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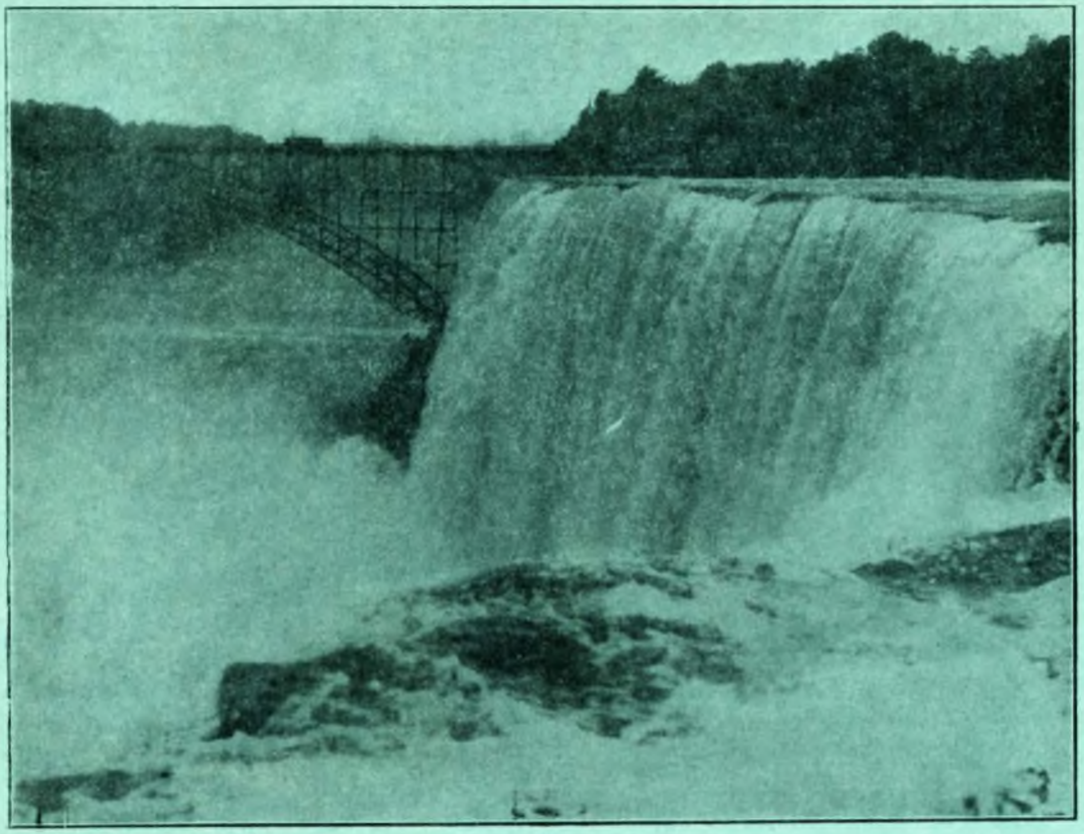

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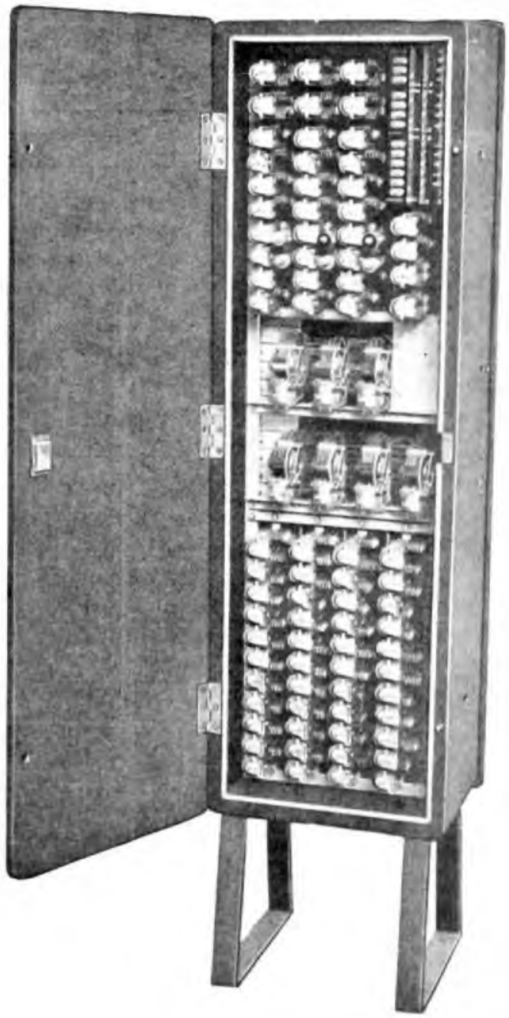

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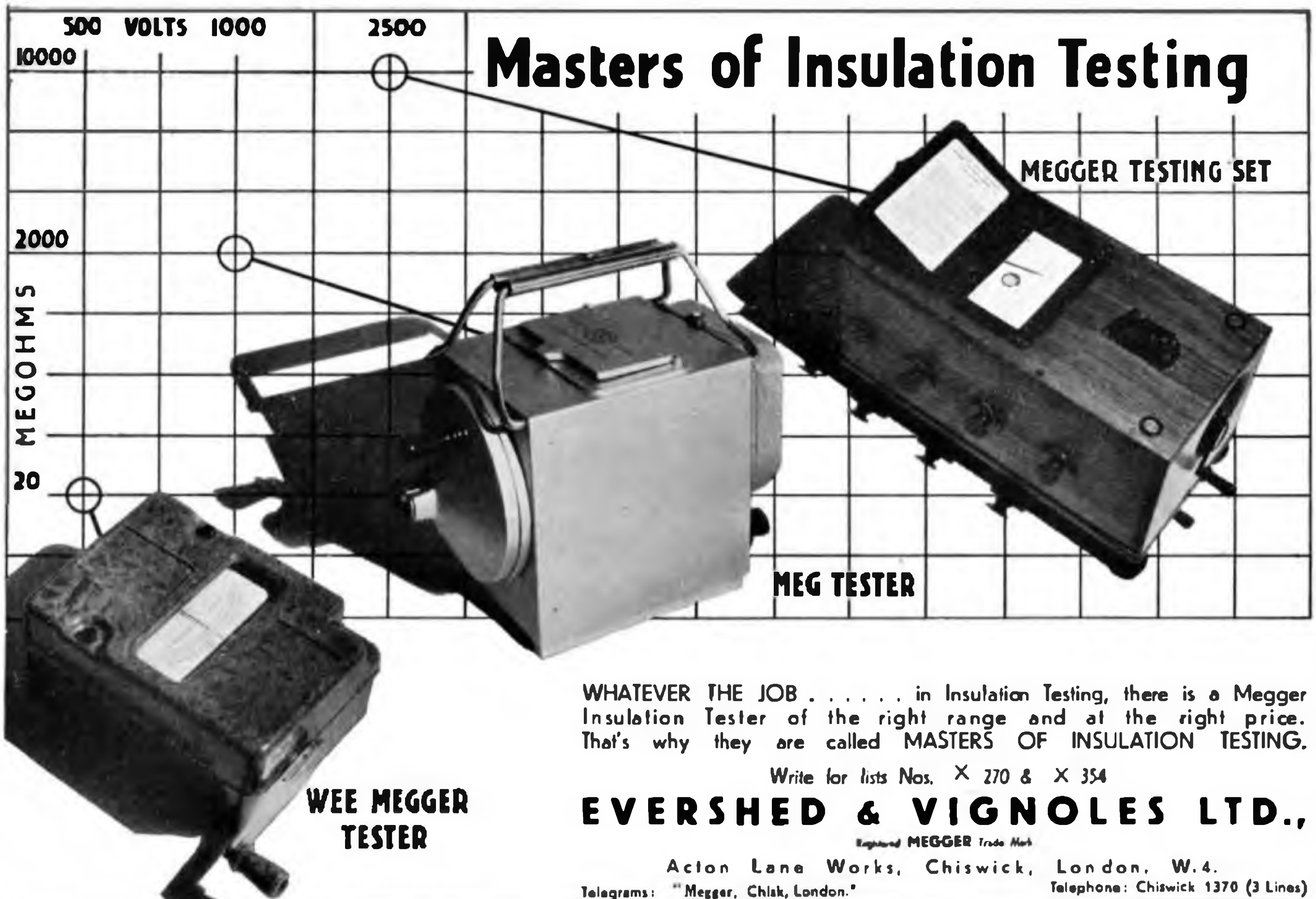

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXVIII October, 1935 Part 3

Some Performance Characteristics of the Subscriber's Telephone Transmitter

D. McMILLAN, B.Sc.

Summary.

A SERIES of measurements of frequency characteristics of the Inset No. 10 transmitter has been made during which tests some new or little known effects have been observed. Further work, with a view to a more critical observation of these effects, has been carried out and some of the results are discussed. In some cases it is found that these results give a new conception of the magnitudes of some well known distorting influences and in others they reveal little known (or possibly quite new) effects.

A new method of observing the performance of a carbon granule transmitter is described.

Introduction.

It has long been recognized that much of the distortion of the characteristics of a voice during transmission over a telephone link is due to the inferior performance of the carbon transmitter usually associated with the telephone circuit. It is true that the average telephone conversation, taking place under average conditions, is a conversation conducted with a fair degree of ease and comfort, nevertheless, some of the naturalness of the talkers' voices is lost and the distortion is undoubtedly sufficient to magnify the effects of any difficulties introduced by the conditions under which the talk is taking place. The effects of line noise and room noise, and of unaccustomed subjects of discussion may all be mentioned in this connexion.

If a telephone circuit, of such characteristics as are usual in practice, be tested first with the ordinary carbon transmitter and then with an almost perfect transmitter replacing the carbon instrument, it will be observed that the change of transmitter results in a very marked improvement in the naturalness of reproduction of the talker's voice. In fact, an old test figure was found which recorded an improvement in articulation efficiency when such a change was made of from 78% to 93%. It must be realized that these figures apply only to the precise conditions under which this particular test was made. They indicate, however, that an improvement in the performance of the subscriber's transmitter is most desirable. At the same time it is essential that, desirable as such improvement may be, it must not involve any sacrifice of sensitivity or increase the cost of production. The distortions produced by the carbon granule microphone are intimately connected with its *modus operandi,* upon which the success of commercial telephony still depends. Attack on these distortions must therefore be made with circumspection and must be based on the results of careful analysis.

With this point in view an investigation of the performance characteristics of the Inset No. 10 type of transmitter was commenced during November, 1934, and is still in progress. This article represents a précis of the results of tests performed to date. It is hoped to deal more fully with certain of the characteristics in a later article. The tests have pursued the following general plan :— Tests of frequency characteristic were first made, relating the R.M.S. sound pressure at the transmitter with the R.M.S. electro-motive force developed by the transmitter. These tests were carried out over a range of sound pressure inputs and a measure of amplitude distortion introduced by the inset thus obtained at the same time. Then followed a series of measurements of non-linearity, as evidenced by the production of harmonics and by intermodulation between two separate, simultaneous, sound inputs. Articulation tests were made at this stage in an attempt to determine the practical significance of the various distortions observed.

Some attempt has been made to discover explanations for these distortions in terms of the physical performance and properties of the various portions of the transmitter. Further work will be necessary, however, before the explanations are converted from informed guesses into indisputable facts.

I. *Measurements of Frequency/Response Characteristics and of Amplitude Distortion.*

For these tests the transmitter was suspended in front of a loudspeaker having a known frequency response characteristic. This loudspeaker was situated in a room which was acoustically treated so as to simulate a free space condition and was supplied with current (closely sinusoidal) from a heterodyne oscillator. The **E.M.F.** produced by the transmitter under test was amplified and rectified (by a rectifier having a linear characteristic) and caused a galvanometer spot to deflect in proportion to its amplitude. This galvanometer spot moved across the width of a sheet of paper which was arranged to move along its length as the frequency of the current from the heterodyne oscillator was varied. The position of the spot of light on the paper could be traced as the frequency of the current was increased from a low to a high value. A range of from 200 to 5,000 cycles per second (c.p.s.) was covered by the apparatus used. The sound pressure developed at the transmitter under test was measured by means of a microphone which is specially adapted to introduce negligible distortion of the sound field by its presence. It consists essentially of a tube of about ¼″ diameter which is inserted into the sound field at the point at which a measurement is desired and which " conducts " the sound pressure to a remotely situated condenser microphone. This latter instrument is used as the actual measuring device. The arrangement has been described by W.West[1] and is referred to below as a " probe-tube microphone."

The carbon transmitter under test was supplied with polarizing direct current from a 200-volt battery in series with a large resistance. The resistance changes occurring in the transmitter were then not sufficient to result in a change of feed current. The alternating component of the open circuit E.M.F. developed by the transmitter for various sound pressure inputs was first recorded.

A sound pressure which was substantially independent of frequency was obtained for this test by the use of a small, moving coil source mounted in a heavily damped metal case. The frequency response characteristic of this loudspeaker is shown in Fig. **1**.

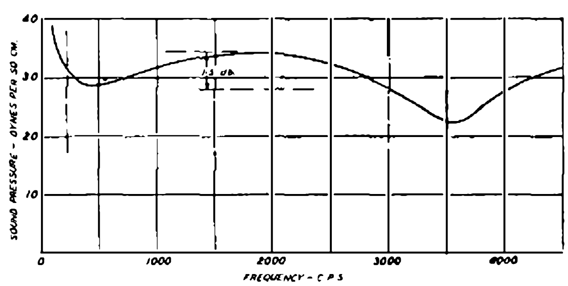

FIG. 1. — FREQUENCY CHARACTERISTIC OF LOUDSPEAKER. SOUND PRESSURE MEASURED 1″ FROM LOUDSPEAKER WITH CONSTANT CURRENT (27 MA) IN SPEECH COIL.

The first set of characteristics to be traced are reproduced in Fig. **2**. They refer to an Inset No. 10 used alone (without a case) with 50 milliamps of polarizing current. The sound pressures employed ranged from 47 down to 0.09 dynes per square cm. (Some tests with the probe-tube microphone close to an actual mouth showed that this range of sound pressures was well within the limits experienced by a subscriber's transmitter in average use). The curves I. to **VI**. were taken in that order with pro-

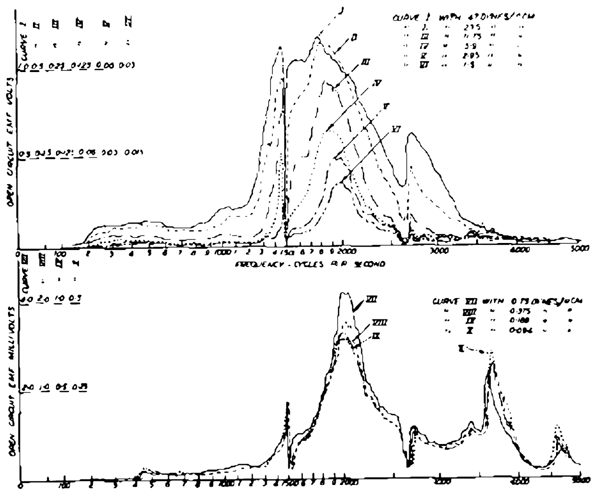

FIG. 2.—FREQUENCY CHARACTERISTICS OF INSET No. 10 WITH 50 MA FEED CURRENT.

gressive reductions in sound pressure—the pressure being halved for each successive curve. At the same time the sensitivity of the recording device was doubled for each successive curve so that all six curves would have been exactly coincident if the transmitter had exhibited a constant form of frequency characteristic for each value of sound pressure input. It will be seen that such is far from being the case and the necessity for a constant sound pressure input is apparant. It is obviously impossible to apply a correction for known variations in the sound pressure when the transmitter under test introduces amplitude distortion.

The curves are generally similar in that each shows a maximum sensitivity at about 2,000 c.p.s. The resonance becomes much more damped, however, as the sound pressure is increased. Curves VII. to X. of Fig. **2** show the shape of the characteristic for low sound pressures and it will be seen that the curves tend to be alike at these smaller pressures. A second peak, at about 3,700 c.p.s. becomes evident at low sound pressures but is not observable at pressures above about 3 dynes per square cm. The shape of the curve at low frequencies also alters as the sound pressure is reduced. At pressures below about 3 dynes per square cm. the sensitivity of the transmitter is extremely low for all frequencies below about 400-450 c.p.s. Above a critical frequency in this range the sensitivity suddenly rises. At sound pressures greater than 3 dynes per square cm. the sensitivity of the transmitter shows a progressive increase as the frequency of sound input is raised above 200 c.p.s.

Fig. **3** shows a similar family of curves taken with the same Inset No. 10 but with 150 milliamps polarizing current and Fig. **4** shows a third family taken with 20 milliamps. The general remarks referring to the curves of Fig. **2** may equally well be applied to Figs. **3** and **4**. It will be noted also that the curves taken with 150 milliamps polarizing current exhibit a more heavily damped resonance at about 2,000 c.p.s. than do the curves taken with 50 milliamps and that those taken with 20 milliamps show a more lightly damped resonance at about the same frequency. A rough computation shows that,

[1] P.O.E.E.J., Vol. 26, Pt. 4.

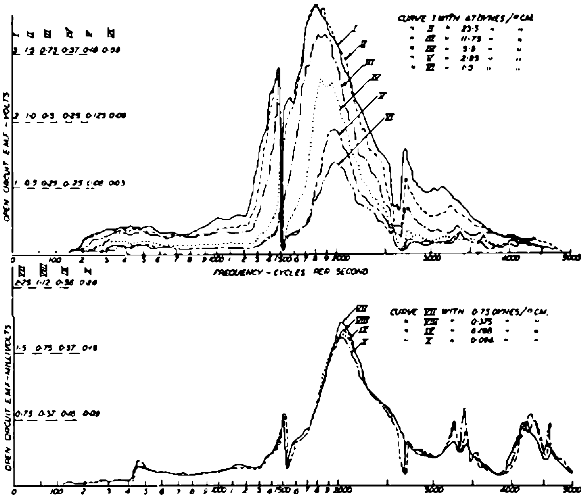

Fig. 3.—Frequency Characteristics of Inset No. 10 with 150 MA Feed Current.

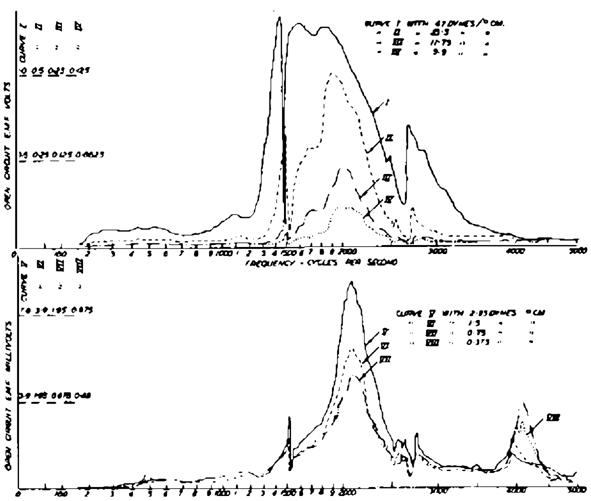

Fig. 4.—Frequency Characteristics of Inset No. 10 with 20 MA Feed Current.

for low sound pressures, the 20 milliamp curves have a decay factor of about 800, the 50 milliamp curves have a decay factor of about 1,000, and for the 150 milliamp curves the factor is about 1,400.

At all values of feed current the transmitter exhibits marked amplitude distortion. That is to say, a change in the R.M.S. value of sound pressure input is not followed by a proportionate change in the R.M.S. value of E.M.F. developed by the inset. Fig. **5** has been plotted from the curves of Fig. **2**. The change in output voltage is plotted against change in sound pressure on the transmitter. A scale of decibels is employed for convenience. It will be seen that increasing the sound pressure by 50 db. results in an increase of voltage output by 80 db. (at 1,300 c.p.s.). Fig. **6** has been plotted from the results of a separate test made to determine the relation between input and output at low sound pressures.

It is already well known that the direct current resistance of the carbon transmitter inset varies with the sound pressure actuating the inset. The extent of this variation for a typical condition of use

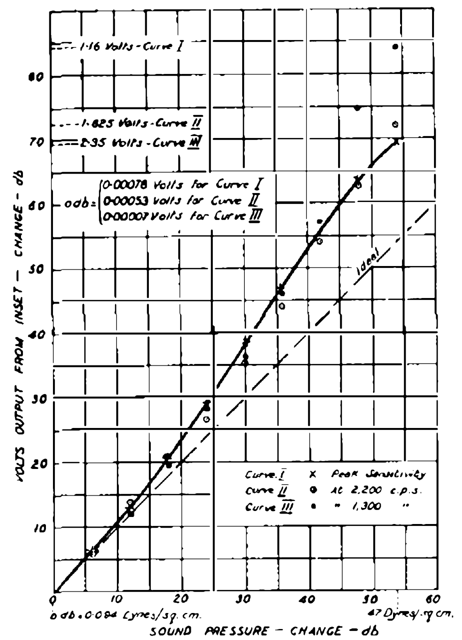

Fig. **5**.—Load Characteristic of Inset No. 10 (50 MA Feed Current).

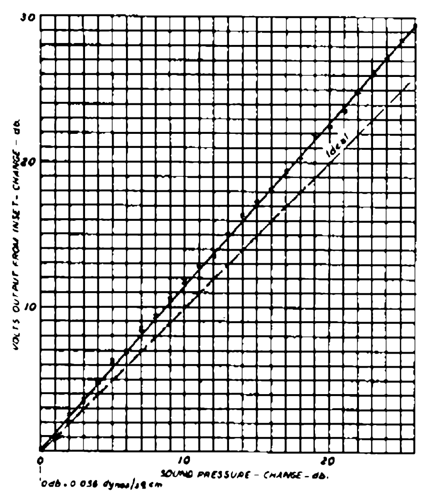

Fig. **6**.—Load Characteristic of Inset No. 10 at Low Sound Pressures. Test made at 1900 c.p.s. with 50 MA Feed Current.

is shown in Fig. **7**. The resistance of the transmitter always returned to about the same value when the sound was switched off. The curves of direct current resistance versus frequency of sound are very similar in general shape to the frequency response curves shown in Fig. **2**.

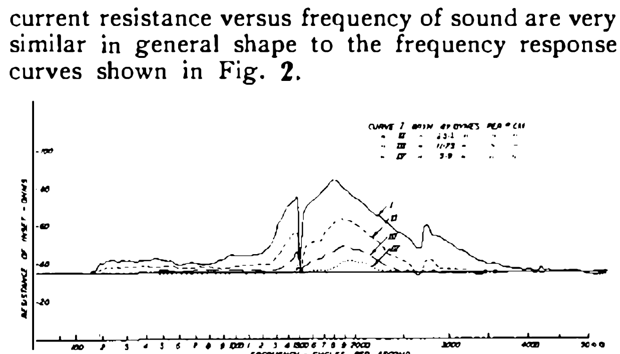

Fig. **7**.—Direct Current Resistance of Inset No. 10.

All the measurements recorded so far refer to the performance of an Inset No. 10 without a case. It will be instructive at this point to examine the effect of enclosing the inset in standard types of telephone cases. Fig. **8**(*a*) shows a family of frequency characteristics for an Inset No. 10 working in a Transmitter No. 22 (the new form of pedestal telephone). Fig. **8**(*b*) shows two curves from a similar family obtained when the same inset was used in a hand-micro-telephone. Actually the same specimen of inset was used for these tests as for the tests recorded above. It was close to the average of about 30 insets in most of its characteristics. The curves of Fig. **8**(*a*) are generally similar in shape to curves obtained from a system of two resonators closely coupled. The main resonance peak occurs at about

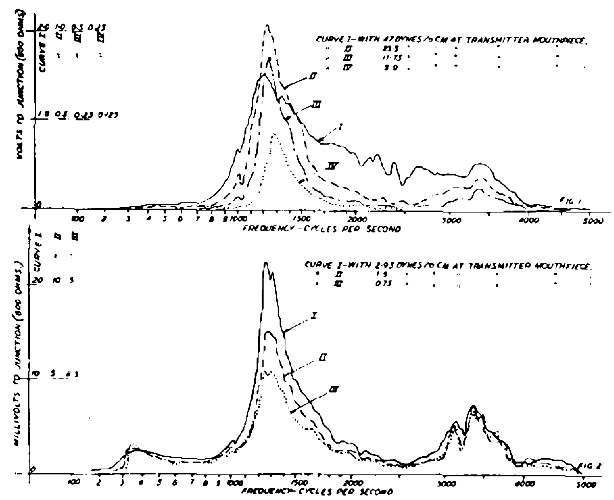

Fig. **8**(*a*).—Frequency Characteristics of Transmitter No. 22 with Inset No. 10 Tested on Bell Set No. 1 with 300 ohms Local Line. Receiver on Rubber Pad.

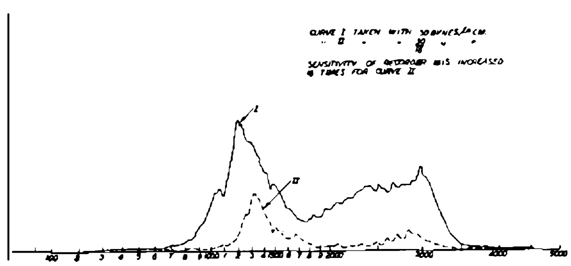

Fig. **8**(*b*).—Frequency Characteristics of Inset No. 10 in Tele. 162.

1,200 c.p.s. and a second peak may be observed at about 3,300 c.p.s. It will be observed that the Transmitter No. 22 was working on a standard Telephone 162 circuit with a 300 ohm local line and a 24 volt cord circuit. (This gives approximately 50 milliamps through the transmitter under quiet conditions). Reference to Fig. **8**(*a*) shows that the extent of amplitude distortion has not been greatly (if at all) varied by the change from the constant feed current arrangement used when testing the inset alone. It is necessary to find out how much effect the change has had upon the shape of the frequency characteristic of the inset. Fig. **9** shows a comparison of two curves taken under the two

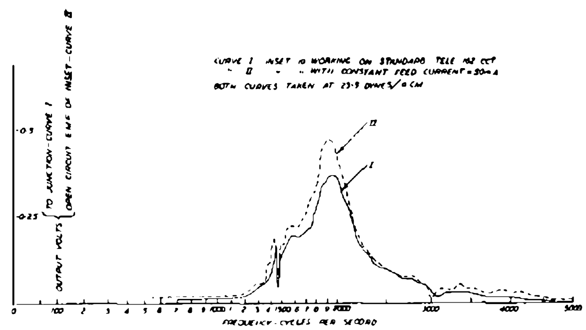

Fig. **9**.—Effect of Subscriber's Circuit on Frequency Characteristics of Inset No. 10.

conditions. They refer to an inset alone and show that the effect of the subscriber's circuit feed conditions are negligible. Fig. **8**(*a*) may therefore be directly compared with Fig. **2**, and, at the same time, may be taken as representing the performance of a Transmitter No. 22 under a practical condition of use. It will be seen that the case of the transmitter plays a large part in determining the shape of the frequency characteristics of the instrument. (This has already been pointed out by G. W. Sutton.[2]) A few tests have been made to determine more precisely the effects of the individual component parts of the complete transmitter.

It is convenient to discuss **first** the effects of the various portions of the case upon the performance of the inset—considered as a single unit. The effects of individual parts of the inset itself will be considered later. Fig. **10** shows a diagrammatical view of the

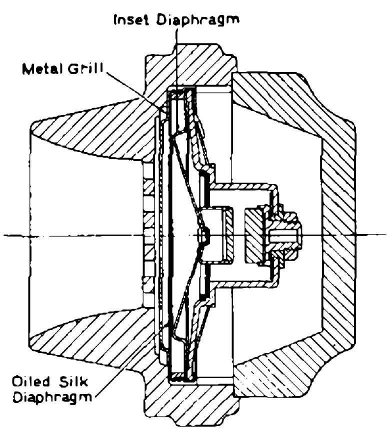

Fig. **10**.—Diagram of Inset No. 10 in Transmitter No. 22 Case.

cross section of an Inset No. 10 in a Transmitter No. 22 case. The main effect of the case is to enclose a volume of air between the moulded grille and the diaphragm of the inset. There are **21** holes in the grille—each of about $\frac{1}{8}''$ diameter. Curve I. of Fig. **11** illustrates again the performance of the transmitter at 23.5 dynes per square cm. Curve II. shows the effect of closing **12** of the **21** holes and Curve III. shows the effect of closing all the holes but one. The effective mass controlling the main resonance is

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[2] " Siemens Magazine ": March, 1935.

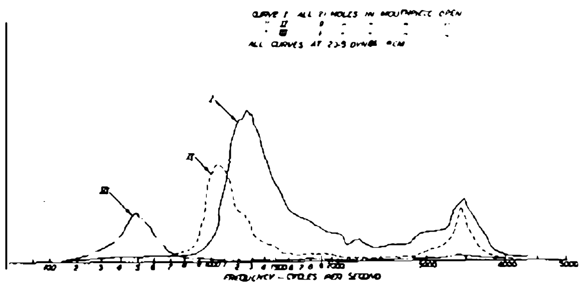


FIG. 11.—FREQUENCY CHARACTERISTICS OF COMPLETE TRANSMITTER NO. 22 WITH 50 MA FEED CURRENT.

increased, and the frequency at which resonance occurs is decreased as more and more holes are blocked up. The resonance becomes less sharp as the resonance frequency is reduced by this means. The resonance of the stiffness due to the volume of air trapped between the mouthpiece grille and the diaphragm of the inset with the effective acoustical mass of the 21 holes in the grille appears to account for the 1,200—1,300 c.p.s. peak observed with the complete transmitter. The effect of the " horn " or " flare " portion of the mouthpiece upon the overall characteristic is illustrated by the curves of Fig. **12**. The horn is seen to cause a slight reduction in the frequency of the main resonance peak and to

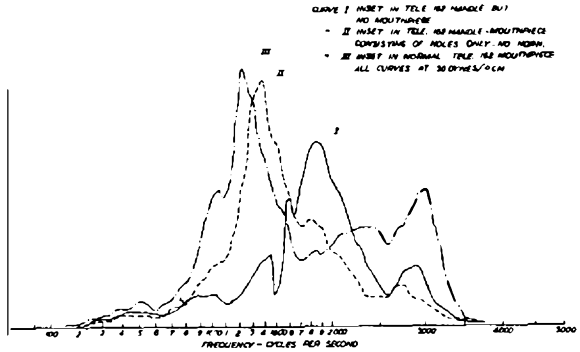


FIG. 12.—EFFECT OF TELE. 162 MOUTHPIECE ON PERFORMANCE OF INSET NO. 10 WITH 50 MA FEED CURRENT.

introduce a second peak at about 3,000 c.p.s. This latter peak is probably varied greatly in both frequency and magnitude by the position of the user's mouth relative to the transmitter mouthpiece. The curves of Fig. **12** were taken with a loudspeaker situated about $1\frac{1}{2}''$ from the transmitter.

The metal guard and oiled silk membrane which form part of the Inset No. 10 seem to play comparatively little part in the production of the main peak. Fig. **13** shows the effect of removing the guard and the oiled silk from the inset—the tests of Fig. **11** being repeated. The combined effect of the silk and the guard seem to be the addition of a small mass and a resistance to the complete system. The resonance peaks of Fig. **13** are sharper and occur at a relatively higher frequency than do those of Fig. **11**. (All the curves of both figures are drawn to the same scale of output).

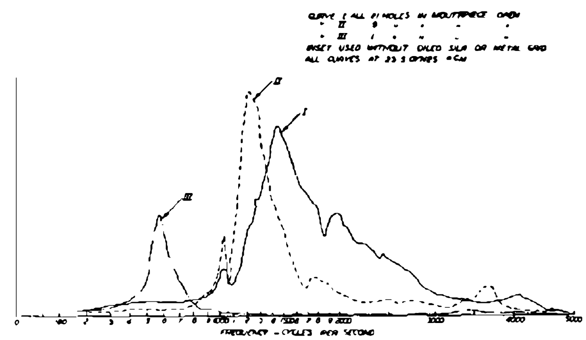


FIG. 13.—FREQUENCY CHARACTERISTICS OF TRANSMITTER NO. 22 WITH 50 MA FEED CURRENT.

The effects of the oiled silk membrane and of the metal inset guard were confirmed by tests with an inset alone. Curve I. of Fig. **14** shows the frequency response curve of an Inset No. 10 as received from the makers. Curve II. shows the response curve of the inset without the oiled silk membrane (but with the metal guard), and curve III. shows the performance

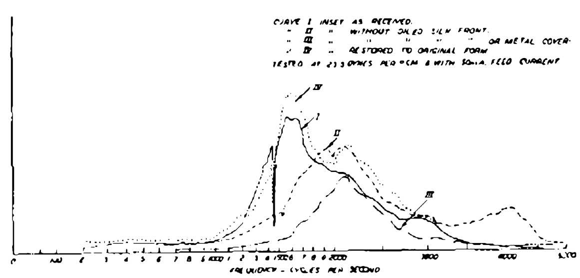


FIG. 14.—VARIOUS FREQUENCY CHARACTERISTICS OF INSET NO. 10.

of the same inset when both oiled silk and metal guard were removed. The guard itself will be seen to have a comparatively negligible effect on the frequency of the main resonance. Curve II. shows some evidence of a second resonance at about 4,000 c.p.s. which may be due to the resonance of the stiffness caused by the enclosure of air between the metal guard and the diaphragm, with the small mass due to the holes in the metal guard. There is some indication that the general sensitivity of the inset has been increased by the addition of the metal guard. This effect is not fully understood at the present time. (A comparison of Figs. **2** and **8**(*a*) shows that the addition of a mouthpiece to the complete inset has a similar effect. In this latter case, however, consideration must be given to the relative decay factors of the inset resonance and the mouthpiece resonance). The addition of the silk membrane introduces an additional mass which is apparently tightly coupled to the mechanical system of the inset proper. Some form of mechanical resonance of the silk membrane itself seems to cause the sharp dip at about 1,450 c.p.s. which may be observed in curves I. and IV. (Compare also the curves of Figs. **2**, **3** and **4**).

Curve III. of Fig. **14** is worthy of some further consideration. It represents the frequency response curve of an inset without either perforated metal guard or oiled silk membrane. A marked resonance may be seen to occur at about 2,100 c.p.s. Fig. **15** shows a family of such curves and indicates that the incomplete inset introduces considerable amplitude distortion. It is interesting and profitable to attempt

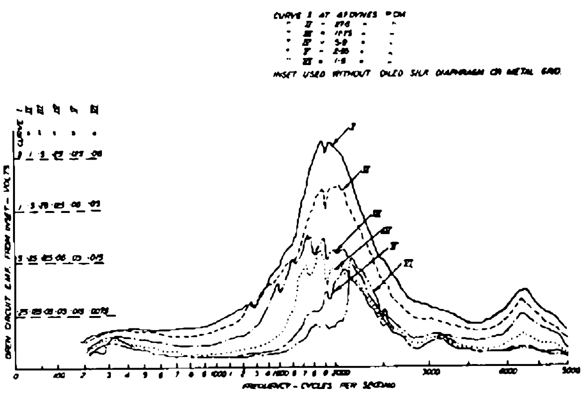


Fig. 15.—Frequency Characteristics of Inset No. 10 with 50 mA Constant Feed Current.

to discover the reason for the resonance peak at 2,100 c.p.s. It does not appear to be a reasonable frequency for an acoustic resonance due to the concave shape of the face of the inset This possibility was checked, however, by making both a field and a pressure calibration of the incomplete inset. The field calibration was made by suspending the inset at a point of known sound pressure in a sound field, and recording the frequency characteristic in the neighbourhood of the resonance, (curve I. of Fig. **16**). The pressure calibration was made by the tube

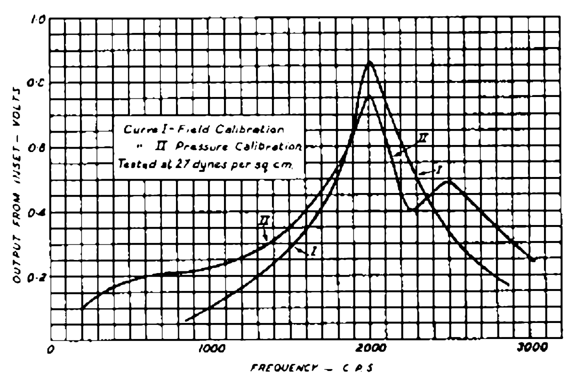


Fig. 16.—Comparison of Field and Pressure Calibrations of Inset No. 10.

method (described by W. West[3]) and produced a characteristic which connected the actual sound pressure on the diaphragm with the E.M.F. developed by the instrument, (curve II. of Fig. **16**). This latter calibration eliminates the effect of any acoustic resonance occurring in front of the diaphragm. The close agreement of the frequencies of resonance, as obtained by the two methods, indicates that the peak at about 2,000 c.p.s. is not due to any such acoustic effect.

The possibility that the resonance was due to a particular mode of vibration of the diaphragm of the inset was next considered. The frequency appeared to be rather low for such an effect since the diaphragm is very light and stiff and is further stiffened by the small volume of air which is enclosed behind it. The back case and the diaphragm of an inset were cut away leaving only the plunger, held by the Swiss silk washers, and the carbon chamber. Frequency response curves were then taken for this small " button " transmitter; Fig. **17** illustrates the

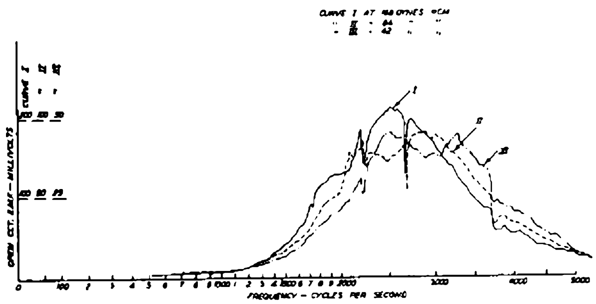


Fig. 17.—Frequency Characteristics of Carbon Button portion of Inset No. 10 with 50 mA Constant Feed Current.

results obtained. High values of sound pressure had to be used for this test since the area over which the pressure was developed was small. The resonance peak is seen to persist with this elementary transmitter. It has moved slightly up in frequency to about 2,500 c.p.s. The amplitude distortion still exists although there is some indication that its severity may have been reduced. The small change in the frequency at which resonance occurs may be due to the simultaneous effect of reduction of the mass of the moving parts (by cutting away the diaphragm) and reduction of the stiffness controlling the system (by release of the volume of air trapped behind the diaphragm). Alternatively it is possible that the resonance peak is due to some effect occurring within the granule chamber itself. The writer intends to enquire further into this point when opportunity presents itself. An investigation into the effects produced by the use of different sizes of carbon granules appears to be a possible method of preliminary attack.

II. *Measurements of Sub-harmonics produced by the Inset No.* 10.

During the performance of the tests of frequency characteristics the opportunity was taken to listen to the output from the Inset No. 10 as reproduced by a telephone receiver. The tone input to the inset was substantially pure (some figures of harmonic content are given in the ensuing section) but the output from the telephone receiver was far from pure. A marked second harmonic could almost always be heard. This, however, was expected; it is predicted by the simple theory of a variable resis-

[3] " Acoustical Engineering ": page 207.

tance transmitter.[4] A more unexpected result was the observation of a quite loud sound from the receiver at a *lower* frequency than that of the input sound to the transmitter. The frequency of this unwanted output appeared, at first impression, to be about half the frequency of the sound from the loudspeaker. This was later confirmed by measurement—a second sub-harmonic being produced by the inset under certain conditions of input. The effect seems to be similar in some respects to that noticed by various observers when testing loudspeakers,[5] but there are important differences.

The inset was found to generate a second sub-harmonic over a wide range of frequencies, but the value of the sound pressure on the diaphragm to produce the sub-harmonic was somewhat critical. The half-frequency output was first observed with a sound input of 47 dynes per square cm. It was afterwards discovered that this particular value of sound pressure was close to the optimum.

Fig. **18** shows the variation in the value of the sub-harmonic output for a constant sound pressure

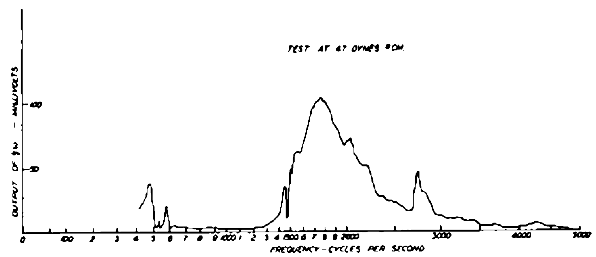


Fig. **18**.—Record of Sub-harmonic from Inset No. 10 with 50 mA Constant Feed Current.

input as the pitch of sound is changed. This curve relates to an Inset No. 10 used alone; *i.e.*, with no transmitter case. The curve was recorded with the aid of a series of very efficient low-pass filters which allowed the sub-harmonic through to the recorder, but effectively stopped the fundamental frequency. The general shape of the curve is similar to that obtained for the overall frequency response of the inset at the same sound pressure (47 dynes per square cm.). Curve I. of Fig. **2** refers. The maximum output of sub-harmonic occurs when the input sound frequency is about 1,750 c.p.s.; the sub-harmonic is then at about 875 c.p.s. It may be noted in passing that this latter frequency is particularly well reproduced by the average telephone receiver, so that the comparatively small voltage of sub-harmonic is somewhat deceptive. Its effect is very considerable when heard in conjunction with the fundamental tone. It appears to be probable that the psychological effect on the listener ("annoying" effect) of a sub-harmonic may be greater than that of a higher harmonic of equal magnitude. Particularly is this the case when the sub-harmonic is compared with a second harmonic.

It was noticed, from the curves of Fig. **5**, that the sensitivity of the inset began to show signs of becoming less as the sound pressure input was increased beyond about 40 dynes per square cm. Since the sub-harmonic makes its appearance at about the same value of sound pressure input, a series of tests was undertaken in order to relate the sensitivity of the inset with the value of sub-harmonic output, and also with the sound pressure input. These measurements were made with an input at 1,650 c.p.s. Fig. **19** illustrates the results. Curve

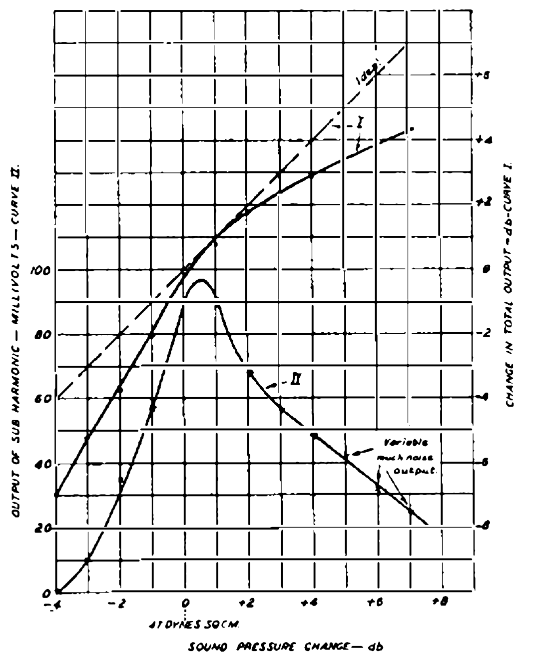


Fig. **19**.—Output of Sub-Harmonic from Inset No. 10 at 1650 c.p.s.

I. shows the variation in total output from the inset for a range of variation of sound input of from 30 to 105 dynes per sq. cm. It is really a continuation of curve I. of Fig. **5**. The sensitivity of the inset is seen to decrease for inputs above about 40 dynes per sq. cm.—the "knee" of the curve appearing at about 50 dynes per sq. cm. Curve II. shows that this latter value of sound pressure input results in a maximum output of sub-harmonic. No sub-harmonic is observed until a sound pressure greater than 30 dynes per sq. cm. is used, and sound pressures above about 75 dynes per sq. cm. result in so much noise output that the value of the sub-harmonic produced is somewhat in doubt. The range of 30-75 dynes per sq. cm. is therefore the range most conducive to the production of the sub-harmonic.

The small, "button" transmitter used for the frequency characteristic tests of Fig. **17** was found to produce an output at the second sub-harmonic frequency when subjected to a sound pressure of 168 dynes per sq. cm. It therefore seems likely that the half frequency output is produced by the carbon granule system and not by the diaphragm system of the Inset No. 10.

In all tests where the sub-harmonic has been observed it has risen to its final value almost instan-

[4] "Acoustical Engineering": W. West.

[5] F. Von Schmoller: "Telefunken Zeitung": June, 1934.

taneously as the sound input to the transmitter was switched on. This is so irrespective of the value of the sound pressure used—provided that the pressure is great enough to cause the generation of a sub-harmonic. In this respect the effect is different from that observed by a number of investigators when testing loudspeakers. Von Schmoller[6] (and others) observe that a long " build up time " is frequently associated with the production of sub-harmonics by an electrodynamic loudspeaker. This slow increase may persist over a period of a minute of more.

The same investigator also notes that, at low values of current in the moving coil, the incidence of sub-harmonics is critical to frequency and current value. The amplitude of sub-harmonics (once produced) seems to be independent of the value of the current. At higher values of current the frequencies at which the half-frequency occurs increase in number and spread out into bands so that, at relatively high current values, the sub-harmonic is produced over almost the entire frequency range.

With the Inset No. 10—a sub-harmonic is produced over a continuous and wide frequency range for any amplitude of sound pressure which is sufficient to produce a sub-harmonic at all. The amplitude of the output at the half-frequency varies with the sound pressure input—attaining a definite maximum at one particular value of sound pressure input.

The whole problem of the production of sub-harmonies in forced oscillations has been investigated mathematically by P. O. Pedersen.[7] He finds that only second sub-harmonics can exist in systems with only one degree of freedom. They may be caused by the applied force actuating the system being variable—*e.g.*, a function of the displacement of the system — or by the stiffness factor of the system being variable (again, this may be a function of the displacement). Both these effects may operate simultaneously to produce a second sub-harmonic, but Pedersen states that " sub-harmonics cannot appear when the parameters M, R, S, and F are all even functions of the displacement." (M, R, S, and F refer to mass, resistance, stiffness and force respectively).

Von Schmoller[8] has investigated the problem for a loudspeaker by considering a diaphragm with variable stiffness. He obtains a Mathieu equation for the motion of the system under the influence of a constant applied force and finds that the complete solution of this equation involves displacements at half the frequency of the applied force. These half-frequency solutions are stable only within certain ranges of applied force and frequency.

A consideration of the effects observed with the Inset No. 10 in the light of the work of Pedersen and Von Schmoller makes it appear likely that the sub-harmonic produced by the inset is due to a variation in the stiffness factor introduced by the carbon granules as the electrode displacement varies.

More work is necessary on this particular problem before this last assumption is proved or disproved.

[6] Loc. cit.

[7] " Journal of Acoustical Society of America," Vol. VI.

[8] Loc. cit.

III. *Measurements of Non-Linearity of response of the Inset No.* 10.

Non-linear distortion is here regarded as the form of distortion arising from a lack of proportionality between the instantaneous value of sound pressure operating the inset and the resulting instantaneous E.M.F. developed by the transmitter. It is characterized by the production of higher harmonics of any single input frequency in the output from the inset, and by intermodulation between two simultaneous inputs at different frequencies.

The extent of the non-linearity of response of the inset was determined by measurement of the amplitude of the individual E.M.F's. at various frequencies developed by the inset when actuated by a single pure tone and by two simultaneous pure tones. Two loudspeakers, of the type mentioned in Section I. of this article, were used to supply the sound input to the transmitter under test. The complex output from the transmitter was analyzed into its component frequencies by means of a Harmonic Analyzer. This instrument employed the search tone method (described by M. Grutzmacher)[9] and has been developed by J. F. Doust (of the P.O. Research Staff).

The sound output from the loudspeakers was first tested for harmonics. A condenser transmitter and a good amplifier were used for this test in conjunction with the Harmonic Analyzer. A second harmonic about 45 db. below the fundamental was observed. The third and fourth harmonics were discernable but could not be measured. (They were more than 55 db. below the fundamental).

The first measurement made with the inset was in the nature of a confirmation of the results illustrated in Fig. **5**. The curves of Fig. **5** were obtained by scaling the frequency characteristics of Fig. **2**. These frequency characteristics were recorded in such a way that the *total* output from the transmitter (*i.e.*, fundamental, higher harmonics and sub-harmonics) is related to frequency and input. A test of amplitude distortion was therefore made using the analyzer which could be employed to measure the output at the fundamental frequency only. It was found that a change of sound pressure of from 5 to 20 dynes per sq. cm. (*i.e.*, 12 db. change) resulted in a change of output of about 22 db. This test was conducted at 1,600 c.p.s. and approximately confirms the results shown in Fig. **5** (23 db. from the curve). A change of sound pressure of from 5 to 40 dynes per sq. cm. (18 db. change) resulted in a change of output of 40 db. This again is approximately confirmed by the results of Fig. **5**. Thus we may say that the frequency characteristics, drawn in families, do represent a fair picture of the extent of amplitude distortion introduced by the transmitter although the outputs recorded include the effect of any unwanted components.

Some measurements of the amplitudes of individual harmonics produced by a single frequency input were next made. The results are shown in the table below :—

[9] " Electriche Nachtrichten Technik," 1927 : p. 533.

Sound pressure dynes/sq. cm.	Change of output at 1,600 c.p.s. —db.	Harmonics—db. below fundamental.		
		2nd.	3rd.	4th.
5	0	17.5	—	—
10	+ 9	17	33	—
*20	+ 23	17	34	44
40	+ 40	17	30	37

* NOTE :—These figures also apply at 1,000 and 2,000 c.p.s.

The third and fourth harmonics are seen to be negligible in comparison with the second. The last apparently bears an almost constant relation to the fundamental, which relation is not altered by changes in the operating sound pressure. This result confirms an earlier figure (obtained about two years ago) for a C.B. No. 1 (solid-back) transmitter working under Reference Standard conditions. The second harmonic output from this instrument was about 19 to 21 db. below the fundamental output for all sound pressure inputs between 5 and 60 dynes per sq. cm. (The third and fourth harmonics were negligible with this instrument also).

The elementary theory of a carbon transmitter indicates that the relative magnitude of second harmonic generated by the instrument will depend upon the load resistance into which it is working. A test showed, however, that the figure of 17 db. below the fundamental (at 20 dynes per sq. cm.) was not appreciably affected by a change of load over the range of from 50 to 1,800 ohms. (The figures of the table above refer to a 600 ohm condition). The relative sizes of third and fourth harmonics also remained substantially constant for any value of load resistance within this range. No greater range of values of load was tried.

The inset was then exposed to two simultaneous sounds of different pitches. Frequencies of 1,600 c.p.s. and 300 c.p.s. were chosen for this test. The first of these frequencies is near the value for maximum sensitivity of the inset and the second is low enough to represent crudely the more or less constant input of larynx tone experienced by a transmitter in normal use. These two values are not harmonically related and are therefore particularly suited to the purpose of the test.

The output of 1,600 c.p.s. was first measured—over a range of input pressures—with various amounts of 300 c.p.s. tone simultaneously applied. Fig. **20** shows the results obtained. It will be seen that the presence of the low frequency sound (of constant intensity) tends to improve the amplitude response of the inset to a second sound input of variable intensity. The greater the intensity of the low frequency—the greater the resulting improvement. The improvement takes the form of an increase in the sensitivity of the inset for small sound inputs. With 40 dynes per sq. cm. of 300 c.p.s. the response of the inset to 1,600 c.p.s. is almost linear up to 20 dynes per sq. cm. of sound pressure at the latter frequency.

Fig. **21** shows the relative magnitude of the second harmonic of 1,600 c.p.s.—curve I. for a single input of 1,600 c.p.s., and curves II., III. and IV. for an

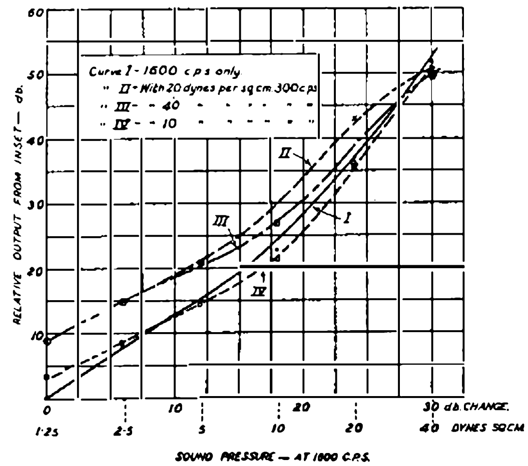


FIG. **20**.—OUTPUT FROM INSET NO. 10 WITH ADDED 300 C.P.S. TONE.

input of 1,600 c.p.s. in the presence of various amounts of 300 c.p.s. The improvement in load characteristic illustrated in Fig. **20** is seen to be accompanied by a reduction in the relative amount of second harmonic produced.

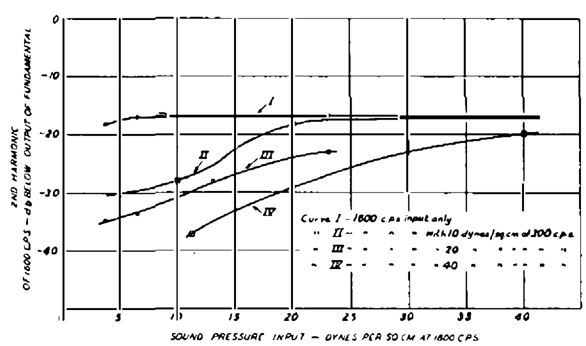


FIG. **21**.—SECOND HARMONIC PRODUCED BY INSET NO. 10.

It now remained to determine the relative size of the " sum " and " difference " frequencies arising in the output from the inset due to intermodulation between the two simultaneous inputs. These unwanted outputs occur at 1,900 c.p.s. and 1,300 c.p.s. respectively and are pictured in Figs. **22** and **23**. The 1,900 c.p.s. output shows a maximum at from 5-12 dynes per sq. cm. of 1,600 c.p.s. input, depending upon the amount of 300 c.p.s. present. The 1,300 c.p.s. output reaches a sharper maximum at about 2-3 dynes per sq. cm. of 1,600 c.p.s. input and may attain the somewhat astonishing value of about

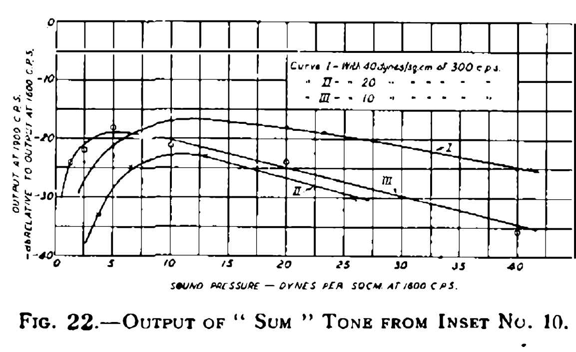


FIG. **22**.—OUTPUT OF " SUM " TONE FROM INSET NO. 10.

5 db. below the output of 1,600 c.p.s. All three curves of Fig. **23** must reach the point O, $-\infty$, when the 1,600 c.p.s. input is switched off. The 1,300

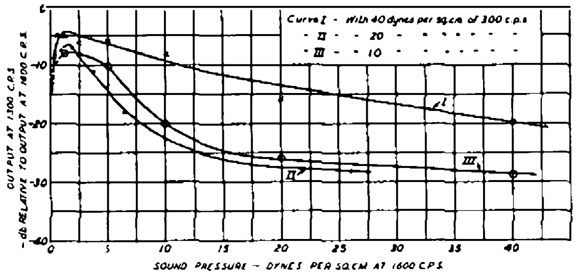


FIG. **23**.—OUTPUT OF " DIFFERENCE " TONE FROM INSET NO. 10.

c.p.s. component is thus seen to increase very rapidly with increase of 1,600 c.p.s. input when the latter is small.

This last effect may conceivably have considerable influence upon the articulation efficiency of the transmitter. In normal use it is submitted to a comparatively large, low frequency, larynx tone upon which is superimposed the higher frequency, and smaller intensity, consonant sounds. These higher frequency sounds determine the articulation and may be seriously affected if a masking sound of almost equal intensity and slightly lower frequency is superimposed upon them.

IV. *Articulation Tests to determine the effect of Non-Linearity and Amplitude Distortion.*

At this point in the investigation it was decided to try and find out how much articulation loss is introduced by the various distortions resulting from the use of an Inset No. 10 in practice. For this purpose a Transmitter No. 22 was used. It was desired to determine how much of the total articulation loss introduced by the Transmitter 22 was due to causes other than shape of the frequency response characteristics.

An ordinary subscriber's telephone receiver was modified to act as a transmitter. Its frequency characteristic, when so used, was adjusted to be similar to the frequency characteristic of the Transmitter No. 22 at an average value of sound pressure. This was done by controlling, in a suitable manner, the mechanical and acoustical conditions which affected the motion of the diaphragm of the receiver. A new, and thicker, diaphragm was also fitted. Fig. **24** shows frequency characteristics of the electromagnetic transmitter and of the Transmitter No. 22 (at 23.5 dynes per sq. cm.). A negligible amount of harmonic was introduced by the electromagnetic transmitter. It was used in conjunction with an

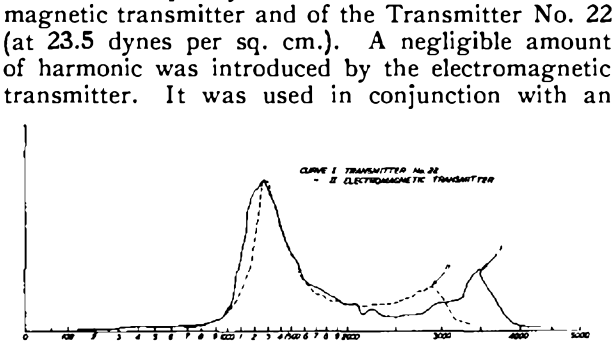


FIG. **24**.—COMPARISON OF TRANSMITTER NO. 22 AND ELECTROMAGNETIC TRANSMITTER.

amplifier—the gain of which was adjusted so that the overall volume efficiency of the combination of transmitter and amplifier was equal to that of the Transmitter No. 22 (together with its local line and cord circuit equipment) when tested by subjective methods.

A long series of articulation tests was then carried out on the two transmitters. Six observers were employed and single logatoms only were transmitted. No room noise was present at either the listening or the sending end. Fig. **25** (curves I. and II.) shows the relation between articulation efficiency and

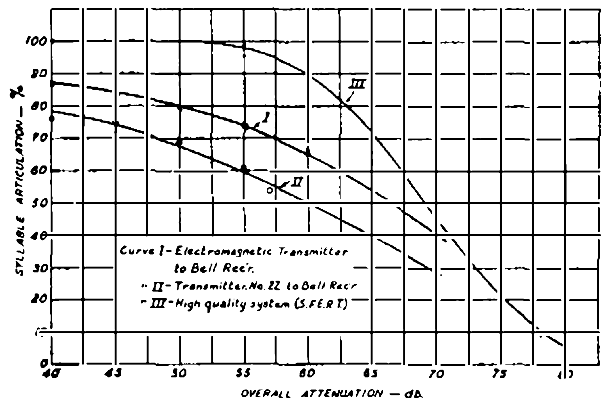


FIG. **25**.—ARTICULATION EFFICIENCY OF TRANSMITTER NO. 22 COMPARED WITH OTHER TRANSMITTERS.

junction attenuation for the two transmitters. The observers listened on Bell receivers and the volume from the two transmitters was maintained equal at the listening end. It will be seen that for the same effective articulation the electromagnetic transmitter could be used with a junction of about 7 db. greater attenuation than that employed with the Transmitter No. 22. The difference might have been greater if room noise had been present at the transmitting end, since intermodulation between the room noise and the speech would have occurred with the Transmitter No. 22. Curve III. of Fig. **25** has been added for reference. It shows the articulation obtained over various line attenuations when the complete transmission system used has a uniform frequency characteristic over the useful frequency range and does not introduce amplitude or non-linear distortion.

The tests yielding the results illustrated in Fig. **25** were made by talking to the Transmitter No. 22 at a distance of ¼″ from the mouthpiece. A few tests were made speaking close in to the transmitter and also at ½″ from the transmitter. They indicated that the articulation efficiency of the Transmitter No. 22 compared less and less favourably with that of the electromagnetic transmitter as the talking distance from the carbon transmitter was decreased—the tests being conducted at equal listening volumes. It should be noted that a direct comparison of curves I. and II. of the diagram means that we are ignoring any effect arising from differences in the " transient response " of the two transmitters. The magnitude of this effect is probably small but no tests have been made to check this point. Also, the whole of the 7 db. " impairement " resulting from the use of the Transmitter No. 22 instead of the electromagnetic instrument cannot be said to be directly due to amplitude and non-linear distortion introduced by the carbon transmitter. Some of the loss may be due to the internal noise generated by the Transmitter 22. A background of " carbon hiss " undoubtedly exists with this instrument. There is evidence to indicate that this unwanted noise increases with the total effective sound pressure applied to the inset (see curve II. of Fig. 19). It may therefore " mask " weak, but important, sounds. It may also combine with the wanted currents in the transmitter, by intermodulation, to produce further unwanted outputs. In general we may say that the 7 db. impairement results from the combined effect of all distortions arising from the particular method of use of carbon granules, polarized by direct current, adopted in the Inset No. 10. It is obvious that the elimination of these latter distortions would have a real effect on the efficiency of a telephone link—particularly when the line length in use results in a high overall attenuation. It would have a beneficial effect on the naturalness of reproduction whatever the length of the line in use.

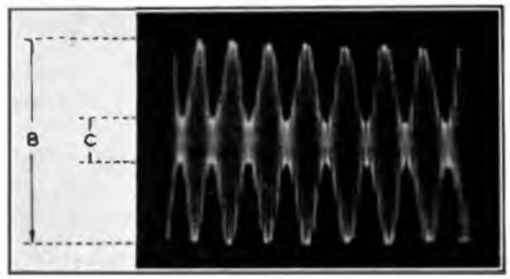
V. *An alternative method of measuring the amplitude and non-linear distortion introduced by an Inset No.* 10.

Since the carbon inset transmitter operates by virtue of changes of resistance occurring between the electrodes of the inset, it is logical to suppose that the performance of the instrument may be completely determined by observation of these changes of resistance. The tests described in this section were undertaken in order to provide a means of measuring the instantaneous resistance of the inset. A cathode ray oscillograph was used for the purpose. The inset was fed with a constant value of alternating polarizing current at a comparatively high frequency (11,000 c.p.s.). A " time base " unit was used in conjunction with the oscillograph to give a " sine wave " picture when a sinusoidal voltage was applied to the plates of the cathode ray tube. The oscillograph was arranged to show the open circuit E.M.F. developed by the transmitter under test. The frequency of the time base voltage was adjusted so that the 11,000 c.p.s. appeared as a luminous band on the screen of the tube. When a sound pressure, at a low or medium audio frequency, was developed on the diaphragm of the inset the polarizing current was modulated at the audio frequency and a picture of the envelope of the modulated wave was obtained on the screen. A camera was used to photograph the oscillograms as required.

The use of the alternating polarizing current enabled the middle of the tube screen to be used for each picture and eliminated any uncertainty as to the position of the " zero " line in each case. Fig. 26 shows a typical oscillogram. The resistance of the inset before the sound was switched on is shown by the dimension A. The mean of dimensions B and C gives the average resistance with the sound on, and the ratio 100 (B – C) : (B + C) gives the percentage modulation of this mean resistance.

A series of tests was carried out with different frequencies of sound input to the inset and different values of high frequency feed current. The oscillograms obtained were scaled by projecting them on to a screen with the aid of an enlarging camera. The results obtained are shown in Figs. 27 and 28.

Before Sound switched on.



After Sound switched on.

FIG. 26.—TYPICAL OSCILLOGRAMS, SHOWING RESISTANCE OF INSET.

The first of these figures shows the relative change of average resistance of the inset which occurred when sound pressures of various amplitudes and frequencies were applied to the instrument. The second figure shows the extent to which these mean

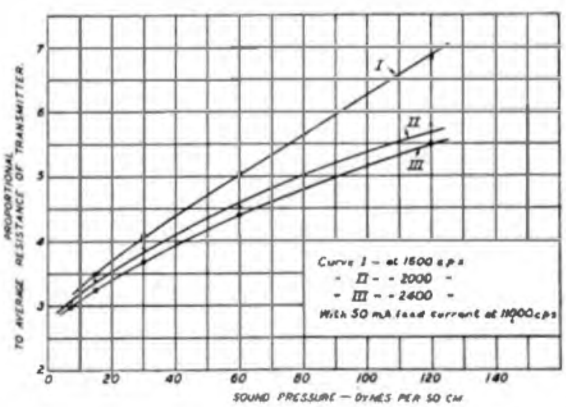


FIG. 27.—RELATIVE CHANGE OF AVERAGE RESISTANCE OF INSET No. 10 FOR VARIOUS SOUND INPUTS.

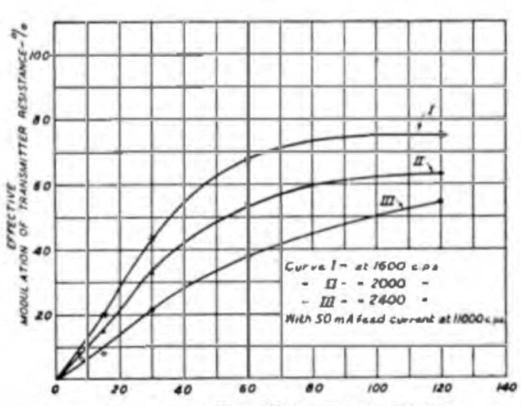


FIG. 28.—MODULATION OF TRANSMITTER RESISTANCE FOR VARIOUS SOUND INPUTS.

resistances were modulated at the frequency of the sound. These curves illustrate the performance of the transmitter with a high frequency feed current of 50 milliamps. Very similar families of curves were obtained for 20 milliamps and 150 milliamps of polarizing current.

This method of use of a cathode ray oscillograph did not give a sensitive indication of the wave form of the audio frequency output from the transmitter under test. It was found, in general, that an oscillograph was comparatively useless for this purpose. Very little visible distortion of wave shape could be detected even when the oscillograph was used to picture the direct audio frequency output from an inset (fed with direct current) which was producing a considerable sub-harmonic.

A somewhat illuminating picture of speech currents was obtained with the cathode ray tube. It is reproduced in Fig. 29. The upper oscillogram represents the amplified output from a condenser microphone of good quality, and the lower oscillogram represents the output of a Transmitter No. 22 — see below.

years. Improvements have been incorporated only after they have withstood the test of use under practical conditions. It is therefore reasonable to suppose that it represents a very close approximation to the best instrument that can be produced by development along the lines followed. Such a method of design, however, does limit the trend of development to a more or less single line of approach.

The author is of the opinion that modern methods of measurement now make it possible for the physical characteristics of the subscriber's transmitter to be defined fairly accurately and for the direction of future development to be determined from a knowledge of these characteristics. Much useful data have been recently published (notably by F. S. Goucher[10]) relating to the physics of the operation of carbon granules used as a microphone contact. Further work along these lines will no doubt soon result in a more complete understanding of the effects involved.

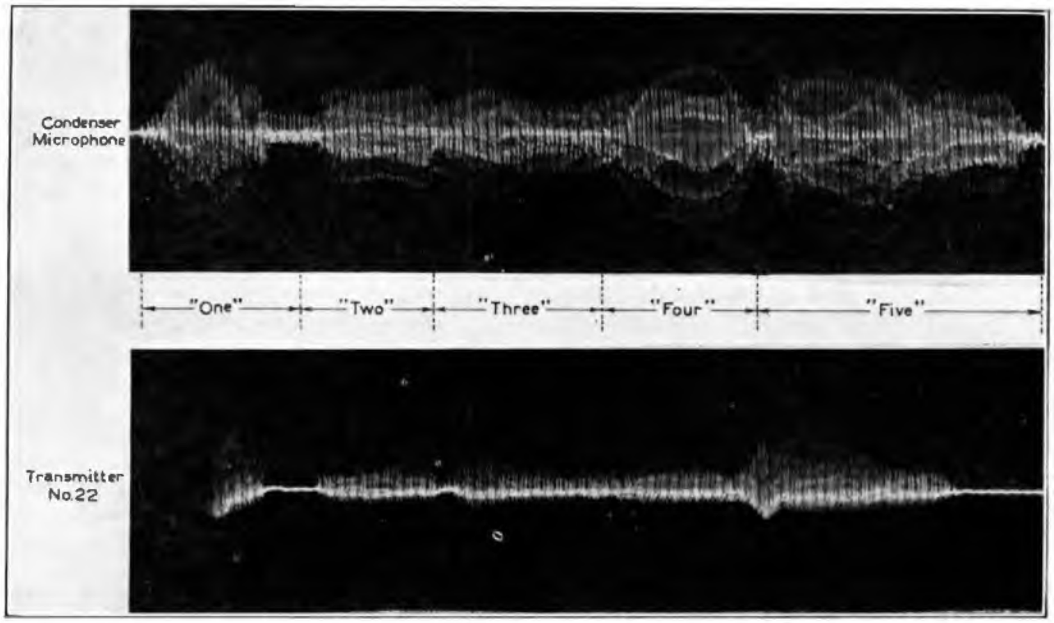


Fig. 29.—Oscillograms with Condenser Microphone and Transmitter No. 22.

transmitter when spoken to from a short distance. (The phrase spoken was—" one, two, three, four, five.") The lower oscillogram shows the reproduction of the same phrase by a Transmitter No. 22. A very considerable rectification effect is apparent. The increase of average resistance of the inset upon application of an alternating sound pressure may be regarded as another manifestation of this same effect.

Conclusion.

It is thought that the above summary of the results of various tests made with the standard type of subscriber's inset transmitter will serve to indicate the directions in which the instrument may still be improved. The existing type of transmitter undoubtedly gives good service from many points of view. Nevertheless, it may be possible to improve it and still retain its essential properties of cheapness, high sensitivity, stability and convenient size. The type at present in general use has been evolved by slow development extending over a long period of

It has recently come to the author's knowledge that Dr. G. W. Sutton, of Messrs. Siemens Bros., has carried out further research on the performance of the Inset No. 10 Transmitter and that his discoveries cover some of the effects published above—particularly in reference to the performance of the Inset when subjected to two simultaneous inputs. It is thought that some of these effects which are revealed for the first time in this article, have been simultaneously observed in the laboratories of Messrs. Siemens Bros. and those of the Post Office Research Department.

In conclusion the author wishes to tender his thanks to the Engineer-in-Chief of the Post Office for permission to publish these notes and to his colleagues in the Research Department at Dollis Hill for valuable advice and assistance in connexion with the research work carried out.

[10] " Bell System Technical Journal " : Vol. XIII., 1934, p. 163. " Bell Lab. Record " : 1930, p. 566 and 1935, p. 332.

The Effects of Anti-Spray Oil Layers on the Performance of Secondary Cells

M. E. TUFNAIL, A.M.I.E.E., and
D. W. GLOVER, M.Sc., A.I.C.

Synopsis.

INVESTIGATIONS on lead-acid secondary cells indicate that anti-spray layers of insulating oil can adversely affect the performance and life of the negative plates. This disadvantage is very pronounced if an insufficiently refined oil is used and overcharging consistently occurs. Reasons are furnished and a specification for a less harmful oil is given. A process for restoring the capacity of inactivated batteries is also proposed.

Introduction.

The use of a floating layer of insulating oil on the electrolyte of exchange batteries for suppressing acid spray was standardized in 1921.[1] Experience has indicated, however, that cells so treated are likely to give reduced efficiency, capacity and life, but the statistical evidence available has been somewhat confused by the fact that in 1927 the Departmental Specification was amended to ensure that no carbon expanding material be given off into the electrolyte. This was interpreted by some of the contractors as completely prohibiting the use of carbon expander. It has, however, been ascertained that this matter has no direct bearing on the question of oil inactivation.

Examination of oil inactivated plates.

Planté positive and box negative plates from oil floated exchange cells of various ages have been examined. No free oil has been observed by microscopic examination, but petroleum ether extraction of the ground up materials has yielded quantities varying between 0.6% and 4.7% of oil from the negative pastes. Detailed results show that in any particular negative plate the oil content decreases smoothly from top to bottom compartment.

The outstanding feature of oil contaminated cells is the charging voltage characteristic at constant current; this rises to a value about 0.3 volt higher than normal when the cell commences to gas; the effect is located at the negative plate and is due to the difficulty with which the hydrogen bubbles are released.

Means of access of oil to negative plates.

Visual observation indicates that the oil is emulsified during the gassing period by impingement of the bubbles on the acid oil interface, and carried down the plates by convection. Its reactions at the plate surfaces have been examined by lightly forming two lead plates in battery acid and subsequently reducing one of them to sponge lead. Such a plate was incorporated in a cell surfaced with a layer of insulating oil. When drawn up through the latter a perfect and substantial film of oil was immediately formed upon it; this film was not displaced on re-immersion in the acid. No such action occurred with the accompanying positive plate, but in the case of a similar cell which was gassed slowly, oil crept down the negative plate to a marked extent.

Oil films, so formed, have been found to remain stable for variable periods up to one hour. If, however, the cell is discharged electrolytic sulphation commences, usually at the edges and ultimately strips almost the whole of the oil film away. The surface is then no longer susceptible to preferential oil wetting.

It is thought that the limited stability of the film on open circuit is due to local action, as it cannot be completely removed by vigorous gassing, owing to its marked tendency to respread under such conditions.

Adherence of liquids to solid surfaces.

The wetting of a solid by a liquid may be regarded as due to the complete or partial neutralization of the otherwise unbalanced cohesional forces which exist at the surface of each, and the extent to which these satisfy one another gives a measure of the wetting power of the liquid for the solid. Although the precise mechanism of the molecular interaction is somewhat obscure the degree of attraction is probably influenced by molecular orientation at the surfaces of the bodies concerned.

Many asymmetric liquid molecules are electrostatically polarized to a high degree and the direction in which some of these orient themselves at a surface has been shown by experiment. Such liquids in general tend to interlock themselves firmly with certain solid surfaces, particulary those of metals, and are said to be absorbed.

Commercially refined mineral oils such as insulating oil contain in addition to inert paraffin hydrocarbon molecules small quantities of highly polar compounds. The most important of these are :—

1. Unsaturated chain compounds.
2. Saturated or unsaturated fatty acids.
3. Naphthenes.

It is supposed that these bodies are able to key relatively large quantities of oil to negative plates when in the form of sponge lead. In the case of acidic compounds the union may be of a definitely chemical nature.

In accordance with these considerations it has been found that when a formed negative plate is tested with partially oxidized mineral oil, containing a large proportion of polar compounds, the oil is absorbed even more readily than insulating oil by the sponge

[1] Lucas. *P.O.E.E.J.*, 1921. Vol. 14, p. 189.

lead. Conversely, when Paraffin B.P. free from such active bodies is substituted only a few droplets remain attached to the lead plate. A similar result has been obtained with a laboratory refined paraffin mixture.

Life tests on cells with oil layers.

The conclusions thus arrived at were rapidly confirmed by accelerated trials of cells into which oils of varying degrees of purity were mechanically stirred. Hence a life test under normal working conditions was carried out in the following manner :—

Cells Secondary Stationary No. 6 (nominal capacity 72 ampere hours) with Planté positives and box negatives were used. Since the major effect is known to occur at the negative plates, six duplicated sections of these were obtained to cover variations due to different manufacturers. The positive sections were identical throughout. Two similar batteries of six cells were thus formed, one of which was provided with a ⅛ inch layer of Oil Insulating No. 3. The cells were worked to their full capacity at about 9 and 8 hour rates of charge and discharge respectively.

Observations on 566 cycles are summarized in the following Tables and compare the behaviour of similar cells worked with and without oil. Average output figures over 25 cycles at the beginning and end of the tests have been used.

TABLE I.

Cells.	Capacity of cell with Oil Layer, expressed as a percentage of the capacity of its oil-free control cell.	
	Cycles 2-26.	Cycles 525-566.
Pair 1	102	86.5
2	97.5	61 *
3	90	77
4	98.5	75.6
5	96.5	68.1
6	89	72.8

* Figures given for cycles 428-446.

TABLE II.

Cells.	Capacity after 566 test cycles expressed as a percentage of initial value.	
	Oil Layer Cells.	Control Cells.
Pair 1	85	100
2	64.6*	91
3	88.1	102
4	60.4	77.6
5	65	91.5
6	72.5	88

* After 446 test cycles.

These results clearly demonstrate the adverse effect of the oil layer, and indicate its magnitude. In addition the ampere hour efficiency is reduced by about 7% and the watt hour efficiency by a greater amount.

The detailed figures show that the stage at which the effects of the contamination first manifest themselves varies with different cells and depends upon the amount of excess negative plate capacity normally provided in manufacture.

It is to be stressed that the tests have been carried out under ideal conditions, so that in exchange working the reduction of useful life is probably greater than the results would imply, on account of incomplete discharging and of overcharging which is often resorted to in order to recover capacity. In this latter connexion it has been noticed that an equalizing charge on the test battery is followed invariably by a period of temporary capacity depression.

A further battery of identical cells has also been tested with different oils in order to confirm the conclusion that a pure paraffin hydrocarbon oil will reduce the rate of inactivation of the negative paste. The results are summarized below and indicate that this is definitely the case :—

TABLE III.

Cell.	Oil.	Initial Capacity (ampere hours).	Capacity at 500 cycles (ampere hours).
1	Laboratory refined	72	63
2	Oil Insulating No. 3	72	37
3	Commercial semi-refined	72	58
4	Commercial refined	72	62

The specification of the laboratory refined oil, which is now commercially available at a competitive price and is at present under trial on a 1300 ampere hour exchange battery is as follows :—

Specific Gravity 20°/20°C....	not greater than 0.865.
Viscosity (Redwood) 70°F....	not greater than 150 seconds.
Flash Point (Pensky Martin)...	greater than 240°F. Close Test.
Acidity	Nil.
Residue on ignition ...	Nil.
Colour	Colourless.
Freedom from Polar compounds...	To be such that when 10 ccs. oil and 10 ccs. 95% A.R. sulphuric acid are placed together in a Nessler cylinder, vigorously shaken for one minute and then allowed to stand for twelve hours, no brown colouration or blackening of the oil shall be produced.

This differs from the Oil Insulating No. 3 specification essentially in the inclusion of the sulphuric acid test.

Treatment of Batteries to recover loss of capacity due to oil Contamination.

It has already been mentioned that the conversion of negative active material (sponge lead) to lead sulphate releases adsorbed oil, so that during a normal discharge the plates will tend to become decontaminated.

In practice however this action is slow, and if the discharge is terminated at 1.83 volts does not proceed sufficiently far to restore the plate to a fully active condition. A progressively increasing balance of oil thus remains in the plate and produces capacity loss. By extending the range of the discharge, however, considerable quantities may be freed, but unfortunately much of it remains in the pores of the plate and is reabsorbed on the next charge. If, however, the cell be taken to zero volts and then charged in the reverse direction this oil is completely expelled when gassing commences, and on restoration to normal polarity a permanent improvement in performance is observed. The reverse charge is necessarily carried out at a low rate to minimise plate strain, and must be continuous or heavy local action results.

With these precautions the treatment has been successfully applied to a number of cases quoted in Table IV.

it may have hardened owing to inefficient expanding agents.

In the tests made it has been found that buckling of the end negative plates occurs, but this could probably be avoided by fixing a dummy plate in the hydrometer space during reversal. Arrangements are now in hand for a trial of the process on an exchange battery as an alternative to replatal.

Conclusions.

It has been shown that the working of secondary cells with insulating oil anti-spray layers results in lower efficiency and reduction in life. The increase in cost of operation and plate renewals must therefore be set against the savings, for example, in battery accommodation, in order to obtain a true estimate of the economic advantage of the anti-spray layer. A highly refined paraffin hydrocarbon oil conforming to the specification given will minimise the disadvantages, and its use may therefore be justified under circumstances where ordinary insulating oil would prove uneconomical.

TABLE IV.

Cell Type and nominal A.H. Capacity.	History before reversal treatment.	Capacity before reversal treatment.	Capacity after reversal treatment.	History after reversal treatment.
Box Negative 72 A.H.	Worked normally for 450 cycles with oil layer.	40 A.H.	90 A.H.	Worked 160 cycles, capacity maintained.
Pasted Negative 250 A.H.	Worked normally 3 years with oil layer.	130 A.H.	250 A.H.	Worked 50 cycles, capacity maintained
Box Negative 72 A.H.	Worked normally for 560 cycles with oil layer.	40 A.H.	80 A.H.	do. do.
Box Negative 72 A.H.	do. do.	45 A.H.	85 A.H.	do. do.
Box Negative 72 A.H.	New cell, reversed after 5 cycles.	75 A.H.	75 A.H.	Worked 450 cycles capacity 80 A.H.

The last example given shows the effect of the treatment on an oil free control cell.

It should perhaps be pointed out that the whole of the capacity gain is not necessarily attributable to oil freeing as the treatment also has the effect of rendering the negative paste more porous in cases where

Although there is no direct adverse effect of oil layers on positive plates, it is likely that they will have a reduced life in cells with oil contaminated negatives owing to high local current densities, produced by varying degrees of inactivation over the negative surface.

A Four-Channel Duplex Voice-Frequency Telegraph System

C. W. A. MITCHELL

DURING 1933 a large part of the Inland Telegraph cable network was replaced by multi-channel voice-frequency telegraph systems working over the telephone cable network. Since then installation work has progressed steadily towards the complete conversion of the telegraph system, including many private wires, to this method of working.

Among the many important advantages of the new system is the uniformity of performance of the channels and the ease with which they may be linked together or interchanged, no re-balancing operations or adjustment of any kind being necessary and length being no longer an important consideration. These factors have imparted an unprecedented flexibility to the main line network.

To extend these advantages to minor routes which do not justify the provision of a 12 or 18 channel main line system, a smaller type of system has been introduced, which operates on a similar principle and is suitable for use between a centre already equipped with voice-frequency systems and a small sub-centre.

General Description.

The system provides for a maximum of four duplex channels working over a 2-wire telephone line. The line may be repeatered or non-repeatered, the allowable attenuation being 18 db. over a range of 300 to 2220 c.p.s. The components, such as relays, filters, detector-amplifiers, etc., are of the types standardized in the main line systems and, as in that case, double-current working is employed on the extensions of the channels to the instrument room.

The carrier frequencies used are equivalent to the odd channels of the 18 channel equipment and are necessarily different in opposite directions of transmission owing to the adoption of 2-wire working. Table I shows the allocation of carrier frequencies to the channels.

18, having their outputs connected in parallel, an impedance correcting network has been included in the filter circuit at both stations to compensate for the missing filters.

In order that the range of the system may be as great as possible and as terminal repeaters are not used the output is adjusted to 100 microwatts per channel.

The in-station or main office equipment is arranged to operate from the power supplies of the main voice-frequency telegraph installation and to obtain its carrier supplies from the multi-frequency generators, whereas the out-station equipment is designed to operate entirely from A.C. mains, carrier supplies being provided by valve oscillators.

The out-station equipment is a self contained unit mounted on one rack and is therefore transportable and suitable for use for special events. The only connexions external to the bay are the line, the extensions to the teleprinters and the A.C. mains. The equipment provides ± 80 volt supplies to the transmitting contacts of the telegraph instruments, thus avoiding the necessity of providing a separate power supply for this purpose.

In-Station Equipment.

The equipment is arranged so that four systems of four channels can be mounted on three bays and occupy the space of an 18-channel system. The components are suitably disposed to line-up with existing main line bays, the meter panel and test jack field being at the correct levels. The filament, anode and telegraph battery supplies are obtained *via* the fuses and protective lamps on the main V.F. battery supply equipment. The " Send " and " Receive " sides of the channels are extended *via* the jacks on the Special Apparatus Bay to the Control Board in the instrument room and so obtain the testing and control facilities standardized for all voice frequency channels.

TABLE I.

Direction of Transmission.	Channel. 1	2	3	4
In-Station to Out-Station ...	420 c.p.s.	660 c.p.s.	900 c.p.s.	1140 c.p.s.
Out-Station to In-Station ...	1380 ,,	1620 ,,	1860 ,,	2100 ,,

The spacing of 240 c.p.s., as against the 120 c.p.s. spacing of the main line systems, allows of the use of a receiving filter having fewer sections, a flatter characteristic, and a smaller attenuation at the mid-band or carrier frequency. Normal main line equipment sending filters are used for the purpose and, as they were designed originally as units in a group of

Carrier supplies are obtained from the mutli-frequency generators, the supply network resistance spools being mounted on the channel bays. The four systems of a group, each using the frequencies 420, 660, 900 and 1140 c.p.s., are supplied in parallel from the feeds proper to channels 1, 3, 5 and 7 of an 18-channel system. The commoning points are on the first channel bay of the group and, to guard against possible earth faults short-circuiting the whole output of the generator at those frequencies, a 7 ohm spool is fitted in each lead. In this way the supplies to other systems fed from the same generator are protected from a drop in excess of 5 db. in the event of a fault.

Adjustment of the output of each channel to the specified value of 100 microwatts is carried out by means of tapped shunt resistances across the input of the send filters.

The arrangement of the system at the in-station is similar to that of the main line equipment except that a common line transformer is used for the sending and receiving sides of the system. Provision is also made for the introduction of a balanced attenuator into the line circuit for use on lines of low attenuation.

Out-Station Equipment.

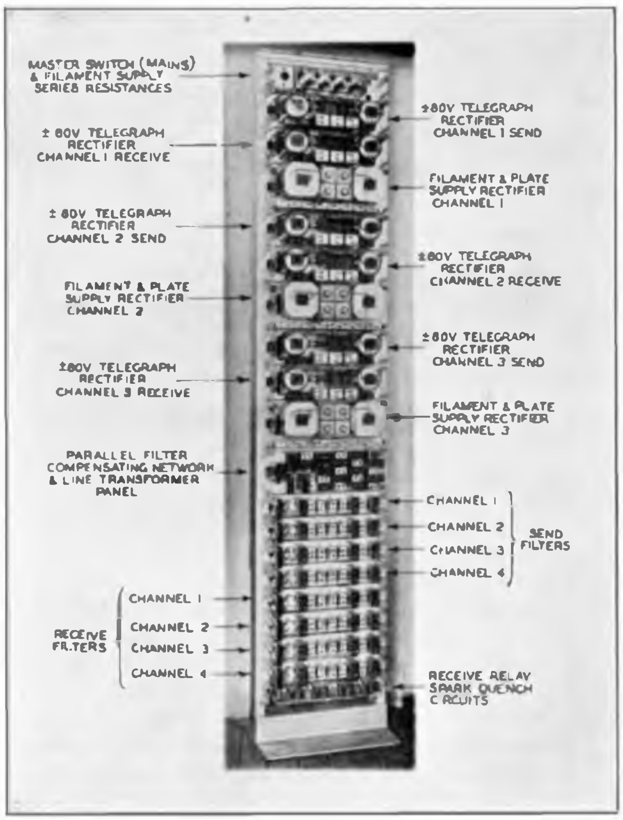
The out-station equipment is mounted on an 8′ 6″ bay which is provided with a wide flanged base to enable it to stand securely without structural supports. The bay is illustrated in Fig. 1 and is a complete unit including all the necessary rectifying equipment for A.C. mains working.

With the exception of the power and carrier supplies the circuit is similar to the in-station equipment and from a transmission viewpoint the two stations are identical. The circuit arrangement is shown in Fig. 2.

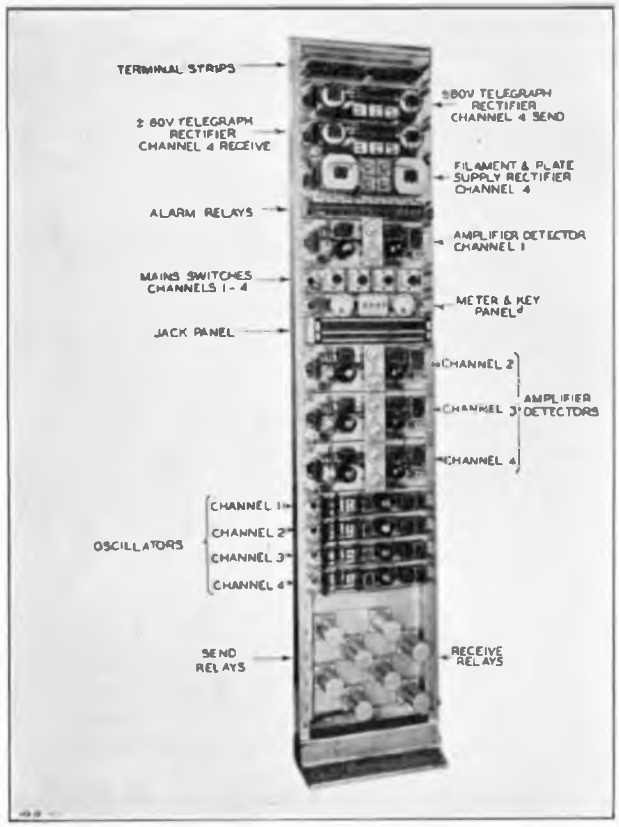
Each channel is provided with three separate rectifier units of which one supplies the filament and plate circuits of the detector panel and oscillator, the second the ± 80 volt telegraph supply to the contacts of the receiving relay and the third the ± 80 volt telegraph supply to the transmitting contacts of the telegraph instrument. The rectifiers are of the copper-oxide type and are mounted on separate panels, together with transformers and smoothing apparatus, the whole being protected by perforated covers. The mains supply to each channel is separately fused and provided with an individual cut-out. A master cut-out is also fitted.

The ± 80 volt telegraph supply rectifiers, being subject to fluctuating loads and possibly to accidental short-circuiting, are provided with shunt output resistances to avoid excessive voltage rise on light load and series output resistances to guard against excessive overloads. The temperature rise, even on prolonged short circuit, is kept within safe limits by these means.

The mains transformers have two equal primary windings which are connected in series for 200-250 volt mains and in parallel for 100-125 volt mains. The secondary windings are tapped to allow fine adjustment of the output voltage.



Front.



Rear.

FIG. 1.—BAY CARRYING OUT STATION EQUIPMENT.

The filaments of the three 0.25 ampere valves in the oscillator and detector panels of each channel are supplied from the H.T. rectifier in series with a 520Ω resistance. This arrangement requires a large H.T. rectifier unit to supply the necessary current, but the large steady load of the filament circuit ensures a stable anode voltage.

A test jack is provided, across the filament supply leads, on each channel for use in conjunction with a portable double scale voltmeter by means of which a periodic check of the supply voltage may be made. This check verifies that both filament and plate voltages are in order since one cannot vary without the other. As the potential drop across the series resistance in the filament circuit is used for grid bias purposes, it is important that the filament supply voltage be maintained within the limits 19.5 ± 0.75 volts.

The detector panels are the same as for the main line equipment and provide automatic compensation for a variation in input signal level of $\pm 7\frac{1}{2}$ db.

The oscillators for the carrier supplies are single valve units having high series resistance in their output circuits to prevent the modulation of the carrier by the relay contacts affecting the anode load-impedance sufficiently to cause variations in frequency. The tuning condenser of the oscillator is provided with a tapped section for adjustment purposes and a small pre-set adjustable section is provided for fine adjustment, the ultimate frequency standard being a 1020 c.p.s. tuning fork oscillator located at London from which all multi-frequency generators are periodically checked. A machine running at correct speed by the standard frequency may then be used as a sub-standard at any of its 18 output frequencies. By this means an in-station is able to check the frequencies received from a 4-channel out-station and request any necessary correction to be made at the out-station.

The method commonly adopted for frequency comparison is that of mixing the outputs of the standard frequency generator and the source to be checked and counting the " beats " as heard in a receiver or observed on the plate current meter of a detector panel. Commoning jacks and a suitable amplifier-detector are provided on the test bays installed at main line voice-frequency centres and are used for this purpose. The difference in frequency between the two compared sources is equal to the number of " beats " observed per second.

A portable A.C. voltmeter, calibrated in decibels, is provided for the purpose of checking the output of each channel to line. When the system is installed the output is adjusted to the correct value of 100 microwatts (10 db. below 1 milliwatt) by means of the sending filter input shunt resistances, the oscillators

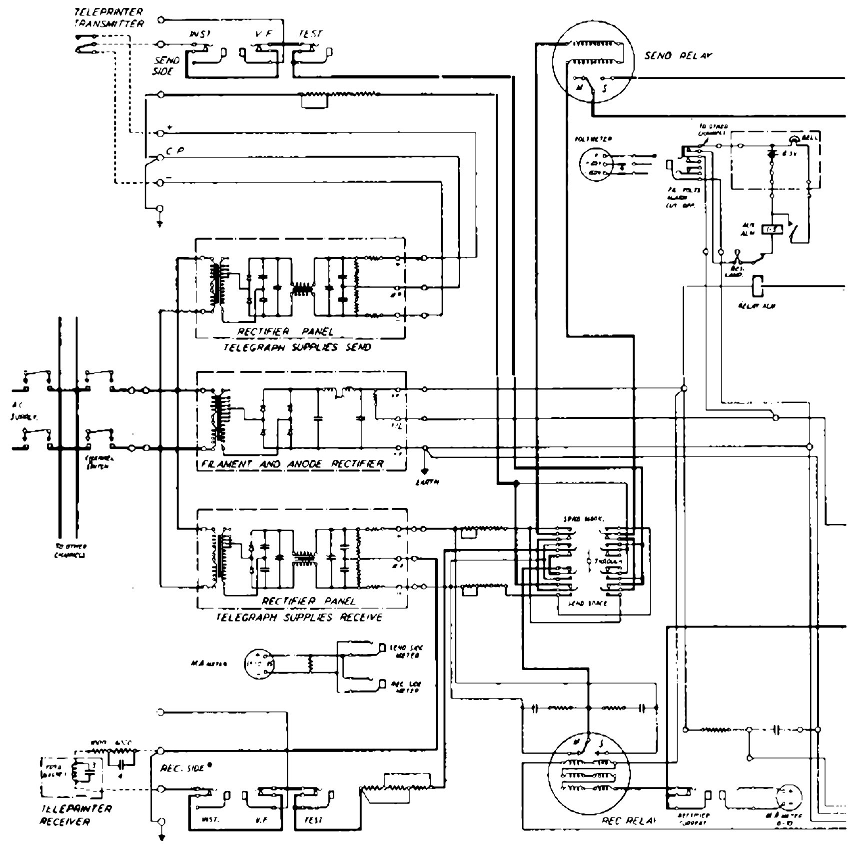
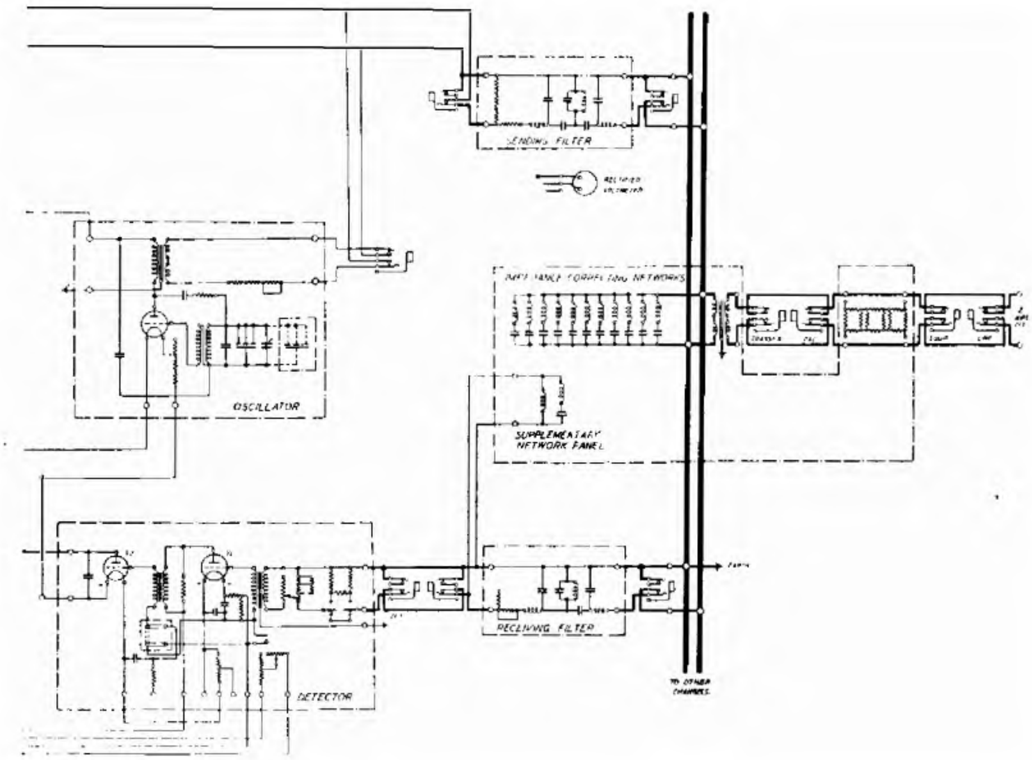


FIG. 2.—CIRCUIT OF

having been previously adjusted to their correct frequencies. Measurements are taken at the line transformer jack. The adjustment should not normally require alteration, any reduction in output which may occur in service being most likely to be due to deterioration of the oscillator valve.



OUT STATION EQUIPMENT.

A relay test table similar in design to those provided at main line stations is supplied for maintenance and adjustment of the telegraph relays.

Performance.

The first system of the type described in this article was installed between London and Oxford in January of this year. Before being put into service the system was subjected to extensive tests over lines of various types and characteristics. The performance of the system is in every way satisfactory and is comparable with that of the main line equipment. The apparatus requires little maintenance, the oscillators and rectifying equipment giving stable results. The fault record since the system was put into service bears out the results of the initial trials and it is probable that this type of equipment will enable voice frequency methods to be extended to a number of the minor routes of the telegraph network.

In conclusion, the author wishes to thank Messrs. Standard Telephones & Cables, Ltd., for the supply of the photographs and diagram which are reproduced in this article.

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Some Notes on Glass and its Manufacture

C. J. CAMERON, A.M.I.E.E.

Introduction.

THE art of glass making is one of the oldest on earth. According to records the Phœnicians first discovered how to make it. Legend ascribes its origin to the lighting of fires on the foreshores, where the sand contained silica, beads of glass being found in the remains of the fires.

According to Egyptologists, the Egyptians made sham jewels of glass at least 3000 or 4000 B.C., so that the art is at least 5000 to 6000 years old. Venice, the great centre of glass making in mediæval and modern times, commenced the industry with the foundation of the city itself in the 7th century A.D. Germany took up the art in the 16th century, and in 1665 a number of Venetians founded the industry in Paris.

In this country the industry commenced in 1557 with London as the first centre, closely followed by Newcastle-upon-Tyne, Stourbridge, Bristol and other districts. In the 17th century coal rapidly superseded wood as the fuel used for the firing of furnaces, in fact the use of the latter was later prohibited by the Government, and the industry moved to the proximity of the coalfields. In 1696 the number of glass houses in England and Wales totalled about 70; 38 making bottles, 2 looking-glass plates, 5 crown glass plates, 6 window glass, and 19 flint, green and ordinary glass. The first large English factory for the production of cast plate glass was established by the British Plate Glass Co., in 1773, at St. Helens, Lancashire. It is interesting to note that the original site is now occupied by Messrs. Pilkingtons, the central aisle of the old casting hall being preserved to this day on account of its historical associations.

The Theory of Glass Making.

All substances have in general a temperature at which they solidify. This temperature is referred to as the freezing point of the substance, the solids being formed by inter-atomic attraction during cooling. Freezing points for water, or for any crystalline substance, can be conveniently shown by plotting time temperature curves. Such a curve is shown in Fig. 1. It is particularly noticeable that for substances A and B the freezing point is clearly defined, whereas for the Felspars (Silicates) the solidifying temperature extends over a much wider range and is not nearly so well defined.

Freezing depends upon the building-up of a crystal structure and is simplified in liquids of low viscosity where the molecules can arrange themselves without much friction, but as silicates in the molten state are among the most viscous of liquids they tend to oppose crystallization upon cooling. The silicates of glass are in fact so viscous in the liquid state that any attempt at crystalline formation is extremely slow and, as their plastic state extends well below the true freezing point, often by several 100°, a super cooled, non-crystalline solid is obtained. Manufacture of glass then, consists in the production of suitable mixtures of silicates, and arranging that the subsequent cooling prevents the formation of crystals.

Raw (Batch) Materials.

Materials for supplying the necessary salts used in the manufacture of glass are perhaps best considered separately under the following headings :—

(1) Silica.
(2) Alkalis.
(3) Bases.
(4) Special character-giving oxides.
(5) Colouring agents.

(1) *Silica*—SiO_2.

Among the acidic oxides (corrosive compounds of oxygen with other elements) silica is the only one which of itself is valuable for producing commercial glasses. In its natural state it is found as quartz, tridymite, oristobalite, etc. The three varieties mentioned differ only in their crystalline form, but as quartz is by far the most common it provides the general source of supply.

Quartz is found as a constituent of Igneous Rocks (Volcanic Lava) and of products formed therefrom by weathering. It is usually referred to as sand

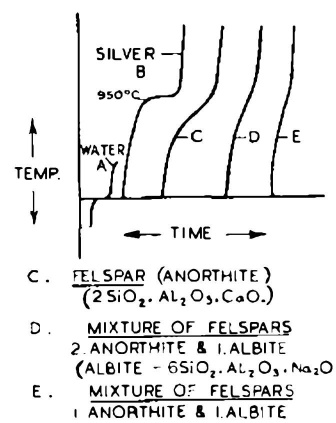

Fig. 1.—Freezing Points.

although that term is a geological one having reference to the size of grains of a mineral and not to its composition.

The chief requirements of sand for glass making are high silica content with low iron oxide content.

TABLE I.

Sand.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Alkalis	Remarks.
British.							
Kings Lynn (Boams Double Washed)	98.82	0.56	0.06	0.16	0.02	—	—
Aylesbury	98.70	0.42	0.20	0.40	0.10	—	—
Leighton Buzzard ...	98.60	0.50	0.14	0.50	0.29	Trace	—
Waen	98.63	0.41	0.03	0.16	—	0.26	Crushed Rock.
Irish.							
Muckish Mt.	99.55	0.17	0.02	0.20	Trace	—	Crushed Rock.
French.							
Fontainbleau	99.50	0.23	0.04	—	—	—	—
German.							
Hohenbrocka	99.70	0.35	0.03	0.08	Trace	—	—

Table I shows a number of sands with places of origin, together with their chemical composition.

Kings Lynn sand of iron oxide content 0.06% is considerably used in England together with large importations of Belgium and Fontainbleau sands.

(2) *Alkalis.*

The most important of these are :—

(*a*) Soda.

(*b*) Potash.

Soda. Common salt (sodium chloride) is found in sea water and as rock salt in enormous quantities. From rock salt beds it is pumped out as brine and crystallized, but unfortunately the use of salt as a batch constituent is rendered impossible by the fact that it is volatile at white heat and only decomposed by silica in the presence of steam; consequently before it can be used in glass manufacture it must be converted to other sodium compounds which readily react with silica. The two sodium compounds used are saltcake (sodium sulphate) and soda ash (sodium carbonate). Besides being manufactured from salt sodium sulphate is also found in its natural state in places such as Spain, Peru and Siberia. When this batch material is used in quantity carbon must also be added otherwise stoney glass results. Sodium carbonate also occurs naturally in Nevada and South California.

Sodium alone with silica would provide a soluble glass, and although it is an important constituent, it is only used together with such substances as lime or lead which impart the necessary stability to the glass. It is a flux, allows ready melting of the glass, and increases its viscosity range, thus providing greater working temperature ranges, a condition ideal for machine produced ware. Sodium glasses are soft and whereas this factor aids easy blowing, the durability of such glasses is low, being readily attacked by the atmosphere, and liquids.

Potash. Potassium compounds are found in the ashes of wood and land plants, and as a batch material, is usually added in the form of a carbonate or nitrate. Sources of mineral supplies, from which these products are obtained, are Strassfurt in Germany, and Mülhausen in Upper Alsace. As compared with sodium, the amount of potash obtained is small and consequently much more expensive. Potassium compounds act as a flux, but give to the glass greater brilliance and a better colour. The glasses are harder, and possess a higher melting point than that of soda glasses. Higher temperatures are required to found, and at ordinary working temperatures potassium glasses are more viscous than soda glasses, and have a lower density.

Potash-lime glasses provide a material for fine glass work, whereas soda-lime glasses are usually utilized for ordinary articles, and window panes.

It is rather interesting to note that potassium glasses are chiefly supplied by wooded countries like Germany, whereas the coast lands of Egypt, and Venice supply chiefly sodium glasses. This remark has an easy association with the foregoing references to the alkaline ingredients used.

(3) *Bases.*

In addition to the alkaline oxides it is essential to use a basic oxide in order to impart stability and resistance to glass. Lime and barium oxide are the two oxides chiefly used.

Lime (calcium oxide) is most commonly used, not only because it provides stable and resistant glass, but also because its derivatives occur widely in nature. The most important of these is its carbonate which is found as (1) transparent crystals of Iceland spar, (2) opaque crystals of calcite, and calcspar, (3) limespar (fairly pure variety of calcium carbonate and used in general for high class quality products), (4) limestone, and chalk (less pure varieties of calcium carbonate). These substances undergo treatments to make them specially adaptable for use in glass manufacture.

Lime acts as a flux, gives great chemical stability and low viscosity when hot, although the viscosity range is short for glasses of high lime content. Lime glasses are particularly suitable for hand working, and for the slower semi-automatic machines when fairly rapid setting is desirable.

Barium oxide is obtained from witherite (barium carbonate) and barytes or heavy spar (barium sulphate). Witherite is chiefly used, impure varieties being improved by chemical treatment.

Barium oxide decreases the solubility of glasses, and gives greater strength and brilliancy to ware. Barium glasses are largely used for optical purposes and are particularly suitable for pressed glassware owing to their short viscosity range. They have a strong corrosive action on the walls of manufacturing pots, and glasses of high content tend to devitrify.

(4) *Special character giving oxides.*

The most important of these are alumina, lead oxide, zinc oxide, magnesium oxide and boric oxide.

Alumina (Aluminium oxide). The mineral products kaolin, felspar, etc., the oxide itself, or the hydroxide are used to provide hardness, brilliancy, and homogeneity. Glasses containing alumina are particularly suitable for bottles and similar products.

Lead oxide is added in the form of litharge, or red lead, to give great brilliancy, the greatest brilliancy being obtained when used with potash as the alkaline oxide.

It increases the density and refractive index. The resulting glass is softer than lime glasses and can easily be cut and polished and it is therefore greatly used for cut glass ware. Colouring agents give better effects in lead glasses, a factor undoubtedly accounting for its use in the manufacture of artificial gems. The addition of lead oxide tends to lower the durability of glasses.

Zinc oxide (known as zinc white) is used for special glasses, being particularly suitable on account of its low coefficient of thermal expansion for glasses subjected to sudden changes of temperature, and the chemical stability of glasses containing zinc oxide makes them particularly suitable for use as laboratory ware.

Magnesium oxide is obtained by calcination of magnesium carbonate provided by nature in the form of magnesite. Its use in the past has been limited, but it is now used, to some extent as a substitute for lead oxide in the manufacture of electric light bulbs.

Boric oxide. This product, obtained by heating boric acid which is found in volcanic districts, or borax, the salt of pyroboric acid, also found naturally as a mineral, is used as a batch constituent in the manufacture of glasses of high thermal endurance, *e.g.,* lamp chimneys, thermometer tubes, cooking ware, etc. When the addition of boric oxide is less than 12% the coefficient of expansion is decreased, but it is increased with contents over 12%.

Boric acid glasses are also suitable for optical purposes giving satisfactory refractive index and dispersion properties.

(5) *Colouring Agents.*

The colouring of glassware depends upon the amount of colouring matter, the general composition of the glass and frequently also upon the temperature, time of melting, and furnace atmosphere.

Nickel oxide, and manganese dioxide tend for example to produce purple colour in potash glasses, but brown in soda glasses.

Table II shows the substances usually used for imparting colour.

Intermediate shades are obtained by combinations of colouring oxides, *e.g.,* carbon and sulphur give amber coloured glass.

TABLE II.

Substance.	Colour Provided.	Remarks.
Oxides of Iron	Bright Green Bluish ,, Dark ,, Brown or Red (according to conditions)	Oxides of iron constitute the greater portion of impurities in batch materials.
Oxides of Copper	Blues and Reds	
Cobalt Oxide	Blue	
Nickel Oxide Manganese Oxide	Purple to Brown	
Chromium Oxide	Fluorescent Green or Yellow	
Selenium	Pink	Red when used in conjunction with cadmium sulphide.
Gold (Finely divided collodial solution)	Ruby	Accounts for high cost of Ruby Glass.
Silver Salts	Yellow	
Carbon	Yellow Brown	
Sulphur	Yellow	
Tin Oxide Zirconia Fluorspar Cryolite Bone Ash Bone Ash (Calcium Phosphate) Excess Silica	Opals (Glasses containing white crystals)	Tin oxide and Zirconia are expensive and not used commercially on that account. Excess silica gives a weak glass and is little used. Fluorspar, cryolite and calcium phosphate are greatly used, particularly cryolite.
Titanium Oxide.	Yellow to Brown.	

Owing to the fact that iron compounds are found in nearly all batch materials and that very little serves to add a distinct colour to the glass, the decolourizing of glass becomes an essential feature of the industry for all but very inferior ware.

Decolourization is affected by either reduction of the colour by oxidation, or decolourization by addition of complementary colours.

MANUFACTURE.

Mixing. From what has so far been written it will be appreciated that the variety of glasses it is possible to produce from the numerous available constituents covers a fairly wide field.

The composition chosen depends upon the cost and the properties required.

From a manufacturing point of view the following general properties are considered :—

(1) Ease of melting.
(2) Rate of setting.
(3) Stability and durability.

The service to be given by the glass determines the special properties to be aimed at during manufacture. Table III gives a general idea of the various compositions used to meet specific requirements.

TABLE III.

Substance.	English Crystal.	Electric Light Bulbs (Lead Glass).	Electric Light Bulbs (Lime Magnesia Glass).	Window Glass. Hand made.	Window Glass. Fourcault.	Window Glass. Plate Glass.
Silica	53-55.5	58-59	71.5-73.5	71-72	70-73	72-73
Iron Oxide ...	.02-.03	.04-.06	.06-.1	.15-.3	.15-.2	.08-.1
Alumina	.2-.4	.2-.4	1-2	1-1.5	1-1.5	.6-1.0
Lime	—	—	5-6	14-15	9.5-11	12.5-15.5
Magnesia	—	—	3.5-4.5	—	—	—
Soda	—	7-8	14-17	11-12.5	15-18	12-13
Potash	11-13	4-5	0-1.5	—	—	—
Lead Oxide ...	31-35	28-30	—	—	—	—

Figures denote % content.

TABLE IIIA.

Substance.	Heat Resisting.			Thermometer Glasses.		Optical Glasses.	
	Monax (British).	Pyrex (American).	Sun Brand Lamp Glasses (Czecho-Slovakia).	Jena. 59‴	Jena. 16″	Hard Crown.	Medium Flint.
Silica	75.3	80.6	76.8	72.9	66.6	71	46
Iron Oxide ...	.1	.1	.06	.15	0.1	0.3	0.02
Alumina	3.0	2.0	.6	6.1	3.8	0.33	0.15
Lime	.5	.2	6.5	0.3	7.2	10	—
Magnesia	—	.2	.2	.2	.2	—	—
Zinc Oxide ...	2.8	—	—	—	6.2	—	—
Soda	6.3	3.8	11.1	9.8	14.8	4.5	0.5
Potash	1.2	.6	4.7	0.1	—	13	8.5
Boric Oxide ...	11.3	11.9	—	10.4	0.9	—	—
Lead Oxide ...	—	—	—	—	—	—	44.5
Arsenious Oxide ...	—	—	—	—	—	0.8	0.3

The raw materials are carefully segregated in suitable receptacles in the storage room, which is kept as dry as possible in order to obviate variation in the moisture content of the materials, a factor having far-reaching effects in the subsequent manufacture—soda ash for instance readily absorbs moisture and carbon dioxide, and reverts under such circumstances to sodium bicarbonate. Regular determinations of moisture contents are made, readjustments being made where necessary.

The sand prior to transference to the mixing room is subjected to sieving, washing and magnetting operations, whereby the silica is greatly purified. " Cullet " (waste glass usually of the same composition as the batch), after crushing and magnetting, forms part of the batch. The proportion of cullet added varies considerably, its addition facilitating melting in addition to giving homogeneity to the resultant glass by breaking up cords and stiræ which tend to develop in most glasses.

Machine mixing has gradually superseded the older method of hand mixing, a machine of the Ransome drum type with internally fitted lifting wings, and baffle plates, being used for the purpose.

Furnaces. After mixing, the batch is dealt with by the furnaces which may be of the Pot or Tank types fired by direct, semi-direct, producer gas, or oil systems, the latter two employing the processes of either regeneration or recuperation. Regeneration and recuperation increase the thermal efficiency of furnaces, the former process preheating both the combustible gas and secondary air, whereas recuperation preheats the secondary air only.

Pot furnaces are those in which the glass is melted in pots or crucibles placed in the combustion chamber, whilst tank furnaces are those in which the floor and lower walls of the combustion chamber actually serve to contain the molten glass without the intervention of a pot. Generally, pot furnaces are used in the production of (1) Plate Glass, (2) Glasses worked by hand and (3) Quality glasses—the glass being protected from injurious furnace gases by the pot.

Where machine methods are used in fashioning articles and where quantity and steady output, with constant level of metal is required, tank furnaces are employed.

Figs. **2** and **3** show the respective types of furnaces.

Silica bricks (Dinas bricks, Ganister bricks and clay-silica bricks) in which a minimum of lime slurry, never greater than 2% of the brick, has been used as the bond, meet the requirements of glass furnace refractory materials, a silica cement (Silica plus 5% to 6% of clay) being used to bind them in position. Sillimanite, a refractory block, is also often used in

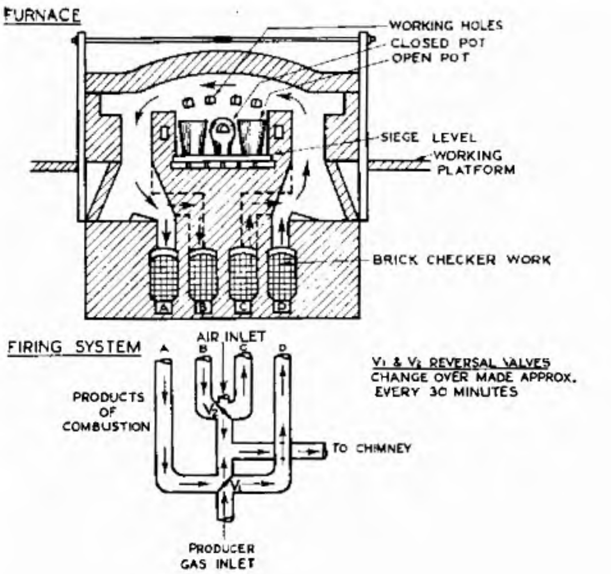

FIG. 2.—POT FURNACE.

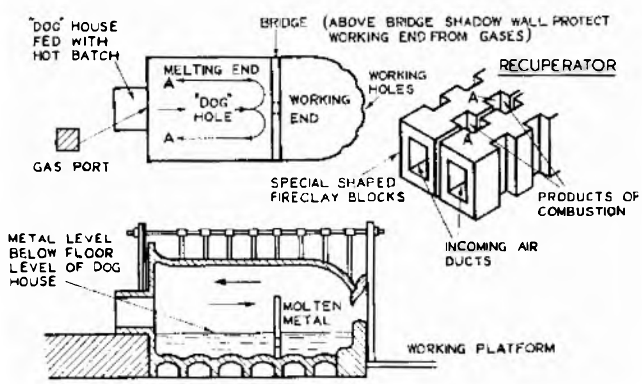

FIG. 3.—TANK FURNACE.

the construction of the siege. Glasshouse furnaces are generally worked in the region of 1450°C, seldom higher except in special cases.

Pots. Good pots are of extreme importance in the manufacture. They are required to resist the corrosive action of the raw materials and molten glass within, and at the same time withstand the very intense heat of the furnace, without giving way under the great weight of glass held. Should a pot of metal give way whilst in the furnace, the loss is considerable and serious, for not only is the metal lost, but considerable damage is suffered by the furnace.

Pot clays are carefully selected, after which they are seasoned, and weathered before use. They are first ground to a very fine flour and then mixed with "chamotte" (ground burnt clay) after which the mixture is sieved into a trough, and mixed with water to form a stiff paste. It is next moved into a large tank where it is allowed to soak for some time and is then well tempered by treading with the feet until the whole mass becomes plastic and tough. The mass is turned and trodden several times in order to consolidate the clay particles. Many efforts, with some success, have been made to do this work mechanically, but the older method of treading is still looked on with favour by the pot makers. The tempered and toughened clay is then allowed to sour and mature for a few weeks before use.

Conditioned rooms are provided in which the work of constructing pots is carried out. The pot-maker begins by forming the pot bottom first, and working the plastic clay paste into rolls about the size of large sausages. The rolls are then applied one after another in circular form upon a round level board the size of the pot bottom. As the rolls are applied, they are pressed together so as to exclude all air spaces between them and are worked on top of each other in circles to form a circular slab of clay about 4″ thick.

Work is then commenced on the walls, the clay sausages being worked round the circumference to the required thickness. Roll after roll is pressed home until the walls reach a height of about 6″ when work is suspended. The height is increased about 6″ every other day, the time intervals being given to allow the last section built to stiffen a little before work on the next section is begun. When the pot walls reach a height of approximately 30″, a preformed clay ring about 18″ in diameter is placed within the pot. These rings float on the molten glass and help to keep the pot scum from the centre of the pot, where gathers are taken during glass manufacture. In the case of closed pots the domes are then formed and while the clay is still soft the working hole is cut out, the whole then being finished smooth by wooden floats. Open pots require little more treatment other than the finishing off of the top edges of the pot walls.

Upon completion of the operations described, the pots are left to dry gradually at moderate heat, which is increased a little at the end of a few months in order to dry them thoroughly. They are then taken to a small subsidiary furnace called a Pot Arch where they are thoroughly annealed before transference to the furnace proper.

Manufacture of the pots takes anything from 3 to 14 days and drying periods anything from 6 to 9 months, depending upon the size of the pots. Holding capacities vary from 6 cwts. to 2 tons, taking 10 hours and 18/20 hours respectively for the melting of the batch contained. The average working life of the pots is round about 9 weeks and their fusion point is in the neighbourhood of 1710°C.

Tools.

The following are some of the tools commonly employed in the manufacture :—

Blow Pipes. Straight iron pipes varying in size according to the work to be done. They are usually 5′ in length, ¾″ to 1″ in diameter, with a ¼″ bore, the nose being slightly larger than the rest of the pipe. The blowing end is usually faced with wood to facilitate rotation of the rod by the blower.

Marver. A large flat stone 3′ × 1′, and about 6″ thick. *In situ* it is mounted tilted away from the blower who uses its edge ("cranny") for drawing the gather of glass to the extreme end of his blowing pipe, afterwards using the smooth surface of the marver to consolidate the gather (the metal gathered by dipping the pipe in the molten glass) at the same time giving it regular shape. After marvering, blowing commences, the gather being distended into a hollow bulb called a parison.

Bottle Maker's Chair. A small trestle shaped seat having two horizontal parallel arms fixed either side of the sitting position, and extending in a direction faced by the operator. Sitting in the chair, the operator rests the partly worked glass to which the punty is fixed across the two arms. The punty is revolved by hand and the glass moulded by a few subsidiary tools to the desired shape.

Punty. A split cylinder of iron fixed to the end of an iron rod. The split cylinder gently grips the article, and is used as an aid to moulding operations as described in the previous paragraphs. In some cases the punty merely consists of an iron rod, a small gather of glass being picked up on its end, and so attached to the article under construction.

Shaping Block. A block of wood having hemispherical and conical recesses in which the parison is shaped.

Tongs and Shears, need little description other than that they are of various shapes to meet the many purposes for which they are employed in fashioning of the ware.

Moulds. Wood or metal moulds are used. In the former, lime, poplar, or alder is used on account of the fact that soft charcoal produced during continuous moulding, does not destroy the smooth surface finish of the glass required. Woods giving hard charcoal are unsuitable for use in the construction of moulds.

Metal moulds are usually made of cast iron, the impression surfaces being coated with a carbon paste.

Sheet Glass.

Hand production methods as will be readily appreciated, limit the size of the sheets obtainable and are rapidly being superseded by machine methods. Briefly, hand production consists of gathering from open pots, blowing and marvering to obtain cylinders of glass having walls of uniform thickness. The end of the cylinder remote from the blow pipe is then opened, and with further heating opens out, leaving a cylinder closed at one end only. The closed end is then cracked off and the cylinder opened lengthwise with red hot irons, or by cutting with diamonds. The cylinders so prepared pass to flattening ovens, where they rest on stone slabs and are pressed flat by wood blocks attached to iron handles.

When the annealing is complete, the flat slabs of glass are dipped into tanks containing dilute hydrochloric acid, being then washed, and reared up to dry, after which they pass to the cutting shops.

Machine drawing of sheet glass is successfully carried out by Fourcault's method, or that of Colburn, both processes being illustrated diagrammatically in Fig. 4. Tank furnaces are used for both methods, which are similar with the exception that a floating trough is used to maintain uniform width of drawn sheet in Fourcault's method, whereas water cooled, revolving channel rollers are used to produce the same effect in the Colburn process.

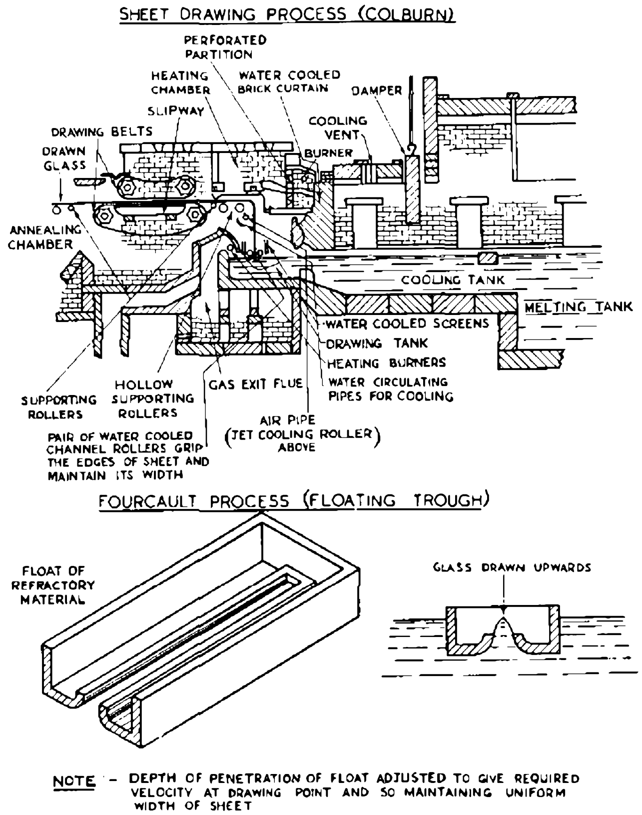

Fig. 4.—Colburn and Fourcault Processes for the Manufacture of Sheet Glass.

Methods of cylinder drawing by machine also exist, but it is not proposed to describe them.

Plate Glass.

Three varieties of cast plate glass exist (1) Rolled plate—rough cast plate untreated after rolling and annealing, (2) Polished plate—rolled plate ground and polished after annealing, (3) Figured rolled plate —pattern impressed on one side of the glass during rolling.

Continuous tank furnaces are used in the production of rolled plate glass, the molten glass being gathered from the furnaces by large iron ladles capable of holding 200 lbs. of metal. The ladles are supported by sling suspensions from an overhead runway, the gatherer exercising the necessary control over the subsequent movements of the ladle. The glass in the ladle is skimmed and then poured immediately in front of the roller of the casting table—a large iron table, over which the roller, also of iron, is driven mechanically. Iron slips along each side of the table provide the regulation necessary for obtaining the desired thickness of glass. Upon completion of rolling, the glass is allowed to set sufficiently to allow of its removal, being transferred in turn to a flat stone slab and annealing furnace, after which it is trimmed and cut, faulty parts being removed.

Glass for Polished Plate is melted in open pots, the capacities of which depend upon the size of the casting table. The average capacity is about 2000 lbs., the metal being capable of covering a 24′ × 14′ table. The pots are arranged usually in rectangular furnaces in which counterpoised gates are fitted to allow of ready removal of the crucibles. When the melting and fining of the batch materials is completed, the furnace is allowed to cool off to the casting temperature, usually about 1000°C, and the pots of metal are removed, the metal is skimmed, and then poured in front of the casting table roller, the pot being carried in a direction away from the roller during tipping.

After rolling, the glass is transferred to the Lehr (annealing furnace) and after annealing, is ground and polished. The last two operations are identical with the exception that coarse and fine sands or carborundum are used as the abrasive in the former operation, and rouge is used in the latter. The glass is fixed by plaster to a rotating circular cast iron table mounted on wheels for ease of movement between grinding and polishing rooms. In both these rooms the table with its glass is lifted from the floor, and placed over the driving mechanism, being suitably geared thereto. Immediately above the driving appliance and table are the grinding rollers which are circular discs shod with a number of small iron blocks, arranged to sweep the whole surface of the glass, regulation being provided for increasing or decreasing the pressure exerted on the glass by the grinders, as occasion demands. One face of the glass is ground and polished, and the operations repeated for the other surface. Usually, something like 90 and 75 minutes are taken respectively, to grind, and polish one face of the glass. The glass is then washed in dilute hydrochloric acid, finally polished with rouge, after which it is inspected, and any faulty portions of the glass marked, for further attention.

Bevelling and silvering are minor operations sometimes required with polished plate, but it is not proposed to describe them.

Figured plate is produced in a manner similar to that of polished plate, with the exception that the surface of the casting table is engraved with the required design. In such cases the upper surface of the glass is plain. In some instances, the design is engraved on one of the three rollers used in the figuring process, the engraved roller being set so as to give a pattern lying through the central zone, both the upper and lower surfaces of the glass being left plain.

Wire glass is produced from rough plate glass, the wire being introduced by the sandwich or solid method. In the former a thin sheet of glass is rolled out, and the wire laid over its surface, a second thin sheet being then rolled over the top, the two thin sheets uniting to enclose the wire.

The solid process is performed by rolling the glass at once to its true thickness, the wire from a subsidiary roller being rolled into the semi-molten mass.

Rods and Tubing.

Rods and Tubing are produced by taking a gather of glass, which is marvered into the shape of a thick cylinder, being solid for rod, and hollow for tube, a punty is then attached to the parison remote from the gathering iron, and two workmen, one with the blow pipe, and the other with the punty, walk quickly apart in opposite directions, so drawing out the ware. Machine methods also exist for the execution of this work.

Optical Glass.

For optical glass carefully selected batch materials are melted in closed pots, on account of the protection they afford from impurities within the furnace. The pot is first baked within the furnace at the melting temperature for about one hour, in order to give it as dense a condition as possible, so that it may resist the corrosive action of the glass. Cullet is then fed in to provide an internal glaze, and then the batch materials.

Melting occupies about 10 hours, but as the glass is exceedingly " seedy " at the end of that time (the furnace temperature is increased to facilitate fining (removal of " seed " or small bubbles of trapped gas)). After fining, the glass is stirred by means of water cooled iron cylinders totally covered with a high quality fireclay; this is performed as an additional aid to homogeneity of the metal. The stirring is executed in stages, and ceases with cooling of the furnace (after about 24 hours), the stirrer then being removed, and the pot of fluid glass lifted from the furnace, in order to solidify the layer of glass at the bottom and sides. Water is often splashed on the outside of the pot to quicken this process, impurities within the pot which normally settle and cling to the inner walls of the pot being thus trapped.

The pot is then transferred to a pot arch where it is allowed to cool at a carefully regulated rate. When cold, the pot is smashed and the glass broken into many pieces, falls out. Examination of the pieces then follows, satisfactory lumps being selected and annealed in electrically heated furnaces, afterwards being allowed to cool over a period of weeks. Grinding, polishing, and shaping operations are then carried out.

Hollow Ware.

Hollow ware is produced both by hand, and machine methods, and may be of the pressed class or that which is fashioned solely by hand.

Plunger type machines are used for the production of pressed glass ware, quantities of molten glass being poured into cylinders or moulds upon which the plunger descends, forcing the glass into the desired shape, mould joints allowing the escape of air which would otherwise be trapped.

In hand fashioning, the tools are few and simple, the results obtained being solely due to the skill and manipulative art of the workmen. The crude form of the article is produced by blowing out a gathering of hot glass into a pear shaped bulb the size and thickness of which is regulated by the amount of the gather. Further blowing follows, and with the aid of moulds in some cases, the desired form is produced. The tools employed in hand worked glass are mainly for finishing, and shaping; flutes, spiral decorations, jug handles, and wineglass stems being formed by manipulation.

Fig. 5 shows a number of blowers with their assistants at work. In the background are the furnace and one of the working holes, and the various marvers can be seen. In the foreground is a split wooden mould with the "taker in" waiting to transfer the blown article from the finisher to the annealing furnace where he detaches it from the blow pipe.

Fig. 5.—Glass Blowers at work.

For machine produced bottles, and electric light bulbs, the requisite amount of metal is picked up either by compressed air suction devices, or is fed from plunger controlled "deliveries," after which it is subjected to blowing and marvering processes, all operations being executed by the ingenious machines designed for this class of work.

Annealing.

Owing to the peculiar structure of glass and its liability to fly or collapse when exposed to sudden changes of temperature, most glasses undergo a form of annealing at some time during the process of their manufacture—subsidiary annealing furnaces or Lehrs are employed for this work.

These usually consist of a conveyor system travelling along the length of an arched tunnel, hot at the glass house end, and cool at the warehouse end.

The rate of travel of the conveyor which is variable and controlled, is set so as to ensure maximum equalization of the strains throughout the structure of the ware.

Strained glass has the power of rotating the plane of plane-polarized light passing through it, and this phenomenon is made use of in apparatus utilized and provided for the detection of strains in the examination of glasses.

Decorations and after treatments of suitable glasses are many, and varied, as will be appreciated from the numerous existent examples of the craftman's art. One has only to examine a valuable piece of cut glassware to realize the intricate and painstaking work involved. An extensively cut piece of ware may easily take weeks to complete, and the price requires no great amount of justification after one has watched the long and tedious processes through which each piece has had to go, and when it is realized that potential sources of failure exist at each stage of the manufacture.

Acknowledgments.

In conclusion, the writer desires to express to Miss G. B. Hailwood, of Messrs. Hailwood & Ackroyd, Morley, Leeds, appreciation for the able assistance she has afforded in the writing of this article and to Miss Hailwood and colleagues of the Department for scrutiny of the draft, assistance, and helpful criticisms.

Note on the Extension of Campbell's Formula to Lightly-Loaded Music Pairs

H. J. JOSEPHS

It is sometimes useful to have a simple formula for the calculation of the attenuation constant of a music pair, in which the natural distributed inductance of the line cannot be neglected with respect to the lumped loading coil inductance. This note contains an extension of Campbell's[1] formula to cover this case.

All electric circuit theory is embodied in the Duhamel[2] superposition formula,

$$I(t) = \frac{d}{dt}\int_0^t E(t-\psi)A(\psi)\,d\psi \quad \text{.......................(1)}$$

where,

$I(t)$ = current response of a network.

$E(t)$ = applied voltage of arbitrary wave shape impressed on the network at reference time $t = 0$.

$A(t)$ = indicial admittance of the network.

The constants and connexions of the network enter the problem through the impedance function $Z(p)$; and this function is related to the indicial admittance $A(t)$ by the Laplacian[3] integral equation,

$$\frac{1}{Z(p)} = \int_0^\infty p\epsilon^{-pt}A(t)dt \quad \text{...........................(2)}$$

where $1/Z(p)$ is the Heaviside operational equation describing the network, and is the mathematical convert of $A(t)$. The mathematical revert of $A(t)$ is obtained by applying the Mellin-Fourier[4] theorem to equation (2); and we obtain,

$$A(t) = \frac{1}{2\pi j}\int_{C-j\infty}^{C+j\infty} \epsilon^{\lambda t}\cdot\frac{d\lambda}{\lambda Z(\lambda)} \quad \text{.......................(3)}$$

where the integration is in the complex plane λ, and is along a curve from $C - j\infty$ to $C + j\infty$, where C is positive and finite, and the path is such that all singularities of the intergrand are on the left-hand side of the path of integration.

If all the electrical parameters L, G, C and R of the music pair are uniformly distributed, equations (2) and (3) give for the indicial admittance[5] at distance x along the line, the result,

$$A_x(t) = F_a(\psi) + (\beta_1 - \beta_2)\int_x^\psi F_a(\psi_1)d\psi_1 \quad \text{...........(4)}$$

where,

$$F_a(\psi) = \sqrt{\frac{C}{L}}\,\epsilon^{-\beta_1\psi}\,I_0(\beta_2\sqrt{\psi^2 - x^2})$$

$$\psi = vt$$

$$v = \frac{1}{\sqrt{LC}}$$

$$\beta_1 = \left(\frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}\right)$$

$$\beta_2 = \left(\frac{R}{2}\sqrt{\frac{C}{L}} - \frac{G}{2}\sqrt{\frac{L}{C}}\right)$$

$I_0(----)$ = modified Bessel function of the first kind.

If now the electrical parameters are lumped in such a way that the network has the same nominal characteristic impedance and the same critical frequency as the actual loaded line, then equations (2) and (3) give for the indicial admittance of the nth section, the result,

$$A_n(t) = F_b(\psi) + \tfrac{1}{2}(\beta_1 - \beta_2)\int_0^\psi F_b(\psi_0)d\psi_0 \quad \text{..........(5)}$$

where,

$$F_b(\psi) = \sqrt{\frac{C}{L}}\,\epsilon^{-\frac{1}{2}\beta_1\psi}\int_0^\psi \Phi(\psi_0)d\psi_0$$

$$\psi = \frac{t}{\sqrt{LC}}$$

$$\Phi(\psi_0) = J_{2n}(\psi_0)\,I_0(\tfrac{1}{2}\beta_2\sqrt{\psi^2 - \psi_0^2})$$

$J_{2n}(----)$ = Bessel function of the first kind.

In equation (5), R, L, C and G denote the lumped parameters per section of a periodically loaded line, whilst in equation (4), R, L, C and G refer to parameters per unit length. In the above equations the current at the point where the distance x is equivalent to n sections is under consideration.

Formulæ describing the building up of sinusoidal

[1] Campbell, G. A., Phil. Mag., March, 1903.

[2] Duhamel, J. Ec., Polytech., Paris, 14, p. 20, 1833.

[3] Carson, J. R. A.I.E.E., Vol. 38, March, 1919.

[4] Bromwich, T. J., Proc. Lond. Math. Soc. (2), 15, 1916.

[5] Carson, J. R., loc. cit.

currents in lightly loaded lines are obtained by putting,

$$E(t) = E \sin(\omega t + \theta)$$

in equation (1), and using $A(t)$ from equations (4) and (5) respectively. Making these substitutions, we obtain,

$$I(t) = I_S + I_T$$

where,

I_S = steady state component.

I_T = transient distortion.

and,

$$I_S = E \sin(\omega t + \theta) \left\{ A(0) + \int_0^\infty \cos \omega\psi A'(\psi) d\psi \right\}$$

$$- E \cos(\omega t + \theta) \int_0^\infty \sin \omega\psi A'(\psi) d\psi \quad \ldots\ldots(6)$$

$$I_T = E \cos(\omega t + \theta) \int_t^\infty \sin \omega\psi A'(\psi) d\psi - E \sin(\omega t + \theta) \int_t^\infty \cos \omega\psi A'(\psi) d\psi$$

A numerical analysis of these equations leads to the conclusion that :

if in a lightly loaded line the loading coil inductance is less than 35 millihenrys and the number of sections n is great enough to make,

$$n\left(\frac{R}{2}\sqrt{\frac{C}{L}}\right) \geqslant 15$$

then the lumped electrical parameters of the loading coils will behave as if they were approximately uniformly distributed, and the attenuation constant β may be taken as,

$$\beta = \left(\frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}\right) K_1 \ldots\ldots\ldots(7)$$

where,

$R = R_c + SR_mK_2$

R_c = resistance of loading coil at given frequency f.

R_m = resistance per mile of line.

S = loading coil spacing in miles.

$C = SC_m$.

C_m = capacity per mile of line.

$L = L_c + SL_m$.

L_c = inductance of loading coil.

L_m = inductance per mile of line.

$G = SG_m$.

G_m = leakance per mile of line at given frequency f.

$$K_1 = \sqrt{\frac{\cos\theta}{1 - y^3}}$$

$$\theta = \tan^{-1}\frac{R}{\omega L}$$

$$K_2 = 1 - \tfrac{2}{3}y^2$$

$$y = \frac{f}{f_c}$$

$$f_c = \frac{1}{\pi\sqrt{C(L_c - SL_m)}}$$

An example of the use of this formula is given in Fig. 1. From the curves it can be seen that the probable error involved in the application of equation (7), is of the same order as the probable error due to seasonal variations of measured attenuation-frequency characteristics.

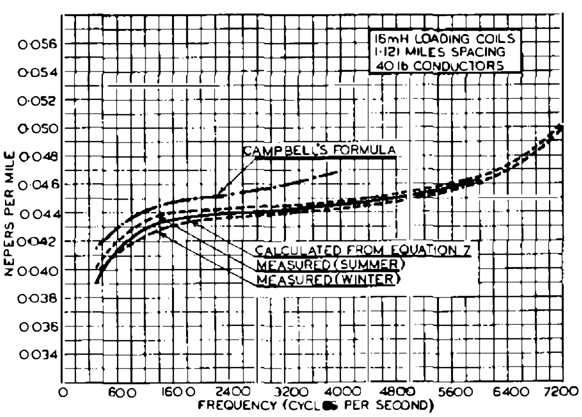

FIG. 1.—ATTENUATION/FREQUENCY CHARACTERISTIC OF LIGHTLY-LOADED LINE.

The Plymouth Automatic Area

D. A. BARRON,
B.Sc. (Hons.), A.M.I.E.E., Assoc. I.R.E.

PROGRESS is the keynote of the age, and modernity won another victory, in a stronghold of historical fame, when on July 6th the conversion of five exchanges in the Plymouth area from magneto to automatic working was successfully effected.

To most people the name of Plymouth conjures up shades of the Hoe, of Drake, Frobisher and the Mayflower. The high limestone plateau of the Hoe has indeed watched over many a venture famous in history, but now the face of the Hoe itself is changing. The green slopes are being moulded into gardens and promenades, and the rocky foreshore is being provided with spacious sun terraces, and bathing pools. It is perhaps in keeping with the general modernization of this proud city that the Post Office should have played its part by providing a telephone system which is the last word in automatic efficiency.

The Plymouth main automatic exchange is housed in an imposing new building in the heart of the city, and contains also the Section Stock Stores and garage on the ground floor, the Sectional Engineer's Offices on the second floor, and the manual switchroom on the third floor.

The general lay-out of the area is indicated in Fig. 1, the exchange areas now working on an automatic basis being shown cross-hatched. Conversion of the remaining exchanges within the automatic area, will, in accordance with standard policy, be effected as and when the existing manual buildings and equipment approach the end of their economic life. The exchanges so far converted, and their capacities, are shown in Table I.

TABLE I.

Exchange.	D.E.L.'s. Transferred.	Multiple Capacity.	
		Initial.	Ultimate.
Plymouth ...	3471	4700	9800
Crownhill ...	493	700	1900
Plympton (U.A.X.)	239	400	700
Plymstock (U.A.X.)	297	400	800
Saltash (U.A.X.)...	183	300	600
Totals :—	4683	6500	13800

Transfer Arrangements.

Owing to shortage of line plant between the old and new Plymouth exchanges only a small proportion of circuits could be teed into the new exchange and the transfer was, in the main, effected by means of change-over strips.

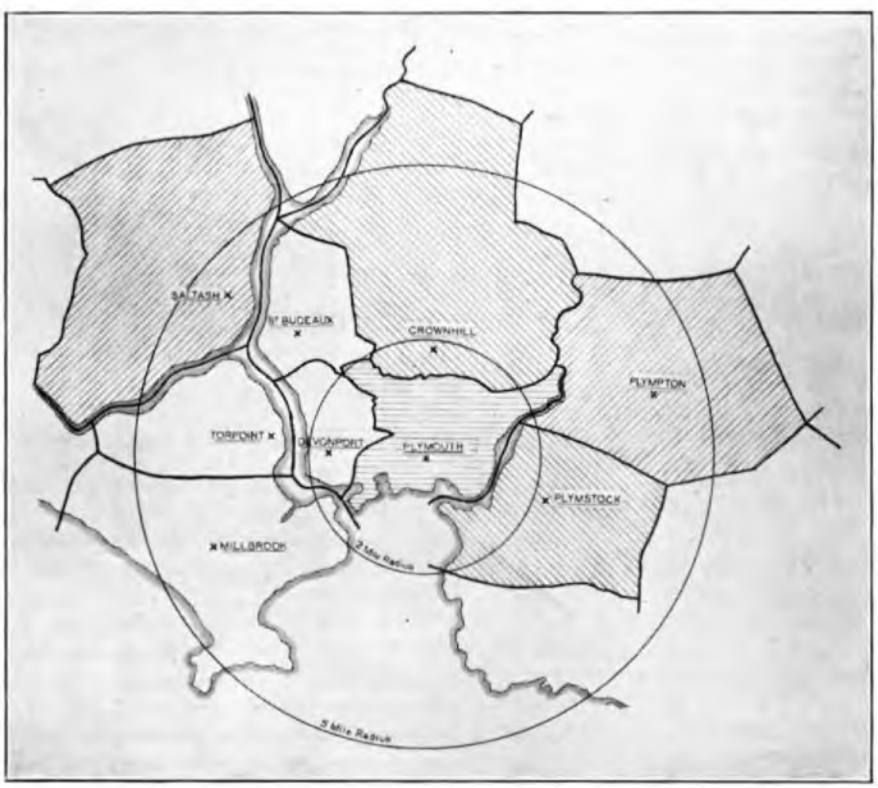

FIG. 1.—PLYMOUTH AUTOMATIC AREA.

Thirty strips change - over 200/200 were used at the new exchange and 26 at the old exchange, involving temporary wiring for a total of some 11,000 pairs. This was a work of considerable magnitude and difficulty at the old exchange, where there were three main frames on two floors and the complexity usual in old exchanges of different types of line terminations, tie cables, etc.

Fig. 2 shows the change-over strips and cabling at the new exchange. To provide a teeing scheme for the transfer would have involved the wasteful provision of a considerable amount of additional cable between the new and old exchanges and it is estimated that the adoption of the double break jack arrangement in lieu of teeing saved, in this instance, some three thousand pounds.

A feature of the leading-in arrangements at the new exchange is the utilization of a new

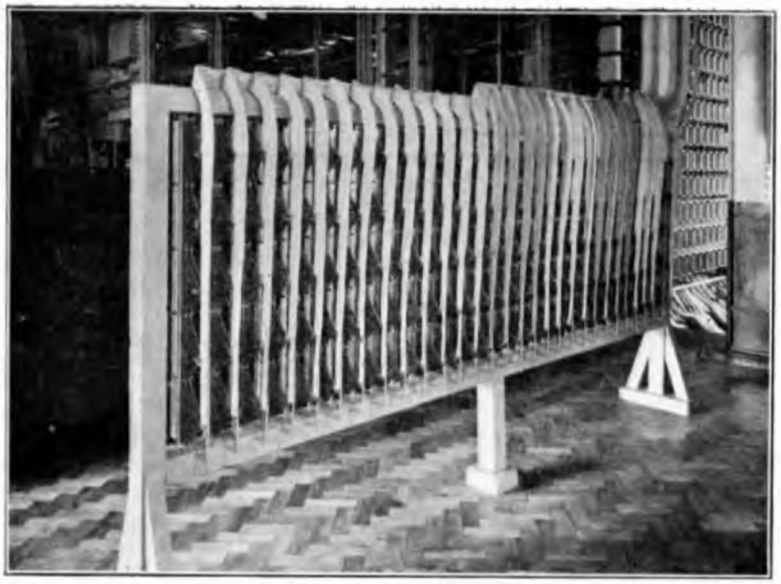

Fig. 2.—Cabling of Change-over Strips.

Fig. 3.—Leading In Arrangements.

type of plug for connecting the 200 pair E.S. & W. tails to the leading-in cables in the cable trench. The plugs, varying between a two-way and seven-way, can be made on the bench, and the 200 pair E.S. & W. cables can be double-formed and subsequently placed into position individually on the M.D.F. When a group of terminating cables is ready in position, it is only necessary to slip the ends, previously stripped, into the collars of the plug and seal them with a finger wipe. The jointing and plumbing of the main joint then proceeds on standard lines. A general view of the cable trench and joints will be seen in Fig. 3.

All coin-box installations throughout the automatic areas were transferred to automatic working in advance of the main automatic transfer in accordance with the latest scheme, a temporary notice being exhibited instructing callers to dial " 0 " for all calls.

A partial pre-transfer of trunks and junctions took place at 1 p.m. on July 6th, and the main transfer was effected at 2 p.m. on the same day.

Numbering Scheme.

The subscribers' numbering arrangements are somewhat unusual, being based on the new scheme of restricting common numbering to exchanges within the two mile radius of the main exchange. The local numbering schemes in the exchange areas between the two and five mile radii can be duplicated, as these exchanges are obtained by dialling suitable routing digits. The Plymouth area numbering scheme is indicated in Table II, and Table III shows the routing digits which it is necessary to dial in order to obtain any one exchange from another. It will be noticed that it is at present necessary to dial " 0 " in connexion with calls between Saltash and

Table II.

Plymouth Main, Satellite, and U.A.X's.		
Plymouth	2000-5999 60000-60699	
Crownhill (Sat.)	71100-71799	
Plympton (U.A.X.) ...	792100-99 792200-99	793100-99 793200-99
Plymstock (U.A.X.) ...	782100-99 782200-99	783100-99 783200-99
Saltash (U.A.X.)	772100-99 772200-99	773100-99

Special and Miscellaneous Services.	
Torpoint (Manual)	86
St. Budeaux ,, ...	84
Millbrook ,, ...	82
Devonport ,, ...	69
Enquiry ,, ...	91
Service P.B.X.	92
Rural Party Line	93
Trunk Demand and Record	94
Phonogram (Sub. P.O's)	95 96 97 98
Test Desk	99
Phonograms	90

the other U.A.X.7 exchanges, Plympton and Plymstock.

The proposed provision of zone metering facilities will later enable these calls to be completed through the automatic apparatus without manual assistance, by dialling the appropriate routing digits.

TABLE III.

From/To	Plymouth & Crownhill.	Plympton.	Plymstock.	Saltash.
Plymouth & Crownhill.	D.	79 + D.	78 + D.	77 + D.
Plympton.	9 + D.	D.	978 + D.	0
Plymstock.	9 + D.	979 + D.	D.	0
Saltash.	9 + D.	0	0	D.

D. = Directory Number.

Features of the new Automatic Equipment.

Plymouth is one of the first provincial exchanges to be equipped with the new 200 outlet line finder scheme with partial secondary working. The P.O. 3000 type relay is used throughout the automatic equipment, except in the case of the subscribers' L and K relays at the Plymouth and Crownhill exchanges.

A general view of the Plymouth main exchange is shown in Fig. 4. Crownhill exchange is of the standard D.S.R. Satellite type with 200 point line finders.

Fig. 5 shows an exterior view of this exchange, which is of an especially pleasing appearance.

THE UNIT AUTO EXCHANGES.

Perhaps the most interesting feature of the area is the inclusion of three exchanges of the latest U.A.X.7 type. These exchanges provide many new features, to which some reference will, it is thought, be of general interest, and details of some salient aspects of the design, lay-out, and facilities are given below.

Detailed circuit explanations can be obtained from P.O. Technical Instructions, Telephones Automatic G. 4201-4299.

Views of Plympton exchange are shown in Figs. 6 and 7.

The apparatus racks are of uniform height and width, and conform generally to P.O. standards for Strowger exchanges. Each rack is self-contained, but facilities are provided for interconnexion between racks *via* connexion strips mounted at the top. The rack cabinets are of the cavity type, consisting of a mild steel framework, to which are fitted single sheet iron side panels and after installation cavity type end panels are fitted at each end of a suite of racks to make the cabinet air-tight. All doors and the end panels have double air-spaced walls of sheet iron to give maximum heat-insulating properties. The cabinets enclose the whole of the racks, the cables entering through cable holes which are suitably packed to preserve the air-tight properties of the cabinets. The front and rear doors and end panels are readily removable for maintenance purposes and several doors are shown removed in the photographs (Figs. 6 and 7).

The apparatus components include the Strowger 2-motion switch as a 100 point line finder, first and final selector; the 25 contact uniselector as a secondary finder and distributor; and the P.O. 3000 type relay for all general purposes, including the subscribers' line circuits.

Apparatus lay-out.

The apparatus is divided between three groups of racks which may be conveniently called A, B and C.

Rack A. This rack accommodates the complete line equipment for 100 lines and has two variations because the Primary Control equipment is only required on a " per 200 lines " basis.

Rack Aa is therefore the first of the pair of racks A and carries the Line Finder, Control, and Distributor equipment with its associated wiring and facilities for extending this wiring to its partner Rack Ab. The latter is not equipped with control equipment, but the wiring of the rack is arranged to bring into use the control equipment of the Associated Rack Aa.

Rack B is designed primarily to take the secondary finders and local 1st Selectors, each rack having capacity for sufficient of this equipment for a 400 line exchange.

FIG. 4.—PLYMOUTH MAIN EXCHANGE.

Fig. 5.—Crownhill Satellite Exchange Building.

Rack C is designed to accommodate the junction and supervisory equipment for the exchange and under normal conditions when 2nd Selectors are not required one Rack C will serve 400 lines. Typical equipment, *e.g.*, Plympton (400 lines) is as follows:—

2. Racks Type Aa, each fitted with :—
   - 8 Final Selectors.
   - 7 Line Finders.
   - 2 Primary Control Sets.
   - 100 Subs. Meters.
   - 80 L & K relays.
2. Racks Type Ab, each fitted with :—
   - 2 Final Selectors.
   - 7 Line Finders.
   - 100 Subs. Meters.
   - 80 L & K relays.
1. Rack Type B, fitted with :—
   - 16 Local 1st Selectors, 24 Banks.
   - 8 Secondary Finders, 12 Banks (2 groups of six).
   - 4 sets of secondary Control Relays and Distributors.
2. Racks Type C, each fitted with :—
   - 6 I/C 1st Selectors, 8 Banks.
   - 6 Parent Exchange B/W relay sets. 8 Positions.

The first C type rack also accommodates the exchange supervisory relay sets.

On local calls the first selectors are digit absorbing and provide the transmission bridge.

At present levels 1 and 2 have access to two groups of 200 line final selectors, giving a capacity of 400 lines and leaving levels 3-8 available for direct junctions to adjacent exchanges if required.

By utilizing these levels and level 0 the line capacity can of course be increased to a maximum of 1800 lines if desired.

Outlets from level 9 are connected to relay sets associated with the junctions to the parent exchange, and " cut in " on this level occurs whether " 9 " or " 0 " is dialled, the selector being prevented from stepping to the " 0 " level except when the first digit of a local number (2 or 3) has been previously dialled.

Local Service.

Local connexions are established by dialling four digits. The first (" 2 " or " 3 ") steps the first selector and in the case of " 2 " prepares a discriminating signal which is later extended to the final selector to cause it to switch its wipers to the second hundred line group. The first selector then releases and again steps under the control of the next digit which positions it for selecting a final selector in the required group. The remaining two digits are effective in positioning the final selector.

Ringing is fed from the 1st selector which also provides the speaking bridge and returns busy tone if the called subscriber is engaged. The final selectors may be either regular, regular + P.B.X 2/10 or Regular + P.B.X. 2/100, the night service facility being given in the latter cases.

In the event of all final selectors in any required

Fig. 6.—" A " Racks, Plympton U.A.X.7.

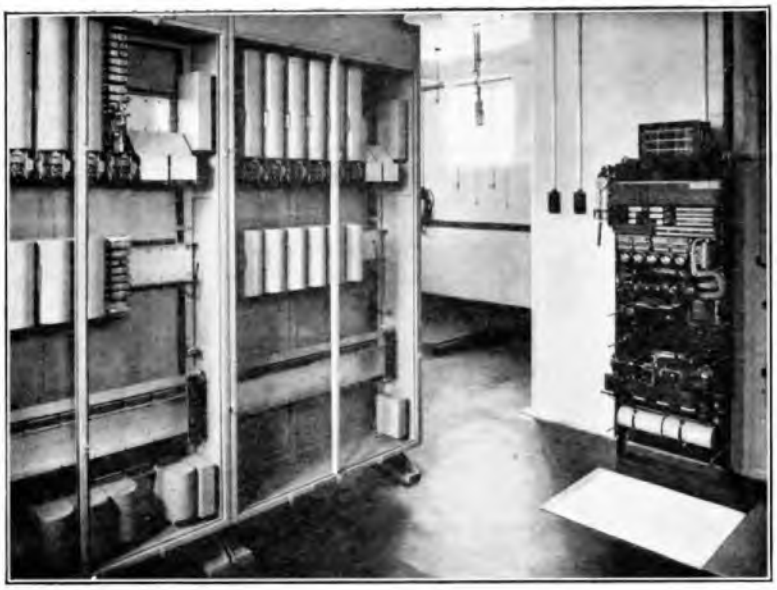

FIG. 7.—C RACKS, PLYMPTON U.A.X.7.

group being busy the 1st selector steps to the 11th contact and returns busy tone to the calling subscriber.

Outgoing Services.

Operator at Parent Exchange (Dial " 0 "). The selector is stepped to the 9th level where the 10th impulse is diverted from the vertical magnet and caused to set up a discriminating condition in the selector to enable it to differentiate between this and a dial " 9 " call.

The switch cuts in on the 9th level and selects a relay set and junction to the parent exchange.

The discriminating condition is signalled to the relay set and causes it to extend manual calling conditions to the junction so that the call is routed to the manual board at the parent exchange, the ringing tone being returned to the subscriber from the relay set.

Coin Box or Barred Trunk subscribers (which can be indiscriminately mixed in the same groups with ordinary lines) on seizing the selector set up a special discriminating condition which, being signalled to the relay set when " 0 " is dialled, causes it to extend a different manual calling signal to the junction and a separate calling lamp is taken into use at the manual board to signal the operator and at the same time advise her that the call has originated from a Coin Box line.

In either case, operator hold and re-ringing facilities are given for the purpose of Trunk Demand working.

Main Auto Exchange Subscriber. (Prefix " 9 "). The 1st selector steps to the 9th level, cuts in, and selects a relay set and junction to the parent exchange. The discriminating condition set up in the case of the dial " 0 " call no longer obtains and the relay set therefore extends auto (loop) calling conditions to the junction, thereby causing the call to be routed to the auto equipment at the parent exchange. The subscriber then dials the directory number of the required subscriber.

Incoming Service.

From Parent Exchange. Loop dialling facilities from the parent exchange (manual or auto) are provided. The junctions terminate on Incoming 1st Selectors of the battery feeding type having all the facilities of the local 1st Selectors with one or two additional features. The latter include busy flash, trunk offering and completion (*via* any final selector) and operator control of ringing.

The trunk offering facility is arranged so that no potential is applied to either leg of the subscriber's line, thus affording the means for giving an assistance service.

Spare Prefixes, Levels and Numbers.

If a spare prefix or an unused level is dialled the first selector is arranged to send back N.U. Tone to the calling party, the circuit arrangements being such that separate spare level equipments are not required.

N.U. Tone can also be applied to unallotted numbers at the M.D.F. in the usual way, the resistance spools which simulate the cut-off relay being connected at the L.I.D.F. blocks on Racks A using the " spare number " tags.

Metering.

Metering is on the " fourth wire " principle and is controlled from the first selector in the case of local calls and from the relay sets for outgoing calls.

Arrangements are made at the rear of the meter mounting shelf for any subscriber's meter to be connected to earth (Regular Subs.) or battery (Coin Box and Barred Trunk Subs.).

Maintenance Testing Facilities.

All switches and relay sets are fitted with test jacks and the group and final selector banks have a 24 pt. jack wired into each multiple for routine testing purposes.

General.

The whole of the automatic equipment was provided and installed by Messrs. Automatic Electric Company, Limited, Liverpool.

Reference to the official opening of the exchange is made in this Journal under " District Notes."

Suffocating Gases, and their Detection

C. E. RICHARDS, A.I.C.

Introduction.

THERE are two principal gas hazards to which telephone workers engaged on the installation or maintenance of underground plant may be exposed. These are the infiltration of explosive or inflammable gases (usually illuminating gas, in which case there is also a danger of poisoning) and the occurrence in underground workings of suffocating gases which are not inflammable and may not be extremely poisonous, but which nevertheless will not support life. This article only deals with the second of these problems, and includes some elementary information which may not be generally known.

Composition of Air and its Effects.

Pure dry air contains 20.99% oxygen, 78.98% inert gas and 0.03% carbon dioxide by volume. As normally existing it is always more or less moist, but for the present purpose the presence of this moisture may be ignored. Strange as it may seem there is practically no difference in the composition of city air and seaside or country air.

In the action of breathing, air containing 21% oxygen and 0.03% carbon dioxide is taken into the lungs. At the lung surface some of the oxygen is removed and dissolved in the blood stream, being replaced by carbon dioxide from the blood, so that exhaled air contains only 16% oxygen, but 4% carbon dioxide. The fact that air has been once breathed does not mean that it will no longer support life, it can be breathed a number of times, but after each breath the exhaled air will contain rather less oxygen and rather more carbon dioxide than at the previous breath. Since the lungs are acclimatised to air of normal composition they are not so comfortable when dealing with air deficient in oxygen and having a high content of carbon dioxide. Oxygen is not absorbed and carbon dioxide not discharged so readily from the blood. Breathing becomes deeper and more frequent and, if the supply of fresh air is not resumed this continued respiration of air becoming progressively more vitiated will lead to unconsciousness and death.

In considering the effect on the animal of air which has been polluted by breathing we are dealing with two simultaneous actions. The first action of breathing is to lower the oxygen content of the air and so render it less capable of supporting life and the second is to increase the carbon dioxide content, making the air less capable of removing waste products from the blood stream. In many cases it is not necessary to deal with the two actions separately, but there are occasions when one action may predominate, hence it is desirable to know the separate effects of reduced oxygen content and of increased amounts of carbon dioxide.

This subject does not appear to have received overmuch attention, but a paper very much to the point was published by Haldane and Lorrain Smith[1] whose results may be summarized thus :—

1. The immediate dangers of breathing air highly vitiated by respiration arise entirely from excess of carbon dioxide and deficiency of oxygen.
2. Hyperpnoea[2] is due to excess of carbon dioxide and is not appreciably affected by corresponding oxygen deficiency. It begins at 3-4% carbon dioxide and at about 10% there is extreme distress.
3. Excess of carbon dioxide is one cause of headache.
4. Hyperpnoea due to lack of oxygen differs with different individuals, but may start when the oxygen content of air drops to about 12%.

Pollution of Air.

It can now be considered how this dangerous carbon dioxide content may occur, either with or without a corresponding decrease in the oxygen content of the air.

There are two main classes of action : firstly, all those actions which may be classified broadly as combustion, in which oxygen is taken from the air and is replaced by some other substance, and, secondly, by the addition of carbon dioxide to air, without removal of a corresponding quantity of oxygen.

Taking the first class and subdividing we have the following heads :—

Respiration, already mentioned, where oxygen is removed from the air and carbon dioxide replaces it.

Combustion of carbonaceous matter, such as paraffin oil, coal, gas, etc. This gives a similar result to the above, the difference being in the relative amounts of CO_2 formed and oxygen absorbed :—

$$e.g., \quad C_5H_{12} + 8\,O_2 \rightarrow 5\,CO_2 + 6\,H_2O.$$

One volume of pentane vapour will combine with eight volumes of oxygen and produce by combustion five volumes of carbon dioxide. (N.B. Pentane is a typical constituent of petrol.)

$$C_2H_5OH + 3\,O_2 \rightarrow 2\,CO_2 + 3\,H_2O.$$

One volume of alcohol vapour combines with three volumes of oxygen and produces two volumes of carbon dioxide.

Combustion of non-carbonaceous matter reduces the oxygen content without materially increasing the proportion of CO_2.

$$2\,H_2 + O_2 \rightarrow 2\,H_2O.$$

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[1] J.Path., Vol. 1 (1893). p. 168.

[2] Hyperpnoea denotes a condition in which the blood is moderately deficient in oxygen and respiration is correspondingly accelerated, *i.e.*, breathing becomes deeper and more frequent, eventually turning to panting.

Two volumes of hydrogen react with one volume of oxygen and produce no carbon dioxide.

The addition of carbon dioxide to the atmosphere is a process of air pollution almost peculiar to telephone working and results from the use of carbon dioxide for desiccating paper cored cables. In this case the carbon dioxide content of the air is greatly increased with only a small drop in the proportion of oxygen.

Methods of Detecting Polluted Air.

It will be realized that since the dangers of foul air depend far more on the carbon dioxide than on the oxygen content, an ideal method of testing the condition of underground workings would be primarily sensitive to carbon dioxide and not necessarily so sensitive to lack of oxygen. It is however almost essential that testing apparatus should be able to detect large oxygen deficiency, and it is also desirable that the apparatus should work without definite periodical tests being made, *i.e.*, it should act as a sentinel. It is not at all easy to get an outfit which will fulfill all these requirements, and at the same time be cheap enough and robust enough to make a general issue practicable.

The methods actually available comprise such things as Gas Leak Indicators, in their various modifications, Portable Gas Analysis Apparatus, and Flame Type Safety Lamps. It is the purpose of this article to deal mainly with Flame Type Safety Lamps, but since many will be familiar with Gas Leak Indicators, a few remarks may not be out of place.

The Gas Leak Indicator.

This instrument depends for its action on the different rates at which gases of different densities will diffuse through a porous diaphragm. The rates of diffusion of gases through porous diaphragms are inversely proportional to the square roots of their densities. Thus if hydrogen is taken as of unit density, air will be about 14, and the rates of diffusion of the two gases will be as $\sqrt{14} : 1$, and carbon dioxide, density 22, will diffuse through a diaphragm at a rate of $\sqrt{14}/\sqrt{22}$ that of air.

If a sealed porous pot containing air is plunged into an atmosphere of hydrogen, hydrogen will get in faster than air can get out, so developing a pressure within the pot. By attaching an aneroid diaphragm to the pot this change of pressure can be measured, thus giving a simple gas leak indicator. This is a very convenient instrument, but is subject to one or two major disadvantages. The first of these is that it can only differentiate between gases of different densities, so if a gas is tested consisting of air containing both a light and a heavy gas (say hydrogen and carbon dioxide) in suitable proportions the indicator would give no reaction at all. Actual tests with gas leak indicators have shown that a mixture of about 13% hydrogen and 87% carbon dioxide does not cause the needle to move appreciably. Air polluted therefore with a mixture of 1.3% hydrogen and 8.7% carbon dioxide will therefore fail to operate a gas leak indicator and yet be quite dangerous to breathe. Mixtures of coal gas and carbon dioxide may be imagined which are even more deadly. Fortunately this trouble is more academic than practical, and need not be visualized. Another and more serious phase of this difficulty is due to the popular belief that light gases are inflammable, but heavy gases are suffocating and non-inflammable. The former assumption is substantially true, there being few common gases lighter than air which are not inflammable, but the latter idea is untrue. To take the most common example, petrol vapour is much denser than air, and pentane can be taken as being a typical component of petrol. Its density is 36 (hydrogen being 1) and is thus even denser than carbon dioxide.

The other principal fault of the gas leak indicator is that it will only register comparatively quick changes in the gases surrounding it. In order to test for the presence of polluting gas it is necessary to set the indicator in fresh air and then plunge it into the atmosphere to be tested. It is no use taking it down a manhole and hanging it on the wall. A slow infiltration of gas would pass completely unobserved and the needle would either remain at zero or shortly return to that position. Fig. 1 shows the graph of

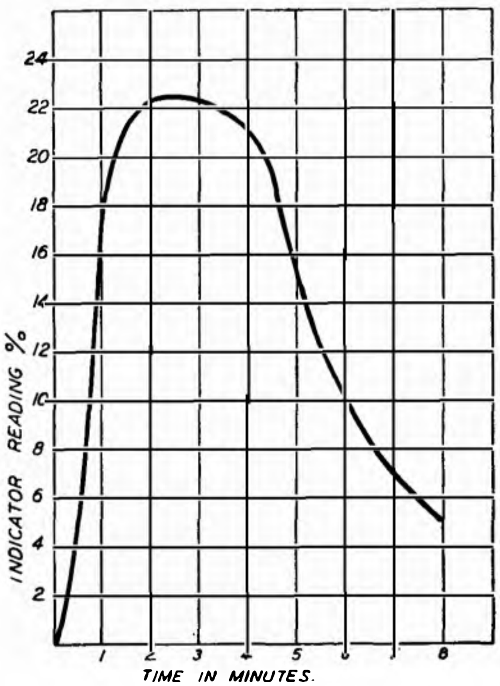


Fig. 1.—Indicator Exposed to 9% Coal Gas in Air.

an actual test, demonstrating the rise to a maximum reading followed by a gradual return to normal although the gas concentration has remained constant throughout the test.

(Note.—This curve was not measured with an instrument of the particular type used in the Department.)

Flame Type Safety Lamps.

These instruments are necessary articles when working underground, and, as they can be used for detecting any kind of inflammable gas as well as the presence of suffocating gases, it is perhaps natural to desire to use them for both purposes. Incidentally the manipulation of a miner's lamp is so simple, and the construction so robust that if it can be used for routine testing it is almost an ideal instrument.

The miner's safety lamp is almost universally used below ground in the coal mine for detecting the presence of both inflammable " fire damp " and also the suffocating " black damp " which is a popular name for carbon dioxide. The plain miner's lamp is, however, not suitable for testing manholes for the presence of inflammable gas, and for this and similar purposes many interesting modifications have been developed, one of which is at present being tried by the Post Office. Any of these safety lamps, however, can be used to test for the presence of suffocating gas, which causes the flame to burn dimly or to go out.

It is usually stated that about 4% of carbon dioxide will extinguish a safety lamp flame. This statement is correct, but is incomplete and liable to be misleading. It makes no reservation as to *how* the carbon dioxide has been formed, but assumes it to have produced by burning carbonaceous matter. *Added* carbon dioxide is not covered by this statement, and it must be realized that a miner's lamp is not so sensitive when used to detect added carbon dioxide as when applied to the more orthodox purpose.

Many years ago, Clowes made comparative tests in which the extinction point of flames was determined in three types of atmosphere.

1. The flame was tested by burning in a closed space until extinguished by its own combustion products.
2. An atmosphere formed by adding CO_2 to air until the flame was extinguished immediately on immersion.
3. An atmosphere formed by adding nitrogen to air until the flame was extinguished immediately on immersion.

Some of his results are quoted in the Table below.

Illuminant.	Composition of air to extinguish flame.							
	CO_2 by combustion, with deficiency of oxygen.			CO_2 added.			Nitrogen added.	
	O_2	N_2	CO_2	O_2	N_2	CO_2	O_2	N_2
Candle	15.7	81.1	3.2	18.1	68.5	13.4	16.4	83.6
Paraffin oil	16.6	80.0	3.0	17.9	67.8	14.3	16.2	83.8
Colza and paraffin ...	16.4	80.5	3.1	17.6	66.6	15.8	16.4	83.6

From these figures it will be seen that oxygen shortage rather than carbon dioxide content is the primary controlling factor in extinguishing a flame. It would also appear at first sight almost a forlorn hope to use a safety lamp to test a manhole atmosphere which is suspected of having been contaminated with the carbon dioxide from the desiccating plant. The position, however, is not quite so bad as this, for two reasons. Firstly, carbon dioxide is a gas 1.5 times as heavy as air, so when it escapes into a manhole it tends to fall to the bottom and lie there in a dense layer consisting of the practically pure gas. This gas will extinguish any safety lamp in a few seconds. Secondly, tests have shown that by adopting suitable means, an oil burning safety lamp may be used to detect considerably smaller amounts of carbon dioxide than would be inferred from inspection of the above table. The difference lies in the height of flame used at the start of the test. All miners lamps have devices of one kind or another to raise or lower the flame without opening the lamp. Tests were made on a number of lamps of assorted types and showed that there were appreciable differences in their behaviour towards atmospheres containing added carbon dioxide. These tests also showed that if the flame in the lamp were initially lowered it became more sensitive to carbon dioxide. The curves in Fig. **2** show this effect distinctly, and they

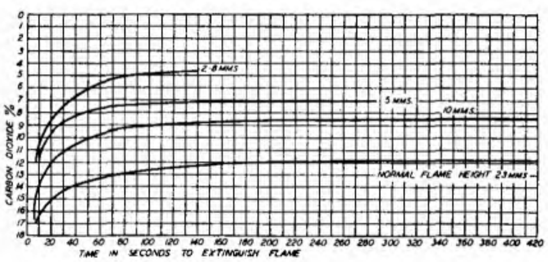


FIG. **2**.—EFFECT OF FLAME HEIGHT.

were obtained using a " Spiralarm " lamp of the type which is at present on trial in the Post Office (Lamp, Safety, No. 2). It will be seen that whereas it takes 13% of added carbon dioxide to extinguish a normal sized flame in two minutes, if the flame is lowered to 2.8 millimetres (the lowest to which it can readily be set) in fresh air, between 4 and 5% of carbon dioxide will extinguish it in this time. This is a comparatively satisfactory result and by adopting this method of testing, particularly in cases where carbon dioxide desiccation has been taking place, workmen can easily safeguard themselves from entering dangerous places.

When once work has commenced in a manhole or tunnel the safety lamp will be kept below ground and adjusted to normal flame height. Small concentrations of carbon dioxide will not then extinguish the lamp, but a normal sized flame is quite a sensitive detector, as it becomes dimmed though not extinguished by comparatively small amounts of carbon dioxide. The curves in Fig. **3**, also obtained with a Spiralarm lamp, show how much a normal sized flame is reduced in size by immersion in different atmospheres. Spiralarm lamps are all fitted with divided pointers which indicate the correct flame height, and in use the flame is set at this level before taking the lamp down a manhole. By occasionally glancing at the lamp, therefore, a sufficient indication of the state of the atmosphere will be obtained, and should the flames show a persistent tendency to drop the atmosphere should be suspected of contamination, since when the lamps (clean lamps !) burn in clean air the flame if anything tends to increase in height rather than to fall.

It is hoped that this description of the danger of carbon dioxide and methods of testing its presence may be of some interest especially to those whose work takes them below ground.

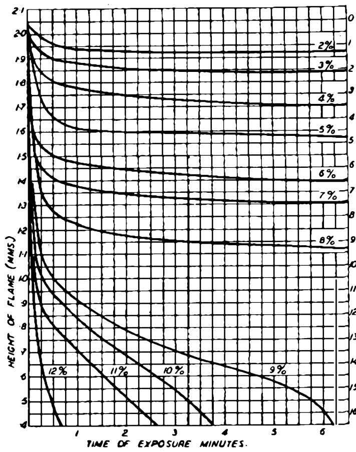


FIG. 3.—EFFECT OF ADDED CO_2 ON FLAME HEIGHT

Telegraph and Telephone Plant in the United Kingdom

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1935.

Number of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange*	Spare.		Telegraph.	Trunk.	Exchange	Spare.
897,857	434	5,672	49,156	6,478	London	37,240	226,175	3,893,618	91,919
112,022	2,138	16,187	49,527	7,952	S. Eastern	5,170	76,836	388,659	44,436
128,699	4,196	37,041	81,502	5,448	S. Western	24,377	69,169	304,847	80,957
89,090	4,242	38,180	75,042	12,750	Eastern	16,322	78,298	184,801	50,883
138,903	5,156	37,166	61,420	22,282	N. Midland	6,856	202,258	350,947	95,374
112,586	3,467	23,461	69,440	13,256	S. Midland	8,925	82,126	339,185	63,562
75,924	3,071	26,317	61,665	8,754	S. Wales	6,219	64,044	170,582	33,047
150,587	4,594	22,560	63,002	15,156	N. Wales	8,391	106,036	482,819	68,420
194,727	1,294	5,609	28,732	9,827	S. Lancs.	7,938	129,678	688,028	75,242
126,866	5,264	24,139	42,004	7,941	N. Eastern	11,723	104,264	362,615	41,981
82,818	1,211	15,226	29,785	13,612	N. Western	5,363	71,958	265,392	88,506
64,278	1,286	13,402	23,289	7,360	Northern	4,280	55,287	203,500	14,412
31,930	3,068	11,392	13,334	1,167	Ireland N.	413	6,034	75,180	17,294
92,860	4,522	27,869	43,968	8,361	Scotland E.	2,082	63,604	185,148	49,867
115,451	3,992	20,979	36,789	7,585	Scotland W.	9,366	73,108	287,770	18,675
2,414,598	47,935	325,200	728,655	147,929	Totals.	154,665	1,408,875	8,183,091†	834,575
2,371,697	47,974	335,171	713,508	139,206	Totals as at 31 Mar., 1935	153,969	1,347,029	7,947,764	1,051,250‡

* Includes low gauge spare wires (*i.e.*, 40 lb. bronze in open routes and 20 lb. or less in aerial cables).
† Includes all spare wires in local underground cables.
‡ Includes heavy gauge local spare wires (178,401 miles),—transferred to " Exchange " in June quarter.

A New Method of Testing Subscribers' Lines after Transfer to an Automatic Exchange

A. D. STEWART

Introduction.

FOR a number of years it has been the practice of the Engineering Department to test each subscriber's line immediately after an automatic exchange transfer is effected. The test is to prove that all lines have been connected at the new main distribution frame after the isolating wedges have been removed and that each line is free from contacts, earths, etc.

This test has been conducted, until quite recently, from the new automatic exchange main distribution frame and a short review of the past procedure will be given before describing the new method of testing.

The Superseded Method.

A number of testing officers, depending upon the size of the exchange, was stationed in front of the exchange side of the main frame, each having a Tester No. 25 mounted upon a Stand Testing No. 1. Each testing officer had an assistant and was provided with a numerical list of the working exchange lines to be tested. The assistant inserted the test clip, associated with the tester, into the arrestor test springs of an exchange line and, after the line was tested, withdrew the clip and inserted it in the test springs of the next working line. One of the disadvantages of this method was that the assistant had to count down the lines in the vertical strip before inserting the test clips into the required arrestor, and often, at the first attempt, proper connexion was not made, with the result that a re-test was necessary.

If a subscriber happened to be in conversation the insertion of the test clip invariably broke down the connexion and the test would show, instead of a condenser discharge, the apparent fault of a loop. This apparent fault would be recorded, and the line re-tested from the test desk, whereupon the line would be found to be satisfactory. At one transfer of 1500 working lines, 57 faults were recorded from the first test, but upon re-test later by the test desk, 46 were found to be satisfactory.

The method also had the fundamental defect that congestion was caused at the main distribution frame which, at the time of a transfer, should be left clear for fault localization, etc.

The New Method.

In order to eliminate the foregoing defects a new method has been developed whereby the test final selectors are utilized for gaining access to the subscribers' lines.

Apparatus required.

A Test Panel (Fig. 1) has been designed which contains the essential testing facilities of the Tester No. 25 together with the necessary keys and dial which enable the test final selector to be stepped to the line to be tested. The number of Test Panels required depends upon the number of lines in the exchange multiple and varies from one per 200 lines (that is one for each test final selector) at small exchanges up to about 400 lines, to one per 400 lines at large exchanges.

Fig. 1.—Test Panel.

Connexion of the Test Panel to the Test Final Selector.

The Test Panel is connected to the test final selector in one of the two following methods depending upon the lay-out of the final selector racks and the size of the exchange :—

(*a*) Each Test Panel is mounted upon a Stand Testing No. 1 and located between the Final Selector Racks. Temporary jacks are fitted to each test final selector and wired to the circuits of the Privates, Vertical, Rotary and Release magnets. The Test Panel is then connected to the desired test final selector by means of plugs and cords. This method is liable to cause congestion between the final selector racks.

(*b*) The better method is to stand the Test Panels on a table situated in a position remote from the final selector racks. The test final selectors are then wired *via* temporary connexion strips to strips of jacks mounted on the Test Panel table, the jacks being labelled with the " hundreds numbers " of the test final selector to which they are connected.

The connexions are shown in Fig. **2** and are tabulated below :—

From Test Table.		To each Test Final Selector.
Jack No. 310 BN Labelled " L "	Tip Ring Sleeve	– Line, Left Test Jack } by means of a + ,, ,, ,, ,, } Plug No. 411. P2, U Point 18.
Jack No. 310 BN Labelled " R "	Tip Ring Sleeve	– Line, Right Test Jack } by means of a + ,, ,, ,, ,, } Plug No. 411. P1, U Point 9.
Jack No. 310 BN Labelled " M "	Tip Ring Sleeve	Z, U Point 23. R, U Point 24. V, U Point 17.

Terminals are fitted on the right hand side of each Test Panel (see Fig. **1**) and plugs, battery and earth, and a Detector No. 4 are wired to these terminals as shown in Fig. **2**.

Each Test Panel is connected as follows :—

From Test Panel.			To :—	
Terminal No.	1	Tip	Plug No. 310 labelled "L"	Labelled with the Panel Number.
,, ,,	2	Ring		
,, ,,	3	Sleeve		
,, ,,	4	Tip	Plug No. 310 labelled "R"	
,, ,,	5	Ring		
,, ,,	6	Sleeve		
,, ,,	7	Tip	Plug No. 310 labelled "M"	
,, ,,	8	Ring		
,, ,,	9	Sleeve		
,, ,,	10		Battery	
,, ,,	11		Earth	
,, ,,	12		+ Detector No. 2 or 4.	
,, ,,	13		– ,, ,, ,,	

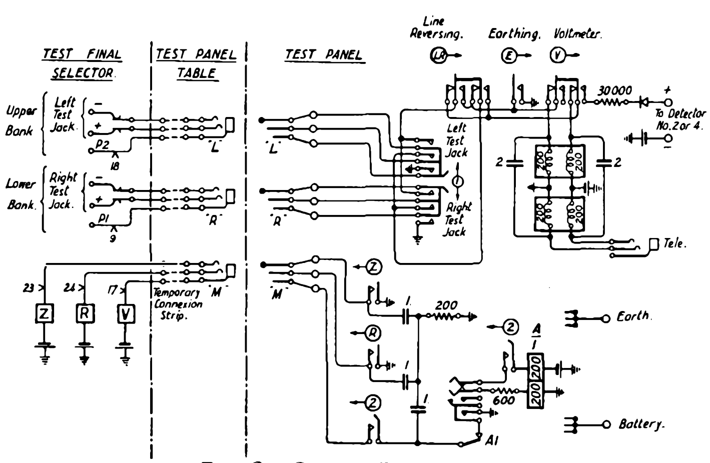


Fig. 2.—Circuit Connexions.

It is possible to connect any Test Panel to any test final selector by inserting the plugs " L," " R," and " M " into the relative jacks, and thereby a testing officer can gain access to any number of test final selectors in turn.

In order that the testing officer may listen on the lines being tested a head-set with the transmitter and receiver in series is connected to the transmission element of the Test Panel by means of a plug and jack.

In both the foregoing methods (*a*) and (*b*) the installation of the Test Panels and the temporary connexions to the final selector racks are made approximately one week prior to the transfer.

Testing Procedure.

For the guidance of the testing officers, a record card (E.Q.F. 90 modified) is prepared for each group of 100 lines, and represents the numbering of the lines in bank order. Spare, service, and unidirectional lines are suitably marked as follows :—

Unit No. 2300. E.Q.F. 90

	1	2	3	4	5	6	7	8	9	0
0										
9			S	S	S	S	ST			
8		U	U	U						
7									S	S
6				ST						
5										
4									ST	
3		S	S	S						
2										
1										

" S " denotes Spare Lines.
" ST " ,, Service Lines.
" U " ,, Unidirectional Lines.

Each officer is given a record card numbered with the " hundreds " number of the lower bank of a final selector multiple (assuming 200-line final selectors are installed) and inserts the plugs " L," " R " and " M " into the jacks labelled with the corresponding " hundreds " number. Each working line in the bank is tested, commencing with " 11 " and finishing with " 00 " and, in addition, each spare line is tested for receipt of Number Unobtainable tone.

The operating procedure is as follows :—Key 1 on the Test Panel is operated for testing the subscribers' lines on the lower final selector bank. The operation of Key 2 completes the circuit for relay A, which responds to the dialled impulses. One is then dialled and the test final selector steps up to level 1. The depression of Key " R " operates the test final selector rotary magnet once, and the selector wipers are rotated one step to the first contact, *i.e.*, line 11. The earth *via* Key 1, sleeve of " L " jack, and private wire, operates the respective subscriber's K relay, leaving the negative and positive lines clear.

The officer listens before testing, and assuming " 11 " is a working line with no conversation being carried on, it is tested for condenser discharge by depressing the voltmeter key, then the earthing key, and while both these keys are held depressed, the line reversing key is depressed two or three times. By operating the keys in this order the tinkling of the subscriber's bell is eliminated.

The result of the test is recorded in the space " 11 " on the record card. If satisfactory, a tick is inserted, or if otherwise the nature of the fault is shown.

Spare lines are ticked as satisfactory if Number Unobtainable tone is received.

An engaged line, that is one on which a conversation is heard, is assumed to be satisfactory and the card marked accordingly.

On completion of the test on Line 11, key R is again depressed once and the test final selector wipers step to the next contact, *i.e.*, line " 12," which is tested. This procedure is repeated until all lines on the first level have been tested.

The test final selector is released from level 1 by depressing Key Z once, which operates the release magnet. Two is then dialled followed by the depression of Key R once. The test on the second level is then carried out, and so on until all lines on each level have been tested.

As soon as the test on the first 100 lines is completed, the record card is handed to the officer-in-charge of the tests, and a second record card, numbered with the " hundreds " number of the upper bank of the final selector multiple, is handed to the testing officer, who then commences to test as described for the first 100 lines. The only difference is that Key 1 is operated in the reverse direction, thereby connecting the Test Panel to the upper final selector bank. Upon the completion of this test, the Test Panel can be connected to another final selector multiple by transfering the plugs " L," " R " and " M " to the required jacks.

The officer-in-charge of the tests scrutinizes each record card as collected, and all faults are re-tested from the Test Desk and dealt with in the usual manner.

Conclusion.

The new method has the following advantages when compared with the previous practice :—

(*a*) there is no congestion at the main distribution frame;
(*b*) fewer staff are required for the tests;
(*c*) a greater accuracy in testing is obtained;
(*d*) there is no interference with a subscriber who happens to be in conversation;
(*e*) spare lines are tested in addition to working lines.

The approximate time taken to test 100 lines, including spares, is 15 minutes, whereas under the previous method at least twice this time and double the staff would have been required.

At the recent transfer to automatic working of Central Exchange, London, 25 Test Panels were employed, and the whole of the 9300 lines including 3300 spares were tested in one hour.

The Uses of "Seekay Wax"

This range of waxes is manufactured by the chlorinaion of naphthalene. Their outsanding properties are non-inflammability and resistance to attack by insects. In the case of the specimens examined by the Research Branch, the volume resistance is lower than that of paraffin wax, but it is not found that, in either condenser tissue or wire covering impregnation, this results in any marked loss of insulation resistance. In addition to the above uses, the Research Branch's tests indicate that several members of the range merit serious consideration as substitutes for paraffin wax and beeswax when freedom from inflammability is an important factor. Such cases include paper core cable impregnaton and block terminal sealing.

The Replacement of Busy Tone by Verbal Announcement. Trial in the Folkestone Exchange Area

H. WILLIAMS, A.C.G.I., A.M.I.E.E. and W. A. HIBBERD, A.M.I.E.E.

Introduction.

IT is well known that some subscribers and telephone operators have difficulty in distinguishing between the various tones used in an automatic exchange, particularly between the ringing and busy tones. Ringing tone is sometimes mistaken for the busy tone and has led to the called subscriber being rung and, upon answering, receiving dial tone owing to the calling subscriber having replaced his receiver. The mistaking of the busy tone for ringing tone has led to the calling subscriber holding on and thus keeping switches and possibly junctions engaged.

In order to attempt to overcome this difficulty it was proposed to make an experiment in a suitable area, and to replace the busy tone by a robot operator, saying " number engaged," " line engaged," or " engaged," and to replace the ringing tone by a sound record of a bell ringing. After consultation with the Traffic Section, however, it was decided initially to replace only the busy tone by the robot operator and to use the word " engaged." Folkestone exchange area was considered to be a suitable one for the trial for the following reasons :—

(i) It was a self-contained area with main exchange and four satellite exchanges (Hythe, Sandgate, Cheriton and Lyminge).

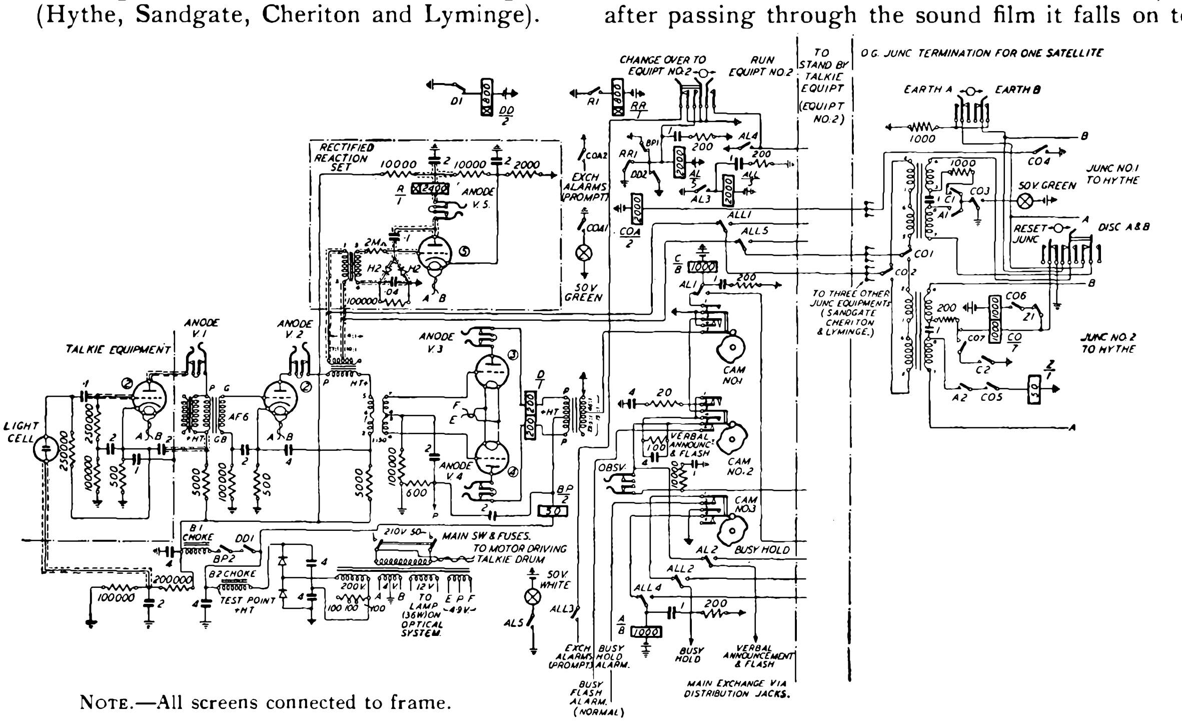
(ii) The average holding time of the switches on busy connexions was abnormally high.

(iii) The distances of the outlying satellite exchanges (Hythe and Lyminge) from the main exchange were representative of many others in the country.

General.

The " voice " used was that of a selected telephone operator and the recording was carried out by Messrs. Associated Sound Film Industries, of Wembley Park, Middlesex, on the sound track of an ordinary motion picture film, using a variable density system of recording.

The " voice " is reproduced from the sound track film which is clamped to the periphery of a circular drum. The drum is rotated by means of an induction motor *via* a spring clutch approximately once every 3 seconds and as its circumference is 54 inches the peripheral speed is approximately 90 feet per minute which is the correct speed for operating the sound track. The film is illuminated through an optical system by means of a 12 volt, 36 watt lamp, the lamp being under-run at a P.D. of 11 volts in order to increase its life. The light, which passes vertically downwards, is focussed on to the sound track, and after passing through the sound film it falls on to a



NOTE.—All screens connected to frame.

FIG. 1.—FOLKESTONE EXCHANGE, NO. 1 TALKIE EQUIPMENT.

photo-electric cell (Osram Type C.M.G.8). The photo-electric cell and the first amplifying valve are housed together in a small screening box to prevent " pick up " troubles. In Fig. 3, which is a rear view of the equipment at the Main Exchange, these are shown on Equipment No. 1 with screening box in position and on Equipment No. 2 with screening box removed.

pull. To avoid the possibility of cross-talk the " voice " voltage is stepped down to a little above normal speech level before being fed to the junctions.

Folkestone Exchange. (Figs 1 and 3).

The output from the power stage is fed to the Folkestone Exchange from the step down transformer *via* cam springs (this transformer replaces the

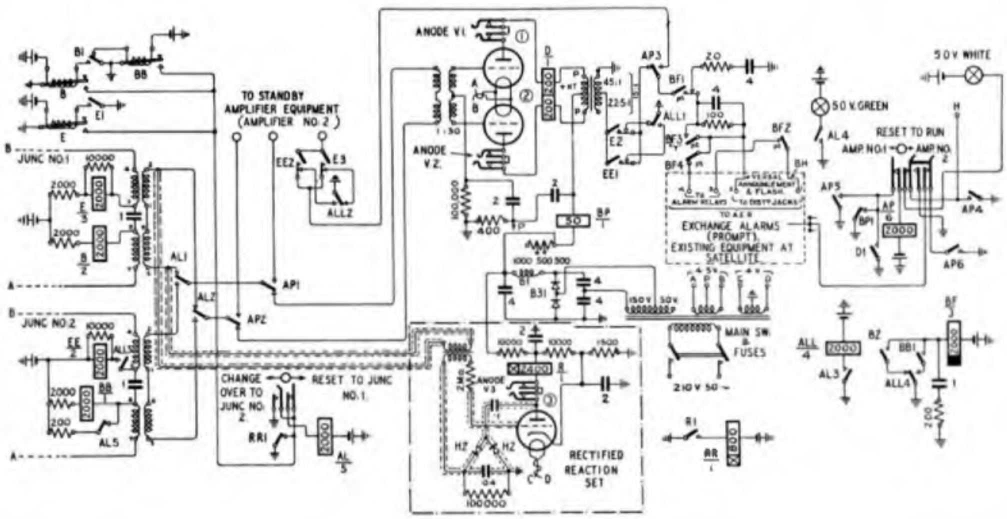


FIG. 2.—JUNCTION EQUIPMENT AND NO. 1 AMPLIFIER, SATELLITE EXCHANGES.

The voltage variations on the photo-electric cell caused by the varying intensity of the light passing through the sound track are impressed on the grid of amplifying valve No. 1. The strength of these variations may be controlled by varying the resistances (250000 ohms, Fig. 1). The input to the grid of amplifying valve No. 1 also can be increased by increasing the intensity of illumination and by increasing the voltage on the light cell.

Owing to the fact that the " voice " is generally fed out to line through the " A " relay, which has a higher impedance to the higher frequencies than to the lower frequencies and owing to the line capacity attenuating the higher frequencies more than the lower ones, the " voice " when heard over a line was " muffled " in character. In order to be able to vary the pitch of the " voice " an inductance has been connected across the primary of the input transformer feeding the grid of the second valve. By drawing the stampings out and so increasing the air gap the equivalent inductance in the anode circuit of valve No. 1 was reduced so that the pitch of the " voice " was raised. In this connexion also, the primary inductance of the input transformer to the power stage at both main and satellite exchanges has been made low. It was considered by several observers, when listening under various line conditions, that a value of 0.3 henry for this inductance was satisfactory.

The output from valve No. 2 is fed to the four junctions in parallel (one to each satellite) by means of a step down transformer and to the primary of the input transformer of the power output stage of the amplifier incorporating valves Nos. 3 and 4 in push

normal busy tone transformer used in the exchange). Cam No. 1 operates springsets for approximately 0.85 seconds every 3.0 seconds and during the 0.85 second period the word " engaged " will be connected *via* springsets on cams Nos. 1 and 2 to the exchange common busy lead. The word " engaged " therefore will be heard by a subscriber once during every 3 seconds period as against hearing the busy

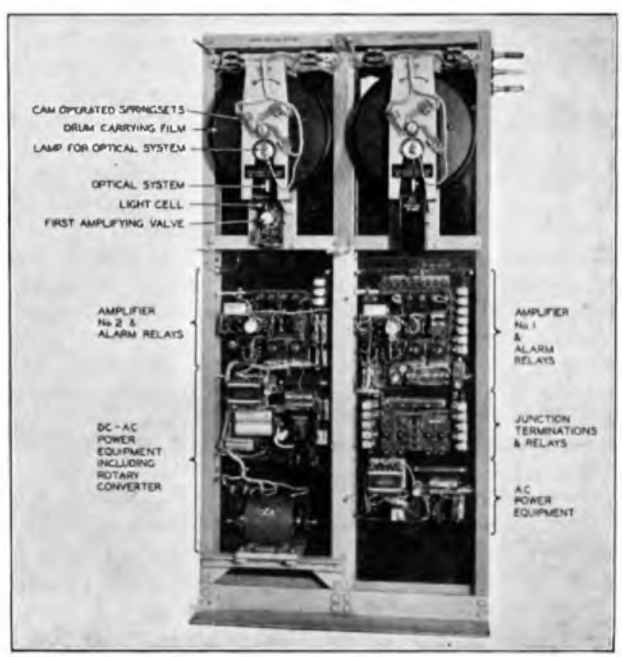


FIG. 3.—MAIN EXCHANGE EQUIPMENT.

tone nominally for 0.75 seconds every 1.5 seconds. In order to give busy flash every 1.5 seconds and to give busy hold conditions it was necessary to fit extra springsets on cam No. 2 and to fit cam No. 3. Cam No. 3 operates springsets for 0.85 seconds and releases the springsets for 0.65 seconds (approximately) continuously. The busy flash signal will be given during the 0.65 second period. Cam No. 3 operates springsets which change over from the verbal announcement to flash conditions, suitable apparatus being incorporated to reduce the click as far as possible and to act as a spark quench. During the 0.85 second silent period (between the two flash periods and 1.5 seconds after the commencement of the announcement period) earth is connected to the exchange verbal announcement and flash lead *via* a springset on cam No. 1.

It was necessary to increase the length of the " voice " period as the sound track used occupies more than a quarter of the circumference of the drum. The actual announcement and flash periods given by the cams at the main exchange are :—

(i) 0.83 second " voice."
(ii) 0.67 ,, flash.
(iii) 0.83 ,, earth.
(iv) 0.67 ,, flash.

At the satellite exchanges there are variations of from 0.82 to 0.9 seconds for the " voice " and " earth " periods and corresponding differences in the flash period due to battery voltage variations (46 to 52 volts) and to differences between individual relays.

Two complete sets of equipment have been provided. Equipment No. 1, which will normally be used, has been designed to run direct off the 210 volts, 50 c.p.s. supply mains; Equipment No. 2 is similar to No. 1 except that a rotary converter has been incorporated (50 volts d.c. to 240 volts 50 cycles/sec.), so that the equipment can be run off the exchange battery. Should the mains power supply fail or certain faults develop in the apparatus, alarm relays will operate, and equipment No. 2 will be started up and switched into circuit.

A test set controlled by the " voice " and operating on the principle of rectified reaction (*P.O.E.E. Journal,* Volume 25 (1932), page 190, " Rectified Reaction," by L. H. Harris) has been included in equipment No. 1 and this has been connected across the output side of valve No. 2. Since the voice sound track heard by a subscriber only occupies about a quarter of the circumference of the drum, the relay R would only be operated during this period. In order to operate the relay when the " voice " is not connected to the exchange the " voice " sound track has been repeated three times and has been equally spaced round the circumference of the drum. During the interval between the end of one " voice " sound track and the beginning of the next, the relay R may release, but the slow to release relay RR will remain operated. Should the lamp on the optical system burn out, the light cell or valves Nos. 1 or 2 fail, relays R and RR will release. Should either valve No. 3 or 4 fail the differential relay D will operate and release the slow to release relay DD : should both valves fail relay BP will release. (A power supply failure would of course be equivalent to failure of all valves, etc., simultaneously.)

The release of one or more of relays RR, BP, DD will operate relay AL; AL3 operating relief relay ALL.

AL4 extends earth to the Power Relay of Equipment No. 2, which operating starts up Rotary Converter, hence, film wheel motor, amplifier, etc.

AL2 changes V.A. and Flash Main Exchange feed over to Equipment No. 2.

ALL2 changes Busy Hold Main Exchange feed over to Equipment No. 2.

ALL1 and ALL5 changes " Voice " output from O.P.M.5 on Equipment No. 1 to Satellite Junction Common, over to Equipment No. 2.

AL1 changes operating lead for relay C from Equipment No. 1, over to Equipment No. 2.

ALL4 changes operating lead for relay A from Equipment No.1, over to Equipment No. 2.

ALL3 extends earth to operate Exchange Alarms.

AL5 extends earth to light equipment alarm lamp (No. 7 white) on side of rack.

As soon as the fault on equipment No. 1 is rectified, the circuit of relay AL will be broken (by the operation of RR1, BP1 or DD2), relays AL and ALL will be released, the exchange connexions automatically will be switched back to equipment No. 1 and equipment No. 2 will be stopped.

A key has been provided which will run equipment No. 2 if required without changing over the exchange from No. 1 or the exchange may be run from equipment No. 2 without operating the exchange alarms. The equipment alarm lamp (No. 7 white) will however be lit.

Should either or both of the power valves (Nos. 3 and 4) fail on equipment No. 1 or No. 2, the H.T. voltage from the rectifier will rise considerably due to decreased load and the increased voltage will probably damage the light cell. In order to prevent this the H.T. supply to the light cell and to valves Nos. 1 and 2 (and to valve No. 5 in the case of equipment No. 1) have been disconnected by contacts DD1 or BP2 in the case of equipment No. 1. In this connexion it was necessary to fit relay DD as a slow to release relay on the contact of relay D, as otherwise interaction was liable to occur between the amplifying valves.

Junctions and Junction Equipment.

The " voice " is fed-out to each satellite exchange over two junctions. The first will normally be used, but, should a fault occur on this junction, junction No. 2 will automatically be brought into use.

As it is essential to synchronise the " voice " with the normal busy tone periods it is necessary to obtain the verbal announcement and flash periods from the cams at the main exchange. This has been arranged as follows :—

Cam Nos. 1 and 3 (Fig. **1**) in addition to other functions already described, operate relays C and A respectively, the contacts of which operate relays E and B (Fig. **2**) at the satellite exchange over junction No. 1 if this junction is in use, or relays EE and BB if junction No. 2 is in use. (Contacts of relay A operate relay B or BB over the A line of the junction, and contacts of relay C operate relays E or EE over the B line of the junction concerned.)

Each junction is terminated with a transformer 48A and in order to allow the signalling arrangement just described a 1 μF condenser has been connected between the two halves of the winding connected to the junction.

Resistances of 1000 ohms in junction No. 1 and 200 ohms in junction No. 2 were introduced into the " B " line between the " C " contact and No. 3 terminal of the transformer in order to reduce the discharge of the 1 μF condenser when contacts of A close before or after contacts of C, since in either case the condenser will have been charged to a PD of 50 volts from the battery at the satellite exchange. Such heavy discharges are known to cause growths on the contacts. The value of this resistance was made as high as possible, but in the case of junction No. 2, the CO relay has to be operated through this resistance and it was not thought desirable to use a value greater than 200 ohms.

Apparatus to test Junction No. 1.

A test set operated by the " voice " and similar to the set at the main exchange has been connected across junctions No. 1 at the satellite exchanges (Fig. **2**) and is run off the power mains in conjunction with amplifier No. 1. The relay R and relief relay RR are normally operated by the "voice " in the same way that the rectified reaction set is operated at the main exchange. Should the " voice " not be received at the satellite exchange due to a short-circuited or disconnected junction or a failure of the talkie equipment at the main exchange relays R and RR will release. Relay AL and its relief relay ALL then operate to change over the connexions of the amplifiers in use at the satellite from junction No. 1 to junction No. 2, and light the green junction alarm lamp on the panel.

The change-over at the main exchange is effected as follows :—

Contact ALL3 at the satellite exchange connects battery through the EE relay coil with 10,000 ohms in shunt to the B line of junction No. 2. At the main exchange relay CO is operated over one of its 1000 ohms coils *via* 200 ohms, the break contact of CO7 to earth through reset key. Once operated this relay locks-up over its other coil. Contacts CO1 and CO2 change over the connexions from junction No. 1 to junction No. 2. Contact CO3 operates and prevents contacts A1 and C1 (in the case of Hythe junction No. 1) from operating relays B and E at the satellite (should the nature of the fault on junction No. 1 allow this) and lights the green alarm lamp particular to that junction. Contact CO4 operates relay COA which lights the green equipment alarm lamp and operates the exchange prompt alarms. Contacts A2 and C2 (in the case of Hythe junction No. 2) now operate relays BB and EE at the satellite exchange, to give the verbal announcement and flash and busy hold conditions, *via* contacts CO5 and 50 ohms coil of relay Z and contact CO7 respectively.

In order to guard against an earth fault on junction No. 1, thermal bimetallic spring sets have been connected to contacts of relays B and E. These thermal spring sets will not operate under normal working conditions (relay B operated approximately 0.85 seconds, released 0.65 seconds continuously and relay E operated 0.85 seconds, released 2.15 seconds continuously), but will be operated if either or both relays are operated by an earth on either one or both junction lines. The operation of either of these thermal spring sets will operate relay AL, etc.

In order to guard against the fuse connected to relays B and E blowing at the satellite exchanges and putting the verbal announcement and flash and busy-hold arrangements out of action until it has been replaced, another thermal spring set has been connected to the back contact of B1 ; this spring set also will not operate under normal conditions, but will operate if relay B is permanently released and will then operate relay AL, etc.

Keys have been arranged at both main and satellite exchanges to reset from junction No. 2 to junction No. 1. To reset the junction from the main exchange, the reset key is thrown which breaks the locking circuit of relay CO and allows it to release, thus changing back the connexions at the main exchange to junction No. 1. The " voice " passing over junction No. 1 will re-operate the rectified reaction set, relays R and RR will operate and relays AL and ALL will be released, changing back the amplifier connexions to junction No. 1 and releasing the exchange alarms.

To reset the junction from the satellite exchange, the reset key is thrown, relays AL and ALL are released, battery is connected to the A line through 200 ohms and the back contact of AL6 (in parallel with 2000 ohms and the BB relay coil) to the A line of junction No. 2. At the main exchange relay **Z** is operated *via* CO5 and during the operated period of relay A and at Z1 disconnects the locking circuit of relay CO, relay CO is released, etc.

For testing purposes keys have been provided at the main exchange which will earth or disconnect the A or B lines of junction No. 1. After restoring the fault key and operating the reset key it is essential to allow a period of at least 30 seconds to elapse before the reset key is restored. This is necessary in order to allow the thermal relays to restore so that relay AL, etc., at the satellite can be released by the operation of relay RR.

At the satellite exchange, if the reset key is thrown in the opposite direction, junction No. 2 can be brought into use by the operation of relay AL. It will, however, light the green alarm lamp on the amplifier panel and the green alarm lamps at the main exchange (due to the operation of relay CO). The main exchange prompt alarm also will be operated.

Satellite Exchanges. (Figs. **2** and **4**).

The operation of relay B over junction No. 1 will operate relay BF or if junction No. 2 is in use operation of relay BB will operate relay BF. The contacts of relay BF in conjunction with the contacts of relay E or EE provide the change-over from verbal announcement to flash and busy hold conditions in a manner similar to that of the cam springs at the main exchange.

In order to reduce the click heard by the subscriber on changing over from V.A. to flash conditions relay

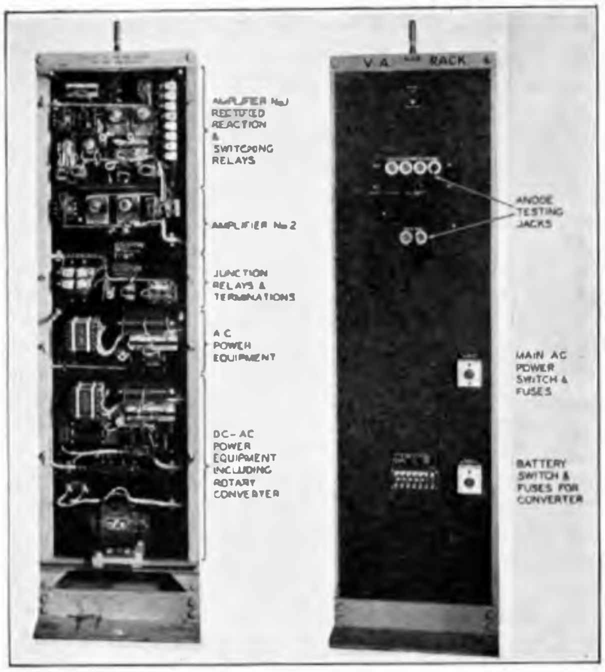


FIG. 4.—SATELLITE EXCHANGE EQUIPMENT.
Rear view. Front view.

BF has been made slow to operate and slow to release. As the spring sets on relay BF must be operated in synchronism with the spring sets on cams Nos. 1 and 2 at the main exchange, cam No. 3 has been given a lead over cam No. 2 to compensate for the operating times of relays B and BF in tandem at the satellite exchanges. Further as the release lag of relay BF is longer than the operating lag, cam No. 3 has been arranged to operate its springsets for a shorter period than cams Nos. 1 and 2 so that the springsets of relay BF and the springsets of cams Nos. 1 and 2 at the main exchange release approximately in synchronism. The release lags of the various BF relays may vary somewhat between themselves and to compensate for this and battery voltage variations, the length of cam No. 3 has been designed to cover the shortest of these operated periods. If therefore the release lags are longer than this the " voice " period will be lengthened and the busy flash period will be shortened accordingly.

Two amplifiers are provided at each satellite exchange. No 1 amplifier has been designed to operate from the 210 volts 50 cycles/sec. supply mains and will normally be used. No. 2 amplifier is similar to No. 1 except that a rotary converter has been incorporated (50 volts D.C. to 240 volts 50 cycles/sec. nominal) so that the equipment can be run off the exchange battery. The amplifiers are similar to the power stage at the main exchange except that VT25 valves have been used. The alarm arrangements, should amplifier No. 1 fail, are also similar to the alarm arrangements on the power stage at the main exchange.

Should valve Nos. 1 or 2 fail the differential relay D will be operated; should both valves burn out relay BP will be released. The operation of relay D or the release of relay BP will operate relay AP which will lock itself *via* AP5 and a normal contact of the reset key. Contacts AP1 and AP2 will change over the connexions from the junction from amplifier No. 1 to amplifier No. 2, contact AP3 changes over the exchange connexions from the output transformer on amplifier No. 1 to the output transformer on amplifier No. 2. Contact AP6 will operate the exchange alarms *via* a normal contact on the " run amplifier No. 2 " key. Contact AP4 operates the power relay associated with standby equipment which starts up the rotary converter for amplifier No. 2, and lights the white alarm lamp on the amplifier panel.

A key has been provided to reset from amplifier No. 2 to amplifier No. 1, this key when operated breaks the locking circuit of relay AP which releases, etc. This key when thrown in the opposite direction starts-up amplifier No. 2 by operating the power relay from an earth on the key.

Fuse Alarms.

At main and satellite exchanges the fuse alarm arrangements are similar to the existing alarms.

Equipment No. 2 at Main Exchanges, Junctions No. 2, and Amplifiers No. 2 at the Satellite Exchanges.

No alarms have been fitted to any of this equipment. Equipment No. 2 at the main exchange may be tested by listening at the observation jack, junctions No. 2 and amplifiers No. 2 at the satellite exchanges by changing over the equipment by throwing the appropriate key and listening on a busy connexion.

Testing Facilities.

At both main and satellite exchanges a break jack has been provided in series with the anode circuit of each valve for checking the anode current.

At the main exchange an observation jack has been fitted on each equipment, this is similar to the busy tone jack normally fitted on the ringer panel.

For testing at the main exchange the verbal announcement from main and satellite exchanges, an ordinary subscriber's line has been terminated on a telephone 162 fitted on the panel. At the satellite exchanges a number within the exchange numbering scheme has been artificially busied. To check that the verbal announcement is satisfactory

(i) from the main exchange equipment, the number allocated to the test telephone is dialled, thus establishing a busy connexion;
(ii) from a particular satellite exchange, the number artificially busied at that particular exchange is dialled.

Relays.

All relays used except the power relays are of the Department's type 3000 and are in standard adjustment.

Conclusions.

The apparatus was installed and tested and brought into use in the Folkestone Exchange Area on 29th April, 1935. Observations to date show that the average holding time has been reduced from approximately 11 seconds to approximately 6.5 seconds, and as far as can be ascertained the change has been received favourably by the subscribers.

A definite saving may thus be effected, but this is probably not so important as the service aspect. It is thought that subscribers will greatly appreciate this effort to help them get the most out of their telephones.

A Combined Cable Drum and Pole Trailer

J. J. EDWARDS, A.C.G.I., B.Sc.(Eng.), A.M.I.E.E.

THE economical handling and transport of cable drums and poles is a problem which has been discussed in the pages of this Journal periodically over a number of years. Various types of trailer have been designed to meet particular needs, but the rapidly changing road conditions and the changing character of the Department's external work have rendered the design of units to meet the majority of conditions a matter of extreme difficulty. The tightening up of road traffic regulations and particularly the compulsion to use pneumatic tyres has introduced new problems, as regards springing, load levels and loading. During the last year or so, however, the issues have become somewhat clearer and it is now apparent that the design of special trailers for town and country conditions must be controlled by entirely different factors. Town conditions tend to the development of specialist or single purpose units whereas the tendency for suburban and rural work is in favour of general purpose units for cable drum and pole handling.

The Department has owned for a number of years a Carrimore Cable drum trailer capable of carrying a 4 ton drum of cable, and a heavy pole trailer with telescopic chassis and a maximum load carrying capacity of 6 tons. These are both single purpose vehicles and were obtained principally for certain large works in the N.E. District. Following the completion of these works it was found that the volume of the work available in any one area was insufficient to keep one of these special purpose vehicles fully employed and the utilization factor was consequently very low. The Engineer-in-Chief's Engineering Transport Efficiency Committee, in examining the requirements for cabling and poling units, speedily came to the conclusion that any vehicle or trailer supplied generally for suburban and rural work should be capable of carrying both cable drums and poles, and of doing so at the maximum permissible speed.

A starting point for the design of a suitable vehicle was found in a light two-wheeled trailer of American origin which used the same chassis, but with different fittings, for poles and cable drums. In the design adopted for experimental purposes, the principle of the American trailer has been retained, but certain variations have been introduced to meet the requirements of British Post Office practice. The design was prepared in detail by Messrs. J. Brockhouse & Co., Ltd., of West Bromwich, to P.O. Specifications, and provides facilities for carrying cable drums up to 7′ 0″ in diameter and 3 tons weight, or poles up to 32 ft. in length and 3 tons total weight.

The trailer is of the two wheeled type with the axle cranked to give a low centre of gravity for the load. The main chassis members are of 4″ × 2″ rolled steel channels with tubular trusses. Quarter elliptic springs are used to mount the frame on disc type wheels with 36″ × 8″ pneumatic tyres. As the load is carried slightly forward of the wheel axle to give stability while travelling and while cabling direct from the trailer, counter-balance weights are provided at the rear of the chassis to reduce the load at the towing hitch and to relieve some of the weight of the drawbar during the cable drum loading operation which is described below. An adjustable telescopic foot under the front of the drawbar takes the weight when the trailer is uncoupled from the towing vehicle.

The Trailer Used as a Cable Drum Carrier.

For use as a cable drum trailer (Fig. 1) the chassis is fitted with heavy cast steel saddles, which are bolted to the main chassis members. The top of each saddle is so shaped as to form two " horns " or hooks, the forward one being fitted with a locking pin, to secure the cable drum spindle in position. The cable drum spindle, which is one of the trailer fittings and not the ordinary stock item, is 2″ square turned down at the ends to suit the hooks of the saddles, and fitted with loose collars and retaining pins for keeping small drums central on the spindle.

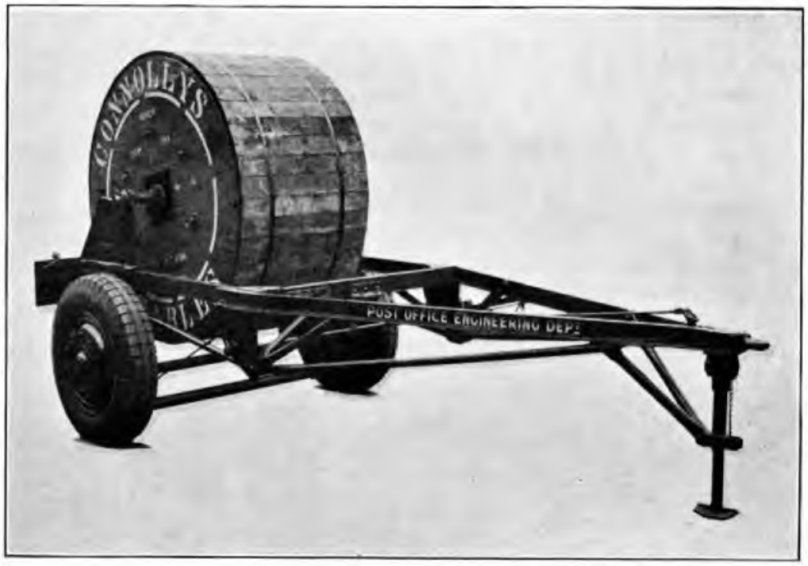


Fig. 1.—Trailer equipped with Saddles for carrying Cable Drums.

FIG. 2.—LOADING A 7′ 0″ DIAMETER CABLE DRUM.

The operation of loading a cable drum is effected as follows:

The locking pins are removed from the saddle hooks and the cable drum spindle passed through the drum to be loaded. The trailer is backed up to the drum and then uncoupled from the towing lorry. One end of a flexible steel wire rope is connected by a standard D shackle to the towing eye of the trailer and the drawbar of the trailer is raised by two men till the balance weights of the trailer rest on the ground (Fig. 2). The drum or trailer is manœuvred until the hooks are over the cable drum spindle ends and the locking pins inserted. With the trailer wheels chocked back and front, the towing lorry (to the towing hitch of which has been coupled the other end of the steel wire rope) is driven very slowly forward, so drawing down the trailer drawbar until the latter comes to a position of balance, when two men at each side take the weight while the lorry backs up to the trailer. The removal of the steel wire rope and chocks and the coupling up of the trailer to the lorry, complete the operation and leave the lorry ready to drive away.

On account of the fixed height of the saddle hooks, the locking pin cannot be inserted when the smaller drums are on the ground and then the rear hook at each side picks up the end of the cable drum sprindle as the trailer drawbar is drawn down by the lorry, and the locking pins are not inserted until the position of balance has been reached and the drum rolled forward from the rear to the front hook.

To unload a drum of cable the operations are reversed, the drawbar being raised to the point where a steel rope connecting trailer and lorry takes the load and the subsequent control is by the lorry backing until the rear of the trailer is on the ground. The remainder of the operation will be apparent from the loading description already given.

Thus loading and unloading operations can be effected quickly and easily without the aid of the hand winches normally necessary on ordinary trailers, and without the aid of jacks to raise the drum from the trailer floor. A still more important point is that the trailer is easily manœuvrable by hand and it can, therefore, be used close up against a footway joint box, as shown in Fig. 3, for cabling to proceed without removing the drum from the trailer. The capital cost of the combination trailer is little more than half that of the Carrimore trailer.

The vehicle mainly used for the transport of cable drums has in the past been the S.D. Freighter. The small wheels, and consequent low platform level, together with the presence of winches has made this a popular vehicle for cabling works, but with recent legislation compelling the use of pneumatic tyres the floor level must be substantially raised and its effectiveness for the class of work much reduced. As a cable drum transporter the combined trailer bids fair to take the place of the S.D. Freighter as well as the single purpose trailer.

For work in congested towns the raising of the drawbar to effect loading and unloading of drums would undoubtedly constitute an obstruction to traffic and an entirely different type of trailer is being developed for such work. It is hoped to describe the "Town Type" cable drum trailer in a later issue of the Journal.

The Trailer Used as a Pole Carrier

When it is desired to use the trailer as a pole

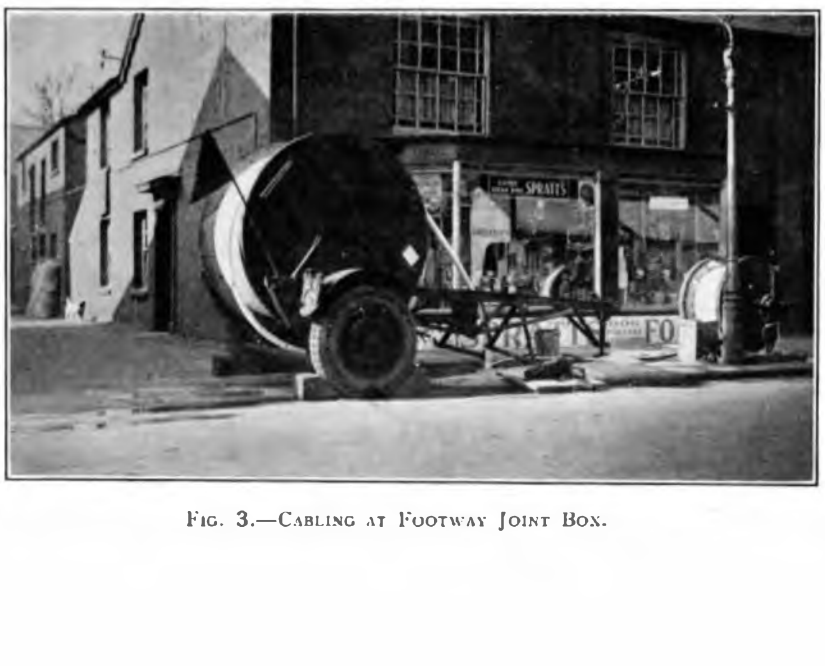


FIG. 3.—CABLING AT FOOTWAY JOINT BOX.

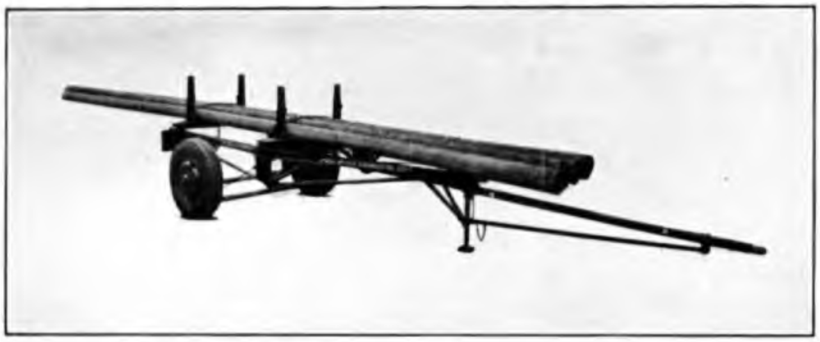


FIG. 4.—TRAILER EQUIPPED WITH BOLSTERS FOR CARRYING POLES.

carrier (see Fig. 4) the conversion takes about 15 minutes. The cable drum saddle bolts are withdrawn, the saddles slid off and pole bolsters, mounted on cross frames, are dropped into position at front and rear of the trailer chassis. The cross frames carry fixed vertical pins which drop into corresponding holes in the frame gusset plates. The bolsters slide on the cross frames and are, therefore, adjustable to the width of the pole load, and they are in addition fitted with chains, tightened by cam levers, to secure the poles.

The length of the trailer as a cable drum carrier is 12′ 0″ from wheel axle to towing eye, and to accommodate the lengths of the poles, which are, of course, loaded with their centres of gravity just forward of the axle, a light, trussed, tubular drawbar extension is added. This drawbar extension is inserted through two collars, one near the towing eye and one under the chassis front cross member and locked at the second of these collars by a pin. With this addition the length from axle to towing eye is increased from 12 ft. to 20 ft. and so poles up to 32 ft. in length may be transported.

Typical pole loads which are within the capacity of the trailer are eleven 32 ft. medium poles or sixteen 26/28 ft. light poles.

As a means of transporting and handling poles, this trailer possesses considerable advantages over existing means. It is very much lighter than the heavy pole trailer referred to in the opening paragraphs and carries a load big enough for all normal requirements at considerably less effective cost. Its initial cost is just about half that of the heavy pole trailer. As compared with the standard W.D. lorries, it can carry a pole load as large as the heaviest lorry (3 ton Albion) and impose an effective load of only 15 cwt. on the towing vehicle, leaving the balance of the vehicle's load capacity and the whole of the body space free to transport men, tools and stores. In addition, side loading and unloading is possible and thus poles can speedily be laid out in a narrow thoroughfare with the men working all the while within the width of the vehicle.

This trailer may be towed by any vehicle of 30 cwt., or greater, load carrying capacity when carrying poles, but when full-sized cable drums (*i.e.*, of 7′ 0″ diameter) are carried, vehicles of lower rating than 2 ton load carrying capacity should not be used, as otherwise there is not sufficient weight in the back of the vehicle to prevent the rear of the lorry being lifted when the trailer drawbar is drawn down in the process of loading a drum. The foregoing assumes, of course, that the load in the vehicle is reduced so that the effective load added by the trailer does not cause the rated load of the vehicle to be exceeded.

The estimated running cost of the trailer is of the order of 2d. a mile, assuming an average of 3,500 miles per annum. The low cost, in addition to the dual nature of the trailer and the advantages it possesses in lightness, manœuvrability and ease of loading, makes this vehicle an attractive proposition, and it is confidently anticipated that the demand will be general and extensive.

Experience with the first experimental trailer has shown the desirability of fitting additional hooks for raising small cable drums, and of increasing the length of the drawbar extension to permit the trailer to carry poles up to 36 ft. in length. An appreciable proportion of poles handled to-day lies between 32 ft. and 36 ft. in length and the utility of the trailer will be improved to a marked degree by the increased dimensions which have been arranged for on the later supplies.

Recent Modifications at Portishead Radio Station

E. POTTS, A.M.I.E.E.

SHORT WAVE TRANSMITTERS

THE third short wave transmitter which has recently been constructed at Portishead Radio Station by the Radio Branch, has been provided to replace the original short wave transmitter which has now become rather out of date in many features. This original transmitter which was first installed in 1927 at Devizes, and was later transferred to Portishead, has been fully described in the P.O.E.E. Journal, Vol. 23, Part 1. When this first transmitter was built, the frequency tolerances allowable were not so rigid as they are at the present day, and the transmitter gave excellent service with the comparatively few ships which were, at that time, equipped with short wave apparatus.

As the merits of short wave radio communication were gradually appreciated by the ships passing their traffic through Portishead, so the volume of traffic on these waves grew, until, in 1931, the first transmitter became unable to handle the increased traffic. A second transmitter, incorporating all the latest improvements, such as crystal control of frequency, was therefore installed and put on traffic early in 1932.

As more and more short wave services were being operated all over the world, the frequency tolerances became rather more stringent than could be met conveniently by the original transmitter. It was therefore decided that, rather than apply crystal control to the old transmitter, a new and completely up-to-date transmitter should be constructed, the old set being retained as an emergency transmitter. This scheme thus would give Portishead two modern crystal controlled transmitters, with an emergency transmitter which could be readily tuned to any of the frequencies used by the two main transmitters.

The design and construction of the third transmitter was therefore put in hand, and it is thought that some of the unique features of this transmitter might be of interest.

Accommodation.

The first problem which was encountered was that of finding a suitable position for the proposed transmitter in the transmitting room of the station. The transmitting room floor space was already fully occupied by four transmitters, a main switchboard, the tuning fork control units for the medium wave transmitters, and the control tables, so that the placing of the transmitter on the floor was ruled out. The only alternatives appeared to be to enlarge the building, close up drastically some of the existing apparatus, or build upwards. After some thought it was finally decided that, from a point of view both of economy and speed, the transmitter should be built on top of the existing No. 2 short wave transmitter. No. 2 transmitter was therefore strengthened, and steel joists were passed across the top of the transmitter and its rectifier, which is built just behind the transmitter, to form the supports for the new transmitter. A wooden platform, complete with staircase and handrails, was then constructed, having as its main supports the rolled steel joists, and a space of about 9" was left between the underside of the wooden floor and the top of the steel joists to allow for a cabling chase. A general view of the two short wave transmitters is given in Fig. 1 and a view of the main transmitting room is shown in Fig. 2.

Having decided upon the location of the transmitter the next step was to get out the necessary design details and drawings. On a service with ships in any part of the world such as Portishead provides, it is imperative that the transmitters shall have adequate power to enable this service to be given consistently. The use of water cooled valves is precluded at Portishead owing to the fact that there is no suitable water supply available, but experience has shown that the No. 2 transmitter, using two silica envelope valves as the final amplifier, has a power output which is quite sufficient to give the service required. Each silica valve is capable of continuously dissipating 2.5 k.w. at the anode so that, allowing for only 50% efficiency, the final amplifier can handle an input of 10 k.w.

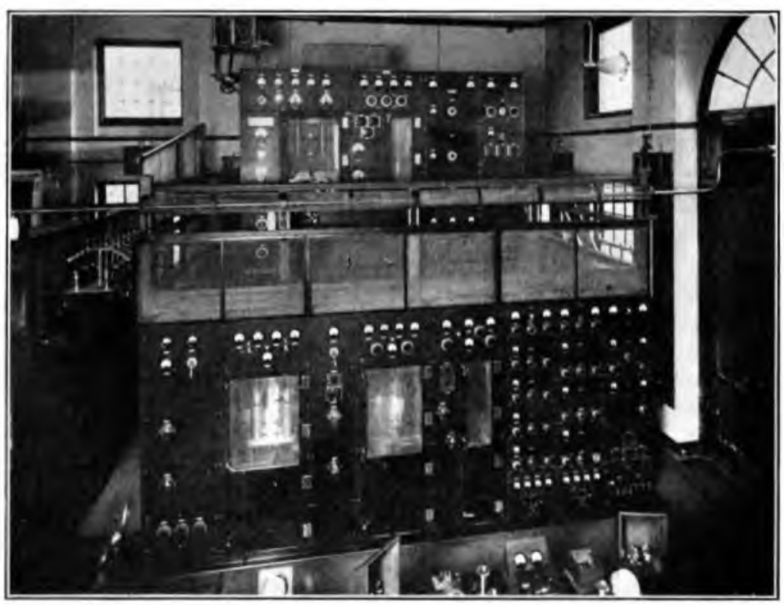


FIG. 1.—SHORT WAVE TRANSMITTERS.

FIG. 2.—MAIN TRANSMITTING ROOM.

Since the new transmitter was to be erected above the existing transmitter, to allow for a gangway round the transmitter, it was obvious that the new transmitter would have to occupy considerably less space than the lower transmitter, and so the next problem arose—how to arrange for the new transmitter to have the same power compressed into a space of about two thirds of that taken by the No. 2 transmitter. This problem was overcome by two drastic modifications, one of which was to eliminate one stage of high frequency amplification, and the second, to cut out a complete frequency control rack. The scheme of frequency control of short wave transmitters constructed by the Department has already been described in the P.O.E.E. Journals, Vol. 24, Parts 2 and 3, and this type of control unit is fitted on the No. 2 transmitter. The scheme is that for a transmitter which is scheduled with three or more working frequencies, at least two frequency control units are provided, each control unit serving for two frequencies. These control units are usually arranged so that they cater for either two frequencies fairly near to each other or two frequencies one of which is nearly twice the other. By this arrangement the tuning condensers in the amplifying and frequency doubling stages can be arranged to cover the two frequencies without any adjustments being necessary to the tuning coils. This feature of the tuning condensers being able to cover the various working frequencies, without change in tuning coil inductance, is extremely important in the case of short wave transmitters where the emitted frequency may have to be changed, perhaps, several times daily, depending upon the time of the day or the distance over which communication is to be effected, and further mention will be made of this feature.

Frequency Control Units.

The wavelengths allocated to the new transmitter were of the order of 18, 24, 36, and possibly 60 metres. In the ordinary way two frequency control units would have been provided, one rack having one amplifying and three frequency doubling stages, dealing with 18 and 36 metres, and one, having one amplifying and two frequency doubling stages, dealing with 24 metres, and possibly 60 metres if, and when, required. The method of operating would then have been that to change from 18 to 24 metres, the racks would have been changed over which is a comparatively simple operation, involving changing over the filament, grid bias, H.T., and high frequency output from one rack to the other, by means of four switches and retuning the various stages if necessary. Should the required change be from 18 to 36 metres the only operations necessary would be to short circuit one stage of frequency doubling and retune the stages. The provision of two frequency control units was ruled out by the space limitations and some thought was given to the provision of at least three and possibly four frequencies on one control unit. The first detail of the frequency control equipment considered was that of the thermostatically controlled oven in which the crystal controlled oscillators were to be fitted. Up to this time it had never been considered a good proposition to fit more that two oscillators in one oven, but, by judiciously modifying the interior arrangement of the oven, it was found to be possible to cater for three oscillators, and it was arranged that, since the 60 metre wavelength was only a seasonal wavelength, the appropriate change could be made to the crystal oscillator when required. A view of the completed oven with the back removed is shown in Fig. 3.

The next detail considered was the design and layout of the amplifier and the two frequency doubling stages. It has been said that it is imperative that the tuning coils of the frequency control unit be suitable for all the frequencies catered for by the unit, in order that the time taken for changing the working wavelength be kept down to an absolute minimum. Since the working frequencies of the new transmitter were so different from each other, it was impossible to arrange for the tuning coil of each stage to be suitable for all frequencies when using the usual variable condensers. Several schemes were therefore considered, such as switching-in additional condensers in parallel with the tuning condensers and retaining the same coil for all frequencies, but the scheme finally decided upon was that of switching on the coils, and either altering the tapping points or short circuiting various numbers of turns of the coils. This process was, of course, necessary in the crystal amplifier and both frequency doublers, so the next point to be decided was how to accomplish the necessary switching having regard to the time taken and the ease of making the change. The final design of the switch consisted of a number of rotating blades

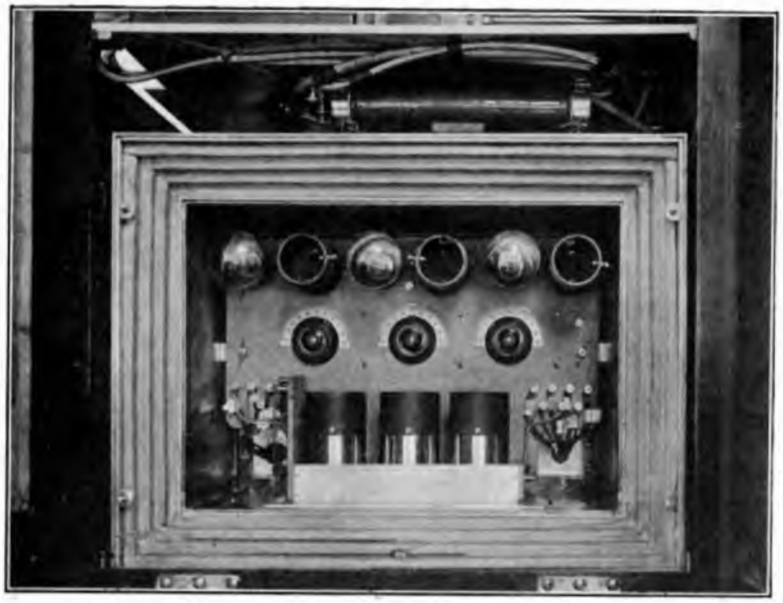


FIG. 3.—THERMOSTATICALLY CONTROLLED OVEN.

situated near the coils concerned, all the blades being controlled by one knob, on the front of the transmitter, *via* worms and wheels. A back view of the frequency control unit showing the switches is shown in Fig. 4.

Having designed a suitable set of switchgear for wavelength change which appeared to be excellent on the drawing board, it was thought that, if satisfactory switching could be accomplished in the frequency control rack, it should be possible to extend it to the main high frequency amplifying stages. This was considered to be well worth while since any means whereby the time taken to change wavelength was decreased or avoided coils being handled, deserved to be explored. The switchgear control system was therefore extended into the first main amplifying stage, so that the wave change switch controlled all stages previous to the final amplifying stage. This constituted a great step forward, for whereas, previously, it had been necessary to change coils by hand in the final frequency doubler and the first main amplifying stage besides, perhaps, changing over the frequency control units, it was now possible to change all coils by means of one knob without opening any gates, touching any coils, or switching any supplies off.

Before leaving the frequency control rack there is one further point of interest which might be observed. It will be noticed from Fig. 1 that the frequency control unit of the No. 2 transmitter (the three narrow racks at the right of the lower transmitter in the figure) has a large number of control handles and dials, whereas the frequency control unit of the new transmitter has only one control handle per stage (the frequency control unit is the second rack from the right). This reduction of controls was made possible by the use of screened grid 75 watt dissipation valves in the unit. The No. 2 transmitter uses triodes in the frequency doubler stages, and the output from these valves is very critical on filament voltage and grid bias, consequently, individual control of these supplies must be fitted. In the case of the new transmitter, where dull emitter screened grid valves are used, it has been found that the output from these valves is not nearly so critical as in the case of the triodes and, as a consequence, the grid bias for each valve was fixed and all the filaments connected across a common pair of bus bars.

H. F. Amplifying Stages.

The design of the frequency control rack, complete with switching, having been dealt with successfully on paper, attention was next turned to the main H.F. amplifying stages. It has been said previously that, in order to keep the overall length of the transmitter down, only two stages of amplification would be used, as against three employed by the No. 2 transmitter. Experience has shown that the excitation to be obtained from a normal frequency control unit is quite sufficient to excite an amplifier taking an input of the order of 300 or 400 watts, but if the rating of the amplifier is raised much above this limit, there is a possibility that the excitation would be insufficient thus leading to rather inefficient working. These facts, therefore, limit the choice of valves and components which could be considered for the first

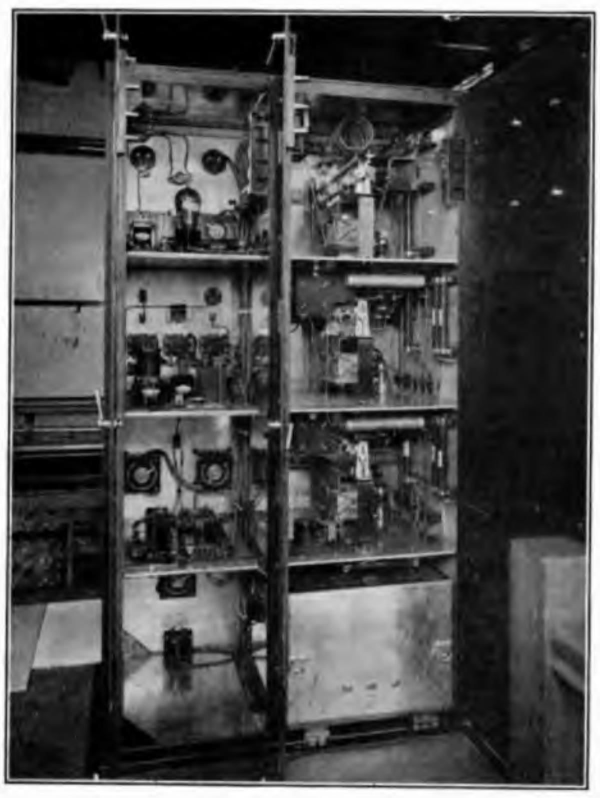


FIG. 4.—FREQUENCY CONTROL UNIT.

amplifier, and it was thought that a repetition of the equipment already in use on the No. 2 transmitter, would prove to be the most satisfactory. The first amplifier stage was therefore designed for a 250 watt + 250 watt glass envelope heptode. This type of valve should not be confused with the popular type of heptode valve now in fairly common use in the latest type of radio receivers. The heptode now being considered is, in effect, a pair of valves working in balanced push-pull having a common filament, the balance being obtained by fitting, near the anode on the side away from the filament a small balancing set of grid wires which are connected directly to the opposite grid, thus providing a fixed balancing capacity equal to the permanent grid anode capacity. This type of valve has been developed by the Post Office engineers and has been described in some detail in the P.O.E.E. Journal, Vol. 24, Part 4. The valve is rated as being able to dissipate 250 watts at each anode, and the amplifying stage is usually referred to as the 2/250 watt stage. The excitation to this stage is taken from the anode tuning coil of the final frequency doubler *via* two fixed blocking condensers, the grid bias being supplied to the centre point of a high frequency choke fitted across the two control grids of the heptode. The anode circuit is a conventional tuned anode with the anode D.C. supply voltage taken to the centre of the tuning coil, the excitation to the final amplifier being taken from the anode *via* two equal variable blocking condensers mechanically coupled. This stage is shown in Fig. 5, in which can be seen the switch for wavelength changing, the tuning coil which covers all wavelengths and the variable condensers. The fixed condenser seen in the foreground is provided for 60 metres when required, and is automatically switched in parallel with the main tuning condenser when the wavelength change switch is in the appropriate position.

When the design of the final amplifying stage came to be considered the first problem was that of providing quick wave change switching so that the time saved in changing the previous stages would not be wasted on changing the final stage. Having arranged for the switching of the frequency control unit and the first main amplifier by means of a single knob, consideration was given to the possibility of coupling further switchgear to the control, to switch the final amplifier tuning coils. There was, however, difficulty in carrying out this scheme, and a switch separately controlled was provided, the principle of which can be seen clearly in Fig. 6 which shows the final amplifying stage. In previous transmitters it has been the practice to change the coil used by unscrewing two fixing screws and inserting the correct coil. This procedure necessarily takes some little time and, in the case of larger coils, two attendants may be necessary for the operation. The switch fitted to this transmitter is operated by a handle fitted to the front of the transmitter and can be operated easily and quickly by one man. The operating handle is first pulled away to disengage the switch contacts on the coils, then rotated until the appropriate coil is in position, and finally let in to

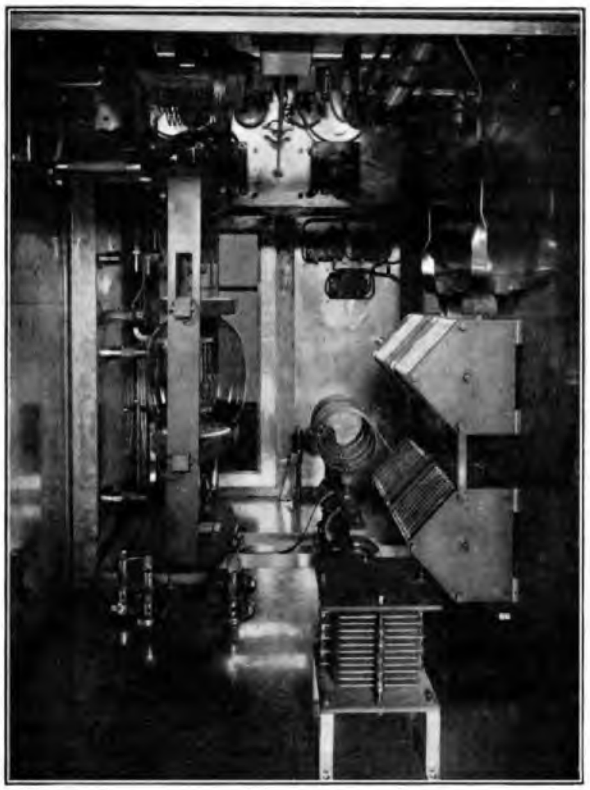


Fig. 5.—1st Amplifying Stage.

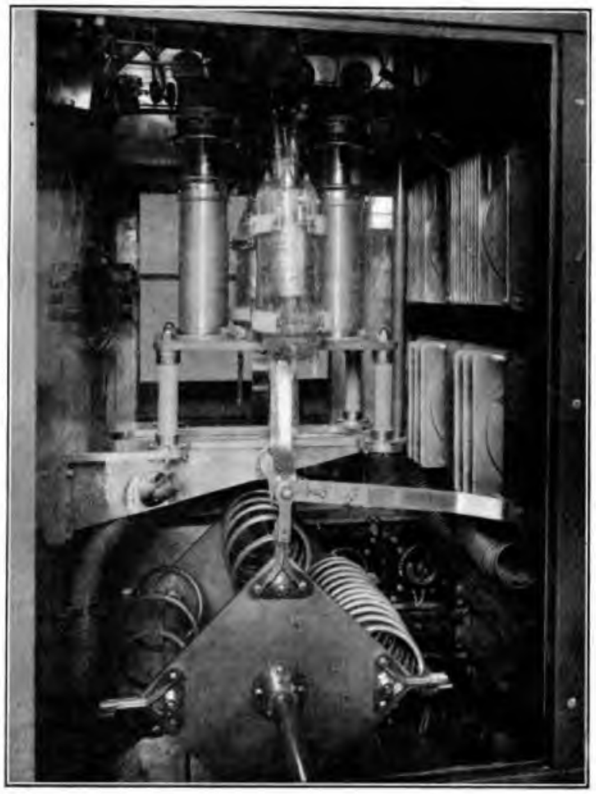


Fig. 6.—Final Amplifying Stage.

engage the switch blade contacts, a stop being provided so that the handle cannot be let in until the coil is in the correct position.

The final amplifier differs in one or two points from the generally accepted idea of a high power, high frequency, amplifier, and therefore may be of interest. The grid excitation from the 2/250 watt stage is applied in the conventional manner to two 2.5 k.w. silica valves arranged in push pull. In addition to the normal grid bias a leak, the function of which will be apparent later, is connected between the centre point of the grid choke and earth. The anode circuit is a parallel tuned circuit, the total tuning capacity being made up of four variable condensers in series, with the aerial load taken across the two inner condensers. In addition to the variable anode tuning condensers, two tubular reaction condensers are provided and can be clearly seen in Fig. **6**. Each of these reaction condensers is connected from the anode of one valve to the grid of the other valve, and they provide an extremely sensitive control of reaction. The reason for these reaction condensers is to obtain more output from the valves than would be possible if the stage were used as a normal class C amplifier. In lining the set up for traffic, the excitation is applied to the last stage in the usual way and the anode circuit tuned, the line coupling condenser being adjusted for optimum coupling. This having been done, the normal grid excitation is removed, and the reaction condensers adjusted until the stage is just oscillating weakly. The excitation is then re-applied and, provided that the reaction is not too great, the frequency of the self oscillation will pull into step with the driving frequency and give a much greater output than with no reaction. This system is employed on both No. 2 and the new transmitter with much success.

Aerial Switching.

Since the Portishead short wave transmitters work with ships in all parts of the world, it is impossible to provide directive aerials for all directions simultaneously with adequate power so a system of zone working has been adopted. This is a system whereby, during certain fixed hours, a preferential service is given to ships in a certain zone of the world, the zones, but not necessarily the working wave-length, being changed about every two hours. This scheme of zone working therefore demands facilities whereby any one of a number of directive arrays may be connected speedily to the transmitter. In the case of the new transmitter provision had to be made for the selection of any one of eight aerial systems. Here again the design of a suitable switch called for considerable thought.

It is usual, in the case of short wave transmitters, to energize the aerials by means of an open, two-wire, transmission line having a characteristic impedance of about 600 ohms. The aerial load is connected to this line by an impedance matching device, in such a manner that the line simulates a line of infinite length, and consequently the current flowing suffers no reflection at the distant end. The elimination of reflection is important because, if reflection exists, power is wasted and moreover the impedance of the line at the transmitter end cannot be calculated with certainty and trouble may be experienced when coupling the transmitter to the transmission line. Should the line constants vary abruptly in any way along their length, reflection will be set up, and it is this fact which makes the switch design a little difficult. The transmission lines are usually built with 200 lb. copper wires spaced 9″ apart, and in designing the switch every effort was made not to disturb unduly the size and spacing of conductors. In addition to this requirement, the insulation of the switch had to be considered, and the complete specification for the switch was (*a*) the spacing of the lines passing through the switch should not depart appreciably from 9″, (*b*) the conductor size should remain 200 lb., (*c*) the switch should be insulated for 3000/4000 volts at radio frequency, (*d*) the switch should be an eight throw double pole switch, (*e*) the switch should be easily operated, and, finally, (*f*) the switch should be capable of being fitted adjacent to the transmitter. The majority of the points enunciated above were successfully covered in the final design adopted which can clearly be seen in Figs. **1** and **2**, and may be compared with the switch fitted to the No. 2 transmitter seen on the extreme left of Fig. **1**.

1000 *c.p.s. Modulation.*

The high frequency carrier output is modulated with a 1000 c.p.s. tone not, as might be imagined, in order that reception might be accomplished without the use of a heterodyne, as in telephony, but to give a slight spread to the carrier. This spread of the carrier is to facilitate reception when otherwise it might be difficult due to selective fading, the symptom of which is that the carrier frequency may be fading badly, but frequencies a little removed from the carrier may be quite steady, and hence receivable in a normal receiver. The low frequency is generated by a small receiving valve working as an oscillator, amplified in two stages up to a power of about 40 watts, and inserted into the grid of the first amplifier by means of a transformer. As the quality of the modulation is not of primary importance this method has proved to be satisfactory.

Due to the last stage being used as a synchronized self oscillator, the keying of the transmitter is carried out by two Creed keys working together at different points in the circuit. One key works in the crystal frequency amplifying stage; on " mark " a normal grid bias of about 40 volts negative is applied to the grid and on " space " the full negative voltage of 600 volts is applied to the grid which is quite sufficient to completely suppress the excitation. The key fitted in the final amplifying stage disconnects the grid lead on " space " and connects it for a " mark," and no trouble has been experienced in synchronizing the keys for hand speed working.

Power Supplies.

The various A.C. and D.C. supplies necessary for the transmitter are all obtained from the 3 phase, 400 volt mains, no rotating machinery being provided. All the filaments are lighted with A.C. *via* transformers. The grid bias supply of 600 volts, 1 ampere, and the intermediate anode voltage supply of 2500 volts, 1 ampere, used for all stages except the final amplifier, are both obtained from Westinghouse metal rectifiers shown in Fig. 7. On the No. 2 transmitter these supplies are obtained from mercury vapour rectifying valve systems, and the rectifiers can be seen to the left of Fig. 7. The metal rectifiers were tried more or less as an experiment, since they have the great advantage of having no moving parts or items requiring renewal and they have proved to be quite satisfactory. The main high tension D.C. supply of 10,000 volts, for the final amplifying valves is obtained from a conventional 3 phase thermionic valve rectifier. This rectifier is shown to the right of Fig. 8, with the No. 2 main rectifier to the left. The D.C. voltage obtained from the rectifier is controlled by an induction regulator wired in the primary supply to the main transformer. The movement of the regulator is controlled by a small switch fitted to the transmitter, and stops have been fitted to the regulator to prevent the D.C. voltage rising above 12,000 volts.

FIG. 7.—POWER SUPPLY RECTIFIERS.

The controls of all supplies to the transmitter are by means of press buttons fitted to the transmitter, so that the whole process of starting up and tuning can be carried out by one attendant from the transmitter.

Once the transmitter is tuned, it is handed over to the operators at Burnham Radio Station for keying since all reception is carried out at Burnham, which is about 30 miles from Portishead, and it is essential that the operator at the receiver is able to reply to the ships at will. Burnham has also been provided with facilities to shut the transmitter down or start it up as an economy measure. The keying and the starting of the transmitter are carried out over one land line by means of specially biased relays.

A block schematic diagram of the transmitter is shown in Fig. 9, in which the various units are arranged in the relative positions they occupy in the front elevation of the transmitter. All working drawings and wiring diagrams were prepared by the Post Office engineers, and Messrs. Radio Instruments Ltd., of Croydon, manufactured the majority of the apparatus, which was afterwards assembled, wired, cabled, and tested by the Post Office staff.

MEDIUM WAVE TRANSMITTERS.

In addition to the short wave transmitters referred to in the foregoing, Portishead is fitted with three medium wave transmitters working on wave-lengths between 2000 and 2500 metres. As in the case of the short wave transmitters, the medium wave transmitters are for communication with ships and are controlled by the receiving station at Burnham, so that the station performs the functions of a normal coast station with a world wide range. There are numerous Post Office coast radio stations situated round the coast of the British Isles, those nearest to Portishead being at Niton, Isle of Wight, Lands End, Valentia, and Fishguard. The Portishead medium wave transmitters differ from the normal 1.5 k.w. coast stations in that the power output and the wave-length are very much higher. The normal wave-lengths used at coast stations are 600 metres for calling, with a traffic wave-length between 600

FIG. 8.—HIGH TENSION RECTIFIERS.

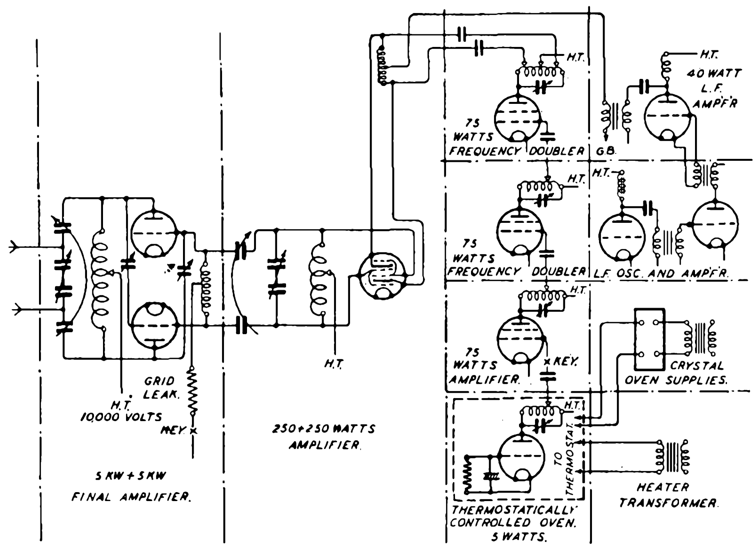


Fig. **9**.—Schematic Arrangement of Circuits.

and 800 metres, and a power output of the order of 1.0 k.w., and the ships worked are always in the vicinity of the coast station.

For some time past it has been obvious that since so much traffic was being cleared on the short wave transmitters, the medium wave transmitters were not being used to their full capacity and attention was given to the problem of giving the transmitters more work to perform. It was finally decided that the coast station at Fishguard be closed down, and the traffic passed *via* a transmitter at Portishead with the complementary receiver at Burnham. This decision meant that one of the medium wave transmitters had to be converted to work on 600 and 625 metres while retaining the original wave-length of 2256 metres, and it was decided that the No. 2 transmitter be modified. This transmitter can be seen in Fig. **2** and is the second transmitter from the left.

Normal Coast Station Working.

Before going further it might be as well to explain the method employed in communicating with ships by means of telegraph signals from coast stations. Two, or in some cases three, different wavelengths are allocated to each coast station between the limits 600-800 metres one of which must be 600 metres, the other wavelengths being distributed to the various stations in such a manner as to cause minimum mutual interference. The 600 metre wavelength is used solely for making contact between the ship and coast station or ship and ship and for distress and navigation warning messages; consequently this wavelength is very congested and liable to severe interference. To overcome the difficulties of working traffic on such a congested wavelength, as soon as contact between the two stations is established a reversion to the working wavelength is made and traffic cleared, and it is essential that this change of wavelength be made very quickly, especially at stations where considerable traffic is handled. At the normal coast stations the receiver and transmitter are housed in the same room, and to change wavelength the operator merely has to throw a switch, but in the case of Portishead now being discussed such a simple method could not be used since the reception was being carried out 30 miles away. Further, to avoid unnecessary interference and to economize in power consumption it is usual to reduce power when working to a ship which is close to the transmitting station, and finally all coast station 600/800 metre transmissions are modulated with a separate distinct note to facilitate reception, but in the case of 2256 metres pure carrier is used to avoid interference with other services. Thus the problem was to provide all the necessary facilities referred to above by some quick method which could be controlled over a land line, and the conditions to be met may be summarized as shown herewith.

Condition 1	2256 metres	Full Power	CW
Condition 2	600 metres	Full Power	CW
Condition 3	600 metres	Full Power	ICW
Condition 4	600 metres	Half Power	CW
Condition 5	600 metres	Half Power	ICW
Condition 6	625 metres	Full Power	CW
Condition 7	625 metres	Full Power	ICW
Condition 8	625 metres	Half Power	CW
Condition 9	625 metres	Half Power	ICW

Further points to be taken into consideration in the design of the switching system were that the power supply to the transmitter must be removed before any switching was done and automatically restored when all switching was finished, and that it should be impossible to key the transmitter until the switching had been completed.

Switching Arrangements.

The standard Post Office automatic dial immediately suggested itself as a convenient means for the operator at Burnham to select whatever condition of the transmitter at Portishead he desired, since it was both quick and neat, and could be easily fitted to the operator's desk. A rough scheme was then worked out in the Radio Branch embodying the points referred to in the foregoing, and in addition, giving the transmitting station facilities for testing out the switch control circuits. Having got out the rough scheme it was realized that, in order to obtain the simplest and most reliable circuits, the final design should be in the hands of experts in automatic switchgear and the matter was therefore referred to the Circuit Laboratory for advice. The laboratory arranged the circuits into the best practical form and set up experimental sets which, after tests, were despatched to Burnham and Portishead. The final circuits fitted are shown in Figs. **10** and **11**, and the equipment is mounted on small racks fitted to the control tables at the stations.

The operations of the equipment may be summarized as follows : To send on 2256 metres at full power the operation of the " Start " key at Burnham energizes a relay which connects a 40 volt negative current to line. The polarized relay LN at Portishead responds to the negative current and energizes T relay which completes a local transmitting circuit. To send on other wave-lengths with different powers the operation of the dial off normal at Burnham energizes the " A" relay and an 80 volt positive current is sent to line to energize G relay at Portishead. The uniselectors at both stations are positioned under control of the associated relays operated by the dialled impulses. The transmitting condition may be verified by means of the lamp signal prepared by the positioning of the uniselector at Burnham. The uniselector at Portishead completes the circuit for the operation of relays associated with the transmitter control relays. The transmitter keying circuit is reconnected to the line at the termination of dialling conditions. By means of " Start-Hold " and

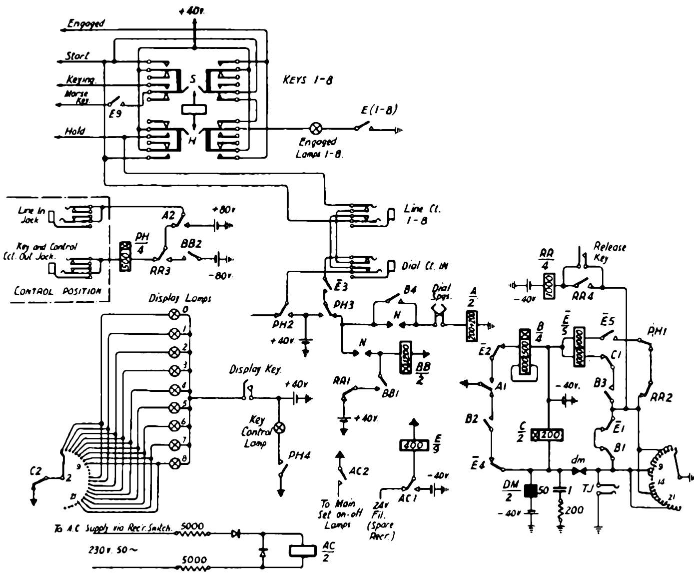


FIG. 10.—CONTROL CIRCUIT, BURNHAM.

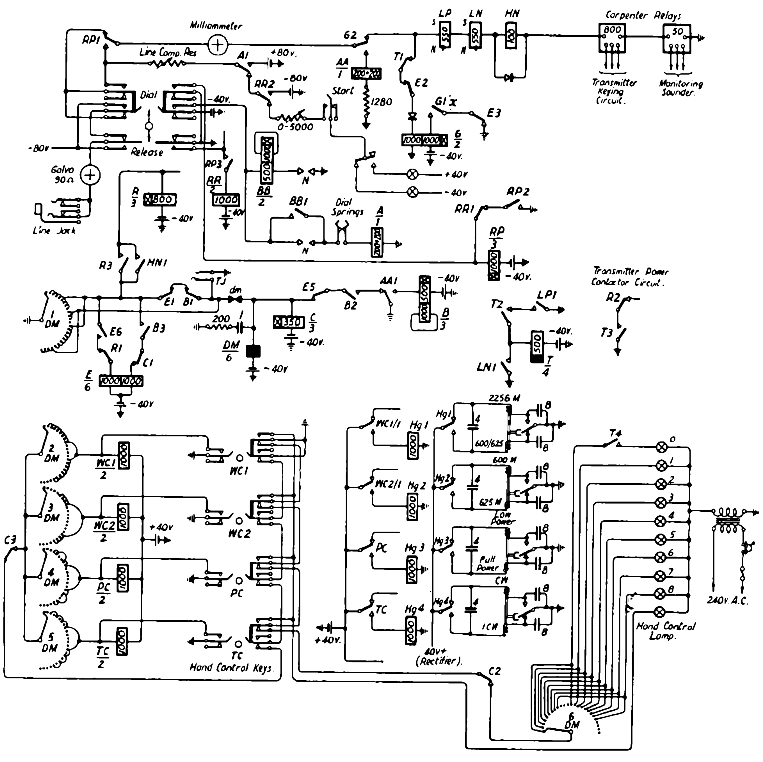


FIG. 11.—CONTROL CIRCUIT, PORTISHEAD.

" Release " keys the operator at Burnham can start and stop the transmitter independently of the relays controlling the dialled condition of the transmitter or can release the whole equipment.

Circuit Operation.

The more detailed operation of the circuit will now be described. The E relay is normally operated via the AC 1 contact, the AC relay being operated from the 230V A.C. mains supply.

To send on 2256 metres at full power, operate key S at Burnham; this allows a light negative current to be sent to line and thus operate the LN relay at Portishead. LN1 operates the T relay and T3 completes the circuit of the local transmitter, while T4 provides a circuit for the 2256 metre display lamp. During " keying," relays LN and LP (polarized) are alternately operated by the spacing and marking currents, thus maintaining relay T.

To send on other wave lengths; throw the key H, after which the appropriate number is dialled. Immediately the dial is taken off normal, A and BB relays at Burnham operate to a 40 volt battery on the hold key; A2 sends a heavy positive current to line and operates G at Portishead. G1 " x " provides a locking circuit for G, and G2 contact disconnects the operating circuit of G, LN, LP and HN relays. AA relay is connected to the incoming line for impulsing, and is operated by the heavy positive current. A1 at Burnham operates B and prepares the display apparatus, while AA1 at Portishead operates B and prepares the control apparatus. Relay A at Burnham responds to the dialling and repeats the impulses at A1 to the uniselector drive magnet, A2 transmitting the heavy positive pulses to line. The A relay is maintained operated by B4 for a short period after dialling to prevent relay AA at Portishead releasing before the Ē relay has operated and thus homing the uniselector.

The operation of the apparatus at Burnham is as follows :—A1 operates C relay continuously during impulsing; after the last impulse C releases and Ē relay operates via C1 normal, B3 operated to earth via wiper No. 1. Ē locks via its other coil, Ē5, PH1, RR2 to earth via wiper No. 1, and Ē2 disconnects B relay. The release of C2 completes the display lamp circuit. It will be seen that relay Ē controls the release of the display and is locked until RR or PH operates. When the control apparatus is to be released the key H is restored and the release key is depressed; this allows RR to operate and lock via RR4. RR2 disconnects the hold circuit of Ē relay and the uniselector homes via the dm. springs, B1, E1 normal to earth via the wiper. When RR operates, RR1 disconnects BB and during the slow release period of BB a heavy negative impulse is applied to line via BB2 and RR3. This impulse allows the release apparatus at Portishead to function.

The heavy positive impulses transmitted to line by A2 at Burnham operate the apparatus at Portishead as follows :—G relay operates and connects AA relay to the incoming line as previously explained. AA then responds to the heavy positive impulses, and at AA1 impulses the uniselector drive magnet according to the digit dialled. C relay is operated during the impulsing but releases after the last impulse, and on releasing allows E to operate via C1 normal. E, on operating, disconnects the hold circuit of G at E3, and G2 on releasing connects the line through for keying. The heavy positive current is maintained on the line for a short period after the release of G2 as previously mentioned, and a rectifier is fitted across relay HN in order to prevent its operation under these circumstances. Keying can then take place as explained for 2256 metres by throwing key S at Burnham.

At the conclusion of dialling, C relay releases and completes the circuits via C2 and C3 for the appropriate lamp display and relays WC1, WC2, PC or TC in accordance with the position of the uniselector.

When the operator desires to release the transmitting apparatus, while still holding the uniselector in position, the operation of key H at Burnham releases relays LN and T at Portishead, which in turn disconnect the local transmitting circuit.

To release the equipment a heavy negative impulse is sent to line from Burnham and operates relay HN at Portishead. HN1 operates relay R, which locks via R3, and R1 disconnects E relay, E1 being normal then allows the drive magnet to home the uniselector.

When Portishead desires to take control for test purposes the dial key is thrown. This connects the Portishead dialling circuit to the selecting and display apparatus, and at the same time connects a heavy negative battery back on the line to Burnham thus operating PH. PH4 completes a circuit for the Key Control lamp, thus indicating to the staff at Burnham that Portishead is testing. Should the Burnham uniselector be off-normal then the operation of PH1 disconnects Ē relay and allows the uniselector to return to its home position.

If the uniselector at Portishead is off-normal the dial key is operated to energize relay RP, then operated to " Release " thus allowing R to operate, lock and return the uniselector to its home position as previously mentioned. On restoring the release key, the dial key is again operated and normal dialling conditions ensue. In addition relay RP operates and locks when the testing dial is taken off-normal and prepares for the release of the control apparatus. RP1 maintains the test circuit until release is affected.

In order to key the transmitter the start key is thrown in addition to the dial key. The release of the local transmitting apparatus while still holding the control apparatus in position, can, if required, be accomplished by restoring the start key.

The solenoid switches shown on Fig. 11 are of a special design and are, in effect, 4 pole 2 position switches suitably insulated for 10,000 volt working. In view of this high working voltage they are of fairly heavy design and require considerable power to operate, and they have been designed so that, as soon as they have operated, the coil energizing current is cut off, the switches being held in position by means of springs.

Since the transmitter to be modified had been working previously on a wavelength of 2256 metres and was now to be made suitable for 600 and 625 metres, the existing tuned circuits and the aerial could not be modified to meet the new demands; the only common components which could be used being the valves. A new aerial was suspended from the top of an existing mast and a complete duplicate system of tuned circuits fitted inside the transmitter, the high frequency switches selecting the particular circuit required by Burnham.

The apparatus has now been in successful operation for several months.

A New "Feed-Back" Repeater

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(of the Dutch P.T.T. Engineering Department)

General.

IN this article a repeater is described which embodies some new principles and which it is thought will be of considerable interest to readers of the Journal. The chief advantage which is claimed is the freedom from fluctuation of amplification due to battery variations, ageing of the valve, etc. To obtain this the "feed back" principle is employed in a manner somewhat similar to that used in the well known Black repeater of the American Telephone and Telegraph Coy.

Description and Theory of Action.

The repeater, which is of the single valve type, has a maximum undistorted output of 50 mW over its frequency range.

The repeater uses a screened grid pentode valve as amplifying element, having a very high amplifying factor, based on the following characteristics :—

Slope of characteristic curve	= 2.5 mA/V
Internal impedance	= approx. 2.0 megohms
Anode voltage	= 220 V
Screen voltage	= ± 130 V
Anode current	= 3 mA
Screen current	= 1.5 mA
Grid voltage	= 2.7 V

In this system the line transformers have been combined with the input and output transformers of the repeater. The screened grid voltage is obtained by tapping the anode feed through resistances and with a valve of the above characteristics an amplification of about 5.6 nepers can be obtained. This degree of amplification is, for most practical purposes, unnecessarily large and could be diminished by means of a potentiometer device. There is, however, a more useful method of accomplishing this, namely, that of "negative back coupling." The principle of normal back coupling, whereby a part of the anode energy passes back to the grid in the same phase as the grid voltage variation is well known. The "negative" back coupling is in principle the same, but is in "counter-phase."

Use of Screened Grid Pentode Valve.

The theory of operation using a screened grid pentode valve is described below.

From the known anode current-grid voltage curve of a valve, at the correct position on the curve for amplification, the slope (S) gives the anode current variation in milliamps for a variation of 1 volt in the grid pressure. S is generally measured in *mA per volt* and is known for a constant anode voltage. With a triode this value S is of relatively small importance, since a valve must be loaded with the impedance across the secondary of the transformer connected in the anode circuit. If an alternating current subsists in the anode circuit, then there is an alternating voltage across this impedance which must be maintained by the battery connected in the anode circuit. It thus follows that the anode voltage in practice is never constant but continually varies with the grid voltage, backwards and forwards, giving the effect of lessening the slope of the characteristic curve.

With a screened grid pentode the slope of the characteristic curve depends on the screened grid voltage. This can be kept constant so that a resistance in the anode circuit does not decrease the slope. The anode current is nearly independent of anode voltage with these valves, but is entirely dependant on the grid and screened grid voltages. The third grid, between the screened grid and the anode, serves to minimize undesired phenomena (secondary emissions from anode or screened grid).

From the above statements it can be deduced that in a screened grid pentode with slope S and with 1 volt alternating pressure on the grid, an anode current of S mA results, independent of the anode resistance R_u.

If the resistance wherein the energy is absorbed be R_u then, per volt of alternating grid pressure, we get a pressure (e_u) of $i \times R_u$ or $\frac{S\,R_u}{1000}$ volts. If for convenience we take S in amperes per volt instead of mA the figure 1000 disappears and $e_u = S\,R_u$ with a grid pressure of 1 volt and thus for a grid pressure e_g volts, $e_u = S\,R_u \times e_g$.

For "voltage amplification" we can take the ratio $\frac{e_u}{e_g}$ which equals $S\,R_u$.

For a given valve this ratio could be increased to any value by chosing a sufficiently large value for R_u. There is, however, a practical limit; in the first place the alternating voltage of the anode $i \times R_u$ will rise steadily with R_u, and in practice this "anode swing" can actually never rise higher than the anode effective voltage, but only approximate to it. In order to keep within limits, i must be chosen smaller and then the output, $R_u\,i^2$, decreases.

The most favourable value of R_u for line repeaters is obtained, since the anode alternating current varies over the whole range of the straight part of the characteristic, when the anode pressure swing reaches at its peaks the normal anode D.C. voltage value. Roughly this happens when

$$R_u = \frac{\text{anode D.C. voltage}}{\text{anode direct current}}$$

for the above valve therefore

$$R_u = \frac{220\text{ V}}{0.003} = 73{,}000\text{ ohms}$$

In the development of this amplifier the anode current swing has been kept smaller in view of the curvature in the characteristic and secondary emission and R_u has therefore been taken at a somewhat higher value—about 120,000 ohms.

The amplification ratio between grid and anode is

$$\frac{e_u}{e_g} = S\,R_u = 0.0025 \times 120{,}000 = 300,$$

In nepers $\log_e \frac{e_u}{e_g} = \log_e 300 = 5.7$.

The greatest undistorted output, which can be delivered into 120,000 ohms, is $\frac{e_u^2}{R_u}$

Now e_u is the effective value of the anode alternating voltage, whose maximum value must not exceed the D.C. anode voltage (220).

Hence e_u must not exceed $\frac{220}{\sqrt{2}} = 155$ v.

and thus $N_u = \frac{155^2}{120{,}000} = 200$ mW, where N_u is the output power.

In practice it happens that before e_u reaches this value a noticeable distortion occurs. It is for this reason desirable to diminish the maximum peaks from 220 V to about 160 V. With 220 V D.C. voltage and 160 volt peak voltage, the smallest value the anode pressure can reach is 66 V. Below this range the working is not ideal, but above it is good.

Hence e_u max $= \frac{160}{\sqrt{2}} = 113$ V

and $N_u = \frac{113^2}{120{,}000} = 100$ mW.

When we enumerate the A.C. voltages and currents which are present in the valve circuits we have

Anode alternating voltage
= 113 V eff, 160 V max.
Anode alternating current
= 0.94 mA eff, 1.3 mA max.
Grid alternating voltage
= 0.375 V eff, 0.53 V max.

where $R_u = 120{,}000$ ohms
and $S = 2.5$ mA/volt

In practice it is necessary to have a transformer in the anode circuit which will transform down from 120,000 ohms to the line impedance. Since the internal resistance of the valve is very high it has no practical closing effect on the line, even when this is transformed up to 120,000 ohms. This closing of the line is definitely desirable and has to be done artificially. It could be effected by transforming the line to a higher impedance, *i.e.*, 240,000 ohms, and by putting in parallel a 240,000 ohms resistance to obtain $R_u = 120{,}000$. In practice, however, a transformer is used with one anode winding and two separate line windings.

The line is connected to one line winding and to the other a resistance of 600 ohms. This is practically equal to 600 ohms directly across the line, but has the advantage that this winding can be used as well for other purposes.

To find the transformer ratio therefore we shall have to take 120,000 ohms and 2 × 600 ohms in parallel and the ratio becomes

$$U = \sqrt{\frac{120{,}000}{300}} = \sqrt{400} = 20.$$

The output transformer has therefore two equal windings of 600 ohms and one winding of 120,000 ohms. In constructing transformers, windings which are joined to very high impedances have a drawback if it is desired to keep the same value of amplification over a wide frequency band. For high frequencies the capacity of the winding soon shows a perceptible shunting effect and for low frequencies another difficulty arises due to the small value of the self inductance. If one transforms to an even higher impedance the effect of the losses at both ends of the frequency range shows up more, so that in effect the range available becomes smaller. With an impedance of 120,000 ohms between 100 c.p.s. and 5000 c.p.s. a more or less flat curve can be obtained. The output transformer is therefore designed for this range. It would be possible to increase the frequency range of the input transformer somewhat, but for simplicity the same type of transformer is used. The second line winding is used for closing the line. If we use an input ratio of 1 : 20 and transform down in the same proportion at the output the ratio of the pressure at the line-output and at the line-input E2/E1 will be just the same as that of e_u/e_g save for the losses in the transformers.

$\log_e$ E2/E1 will be therefore 5.7 nepers (if $S = 2.5$ mA/V).

The closing resistance of 600 ohms at the output absorbs half the output energy, so that at the line terminals at the most about 50 mW can be usefully employed. This value is in close relationship with that of other line amplifiers so that the same level limits (max. measured level + 1.1, max. speech level + 2 neper) can be permitted.

Principle of Negative Back Coupling.

The principle of negative back coupling is as follows :—Suppose we insert in the anode circuit, in series with the anode transformer, a resistance R, then there will flow a current $S.e_g$ through this resistance at an A.C. grid voltage e_g, and the voltage at the terminals of this resistance R will be :

$$e_t = SR.e_g$$

When now this voltage is fed back to the grid in counter phase, so that e_t is in series with the input transformer, the voltage between grid and cathode (e_g) will be the difference of the voltage which the input transformer causes (e_i) and e_t.

i.e., $e_g = e_i - e_t$

or :

$$e_i = e_g + e_t = e_g + SR.e_g = e_g \cdot (1 + SR)$$

In the foregoing we found that the amplification between grid and output (without back coupling) :

$$\frac{e_u}{e_g} = SR_u$$

With back coupling the ratio becomes

$$\frac{e_u}{e_i} = \frac{e_u}{e_g(1 + SR)} = SR_u \cdot \frac{1}{1 + SR}$$

The natural log. of this ratio is the active degree of amplification between the secondary of the input transformer and primary of the output transformer. When these transformers have the same ratio, this is also, except for the losses in the transformers, the degree of amplification between the incoming and outgoing lines. We see that the back coupling gives a degree of amplification which is $\frac{1}{1 + SR}$ lower (in nepers $\log_e (1 + SR)$ lower). For R = 0 the above fraction will be equal to 1 and the degree of amplification will not be influenced, but decreases, as soon as R has a definite value. The influence of R is seen in the table below which is based on a value of S = 0.0025 A/V. The last column gives the attenuation in nepers.

R	1 + SR	$\frac{1}{1 + SR}$	$\log_e (1+SR)$
0	1	1	0
40	1.1	0.9	0.1
400	2	0.5	0.7
4000	11	0.09	2.38
10000	26	0.038	3.25

Advantages of Back Coupling.

The application of a sensible degree of back coupling has several important advantages, viz. :—

(1) The degree of amplification becomes largely independent of normal variations of the voltage of the batteries.

(2) The undesirable phenomena such as battery-noise, cross-talk due to the batteries, etc., harmonics produced by the valve, are reduced in a large measure.

In order to understand this, take as example the fact that S has become smaller through deterioration of the valve, *e.g.* = S (1 − *d*) where *d* represents a small number; without back coupling the degree of amplification would vary (in nepers) by $\log_e (1 - d)$, thus

$$\log_e SR_u (1 - d) = \log_e SR_u + \log_e (1 - d)$$

The last value is negative as 1 − *d* is smaller than 1. For very small values of *d*, $\log_e (1 - d)$ is approximately equal to −*d*. The variation therefore, for *d* = say 0.1, will be = 0.1 neper. If there were a high amount of negative back coupling *e.g.*, so that SR = 10 and 1 + SR = 11, the degree of amplification would become :

$$\log_e SR_u(1 - d) \left[\frac{1}{1 + SR(1 - d)} \right]$$

which can be transposed as follows :

$$\log_e \left[\frac{SR_u}{1 + SR} \right] + \log_e \left[\frac{(1 + SR)(1 - d)}{1 + SR(1 - d)} \right]$$

The first term gives the original degree of amplification, the second term the variation. When we effect the division in the second term, we get for the variation :

$$\log_e \left[1 - \frac{d}{1 + SR(1 - d)} \right]$$

which will be equal to $\frac{d}{1 + SR(1 - d)}$ for small values of *d*. Without back coupling the variation would have been equal to *d*.

From the foregoing it is evident that if *d* is small with respect to 1 and SR, and therefore the denominator great with respect to 1, the variation has become much smaller. For the above mentioned values we find for *d* = .1 a variation *without back coupling* of .1 neper and *with back coupling* (SR = 10) of .01 neper. We see therefore that if the degree of amplification (1 + SR) has been made smaller by the negative back coupling, the variation will be SR times as small. If SR is large in respect to 1 this effect is considerable. In practice this is of great importance. It means that, if we are working with SR = 10, the degree of amplification will not deviate appreciably before the valve is already so old that it must be replaced. For SR = 10 the degree of amplification is expressed by $\log_e (1 + SR) = \log_e 11 = 2.4$ nepers. The full amount of amplification is as stated above 5.7 nepers so that there remains 3.3 nepers as the effective value.

From the foregoing it will be clear that, if the degree of amplification must be reduced, this cannot be done in a better way than by back coupling. The variation of the coupling resistance has moreover the advantage that it is possible to adjust gains over a large range, with only a few variable values. In service we need as far as possible a fixed degree of amplification. If it is possible to obtain this with SR considerably greater than 1, a degree of amplification once adjusted will be kept constant.

Now consider the influence of the back coupling on an undesirable disturbance (noise, cross-talk, harmonics) which is generated in the repeater between the input and output transformer. This can be represented in a repeater without back coupling by a current of *x* amp. through the output resistance R_u.

As soon as we introduce back coupling, this disturbance passes also through the resistance R and gives a voltage of *x*R at the grid. This grid voltage is such that it works against the current *x* in the anode circuit, and thus attenuates the back coupled grid voltage until there is equilibrium. If we express the resultant disturbance by *px* amp. in the anode circuit, as there is equilibrium, an anode current must be furnished from the grid of $-x + px$. The voltage which returns to the grid through back coupling is R*px* volts. This gives an anode current of R*px*S amp. For equilibrium $RpxS = x - px$ and so

$$p(1 + SR)x = x$$

$$p = \frac{1}{1 + SR}$$

The disturbance with back coupling is *px* times that without back coupling, and since *p* is always less than 1 it is evident that the disturbance is attenuated in the same measure as the amplification has been reduced. This means for the values mentioned in the foregoing (SR = 10) that the noises will be 11 times as small and the noise level will be 2.4 nepers lower. This reasoning applies to all types of noise, battery-noise, cross-talk, harmonics, etc., except screened grid disturbances and, in this case, the effect of back coupling is negligible.

There is thus an important gain with this type of repeater with respect to the distortion caused by harmonics. For other noises an improvement is evident in comparison with repeaters having the same gain but without back coupling.

The repeater with screened-grid pentode and negative back coupling has made for progress on the following points :

(1) constant degree of amplification (about 10 times better than the older types, for the same output);
(2) few valve harmonics (about 10 times better than the older type at the same degree of amplification);
(3) simple method of regulation (by means of R).

If we add to this that, with the transformers as designed, we have a flat characteristic for a frequency range of 100-5000 cycles, there is also a gain on band width with respect to the older repeaters.

By applying an impedance, varying with the frequency instead of a pure resistance for R, it is possible to obtain a different effect of back coupling for different frequencies and therefore different frequency characteristics. The repeater can thus be made to compensate for line attenuation distortion.

Construction.

The following principles have been taken as a basis for constructing bays of line repeaters :—

(1) Line transformers will be omitted.
(2) Spring contacts will be avoided as much as possible, which is important in circuits in which small currents are circulating.
(3) The repeaters will be made suitable for valves with A.C. indirectly heated cathodes and will have automatic negative grid bias and back coupling from the anode circuit.
(4) The repeaters will be supplied with an arrangement for automatic compensation of the variations of cable-attenuation with the temperature.
(5) The control will be limited to that of the anode current and to monitoring (level measuring for faults).
(6) The repeaters will be mounted on bays of the normal type and will be made suitable for loaded and unloaded cable conductors and can be used either as through or terminal amplifiers.
(7) In case of faults the repeaters will automatically give a signal to the end of the line if the line is in use for automatic traffic.
(8) The normal number on each bay will be 40.
(9) The external connexions will be in accordance with existing plant.
(10) The transformers, valves, etc., will have adequate manufacturing tolerances in view of the possibility of more than one manufacturer.

Repeater Circuit.

These principles have been incorporated in a repeater, known in Holland as repeater RT type 1. The schematic diagram is given in Fig. 1. It shows the connexions to the in- and output transformers, but these have been omitted for simplicity. The secondary winding of the input transformer has been shunted by a resistance of 1 megohm, which makes it possible to insert a series condenser in order to attenuate the low frequencies to some degree. The

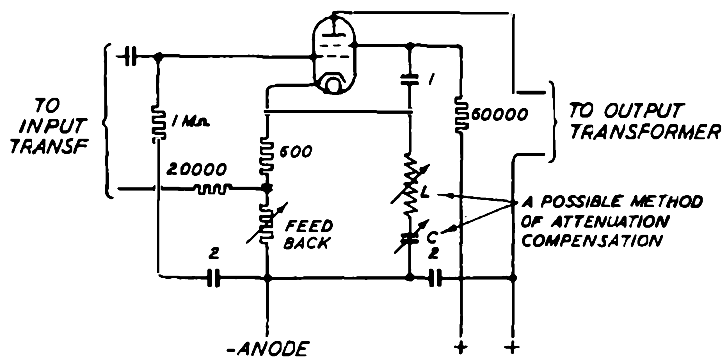


Fig. 1.—Repeater Circuit.

grid is connected to a voltage divider consisting of this condenser and the resistance of 1 megohm. The value of the resistance should be as high as possible, and is fixed at 1 megohm in order to obtain reasonable values for C (of the order of 300 $\mu\mu$F in accordance with the characteristic desired). In series with the voltage across this resistance is the back coupling voltage, which is transmitted from the anode-A.C. to R. The lower terminal of the input transformer is connected *via* a large capacity (2 μF) to earth, and the resistance R which is inserted in the anode and grid circuit connects from there to the cathode.

For the operation of the valve, the voltage between grid and cathode is the deciding factor and this is the difference between the voltage across the resistance of 1 megohm and that across R. The anode A.C. goes from the anode through the output transformer, from there *via* a condenser (2 μF) to earth and *via* R to the cathode. The screened grid is directly connected by a condenser (2 μF) with the cathode, so that the A.C. can pass direct. The D.C. is obtained *via* a high resistance (60000 ohms) from the anode supply. The anode D.C. comes from the anode supply, *via* an anode relay to the transformer. The screened grid current is also fed through that relay for decoupling the screened grid circuit. The position of the back coupling resistance R makes a very simple arrangement, but there is, however, a need for an automatic negative grid bias (D.C.). This is obtained from a fixed part of R (600 ohms) *via* a high impedance (20000 ohms). The minimum value of R for the purpose of regulation is thus 600 ohms. The part of R between the fixed 600 ohms and earth is regulable and formed of resistance values of 50-100-200-400-800-1600-3200-6400 ohms. By a variable connexion different settings in steps of 50 ohms up to a value of 12800 can be obtained, which gives a large adjusting range. Fig. **2** shows a curve of gain plotted against varying values of R.

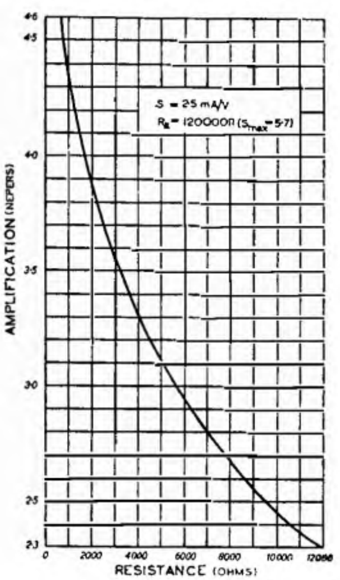


FIG. 2.—AMPLIFICATION/FEED BACK RESISTANCE CHARACTERISTIC.

In order to obtain amplification curves suitable for use with unloaded cable conductors or conductors with heavy loading, it is possible to insert besides the above mentioned correction condenser a series inductance-capacity circuit, shunting the whole resistance R. For the frequency at which L and C are in resonance ($\omega^2 = 1/LC$) this circuit constitutes a short-circuit of R, and therefore also of the 600 ohm for automatic negative grid bias. For that frequency the whole 5.6 neper comes into operation. Out of resonance the short-circuit decreases rapidly and the amplification falls to the value proper to R. In order to obtain a number of differing curvatures, tappings are provided on L (40-35-30-25-20-15-10 mH) and C is built up of four condensers (.08-.06-.04-.02 μF). Resonance can be obtained between 3000 and 40000 cycles with the different values of L and C. If necessary the extent of short-circuiting can be diminished by inserting a resistance in series with L and C (not specially provided in the repeaters) or by placing L and C across a part of R. The anode relay constitutes also a decoupling-choke and forces the anode A.C. to go through the condenser to earth. For the screened grid the resistance of 60000 ohms plays the same role and at the same time stabilizes the fixed screened grid D.C. voltage.

Fig. **3** shows curves of normal and "compensated" gains.

Fig. **4** shows a complete diagram of connexions for one unit. The output transformer has the two line windings, already mentioned. For a through-amplifier the line winding (600 ohm) is connected *via* the frame to the outgoing cable conductor and the centre point, together with that of the adjacent repeater, is brought as a "pair" to the frame for telegraph purposes. The second winding has a resistance of 600 ohm for closing the line. The impedance produced by the internal resistance of the valve is so high, that it may be neglected in comparison with 600 ohm.

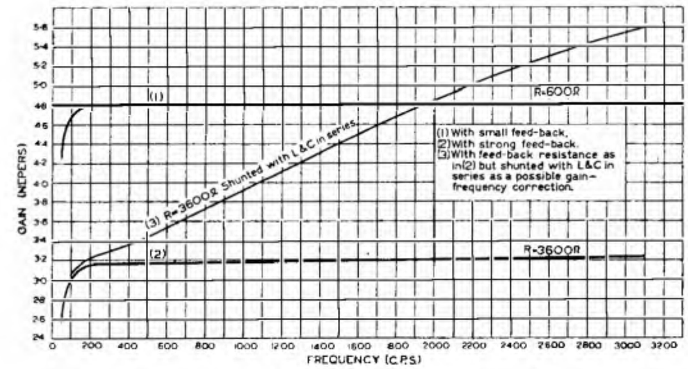


FIG. 3.—GAIN-FREQUENCY CURVES.

The second winding which is equivalent to the secondary of a normal line transformer, is also used for connexion to a jack for listening in and level measuring. At the same time there will circulate through this winding a signalling current when the

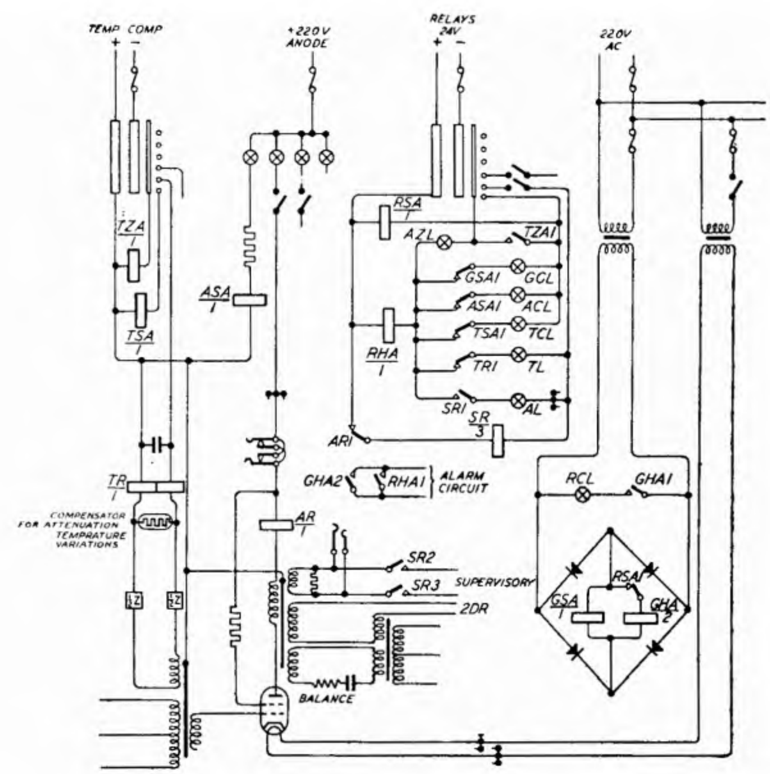


FIG. 4.—FULL CIRCUIT CONNEXIONS.

anode relay (AR) releases and the signalling relay (SR) operates, in the case of automatic operation.

The input transformer has a line winding with centre-tap, which is connected in the same way as the output transformer *via* the frame with cabling to the telegraph frame. The second winding must again be loaded with the line termination. The latter is also used for automatic compensation of the cable attenuation variations with temperature. If the increase of the copper resistance in summer makes the attenuation increase, the termination resistance is automatically raised, so that the voltage, given constant voltage transmitted from the far end, will remain constant. As a method of regulation, the filament of a 30 mA telephone lamp is used, the resistance of which is controlled by a direct current. This lamp serves as a part of the termination resistance, and is in fact a variable resistance. The rest is constituted by two artificial lines $\frac{1}{2}$ Z, which have, together with the lamp resistance at an average adjustment, an impedance equal to that of the cable.

Calculations (see Appendix I) show that with this adjustment the termination impedance changes in such a way that sufficiently exact compensation for the variation of the cable attenuation can be obtained for the whole frequency range. For unloaded cables the artificial lines consist of a combination of resistance and capacities. For loaded cables resistances are usually sufficient if the range used is restricted to the flat part of the attenuation-frequency characteristics. As mentioned the variation of the lamp resistance is obtained by means of a direct current heating of the filament. This current must be supplied *via* impedances which are very high for A.C. and two relay windings, used for the signalling apparatus, have been combined as an inductance coil. In order to prevent cross-talk, the coupling points of these relays are short-circuited for A.C. by means of condensers (2 μF).

Auxiliary Circuits (Fig. **4**).

It has been considered desirable with respect to the mounting, to combine 6 repeaters into one unit, for battery feed, fusing and other similar purposes. A bay of repeaters contains 7 groups of 6 units of which 40 have been designed for normal service with two spare.

(*a*) *Filament current.* The valves are designed for 4 volt A.C. filament current. The groups of 6 are connected in parallel, each group is fed from a separate transformer (sec. 4 volt, prim. 125 or 220 volt). Switches and fuses ($\frac{1}{2}$ A) have been provided in the high-tension side in order to keep the low tension losses low. Seven groups have been provided; together they have one 2 amp. fuse. The fuses have no alarm; the alarm is given by means of the anode relay.

(*b*) *Anode current.* The anode current of each valve reaches the anode *via* the anode relay AR (operating at 2 mA, resistance about 3800 ohm). From there the coupling points for 6 circuits are available *via* measuring plugs (anode and screened grid current are measured together). Each group of 6 is connected *via* a switch and a resistance lamp (110 V – 15 W) with the bay-anode fuse (2 amp.).

(*c*) *Temperature compensation current.* The D.C. feeds the compensation lamps (30 mA – 800 ohm max.) *via* the TR relay (2 × 350 ohm). These relays are connected in groups of 6 in parallel. Each group has a decoupling condenser of 2 μF and is connected to the alarm fuse panel (1.3 amp.) and to the bay-compensation voltage *via* a mains-fuse (2 A).

(*d*) *The relay current.* The relay circuits are fed by a 24 V relay battery or by a rectifier, main fuse 2 A, group alarm fuses (1.3 A). In each group there is a switch in order to make it possible to switch off the appropriate alarms together with the repeaters. The main function of this battery is to furnish the current for the relays SR which operate the anode alarm lamp. The relay battery also furnishes current for the temperature compensation indicating lamps TL (one for each repeater) which are controlled from the TR relay.

The main alarm circuits. The filament voltage alarm relay GSA is connected *via* a rectifier (24 V) and a step down transformer with the general feed for the bay. If relay GSA releases a filament voltage alarm lamp GCL is lighted in series with the relay battery main alarm relay RHA. The relay voltage alarm RSA has a similar function. The relay voltage alarm lamp RCL is fed from the filament battery. The anode voltage alarm relay ASA, when released, lights the anode control lamp ACL *via* relay RHA.

The temperature compensation voltage alarm relay TSA gives an alarm in the same way, *via* a temperature voltage control lamp TCL and relay RHA.

The fuses of the temperature compensation voltage give an alarm, *via* a relay TZA, lamp AZL and relay RHA. This relay TZA has been provided in view of the variable voltage of the temperature compensation.

Construction. For constructional purposes 6 units occupy the breadth of the bay. The principal parts are mounted in panels of 6 of the same type. A repeater group consists of 4 such horizontal panels. The lower row contains 6 input transformers, the second one 6 valves and the accessories shown in Fig. **4**, the third 6 output transformers, the fourth (for terminal repeaters) the second transformer for the forks. The other parts have been brought together as much as possible in groups of the same type. The main fuses and connexion strips have been placed at the top. The bays are double-sided, with the cabling in the middle.

The repeater plates contain three sets of components besides the valves. The lower set comprises the decoupling condensers and the resistances of 1000000, 60000 and 30000 ohms mounted in a condenser box; the middle set, the variable resistances for " R," which are connected to a connexion strip and can be short-circuited as desired, and the upper set, the self-inductance and capacitance for attenuation compensation.

The valves are mounted vertically, which has considerable advantages as regards the electrodes, whilst short connexions and a large degree of latitude for valve dimensions are obtained.

The fact that the potentiometer device is only accessible after having removed the valves has not been found troublesome bearing in mind the large degree of automatic regulation.

APPENDIX I.

Compensation of the Variation of the Cable Attenuation with Temperature.

If Z_0 is the cable impedance at 0°, r_0 the inserted part of the resistance of the lamp at 0° cable-temperature, and c the temperature coefficient of the regulation resistance in the termination impedance of the repeater, then the termination impedance is equal to $Z_0 + r_0ct$.

If Z is the cable impedance and E the E.M.F. at the cable end, then we can calculate the voltage supplied to the repeater from the system shown in Fig. 5.

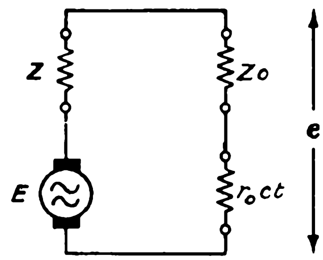


FIG. 5.

The " extra attenuation " is

$$\log_e \frac{E}{2e} = \log_e \frac{E(Z + Z_0 + r_0ct)}{2(Z_0 + 2\,r_0ct)E}$$

$$= \log_e \left(1 + \frac{Z - Z_0 - r_0ct}{2(Z_0 + r_0ct)} \right)$$

(this value contains attenuation and phase retardation as Z can have a phase).

For small values the second term will be :

$$\log_e \frac{E}{2e} = \frac{Z - Z_0 - r_0ct}{2(Z_0 + r_0ct)}$$

If Z is independent of the temperature, then Z_0 will be equal to Z and the second form changes into :

$$\log_e \frac{E}{2e} = \frac{-\,r_0ct}{2(Z_0 + r_0ct)} \quad \ldots\ldots(1)$$

If Z is a function of temperature $= Z(1 + \frac{1}{2}t)$ (see further on) (that means that Z_0 has been chosen $= Z$ at 0°) then :

$$\log_e \frac{E}{2e} = \frac{Z_0t - r_0ct}{2(Z_0 + Z_0\,t + r_0ct)} \quad \ldots\ldots(2)$$

If we substitute in (1) and (2) $\frac{r_0}{Z_0} = p$, then (1) and (2) change respectively into :

$$\log_e \frac{E}{2e} = \frac{-\,pct}{2(1 + pct)} \quad \ldots\ldots(3)$$

$$\text{and } \log_e \frac{E}{2e} = \frac{\frac{1}{2}\,\alpha t - pct}{2(1 + \frac{1}{2}\,\alpha t + pct)} \quad \ldots\ldots(4)$$

If now $\frac{1}{2}\,\alpha t$ and pct are small in comparison with unity

$$(1) \text{ becomes } \log_e \frac{E}{2e} = -\tfrac{1}{2}\,pct \quad \ldots\ldots(5)$$

$$\text{and (2) becomes } \log_e \frac{E}{2e} = \tfrac{1}{2}\,(\tfrac{1}{2}\,\alpha t - pct) \quad \ldots\ldots(6)$$

In (6) $\frac{1}{2}\,\alpha t$ will always be small in comparison with pct (see later), so that (5) may be used in that case as a reasonable approximation. In general pct will indicate both the attenuation and also the phase angle. For the compensation only the real part is important. This can be denoted provisionally as $R(pct)$. The purpose of the compensation is to obtain a constant value of attenuation. If we consider separately (*a*) loaded cables, (*b*) unloaded cables:

(*a*) *Loaded cables.*

The attenuation is almost independent of the frequency over the speech range if the cable is sufficiently lightly loaded; Z is constant and independent of the temperature.

$$\beta l = b = \frac{Rl}{2Z} = \frac{R_0l}{2Z}(1 + \alpha t) = b_0(1 + \alpha t)$$

The total attenuation (with compensation) is :

$$b_0(1 + \alpha t) - \tfrac{1}{2}R(pct)$$

The condition for constant attenuation is

$$b_0\alpha t = R(\tfrac{1}{2}\,pct)$$

as Z is real, $R(\frac{1}{2}\,pct) = \frac{1}{2}\,pct$

$$\therefore \quad b_0\alpha = \tfrac{1}{2}\,pc = \tfrac{1}{2}\,\frac{r_0}{Z_0}\,c$$

$$c = \frac{2\,b_0\alpha\,Z_0}{r_0} = \frac{\alpha R_0 l}{r_0}$$

(*b*) *Unloaded cables.*

$$b = \sqrt{\frac{\omega RC}{2}}\;l$$

$$= b_0\,\sqrt{1 + \alpha t}$$

and is approximately $= b_0(1 + \frac{1}{2}\,\alpha t)$

$$Z = \sqrt{\frac{R}{j\omega C}}$$

$$= Z_0\,\sqrt{1 + \alpha t}$$

and is approximately $= Z_0(1 + \frac{1}{2}\,\alpha t)$

The total attenuation with compensation is

$$b_0(1 + \tfrac{1}{2}\,\alpha t) - R(\tfrac{1}{2}\,pct)$$

The condition for constant attenuation is

$$\tfrac{1}{2}\,b_0\alpha t = R(\tfrac{1}{2}\,pct) = \tfrac{1}{2}\,pct$$

$$\therefore \quad b_0\alpha t = R(pct)$$

$$= R\left(\frac{r_0}{Z_0}\,ct\right)$$

The effect of frequency will be evident if we substitute $l\sqrt{\frac{\omega RC}{2}}$ for b_0 and $\sqrt{\frac{R_0}{j\omega C}}$ for Z_0

$$\alpha tl\sqrt{\frac{\omega RC}{2}} = R\left\{\frac{r_0ct}{\sqrt{\frac{R_0}{j\omega C}}}\right\} = \frac{rct}{\sqrt{\frac{R_0}{2\omega C}}}$$

It is evident that for different values of ω all values can be met if

$$C = \frac{\alpha R_0 l}{2r_0}$$

and that $R(pct) = b_0\alpha t$, that is to say is b_0 times as great as αt; hence neglecting $\frac{1}{2}\,\alpha t$ with respect to $R(pct)$ is permissible at great attenuations.

District Jointing and Fitting Schools

G. B. W. HARRISON, and
F. GUEST

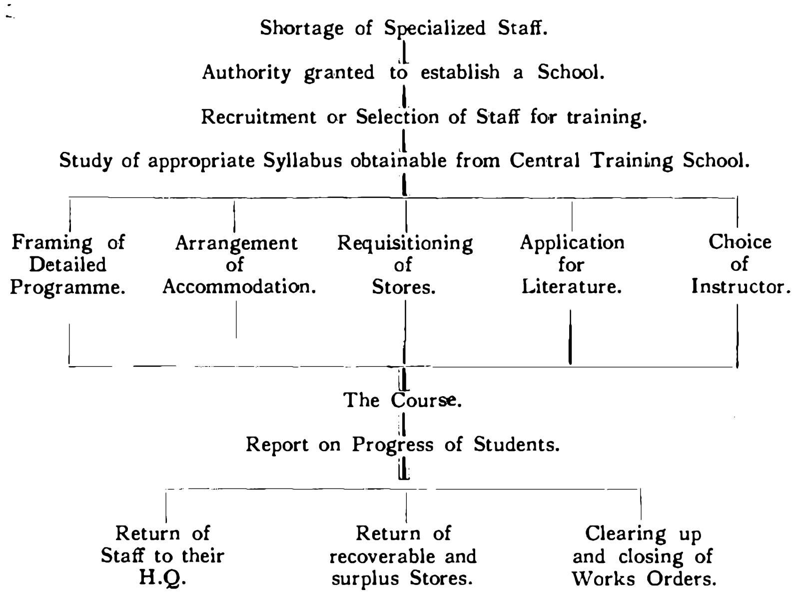
BY now, everyone is acquainted with the effects of the October, 1934, tariff reductions on the absorption of spare plant, but another and probably severer tax on the resources of the Department was the mobilization of adequate staff to cope with the exceptional Engineering demands that resulted. In the District Engineering programmes the 1931 economy measures had taken the form of a summary reduction of the forecasted telephone development, but to cater for the anticipated spurt in development after October, 1934, the original figures were re-instated from that date. In the meanwhile staff recruitment had been arrested and the paucity of external and internal construction work limited the ordinary opportunities for training men in the field. Those most urgently required were :—

(1) Works Supervisors, to watch the Department's interests on schemes being carried out by Contractors.
(2) Plumber-Jointers in sufficient numbers to enable the benefits of underground development planning to be immediately realized.
(3) Fitters.

To satisfy the first need the Central Training School advanced the dates of courses already scheduled and arranged for their early duplication, while deficiencies under the other two headings were met by the organization of District Training Schools. In this connexion Jointing Schools were held in the Eastern Engineering District at Cambridge and Southend-on-Sea, between November, 1934 and March, 1935, and later, during May of this year a Fitting School was established at Southend-on-Sea.

Limitations of staff and accommodation at the Central Training School prohibit their producing " shock " courses to meet a demand as sudden as the one mentioned above. Nevertheless by drawing up detailed syllabuses, lending special stores and acting in an advisory capacity they have made the organization of Regional or District Schools not only possible but easy. Table I shows the progress of a particular course from its origin to consummation.

TABLE I. PROGRESS CHART.



SOUTHEND-ON-SEA JOINTING SCHOOL.

The authors were concerned with the organization of schools conducted on the lines of the Training School syllabus. As this publication treats the matter in considerable detail only the points arising out of its application will be referred to here. The first course to be held in the Southend-on-Sea Section was for Plumbing and Jointing.

Accommodation.

Fig. 1 shows the linesman's room, some 48 ft. × 18 ft., temporarily adapted for use as a lecture room and workshop. The jointing bench built from scrap arms, a plank of wood, and some packing barrels took two men half a day to construct. Fortunately the screen and blackboard, the property of the local centre of the I.P.O.E.E. Junior Section, were kindly

Fig. 1.—Improvised Jointing Bench.

Fig. 2.—Lecture at the Jointing School.

placed at our disposal. No slides of jointing were available at the time but the official jointing film, alas now somewhat dated by the absence of Silica Gel, was shown in the middle of each course both with the idea of giving a perspective view of the art of making a joint and of relieving the monotony inseparable from periods of intensive instruction. The films, obtainable on application to the Central Training School, are actually non-inflammable, but to make assurance doubly sure, large quantities of fire fighting equipment were available, these having been obtained also as a safeguard against the potential incendiary properties of plumbing stores. Except for the latter items the stores and tools not in use were kept in an adjoining room which happened to be available.

Fig. 2 shows one of the daily lectures in progress. These were given during the first fortnight of each course and were rigidly limited to an hour's duration. The walls of the room were partially decorated with cable and conduit diagrams to afford the students an opportunity of familiarizing themselves with the type of drawing to which they would eventually work.

The usual linesman's gas stove was at the disposal of the students for cooking their meals and, there being no domestic hot water in the building, it had also to be used for boiling water for washing purposes. Incidentally it is easy to forget that a jointing school requires a large supply of soap and towels and, although not very useful as practical work, the simplest way to keep the towels clean is by washing them as and when required!

Table II. JOINTERS TRAINING SCHOOL. SOUTHEND-ON-SEA.
DETAILED PROGRAMME.
10/1/35.

	SUBJECT.	a.m. 8—9	9—10	10—11	11—12 p.m.	12—1	2—3	3—4	4—5.30
THURSDAY	Demonstration of making Blowpipe Joint	—							
	Practice making Blowpipe Joint		—						
	Lecture			—					
	Practice making Blowpipe Joints and Jointing*				—	—			
	Practice Plumbing and Jointing*						—	—	
	Making out Requisitions, D. Notes, Diary Pages and Permanent Notes. Study of Schedules of Construction and Maintenance Items (Rg. 71)								—

*50% of Class to be Jointing and 50% Plumbing Simultaneously.

Time Table.

It has been found as a result of experience in the Central Training School that the success of a course depends largely on the formation at the outset of a detailed time table. A sample day's programme is given in Table II. It has been taken from the first fortnight's work, the remaining two weeks being devoted entirely to demonstrations and practical work except for the last half hour of each day which was reserved throughout the course for making out requisitions, diary pages and writing out notes, etc. It cannot be too strongly emphasized that besides covering the syllabus methodically, the time table should specifically allot work for every minute of the day and it can with advantage be displayed in a prominent place, thereby forming an ever present incentive against it being ignored.

Items of Special Interest.

The lecturer was an Inspector, the instructor an S.W.I, and 80% of the students were labourers, some of only a few weeks' service. It may be worthy of a reminder that a special allowance is due to men acting as instructors unless they are Skilled Workmen Class I.

Because of the pressing need for precaution against explosions the pot and ladle method of plumbing was adopted wherever practicable. Demonstrations of the efficacy of a Palladium Chloride Carbon Monoxide indicator were arranged with the assistance of the gas stove and a glass battery jar.

The general introduction of Silica Gel for joint desiccation was contemporary with the opening of the Southend School. Demonstration and practice in the making of this new type of joint were therefore given, delay in the arrival of stores being effectively overcome by the use of Epsom salts. In the later stages of the courses small dry built joint boxes were employed to accustom the pupils to working in the more restricted conditions usually encountered.

Assessment of Students' Attainments.

Constant observation of methods and results provides the best means of gauging skill at practical work. As a stimulus to competitive effort each student's work was initialled and retained for display in an exhibition at the end of the course. In addition, a simple written test in the form of a questionnaire was given. For reporting and record purposes the usual jointing certificate (Form TE 673) was modified to include recent additions to jointing practice, a suitable running record being kept by the instructor, having in mind the eventual completion and issue of these certificates at the end of the course.

Some Reflections on Closing the Jointing School.

The success of a school of this nature can be measured in something other than the percentage of marks awarded for examination results, rather is it measurable in terms of the atmosphere of enthusiasm with which it must of necessity be permeated. This in turn is most likely to be engendered by ensuring that the courses run to schedule and that the stores are always available, although even then it must ever be dependent on the successful choice of an inspiring instructor. Competition has been mentioned already as one desirable incentive to good work and another is the inculcation of a sense of responsibility. An effort in this direction was made by carrying out end to end and pressure tests on a cable consisting of a number of joints made when the whole class were simultaneously engaged on this work. (Fig. 3). It was hoped thereby to emphasize the importance not only of each joint being beyond reproach but also of it being brought speedily to a state of completion so that others concerned are not delayed.

Fig. 3.—Co-ordinated Practical Work.

Although at the outset several students possessed only such experience as can be gained by acting as jointers mates for five or six weeks, at the end of four weeks' training most had attained reasonable proficiency, being by then able to "fetch off" a presentable wipe on a multiple joint and tackle a Progress Report without apprehension. Most would require considerable further experience which, however, should not prove expensive to the Department in labour costs or defective work.

Given the Central Training School syllabus, in the authors' opinion, a month is required in which to make the preliminary arrangements if the School is to open without a hitch.

A Refresher Course on Plumbing by the Pot and Ladle.

Before closing the jointing school, the opportunity was taken of calling up a number of jointers in the Eastern District to confirm their competence in plumbing by the exclusive use of the pot of metal and ladle. Various degrees of skill were encountered, although some of the experienced plumbers showed a conspicuous lack of familiarity with the method. One week's practice was allowed to each man and it is felt that this was an eminently practical attempt to secure the extended use of this very desirable method of plumbing. Incidentally the assembly of so many experienced jointers afforded a timely opportunity for acquainting them with the use of Silica Gel, for, as mentioned above, it was about this time that the general order for its introduction was received.

Southend-on-Sea Fitting School.

Apart from the lack of margin of general fitting staff over recent requirements, consideration of the staff available led to the conclusion that they were not numerically adequate to cope with the prospective U.A.X. programme. Here again the Central Training School had forseen the difficulty and drawn up a comprehensive scheme for the organization of District Subscribers', Exchange, and U.A.X. fitting schools, it being possible to select appropriate parts of the programme to meet local requirements. The first school planned on these lines was held at Southend-on-Sea in the Eastern Engineering District.

Scope of the Course.

The choice of a duration of three weeks for the course was governed by two factors. Firstly, although a period of one week is specified by the syllabus for U.A.X. fitting, an isolated week would undoubtedly prove inadequate because of the ineffective time so often associated with school courses on the days of arrival and departure. This deficiency is further accentuated where it is the first or only course being held and minor hitches may reasonably be expected to occur. Secondly, it was desired to take advantage of the school to train some new recruits in subscribers' apparatus fitting. These two requirements were met by allowing the latter officers to attend during the first two weeks and the men selected for U.A.X. work to attend the whole course. The idea proved entirely effective, as the early part served as a refresher course for the men who, when fitting U.A.X's., will frequently be called upon to fit the auto. apparatus at the subscribers' premises. Again an hour by hour programme was drawn up. This included two half day visits to U.A.X's., the preliminary visit to show what was required and the final one to correlate the week's training with the finished product. For these two visits exchanges differing appreciably in equipment and power plant were selected in order to maintain the students' interest as well as to widen their experience.

Accommodation.

The room available was only 14′ × 25′ which did not afford a high degree of comfort during lectures but otherwise proved adequate. The work bench was a postal " Christmas Pressure " table kindly loaned by the local Head Postmaster and covered with planks to protect its surface. A super-structure was erected to act as a book shelf enabling the students to keep their diagrams, T.I's, etc. out of the way and in a clean condition. An easel had to be constructed to accommodate the blackboard which was borrowed from the Central Training School, the latter also providing a projector and a selection of slides from their copious library. Where time is so limited, a projector is indispensable and a reasonably white wall precludes the necessity of borrowing a screen.

Points of Special Interest.

A point to which reference has already been made —do not rely on the first day as being effective for training purposes, the most you can hope to do is to get to know your students. The rest of the time is taken in travelling to the School and looking for lodgings, addresses of which may with advantage be obtained beforehand.

At the time, Units were very scarce and had to be simulated by wooden frames and appropriate tag blocks. In addition, the general exchange layout was chalked on the floor and the power plant drawn on a piece of three ply. For a subsequent course a complete set of stores could probably be obtained, but having in mind that the object of the course was to teach fitting and not circuit principles and mechanism adjustment, the arrangement was considered satisfactory.

Assessment of Qualifications.

The methods adopted were, broadly speaking, those outlined above in the description of the jointing school.

Conclusion.

The Central Training School have prepared syllabuses which form the basis of comprehensive but flexible District courses on :—

(a) Plumbing and Jointing.
(b) Fitting.
(c) Overhead Construction (Wireman's Course).
(d) Maintenance of Subs Apparatus including P.B.X's.

These syllabuses are intended to be adapted to meet local requirements and are easily interpreted for this purpose. Incidentally the running of the courses is found to be a most interesting and profitable diversion for instructors as well as students.

The very necessity of these District Schools constituted further evidence of the tremendous fillip given to the work of the Engineering Department by the October, 1934 tariff reductions. This Department has again proved what a desirable attribute of a good engineering design is flexibility, by bearing it in mind in the design of its training organisation.

As will no doubt be appreciated, the authors are indebted to the Central Training School for a great deal of detail over and above that given in the syllabuses prepared by that body and to the Research Section Photographic Group for the illustrations of the jointing school. The latter were taken after a visit of Training School representatives collecting information of the results of applying the syllabuses they had compiled.

The Newcastle-on-Tyne New Sorting Office

J. H. ALDERSON, B.A.

THE new Sorting Office, on a site adjacent to the L.N.E.R. Central Railway Station, is nearing completion, and when finished will be one of the best equipped Sorting Offices in the country. The foundations were commenced on March 20th, 1933, and the transfer from the existing office has been arranged for October 26th next; the building will be opened officially on November 6th by Sir Ernest Bennett, the Assistant Postmaster-General.

The Sorting Office has been built on a site, 31,000 square feet in area, at the back of the existing Newcastle Postal Garage. There is no dividing wall between the Garage and the Sorting Office yard, and the vans will be driven straight from the Garage up to the loading platform, a few yards distant, thereby keeping dead mileage down to the absolute minimum. The yard is provided with a sprinkler fire extinguishing system as a precaution against fire. At one end of the garage is the workshop, where all vehicles, both engineering and postal, in the Newcastle area are repaired and overhauled.

A special feature of the new building is the subway connecting the Sorting Office directly with the principal departure and arrival platforms of the railway station. By this means mails are conveyed to and from the station without using the public street.

The present Sorting Office is situated in the Head Post Office block nearly a quarter of a mile from the station, and the vans used for the conveyance of mails between the two points will be replaced by three electric trucks in the subway, thus enabling a substantial financial saving to be made.

As will be seen from the sectional elevation of the building, Fig. 1, there are six floors. The sub-basement occupies only about half the site and is built at such a depth below street level as will give access to the subway, Fig. 2, which is driven at a depth of 8 feet below street level and about 28 feet below platform level. A small loading platform is provided on to which the various chutes deliver the sealed bags of outgoing mail from the Sorting Office floors. The rest of the space will be used principally for the storage of the bags pending the departure time of the trains. The electric truck batteries will be charged by plant installed on this floor. The inward parcel bag conveyor is also installed in the sub-basement to convey the bags, which have been brought along the subway from the station, to the parcel office on the ground floor.

The Electric Supply Co.'s high tension substation, transformers and associated switchgear, and the Department's low tension switchboard are situated in the basement, as is also the boiler room containing the boilers for heating the building and the domestic hot water supply. Storage space is provided and the main portion of the floor will be available as extra sorting space at Christmas time, the electric wiring having been specially arranged to allow higher powered lamps to be fitted.

The ground floor contains the yard, loading platform and parcel office. There is a small public office where the public will be able to hand in parcels; stamp vending machines are fitted in the outside wall.

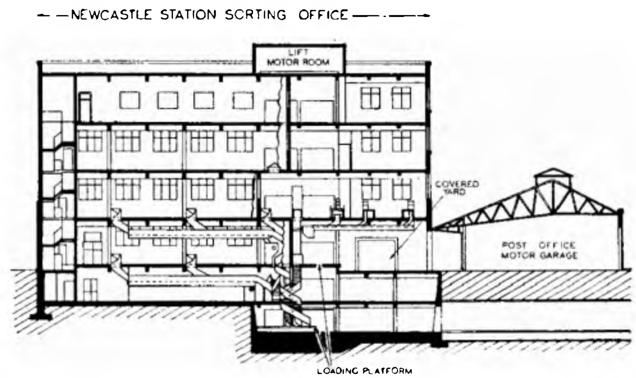


FIG. 1.—SECTIONAL ELEVATION OF SORTING

The Chief Superintendent's room and clerical offices are on the first floor which is mainly occupied by the letter and packet sorting office. The postmen's office is on the second floor, and communication is provided between the two floors by a 2 cwt. service lift for the conveyance of baskets of letters.

The kitchen, dining room and retiring and locker rooms are situated on the third and top floor. The five lift-motor rooms and the water tanks are housed on the flat roof.

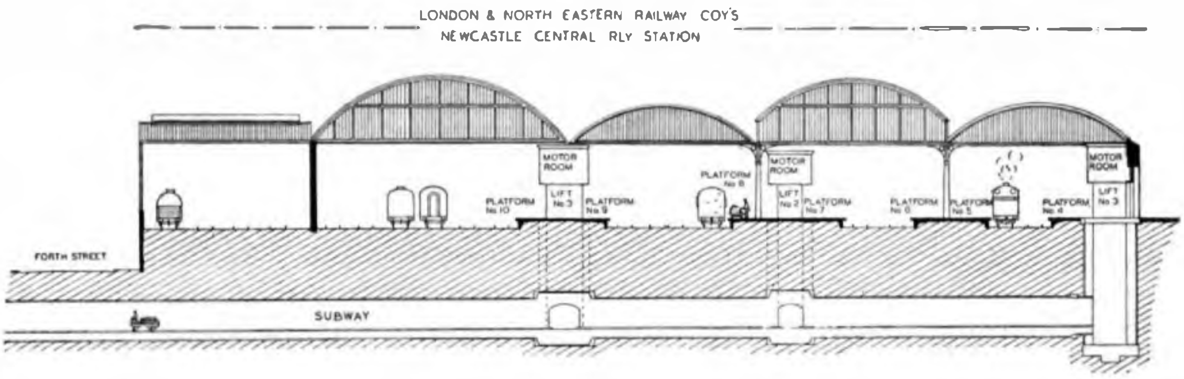
THE SUBWAY.

The subway is 400 feet long, and is lined throughout with cast iron segments, bolted together to form a tube 12′ 6″ in diameter. As a matter of interest, it should be mentioned that the Office of Works were able to place the contract for these castings with a local firm. The roadway is of reinforced concrete with a headroom of 9′ 9″. Access to the platforms is gained by three vertical shafts, each accommodating a lift. The first and third are 17 feet and the second 15 feet in diameter. Lifts 1 and 3 are each of 4 tons capacity and designed to carry two electric trucks, but lift 2 is only of 2 tons capacity, designed to carry one electric truck, as the Railway Company could not allow the Post Office sufficient space for another 4 ton lift on their busiest platform. The shafts of lifts 1 and 2 are reached by short spurs off the main subway and serve the main line platforms, while the remaining shaft is situated at the end of the subway and serves the local platforms. It was not possible for the Railway Co. to agree to the positions of the three lifts being in a straight line drawn from the sorting office, and the subway is therefore not straight, as was originally desired.

The site has proved to be very wet, and special precautions have had to be taken against the ingress of water. Liquid cement has been forced in behind the cast iron lining of the subway, and all joints and bolts have been covered by "Aqualite" sheeting to keep out the water. This covering is heated with a blow lamp and then while plastic is shaped around the joints and bolt heads by hand; it sets hard quickly. A sump has been built at the lowest point of the tunnel and at the bottom of each of the three lift shafts, and a small electrically driven pump is installed near each sump to empty it of any water.

bags to a suitable position under the parcel office floor, whence they are raised to ground floor level by riser conveyor 2 which drops them on to a distributing conveyor in the parcel office. The first four conveyors are designed to run at a speed of 180 feet per minute, the fifth at 90 feet per minute with a maximum load of 2000 lbs. and they are driven by two 4 H.P. motors situated in the basement and sub-basement respectively.

The riser conveyors consist essentially of two bands between which the bags are gripped and raised to the higher level. The upper band has corrugations in the



OFFICE AND RAILWAY STATION.

CONVEYORS.

1. *Inward Parcel Bag Conveyor System.*

This consists of five conveyors and is provided to raise the bags from the sub-basement up to the parcel office on the ground floor. Two riser conveyors, of a special type patented by Messrs. Sovex, of London, the contractor who manufactured and installed the whole installation, are provided to raise the bags vertically through the two floors. The bags are loaded on to conveyor 1, and raised up to basement level by riser conveyor 1. Conveyor 2 conveys the

form of pockets sewn on to it at short intervals into which are placed cast-iron bars a few inches shorter than the band. The ends of each corrugation are then rivetted to the band to prevent the bars slipping out. In this way the upper band is weighted sufficiently to grip the bags without crushing their contents.

2. *Outward Bag Conveyors.*

Two outward bag conveyors are provided, one in the basement for the parcel bags, the other for the letter bags, being suspended from the ground floor ceiling. The bags are dropped into special loading cabinets in the floor built over chutes which deliver the bags onto the conveyor. At the delivery point of each chute a shock absorber of Sorbo rubber is provided under the band to prevent damage to the contents of the bags. The conveyors deliver the bags on to spiral chutes terminating on the loading platform in the sub-basement. On the ground floor two additional loading cabinets are provided opening on to chutes which convey the bags direct to the sub-basement. The parcel bag conveyor is driven by a 2 H.P. motor and the letter bag conveyor by a 1½ H.P. motor. Both are designed to run at 180 feet per minute and carry a maximum load of 1500 lbs.

The width of the bands of the parcel bag conveyors is 36″ and the letter bag conveyor 32″. Dust traps are fixed under the conveyors and consist of a brush held in contact with the band inside a sheet metal box which collects the dust.

FIG. 2.—END OF TUNNEL IN COURSE OF CONSTRUCTION.

3. *Packet Conveyor and associated Conveyors.*

The main packet conveyor is suspended from the ground floor ceiling and is provided to convey the packets from the bag opening tables and stamping tables to the other side of the letter office where they are sorted. A third riser conveyor is provided to raise the packets from below floor level and deliver them into trolleys, whence they are removed to the sorting positions. The two stamping table conveyors are driven by gearing from the packet conveyor beneath the floor which in turn is driven by a 5 H.P. motor. The packet conveyor runs at 180 feet per minute.

A catwalk has been provided, suspended from the ceiling, running along the whole length of the packet conveyor. This will be used by the workmen for the oiling of bearings, etc., and for the periodical inspection of the conveyor to see that no packets have been held up at any point.

The facing table conveyor consists of two bands 10″ wide driven at 30 feet per minute by a 1 H.P. motor. Letters are conveyed to one end of the table by the upper band, while the lower band discharges the packets on to one of the packet stamping tables. Any large letters are placed in a rack above the conveyor bands to be dealt with separately.

There are two bag opening tables each provided with two bands 12″ width driven at 30 feet per minute by a ½ H.P. motor. Letters and packets are dealt with on the facing table conveyor, and any parcels coming in the bags from the sub-offices are kept separate and dispatched for sorting down to the ground floor *via* a spiral chute between the two floors.

The bag and packet conveyors are provided with both local and remote control push buttons for starting and stopping. A change-over switch is fitted on the motor controller in the motor enclosures, allowing one or other set of push buttons to be in use at once, *i.e.,* the conveyors can be operated from the motor enclosures for testing purposes, or from the loading positions by the postal staff under ordinary working conditions.

Lifts.

The lift installation comprises nine lifts, six in the Sorting Office itself and three in the station. The contract for this work was obtained by Messrs. Wadsworth, of Bolton, Lancs.

1. *Sorting Office.*

The building is served by four 2-ton lifts and a 1-ton lift in addition to the 2-cwt. service lift mentioned previously. The 2-ton lifts are situated in pairs at both ends of the side of the building facing the station and are used for bringing the letter bags up to the 1st floor and for general passenger and goods purposes. The 1-ton lift is used mainly by the postmen and office staff in the building.

All the lifts are provided, on both car and balance weight, with safety gear of the cam type which is brought into operation if the ropes break or the fastenings become loose. In addition an emergency handle is provided in the car to stop the lift at any time should it get out of control. This is necessary as the efficiency of the worm gearing is so high that it is not self-sustaining; in fact with full load in the car, the lift may accelerate from rest. The operation of the emergency gear breaks the motor circuit and brings in the emergency brake. Each lift is fitted with limit switches, operating in the same way as the emergency gear, which automatically bring the car to rest 8″ to 10″ beyond the top and bottom landings and prevent it running to the bottom of the lift well or into the lifting gear. A further safety precaution is the overspeed governor which brings in the safety gear if the speed of the lift rises more than a certain amount above normal.

The 1-ton lift is provided with car switch control only, but the 2-ton lifts have dual purpose control, by means of which the lift can be operated automatically or by an attendant. When automatically operated the lift can be called by the landing pushes, but when the attendant is in charge the landing pushes are arranged to ring a buzzer in the car. Either system of operation is obtainable by means of a change-over switch in the car. A special floor-levelling device is fitted on these lifts to ensure that the cage comes to rest within ½″ of the landing level.

The 1-ton lift is driven by a 17.5 H.P. motor, the 2-ton lifts by 35 H.P. motors, all being of the A.C. commutator variable speed type. In this type of motor the two ends of the stator windings terminate on brushes on two sets of brush rings which can be rotated in opposite directions, thereby altering the electrical separation on the commutator and varying the speed. An auxiliary ¾ H.P. motor is used for rotating the brushes, and the control is so arranged that the motor always brings the brushes back to the starting position before the main motor can start. The maximum running speed of the lifts is 200 feet per minute and a very smooth acceleration is obtained.

2. *Station Lifts.*

Lifts 1 and 3 are driven by 50 H.P. motors, lift 2 by a 25 H.P. motor. The motors are similar to those in the Sorting Office and the maximum speed is 150 feet per minute; ½″ floor-levelling is provided. The lifts are push button controlled, " UP," " DOWN " and " STOP " buttons being provided in the car and on the landings. Special double leaved gates are provided on the landings and car for the 4-ton lifts.

The station lifts are provided with steel cars, those of the larger lifts weighing 3 tons, the other weighing 44 cwts. The ropes on lifts 1 and 3 are arranged double purchase to reduce the strain on them by half and enable fewer ropes to be used. Instead of being fastened to the car and balance weight, they pass over pulleys on both and are terminated on the motor room structure.

The power supply is brought into the motor rooms by means of .12 sq. in. 3 core P.I.L.C. single wire armoured cable. The three cables from the L.T. switchboard are brought along the subway and supported on brackets from the highest point of the ceiling.

In addition to the usual safety devices previously described, it was thought necessary to provide the car gates with electro-mechanical gate locks to prevent the gates being opened from the inside except when the car is opposite a landing. These are not provided in the Sorting Office lifts as the lift wells are rectangular and the walls close to the cage, but the station lift shafts are circular in cross-section, and in mid-travel there is a considerable gap between the cage and the side of the shaft.

Electric Trucks.

Three Greenbat trucks driven by " NIFE " nickel-iron batteries of 250 ampere-hours capacity, are provided for the service in the subway. Two 4½ kW motor-generator sets are installed in the sub-basement for charging purposes. The nickel-iron batteries are more expensive than ordinary secondary cells, but are more robust and will stand up to rough usage better.

Electricity Supply.

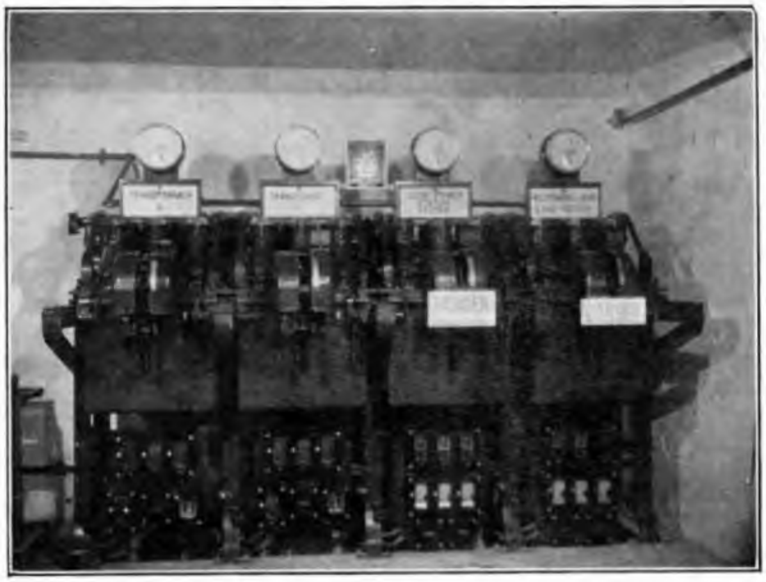


Fig. 4.—Supply Company's H.T. Switchgear.

The Sorting Office is supplied from a 6000 volt 3-phase ring main by the Newcastle and District Electric Lighting Co. The main is fed from a sub-station on each side of the office, and a duplicate supply is therefore available. Duplicate 400 kVA transformers, Fig. 3, are provided to transform the H.T. supply down to 440/250 volts for use in the building. The frequency of supply is at present 40 cycles per second and is due to be changed to 50 cycles per second some time in the future. It has therefore been necessary to provide plant capable of operating at both frequencies. The small motors are of the 40/50 cycle interfrequency type and straight 50 cycle machines have been provided for the eight large lifts in conjunction with auto-transformers which step the line voltage down from 440 volts to 380 volts. This results in a slight loss of speed and increase in current on 40 cycles. It will, of course, be necessary to fit smaller driving wheels on the conveyor motors when the change takes place.

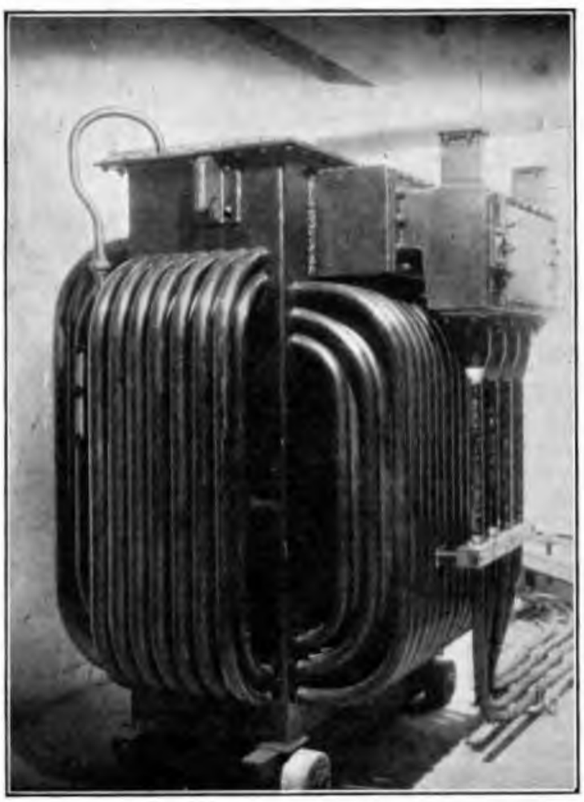


Fig. 3.—One of the two 6000 volt Supply Transformers.

The high tension switching arrangements are carried out by four Reyrolle 6,600 volts 300 amperes iron-clad oil-immersed triple pole circuit-breakers, Fig. 4, the property of the Supply Co.

The various services in the building are controlled from an angle-iron frame totally enclosed L.T. switchboard constructed and erected by the Department; all the ironwork for the board was made in the Department's workshops. Fig. 5 shows the switchboard in course of erection. The main circuit breaker is of 1000 amperes capacity.

There are some 800 lights in the building totalling 63 k.W., and 38 motors totalling 330 H.P. The estimated annual consumption is 100,000 units for lighting and 200,000 for power.

Heating.

The building is heated by two " BEANESS " low pressure hot water boilers each of 1,663,500 B.T.U. per hour capacity. The greater part of the heating surface consists of panels embedded in the concrete of the floors and ceilings. Great care was necessary during installation to get the levels of the panels correct, and the levels were finally tested during the filling in of the concrete to ensure that they had not been displaced in any way. A substantial saving in space on the sorting office floors is effected by the substitution of concealed panels for the usual sectional radiators along the walls. The basement, sub-basement and yard are directly heated by pipes.

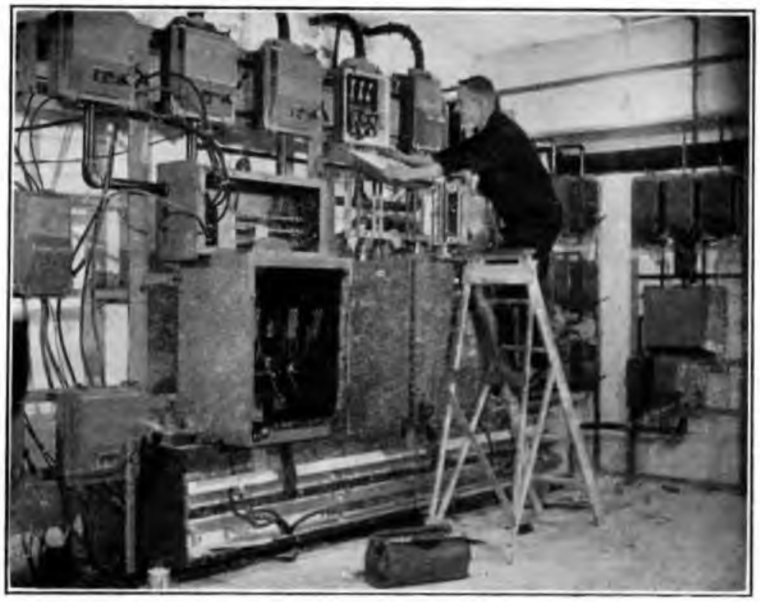


Fig. 5.—Department's L.T. Switchboard.

The separate boiler in the garage was dismantled and the system is connected to the Sorting Office boilers.

The panels are connected to the boilers through two calorifiers which, together with the rest of the system, are connected directly to the boilers. This gives much greater temperature control of the water in the panels and eliminates sudden rises and falls in temperature with the attendant stresses in the reinforced concrete. As a further precaution the flow from each calorifier is regulated by means of a thermostatically controlled valve which is adjusted to close if the temperature of the water rises above 170°F. Such a rise might be caused by excessive boiler temperatures or the failure of the pump in the panel system to maintain the circulation of the water. Duplicate pumps are provided in the panel and main systems to maintain an adequate circulation, and they are changed over daily.

The panels are fed in parallel from pairs of risers and are controlled by a valve on the flow side. Each riser is controlled by a valve in the basement, and to isolate a panel it is necessary to empty all the panels connected to the pair of risers. The risers are arranged to serve, not a portion of one floor, but the same small portions of all the floors vertically above one another. Thus if a panel should go faulty, the resulting loss of heat is spread over the four floors, ground to third, and will not be so noticeable.

The domestic hot water for the building is supplied from two " IONIC " boilers, each of 197,000 B.T.U. per hour capacity. The hot water cylinder holds 300 gallons. In addition a number of radiators provided in the retiring rooms on the third floor are connected to these boilers to heat the rooms during cold days in the summer when it would not be economical to relight the main boilers. They are fed from a separate flow, controlled by a valve, and are not normally in use.

The panel system has proved very useful during the construction of the building which has dried out more quickly than normal; the plaster work in particular set quickly and allowed painting and white washing to proceed almost immediately.

Book Review

" Practical Radio Communication." Arthur R. Nilson and J. L. Hornung. McGraw-Hill Publishing Co., Ltd. 754 pp. 30/-.

This book is a new production and is intended to supply the needs of all classes of radio technicians from operators of radio equipment up to the more highly skilled personnel in radio manufacturing and operating companies. The book thus attempts to cover a very wide range.

It is an American work and deals almost exclusively with American practice. The subject matter appears to be well selected and well presented and should be of considerable interest to British readers as American practice is at least as far advanced as European practice and in some branches of the art is probably leading.

The book is divided into fifteen chapters, the first two dealing with direct and alternating current principles. The last three chapters cover power sources and deal with rectifier units, dynamo electric machinery and meters and storage batteries respectively. The remainder of the book consisting of about 450 pages deals with high frequency and acoustic frequency principles and apparatus. In this portion of the book four chapters deal with principles, commencing with vacuum tubes followed by transmitting circuits, receiving circuits and antennæ and wave propagation. Following on this the text deals with present day practice, commencing with sound acoustics and apparatus and passing on to control room equipment and operation, broadcast transmitters, communication transmitters, radio receivers and finally to radio aids to navigation.

The text is not overloaded with mathematics, but sufficient data and information are provided to enable all normal computations to be made, while numerous worked out examples are given to illustrate the practical application of formulæ.

The broadcasting aspect of the subject is well covered, but not to the exclusion of other equally important branches of the art.

To sum up this appears to be an extremely useful work of direct utility to all radio technicians.

A.J.G.

Notes and Comments

The New Postmaster-General

The news of the appointment of the new Postmaster-General, Major the Right Honourable George Clement Tryon, was received too late for inclusion in the July issue of the Journal. Major Tryon has had a long Ministerial experience, having been in charge of the Ministry of Pensions almost continuously since 1922. In welcoming him as our new Postmaster-General we have no doubt that the Post Office will continue, under his guidance, the vigorous forward policy initiated by his predecessor.

Circulation of the Journal

Concurrently with the preparation of this issue of the Journal, a publicity campaign has been conducted among the staff of the Engineering Department and from the results already received it is evident that, for the first time since the Journal was commenced in 1907, the circulation will exceed 10,000 copies per issue. This number represents over double the circulation six years ago and the increase during this period has enabled a bigger and better Journal to be produced at a reduced price.

Our readers can rest assured that the Board will continue its efforts to make this Journal the most informative, instructive, and " readable " periodical dealing with Telecommunications.

Valveless Differential Echo Suppressor

La Société d'Etudes pour Liaisons Téléphoniques & Télégraphiques à Longue Distance of Paris has drawn our attention to the fact that it has used since the end of 1930 an arrangement of dry plate rectifiers (French Patent No. 708559, of 29th December, 1930, and Supplementary No. 39757, of 13th February, 1931) similar to that described by Dr. Ryall in his article on the Valveless Differential Echo Suppressor published in the April issue of the Journal. The Société has applied this arrangement of rectifiers to echo suppressors, amplifiers (in which the direction of amplification is controlled by the current itself) and to emission control in voice frequency telegraphy. The last application has been in use for four years. The Société has also developed the use of polarity changers and of differential modulators utilizing dry plate rectifiers.

We have pleasure in recording these contributions by the Société d'Etudes to the research on this subject.

The International Conference of Scientific Management and the British Association Meeting

Our readers will be interested to learn that the Engineering Department was well represented at the 6th International Conference of Scientific Management, recently held in London, and at the annual meeting of the British Association which took place this year in Norwich.

At the former function approximately 2,000 delegates from 40 countries attended and were welcomed by the Duke of Kent. Management problems of common interest were discussed at the plenary session after which the Congress divided into six sections for consideration of special phases of the general problem. Two hundred individual papers were contributed and very instructive discussions, in which the Engineering Department took an active part, ensued. At the closing plenary session the Congress was fortunate in being addressed by the Prince of Wales who, in a typically forceful speech, emphasized the importance of the Congress' activities in the sphere of international affairs.

At this year's meeting of the British Association a new departure was made in that an Industrial Section was opened for the first time. We welcome this innovation and hope that the Engineering Department will continue to give it active support.

Erratum

It is regretted that the curve marked " Campbell's Formula " was included in Fig. 1, page 195 of this issue, in error. This curve does not relate to the same cable as the other curves. It has not been possible to prepare a revised diagram in time for publication in this issue, but this will be published in the January issue.

Book Review

" Electrical Water Heating." D. J. Bolton, M.Sc., M.I.E.E., Phillip C. Honey and N. S. Richardson. Chapman & Hall. 188 pages. 7/6 nett.

In view of the development of the grid system the question of electrical water heating has become of great importance and the authors are very qualified to deal with such a subject.

After dealing with general considerations, the construction of various forms of heaters is dealt with and methods of making the necessary calculations are fully explained in a simple manner. The importance of avoiding heat losses is not overlooked, this, of course, being of great importance in considering the relative efficiency of electrical and other methods of hot water heating. When the demand is of an intermittent nature such losses may add very considerably to the cost of the operation of the systems. Methods of converting other hot water installations to electrical operation are given and the final section of the book deals fully with the electric supply aspect.

The book should be very useful to both engineers and students.

W.S.S.

The Institution of Post Office Electrical Engineers

RECENT ADDITIONS TO THE INSTITUTION LIBRARY.

New Books.

1134 Electricity and fire risk.—E. S. Hodges. (1935. Brit.).
1135 State finance: the theory and practice of public finance in the United Kingdom.—R. J. Mitchell. (1935, Brit.).
1136 Elementary practical mathematics: Book III, 3rd year.—E. W. Golding and H. G. Green. (1935, Brit.).
1137 Photo-electric and selenium cells: their operation, construction and uses.—T. J. Fielding. (1935, Brit.).
1138 Problems in radio engineering.—E. T. A. Rapson. 1935, Brit.).
1139 Fractional horse-power motors: principles of construction.—A. H. Avery. (1931, Brit.).
1140 Principles of electricity: an intermediate text in electricity and magnetism.—L. Page and N. I. Adams. (1935, Brit.).
1141 Notes for the use of Accounts Branches of Government Departments.—H.M.S.O. (1929, Brit.).
1142 Worked examples in electro-technics: Part I.—H. T. Aspinall. (1935, Brit.).
1146 Questions and Answers to City & Guilds of London Institute Examinations 1933-1934 in telephony, telegraphy, radio communication and magnetism and electricity.
1152 Introduction to electric transients.—E. B. Kurtz and G. F. Corcoran. (1935, Brit.).
1153 Management, planning and control.—A. G. H. Dent. (1935, Brit.).
1154 Measurement of inductance, capacitance and frequency.—A. Campbell and E. C. Child. (1935, Brit.).
1155 Electrical water heating: with special reference to the domestic storage heater.—D. J. Bolton, P. C. Honey and N. S. Richardson (1935, Brit.).
1156 Training of public employees in Great Britain.—H. Walker. (1935, Amer.).
1157 Elements of loudspeaker practice.—N. W. M. McLachlan. (1935, Brit.).
1158 Electric horology.—H. R. Langman and A. Ball. (1935, Brit.).
1159 Science in the making.—G. Heard. (1935, Brit.).
1160 Romance of the Civil Service.—S. McKechnie. (1930, Brit.).
1161 Modern radio communication: Book I.—J. H. Reyner. (1935, Brit.).
1163 Encyclopædia of Engineering.— — (1928, Brit.).
1164 Notes on building construction: Part IV. Calculations for building structures. — (1928, Brit.).

Later editions.

381 How to estimate: being an analysis of builders' prices.—J. T. Rea. (1932, Brit.).
Notes on building construction:
679 Part I. — (1930, Brit.).
680 Part II. — (1934, Brit.).
907 Problems in electrical engineering with answers.—S. P. Smith. (1935, Brit.).

UNPUBLISHED INSTITUTION PAPERS INCLUDED IN THE LIBRARY.

The Control of Internal Construction Work. H. G. Smith.

Present method of control. Deficiencies in the present system. Origin and scope of revised procedure. Principles of revised procedure. Statistics under revised procedure. Probable cost and probable saving.

Fundamental Physics. G. Franklin.

Molecules—form and size, crystal formations. Atoms—theories of size and shape—Atom building—Radiation. The electron—properties and wave mechanics. The nucleus—action at a distance. Properties of matter—gases, liquids, solids, conductors, conduction dielectrics, magnetism. Further applications, thermionics, radio, alternating currents, direct currents.

Development of Telephone Communications between England and the Continent. G. Manning.

Early history. Pre-war development. Circuit development—Dutch route, Belgian route, French route. Maintenance and exploitation—establishment of international circuits. Maintenance. Fault localization. Transmission complaints. Switched calls.

Some Notes on Faults and Maintenance Organization. Major H. Yorke-Starkey.

Fault liability. Exchange faults. Subscribers apparatus faults. Local Line faults. FOK faults. RWT faults. Total faults. Fault controls. External maintenance staff. Tools and equipment. Rota duties. Maintenance supervision.

Provision and Maintenance of Repeatered and Amplified Circuits. A. T. J. Beard.

This paper gives:

(1) An historical survey indicating the developments in design and use of repeatered and amplified circuits.
(2) A description of modern repeatered and amplified circuits.
(3) A description of the revised procedure under consideration for the provision and maintenance of repeatered and amplified circuits.

Various Phases of Overhead Construction. C. W. Lemney.

This paper defines the mechanical conditions necessary to a stable telegraph line and deals with the subject from first principles of mechanics. It covers mechanical properties of materials, wood poles, line wire, stay wire, theoretical considerations, unstayed poles, unstayed distribution poles in streets, crumbling of stay crutches, regulation tables for open wires, aerial cable suspension.

Local Centre Note

North Western Centre

PROGRAMME—SESSION 1935-36.

1935.

16 Sept. Visit to New Mersey Tunnel.
14 Oct. "Television."—W. C. Ward, B.Sc. (Hons.).
12 Nov. (Tues.). "Maintenance, Use and Development of Motor Transport."—R. T. Robinson (E.-in-C.O.).
16 Dec. "Radio-Telephony (G.P.O. Services)."—H. S. Thomsett, A.M.I.E.E., A.I.R.E.

1936.

20 Jan. "Automatic Developments."—J. W. Gould.
13 Feb. (Thurs.). "Recent Developments in Unit Auto Exchanges."—C. G. Grant and B. Winch (E.-in-C.O.).
16 Mar. "Lancaster Repeater Station."—F. Huntington.

Junior Section Notes

Edinburgh, Dundee and Aberdeen Centres

The number of offers of papers for the ensuing Session is such that no difficulty has been experienced in the preparation of programmes. The subjects cover a wide field and, as the high standard of the past sessions is assured, it is hoped to increase the membership.

Visits to places of interest will again be a feature of our activities.

London Centre

Three years' considered development have enabled the London Centre to offer to the Staff, an Institution which is invaluable to its members, and it is encouraging to be able to report that, not only is the membership increasing, but fuller use is being made of the facilities offered.

The following details of the first half of the winter's programme give promise of another Session full of interest and instruction and our sincere thanks are extended to all who have so readily consented to assist us.

FORMAL MEETINGS.

" City and Guilds Examinations in Telephony."—Mr. A. S. A. Johnson, A.M.I.E.E. (Examiner).

" Electro. Farming." A talkie lecture at the Institution of Electrical Engineers.—Mr. R. Borlase-Matthews, Wh.Ex., A.M.Inst.C.E., M.I.E.E., F.R.Ae.S.

SUBJECTS FOR INFORMAL MEETINGS.

An Evening of Films on a variety of subjects.

" Cable Testing and Localization of Faults."—Mr. W. Bocock, A.M.I.E.E.

" The Mechanical Equivalent of Lifts."—Mr. C. W. Govett (E.-in-C's Office).

" The Growth of a Telephone System—the factors governing the provision of External and Internal Plant."—Mr. J. N. Hill, A.M.I.E.E.

" Picture Transmission Systems."—Mr. G. Carr.

" Radio Interference."—Mr. F. W. Newson.

" Automatic Traffic Signals."—Mr. J. R. L. Burchell.

" Trunking and Grading."—Mr. W. J. Payne.

A total of fifteen lectures will be given throughout the London Engineering District.

VISITS.

Pool of London and environs, by launch.

United Dairies Depot.

Gloucester Centre

At the Annual General Meeting of the Centre held on Friday, the 24th May, 1935, the following officers were elected for the forthcoming Session :—

Chairman—Mr. F. W. Gill (Asst. Engineer).

Vice-Chairman—Mr. A. J. Hodgson.

Hon. Secretary—Mr. R. A. Kibby.

Treasurer—Mr. S. B. Foote.

Committee—Messrs. A. Lee, G. A. Rutland, F. E. Huckfield, S. F. Alder.

Auditors—Messrs. B. Frood and J. V. Lugg.

It was also decided at this meeting that a campaign visit be paid to Worcester in order to create interest in the activities of the Branch among those colleagues who have found it difficult to get to Gloucester or Cheltenham for our papers This was carried out when on 31st May, 1935, some 30 members from Gloucester and Cheltenham journeyed to Worcester and held a very successful propaganda meeting, resulting in the enrolment of 14 new members that evening.

The coming Session is keenly anticipated by everyone, and a programme of interesting and helpful papers is being arranged.

It is hoped that our membership will pass the 60 mark almost immediately the Session commences.

Manchester Centre

Since our last notes appeared we have lost six of our original members owing to promotion including Mr. W. H. Fox, our hard-working secretary since inception, and Mr. J. Lawton, a past chairman. All were keen, ever-present members, and we are confident that they will prove worthy recruits to the Senior Section. The resultant vacancies on the Committee have been filled by the appointment of Mr. C. Wood as Secretary and Messrs. J. A. Barrass and J. H. Watson as members.

On July 20th last we were favoured with a visit by members of the Shrewsbury Junior Centre. By courtesy of the Sectional Engineer MR. Internal and the District Manager, the party was conducted over the various exchanges in Telephone House.

In compiling the syllabus for the 1935-36 Session, including three papers by junior colleagues, the Committee have endeavoured to maintain the high standard set in previous years. At the opening meeting in October Mr. J. Darke, Asst. Supt. Engineer, is kindly contributing a talk on his American experiences; an interesting discussion is anticipated.

C.W.

Rochdale Centre

PROGRAMME, 1935-36.

1935.

15 Oct. " Some Radio Developments."—W. C. Ward, B.Sc. (Eng.), Blackburn.

12 Nov. Visit Messrs. Connollys (Blackley), Ltd., Electric Cable Manufacturers, Blackley.

10 Dec. " Sleeve Control and C.T.I. Working " (Illustrated).—G. V. Stansfield.

1936.

14 Jan. " Rochdale Police Box System." — F. A. Greenwood.

11 Feb. " Office Procedure."—Capt. Halsall, Blackburn.

14 Mar. Visit Automatic Electric Co., Ltd., Strowger Works, Liverpool.

Peterborough Centre

The first programme of the above Centre is announced as follows :—

1935.

9 Oct. " Some Modern Advances in Telegraphy."—J. McA. Owen, A.M.I.E.E.

13 Nov. " Interference with Wireless Reception."—V. P. List.

11 Dec. " Auto Systems with Special Reference to the U.A.X."—H. W. Peddle.

1936.

8 Jan. " The Rate Book and Vocabulary of Stores."—C. Welch.

12 Feb. " Fault Control."—J. E. Daniels.

11 Mar. " Sleeve Control."—R. W. R. Porter.

8 April Annual General Meeting.

Mr. C. W. Brown, the President of the Junior Centres, has promised to attend our first meeting, if at all possible, so come along and give him a welcome. Mr. Owen's lecture is sure to be very interesting to everybody.

District Notes

North Wales

BANGOR-CAERNARVON CABLE.

A 74 pair/40 cable from Colwyn Bay to Bangor continued by a 54 pair/40 cable from Bangor to Caernarvon has recently been completed, giving additional trunk and junction facilities to the most attractive part of the North Wales sea coast. The route followed traversed Conway, Penmaenmawr and Llanfairfechan along a rocky coast road familiar to many holiday makers.

It had been hoped to use a digging machine, but it proved possible to use it for less than a mile of the total distance, boulder rock necessitating the use of manual excavation methods over the rest of the route. Approximately 15 miles of armoured cable were laid, the remaining 14½ miles of cable being laid in duct. The cabling work was carried out throughout by Messrs. Siemens Bros. The loading was dealt with by the Department's staff, buried loading pots on concrete rafts being used in the armoured cable portion. Crossing Conway Suspension Bridge the cable is carried in a steel pipe fixed to the girders supporting the roadway, the work of fixing the pipe being carried out by the local staff.

MIDLAND AUTOMATIC EXCHANGE, BIRMINGHAM.

This exchange was brought into service on June 29th.

Approximately 10,000 stations were involved, including 4,580 exchange lines in addition to 1,200 junctions. This is the thirtieth and largest director exchange in the Birmingham Director Area, and is incidentally the first large exchange in the District to be equipped with Line Finder Equipment. The installation comprised :—

5,200 L and K relays.
632 Line Finders (26 Groups).
119 Secondary Finders (7 Groups).
426 First Code Selectors.
75 Directors.
70 A Digit Selectors.
1,580 Group Selectors.
986 Final Selectors and
22 Coders.

TELEPHONE HOUSE, BIRMINGHAM.

The new building in Newhall Street is nearing completion, and is being shorn of its mantle of scaffolding. This building will contain the new Trunk and Toll Exchange, miscellaneous Service and Keysender Positions, etc., also the new Central Automatic Exchange and a Repeater Station.

With the exception of the repeater station, the equipment is being provided by Messrs. Siemens Bros. & Co., Ltd., and installation has already commenced. Accommodation is also being provided for the Section Offices of the Engineering Department and the District Manager's Staff.

The subsoil of the site consists of fissured sandstone, this being part of the ridge which extends right across the city, and during the excavations for the foundations conjecture arose as to the possibility of obtaining a good earth connexion, owing to the dry nature of the site. Preliminary tests made at the time confirmed the doubts which were expressed. On the advice of the Engineer-in-Chief an earth system consisting of two 100-yard lengths of 8-lb. lead strip 4″ wide laid in coke breeze on opposite sides of the site was provided. This was done at the same time as the laying of the ducts for the underground cables, the strips being laid over the ducts in the same trenches.

The results obtained are quite satisfactory, and tests made during the recent dry spell indicated a resistance of less than a half an ohm for the two strips in parallel.

Eastern District

ROYAL AIR FORCE REVIEW. MILDENHALL AND DUXFORD.

These twin events occurring on the same day and in one Engineering Section (Cambridge) called for extensive provision of Telegraph and Telephone facilities.

Mildenhall Aerodrome.

At Mildenhall public service requirements included 4 teleprinter circuits and 10 trunk circuits, seven terminated on Norwich and three on Cambridge exchanges.

The Air Force requirements included three private wires to Duxford and one to Andover Aerodromes and in addition 14 temporary extensions on their existing P.B.X. for troops assembled around the aerodrome.

The Police, for traffic control purposes, required seven temporary lines to points within a four mile radius in view of the large volume of vehicular traffic expected.

The aerodrome lies 2½ miles from the town of Mildenhall and a further 1½ from the junction of the main Cambridge-Norwich Trunk Route to which point approximately four miles of duct and a 28 pr/20 lb. balanced but unloaded trunk type cable were laid permanently as part of a development scheme.

The Air Ministry placed at the disposal of the Post Office a large room where the eight cabinets, two switchboards, teleprinters and public counter were installed.

Power supply at normal characteristics was available.

A small magneto P.B.X. fitted in the Signal Office of the aeodrome served the police telephones, the conductors for which were run temporarily with Cable I.R.V. B. & C. on existing poles and under hedges—the telephones themselves being housed in packing cases screwed to poles or gates.

Duxford Aerodrome.

The requirements here were heavier than at Mildenhall. Six teleprinter circuits, eighteen London trunk circuits, two B.B.C. circuits and seven police traffic control points were required.

To gain access to the London-Peterborough main trunk route at Royston seven miles distant and to the Ware-Cambridge route at half this distance at Flint House, it was decided to provide a trunk type 28 pr/20 lb. armoured and loaded cable.

The section of the cable Duxford-Flint House was laid permanently by mole draining methods with a view to connexion to a main cable at a later date, but thence to Royston temporary construction in hedgerows was adopted. Fourteen pairs of the cable were looped in and out of a pole test box at Flint House to afford connexion with the Ware-Cambridge overhead route.

As at Mildenhall generous accommodation was offered by the Air Ministry for the temporary Public Office and the lay-out of the 17 silence cabinets, two switchboards and teleprinters presented no special difficulty.

The P.B.X. for the road traffic control circuits was placed in the Aerodrome Signal Office.

At both centres picture transmission was undertaken by London newspapers.

The diversions of so many public trunk circuits for this event was smoothly accomplished, thanks to excellent co-operation between all concerned.

South Western District

60 K.C./SEC. TRANSMISSION OVER UNDERGROUND CONDUCTORS.

The work of installing the plant for the experimental Bristol to Plymouth (approximately 124.5 miles), multi-channel, multi-conductor carrier-on-cable system is now in progress, the drawing-in of the cables having been commenced early in July.

The scheme provides for the transmission of a band of frequencies extending from 8 K.C./sec. to 60 K.C./sec., 12 speech channels per cable pair being thereby obtainable. One cable will provide for transmission in the direction Bristol to Plymouth, a second cable for Plymouth to Bristol transmission. The cables are of uniform electrical characteristics throughout their length, the repeater stations being spaced at distances of from 16 to 20 miles. Sites for three amplifying stations, additional to the repeater stations already existing along the route, have been acquired, the building plans for which are in active preparation. Terminal stations will house the carrier generating, modulating and demodulating equipment. The apparatus for cross-talk neutralization will be accommodated in special buildings, located approximately half-way between the repeater stations. Sites for seven such buildings, the design of which is a modification of the standard 100 line U.A.X. building, have been acquired and the building contracts are being placed.

The carrier cables contain 19 pairs of 40 lb. conductors in twin formation, but the carrier equipment to be fitted initially will be sufficient only for the setting-up of 12 channels per pair upon three up and down pairs between Bristol and Plymouth and six up and down pairs between Bristol and Exeter. The cables will be terminated at all terminal and intermediate stations, by means of lead-covered tail cables, upon special test tablets.

Further interesting features of the installation are the provision of 44 pairs of 20 lb. conductors in Star Quad formation, as an outer layer to each carrier cable between Tavistock and Plymouth. These conductors will be loaded with 120 milli-henry coils at 2000 yard spacing, for normal audio-frequency working. In addition, about 50 route miles of the cables will be of the " protected " (against corrosion) type, whilst substantial anchorage, for anti-creepage purposes, will also be afforded throughout the entire route.

STORM DAMAGE AT LAMBRIDGE, SOMERSET.

As a result of a severe thunderstorm in the Bath District on Tuesday, the 25th June, the main road at Lambridge, near Bath, was flooded. Owing to the pressure of water, the parapet wall on the south side of the road and about 25 yards of footpath were carried away and swept into the Bath Horse Show field. The cast-iron pipe line carrying the Western underground cable and also the S.A. earthenware duct line carrying the Bristol-Chippenham and Bristol-Trowbridge trunk cables as well as a local cable, all lying in this footpath, were put considerably out of alignment as a result of the subsidence. Fortunately, the cables remained intact, and subsequent examination disclosed no serious damage, apart from the fractured iron pipe and a few broken ducts.

The work of restoration was put in hand at once. The pipe and duct lines were brought into alignment, the fractured pipe was repaired by means of a wrought-iron clip, and split ducts were used to replace the broken conduits. At the same time the cables were drawn back slightly into manholes on either side of the site of the subsidence.

Careful examination of the cable sheaths and joints has disclosed no evidence of damage or injury from strain. The ground has been consolidated beneath the duct line and six inches of fine earth used as a cover. In the case of the pipe line which is at a depth of 14 inches only, adequate temporary support has been given by means of cradles improvised from scrap pole arms, pending the work of permanent restoration of the footpath, which will be carried out by the Council.

PLYMOUTH AUTOMATIC EXCHANGE. OPENING CEREMONY.

A description of the lay-out and equipment of the new Plymouth Automatic Exchange system appears elsewhere in this issue. The transfer to automatic working was successfully effected on July 6th last. On the 29th of the same month the new Main Exchange building at Ebrington Ope, Plymouth, was formally opened by Viscountess Astor, M.P., in the presence of a distinguished company of about one hundred persons, including the Lord Mayor, the Lady Mayoress, the Admiral Superintendent of the Dockyard and representatives of the City Council, the Post Office Advisory Committee, the Chamber of Commerce, and the Plymouth and Devonport Mercantile Associations, etc. The Post Office was represented by the Engineer-in-Chief; Mr. P. Thornton Wood, Superintending Engineer; Mr. A. O. Spafford, Surveyor, etc.

The company assembled in the fore-court of the new building at 2.30 p.m. and Mr. H. E. Seccombe, A.R.I.B.A., the Architect, handed to Lady Astor a golden key with which she opened the main door. The company were then conducted by selected guides on a tour of the building and were thus enabled to inspect, under working conditions, all the more interesting parts of the equipment, including the Cable Chamber, the Battery and Power Rooms, the Automatic Apparatus Room, the Voice Frequency equipment and the Auto-Manual switch room.

On the completion of the inspection the proceedings were transferred to the Mikado Cafe, where tea was served. Mr. Spafford, who presided, thanked Lady Astor on behalf of the Post Office for her part in the proceedings, and the visitors generally for their attendance and interest. A vote of thanks to Lady Astor was proposed by the Lord Mayor, who in the course of his remarks expressed the appreciation of the citizens of Plymouth of the improved telephone facilities afforded by the new system. The vote was seconded by Lieut.-Col. Lee, who, referring to the long and intricate series of operations involved in the conversion work, and the incidental minor faults and difficulties which had unavoidably arisen, spoke of the gratitude of the Post Office for the patience and consideration which the public had displayed.

Lady Astor replied in a speech characterized by her unfailing liveliness and wit.

A fortunate illustration of the efficiency of modern telephone systems was provided as an interlude during this part of the programme. Lady Astor originated a call to a friend at St. Briac in France. She was unable to give the number of her correspondent, nevertheless, the connexion was successfully established within twenty minutes, a result which merited and received general commendation.

Staff Changes

PROMOTIONS.

Name.	From.	To.	Date.
Osborn, W. M.	Exec. Engr., Eastern	Asst. Suptg. Engr., Eastern	1-10-35
Bell, R. L.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	2-7-35
Chamney, R. M.	Exec. Engr., E.-in-C.O.	Asst. Staff Engr., E.-in-C.O.	11-8-35
Semple, L. G.	Exec. Engr., S. Western	Asst. Staff Engr., E.-in-C.O.	11-8-35
White, H.	Asst. Engr., London	Exec. Engr., London	1-10-35
Pidgeon, J. E.	Asst. Engr., Eastern	Exec. Engr., Eastern	1-10-35
Dixon, E. J. C.	Asst. Engr., S. Midland	Exec. Engr., S. Western	11-8-35
Chinn, W. E.	Asst. Engr., N. Midland	Exec. Engr., E.-in-C.O.	28-7-35
Stratton, J.	Asst. Engr., E.-in-C.O.	Exec. Engr., E.-in-C.O.	11-8-35
Siddle, W. H.	Chief Inspr., N. Eastern	Asst. Engr., N. Eastern	To be fixed later.
Davey, H. B.	Chief Inspr., N. Wales	Asst. Engr., N. Wales	1-8-35
Storey, W. J.	Chief Inspr., Eastern	Asst. Engr., Eastern	To be fixed later.
Brooke, C. H.	Chief Inspr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	do.
Gambier, J. E.	Chief Inspr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	do.
Douglas, J. H.	Chief Inspr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	do.
Sheppard, R.	Chief Inspr., N. Wales	Asst. Engr., N. Wales	do.
Cameron, C. J.	Chief Inspr., Test Section, B'ham	Asst. Engr., Test Section, B'ham	do.
Cain, S. J.	Chief Inspr., Eastern	Asst. Engr., N. Western	do.
Reeves, T. F.	Chief Inspr., S. Midland	Asst. Engr., S. Midland	do.
White, J. A.	Chief Inspr., Eastern	Asst. Engr., Eastern	do.
Wright, C. H.	Chief Inspr., E.-in-C.O.	Asst. Engr., E.-in-C.O.	19-8-35
Grierson, A.	Draughtsman Cl. I., N. Eastern	Chief Inspr., N. Eastern	1-7-35
Adair, H. J.	Inspr., N. Ireland	Chief Inspr., N. Ireland	19-3-35
MacDonald, N. M.	Inspr , N. Wales	Chief Inspr., N. Wales	7-7-35
Baines, F. G.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-6-35
Boys, E. C.	Inspr., London	Chief Inspr., London	1-9-35
Reynolds, E. J.	Inspr., Eastern	Chief Inspr., Eastern	12-7-35
Green, S. W.	Inspr., St. Albans Radio	Chief Inspr., St. Albans Radio	20-9-34
Williams, C. E.	Inspr., Eastern	Chief Inspr., Eastern	1-8-35
Jackson, J. H.	Inspr., N. Eastern	Chief Inspr., N. Eastern	27-7-35
Jennings, J.	Inspr., N. Eastern	Chief Inspr., Scot. West	1-8-35
Anderson, J. B.	Inspr., Northern	Chief Inspr., Northern	2-11-34
McKinnon, N.	Inspr., Scot. West	Chief Inspr., Scot. West	1-3-35
Shaw, J. W.	Inspr., London	Chief Inspr., London	31-3-35
Burnett, H. J.	Inspr., London	Chief Inspr., London	13-3-35
Chubb, E.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Dudley, J. C.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	3-8-35
Ching, E. A.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	21-7-35
Hopgood, C. L.	Inspr., London	Chief Inspr., London	1-6-35
Abbott, G. A. O.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Magnusson, L. E.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Mills, A. D.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Winch, B.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Young, J. S.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Goman, L. V.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Clibbon, H. A.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Francis, H. E.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	1-7-35
Bourdeaux, N.	Inspr., E.-in-C.O.	Chief Inspr., E.-in-C.O.	21-7-35
Harrison, R. A.	S.C. & T., Preston	Repr. Officer Cl. II., Northern	31-3-35
Hammond, A. G. W.	S.C. & T., Hull	Repr. Officer Cl. II., N. Wales	1-12-34
Newham, A. L.	S.C. & T., Preston	Repr. Officer Cl. II., Northern	4-8-35
Bunn, G. C.	S.W.I., S. Western	Inspr., S. Western	12-5-35
Collyer, A. C.	S.W.I., S. Midland	Inspr., S. Midland	2-1-35
Gore, S.	S.W.I., S. Midland	Inspr., S. Midland	14-7-35
Wilson, W. A.	S.W.I., S. Wales	Inspr., S. Wales	17-5-35
Beer, T.	S.W.I., S. Wales	Inspr., S. Wales	7-7-35
Broadbent, H. M.	S.W.I., N. Eastern	Inspr., N. Eastern	22-5-35
Simpson, J.	S.W.I., Scot. West	Inspr., Scot. West	11-4-35
Craig, M.	S.W.I., Scot. East	Inspr., Scot. East	11-4-35
McLeod, J.	S.W.I., Scot. East	Inspr., Scot. East	16-6-35
Davidson, A. N. B.	S.W.I., Scot. East	Inspr., Scot. East	30-6-35
Smart, G.	S.W.I., Scot. East	Inspr., Scot. East	9-6-35
Park, C.	S.W.I., Scot. East	Inspr., Scot. East	11-4-35
Lockie, J.	S.W.I., Scot. East	Inspr., Scot. East	11-4-35
Mathewson, J. M.	S.W.I., Scot. East	Inspr., Scot. East	11-4-35
Bulloch, W.	S.W.I., Scot. East	Inspr., Scot. East	5-5-35
Salt, J. R.	S.W.I., Scot. East	Inspr., Scot. East	1-7-35
Biggers, P. S. S.	S.W.I., Scot. East	Inspr., Scot. East	17-5-35
Quinn, P.	S.W.I., Scot. East	Inspr., Scot. East	21-7-35
Brough, D.	S.W.I., Scot West	Inspr., Scot. West	27-7-35
Taylor, A. E.	S.W.I., N. Midland	Inspr., N. Midland	19-6-35

Promotions (continued).

Name.	From	To	Date.
Gowland, J. E.	S.W.I., Northern	Inspr., Northern	11-5-35
Johnson, C. W.	S.W.I., Northern	Inspr., Northern	16-6-35
Richardson, R.	S.W.I., Northern	Inspr., Northern	14-7-35
Ashdown, C.	S.W.I., N. Ireland	Inspr., N. Ireland	13-7-35
Owen, F. C.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	21-4-35
King, W.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	25-5-35
Clark, R. J.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	27-4-35
White, H. S.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	16-4-35
Brunel, L. F. J.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	1-6-35
Willis, S. T.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	1-6-35
Wright, F. E....	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	22-2-35
Gillard, C. H.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	27-11-34
Whitehead, W. S.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	1-6-35
Hudson-Davis, J.	S.W.I., E.-in-C.O.	Inspr., E.-in-C.O.	8-5-35
Hardy, J.	S.W.I., N. Eastern	Inspr., N. Eastern	9-6-35
Oliver, J. E.	S.W.I., London	Inspr., London	1-3-35
Harvey, W. H.	S.W.I., London	Inspr., London	6-3-35
Forster, J. H.	S.W.I., London	Inspr., London	30-3-35
Jones, E. T.	S.W.I., London	Inspr., London	21-4-35
Jeans, C. W.	S.W.I., London	Inspr., London	23-6-35
Ellis, G. P.	S.W.I., London	Inspr., London	22-2-35
Foy, A.	S.W.I., London	Inspr., London	25-12-34
Barrett, H. C.	S.W.I., London	Inspr., London	21-12-34
Gardner, E.	S.W.I., London	Inspr., London	16-12-34
Dawson, C. F. O.	S.W.I., London	Inspr., London	19-1-35
Robson, J. T....	S.W.I., London	Inspr., London	23-2-35
Atkins, A. L.	S.W.II., London	Inspr., London	21-10-34
Page, S.	S.W.II., London	Inspr., London	3-8-35
Sinstead, H. A.	S.W.II., London	Inspr., London	26-10-34
Handy, T. A.	S.W.I., N. Wales	Inspr., N. Wales	21-7-35
Halsey, A.	S.W.I., Eastern	Inspr., Eastern	To be fixed later.
Bryant, J. W.	S.W.I., N. Eastern	Inspr., N. Eastern	do.
Roberts, C.	Storekeeper, H.M.T.S. "Monarch "...	Donkeyman, H.M.T.S. " Monarch "	1-8-35
Pool, L. B.	Draughtsman Cl. II., E.-in-C.O. ...	Draughtsman Cl. I., E.-in-C.O. ...	16-8-35
Mountain, A. J. A.	Draughtsman Cl. II., S. Western ...	Draughtsman Cl. I., S. Western ...	29-7-35

Retirements.

Name.	Rank.	District.	Date.
Elston, J. S.	Asst. Staff Engr.	E.-in-C.O.	10-8-35
Ashton, H. E.	Exec. Engr.	N. Eastern	1-7-35
Field, A. W.	Exec. Engr.	S. Lancs.	31-7-35
Lomas, W.	Exec. Engr.	N. Midland	31-7-35
Hollinghurst, W.	Asst. Engr.	E.-in-C.O.	1-7-35
Nichols, J. C....	Asst. Engr.	S. Midland	2-8-35
Leeming, W. T.	Asst. Engr.	N. Western	31-8-35
Buswell, W.	Chief Inspr.	N. Eastern	4-8-35
Sowerbutts, F. C.	Chief Inspr.	London	31-8-35
Wilson, L.	Chief Inspr.	N. Western	9-9-35
Peck, E. E.	Chief Inspr.	N. Wales	31-8-35
Blanchard, A. E.	Chief Inspr.	N. Eastern	30-6-35
Riley, J.	Chief Inspr.	S. Wales	14-7-35
Shepley, G. A.	Chief Inspr.	N. Western	31-7-35
Mortimore, W. H.	Repr. Officer Cl. I.	Northern	31-7-35
Munn, W.	Inspr.	S. Lancs.	31-5-35
Tyler, H. G.	Inspr.	London	30-6-35
Grieve, P. R.	Inspr.	S. Lancs.	30-6-35
Nixon, E.	Inspr.	N. Midland	27-7-35
Hill, E. R.	Donkeyman	H.M.T.S. " Monarch "	31-7-35
Jarvis, J. R.	Draughtsman Cl. II.	Scot. West	20-7-35
Taylour, H.	Draughtsman Cl. I.	E.-in-C.O.	15-8-35

Transfers.

Name.	Rank.	From	To	Date.
Mortimer, H.	Asst. Engr.	E.-in-C.O.	S. Midland	17-7-35
Cox, H. E.	Asst. Engr.	E.-in-C.O.	London	4-7-35
Helman, S. L.	Asst. Engr.	Northern	E.-in-C.O.	3-8-35
Wood, J. A.	Asst. Engr.	Eastern	London	11-8-35
Lewis, N. W. J.	Asst. Engr.	London	E.-in-C.O.	1-9-35
Leckenby, A. J.	Asst. Engr.	Test Section, B'ham ...	N. Midland	18-8-35
McCann, J. L.	Chief Inspr.	Scot. East	S. Western	1-9-35
Tootell, T. E....	Chief Inspr.	S. Western	N. Western	10-9-35

Appointments.

Name.	From.	To.	Date.
Oates, J. G. B.	Actg. Fourth Offr., H.M.T.S. "Alert"	Fourth Officer, H.M.T.S. " Alert "...	20-7-35
Sharp, A. E.	Actg. F'th Eng., H.M.T.S. "Monarch"	Fifth Engr., H.M.T.S. " Monarch "	19-6-35
Cunningham, J. F.	Prob. Inspr., S. Lancs	Inspr., S. Lancs.	1-6-35
Marshman, R. C.	Open Competition, Dec., 1934 ...	Prob. Inspr., E.-in-C.O.	24-6-35
Broad, E. R.	Open Competition, Dec., 1934 ...	Prob. Inspr., E.-in-C.O.	29-6-35
Richards, C. W. C.	Open Competition, Dec., 1934 ...	Prob. Inspr., E.-in-C.O.	1-7-35
Richards, D. L.	Open Competition, Dec., 1934 ...	Prob. Inspr., E.-in-C.O.	20-7-35
Bray, P. R.	Open Competition, Dec., 1934 ...	Prob. Inspr., E.-in-C.O.	8-7-35
Moller, T. D.	Unest'd Draughtsman, London ...	Draughtsman Cl. II., London ...	22-6-35
Bond, F. C.	Unest'd Draughtsman, N. Western...	Draughtsman (Unest'd), N. Western	28-6-35
Ellershaw, O.	Unest'd Draughtsman, N. Eastern ...	Draughtsman Cl. II., N. Eastern ...	6-7-35
Cooper, G. A....	Unest'd Draughtsman, E.-in-C.O. ...	Draughtsman Cl. II., E.-in-C.O. ...	18-6-35
Broomhead, G. A.	Unest'd Draughtsman, E.-in-C.O. ...	Draughtsman (Unest'd), E.-in-C.O....	2-8-35
Ashley, W. R.	Unest'd Draughtsman, E.-in-C.O. ...	Draughtsman Cl. II., E.-in-C.O. ...	25-8-35

Deaths.

Name.	Rank.	District.	Date.
Clarke, C. W.	Asst. Engr.	S. Wales	14-7-35
Collis, S. A.	Chief Inspr.	E.-in-C.O.	21-7-35
Stone, A. E.	Inspr.	S. Wales	14-7-35

CLERICAL GRADES.

Promotions.

Name.	From.	To.	Date.
Shepherd, D. H.	C.O., Eastern	Actg. H.C.O., Eastern	1-10-35
Taylor, W. A....	C.O., S. Western	Actg. H.C.O., S. Western	27-9-35
Smith, W.	C.O., N. Wales	Actg. H.C.O., Scot. West	To be fixed later.
Dunkerley, H. W.	C.O., S. Lancs.	Actg. H.C.O., S. Lancs.	1-10-35
Greig, G. P.	C.O., Scot. East	Actg. H.C.O., N. Ireland	1-8-35
Scrivener, W. H.	C.O., E.-in-C.O.	Actg. Exec. Officer, E.-in-C.O. ...	17-6-35

Retirements.

Name.	Rank.	District.	Date.
Johnston, T.	H.C.O.	Eastern	30-9-35
Aickin, E. E.	H.C.O.	S. Western	26-9 35
MacCallum, H. C.	H.C.O.	Scot. West	31-8-35
Warburton, W. J.	H.C.O.	S. Lancs.	30-9-35

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