meant by a "parallelism." Rule No. 1 reads that "reasonable effort shall be made to avoid new parallelisms." I think all power companies try to do that. We are told to avoid parallelisms, but are not told what a parallelism is. What I

want to know is, when a power line and a telephone line are running in a parallel direction, what is the distance between them and the length to constitute a parallelism?

On this question of air-break switches versus oil-break switches, we have in some of our lines occasion to use air-break switches. Some two or three years ago we had oscillograms taken on these lines. As I remember, the higher frequencies were not present to as great an extent with the air-break switches as they were with the oil switches. We have two lines which we have fought with for some time, and in connection with them I want to ask Mr. Babcock if the committee has made any investigation of the effect of killing the charging current on a steel tower line. My reason for asking that, is this—something like nine or ten years ago we built two lines, 60,000-volt lines, 60 cycles, that paralleled main telephone lines. We operated them many years without any trouble. What is technically known as "bats" had not put in an appearance. A few years ago the bats began to get on the scene, and it puzzled us to know where they came from, as the method of operation had not been changed in the slightest degree. We found that in taking the power off the line, there was no result, but when we came to "kill" the line, breaking the charging current, there was a result.

Now, the connection between this line and the steel tower line is this—several years ago, in order to get rid of the burning of our pole tops, we grounded the pins on both of these lines. The effect is the same on either of them. It has occurred to me since that possibly the ill effects that we get from these lines may be due to the discharge of the condensers—there are over 2000 insulators on each line, which constitute condensers, and I have thought that possibly the rush to ground through the ground wires might cause this trouble. We have solved that problem in a measure by doing our switching on the low-tension side. That in many cases is not a practicable proposition. There are one or two questions which I think will have to be referred to the manufacturers, the requirements as to wave form, etc., of generators, and the transformer requirements.

J. E. Woodbridge: I can answer Mr. Fiske's question about the so-called "bats" probably by a description of the appearance of the same trouble in this territory. There have been reported to the various power companies around San Francisco some very severe bats that in some cases affected telephone operators to such an extent that it drew blood from their ears, etc. These troubles were investigated and it was found that they synchronized with the killing of certain 100,000-volt power circuits by the opening of switches. It was found that the three individual single-pole oil switches, in the three phases of the 100,000-volt line, did not open at exactly the same instant. They were operated by three independent air cylinders, that is, they were not mechanically connected to open

at the same instant. It was partially on account of that difficulty that the ruling was recommended to the railroad commission to provide for mechanical connection between such switches. That slight difference in the time of operation of the three phases is a small measure of what is to be found in the operation of air-break switches. These air-break switches, referring now to the article by Mr. Hammond, required in some cases several seconds, that is, several hundred cycles, for the breaking of the circuit, where oil switches require, as a rule, a fraction of a cycle, and probably at the most from one to two cycles. The three arcs drawn off in air do not break simultaneously, as has been observed visually; and the breaking of one arc ahead of the other two, or two ahead of the other one, leaves full voltage supply to one of two conductors, with the other conductor or phase open-circuited. That gives the same action as the slight difference in the operation of the three oil switches just mentioned, only, presumably to a much greater degree.

J. P. Jollyman: Our study of this matter of inductive interference has pointed out to those of us who have been interested primarily from the power standpoint, one thing that is interesting and very encouraging, that the things which do the most to cause trouble with the parallel communication circuits are not essential to the operation of the power circuits. It is the little odds and ends of things that creep into the power circuits and have nothing to do with the actual business of transmitting power, that cause most of the trouble for the parallel communication circuits. With this point in view, it seems that the power company should reasonably be expected to do what it can to get rid of the things that are not essential to itself but which cause a great deal of trouble to other people.

Fortunately the desirable frequency for transmission of power represents a frequency very materially below the average frequency of voice currents. The power currents of normal frequency, which, of course, are the useful currents for the transmission of energy, where they do set up induction, set up an induction which is not as troublesome in telephone lines, at least, as the induction from the higher frequency harmonics which creep into a power system at times. With the exception of a few instances, I believe that these harmonics are of no particular importance to the power people. They do not serve any particularly useful purpose, nor are they usually of sufficient magnitude to be particularly noticeable to power people. In some cases, however, they are very noticeable to the parallel communication interests, and are a great deal more effective in causing trouble than is the primary or fundamental frequency.

The reduction of the harmonics and of their effect is, with respect to the telephone lines, at least, the principal problem before the committee at the present time; in other words, the problem is to control those frequencies in the power system,

which are not essential to the operation of the power system, but which are very disturbing to their neighbors. In the case of the telegraph lines, the lower frequencies are more troublesome than in the case of the telephone lines. Telegraph lines fortunately, are not as sensitive as the telephone lines, and the operation of parallel circuits is not so difficult. Of course, the power men know the fact, that transformer magnetizing currents do contain a certain amount of harmonics higher than the fundamental. It is possible in a new system to design the transformer connections so that the effects of these harmonics will be very largely eliminated. Some of the existing systems have many transformer connections in which the third harmonic component of the transformer magnetizing current is not taken care of within the bank itself. An important problem before the committee at the present time is to learn how to take care of this locally. It seems that this can be accomplished.

A matter of very great concern at the present time to all of the interests involved is to find out, if we can, the most-practicable forms of line construction, transformer installation, etc., which will be preferable from a non-interference standpoint. A considerable option, especially on the part of the power company, exists in the form of the arrangement of conductors on a supporting structure, without any material difference of cost, or with very little difference in cost. As was pointed out in the discussion presented by Mr. Babcock, the most important problem before the committee at the present day is to find how the circuits may be built to give the least inherent mutual interference.

P. M. Downing: The report of the Inductive Interference Committee has been criticized because it is indefinite, and does not define what constitutes a parallel or a parallelism.

As a member of that committee I do not hesitate to say that neither the power nor the telephone people were able to determine a proper definition of the term.

In view of our knowledge of the subject, neither side was disposed to make any hard and fast rule, fixing the separation between power and telephone lines. Nor are we prepared even yet to say just how great the zone of interference is under every condition of voltage, loading, configuration, etc. In other words, there are so many elements that must be taken into consideration, that a still further study of the subject must be made before a better definition can be given. The further investigations of the committee may enable them better to define the term, and they may not.

J. B. Fisk: As I understood Mr. Woodbridge in answer to my question, his solution of the difficulty was that the three poles of the switch did not break at exactly the same moment. I want to assume the case that they break together as nearly as it is possible to make them break. In this particular case I would state that we have an expert switch man, who goes over our

switches all the time and adjusts them, so that as near as it is possible for any human being to make them, the three poles of the switches break at the same time. Assuming that the three poles break at the same time, then does the fact that the pins are grounded and the insulators act as condensers cause the interference when the charging current is broken?

E. E. F. Creighton: I think it is impossible to answer Mr. Fiskens's question offhand, as so much depends upon conditions. The capacitance of an ordinary suspension type disk is approximately 34 micro-farads, in other words, 34 times ten to the minus twelfth power. A calculation can, therefore, be made which will give the total current which would flow through the insulator to the ground. The capacitance of a string of suspension disks is equal to only a small fraction of the capacitance of the line wire between towers. I should suspect the trouble was due to the accidental arc-over on the line at the time of opening the switch, or to an unbalanced electrostatic condition of the three phases during switching.

J. E. Woodbridge: As I understand the two conditions Mr. Fiskens describes, one is the condition of the neutral between the pins and the other is the resistance of the wood pole between the pins and the ground. We made some computations at one time of the amount of line capacitance which is contained in the insulators themselves, which in the case we had in mind was a string of suspension insulators. We tried to determine what proportion of the total line capacitance was made up of the capacitance between the caps and eyes of the suspension insulators, and we found that this capacitance was a very negligible part of the total, I believe a fraction of one per cent. The capacitance of pin insulators would be some comparative figure, so that I do not think that with the removal of the series resistance of the wood pole, this very small fraction of the capacitance would have any effect whatever on the coefficient of induction between the transmission line and the telephone line.

A. H. Babcock: Your attention is called to the fundamental requirements, not of any particular provision of the rules, but of the rules in general, namely: any switch, regardless of its type, its construction or method of its operation, that causes disturbances in the communication circuits, by those very disturbances renders itself objectionable, and any such switch that does not cause such disturbances is not objectionable. If only that point of view can go home, much of the present unfortunate misunderstanding will be more easily removed.
