

The Transactions of the South African Institute of Electrical Engineers.

Founded June, 1909; Incorporated December, 1909.

VOL. XXV, AUGUST, 1934.

EDITOR: A. B. EALES, A.M.I.E.E., A.M.I.MECH.E.

PART 8

Proceedings at Two Hundred and Fifty-Seventh Monthly General Meeting

23rd August, 1934, at 8 p.m.

Mr. Jos. White, M.C. (Senior Vice-President) was in the chair, and there were present 70 members and visitors and the Secretary.

THE PRESIDENT.

The Chairman: Gentlemen, our President, Mr. Gould, is absent from Johannesburg for a few weeks, and the duty of presiding at this meeting has fallen on to my shoulders.

MINUTES.

The Chairman: The minutes of the last monthly meeting have been circulated, and I would like your permission to sign them.—Agreed.

MEMBERSHIP.

The Chairman: The Secretary has an announcement to make under the heading of "Membership."

The Secretary: Applications for membership were received from Messrs. Robert Maxwell Stephenson and Wilfred John Gibbons, and the Council has graded them as Associate Members. Messrs. Stephenson and Gibbons will stand for election at the monthly general meeting in September.

The Council has admitted Messrs. Adriaan Hendrik Buitenweg and Willem Julius Polis as Associates of the Institute.

GENERAL BUSINESS.

Visit to S.A. Iron and Steel Works.

The Chairman: Gentlemen, under the heading of "General Business," I have two announcements to make: One is to the effect that we have been invited, as an Institute, to visit the Iron and Steel Works at Pretoria on Saturday morning, October 27th; and on Thursday, 25th October—a paper on the electrical lay-out of the steel works is to be given to the Institute by Mr. T. P. Stratten, the Chief Electrical Engineer of the Works.

*Appointment of Assistant Inspectors of
Machinery.*

The Chairman: The second matter is one of which you may have heard. Some time ago the Department of Labour appointed some unqualified persons as Assistant Inspectors of Farm Machinery. This was brought to the notice of your Council, who felt it was a very retrograde step, and, through the Controlling Executive of the Associated Societies, the authorities were approached. It was pointed out to them that it was very unfair to engineers who had gone to the trouble and expense of getting a training to find that untrained and unqualified men could be put into positions from which they might rise to such a further position that they might actually be in charge of qualified men. The representations, I am very glad to say, were successful, and you may have seen in the *Government Gazette* of the 13th July that the Government were calling for Assistant Inspectors of Machinery who must be qualified engineers. I think we can be congratulated on the fact that our representations have been so successful, and, at the same time, we feel that we ought to thank the officers of the

Department of Labour, with whom we dealt, for the very courteous way in which they saw our point of view and for ultimately acting on it. (Applause.)

The Chairman: Gentlemen, it is always a pleasure to be present at our August meeting. As you know, for several years past our August meeting has been devoted to papers given by Students. Without exception those papers have been of a very high standard indeed, and I am perfectly certain that the papers we shall have the pleasure of hearing to-night will not be lacking in that respect. There are three papers down to be read, but there is a little doubt in my mind, due to the length of the papers, as to whether we shall be able to get through more than two of them. The first paper is:

TRANSFORMER COUPLING WITH REGARD TO OVERALL EFFICIENCY AND THE INFLUENCE OF TERMINAL IMPEDANCES.

(Under the auspices of Mr. W. Hilarius of the African Broadcasting Company.)

By Messrs. N. TROOST, R. PRETORIUS and J. C. LAMPRECHT (Students), and Mr. F. W. STUTTERHEIM (Visitor).

The object of the investigation described in the following paper was to examine conditions of efficiency and the effect of impedance matching in the case of back to back coupling of two audio-frequency transformers; the one being an output transformer from the last stage of an amplification unit, and the other the input transformer of a second succeeding amplifier. The matter was brought up in some constructional features of the new Capetown broadcasting station, recently commissioned. As in the latest practice in telephonic transmission, this station has a very flexible system of combining the amplification stages; a system of "jacks" being arranged on a panel whereby any set of, say, microphone amplifiers may be connected to any one "A" amplifier in much the same way as a telephone operator connects two subscribers.

This system necessitates the use of two transformers, the first for feeding the out-

put of the one amplifier into either a landline for distance transmission, or straight into the next amplifier. The second transformer will then take its supply from these communicating links, and feeds into the grid of the next valve. As an ordinary telephonic line has a loop impedance of 500 ohms, both the transformers must match this impedance for best working. Similar considerations of matching make it necessary that the opposite windings of the transformers should match their respective input and output impedances. This fact precludes the possibility of combining the two transformers into a single step-up unit, and so doing away with an additional piece of apparatus liable to introduce a certain amount of distortion.

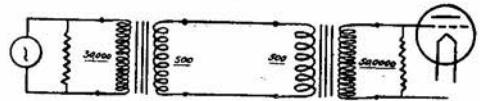


FIG. 1.

The normal condition for such back to back operation is shown in Fig. 1, where the output impedance of the first exactly matches the input impedance of the other transducer. This condition is well known to give maximum power transfer between the two pieces of apparatus. One would, therefore, expect that this simple condition would be universally accepted as being the best and only method. In the Capetown station, however, the contractor put in an arrangement, such as shown in Fig. 2. It

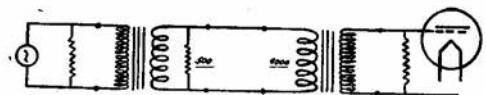


FIG. 2.

is clear that some 90 per cent. of the available output energy is shunted into the resistance, only the remaining 10 per cent. being carried over to the next circuit. To examine the effect of this arrangement is the subject of this paper.

The first step was to analyse the circuit theoretically and see how this shunt resistance alters the power transfer and phase relation of the circuit. To this end the ratio of the output voltage of the circuit to that at the supply was calculated. The square of this ratio then gives the power ratio,

while the phase angle between input and output voltages could also be so obtained. This was done in steps over the audio-frequency range. It is not the intention here to go deeply into transformer theory; be it enough to show the equivalent circuit of the transformer coupling in Fig 3 together

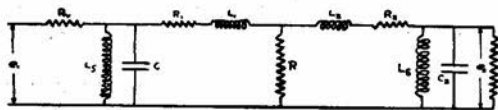
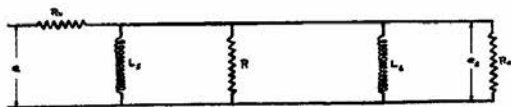


FIG. 3.

- R_v = Internal resistance of valve or generator.
- R_1 = D.C. resist. of primy. of 1st transf. referred to secy. + D.C. resis. of secy.
- R_2 = D.C. resist. of secy. of 2nd transf. referred to primy. + D.C. resis. of primy.
- L_1 = Inductance of secy. of 1st transformer.
- L_2 = Inductance of primy. of 2nd transformer.
- C_1 = Shunt cap. of windg. of 1st transf. referred to secy.
- C_2 = Shunt cap. of windg. of 2nd transf. referred to primy.
- L_{12} = Leakage inductance of 1st transf. referred to secy.
- L_{23} = Leakage inductance of 2nd transf. referred to primy.
- R_0 = Load resistance.
- R = Swamping resistance.



$$\frac{e_2}{e_1} = \frac{\sigma_1 \sigma_2}{1 + R_v(j\omega L_1 + \frac{C_1}{j\omega} + R_0) + \frac{R}{j\omega C_2}}$$

σ_1 = STEP UP RATIO OF 1ST TRANSFORMER

σ_2 = STEP UP RATIO OF 2ND TRANSFORMER.

FIG. 4.

with a list of symbols used. This rather complex circuit is perhaps best analysed by dividing our frequency band into three sections, namely: 1. Low frequency, where the effect of the shunt capacities C_1 and C_2 of the windings themselves can be neglected, and when also the series impedances, representing the flux leakage effects of the windings, can be taken as negligibly small. 2. Intermediate frequency, not high enough to make the capacity effect noticeable, yet so large that the shunting effect of the main inductances, L_1 and L_2 , decreases to negligible proportions. 3. High frequency, when the shunting effect of the

self capacities becomes all important, and when the shunt inductances may also, of course, be neglected. The resistances are, in each case, small, and their effect is automatically included in the load resistances, owing to our method of measurement,

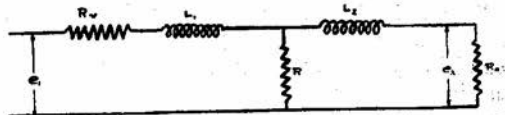
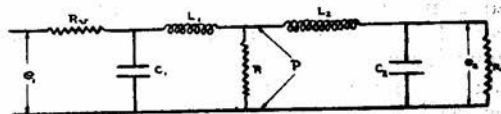


FIG. 5.

$$\frac{e_2}{e_1} = \frac{R_0 R_v}{(R_v + j\omega L_1)(R + j\omega L_2 + R_0) + R(j\omega L_1 + R_0)}$$

$$\frac{\phi_2}{\phi_1} = \frac{1}{-\omega^2 \left\{ \frac{L_1 L_2}{R R_0} + j\omega \left(\frac{R_v L_2}{R R_0} + \frac{L_1}{R_0} + \frac{L_2}{R} + \frac{L_1}{R_0} \right) + \left(\frac{R_v}{R_0} + \frac{R_v}{R} + 1 \right) \right\}}$$

FIG. 5.



$$\frac{e_2}{e_1} = \frac{R_0 R_v}{R_v(j\omega L_1 + \frac{C_1}{j\omega} + R) + (j\omega C_1 + R_0)(j\omega L_2 + R R_0) + j\omega(j\omega C_1 + R_0) + \frac{R}{j\omega C_2}}$$

$$\frac{\phi_2}{\phi_1} = \frac{1}{\omega^2 \left\{ L_1 C_1 L_2 \frac{R_v}{R_0} - j\omega \left[\frac{L_1 C_1 R_v}{R_0} + C_1 C_2 L_1 R_v + \frac{L_1 L_2 C_1}{R} + C_1 C_2 L_1 R_v \right] - \omega^2 \left[\frac{C_1 R_v L_2}{R_0} + \frac{L_1 L_2}{R_0} + L_2 C_2 + \frac{L_1 C_1 R_v}{R} + \frac{L_1 C_1 R_v}{R} + L_1 C_1 \right] + j\omega \left[\frac{L_1}{R_0} + \frac{L_2 R_v}{R R_0} + C_1 R_v + \frac{L_1}{R} + \frac{L_2}{R_0} + C_2 R_v \right] + \left[1 + \frac{R_v}{R_0} \right] \right\}}$$

FIG. 6.

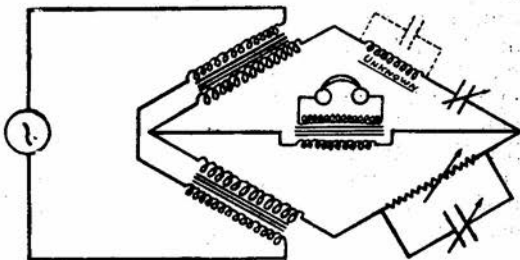


FIG. 7.

as will be seen below. These assumptions seem to have been justified by much of the previous work that has been done on similar transformers, and reference to which is made in the bibliography.

These three conditions give rise to the three equivalent circuits shown in Figs. 4, 5 and 6. The mathematical theory of these may be found in the appendix, the final equations being in each case given with the figure.

The actual transformers used in Capetown were not available; but a suitable pair was kindly lent to us by the African Broadcasting Company. A simple bridge circuit, as shown in Fig 7, was constructed and fed from a heterodyne oscillator at some known frequency of, say, 1,000 cycles. This frequency is commonly employed for such measurements, and may, in fact, almost be called a standard. One of the transformers was then loaded with its rated load on the valve side, this being taken to consist of a pure resistance, which, in practice, would generally hold good. The open winding was placed in one arm of the bridge, together with a series capacity. The fourth arm contained a pure resistance. The procedure was then to put in some value of the capacity and obtain a balance by means of the resistance. Capacity and resistance were varied in turn until, finally, the least sound was heard in the earphones. This is clearly obtained when the series capacity resonates with the leakage inductance, and the resultant pure resistance is balanced out by an equal resistance in the fourth arm. Finally, any self capacity of the transformer windings was balanced out by placing a small variable capacity in parallel in the fourth arm. This latter will give, to a first approximation, the value of the self capacity of the transformer referred to whichever winding we have connected in the bridge arm. The load-cum-internal resistance is given by the balancing resistance, and from the series capacity the leakage inductance may be calculated. These figures are also given referred to the same winding. The required constants are thus directly obtained, referred to whatever side we please, and can be directly substituted in the formula to give the theoretical voltage ratio at any given frequency.

The inductances L_s and L_p could also be obtained in this manner by leaving the secondary of the transformer open circuited, instead of placing rated load there; but this method was found not to answer too well in this particular case, and seeing that the figures were only required at low fre-

quency, it was decided to measure them with a volt- and ammeter and a low voltage 50 cycle supply.

The constants so obtained were inserted in the various equations, and the voltage ratio was found for a complete range of frequencies and given conditions of R, the swamping resistance. Actually four conditions were investigated, these being as follows:—

1. Straight through, the secondary of the first transformer being connected to the primary of the second with infinite shunt resistance. With the loading we had on the opposite ends of the apparatus this resulted in very close matching, the figures being 550 ohms and 546 ohms. Consequently we should expect best efficiency, and this is borne out by the theoretical curve given in Fig 9, No. 1. This shows the high relative gain obtained by this matching. It moreover shows the excellence of the transformers under test, as the response curve is very flat. It will, of course, be realised that the ideal circuit gives a constant gain from the lowest to the highest audible frequency, and any circuit not fulfilling this condition tends to introduce distortion.

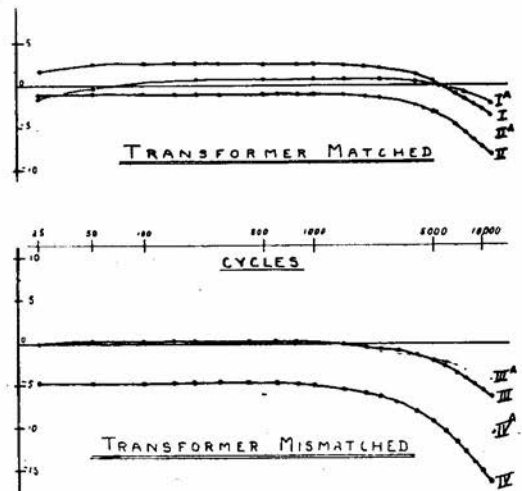


FIG. 9.

The effect of introducing a shunt resistance, matched with the primary output impedance of 550 ohms is also shown in Fig. 9, curve No. 2. There seems to be no apparent reason for exactly matching this resistance, but it is taken to be good practice. The effect of the change, as was to be expected, is to bring down the transmission

efficiency considerably, namely, by about $3\frac{1}{2}$ decibels. If anything, the effect is, moreover, to give better response at the extremities of the range, *i.e.*, a less pronounced droop may be noted in the curves at the ends. A very pronounced improvement is, however, not to be expected, owing to the already excellent response curve.

Curve 3, Fig. 9, represents another quite usual case, namely, where the first output transformer looks into an impedance of three or four times its own value of the second transformer, the actual figures being 147 ohms and 546 ohms. We see that there is little to be gained and much to lose, as the response is sensibly unaltered, but the amplification is reduced. Matching the secondary with a shunt resistance of 147 ohms, curve 4, reduces the efficiency still further without improving the response. In fact, if anything, this curve exhibits an increased droop at high frequency. These last two conditions were obtained by taking only half the secondary winding of the first transformer.

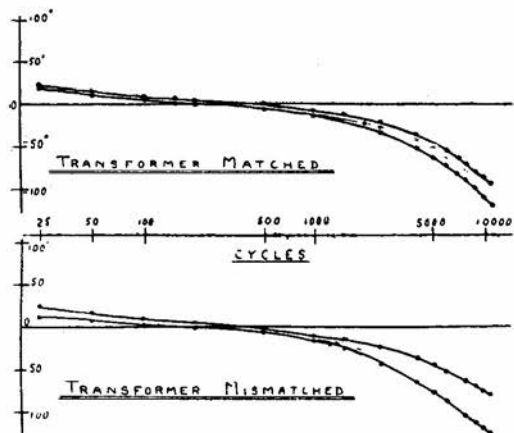


FIG. 10.

The phase angle of output w.r.t. input voltage was also calculated in every case and the curves shown in Fig. 10. These curves all have the characteristic of being positive at the lowest frequencies, and later becoming negative, *i.e.*, the output lagging the input. Due to the fact that there are two transformers in series we find that at the highest frequencies the angle goes beyond the 90° mark. The general shape of these curves does not vary appreciably, the shunting resistance increasing the angle as a general rule. In audio-frequency

apparatus this effect is, however, not at all serious, as the human ear seems incapable of distinguishing any relative change in the phase angle of different musical frequencies; in other words, the human ear compensates for this effect. It may be noted here, however, that in television work this effect must not be present, and this leads to elaborate phase correcting circuits.

In order to test the accuracy of the above deductions it was decided to take the transformer units and measure the input and output voltages, and the phase angle between them, over a complete range of frequencies, for each of the conditions set out above; in other words, to draw curves corresponding to those just shown from experimental observations. The original intention was to use a valve voltmeter at each end of the set, *i.e.*, one to measure the output voltage of the oscillator before it was passed through the load resistance into the transformers, and the second, to measure the output voltage across the resistance. This would have given us the voltage ratio with a fair degree of accuracy, but it would have left us entirely in the dark in regard to the phase angle. The only apparent way to determine the latter was by means of an oscillograph.

The one type of oscillograph that will respond satisfactorily, at the higher frequencies we employed, is the cathode ray type. The instrument used was one of the low voltage, heated cathode variety, and was manufactured by the Standard Telephone Co. In essence the instrument consists of an evacuated tube, about 16 inches long, and $1\frac{1}{2}$ inches thick at the cathode, but widening towards the other end and terminating in a slightly convex end of about 5 inches diameter, thickly coated inside with phosphorescent material. The anode is only a few inches from the cathode and consists of a circular plate in the tube with a small hole in the centre. The cathode is an ordinary coated filament, as used in radio-valves, and is heated from a 2-volt accumulator. When a potential is applied between anode and cathode this accelerates the electrons, and some of these high-velocity particles shoot through the hole and, emerging as a thin stream, fall on the phosphorescent screen and light it up. Focussing of this spot is done by connecting a metallised covering on the outside of the tube, through a potentiometer, to the high

tension supply. On its way to the screen the ray passes between two pairs of parallel deflecting plates, which are mutually at right angles. By applying a potential to any one or both of these pairs of plates the electron stream may be deflected in any direction. The tube is mounted in a box which contains all the necessary resistances, filament-rheostat and ammeter, focussing potentiometer and the necessary outside connections brought to convenient terminals.

A time base was also provided by the manufacturers as a separate unit. This consists essentially of a Rogowski trigger circuit, and requires two separate 4-volt supplies, as well as 500 volt H.T. By suitably connecting up to the cathode tube this unit will impress a saw-tooth wave of E.M.F. on one pair of plates, *i.e.*, the cathode stream will move according to a linear time-distance relation along one axis. This may be synchronised with the alternating wave-form applied to the other pair of perpendicular plates, which will deflect the cathode ray in a perpendicular direction, and this then enables the wave form to be examined. This unit, however, was not used, as most of the measurements were taken from so-called "lissajous" figures.

Lissajous figures are figures obtained when two waves of the same frequency, but varying in phase and amplitude, are impressed on the two perpendicular sets of plates in the tube. They take the form of straight lines or ellipses, and are stationary. For example, in our case the input wave to the circuit, *i.e.*, the output of the oscillator, was impressed across one pair of plates, and the second transformer's output was applied to the other pair. This produced an ellipse, or straight line, depending on whether there was a phase displacement between input and output or not. At different frequencies different figures were obtained, due to variation of phase angle and amplification.

As we have mentioned different frequencies, it might be of interest at this juncture to describe the source from which these were obtained. We had been provided with a beat oscillator, made by Siemens & Halske. This instrument incorporates one oscillating valve circuit with a fixed frequency. This is lined up at that frequency with a crystal of known constants, and this forms one of the references of the instrument. A further valve has an adjustable circuit and these two oscillators are made

to heterodyne to give a resultant wave, which is then rectified. The output is passed through two stages of R.C.C. amplification in a separate unit, and can be varied in amplitude by means of a potentiometer. The frequency is altered by changing the capacity. The beauty of this instrument is the fact that it requires only two adjustments, one at high frequency to align the condenser circuit with the crystal, and one at zero frequency. All intermediate frequencies can then be read off directly from the scale. These two units give a remarkably good approximation to a sinusoidal wave at all except the lowest frequencies.

The procedure was then to photograph the lissajous figures, obtained as described above. For this work a Voigtlander "Tourist" plate camera was used of 2½ in. x 3½ in. slide. The camera was used with double extension, and a standard "Helier" lens, the distance from object to lens being 24 cms., and from lens to sensitized surface 18 cms. In this position the focus was not very critical, yet fairly good, and a figure of reasonable dimensions was obtained. Whereas with a much shorter focal length, using single extension, a better image could be procured, the size was found to be sadly deficient. A telephoto lens was tried out on the same camera, but the image was again found lacking in magnitude. The plates used for this work were ordinary commercial Isochromes (H. & D. 2,700), while the exposure time ranged from 40 to 50 seconds at *f.* 3.5 for the ellipse. On the same plate the axes of the ellipse, or rather the component motions, were also taken by isolating in turn either set of cathode-tube plates and connecting them to earth. This then gave the amplitude of the impressed wave, both input and output. Exposure time for these axes ranged from 12 to 25 seconds.

The resulting slides gave all the required information. The voltage ratio is clearly given by the ratio of the amplitudes of the waves, assuming input and output waves to be similar. This ratio is obviously the ratio of the axes on the figure, corrected by an instrument factor. This factor enters because, for a given voltage on the X-deflecting plates, the light-spot might not give the same deflection as for the same voltage applied to the Y-axis plates. The correction turned out to be very small, to be precise—1.013.

The analysis of the elliptical figure may be found in the appendix to this paper, and it is not the intention to repeat it here. It is sufficient to state one interesting result of this analysis, and that is, that the sine of the phase angle between the two impressed motions is given by the ratio of

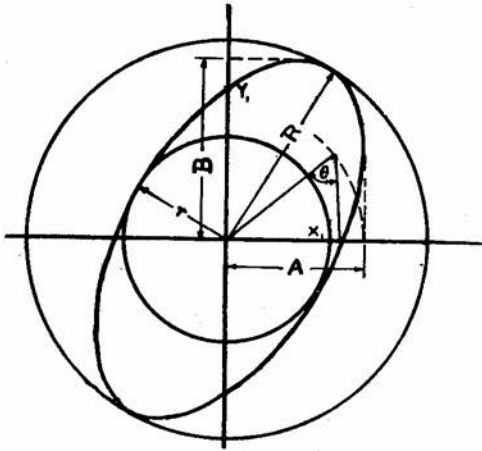


FIG. 8

the intercept of the ellipse on any axis to the total length of that axis. Hence by a few simple measurements on these figures we can determine all the quantities required. All measurements on these slides were done by projecting them through an epidiascope and measuring the large figure with a metre stick. It is estimated that the accuracy of this method is of the order of ± 2 per cent. and compares very favourably with other applicable methods.

We should here like to stress the suitability of the cathode ray oscillograph for this type of research for the following reasons:—The instrument is simple to operate and does not require any elaborate calibrations, as in the case of a valve voltmeter. It is a single unit, while we would have needed two valve voltmeters, which, in any case, would not have given us values for the phase angles. Due to its high impedance and simple construction it does not impose any appreciable load on the system, and no reflection effects are noticeable; nor is there any possibility of feed-back. The system is adaptable to very high frequencies. Moreover a single photographic record can be made to yield all desired quantities.

All the conditions previously analysed theoretically were experimentally reproduced and examined in this way, and the resulting curves are plotted to the same base and scales as the theoretical ones in Fig. 9, Nos. 1a, 2a, 3a and 4a. The first thing that is apparent is the fact that over practically the whole range the actual curves are consistently lower than the theoretical. This is probably due to the various assumptions we made regarding certain effects being negligible, *i.e.*, to losses in the transformers not being negligible, etc. Further, we see that the theoretical response is generally worse than the actual, more particularly at the higher frequencies. As stated before, in the determination of the shunt capacity effect by the bridge method, the value obtained was taken to be a first approximation to the true value. Actually it can easily be seen that the true value in every case should be considerably lower, and this would result in a less definite droop in our theoretical curve at the high frequency end. Further, it seems that our determination of primary inductance by the volt- and ampèremeter method gave too high values. The bridge method was attempted and gave consistently lower values, but the readings were not consistent among themselves, and could not be repeated to give the same results, with the consequence that they were deemed unfit and rejected in favour of the other method.

Comparing the difference of conditions there is really very little to be said. In general, the curves bear out the remarks that have previously been made with regard to the theoretical graphs. Due to the excellent overall response of the units very little improvement can be effected by alterations in the terminal circuits. If anything, condition No. 2 gives a better response than condition 1, at the expense of amplification, of course. It is interesting to note, however, that condition 4 can be called inferior to case 3 in spite of the swamping resistance.

In the phase angle characteristic the most remarkable thing is perhaps the very close agreement between the theoretical and observed values. The overlapping of the curves in some instances is almost complete. This tends to confirm the opinion that no very great errors were made in our assumptions and measurements.

To these somewhat indefinite results can be added the following curves, showing the effect of a large self capacity in one or other of the transformer windings. Perhaps it may be of interest to give the history of these curves, as a warning to the unwary and foolish who may attempt a similar investigation and meet with unexpected results. When this work was first attempted the normal loads of the transformers were ascertained, and we went to the electrical instrument room and un-earthed two resistance boxes. One ranged up to one megohm, and we tapped a quarter and loaded our second transformer with it. Similarly we placed around 25,000 ohms in the other. Next the bridge measurements were taken, the constants determined, the theoretical curves were laboriously calculated, and, furthermore, a complete series of photographs taken, all exactly in the manner we have already described. Next all the graphs were drawn, and the results are shown in Fig. 11. These could hardly

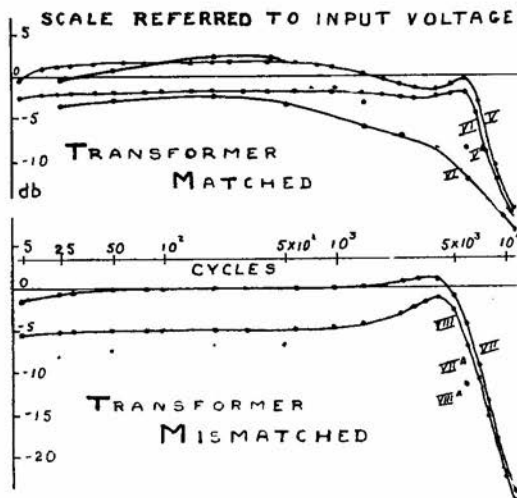


FIG. 11.

be called satisfactory in any respect. If, for example, we were to publish the names of the manufacturers of the transformers, and made out that these were the characteristics of their product, they would be bound to sue us for damages for our libellous statement. Quite apart from this, however, was the complete impossibility of explaining the difference between theory and practice. The whole trouble, of course, was in the resistances used. These, apart from being resistances, had large capacities,

and, at medium frequencies even, the capacity effect completely overshadowed the resistance. Hence all our assumptions were not justifiable, and the results clearly bring this out.

It may be seen from these curves, however, that if the characteristics are really bad, much improvement can be effected by the suitable adjustment of the external circuit. For example, curves 6a and 8a on this figure are rather better than curves 5a and 7a. Further, the calculated curves show an effect which was present in all old-time transformers, before designs reached their present-day high standard, and this is the resonance peak at the higher frequency. This peak is due to the leakage inductance of one unit resonating at that frequency with its own self-capacity. Taking, in our case, the figures for these quantities, and calculating the resonant frequency we found this to coincide exactly with the peak point, which was, of course, to be expected.

It is not intended here to go at all deeply into transformer design, but it may well be mentioned why this resonating effect was not, right at the very beginning of these designs, eliminated by a careful balancing of quantities. This frequency can be calculated by the well-known formula

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

Now suppose it is attempted to move this frequency up, out of the audible range. Then either L_1 or C_1 must be reduced. Decreasing L_1 means decreasing the leakage coefficient between the windings. For a given core material, this can only be done by putting the windings closer together, decreasing insulation thickness, and hence increasing C_1 , the self-capacity. Thus the effect is nullified. Similarly decreasing C_1 must inevitably increase L_1 . On the other hand, L_1 may be decreased by decreasing the size of the coils, *i.e.*, the total primary and secondary inductance. This, however, affects the low frequency end of the curve, giving a more pronounced droop there. What is gained at the one end is thus lost at the other. In fact, this merely tends to shift the whole characteristic further along the frequency scale. The best way, indeed, of obtaining a better frequency response over a large range is to employ a core material having a higher initial per-

meability, and this is the direction in which the greatest development has recently been effected.

The curves in Fig. 11 are, of course, quite erroneous, but they may serve to indicate some of the pitfalls that beset the path of anyone working on this type of subject. At the commencement of this paper mention was made of the Capetown station. It must be said that the response curves for the various units in this transmitter are remarkably fine, and the mention made of possible improvements, effected by devices such as we have employed, to inferior quality apparatus does not apply in this case. Possibly the makers made a good transformer better by suitable choice of their circuits. It certainly seems possible to flatten out any response curve by these methods, and the loss in amplification can easily be made up without appreciable distortion in that process.

In conclusion, we should like to express our thanks and appreciation to the African Broadcasting Company for the loan of various items of apparatus, and in particular to the Chief Engineer of that Company for his invaluable help and guidance. Further to the members of the University staff, in particular Mr. J. T. Allen, for the loan of a camera and valuable information

on its operation. Last, but by no means least, we express our thanks to the members of this Institution for their permission to present this paper here and for their indulgence in listening to it.

BIBLIOGRAPHY.

- P. W. Willans: "Low Frequency Intervalve Transformers." *Journal I.E.E.*, Vol. 64, No. 358, p. 1065, Oct., 1926.
- B. S. Cohen, A. J. Aldridge and W. West: "The frequency characteristics of telephone systems and audio frequency apparatus, and their measurement." *Ibid.*, Vol. 64, No. 358, p. 1023, Oct., 1926.
- W. L. Caspar: "Telephone Transformers." *Electrical Communication*, Vol. 2, No. 4, April, 1924.
- H. L. Kirke: "Microphone Amplifiers and Transformers." *Experimental Wireless and The Wireless Engineer*, Vol. V., Nos. 58 and 59, July and August, 1928.
- H. L. Kirke: "Some Notes on Intervalve Coupling." *Ibid.*, Vol. III., No. 33, June, 1926.
- Prof. J. A. Fleming: "The Cathode-Ray Tube as a Wattmeter and Phase Difference Measurer for High Frequency Currents." *Journal I.E.E.*, Vol. 63, No. 347, Nov., 1925.
- A. B. Wood: "The Cathode-Ray Oscillograph." *Ibid.*, Vol. 63, No. 347, Nov., 1925.
- Prof. J. T. MacGregor-Morris and R. Mines: "Measurements in Elect. Eng. by means of Cathode Rays." *Ibid.*, Vol. 63, No. 347, Nov., 1925.
- T. E. Shea: "Transmission Networks and Wave Filters." D. van Nostrand. Inc.
- K. S. Johnson: "Transmission Circuits for Telephonic Communication." D. van Nostrand. Inc.

APPENDIX I.

ANALYSIS OF EQUIVALENT CIRCUITS USED.

1. Circuit as shown in Fig. 4.

Using the symbols as given with Fig. 3 we get

$$\frac{e_2}{e_1} = \frac{1}{1 + R_v \left(\frac{1}{j\omega l_5} + \frac{1}{j\omega l_6} + \frac{1}{R_0} + \frac{1}{R} \right)}$$

This is the result without taking account of the turns ratios of the transformers.

Putting these in, the equation becomes

$$\frac{e_2^1}{e_1^1} = \frac{\sigma_1 \sigma_2}{1 + R_v \left(\frac{1}{j\omega l_5} + \frac{1}{j\omega l_6} + \frac{1}{R_0} + \frac{1}{R} \right)}$$

If $R = \infty$ we get

$$\frac{e_2^1}{e_1^1} + \frac{\sigma_1 \sigma_2}{1 + R_v \left(\frac{1}{j\omega l_5} + \frac{1}{j\omega l_6} + \frac{1}{R_0} \right)}$$

II. Circuit as shown in Fig. 5 for intermediate frequency.

Here we have

$$\frac{e_2}{e_1} = \frac{R_0}{R_0 + j\omega l_2} \times \frac{\frac{1}{R} + \frac{1}{R_0 + j\omega l_2}}{R_v + j\omega l_1 + \frac{1}{\frac{1}{R} + \frac{1}{R_0 + j\omega l_2}}} = \frac{R R_0}{(R_v + j\omega l_1)(R + j\omega l_2 + R_0) + R(j\omega l_2 + R_0)}$$

$$\text{This gives } \frac{e_2^1}{e_1^1} = \frac{R R_0 \sigma_1 \sigma_2}{(R_v + j\omega l_1)(R + j\omega l_2 + R_0) + R(j\omega l_2 + R_0)}$$

With $R = \infty$ this reduces to

$$\frac{e_2^1}{e_1^1} = \frac{R_0 \sigma_1 \sigma_2}{R_v + j\omega l_1 + j\omega l_2 + R_0}$$

III. Circuit as shown in Fig. 6.

This circuit can be solved fairly easily by taking it in parts and applying Thevenin's Theorem, which states in effect:

If an impedance Z be connected between any two points of a circuit, the resulting (steady-state) current I through the impedance is the ratio of the potential difference V between the two points prior to the connection, and the sum of the values of (1) the connected impedance Z and (2) the impedance Z^1 of the circuit measured between the two points.

If the circuit is open to the right of P , and V_p is the O.C. voltage at P , then we have

$$\begin{aligned} \frac{V_p}{e_1} &= \frac{R}{R + j\omega l_1} \times \frac{\frac{1}{j\omega c_1 + \frac{1}{j\omega l_1 + R}}}{R_v + \frac{1}{j\omega c_1 + \frac{1}{j\omega l_1 + R}}} \\ &= \frac{R}{(R + j\omega l_1) \left\{ R_v \left(j\omega c_1 + \frac{1}{j\omega l_1 + R} \right) + 1 \right\}} = \frac{R}{R_v \left\{ (R + j\omega l_1) \left(\frac{1}{R_v} + j\omega c_1 \right) + 1 \right\}} \end{aligned}$$

If e_p is the voltage across P with impedance beyond P inserted, then by Thevenin's Theorem

$$\begin{aligned} \frac{e_p}{V_p} &= \frac{j\omega l_2 + \frac{1}{\frac{1}{R_0} + j\omega c_2}}{j\omega l_2 + \frac{1}{\frac{1}{R_0} + j\omega c_2} + \frac{1}{\frac{1}{R} + \frac{1}{j\omega l_1 + \frac{1}{j\omega c_1 + \frac{1}{R_v}}}}} \\ &= \frac{j\omega l_2 + \left(\frac{1}{R_0} + j\omega c_2 \right) + 1}{j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 + \frac{\frac{1}{R_0} + j\omega c_2}{\frac{1}{R} + \frac{j\omega c_1 + \frac{1}{R_v}}{j\omega l_1 \left(j\omega c_1 + \frac{1}{R_v} \right) + 1}}} \end{aligned}$$

$$\frac{e_p}{V_p} =$$

$$\frac{\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left\{ \left(j\omega c_1 + \frac{1}{R_v} \right) \left(j\omega l_1 + R \right) + 1 \right\}}{\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left\{ \left(j\omega c_1 + \frac{1}{R_v} \right) \left(j\omega l_1 + R \right) + 1 \right\} + R \left\{ j\omega l_1 \left(j\omega c_1 + \frac{1}{R_v} \right) + 1 \right\} \left(\frac{1}{R_0} + j\omega c_2 \right)}$$

$$\text{Also } \frac{e_2}{e_p} = \frac{\frac{1}{R_0} + j\omega c_2}{j\omega l_2 + \frac{1}{\frac{1}{R_0} + j\omega c_2}} = \frac{1}{j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1}$$

Therefore, finally

$$\frac{e_2}{e_1} = \frac{V_p}{e_1} \times \frac{e_p}{V_p} \times \frac{e_2}{e_p}$$

$$= \frac{R}{R_v \left\{ \left(R + j\omega l_1 \right) \left(\frac{1}{R_v} + j\omega c_1 \right) + 1 \right\}} \times \frac{1}{j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1}$$

$$\times \frac{\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left\{ \left(j\omega c_1 + \frac{1}{R_v} \right) \left(j\omega l_1 + R \right) + 1 \right\}}{\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left\{ \left(j\omega c_1 + \frac{1}{R_v} \right) \left(j\omega l_1 + R \right) + 1 \right\} + R \left\{ j\omega l_1 \left(j\omega c_1 + \frac{1}{R_v} \right) + 1 \right\} \left(\frac{1}{R_0} + j\omega c_2 \right)}$$

$$\therefore \frac{e_2^1}{e_1^1} = \frac{R \sigma_1 \sigma_2}{R_v \left[\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left\{ \left(j\omega c_1 + \frac{1}{R_v} \right) \left(j\omega l_1 + R \right) + 1 \right\} + R \left\{ j\omega l_1 \left(j\omega c_1 + \frac{1}{R_v} \right) + 1 \right\} \left(\frac{1}{R_0} + j\omega c_2 \right) \right]}$$

When $R = \infty$ this equation becomes

$$\frac{e_2^1}{e_1^1} = \frac{\sigma_1 \sigma_2}{R_v \left[\left\{ j\omega l_2 \left(\frac{1}{R_0} + j\omega c_2 \right) + 1 \right\} \left(j\omega c_1 + \frac{1}{R_v} \right) + \left\{ j\omega l_1 \left(j\omega c_1 + \frac{1}{R_v} \right) + 1 \right\} \left\{ \frac{1}{R_0} + j\omega c_2 \right\} \right]}$$

APPENDIX II.

GENERAL ANALYSIS OF ELLIPTICAL FIGURE.

Referring to Fig. 8.

If $x = A \sin \omega t$. . (1) is impressed along x -axis and if $y = B \sin (\omega t + \theta)$. . (2) is impressed along y -axis

then $\frac{x}{A} = \sin \omega t$ from (1)

$$\text{and } \sqrt{1 - \frac{x^2}{A^2}} = \cos \omega t.$$

and from (2) $\frac{y}{B} = \sin \omega t \cos \theta + \cos \omega t \sin \theta$

$$= \frac{x}{A} \cos \theta + \sqrt{1 - \frac{x^2}{A^2}} \sin \theta.$$

$$\frac{y}{B} - \frac{x}{A} \cos \theta = \sqrt{1 - \frac{x^2}{A^2}} \sin \theta$$

$$\frac{y^2}{B^2} - \frac{2xy}{AB} \cos \theta + \frac{x^2}{A^2} \cos^2 \theta = \sin^2 \theta - \frac{x^2}{A^2} \sin^2 \theta.$$

$$\frac{x^2}{A^2} + \frac{y^2}{B^2} - \frac{2xy}{AB} \cos \theta = 1 - \cos^2 \theta$$

$$\cos^2 \theta - \frac{2xy}{AB} \cos \theta + \frac{x^2}{A^2} + \frac{y^2}{B^2} - 1 = 0. \quad (3)$$

Consider point P, $x = x_1$, and $y = 0$.

$$\cos^2 \theta - 1 + \frac{x_1^2}{A^2} = 0.$$

$$\sin^2 \theta = \frac{x_1^2}{A^2} \text{ or } \sin \theta = \frac{x_1}{A}. \quad (4)$$

Consider point Q $x = 0$ and $y = y_1$

$$\cos^2 \theta - 1 + \frac{y_1^2}{B^2} = 0.$$

$$\sin^2 \theta = \frac{y_1^2}{B^2} \text{ or } \sin \theta = \frac{y_1}{B}. \quad (5)$$

(4) and (5) give simple expressions for θ .

To construct θ on any diagram simply swing up length $OA = A$ until it cuts the perpendicular through P in point R . Then $\angle ORP = \theta$ as shown on diagram.

Consider the central conic

$$ax^2 + 2hxy + by^2 + c = 0$$

and circumscribe a circle radius R ,
i.e., circle $x^2 + y^2 = R^2$.

$$\text{Then } ax^2 + 2hxy + by^2 = -\frac{c}{R^2}(x^2 + y^2)$$

$$x^2 \left(a + \frac{c}{R^2} \right) + 2hxy + y^2 \left(b + \frac{c}{R^2} \right) = 0.$$

For single root of $\frac{y}{x}$

$$\begin{aligned} h^2 - \left(a + \frac{c}{R^2} \right) \left(b + \frac{c}{R^2} \right) &= 0 \\ -h^2 + ab + \frac{c}{R^2}(a+b) + \frac{c^2}{R^4} &= 0 \\ \frac{1}{R^4} + \frac{a+b}{c} \frac{1}{R^2} + \frac{ab-h^2}{c^2} &= 0. \end{aligned}$$

In our conic Eq. (3)

$$a = \frac{1}{A^2}; b = \frac{1}{B^2}; h = -\frac{\cos \theta}{AB}; \text{ and } c = -\sin^2 \theta.$$

While R = length of semi-major axis.

$$\frac{1}{R^4} = \frac{1}{-R^2 \sin^2 \theta} \left(\frac{1}{A^2} + \frac{1}{B^2} \right) + \frac{1}{A^2 B^2} \frac{\cos^2 \theta}{\sin^4 \theta} = 0$$

$$\frac{1}{R^4} = \frac{1}{\sin^2 \theta} \left[\frac{1}{R^2} \left(\frac{1}{A^2} + \frac{1}{B^2} \right) - \frac{1}{A^2 B^2} \right]$$

$$\sin^2 \theta = R^2 \left(\frac{1}{A^2} + \frac{1}{B^2} \right) - \frac{R^4}{A^2 B^2}.$$

This gives θ in terms of R , A and B which can perhaps be more accurately measured.

A similar expression may be developed giving θ in terms of A , B and r , the semi-minor axis of the ellipse.

The Chairman: Gentlemen, our thanks are due to the authors of this valuable paper for the large amount of work they have put into it. Our additional thanks, of course, are due to Mr. Troost for reading the paper.

While I am on my feet, I would like to say how pleased we are to see Principal

Raikes and Professor Paine, who are here, and also Mr. Hilarius, who, as you probably know, is the Chief Engineer of the African Broadcasting Company, and who has been with them ever since the Company started. He is also a past member of the Council of this Institute.

Recently we have heard quite a lot about the tenth anniversary of the establishment of broadcasting in South Africa, and have read its early history; but I would like to have it on record that that history is not quite complete.

The first impetus to broadcasting in Johannesburg came from this Institute—principally from the Wireless Section of the Institute; and, although there had been, I think, two experimental broadcasts by the then Western Electric Company, there was no regular broadcasting carried out. The Council of this Institute thought it was a very fine idea, passed the matter on, with their recommendation, to the Controlling Executive of the Associated Societies, and you all know the result. Had it not been for the initial work done by the Institute, by Mr. Hilarius, and by our first President, Mr. C. W. R. Campbell, I do not think we would have had broadcasting for at least another couple of years later than we did get it. I think it is only fair, when one is talking about history, that these matters should be placed on record. Perhaps Mr. Hilarius would like to say a few words on this paper, or on broadcasting in general?

Mr. W. Hilarius (Visitor): Mr. Chairman and gentlemen, the compilation of this paper by the authors has been a difficult job. The students had all sorts of pitfalls to contend with; although the paper read to-night does not show the amount of work done, and can only be appreciated when reading the appended theory; the investigation of the facts and the setting them down is an admirable piece of work, the success of which is largely due to the facilities afforded by the University staff in granting the use of equipment and the purchase of a Cathode Ray oscillograph to enable the work to be carried out. It is really a pleasure to be present and see the work being carried out by these students. This paper is a record of an interesting investigation which these students have made.

Referring now to local broadcasting and its history. There is no doubt about the

fact that the actual introduction of commercial broadcasting in South Africa was by the Associated Scientific and Technical Societies as parent body and the South African Institute of Electrical Engineers; we might even go further and refer back to the first attempts made by the Transvaal Radio Society, an old radio organisation, of which Mr. Joseph White was the first President, and which afterwards became the Wireless Section of the South African Institute of Electrical Engineers. It was then intended to run a broadcasting service, which was afterwards done by the Associated Societies on the suggestion of the Institute. I have not had an opportunity to speak to your members for some time, but must thank you for your remarks and the pleasure of attending to-night. I thank you, gentlemen.

The Chairman: Has any other gentleman come prepared to discuss this paper? If not, the title of the next paper is:

SOME EXPERIMENTS ON PHOTOMETRIC INTEGRATORS, WITH SPECIAL REFERENCE TO BRITISH STANDARD SPECIFICATION NO. 354.

By Messrs. E. T. PRICE, W. R. GRABE and C. P. MARAIS (Visitors), and P. L. BLIGNAUT (Student Member).

OBJECT OF THIS PAPER.

To demonstrate the order of errors likely to be made in using photometric integrators if the specifications given in B.S.S. 354/1929 are not strictly adhered to.

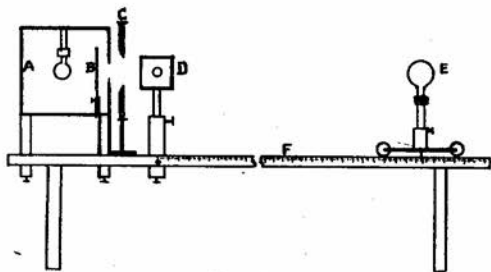


FIG. I.

The above is a line drawing of a photometric bench. It consists of a fixed integrator A with an adjustable screen B placed in front of its aperture. It also contains suitable fittings for inserting lamps.

D is the photometer head, which can be clamped firmly to the bench, and has a thumb screw by means of which it can be raised or lowered. The distance between the photometer and the integrator is small, and this must be kept strictly constant. E is the comparison lamp, which can be moved along a set of graduated rails F. A pointer fixed in line with the centre of the comparison lamp indicates the reading on the scale. The lamp can also be raised or lowered, and is the only movable element on the bench.

Referring to the screen already mentioned, it is capable of such adjustment as to prevent the window or portion of the internal surface used for the photometric measurement from receiving any direct light from the source of illumination. The screen is coated with the same material as that used for the internal surface of the integrator. The size of the screen is such that when the lamp in the integrator is of the maximum size permissible, the screen is intersected by a straight line joining any point on the window to any point on the lamp to be measured.

All internal fittings such as the lamp-holder are made as small as possible, and are whitened in a manner similar to that of the surface of the integrator, these details conforming with the B.S.S.

The procedure adopted was that of first inserting the standard lamp in the integrator and running it at its specified voltage. The comparison lamp was then adjusted to give a balance of intensities as seen in the photometer head. The distance (d_1) of the comparison lamp from the photometer was read directly on the graduated scale. The experiment was repeated, inserting a test lamp in the cube, the corresponding distance (d_2) of the comparison lamp being noted.

If C and C_2 represent the candle powers of the standard and test lamps respectively,

$$\text{Then } C_2 = C \frac{d_1^2}{d_2^2}$$

B.S.S. 354/1929 lays down certain definite conditions relating among other things to the shape and size of the integrator cube, shape and size of the window and the nature of the internal coating.

With regard to the shape of the cube the specification states:

"The interior of the integrator shall be either spherical or cubical. In the case of a cubical integrator the only permissible departure from the cube is the use of small fillets for constructional purposes."

For large lamps the integrator shall be at least $4\frac{1}{2}$ times the overall length of the lamp exclusive of the cap.

As regards the window the specification states:

" The material of which the window is made shall have a transmission factor reasonably independent of the angle of incidence of the light it receives. The diameter of a circular window or the length of side of a square window shall be not less than 2.5 cm. or more than $\frac{1}{2}$ of the size of the integrator."

The conditions of the internal coating are as follows:

"The coating of the internal surface of the integrator shall be matt, durable and such as shall not deteriorate unduly in colour, its reflection factor being between 70 per cent. and 90 per cent. when viewed at an angle of 30° with the normal, the light being incident normally. It shall be so colourless as to pass the following test: Two lamps of the same type are adjusted in voltage until they give light of the same colour at approximately normal efficiency. One lamp is then placed inside the integrator, and the light emitted from the window shall then match in colour the light given by the other lamp when run at a voltage within 10 per cent. of its original colour match voltage."

This section of the specification even goes so far as to give details of constituents for a paint to satisfy the above requirements, a first coating of one paint and a second of another paint being applied. Neither the first coat nor the finishing paint should contain an appreciable amount of lead.

The experiments to be described were intended to demonstrate the effects of failure to comply with B.S.S. 354/1929 in connection with:

- (1) The whiteness of the internal coating.
- (2) The dimensions of the cube as related to the sizes of the lamps to be used with it.

(3) The size of the window.

It was also intended to examine the effect of using an integrator without a glass window, and of varying the transmission factor of the material of the window, and also the effect of introducing a definite colour into the transmitted light by using a suitable window material.

Finally, tests were carried out to find the effect on the apparent M.S.C.P. of a lamp as measured in the integrator by bowl frosting the bulb. The importance of the experiments which deal with colour, whether the colour of the internal coating or the colour of the window, may be considerable if the standard lamp used produces an illumination more or less white than the lamps tested.

As it is generally desirable to run standard lamps at low intensities this condition may often exist.

With regard to the experiments dealing with dimensions, their importance lies in the conflicting nature of the consideration which would normally determine one's choice of a cube.

On the one hand, the smaller an integrator is the brighter the window, and the more easy it is to take accurate readings with a contrast photometer. On the other hand, the larger a cube is the less will the dimensions of the lamp and the internal fittings affect the multiple reflection and so the accuracy of the results. These considerations become important if one proposes to make measurements with a cube just too small, but with a fairly marked colour difference between the light of the standard and the test lamps. A larger cube would probably make the readings doubtful, because of the difficulty of balancing illuminations, but the smaller one would not satisfy B.E.S.A.

The integrator employed in these experiments was of the cubical type having a square aperture of side 2 in., and the photometer was of the Lummer-Brodhun type. The bench rails along which the comparison lamp moved were graduated in cms., the photometer head being fixed at the zero position on the scale and the cube at an arbitrary distance.

EXPERIMENTS ON THE COLOUR OF THE CUBE.

With regard to the internal coating of the cube the following experiments were performed to estimate the likely error incurred by using a cube the surface of which may have become slightly yellowed by age. In a preliminary experiment the inner surface of the cube was covered with drawing paper possessing a matt surface of a slight yellowish tinge. The magnitude of the error occurring was so small as to be within the limits of experimental error. The experiment was, therefore, repeated, employing two shades of yellow—a light and a dark—and as an extreme case brick red was resorted to.

Ten lamps of similar wattage were selected to be used as test lamps, while another similar lamp was used as a standard. This lamp was run below its normal voltage to introduce a colour difference, as is often the case when using a calibrated standard lamp.

In determining the M.S.C.P.'s of the lamps two observers each took a set of three readings, the mean of which gave the required distance of the comparison lamp from the photometer. In the case of the standard lamp this distance was determined both at the beginning and at the end of the experiment, thereby minimising errors due to eye fatigue.

Care was taken never to expose the eye directly to any source of bright light, nor were any readings taken immediately after entering the dark room, but some time was allowed to elapse in order that the eye might accommodate itself to the conditions. No person was allowed in the vicinity of the comparison lamp to avoid error due to light being reflected from his clothes.

A most important factor is the setting of the comparison lamp on a truly horizontal level with the aperture and the photometer head. When correctly set the portion of the filament nearest the photometer obscures that further away. The importance of this precaution is accentuated in cases where the comparison lamp moves over a wide range, the reason being that if it is not at the correct height varied amounts of the lamp filament are exposed as the lamp is moved further or nearer, resulting in varied amounts of light reaching the photometer head. In order further to minimise errors due to this source, an opal globe was used as the comparison lamp.

The M.S.C.P.'s of the set of lamps were taken with the cube already mentioned, no glass window being inserted. The tests were then repeated with the internal surface of the cube completely covered with:

- (1) Light yellow paper.
- (2) The dark yellow paper and
- (3) The brick red paper.

The following are the results obtained:

TABLE Ia.
TESTS ON INTERNAL COATING.
WHITE CUBE.
60W. OPAL COMPARISON LAMP AT 200V.

Lamp.	Volts.	Amps.	d	d^2	α M.S.C.P.
F ₁₅	160	.458	148.0	—	1
F ₁	200	.525	91.7	8,405	2.630
F ₂	200	.520	92.1	8,483	2.620
F ₄	200	.518	95.7	9,167	2.41
F ₅	200	.508	97.0	9,405	2.35
F ₆	200	.520	93.0	8,658	2.552
F ₉	200	.529	93.4	8,722	2.533
F ₁₂	200	.522	93.4	8,718	2.534
L ₁₀₁	200	.518	99.8	9,950	2.210
L ₁₀₅	200	.512	99.0	9,802	2.250
F ₁₅	160	.458	149.2	—	1.000
			148.6	22,080	—

TABLE Ib.
INTERNAL COATING : AMBER.
COMPARISON LAMP AT 180V.

Lamp.	Volts.	Amps.	d	d^2	α M.S.C.P.
F ₁₅ ...	160	·458	—	—	1·000
F ₁ ...	200	·518	104·7	10,970	2·319
F ₂ ...	200	·520	102·1	10,420	2·435
F ₄ ...	200	·518	104·0	10,820	2·343
F ₅ ...	200	·508	106·0	11,240	2·259
F ₅ ...	200	·520	101·1	10,220	2·480
F ₉ ...	200	·528	101·7	10,280	2·490
F ₁₂ ...	200	·522	102·4	10,480	2·430
L ₁₀₁ ...	200	·520	108·2	11,700	2·170
L ₁₀₅ ...	200	·512	108·9	11,850	2·145
F ₁₅ ...	160	·458	153·5	25,400	1·000

TABLE Ic.
INTERNAL COATING YELLOW.
COMPARISON LAMP AT 150V.

Lamp.	Volts.	Amps.	d	d^2	α M.S.C.P.
F ₁₅ ...	160	·458	—	—	1·000
F ₁ ...	200	·518	85·4	7,302	2·310
F ₂ ...	200	·520	81·8	6,691	2·520
F ₄ ...	200	·515	85·6	7,327	2·302
F ₅ ...	200	·508	86·6	7,491	2·250
F ₆ ...	200	·519	82·7	6,840	2·465
F ₉ ...	200	·529	82·1	6,740	2·500
F ₁₂ ...	200	·520	84·5	7,131	2·365
L ₁₀₁ ...	200	·519	89·0	7,921	2·130
L ₁₀₅ ...	200	·512	88·5	7,831	2·155
F ₁₅ ...	160	·458	129·9	16,880	1·000

TABLE Id.
INTERNAL COATING : RED.
COMPARISON LAMP : 150V.

Lamp.	Volts.	Amps.	d	d^2	α M.S.C.P.
F ₁₅ ...	160	·458	—	—	1·000
F ₁ ...	200	·518	78·3	6,131	2·325
F ₂ ...	200	·520	77·5	5,998	2·375
F ₄ ...	200	·514	81·4	6,618	2·150
F ₅ ...	200	·509	80·0	6,400	2·225
F ₆ ...	200	·520	76·9	5,906	2·410
F ₉ ...	200	·529	77·2	5,960	2·390
F ₁₂ ...	200	·522	78·7	6,181	2·304
L ₁₀₁ ...	200	·520	83·7	7,107	2·030
L ₁₀₅ ...	200	·512	83·9	7,040	2·025
F ₁₅ ...	160	·458	120·7	14,200	1·000

Deriving a mean value for each set of readings, the results may be demonstrated graphically as follows:

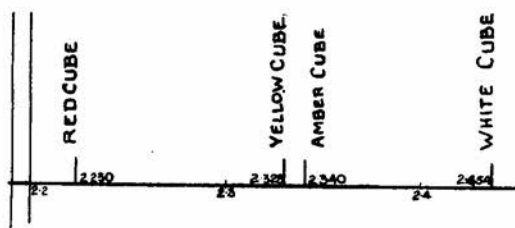


FIG. II.

ABSCISSÆ REPRESENT MEAN VALUES α M.S.C.P.

This result seems to be endorsed by theoretical considerations. The walls of the cube being yellow, will absorb other light and reflect yellow light. As the standard lamp is more yellow than the test lamps a greater proportion of its light will be reflected, hence the test lamps suffer a diminution of intensity as observed in the photometer head with consequent decrease in M.S.C.P.

The magnitude of the error involved is given in Table II.

TABLE II.
PERCENTAGE DIFFERENCES
FROM TABLES I.

Lamp.	Amber.	Yellow.	Red.
F ₁ ...	-11·78	-12·15	-11·60
F ₂ ...	-7·06	-4·20	-9·35
F ₄ ...	-2·76	-4·48	-10·80
F ₅ ...	-3·87	-4·25	-5·32
F ₆ ...	-2·82	-3·41	-5·56
F ₉ ...	-2·10	-1·31	-5·65
F ₁₂ ...	-4·15	-4·22	-9·12
C ₁₀₁ ...	-1·81	-3·62	-8·15
L ₁₀₅ ...	-4·67	-4·22	-10·00
Mean ...	-4·55	-4·65	-8·40

From this it is seen that even in the extreme case, viz., the red coating, the average error is only 8 per cent. In view of this slight error the detailed regulations as laid down by the B.S.S. seem to be rather stringent, and the expense incurred in renewing the coating of the cube and maintaining it strictly up to specification is hardly justified.

EXPERIMENTS ON THE SIZE OF THE CUBE.

As regards the relative sizes of the cube and lamps to be tested, the B.S.S. states

that for large lamps the integrator shall be at least $4\frac{1}{2}$ times the overall length of the lamp exclusive of the cap.

In the experiment performed to estimate the errors introduced by not strictly adhering to B.S.S. in this connection, two integrators were used, the details of which are as follows:

Small Cube.

- Distance between inner walls - 50 cms.
- Size of the square aperture - 5 cms.
- Distance of screen from aperture 10 cms.
- Distance of centre of lamp from screen - - - - - 15 cms.
- Size of screen - - - - - 10.2×10.2 cms.

Large Cube.

- Distance between inner walls 120 cms.
- Size of the square aperture - 7.5 cms.
- Distance of screen from aperture - - - - - 32.5 cms.
- Distance of centre of lamp from screen - - - - - 27.5 cms.
- Size of screen - - - - - 15.3×23 cms.

The standard lamp chosen was a 250-volt 100 watt lamp measuring 11 cms. excluding cap, and was run at 240 volts. This lamp, therefore, conformed to the specification in the case of both cubes.

Seven 240 volt 500 watt lamps, 22 cms. in length, were selected as test lamps. These lamps, therefore, satisfied conditions for the larger cube, but not for the smaller cube.

The M.S.C.P.'s of the lamps were then found for each cube.

The results of the readings are given in Table III.

TABLE IIIa.
SMALL CUBE.

COMPARISON LAMP, L134: 200v.

Lamp.	Volts.	Amps.	d	d ²	^a M.S.C.P.
Y ₆	240	.420	206.1	—	1.000
I ₅₃ ...	240	2.030	75.3	5,690	7.290
I ₅₅ ...	240	2.040	75.3	5,690	7.290
I ₅₂ ...	240	2.030	76.3	5,810	7.150
I ₅₆ ...	240	2.030	75.5	5,700	7.280
I ₅₄ ...	240	2.030	74.9	5,610	7.400
I ₆₅ ...	240	2.030	75.5	5,700	7.280
I ₆₃ ...	240	2.030	76.0	5,780	7.180
Y ₆ ...	240	.420	201.5	—	1.000
		Y ₆ Mean	203.9	41,500	—

TABLE IIIb.

LARGE CUBE.

COMPARISON LAMP, L134, 200v.

Lamp.	Volts.	Amps.	d	d ²	^a M.S.C.P.
Y ₆ ...	240	0.43	234.2	—	1.000
I ₅₃ ...	240	2.01	90.0	8,100	6.760
I ₅₅ ...	240	2.01	90.0	8,100	6.760
I ₅₂ ...	240	2.00	90.4	8,160	6.710
I ₅₆ ...	240	2.01	89.9	8,090	6.775
I ₅₄ ...	240	2.01	90.2	8,140	6.725
I ₆₅ ...	240	2.01	90.5	8,200	6.680
I ₆₃ ...	240	2.01	90.1	8,120	6.740
Y ₆ ...	240	0.43	232.8	54,750	1.000
		Y ₆ Mean	233.5	54,750	—

The errors involved by using the small cube are given in the following table:

TABLE IV.

PERCENTAGE DIFFERENCE
FROM TABLES IIIa AND IIIb.

Lamp.	Diff. %
I ₅₃ ...	+ 5.69
I ₅₅ ...	+ 9.00
I ₅₂ ...	+ 10.50
I ₅₄ ...	+ 7.45
I ₅₆ ...	+ 6.65
I ₆₅ ...	+ 7.95
I ₆₃ ...	+ 7.95
Mean ...	+ 7.85

The experiment was repeated several times with similar results. It is seen from Table IV that the mean error is approximately 7.8 per cent. Hence in testing lamps the relative sizes of lamp and cube, as stipulated by B.S.S., must be approximated to. It will be noticed that in the above experiment the conditions imposed on the small cube were extreme, and are hardly likely to occur in practice. Practical conditions would probably only involve errors of 2 or 3 per cent.

EXPERIMENTS ON THE EFFECT OF A GLASS WINDOW.

Another series of experiments was conducted with regard to the effect of a window in the aperture of the cube.

The same set of lamps and standard were used as in the case of the experiment on the internal coating of the cube. As before, the M.S.C.P.'s were found without a window. The test was repeated with:—

- (1) A single sheet of flashed opal glass.
- (2) Two sheets of glass.

(3) One sheet of glass and one sheet of yellow tissue crepe paper, of the kind commonly used for decorative purposes.

In each case the inner surface of the window was flush with the inner surface

of the cube, with the opal side of the glass facing the interior of the integrator. It was noticed that the introduction of the window gave rise to a slight yellow colouration and experiment (3) was carried out to intensify this effect.

The results follow:—

TABLE Va.
EFFECT OF GLASS WINDOW.
NO WINDOW.
COMPARISON LAMP AT 190V.

Lamp.	Volts.	Amps.	d	d^2	a M.S.C.P.
F ₁₅	170	.471	116.5	—	—
F ₁	210	.533	78.4	6,100.0	2.220
F ₂	210	.539	75.1	5,640.0	2.400
F ₄	210	.528	80.4	6,465.0	2.095
F ₅	210	.522	79.0	6,224.0	2.175
F ₆	210	.530	77.8	6,053.0	2.236
F ₉	210	.540	76.2	5,822.0	2.320
F ₁₂	210	.538	77.7	6,045.0	2.240
L ₁₀₁	210	.533	82.2	6,774.0	2.000
L ₁₀₅	210	.526	81.5	6,642.0	2.040
F ₁₅	170	.471	116.2	—	—
		Mean	116.3	13,530	2.189

TABLE Vb.
EFFECT OF GLASS WINDOW.
1 SHEET.
COMPARISON LAMP: 190V.

Lamp.	Volts.	Amps.	d	d^2	a M.S.C.P.	% Diff.
F ₁₅	170	.471	184.4	—	1.000	—
F ₁	210	.538	120.4	14,500	2.340	+5.410
F ₂	210	.539	117.4	13,800	2.459	+2.478
F ₄	210	.528	125.4	15,730	2.153	+2.760
F ₅	210	.520	125.8	15,830	2.145	-1.380
F ₆	210	.530	122.6	15,020	2.260	+1.075
F ₉	210	.540	120.6	14,550	2.331	- .470
F ₁₂	210	.530	120.9	14,620	2.320	+3.570
L ₁₀₁	210	.534	129.0	16,650	2.036	+1.800
L ₁₀₅	210	.528	128.0	16,370	2.037	+1.618
F ₁₅	170	.471	183.9	—	1.000	—
		Mean	184.2	33,940	2.235	+2.67

TABLE Vc.
EFFECT OF GLASS WINDOW.
2 SHEETS.
COMPARISON LAMP AT 180V.

Lamp.	Volts.	Amps.	d	d^2	M.S.C.P.	% Diff.
F ₁₅ ...	170	.471	200.3	—	—	—
F ₁ ...	210	.538	130.9	17,130	2.340	+5.40
F ₂ ...	210	.539	127.3	16,200	2.410	+4.16
F ₄ ...	210	.528	136.3	18,580	2.160	+3.10
F ₅ ...	210	.521	135.4	18,320	2.190	+ .69
F ₆ ...	210	.530	132.3	17,480	2.290	+2.24
F ₉ ...	210	.540	130.0	16,900	2.370	+2.15
F ₁₂ ...	210	.530	131.0	17,130	2.340	+4.46
L ₁₀₁ ...	210	.534	140.4	19,700	2.030	+1.50
L ₁₀₅ ...	210	.528	138.4	19,140	2.095	+2.70
F ₁₅ ...	170	.471	200.1	—	—	—
		Mean	200.2	40,100	2.247	+2.93

TABLE Vd.
EFFECT OF GLASS WINDOW.
1 SHEET GLASS + 1 SHEET PAPER.
COMPARISON LAMP AT 180V.

Lamp.	Volts.	Amps.	<i>d</i>	<i>d</i> ²	M.S.C.P.	% Diff.
F ₁₅	170	·471	210·3	—	—	—
F ₁	210	·536	136·5	18,360	2·340	+5·415
F ₂	210	·530	138·8	19,240	2·265	—
F ₄	210	·528	142·5	20,300	2·150	+2·627
F ₆	210	·520	142·4	52,340	2·150	—
F ₆	210	·530	137·8	19,000	2·295	+2·640
F ₉	210	·540	136·3	18,600	2·345	+1·077
F ₁₂	210	·538	136·5	18,630	2·340	+4·465
L ₁₀₁	210	·532	145·9	21,340	2·043	+2·150
L ₁₀₅	210	·525	144·4	20,730	2·105	+3·190
F ₁₅	170	·471	207·5	—	—	—
		Mean	208·9	43,600	2·284	+3·080

As before, the results may be shown graphically as follows:—

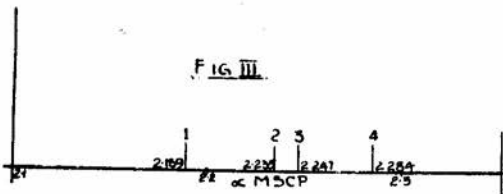


FIG. III.

Abscissa 1: No Glass Window.
Abscissa 2: One Sheet of Glass.
Abscissa 3: Two Sheet of Glass.
Abscissa 4: One Glass, + One Paper.
ABSCISSÆ REPRESENT AVERAGE VALUES.

The graph apparently demonstrates that the effect of the window is to increase the M.S.C.P.'s.

This result is rather unexpected. Owing to the yellow colouration introduced by the window we may assume that the glass absorbs the blue end of the spectrum more readily, but allows the red rays to pass through. The effect of this would be to allow a greater proportion of the standard lamp's light reaching the photometer as compared with the test lamps. The M.S.C.P.'s of the lamps would consequently suffer a loss. This, however, is contrary to the results obtained in the experiment and the explanation must lie in some other effect being introduced which cannot yet be accounted for.

EXPERIMENTS ON THE SIZE OF THE WINDOW.

In performing this experiment the aperture was reduced to 1/3 of its original area. This was effected by closing the window symmetrically with a small piece

of drawing paper blackened on the outside to eliminate any reflection.

The results appear in Table VI, and it shows an increase in the candle power of the test lamps.

TABLE VIa.
NORMAL OPENING.
60W. OPAL COMPARISON LAMP : 190V.

Lamp.	Volts.	Amps.	<i>d</i>	<i>d</i> ²	^a M.S.C.P.
F ₁₅ ...	170	·471	116·5	—	1·000
F ₁ ...	210	·533	78·1	6,100	2·220
F ₄ ...	210	·528	80·4	6,465	2·095
F ₅ ...	210	·522	78·9	6,225	2·175
F ₆ ...	210	·530	77·8	6,053	2·236
F ₉ ...	210	·540	76·3	5,822	2·320
F ₁₂ ...	210	·538	77·8	6,045	2·240
L ₁₀₁ ...	210	·533	82·3	6,774	2·000
L ₁₀₅ ...	210	·526	81·5	6,642	2·040
F ₁₅ ...	170	·471	116·0	—	1·000
		F ₁₅ Mean	116·2	13,530	2·166
				Mean	2·166

TABLE VIb.
OPENING REDUCED.
COMPARISON LAMP : 190V.

Lamp.	Volts.	Amps.	<i>d</i>	<i>d</i> ²	^a M.S.C.P.
F ₁₅ ...	170	·471	227·0	—	1·000
F ₁ ...	210	·536	146·4	21,430	2·380
F ₄ ...	210	·528	153·3	23,470	2·175
F ₅ ...	210	·520	153·3	23,500	2·173
F ₆ ...	210	·530	148·3	21,970	2·330
F ₉ ...	210	·540	146·6	21,500	2·380
F ₁₂ ...	210	·538	147·5	21,740	2·350
L ₁₀₁ ...	210	·532	158·1	25,000	2·045
L ₁₀₅ ...	210	·525	155·8	24,240	2·105
F ₁₅ ...	170	·471	225·4	—	1·000
		F ₁₅ Mean	226·2	51,120	2·242
				Mean	2·242

On repetition the same fact was borne out.

The differences are small and the reason does not seem very clear, unless it is due to the change in brightness resulting from the change in area of the window.

EFFECT ON M.S.C.P. OF BOWL FROSTING.

In order to find the effect of bowl frosting on lamps, twelve 220 volt 200 watt lamps were selected. The M.S.C.P.'s of these lamps were determined, after which seven of the lamps were bowl frosted, the remaining five being left clear in order that the M.S.C.P.'s previously found might be checked.

On determining the M.S.C.P.'s again it was found that the frosted lamps had suffered a decided loss in candle power. The results of this experiment, which appear in Table VII, were checked, using fourteen 500 watt lamps, of which eight were subsequently frosted. On recalibration a similar drop in M.S.C.P.'s was experienced in the case of the frosted lamps.

The results of these tests, therefore, definitely prove that the increased diffusion obtained from a frosted lamp is accompanied by a corresponding loss of candle power.

TABLE VIIa.

FROSTED LAMPS MARKED : *.
COMPARISON LAMP N4 AT 220V.

Lamp.	Volts.	Amps.	Old C.P.	New C.P.	% Diff.
Y ₃ ...	220	.913	170	170	—
*B ₁₀₅ ...	220	1.062	296.5	283.5	-4.4
*B ₁₀₆ ...	220	1.060	294.0	282.0	-4.08
*B ₁₀₇ ...	220	1.061	290.5	281.0	-3.27
*B ₁₀₈ ...	220	1.062	294.0	284.0	-3.4
*B ₁₀₉ ...	220	1.060	290.5	284.0	-2.24
*B ₁₁₀ ...	220	1.062	291.0	285.5	-1.89
*B ₁₁₁ ...	220	1.063	294.0	286.0	-2.72
*B ₁₁₂ ...	220	1.063	298.0	287.0	-3.69
B ₁₁₃ ...	220	1.061	289.0	292.0	+1.04
B ₁₁₄ ...	220	1.062	296.0	296.0	—
B ₁₁₅ ...	220	1.063	293.0	292.3	-.239
B ₁₁₆ ...	220	1.061	290.5	292.0	+ .516
Y ₃ ...	220	.917	170	170	—

TABLE VIIb.

FROSTED LAMPS MARKED : *.
COMPARISON LAMP AT 220V.

Lamp.	Volts.	Amps.	Old C.P.	New C.P.
Y ₃ ...	220	.93	170.0	170.0
*C ₃₈ ...	220	2.32	655.0	650.0
*C ₃₉ ...	220	2.33	674.0	665.0
*C ₄₀ ...	220	2.33	654.0	632.0
*C ₄₁ ...	220	2.34	652.0	632.0
*C ₄₃ ...	220	2.37	657.0	658.0
*C ₄₄ ...	220	2.36	647.0	624.0
*C ₆₇ ...	220	2.37	682.0	673.0
*C ₉₁ ...	220	2.33	651.0	652.0
C ₂₄ ...	220	2.33	660.0	651.0
C ₈₈ ...	220	2.34	643.0	648.0
C ₈₉ ...	220	2.35	644.0	645.0
C ₉₀ ...	220	2.32	665.0	670.0
C ₉₂ ...	220	2.32	643.0	642.0
C ₉₃ ...	220	2.33	660.0	653.0
Y ₃ ...	220	.93	170.0	170.0

In conclusion, we might mention that in all the above experiments the contrast photometer was used. In spite of difficulties arising in obtaining balance at low intensities or when a decided colour difference existed this photometer was preferred to the flicker photometer. The vibration of the latter was found to be a decided handicap at low intensities, whilst the repeated winding of the clockwork and constant handling might easily result in a displacement of the photometer, with consequent errors in the results.

In the experiments on the effect of the glass window the low intensities resulting from the use of thick window material rendered readings difficult. Similar difficulties were experienced where definite colour differences appear, as in experiments on the internal coating of the cube.

Nevertheless, after considerable practice and care readings could be taken with fair accuracy.

During the earlier experiments it was found that the last few test lamps of a set invariably exhibited a peculiar phenomenon. Although all the lamps were similarly rated, these would show a marked decrease in M.S.C.P. Checking of connections and voltages threw no light on the matter. On allowing a few moments to elapse, however, and reading again the lamps were found to gain gradually in candle power until the true values were reached. After some speculation as to the cause of this behaviour it was suggested that the effect might be caused by smoke in the dark room.

Experiments were carried out to verify this. The absorption of the light by the smoke was readily detected in the comparison head. The source of trouble had been discovered, and after that no smoking was allowed in the dark room.

The Chairman: I am sure we greatly appreciate this most excellent paper. You will see from the time that it is quite impossible for us to take the third paper. With the permission of the authors, we will save it over for some future date. Mr. Cocks, our Vice-President, I believe, has a few words to say on the last paper.

Mr. C. T. Cocks (Vice-President): Mr. Chairman and gentlemen, I have listened to this paper with particular interest. I have not yet had an opportunity of reading it.

I must congratulate the authors on the most interesting piece of photometry work that is exemplified in the paper.

The addition of colour in the window may be the beginning of research into the photometric values of the gaseous discharge lamp. At the present moment, to the best of my knowledge and belief, ordinary photometric tests hardly apply in the case of lamps having monochromatic characteristics.

I would also like to place on record, Mr. Vice-President, the really valuable work that has been done recently by students of the Witwatersrand University. I happen to know that they have carried out certain tests which have reflected great credit on

those responsible. There is one little point I would like the authors to make note of in their reply. The American practice is to use a spherical integrator. I would like to know what coefficient, if any, is necessary in comparing results with the cube and the sphere? Thank you.

The Chairman: Gentlemen, in looking over the agenda, I see there is one name conspicuous by its absence. We all of us know that the inception of the Students' Evening, once a year, is due to Dr. Randall, and I would like to take this opportunity of saying that we do not forget what we owe to Dr. Randall. He has been the moving force and inspiration behind most of these papers, and we are very grateful to him. Perhaps Dr. Randall would like to say a few words. (Hear, hear, and applause.)

Dr. O. R. Randall (Member): Mr. Vice-President and gentlemen: It is very kind of you, sir, to mention me as you have done in connection with these students' papers, and I wish to take this opportunity of thanking the Institute for giving my students the opportunity of reading their papers. We quite realise how good it is for them and how much they benefit by being given the hospitality of the Institute on these occasions.

I should like to thank Mr. Hilarius for the interest he has taken in the work of the group of students responsible for the first paper. This is the first time that any of my students have worked under the direction of an engineer practising outside the University, and I hope that we may have many such combinations in the future.

The remarks of your colleague, Mr. Cocks, about the work of my department gave me great pleasure, particularly as it is an expression of goodwill from one who merits our respect on account both of the office he holds in the Institute and his position in the engineering activities of Johannesburg. I can assure Mr. Cocks we are very sensible of the value of such appreciation.

The Chairman: Gentlemen, as it is now after ten o'clock, I will declare the meeting closed, and would remind you that coffee will be served in the lounge.

(Reprinted from *Nature*, Vol. 134, page 177, August 4th, 1934.)

THE DEVELOPMENT OF THE LIGHTNING DISCHARGE

By B. F. J. SCHONLAND (University of Capetown), H. COLLENS (Victoria Falls and Transvaal Power Company, Johannesburg), and D. J. MALAN (the University of the Witwatersrand).

We should like to give a brief account of some further results obtained with the Boys lightning camera, which has now been modified so as to include a means of determining the order of the component strokes of a discharge.

The material available refers to 55 lightning flashes from eleven different thunderstorms, and the total number of separate strokes photographed is 145. Of these, 65 show clearly the two-fold character which we have previously reported,^{1,2} namely, a downward-moving leader stroke which at the moment it strikes the ground causes the development of a faster and more intense upward-moving main stroke. If we exclude those strokes photographed under definitely bad conditions (too great a distance, obscured by rain, etc.), the fraction of the strokes showing the leader mechanism is raised from 45 per cent. (65/145) to 82 per cent. (41/50). Similarly, while 62 per cent. (34/55) of the separate flashes show one or more examples of leaders, the percentage is raised to 86 per cent. (18/21) if we consider the better photographs only.

The results thus suggest that the leader-main stroke sequence is the most common type of development in the discharge to ground. We have not yet met with more than one or two cases which may be considered significant exceptions. The polarity of the cloud-base in the majority of these flashes is negative, and cases of the reverse polarity are too rare in South Africa for us to have much evidence as to their behaviour. In the case of flashes which do not strike the ground, we do not observe the second or main part of the stroke.

An interesting feature of this new material is that it establishes the general manner in which branches are formed. We find that the downward-moving leader blazes these branches as well as the main trunk of the discharge, and that the subsequent main stroke, in its upward course, turns aside to follow the branched leader down such a branch until it catches up with it. We have now 20 cases of downwardly branched leaders, taken from 16 different lightning flashes.

The most important point, however, which emerges from a consideration of these new photographs, is that there is a

characteristic difference between the leader to the first stroke of a discharge and the leaders to subsequent discharges along the same track. While the latter are of a continuously-moving, dart-like character, followed by fainter luminosity, the first leader is a luminous streamer extending in a discontinuous step-by-step manner from cloud to ground. The length of each step is about 50 metres, and after completing a step the streamer luminosity practically disappears for a time of the order of 10^{-4} seconds. After this extinction period, the streamer travels downwards over the old track without developing much light, but as it enters virgin air at the end of the old track it blazes a fresh step very brightly and appears to stop. Since it is difficult to photograph much more than the bright fresh step at the tip of each streamer, the record of this type of leader is usually only a series of elongated dots extending from cloud to ground and separated considerably from one another along the time axis by the camera motion during the extinction period.

This "stepped" leader is shown on 22 out of the 55 first strokes on our records, and is so difficult to see that we consider it must have been present in many other cases. It is shown on 74 per cent. (14/19) of our better records. It has not been found associated with any strokes other than the first of a series along the same track. Conversely, no continuous dart-like leaders have been found blazing the way for first strokes.

Owing to numerous pauses in its progress, a stepped leader takes a comparatively long time to reach the ground, sometimes more than one-hundredth of a second, though the velocity of the extending streamer itself is very high. Electromagnetic radiation from such steps would be on a wavelength of approximately 30 kms., which is that of the ripple on many atmospherics. The sound waves emitted would have a frequency of about 10,000, and could produce the sound of tearing linen sometimes reported for a close discharge.

We wish to thank the Lightning Research Committee of the South African Institute of Electrical Engineers for permission to publish this letter.

¹ *Nature*, 132, 407; Sept. 9, 1933.

² Proc. Roy. Soc. A, 143, 654; 1934.

INSTITUTE ANNOUNCEMENTS

AWARDS.

The Council is empowered each year at its discretion to award the Gold Medal of the Institute, together with a certificate and, if considered desirable, a premium not exceeding £10 10s., to a member of any grade for an original paper of outstanding merit submitted during the year.

It is also authorised to award at its discretion the Bronze Medal of the Institute, together with a certificate and, if considered desirable, a premium not exceeding £5 5s., to a member of the Student grade for an original paper of outstanding merit submitted by a member of that grade.

The Institute is indebted to the Management of the Victoria Falls and Transvaal Power Company, Limited, for an annual donation of £25 for the purpose of awarding premiums, not exceeding £10 10s. in value for any one award, for the purchase of scientific and technical books or instruments for papers and contributions to the discussion of papers, which, in the opinion of the Council, merit special recognition.

The papers and contributions of Student Members are eligible for awards both in their own Section and in the Senior Section, and all awards are at the discretion of the Council, which may vary them in amount according to the merit of the papers and contributions submitted during the year.

PAPERS.

Members presenting papers before the Institute are requested to forward a copy of their paper, in final form, to the Secretary at least one month before the date of the meeting at which it is to be read.

Where symbols or abbreviations are considered necessary, it is desirable that definite standards should be used.

Attention is drawn to the publications of the British Standards Institution dealing with "terms" and graphical symbols used in electrical engineering, with the suggestion that these be employed.

DIAGRAMS FOR TRANSACTIONS.

It is requested that the following rules be observed by members preparing illustrations for publication in the "Transactions":—

Drawings accompanying papers should be made in India ink on white paper; hand sketches, if they are bold and heavy in outline, are suitable for reproduction in the *Journal*.

Drawings or photographs to be shown on the screen by means of the epidiascope should not exceed 5 in. x 5 in. in size, and slides must be 3¼ in. x 3¼ in.

All drawings and photographs require to be numbered to ensure their use in the correct order.

ADDRESSES WANTED.

Addresses are wanted for the following:—

L. C. Lawson. T. W. Forbes.
S. Farthing. J. J. Kruger.
R. R. Rooney. H. Jermyn.

Kindly communicate with the Secretary, P.O. Box 5907, Johannesburg. Telephones, 33-5248/9.

LETTERS OF DESIGNATION.

The attention of members is drawn to Rule 26 of the Constitution and Rules of the Institute, which reads:—

"The authorised letters designating the class in the Institute to which a member belongs shall be as follows:—

For an Honorary Member,
Hon. M. (s.a.) I.E.E.
For a Member ... M. (s.a.) I.E.E.
For an Associate Member,
A.M. (s.a.) I.E.E.
For an Associate,
Associate (s.a.) I.E.E.
For a Student, Student (s.a.) I.E.E.

In each case the letters S.A. shall be in brackets and be less in size than, but not less than half, the size of the other letters."

TO COUNTRY MEMBERS.

The Council is particularly desirous of receiving written contributions from members resident in the country on any of the papers up for discussion as set forth in the Agenda.

Members who are unable to attend the Ordinary General Monthly Meetings should avail themselves of this opportunity.

In this connection members should bear in mind the Institute, V.F.P., and Students' Awards which are available for members presenting a paper or contribution of sufficient merit.

Kindly address all contributions, etc., to the Secretary, P.O. Box 5907, Johannesburg.

MINUTES OF THE BRITISH STANDARDS INSTITUTION.

The Minutes of the above Institution are regularly received by the Institute, and may be obtained for reference purposes on application to the Secretary.

BRITISH STANDARDS SPECIFICATIONS.

H.M. Acting Senior Trade Commissioner, Johannesburg, has advised the Institute that he has received from the British Standards Institution, of London, a complete set of British Standards Specifications.

These Specifications are filed in his office, and may be consulted there when required.

The Specifications are for consultation only, and cannot be loaned from his office.

TECHNICAL PUBLICATIONS.

By the kindness of Doctor H. J. van der Bijl, the chairman of the Electricity Supply Commission, the Institute is favoured with copies of the weekly library extracts of current technical literature prepared by the Librarian of the Commission.

The Council desires to announce that the Extracts are available for reference by members on application to the secretary, and, in future, a copy will also be available on the bookshelves in the lounge of Kelvin House.

W.P.C. AMERICAN COMMITTEE.

The American Committee of the World Power Conference have kindly extended an offer of assistance to South African engineers visiting the United States, and are willing to advise on places of interest to visit, itineraries, etc. The offices of the Committee are at 1419-21, Chrysler Building, 406, Lexington Avenue, New York City.

Intending visitors are invited to communicate with the Committee at the above address.

RECIPROCITY ARRANGEMENTS.

Reciprocity arrangements exist between the South African Institute of Electrical Engineers and the Institution of Electrical Engineers, London, the American Institute of Electrical Engineers, the Société Française des Electriciens, Paris, the Association Suisse des Electriciens, Switzerland, and the Verband Deutscher Elektrotechniker, Germany. It is hoped that members proceeding overseas will avail themselves of the facilities offered. Full particulars are obtainable from the Secretary.

CLIPPINGS FROM TECHNICAL PRESS.

Members are invited to send in any clippings from the Technical Press which may have bearing on papers up for discussion, or may be of general interest. Please state source. These clippings will be submitted to the responsible editor, who will pass for publication such items as can be accommodated in the *Transactions*.

VISIT TO ISCOR WORKS.

By the courtesy of the management of the South African Iron and Steel Industrial Corporation, Limited, members of the Institute are invited to pay a visit of inspection to the Iscor Works, Pretoria West, on Saturday morning, October 27th.

Members will be circularised in this connection in due course.

At the Institute's October General Meeting, which will be held on the Thursday prior to the visit, Mr. T. P. Stratten, the Chief Electrical Engineer of the Iscor Works, will read a paper entitled "The Electrical Equipment of the South African Iron and Steel Industrial Corporation, Limited—A Description with Some Notes on the Construction and Starting-up Periods."