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DEVELOPMENTS IN CARRIER TELEGRAPH TRANSMISSION IN AUSTRALIA—PART 3

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TRANSMISSION CHARACTERISTICS OF CARRIER TELEGRAPH EQUIPMENT

Introduction: In normal telegraph practice the communication of intelligence over a transmission path is achieved by effecting a series of changes in the electrical conditions at the sending end in accordance with an arbitrary time code, the permutations of which represent letters, figures, and signs. Examples are the Morse code employed for manual telegraphy and early printing systems, and the Five Unit code employed with modern machine telegraph systems.

There are two general methods of transmission in common use, namely, Single Current transmission, in which current is applied to line for the "marking" elements, whilst absence of current corresponds to the "spacing" elements, and Double Current transmission, in which the polarity of the applied current is changed for the "marking" and "spacing" elements. In our Administration, negative and positive potentials correspond to "marking" and "spacing" conditions respectively.

At the receiving end the translation of the transmitted intelligence is effected by the receiving equipment, which interprets the code, selecting each element by measuring its time relationship with some transmitted starting point and determining its sense, that is, whether it represents a "marking" or "spacing" element.

In order to assist studies in relation to telegraph transmission, the "Comité Consultatif International Telegraphique" (C.C.I.T.) has listed a number of definitions, the more important ones being as follow:

The operations performed at the telegraph transmitter are termed "telegraph modulation."

The instants at which the characteristic changes occur are termed "characteristic instants of modulation."

The intervals between these instants are termed "elements of modulation."

The process of reproducing the characteristic instants of modulation at the receiving end by some form of relay is termed "restitution of modulation."

The time interval between an instant of modulation and the corresponding instant of restitution is termed "restitution delay."

In general, in carrier telegraph transmission, carrier frequency is applied to line for the duration of a marking element of modulation and cessation of carrier frequency represents a spacing element of modulation. The electrical transmission wave is, therefore, characterised by changes in amplitude which are in effect instantaneous at the origin, but lose their sudden character during propagation over the line and through the terminal equipment. Due to the modification of the wave shape the recognition at the receiving end of the original time intervals may become difficult, and it is usual to restore the abrupt nature of the changes from "marking" to "spacing" by utilising a suitable receiving relay.

If there were no disturbing influences or system limitations, the response of the receiving equipment to a modulation would always be the same, and the instantaneous changes produced by a perfect receiving relay would always occur with a constant restitution delay after the corresponding operation at the transmitting end. Under such circumstances, received signals would be in exact accord with those produced at the telegraph transmitter, and the system would be telegraphically distortionless. In practice, such perfection is not obtainable, nor is it essential, but, as discussed later, there is a limit to the amount by which the received signals may differ from those originated at the transmitter.

The degree of imperfection in signals received in practice is to some extent dependent on the relationship between the duration of the transient effects experienced and the duration of the shortest element of modulation. The duration of the transient effects is dependent on the characteristics of the channel, whereas the duration of the shortest element of modulation will be determined by the type of telegraph equipment used and the speed at which it is operated.

This relationship is of primary importance in telegraph transmission, since for any one type of telegraph system, the rate at which information can be passed over a channel is inversely proportional to the duration of the shortest element of modulation.

The shortest element of modulation has, therefore, been adopted as a basis for the numerical expression of the transmission speed of telegraph signals. The unit is termed the "baud," and may be defined as "the inverse of the duration (expressed in seconds) of the shortest element of modulation"—thus, taking teleprinter transmission as an example, the shortest element of modulation is 20 milliseconds in length, so that the baud speed is equal to $1000/20 = 50$ bauds.

The foregoing definition of the baud is applicable to all types of telegraph systems, and for any particular system, as discussed later, there is a definite relationship between the shortest element of modulation and the transmission capabilities in words per minute.

TELEGRAPH DISTORTION

The process of reproducing the characteristic instants of modulation at the receiving end by means of a relay has been termed "restitution of modulation," while the time interval between an instant of modulation and the corresponding instant of restitution has been defined as the "restitution delay." As previously stated, a telegraph circuit with a constant restitution delay is telegraphically distortionless, but in practice these delays may vary appreciably from one instant to another, and with large deviations it is not possible for the receiving telegraph apparatus to interpret the signals correctly.

Numerically, the degree of distortion of the reproduced signals is expressed as "the ratio of the differences observed between the restitution delays to the duration of the shortest modulation element." In practice, the greatest of these differences expresses the maximum distortion present at the time of measurement. It will be seen that this definition refers to a complete telegraph link, which may be just a simple relay circuit or a complex system of transmission paths and apparatus.

It has been found convenient to classify telegraph distortions as follow:

Fortuitous distortion may be briefly described as that distortion due to irregularities in any part of the circuit or apparatus including crossfire, power induction, momentary battery fluctuations, line contacts, lightning discharge, intermodulation, interference from adjacent channels, and all similar types of interference.

Bias distortion is distortion due to the marking element of a signal being lengthened with a corresponding shortening of the spacing element — marking bias; or, alternatively, the spacing element of a signal being lengthened with a corresponding shortening of the marking element — spacing bias. This form of distortion may be caused by asymmetry in the transmitting or receiving apparatus, such as an incorrect setting of the bias adjustment or a faulty relay.

Characteristic distortion is distortion occurring consistently with any given series or combination of signal elements. It is the inherent distortion which remains when extraneous sources of distortion, such as bias and fortuitous distortion, have been eliminated.

Margins of Telegraph Apparatus. From the fact that telegraph communication channels are subject to some distortions, it necessarily follows that telegraph receiving equipment must be capable of correctly interpreting distorted signals. Receiving apparatus is, therefore, designed to permit of correct reception when received signals have been distorted by a given amount, and the limit of this permissible distortion is termed the margin of the receiver.

The design figure which represents the maximum margin under perfect mechanical conditions is termed the "theoretical margin." The "effective margin" is the margin which can be measured for any particular machine, and is the margin actually secured in practice.

CARRIER TELEGRAPH SYSTEMS

The various types of carrier telegraph systems are:

(a) Amplitude Modulated System (Single Tone): The most commonly used systems which were described in some detail in Parts 1 and 2 are of the amplitude modulated type, where carrier is transmitted to line for a marking element of modulation and suppressed for a spacing element. The operation of the receiving apparatus is dependent upon the amplitude of the received signal, the carrier receive relay being operated to "marking" when the amplitude is such that the rectified current is great enough to overcome the effect of the spacing electrical bias. The transmission properties of this type of system will be dealt with more fully later.

(b) Amplitude Modulated System (Two Tone): The principle on which this system is operated is that a pair of amplitude modulated channels are combined to form a telegraph communication link. A marking element of modulation causes the carrier frequency of one channel to be transmitted whilst a spacing element results in transmission of the carrier frequency of the other channel of the pair. At the receive terminal, the two channels are terminated in a differential or bridge network for carrier receive relay operation dispensing with the necessity for electrical relay bias, thus closely approximating double current working, the advantages of which, in telegraph transmission, are well known.

This method of working has advantages for operation over radio links as dealt with in Part

2, but is uneconomical for general application, in that it requires twice the frequency spectrum per channel as compared with a single tone system.

(c) Phase Reversal System: In this system, tone at a fixed frequency is continuously transmitted to line, the difference between marking and spacing elements being that the phase of the latter is reversed as compared with the former. This phase change is brought about at the sending end by the use of a balanced metal rectifier modulator, which virtually reverses the direction of the carrier applied to the primary windings of the output transformer when the direction of the telegraph loop current is reversed.

At the receiving terminal, the incoming carrier is compared with a tone of identical frequency produced by a local oscillator. The system is so lined up that the local oscillator is in phase with the received marking element, and in this condition the summation of the two tones when rectified operates the carrier receive relay to the marking contact. When, for the spacing element, the phase of the received tone is displaced 180 degrees with respect to the local tone, the resultant cancellation permits the relay bias circuit to take control and operate the tongue of the carrier receive relay to the spacing contact.

The local oscillator is maintained in synchronism by the output of a frequency doubler. Portion of the received carrier tone is applied to a full wave rectifier coupled to a transformer. The resultant output is twice the carrier frequency, and is independent of the phase of the incoming carrier tone.

It is claimed that phase reversal modulated systems give advantages similar to those of double current operation in telegraph working because of the transmission of carrier of one frequency over the line for both the marking and spacing elements of modulation. As the carrier frequency is constant, any variation in the transmission equivalent of the bearer circuit would cause an equal change in the received level of both the marking and spacing elements with a consequent freedom from bias distortion.

(d) Frequency Modulated System: In a frequency modulated system the sending oscillator generates tone continuously, the frequency of oscillation being altered under the control of the telegraph transmitter. The usual arrangement is to provide a fixed tuned circuit which adjusts the oscillations to the midband frequency of the channel. Two supplementary tuned circuits are also provided in parallel with this tuned circuit, but are so connected through rectifiers that one of these supplementary circuits effectively parallels the fixed tuned circuit when a marking element is transmitted, while a spacing element results in a similar connection of the other supplementary tuned circuit. The constants of the supplementary tuned circuits are so chosen that the frequency of oscillation is reduced to a figure which just falls within the band pass filter limits for a marking element of modulation, whilst an equal increase above the midband frequency results from the application of a spacing element. A typical schematic circuit is shown in Fig. 28.

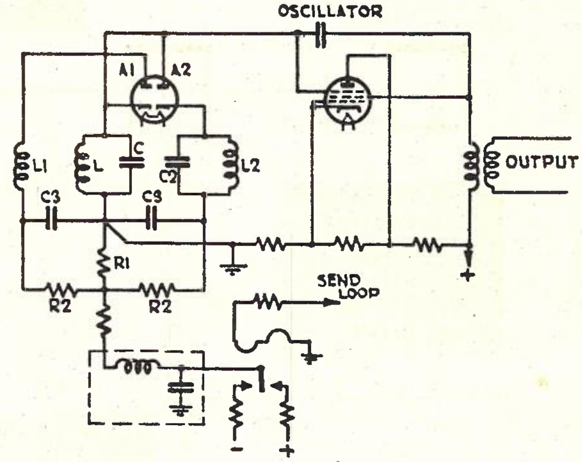


Fig. 28.—Frequency Modulation Transmitting Unit.

After passing through send and receive filters, which perform similar functions to those employed in amplitude modulated systems, the signals are applied via a current limiter to a discriminating network, which consists of two parallel circuits tuned respectively to the marking and spacing frequencies, as shown in Fig. 29.

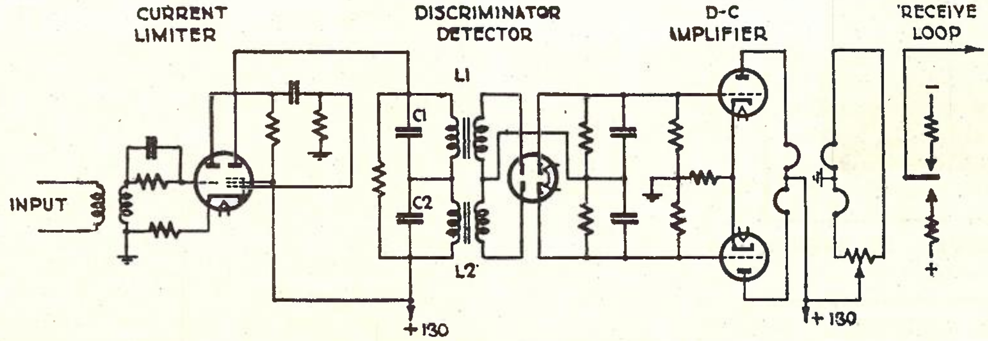


Fig. 29.—Frequency Modulation Receiving Unit.

The outputs of each tuned circuit after rectification and amplification are connected to separate windings of a polarised relay, which is operated on the differential principle. The current limiter, which precedes the discriminator detector, ensures a reasonably constant maximum value of relay current.

The advantages derived from the use of frequency modulation are:

(a) Comparative freedom from fortuitous distortion due to external interference, and

(b) Freedom from the effects of variations in received level because of the similarity to double current operation.

It will be appreciated that the advantages claimed for frequency modulated and phase reversal systems are relatively unimportant if a perfect bearer circuit is used. Although this condition cannot be fully realised in practice, the extended use of improved types of carrier telephone systems with automatic pilot regulation has made available bearer circuits with more stable transmission equivalents and greater freedom from interference. Improvements have also been made in amplitude modulated carrier telegraph systems, and consequently, under existing conditions, it is doubtful whether on wire lines the use of frequency modulated or phase reversal systems would contribute transmission advantages commensurate with the greater complexity entailed as compared with amplitude modulated systems.

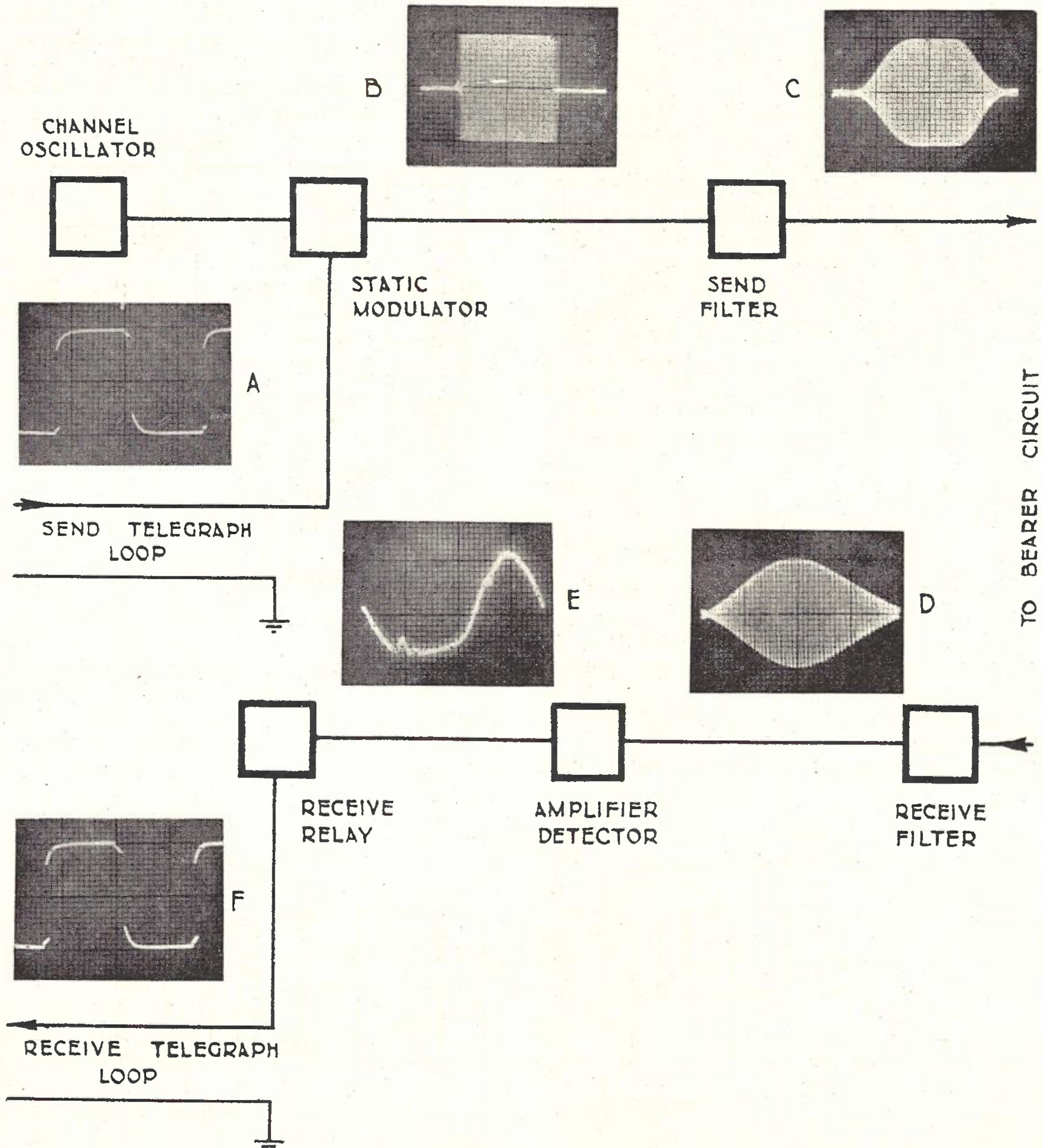


Fig. 30.—Simplified Block Schematic. Amplitude Modulated Carrier Telegraph System.

AMPLITUDE MODULATED SYSTEMS

Transmission Characteristics: A simplified block schematic of the essential elements of an amplitude modulated carrier telegraph system is shown in Fig. 30. The superimposed oscillograms in this figure serve to illustrate the character of a marking element of modulation at the various stages of the circuit. The photographs were taken at a transmission speed of 50 bauds in a system having a nominal spacing of 120 cycles between adjacent channels, the carrier frequency of the particular channel being 1860 cycles per second.

Oscillogram A: The reversals of square wave form in the send telegraph loop as shown are double current signals in which negative and positive potentials are applied during the marking and spacing elements of modulation respectively. The signals were transmitted from a vibrating relay type reversal generator.

Oscillogram B: The signal in the send telegraph loop is applied to the static modulator, which is also supplied with the appropriate channel frequency and the product of modulation consists of a rectangular envelope at the carrier frequency corresponding to a marking element of modulation. During the spacing element the carrier frequency is suppressed.

Oscillogram C: This oscillogram shows the pulse of carrier corresponding to the marking element after passing through the send filter. Here the envelope shows the characteristic rounding off of the rectangular wave form due to the restricted bandwidth of the send filter.

Oscillogram D: The envelope at the output of the receive filter is shown in oscillogram D. The increased rounding of the envelope due to the further restriction of the frequency band by the receive filter can be clearly seen.

Oscillogram E: The output from the receive filter is next applied to the amplifier detector, and the detected current, as shown in oscillogram E, is passed through the line winding of the carrier receive relay. The pulse of rectified current corresponding to the marking element operates the relay tongue to the marking contact against the magnetic bias provided by the bias winding. During the interval of no current which corresponds to the spacing element, the bias winding takes control to return the relay tongue to the spacing contact. An interesting feature of this oscillogram is that, at the instant of operation of the relay, a current oscillation of small amplitude is generated in the line winding of the relay due to the movement of the armature in the magnetic field. This small fluctuation may be clearly seen in the oscillogram.

Oscillogram F: As negative and positive potentials are connected to the "marking" and "spacing" contacts respectively of the carrier receive relay, the output from the relay tongue is of the square wave double current form shown in oscillogram F. For undistorted reception, the instants of modulation at this point should bear the same time relationship to each other as the corresponding instants of modulation in the send telegraph loop.

Restriction of Frequency Band: The division of a channel designed for telephone speech with a frequency range extending from 200-2800 cps into a number of telegraph channels is made possible by the use of band pass filters, which limit the range of frequencies available for use on any particular channel.

The factors governing the number of channels which can be derived from a given frequency range are:

(a) The effective bandwidth required for the satisfactory operation of the telegraph equipment to be employed.

(b) The efficiency of the filters in use. Adequate discrimination between adjacent channels must be provided, and this depends on the characteristics of the filters and the spacing between adjacent nominal channel frequencies.

The two main systems in use in the Commonwealth are based on the use of 18 channels spaced 120 cycles apart, and 9 channels with 240 cycles separation between channels. The nominal carrier frequencies adopted for these systems were listed in Part 1, Table 1.

From (b) above, it will be seen that, with the normal design of filters, the effective bandwidth available for the transmission of telegraph signals is less than the nominal spacing between adjacent carrier frequencies.

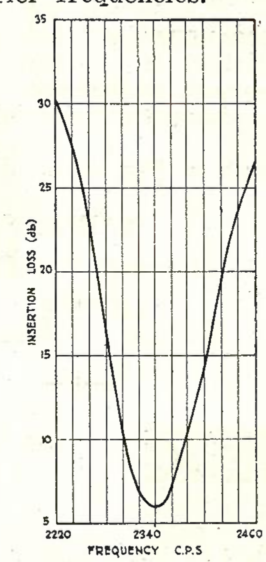


Fig. 31.—Overall Response Curve of M.C.V.F. (120 cycle spacing) Channel.

Küpfmüller has shown that, if the filter attenuation curve is constant over a range and then parabolic on either side, the effective cutoff frequencies are those at which the attenuation is approximately 4.5 db above that experienced at the midband frequency. Referring to

Fig. 31, which shows a typical attenuation frequency characteristic curve for a channel designed for 120 cycle spacing, it will be seen that on this basis the effective bandwidth is 80 cycles or 66 per cent. of the nominal spacing. Similarly, it may be seen that if harmonics of modulation which are equal to the midband frequency of an adjacent channel are present, the attenuation suffered by these harmonics would be of the order of 30 decibel.

Effects of Restricted Bandwidth: This restriction in bandwidth, as can be seen from the oscillograms in Fig. 30, greatly affects the form of the carrier envelope transmitted as a result of the modulation by the telegraph signals.

The building-up time of the envelope has a definite relationship to the effective bandwidth of the filters in the channel. Equations have been developed which show that for the envelope to increase from zero to approximately maximum value, a time equal to $\left(\frac{1}{f_2 - f_1}\right)$ secs. (where f_2 and f_1 are the upper and lower cut-off frequencies respectively) is required. But, unless the shortest element transmitted reaches this maximum value, abnormal distortion will be experienced.

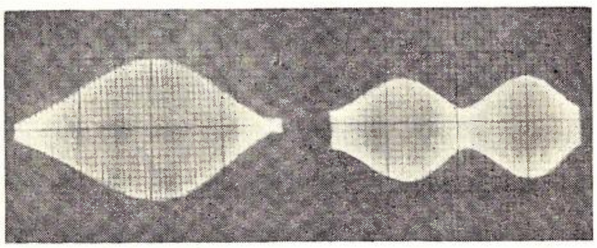


Fig. 32.—Oscillograms of Receive Filter Outputs at Transmission Speeds of 50 and 100 Bauds.

The oscillograms in Fig. 32 show the carrier envelope received at the output of the receive filter of a channel, the effective bandwidth of which is approximately 80 cycles per second. For these two oscillograms the amplitude of the oscillograph was adjusted to give two main divisions on the vertical scale for constant carrier reception. It will be seen that the element transmitted at a speed of 50 bauds reaches its maximum value, whereas that transmitted at a speed of 100 bauds does not even approach this value.

Returning to the equation that the time necessary for the signal envelope to reach its maximum value t is $\left(\frac{1}{f_2 - f_1}\right)$ and co-relating this to the fact that, to prevent abnormal distortion, the envelope must reach its maximum value for the shortest element transmitted, it follows that the maximum speed of telegraph transmission possible is that speed where the signal element equals $\left(\frac{1}{f_2 - f_1}\right)$ secs. in length. But the transmission speed in bauds is equal to $\frac{1}{\text{time of shortest element}}$ therefore, the maximum speech of transmission equals $\frac{1}{\left(\frac{1}{f_2 - f_1}\right)}$ that is, the maximum speed of telegraph transmission in bauds is equal to the effective channel bandwidth in cycles per second.

This speed of telegraph transmission represents the maximum which can be transmitted without the introduction of abnormal distortions. Even below this figure, however, some inherent characteristic distortion is experienced on channels of this type, the distortion decreasing as the transmission speed is reduced. It has been proved that this inherent distortion is caused by

TABLE No. 5—DISTORTION MEASUREMENTS

18-Channel V.F. Carrier Telegraph System—(120-Cycle Spacing)

Channel	Direction	Test Signal	Transmission Speed					
			50 Bauds		60 Bauds		70 Bauds	
			N	R	N	R	N	R
		1 : 1	—	—	—	—	—	—
3	A — B	2 : 2	3	3	4	4	10	10
		5 : 1	6	8	8	10	16	12
		PARIS	3	2	6	7	9	8
		1 : 1	—	—	—	—	—	—
5	A — B	2 : 2	3	3	6	6	9	9
		5 : 1	6	4	7	9	15	9
		PARIS	4	3	8	7	11	10
		1 : 1	—	—	—	—	—	—
15	A — B	2 : 2	3	3	5	5	11	11
		5 : 1	7	8	9	10	20	12
		PARIS	4	3	6	7	13	12

the restrictions imposed by the band pass filters and is no doubt due to the fact that, as telegraph codes consist of irregular rather than recurrent wave shapes, the harmonic frequencies contained in these non-recurring wave forms are subject to attenuation and phase distortion in passing through the band pass filters. Table No. 5 shows a typical series of distortion measurements on a 120 cycle M.C.V.F. system.

It will be apparent that, to secure the most economic utilisation of the telephone speech channel bandwidth, the complete planning should be based on the transmission of the maximum amount of telegraph traffic over the carrier telegraph system, consistent with telegraph operating requirements. These operating requirements depend on such factors as (1) whether a large amount of the traffic is to be handled between two main centres, or (2) whether the carrier channels are to be used to carry a relatively small amount of traffic as would be the case in a leased telegraph circuit. For this purpose the characteristics of the telegraph equipment must be studied in relationship to the effective bandwidth of the carrier telegraph channels.

CHARACTERISTICS OF TELEGRAPH APPARATUS

Speed of Working: Telegraph systems may be divided into two classes:

(a) Those in which the speed of working can be varied to make full use of the transmission capabilities of the channel, or circuit, over which the system operates; and

(b) Those for which the speed is fixed by other factors, such as operating requirements and the need for a standardised terminal equipment.

Wheatstone: The Wheatstone system falls into class (a) in that the speed of working can be adjusted to suit the transmission characteristics of the circuit. In this system, signals in accordance with the Morse Code are transmitted by a motor driven transmitter through which is passed a previously prepared perforated tape. At the receiving end the signals are recorded as printed dots and dashes on a paper slip. No need exists for any synchronisation between the sending and receiving equipments, the receiver speed being adjusted until the received signals are of convenient length for reading. Even in those cases where the received signal is used to operate a Creed reperforator to reproduce a perforated tape, similar to that transmitted, either for printing in a Creed morse printer or for retransmission, no difficulty is experienced in obtaining a suitable speed of the receiving apparatus and maintaining it within the wide margins permissible.

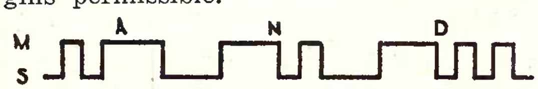


Fig. 33.—Example of Morse Code Elements.

Reference to Fig. 33 in which are depicted the letters A N D in Morse code will show that the shortest signal element is the dot, which is equal to the space between elements of a character and is one-third the length of a dash. If the length in time of this element = t seconds, then the speed in bauds $N = \frac{1}{t}$ or the length in time of one element in milliseconds $= \frac{1000}{N}$. Numerous efforts have been made to arrive at an average value for the length of a word, but in Australia a word is considered to consist of 5 characters and one space, each averaged at 8 signal elements, that is,

$$N \text{ (in bauds)} = \frac{\text{No. of words per minute} \times 48}{60}$$

or speed of working in w.p.m. equal $\frac{N \times 60}{48}$

Teleprinter 7C or 7B: The teleprinter falls in class (b) because the speed of transmission is fixed at 50 bauds, which ensures that the full output of the machine corresponds approximately to the maximum load of a highly skilled operator. In common with other start-stop or asynchronous systems, the code employed in both the 7C and 7B teleprinter consists of a start signal, 5 elements which convey the intelligence, and a stop signal, the only difference being that whereas in the 7C teleprinter the stop signal is the same length as the start signal and the code elements (20 milliseconds), that of the 7B machine is 1½ times the length of a signal element, that is, 30 milliseconds.

The 7C teleprinter therefore provides a theoretical speed of working equal to $\frac{50 \times 60}{7 \times 6}$ equal 71.4 w.p.m., whilst for the teleprinter 7B the theoretical speed of working is equal to $\frac{50 \times 2 \times 60}{15 \times 6}$ equal 66.6 w.p.m.

This theoretical speed of working cannot be obtained when transmitting from a keyboard, due to the short interval which takes place between the transmission of two successive characters. With tape transmission from a 6S transmitter, there is no interval between successive characters, and as the transmitting cam is cut on the 7.5 unit basis, the speed of working obtained is 66 words per minute.

Teletypewriter, Model 15: The teletypewriter, Model 15, makes use of a 7-unit code similar to the teleprinter, with the exception that the start and signal elements are 22 milliseconds in length, whilst the stop signal is of 31 milliseconds' duration. From this we can derive the speed of transmission as approximately 45.5 bauds, and the speed of working as 60 words per minute.

Murray Multiplex: The speed of transmission of Murray Multiplex systems depends on two factors:

(a) The speed of rotation of the phonic motor.

(b) The number of arms of the system.

With respect to (a) the Departmental standard phonic motor speed has been fixed at 270 r.p.m., that is, 4.5 r.p. sec.

With respect to (b) the transmitting ring is made up of equal segments, consisting of 5 segments for each arm and two for the correcting function. The number of segments on any plateau is therefore equal to 5 . (no. of arms), plus 2.

The speed of transmission and the duration of a signal element of the various multiplex systems in use in the Commonwealth are as follow:

Double Arm Multiplex:

No. of segments = 5.(2) plus 2 = 12.

Speed of transmission = 12 × 4.5 = 54 bauds.

Duration of signal element $= \frac{1000}{54} = 18.5$ millisec's.

Triple Arm Multiplex:

No. of segments = 5.(3) plus 2 = 17.

Speed of transmission = 17 × 4.5 = 76.5 bauds.

Duration of signal element $= \frac{1000}{76.5} = 13$ millisec's.

Quadruple Arm Multiplex:

No. of segments = 5.(4) plus 2 = 22.

Speed of transmission = 22 × 4.5 = 99 bauds.

Duration of signal element $= \frac{1000}{99} = 10.1$ millisec's.

For every revolution of the phonic motor, one character is transmitted on each arm. The maximum speed of working of each system is, therefore:

Double Arm Multiplex $\frac{2 \times 270}{6} = 90$ words per minute.

Triple Arm Multiplex $\frac{3 \times 270}{6} = 135$ words per minute.

Quadruple Arm Multiplex $\frac{4 \times 270}{6} = 180$ words per minute.

The above treatment deals with transmission from one end of a circuit only. Where the service is provided on a duplex basis, the telegraph link would be capable of handling in each direction simultaneously the amount of traffic as calculated above.

Margin of Receiving Equipment: As mentioned previously, the margin of receiving equipment is the amount of distortion which can be introduced into the received signal without causing a failure in reception. The theoretical margin is calculated in accordance with the constructional details of the machine, assuming perfect conditions. The margin is provided by so arranging the receiving mechanism that only a small proportion in the centre of the received signal element is used by the selecting mechanism of the receiver.

Teleprinter 7C: The receiving mechanism of a teleprinter is so arranged that the release of the receive timing cam takes place at the instant of modulation corresponding to the commencement of the start signal. The mechanism which determines the polarity of the code elements is timed with respect to this starting instant, and is so arranged that the centre four milliseconds of each 20 milliseconds element is used for this purpose. The 8 milliseconds' duration of the signal element before and after the selecting period each correspond to 40 per cent. of the total signal element and represent the theoretical margin of the machine. In actual practice the figure obtained after overhaul is somewhat less than this (about 35 per cent.) and this figure is gradually reduced when the machine is in use on a circuit due to the wear which takes place at various points in the machine during this period.

Teletypewriter, Model 15: The theoretical margins of the teletypewriter, Model 15, are also 40 per cent.

Murray Multiplex: The margin of a Murray multiplex installation depends on a number of factors. Each receive ring segment is half the angular length of the transmitting segment, and when the former is oriented to be centrally placed with respect to the latter, 25 per cent. at each end of the transmitted element is not used in the determination of the sense of the received element.

This figure is, however, influenced by other factors, such as (1) the response time of printer magnets and (2) the fact that synchronisation is only retained within certain limits. Whereas the proportional relationship of the send to the receive segments is always retained, the printer magnet response time (1) will, when expressed as a proportion of a complete signal element, vary with the number of arms used and the speed of working. The effective margins of multiplex sets will therefore vary with the nature of the installation, but for a quadruple set operating at a phonic motor speed of 270 r.p.m. a margin of 20 to 25 per cent. has been measured experimentally.

Wheatstone System: In Wheatstone operation the amount of distortion permissible depends to a large extent upon the skill of the receiving operator, and in practice signals with up to 40 per cent. distortion can be correctly interpreted.

OPERATION ON CARRIER TELEGRAPH SYSTEMS

Taking firstly the 18 channel VF systems with a nominal spacing of 120 c.p.s., the effective bandwidth is of the order of 70 to 80 cycles, varying slightly over the frequency range. The specification for this type of system requires that each channel be capable of transmitting at a speed of 66 bauds with no greater than 25 per cent. distortion. This requirement must be met with a plus or minus 7.5 db variation in bearer circuit attenuation and with power supply and channel carrier frequency variations of plus or minus 10 per cent. and plus or minus 0.25 per cent. respectively. These factors limit the telegraph equipment which should be used on these circuits to teleprinter and teletypewriter Model 15 machines, double Multiplex systems, or Wheatstone systems operating at speeds of the order of 80 words per minute.

The Type B, Type R, and the 9-channel A.P.O. V.F. systems with a nominal channel spacing of 240 c.p.s. all have an effective bandwidth of approximately 110 to 120 cycles, and are therefore satisfactory for the operation of quadruple Murray multiplex provided the operation is restricted to a circuit consisting of a single carrier telegraph link.

As distortions are introduced in each carrier channel link the effect of joining two or more channels is to increase the measured distortions. If very little margin exists when operating on the single link, operation over two links would, of course, be unstable. From Fig. 34 it will be seen that the bandwidth of the A.P.O. V.F. channel at 4.5 db above the midband frequency is of the order of 100 to 110 cycles per second. The quadruple multiplex operating at a phonic

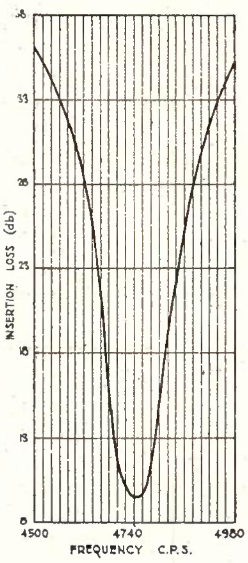


Fig. 34.—Overall Response Curve of Type R (240 cycle spacing) Channel.

motor speed of 270 rpm and a transmission speed of 99 bauds is therefore approaching the limit of margin, and while satisfactory operation is obtained over a single link, it would not be practicable to apply quadruple multiplex operation at this speed to two links in tandem. It would have been possible to provide greater margins if more effective filters had been used. As discussed in Part 2, with the filter material available, it was necessary to restrict the effective bandwidth to secure the required discrimination between channels spaced at 240 cycle intervals.

EFFECTS OF LINKING CHANNELS

In considering telegraph transmission between two widely separated points, there are two factors which affect the design of the circuit. The first is that the distortion introduced in a separate carrier telegraph link is independent of the length of the circuit. Secondly, when channels are linked in tandem, the distortions, whilst cumulative, are not arithmetically cumulative.

While experience has shown that the effect of linking two channels of known separate distortions is to give a distortion figure considerably

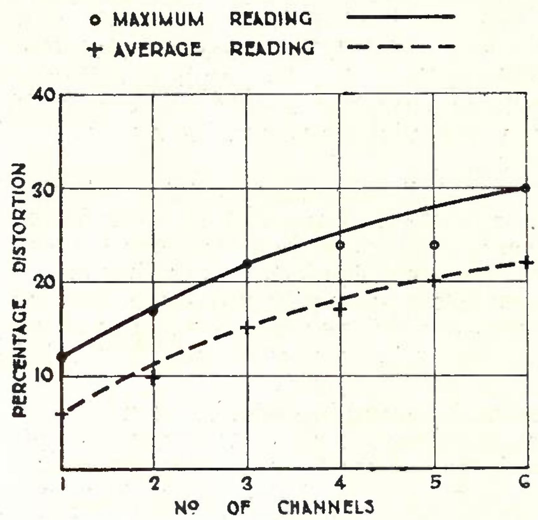


Fig. 35.—Effect of Linking Channels.

greater than either of the separate distortion values, no definite formula is yet available to enable the accurate prediction of the exact distortion which would result from such linkage. In fact, many measurements have led to the belief that the resultant bears no exact mathematical relationship to the individual distortions.

The average and maximum values of distortion obtained from a number of measurements on 120 cycle spaced systems when transmitting the word "Paris" at a speed of 50 bauds are shown in graphical form in Fig. 35. The plotted points show the actual results of the measurements, whilst the curves are indicative of the results which could be expected if the number of tests were extended indefinitely. The maximum distortions which would be experienced in practice limit the number of links which can be connected in tandem, and therefore the full line curve may be taken as a reasonable basis for a consideration of this aspect.

Considering teleprinter operation over a long distance circuit composed of a number of carrier channels in tandem, from the fact that the telegraph equipment has certain definite margins, it follows that only a specified amount of distortion can be tolerated. The effective receiving margin of the teleprinter has been stated as 35 per cent. In practice, however, it is desirable to make some allowance for slight departures from the ideal condition of the machine equipment to ensure stable operation. When the teleprinter is placed in service, even under ideal conditions, some parts of the receiving equipment are subject to slight wear, while transmitter contacts and speed control governor contacts become dirty with continued operation. All these factors tend to reduce the margins of the equipment portion of the service, and to ensure that a machine will function satisfactorily for a reasonable period after overhaul, the permissible distortion of the complete telegraph circuit must be something less than the nominal effective margin of 35 per cent. The C.C.I.T. has recommended that the total distortion of a telegraph circuit used for teleprinter operation should not exceed 28 per cent., which allows a reasonable margin for these factors.

The total distortion of the telegraph circuit is the combination of the distortions introduced in the carrier telegraph links and the transmitting relay network. The latter, operating on a single current basis, generally introduces a distortion of from 3 to 5 per cent., which reduces the permissible total distortion on carrier links to approximately 25 per cent.

From the graph it will be seen that if this figure of 25 per cent. distortion is accepted as a basis for telegraph transmission planning, the number of carrier links in tandem must be limited to three, a practice which has apparently been adopted by overseas administrations. Experience in the Commonwealth has shown that, while reasonably stable operation can be obtained with teleprinter circuits operating over three links in tandem, reliable service cannot be guaranteed when a circuit consisting of four carrier links is used.

The adoption of a fundamental telegraph transmission plan in which the long-distance circuits are limited to three carrier telegraph links in tandem, creates some special problems in the Commonwealth network. For example, if direct communication between Perth and Brisbane were required, the link would normally consist of linked channels—Perth-Adelaide, Adelaide-Melbourne, Melbourne-Sydney, Sydney-Brisbane, a total of four links in tandem. Many other similar built-up circuits could be cited. There are two methods which are applicable to the solution of this problem; firstly, supplementary carrier telegraph systems can be installed to provide links between non-adjacent capital centres, as, for example, the system installed between Melbourne and Brisbane. By this means the circuit under discussion would be provided over three links, viz., Perth-Adelaide, Adelaide-Melbourne, Melbourne-Brisbane. This method could only be adopted if the number of channels required between the centres concerned were such as to justify, on an economic basis, the provision of a direct carrier telegraph system.

A second method is by the adoption of regeneration at intermediate points in such a circuit. By regeneration, a received distorted signal is accepted and retransmitted in its original distortionless form.

Regeneration: A regenerative repeater consists of some form of distributor in which the sense of the received signal is determined by the selection of a small portion of each signal element, as is the case in a normal printer. In the regenerative repeater, however, the received signals, instead of being translated into printed characters, are used to initiate a new distortionless signal for retransmission. A reperforator, which produces a tape in which the received characters are perforated, is normally used in conjunction with a transmitter to provide a ready means of retransmitting messages to selected points. It will be evident that the retransmitted signal is regenerated in this process.

BEARER CIRCUITS

Effects of Bearer Circuits: The grade of bearer circuit has an appreciable effect on the performance of the channels of a Multi-Channel V.F. system. The principal sources of interference in bearer circuits are as follow:

Phase Distortion: The general effect of phase distortion is to delay the building up of the A.C. signal. The influence of phase distortion of the bearer circuit on telegraph distortion can be neglected in carrier telegraph systems of restricted bandwidth, as the difference in delay time over the essential transmission band is exceedingly small. Thus electrical networks employed in telephone transmission lines for phase correction are necessary in A.C. telegraph circuits only in cases where transmission of a wide frequency band is required, such as in picture transmission.

Non-uniformity of Attenuation Over the Transmission Band: The effect of excessive non-uniformity of attenuation over the transmission band is that it delays the increment and decrement of the carrier. This condition only occurs to a limited degree in present-day telephone circuits, as all channels include attenuation equalisers. In these circumstances, the difference in attenuation over the essential transmission band of any one channel in a M.C.V.F. system is negligible.

Non-linear Distortion: Non-linear distortions in thermionic valves, loading coils and transformers are possible causes of distortion because their presence results in the production of second and third harmonics of the carrier frequency. If the bearer circuit equipment measures up to normal standards, distortion due to such causes is negligible. As mentioned in Part 1, the carrier frequencies of M.C.V.F. systems have been chosen so that any even harmonics fall midway between channels, thus greatly reducing interference from this source.

Variations in Circuit Attenuation: As discussed in Part 1, variations in circuit attenuation introduce bias distortion, but the use of a suitable limiter circuit and the introduction of automatic regulation in bearer circuits has greatly reduced the distortion due to this cause.

Crosstalk and Interference: The random interference experienced on a trunk route due to the combined crosstalk from all other circuits on the route, together with induced noise from power parallels, lightning discharges, etc., adds to the total telegraph distortion. Provided that the trunk route is efficiently transposed and that power levels are properly co-ordinated, the additive telegraph distortion from these causes is not serious. It is necessary to ensure that the telegraph power per channel transmitted over the bearer circuit provides a satisfactory signal to interference ratio, and, at the same time, offers as little disturbance as possible to associated telephone and telegraph circuits on the route.

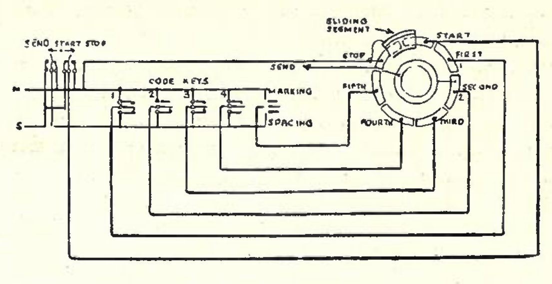
Many test measurements of telegraph distortion have directed attention to deterioration in bearer circuit characteristics which are not apparent so far as speech transmission is concerned. Thus it may be stated that the requirements for satisfactory telegraph transmission are more severe than for normal commercial speech. Crosstalk, interference, and non-linear distortion effects, which would not be regarded as serious so far as speech intelligibility is concerned, can considerably degrade the telegraph transmission.

TESTING

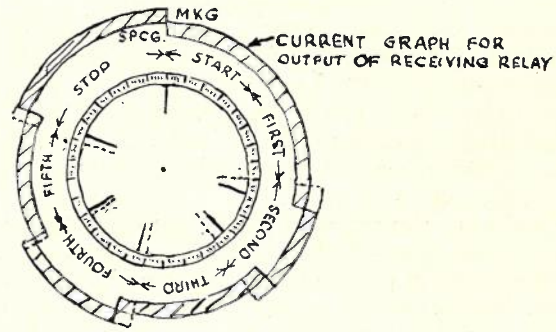
In dealing with the operation of telegraph equipment over carrier telegraph channels, definite figures of machine margins and permissible distortions were stated. For a planned design it is essential that the machine margins be not less, nor the distortions greater, than specified, and to assure compliance with these requirements means must be provided for testing the performance of both machines and carrier telegraph channels.

Testing of Machines: B.P.O. Tester No. TG958 is in use for the testing of Teleprinters. The principle on which this tester operates is shown in Fig. 36A. One revolution of the brushes transmits the seven elements of one character, and by operating the appropriate keys any code combination can be set up on the distributor for transmission to the printer under test. A sliding segment connected to the stop segment and insulated from the start segment can be moved to alter, with respect to the signal elements, the position of the instant of modulation at the commencement of the start signal. By this means the margin of the receiving unit of the teleprinter under test can be ascertained for both "early" and "late" arrival signals.

Incorporated in the Teletypewriter, Model 15, is a device termed a range finder, which enables



(A) Transmitter.



(B) Stroboscope Display of Letter R. (Distortionless signals shown dotted).

Fig. 36A & B.—Teleprinter Distortion and Margin Tester.

the position of the selector cam sleeve to be oriented with respect to the start signal under the control of a lever mounted on a calibrated quadrant. By adjusting this lever while the machine is typing, the limits of the margin of the typing unit can be determined.

Testing of Circuits: Several types of distortion measuring sets have been developed. The equipment provided at carrier telegraph terminals, which is of the stroboscopic type, enables the performance of the carrier channel to be tested, independent of the telegraph equipment. A typical arrangement is shown in Fig. 37. The received signals are displayed on a cathode ray tube having a circular time base, whose period is such that the time for one circle is equal to an element of modulation. Each operation of the receive relay is represented by a radial flash on the cathode ray tube, and if the signals are distortionless the flashes occur at the same point on the cathode ray tube. Any variation from this point which occurs when distortion is present can be readily measured by the calibrated scale provided around the periphery of the circle. Distortionless signals for the purposes of these tests are produced in the transmitter incorporated in the unit. This transmitter provides signals which have mark-space ratios of 1: 1, 2: 2, 5: 1, and "PARIS" (in Morse). A reversing key permits the reversal of the mark-space ratios of the 5: 1 and PARIS signals so that six different test signals can be obtained from the transmitter. A valve oscillator is provided to drive the transmitter and control the cathode ray circular time base, and this enables tests to be made over a wide range of telegraph speeds and facilitates adjustment of speed when the apparatus is receiving from a distant distortion set.

The B.P.O. Tester No. TG958, previously described under "Testing of Machines," can also be used for checking the performance of a teleprinter transmitter or the distortion present in lines or equipment. Incorporated in this tester is a rotating disc mounted on the spindle which carries the transmitter brushes. The stroboscope consists of a neon lamp mounted behind a radial slot in this disc. The neon lamp flashes when the receive relay tongue moves to the opposite contact, and as the rotating disc makes one revolution during the transmission of a complete teleprinter signal, the flashes are distributed around the circular scale at intervals corresponding to the modulation elements of the teleprinter signal. Any variation from the distortionless condition can be readily measured on the scale provided. A typical display for a distorted signal is shown in Fig. 36B, in which the location of flashes corresponding to a distortionless signal are shown dotted.

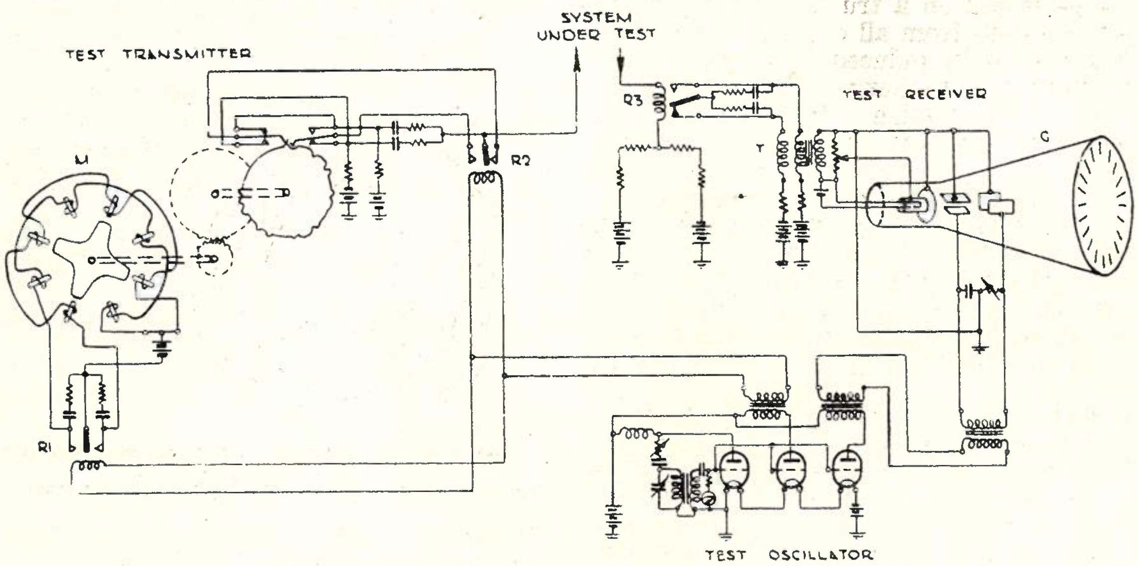


Fig. 37.—Stroboscopic Telegraph Distortion Measuring Set.

A set designed to enable quick measurements to be made of the performance of a telegraph circuit is the 161A telegraph station test set. The circuit arrangement when the set is being used to measure bias and characteristic distortions is shown in Fig. 38.

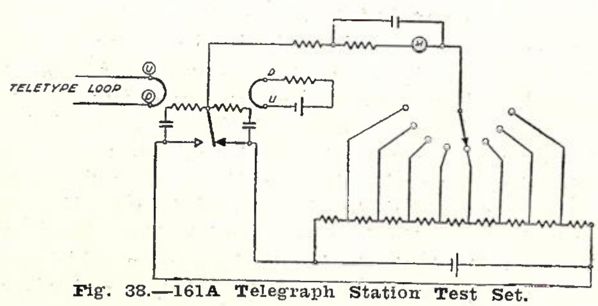


Fig. 38.—161A Telegraph Station Test Set.

The set is arranged on the Wheatstone bridge principle, a neutral reading being obtained when undistorted test signals are being received. The bridge arms can be varied so that the ratio between them corresponds to the mark-space ratio of the test signal. Any distortion of the received signal results in a departure from zero reading. The constants of the circuit are adjusted so that the meter indicates the percentage distortion for teletypewriter signals; that is where the signal element is 22 milliseconds in length.

A more precise set for determining distortions introduced in teletypewriter circuits is the 118 telegraph measuring set. It consists of a distributor, which is released and permitted to rotate on the receipt of a start signal. For the duration of each signal element a constant charging current is applied to a condenser, and the voltage of this condenser is subsequently compared with a reference battery. With a constant charging current the voltage of the condenser will be directly proportional to the time for which it has been charged. If the signal element received is undistorted the voltage of the condenser will be equal to that of the battery, and no current will flow in the indicating circuit. If, on the other hand, the duration of the received signal element is longer or shorter than a perfect element of modulation, the voltage of the condenser will be respectively above or below that of the battery, and a current will flow into the indicating circuit in one direction or the other to indicate the deviation.

CONCLUSION

Advances in the carrier telegraph art, the introduction of teleprinters and teletypewriters, with their associated equipment, and the adoption of improved methods of testing have undoubtedly created a new field for telegraph development. It can be safely predicted that these advances will lead to the development of a large and comprehensive network for the handling of departmental traffic in which the manual retransmission of messages at intermediate points between the offices of origin and reception will be greatly reduced. Parallel with this development further expansion in the already extensive leased service network will no doubt lead to the provision of switching facilities to establish intercommunication between any two teleprinter subscribers, and the possible adoption of automatic switching methods for this purpose. It is certain that these developments will not only result in the more economic utilisation of departmental equipment, but will provide greatly improved telegraph facilities.

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DIALLING ON LONG DISTANCE TRUNK LINES—A REVIEW OF DEVELOPMENTS, 1944

F. P. O'Grady

Automatic Trunk Switching: One of the most important problems facing telephone administrations throughout the world is the introduction of automatic methods of handling trunk traffic over long distances. It seems clear that a telephone service will never be completely satisfactory until any subscriber in a country can dial any other subscriber and obtain a service on demand without the intervention of operators. A few years ago this proposition would have been regarded as fantastic, but until the present war put a stop to progress, a great deal of development had been taking place in the direction of providing complete subscriber to subscriber dialling in various countries. The greatest progress had been made in nations having small geographical areas, but with high population densities, such as Switzerland, Belgium, and Holland. The places with more scattered population have greater difficulties to overcome in achieving the ultimate aim, but an intermediate phase, which offers a good practical goal, is to have not more than one operator per call, and this is applicable to conditions in Australia as a practical aim for the present.

Multi-Metering: One of the important problems in obtaining satisfactory subscriber to subscriber dialling systems is the question of accountancy. The method by which details of the trunk line charge can be assessed and recorded is really a vital problem. The operation of the subscriber's register, a certain number of times for each trunk line call, is one partial solution of the problem. This is known as "multi-metering," and is in use in many localities already. This system necessitates the trunk line charges being arranged as multiples of the local unit fee. This is sometimes a difficult thing to do, particularly for long distance calls where it may become necessary to operate the subscriber's meter a great number of times to record the charge correctly. The system has a fundamental disadvantage also that there is no means of discriminating between local calls and trunk line calls, and if a subscriber disputes the account there is nothing to indicate whether he has had a large number of local calls in a particular period or a few trunk line calls.

Toll Ticketing Machines: The introduction of machines to print a ticket giving full details of the trunk line call has gone a long way to solve the accountancy problem, and there is little doubt now that future development of these machines will remove one of the remaining bars to the introduction of fully automatic subscriber to subscriber dialling over an entire network. These toll ticketing machines include mechanisms which trace the number of the calling party, record the number of the party dialled, determine the trunk line route which is being followed to reach this party, and from this assess the appropriate charge per minute, record the commencing and finishing time, and print all these details on a docket in such a manner that the subscriber's account can be properly rendered. The docket, of course, remains available for use in case of dispute, and the system is therefore obviously very much better than the multi-metering system in this respect. At first mention the machines to carry out the above functions may be thought to be formidable mechanisms, with high capital cost and maintenance expenses, but it appears that even at this early stage of development the complete mechanism likely to be required is by no means complex. The important point to be borne in mind is that if it is possible to eliminate manual operators, either partially or wholly, in setting up trunk line connections, the resultant saving in annual operating expenses would justify the expenditure of very considerable sums of money in capital equipment charges and maintenance expenses for such devices as toll ticketing machines. In addition, and perhaps even overriding this consideration, is the fact that the service rendered to the public is likely to be ever so much more convenient and attractive if the manual operators can be dispensed with.

Subscriber-Subscriber Dialling: The introduction of full subscriber to subscriber dialling in a country such as Australia is likely to take many years before it is finally accomplished because of the very great distances involved and the comparatively low density of population. One of the first questions likely to be asked regarding the introduction of this service is—how can we render a fully automatic trunk line service unless we provide trunk lines as generously as we now provide junction lines between two suburban exchanges in the one city area? In this connection it should be stressed that even were manual operating retained indefinitely it was the clearly stated intention of practically every telephone administration before the war to introduce a "no delay" service on trunk lines, and considerable progress in this direction had been made. In America, for example, well over 80 per cent. of trunk line calls were established on an "on demand" basis, that is, while the calling subscriber remained at the telephone. To provide "on demand" service with manual operating necessarily requires the provision of trunk line channels on a generous basis. Once these channels are provided the introduction of automatic methods of working becomes relatively easy. The method of providing the large number of additional channels obviously lies in the further application of carrier systems and radio telephone channels. There is little doubt now that in the post-war period there will be a very large expansion in the use of multi-channel carrier systems and the application of U.H.F. radio links of types designed to provide large numbers of channels on an economic basis. The universal experience of all telephone administrations has been that the potential demand for trunk line service on the part of the public is always so great that any expenditure in providing additional channels is rapidly recouped by the immediate increase in revenue which results.

Alternating Current Dialling: The introduction of an "on demand" trunk line service leading ultimately to the use of fully automatic subscriber to subscriber dialling with toll ticketing machines will result in a demand for methods of signalling over trunk lines better than those commonly used with manual methods of working in the past. The use of multi-channel carrier systems and U.H.F. radio links makes it impossible to use direct current signalling methods, and before the war put a more or less complete stop to development work satisfactory progress was being made in the introduction of signalling methods which avoided the use of direct current. The systems used were based generally on the use of frequencies which lie in the voice range and which therefore can be transmitted over any path capable of carrying the subscriber's speech.

V.F. Dialling: At first sight it would appear to be a fairly simple problem to design a V.F. signalling method which would provide the necessary signals. The fundamental problem in this respect, however, is the fact that in practically all cases the device which responds to the V.F. signals (usually called a V.F. receiver) must be left bridged across the circuit during conversation. This is necessary so that it can be ready at all times to receive clearing signals from the distant end. This means that the V.F. receiver is subjected to interfering effects of the voice, tones from automatic exchanges, and various noises such as line noise, switching clicks from automatic equipment, etc. To design a receiver which will ignore the human voice, automatic exchange tone, switching clicks, etc., and at the same time be ready always to respond faithfully to genuine signals has proved to be a very difficult problem indeed. Judging by published information it appears that no one yet has succeeded in introducing an ideal receiver, although as has been demonstrated in service, a satisfactory complete V.F. signalling system is practicable if adequate safeguards are provided in the associated equipment. The system in the State of Victoria, for example, was designed to use the best of the known practices, and in service has given very satisfactory results. In contemplating the complete solution of the best design, however, it is desirable to consider the many designs available, the frequencies used, and types of receivers under review in various parts of the world. The human voice has proved on investigation to be an exceedingly complex thing. It contains frequencies extending over the whole range from at least 200 to 3,000 cycles per second, and it exhibits in some respects the characteristics of a carrier system in that one frequency is modulated by others and it appears even to exhibit some of the characteristics of a frequency modulated wave. Practically all transmission paths used nowadays are limited to a band-width of approximately 200 to 2,600 extending upwards to possibly 3,500 in the very latest types of carrier telephone channels. This means that the V.F. signalling system must be designed to use frequencies within this range.

Simple and Compound V.F. Dialling: Designers have approached the problem along well-defined alternative broad lines. One design is based on the use of a single frequency for signalling. This single frequency is used to convey all the necessary signals, and discrimination between them is effected by the duration of application. Thus a short pulse would perform one definite function while a long pulse would perform an entirely different function. Dialling is usually effected by a series of pulses, each equal to the break period of the normal dial. Other designs utilize two distinct frequencies, one to perform certain functions while the other performs a different set of functions. In this case, also, long and short pulses may be used to widen still further the possible range of functions to be performed. Both the above systems are known as simple frequency systems, since only a single frequency is transmitted at a time. Another design utilizes two frequencies which are transmitted simultaneously. The receiver in this case is designed to respond only when the two particular frequencies chosen are received simultaneously and in approximately the correct amplitude relationship to one another. This system is called a compound signalling system, as distinct from the simple signalling sytem.

Receiver Guard Circuits: In order to prevent as far as possible a V.F. receiver from responding to voice, reliance is sometimes placed on the fact that generally speaking the human voice is complex. Thus although it may contain for a moment the frequency corresponding to the one chosen for signalling, it almost certainly contains simultaneously other frequencies. A Swedish invention, usually called a guard circuit, is frequently used in this connection. The receiver is designed so that it will receive the correct frequency and operate a relay if that frequency is present alone. If, however, other frequencies are present simultaneously the guard circuit will function and will disable the receiver and prevent its operation. In some cases the receiver has a guard circuit which functions at all frequencies other than the signalling frequency. This is sometimes referred to as a wide band guard circuit. In other cases, the receiver has a guard circuit which functions only at a comparatively narrow band of frequencies. This is referred to as a narrow band guard circuit. It is very easy to construct a V.F. receiver which will not respond to voice if a wide band guard circuit is introduced. Unfortunately, however, the use of such an efficient guard circuit is impracticable for many reasons. For example, the slightest amount of line noise present on a trunk line would tend to operate the guard circuit and prevent the receiver from responding to the genuine signal. Secondly, any tone from an automatic exchange would prevent the receiver from responding except in the silent intervals. This would prohibit the use of any uninterrupted tones. The most serious difficulty, however, in having the guard circuit too efficient is the fact that when a short-pulse of signalling frequency is transmitted it arrives at the V.F. receiver as a practically square-topped envelope of alternating current. Such a steep-fronted pulse is, of course, equivalent to the simultaneous presence of a number of frequencies (Fourier Analysis). The guard circuit, although it may be tuned to frequencies other than the signalling frequency, is shock-excited into activity at the beginning of the arrival of such a pulse and at its ending. The guard circuit thus tends to disable the receiver at the beginning of a pulse and at the end. This causes serious distortion of short pulses, and it interferes particularly with dialling signals. The effect is not so serious where the signalling pulse is transmitted for long periods, such as 200 milliseconds, or more. The standard dial operating at 10 steps per second necessarily transmits fairly short pulses of tone on a V.F. dialling system. Any distortion introduced by the guard circuit is therefore of serious importance. This difficulty forces the designer to limit the efficiency of the guard circuit to a point where it has scarcely any effect on the distortion of dialled pulses. In this condition the effectiveness of the guard circuit in dealing with voice interference is reduced, and commercial receivers require the addition of suitably designed relay sets to safeguard against incorrect operation. For example, it is usually possible to arrange that during conversation the connection cannot be affected unless a relay is operated for more than a pre-determined period. Occasional flicks of the relays due to voice interference therefore will not affect the automatic connection because they do not last long enough to release the slugged relays which are providing the time delay feature.

Simple Versus Compound Systems: The designers who advocate the use of the compound signalling system rely on the fact that although the human voice is very complex it is not as likely at any given instant to contain two separate and distinct frequencies in approximately equal amplitude as it is to contain any one simple frequency. Thus, if the V.F. receiver is designed so that it will not operate its relay unless two distinct frequencies are present and their amplitudes are within 3db. of one another, then the false operation by voice will be reduced very considerably as compared with the case of the receiver responding to a simple frequency. Tests carried out by the British Post-office under very carefully controlled conditions some time ago confirmed that more extensive safeguards are needed with the simple frequency system than with the compound frequency system. The development at the time of the tests showed the voice immunity of the compound system as superior to that of the systems with simple frequencies. In practice, however, it has been demonstrated that satisfactory guards are available against interference by voice with simple frequency receivers. War has naturally retarded installations considerably, and there appear to be no published figures which show the effect in actual service of the difference between the voice immunity of the compound frequency system and the simple frequency system.

A clear distinction should be made between the compound signalling system and the 2 V.F. simple frequency system used in many localities. Although the 2 V.F. system utilizes two distinct frequencies, they are transmitted only one at a time, each having a separate function to perform. The 2 V.F. system thus is still only a simple frequency system, and it is necessary to use relatively long time delays with each of the frequencies concerned to provide immunity from voice. The compound signalling system is one in which the two frequencies are always transmitted simultaneously. It is, of course, possible to utilize a signalling system in which both compound and simple frequencies are used at various stages of the connection. Thus, for example, the seizing and releasing of an automatic connection may be made by a compound signal, whereas the dialling pulses may be one of the frequencies transmitted separately. In some cases every signal is preceded by a prefix signal whose function it is to turn the V.F. receiver from a condition where it has a protective time delay to another condition where the time delay is removed and the receiver is thus placed in a sensitive receiving condition. In some of these cases the prefix signal is a compound signal, while the latter part of the signal which does the actual signalling is a simple frequency.

V.F. Receiver Design and Choice of Frequencies: The three main features of the design of a V.F. receiver required to be bridged across a trunk line during conversation are thus:

(a) the use of selective circuits to prevent unwanted frequencies reaching the main operating part of the receiver;

(b) guard circuits which will prevent the response of the receiver when extraneous frequencies are present in addition to the correct signal frequency;

(c) time delay in the response of the signalling relays to prevent occasional flicks on the first relay in the chain from causing false signals.

In connection with the use of selective circuits, the choice of signalling frequencies is important. It is a well-known fact that the energy in the human voice is not uniformly distributed over the spectrum. The response of the transmitter is more efficient in the middle frequencies. The result is that on the line most of the energy is in the frequencies below 1,200 cycles per second, although the frequencies above this figure are important as regards articulation. At first sight, therefore, there would appear to be considerable advantage in choosing frequencies which are fairly high since energy from the voice would be low at these higher frequencies and the interfering effects of the voice would therefore be expected to be less than if low frequencies were selected. It is impossible to select frequencies much above 2,200 cycles per second because much of the existing trunk line plant has a comparatively low cut-off, either due to the use of older designs of carrier systems, or the use of old designs of loading coil systems on underground cables. Where it is necessary to contemplate many trunk line channels being switched together in tandem to form a long built-up connection it is necessary to bear this point in mind, since naturally the attenuation/frequency distortion effects are cumulative in such circumstances. There is by no means any unanimity in the choice of signalling frequencies, as the following list of frequencies in use will illustrate:

Great Britain.—600 and 750 cycles per second.

United States.—

(a) Strowger 1,000 cycles per second unmodulated or modulated at 60 cycles per second;

(b) Bell System, 700, 900, 1,100, 1,300, 1,500, and 1,700 cycles per second.

Germany. — 600 and 750 cycles per second simple and compound type.

European Practice.—C.C.I.F. recommendation, 600 and 750 cycles per second simple frequency system, with a trend to compound signalling.

Japan.—2,300 cycles per second.

Switzerland.—3,000 and 3,400 cycles per second.

Australia.—New South Wales: 2,200 cycles per second. Victoria: 600 and 750 cycles per second. South Australia: 2,200 cycles per second.

The frequencies 600 and 750 cycles per second were chosen at a very early stage of the development of V.F. dialling for the following reasons:

(a) 500 cycles per second was already in use for V.F. ringing in most European and British networks.

(b) 1,000 cycles per second was used for V.F. ringing in America and several other countries.

(c) 300 and 1,500 cycles per second were already allocated for Telex systems in Great Britain and elsewhere.

(d) 900 cycles per second was already allocated as a pip tone in trunk exchanges usually to indicate to the subscriber the approach of the three-minute period.

(e) Frequencies higher than 2,000 cycles per second were considered unsuitable because of the rather extensive network of existing trunk cables with low cut-off in Europe.

It was felt that 600 and 750 cycles per second represented the best choice. It is a fact, however, that these frequencies lie in a portion of the spectrum where the human voice contains much of its energy, and the difficulties in the design of the V.F. receiver for these frequencies is therefore increased. The frequencies are relatively close to some of the tones encountered in automatic exchanges, and this has still further increased the difficulty of the designer. There appears little doubt that the use of these two frequencies as a compound signal presents many technical advantages.

Prior to the outbreak of the present war it was the intention of the C.C.I.F. to meet in Paris in December, 1939, to discuss further several problems arising from V.F. dialling and signalling systems. It was expected that a great deal of discussion would have taken place on many of the related problems, and no doubt substantial progress would have been made in solving some of these had the conference been possible. Owing to the outbreak of war various nations have had to make their own decisions on many of the problems which have arisen, and although war itself has retarded the application of V.F. dialling, it is perhaps unfortunate that so much plant has had to be installed which ultimately may not fit in with the final C.C.I.F. recommendations. On the other hand, this freedom of action will give the opportunity for wider experience and new development which will be of considerable benefit when eventually the standardisation is completed.

Low Frequency and Carrier Dialling Systems: It is appropriate here to discuss certain other types of signalling systems which are in use or have possible application in the future for trunk line working. Prior to the introduction of V.F. dialling systems many installations had been made in European countries of 50 cycle dialling and signalling systems. These systems gave satisfactory service, particularly on the trunk cable circuits working on a physical basis which were used before the introduction of carrier on cable systems in the countries concerned. The modern trend towards the use of carrier on cable systems has tended to make the use of physical lines in cables more or less obsolete, and consequently the 50-cycle dialling system is losing favour as compared with V.F. dialling systems, which are capable of operating over any channel on which speech is possible. With the 50-cycle dialling system the signals are transmitted over the same pair of wires as the conversation takes place, but as the signalling frequencies are outside the voice range proper, the system is really equivalent to having the signalling channel operating separately from the speech channel. At such points as V.F. repeaters it is necessary to insert by-pass equipment to preserve the signalling channel. The 50-cycle dialling system has a tendency towards distortion of dialled pulses due to the fundamental fact that because of the short duration of the dialled pulse only a few cycles of alternating current are transmitted for each pulse. The beginning and end of each pulse has a random relationship to the phase of the 50-cycle current, and consequently it is quite possible for successive pulses to differ appreciably in length from one another through this cause alone. Various circuit arrangements have been evolved and put into practice by different administrations with the idea of improving this condition, such as the use of impulse distortion correctors, regeneration of pulses, and so on.

150-cycle Dialling: The most recent development in the direction of low frequency dialling systems is the suggested use of 150-cycle signalling systems in Germany. The advantages inherent in the use of 150 cycles in place of 50 cycles are important ones. In the first place the distortion mentioned above is reduced considerably, and in the second place the 150 cycles per second is transmitted much more efficiently through typical physical line circuits which include transformers and similar devices. The 150 cycles per second system offers an attractive solution to the problem of automatic working over the many short distance trunk lines radiating from a capital city or from a zone centre in the country. It seems clear that, notwithstanding spectacular progress in the application of carrier systems to the trunk line network, there will always remain large numbers of short distance trunk circuits over which automatic working will no doubt be required. The use of direct current signalling systems on these lines is, of course, possible in some cases, but generally speaking direct current signalling methods are unsatisfactory by present standards, particularly if they involve the use of ground return working, with consequent difficulties on open-wire lines due to leakage in wet weather. Although it is possible to provide various circuit arrangements to minimise the effects of such leakage, it is found that the terminal equipment which then becomes necessary is comparable in cost with alternating current signalling equipment. Direct current methods almost invariably necessitate the abandonment of phantom circuits, and in many cases the loss of these phantom circuits is a serious economic factor, particularly, for example, in the case of R.A.X.'s trunking into a parent exchange. The only method by which the phantom can be retained with direct current signalling methods is to use composite equipment, which, in turn, necessitates the use of ground return circuits. With 50-cycle dialling ordinary phantom circuits can be retained. The phantom circuits can also be retained, of course, with 150-cycle dialling. One hundred and fifty cycles is derivable from A.C. mains by simple static frequency changing transformers.

Advantages of 150-cycle Dialling: The use of 150 cycles per second for dialling has the advantage that, because of the low telephone interference factor of such a frequency, it is possible to transmit relatively high sending levels without risk of interference to adjacent circuits. As much as 30 to 50 volts of 150 cycles per second can be applied to the circuit, and, with ordinary attenuations likely to be encountered in practice, it follows that the receiving device can be relatively insensitive. It is possible, for example, to dispense with valves in the receiving device completely if a specially sensitive polarised relay and metal rectifier combination is employed. Alternatively, a very simple tuned circuit with a single valve and an ordinary 3,000 type relay would provide a perfectly satisfactory receiver for use on 150 cycles. The capital cost of the single valve combination is considerably less than the value of a normal sensitive polarised relay, and the life of the valve, which is normally biassed to cut-off, is extremely long, so that the annual charges are very low. It appears that for Australian conditions the single valve receiver is probably the most satisfactory receiver to use. The 150-cycle signal can be by-passed around one or two V.F. repeaters, with simple filter components, in cases where such repeaters are required. It is expected that the maximum use of 150-cycle dialling would be with lines which require no V.F. repeaters, or, at the most, a terminal amplifier at the one end. In this case the terminal amplifier can be arranged to be on the drop side of the line relay set to avoid the necessity for by-passing the repeater. The fact that the receiver is insensitive means that it is automatically immune from voice interference, since the levels of voice ever likely to reach the receiver are far below the figure required to operate the receiver, even if the voice should contain components of 150 cycles occasionally. In a similar manner interference from automatic exchange tones, switching clicks, line noise, etc., cannot possibly affect the 150 cycle receiver. The complete elimination of interference effects makes the design of the associated relay set quite simple, as it avoids the rather complicated circuit arrangements which are necessary with many V.F. systems to minimise the effects of occasional interference by voice.

150-cycle Dialling Applications: The 150-cycle dialling appears to be capable of use in tandem with other methods of dialling, such as the V.F. system, and it is quite likely that future development will take the form of V.F. or other types of dialling from the capital city out to the zone centre, since on such routes comparatively expensive equipment is justified. From the zone centre to the individual small exchanges in the zone area, however, 150-cycle dialling could profitably be used, since this would enable comparatively simple and cheap equipment to be used on the short distance lines. One of the features of V.F. dialling is that signals can be transmitted from one end to the other of a long, built-up connection without the necessity for mechanical repetition of signals at intermediate points. In practice the alternative of repeating the signal with relay sets may not be such a serious disadvantage, because it permits the use of various types of dialling systems in tandem. Thus 150 cycles could be used for portion of the built-up connection with V.F. signalling for the remaining portion. Naturally there are objections to the use of a large number of repetitions of impulses by conventional relay sets, but it appears on present indications that the number of repeating points is not likely to become excessive, provided care is taken in laying out the automatic trunk numbering scheme. In any case, mechanical regeneration or similar impulsing correcting means can be used at important centres.

Dialling Over Special Channels: In addition to the use of 150 cycles (which for practical purposes will replace the 50-cycle system for future applications), it is possible to use other means of signalling which are outside the speech band of the particular channel concerned (quite apart from the use of direct current methods, which for many reasons are now quite obsolete for long-distance dialling). There are many possibilities, and of these perhaps two appear likely to be adopted. One simple method is to separate the signalling functions of, say, 12 telephone carrier channels from the speech transmission functions altogether and send the signals by means of a 12-channel carrier telegraph system. The 12-channel carrier telegraph system can be superimposed on any available speech path or can even operate in a portion of the spectrum not otherwise used. At the send end of each trunk channel the signals are separated by relay sets which are used to control the operation of the associated channel on the carrier telegraph system. By this means the signals are transmitted completely independently of speech, and as the carrier telegraph system normally functions on a duplex basis it is possible to send signals in both directions simultaneously should that ever be required. This feature is usually not available on V.F. or 150-cycle dialling systems, although it is possible that further developments with these systems may make it possible to use duplex signalling. As the band-width required for the transmission of dialling pulses is comparatively small it is possible to arrange a large number of signalling channels in a small part of the spectrum. The equipment required is relatively simple and cheap. The complete elimination of interference by voice, automatic exchange tones, etc., makes the design of the relay sets very simple and the cost is consequently considerably reduced compared with the relay sets required for V.F. signalling, in which complex arrangements are necessary to minimise the effects of occasional interference by voice. The use of this special signalling carrier system is, of course, open to the objection that a failure of this system would disable a large number of speech channels. In practice, the interruption may not be serious, as, generally speaking, the carrier systems can be patched quickly on alternative circuits. The system is particularly applicable to multi-channel carrier systems on cable where circuit failures are likely to be rare, and where large numbers of channels between two terminal points are likely to be required. It is not so easy to visualise its application to smaller trunk routes in Australia, where the number of speech channels is from one to six in many instances.

Carrier Dialling: Another method of providing facilities outside the speech band is to make use of the carrier frequency itself in a carrier telephone system. It will be remembered that some of the early carrier telephone systems transmitted the carrier frequency throughout the conversation. With this system it was possible to devise a simple signalling system by interrupting the carrier momentarily in order to send a signal. The interruption of the carrier current causes the relay to release at the receiving end, and dialling systems are in use in New South Wales on some of these early types of carrier systems using this principle. In all modern carrier systems, the carrier amplitude is reduced to very low levels. One of the principal reasons for this with multi-channel systems, such as the 12-channel type, is to avoid any unnecessary load on the common amplifying valves at repeater stations. Where large numbers of channels are transmitted simultaneously the peak value of the resultant wave may reach very high relative figures instantaneously. To avoid the use of extravagantly large capacity valves it is necessary to take all available steps to reduce the peak value of this complex wave. If appreciable amounts of carrier leakage are allowed to occur the resultant peak value will soon reach undesirably high figures, and with the side band frequencies present on talking channels the valve amplifiers would soon be overloaded. On the assumption, however, that it is unlikely that all channels would be signalling simultaneously, it is possible deliberately to transmit the carrier current of the channel when it is required to send a signal. Probability theory justifies this assumption, and consequently it has been possible to devise practical schemes for dialling which are known as carrier dialling systems. With these systems the carrier current of each channel is normally suppressed as much as possible. When it is desired to transmit a signal a relay set brings about the necessary circuit changes to permit the desired amplitude of carrier current to pass out to line. At the receiving end a high impedance receiver is bridged across the appropriate part of the demodulator band pass filter of the channel. This receiver includes the necessary amplifying, selective, and rectifying circuits to operate a relay when the carrier current is received from the distant end. Usually the incoming carrier current is heterodyned against a local oscillator in order to obtain the advantages of the high selectivity which the heterodyne method of detection offers in the case of the high frequencies normally used. Thus, instead of having the receiver tuned to, say, 68 kC/s., it is arranged that the incoming 68 kC/s. carrier current is beat against a local oscillator of 60 kC/s. to produce an 8 kC/s. signal. The selective circuits of the receiver proper are thus tuned to 8 kC/s. instead of 68. It is possible, of course, to obtain much better selectivity at 8 kC/s. than at 68 with commonly available simple filter components. The amount of carrier current transmitted to line on this carrier dialling system is considerably less than was used with the old transmitted carrier type of carrier systems. The first application of this system in Australia is on the carrier on cable installation between Sydney and Newcastle, New South Wales. In this case the cable is entirely underground, and 9 or 17 channel carrier telephone systems are in use on each cable pair. Two cables are provided on a four-wire basis with repeater stations at frequent intervals. The comparative absence of interfering effects results in a low noise level in the cable system, and consequently it is possible to transmit only a small amplitude of carrier current for signalling while still giving reliable results. This system, of course, is immune from voice interference, and it is possible if desired to provide duplex signalling facilities since the carrier currents in each direction of the four-wire system are quite separate. The relay sets do not need to make any provision for occasional interference by voice, and this results in comparatively simple functional operation of the various relays. With this system, of course, it is necessary to repeat signals mechanically or in some other special manner at the carrier terminals where the derived voice frequency trunk circuits are switched to distant points.

General Features of Existing Systems: The principal features of the various alternating current dialling systems in use in various localities are:—

UNITED STATES OF AMERICA

Strowger V.F. Dialling System: The system which has been developed by the Automatic Electric Company of Chicago, and installed in a number of places, including South America, is a single frequency system so far as the transmission of dialling impulses is concerned, but it utilizes a modulated frequency for other purposes, and is thus equivalent in many respects to a 2 V.F. system in that discrimination between one class of signal and another is afforded by the use of, what amounts to, two separate frequencies. The dialling frequency is 1,000 cycles per second, and the signal used for other purposes, such as seizing, releasing, supervisory signals, etc., is 1,000 cycles per second modulated at 60 cycles per second. As the modulated frequency is used for a variety of signals it is necessary to use long and short pulses to discriminate between some of the signals.

Bell System: The only available published information on voice frequency dialling systems from the Bell Telephone Laboratories is in connection with a recent installation at Philadelphia, where a new semi-automatic cordless trunk exchange has been installed, together with facilities for outlying towns dialling or key-sending into Philadelphia. The voice frequency system adopted is a multi-frequency system specially adapted for key-set sending. It utilizes frequencies of 700, 900, 1,100, 1,300, 1,500, and 1,700 cycles per second. Circuits are seized by transmitting simultaneously two of the frequencies and are released by transmitting another combination of two frequencies. Impulses corresponding to the key-set sender keys depressed are transmitted in the form of various combinations of two of the frequencies. For example, the transmission of 900 and 1,100 cycles per second simultaneously would be registered on the incoming storage registers as denoting the digit 1; 900 and 1,300 transmitted simultaneously would denote the digit 2, and so on. The resulting operation of the receiving relays in the register control the sending out of the required D.C. impulses to the local step-by-step or other type of automatic exchange. The V.F. receivers are designed so that they will respond only to the simultaneous arrival of two frequencies, which must be received without the presence of a third frequency. With this arrangement a single frequency arriving cannot operate the receiver, and if more than two frequencies are present the receivers will not respond. This feature provides a great measure of voice immunity. An additional feature is the fact that in the normal idle condition the receiver is in an insensitive condition through the introduction of time delay relays. Before the digits are actually sent two of the frequencies shown are transmitted, and their effect is to alter the relay conditions so as to place the receiver in a sensitive condition for high speed digit sending. At the end of the digit sending another combination of two frequencies is transmitted which places the receiver back in the insensitive condition.

BRITISH POST-OFFICE

The British Post-office has in use large numbers of 2 V.F. dialling circuits, using 600 and 750 cycles per second transmitted as simple frequency signals and utilizing equipment mainly of its own design. It has also had submitted to it a large variety of models of receivers from various contractors from time to time, and it has carried out many investigations into the characteristics and performance of these receivers. It appears from published information that the British Post-office is far from satisfied with the V.F. equipment with which it has had experience. The principal difficulty appears to be the conflicting requirements of voice immunity and reliable dialling impulse transmission under varying conditions of attenuation on the line. Voice immunity requires that the receiver should respond only to a very narrow band of frequencies, but a highly selective tuned circuit will not permit the currents to build up and die down as fast as desired, so that they cause marked distortion of the dialled pulses. Various devices have been suggested and tried to make the weight of impulse from the receiver independent of the attenuation of the line, but none of those used by the British Post-office appears to be completely satisfactory.

GERMANY

The German Post-office has used extensive installations of single frequency and also 2 V.F. equipment, using 600 and 750 cycles per second, in recent years, and has published a great deal of information on the problems encountered. It seems clear that the German Post-office is not satisfied with any of the designs which have been put into use to date. Development work was apparently going on very actively prior to, and just after, the outbreak of the present war in 1939. There are many installations of 50-cycle dialling on physical lines mainly in underground cable routes in Germany, and recently published information discloses that 150-cycle equipment is being put into use in place of the 50-cycle dialling because of the many advantages of the 150-cycle system.

SWITZERLAND

From information published in the journal "Swiss Technics," it appears that the Swiss Administration is now utilizing a compound frequency dialling system over its newly developed 12-channel carrier telephone system. It uses the frequencies 3,000 and 3,400 cycles per second transmitted simultaneously for all signals. These high frequencies can only be transmitted over a modern wide-band carrier telephone system, and therefore could not be universally applied. No doubt they have been selected for their comparative freedom from voice interference. It has designed the V.F. receiver on the basis that no response will occur unless both frequencies are present simultaneously and at approximately equal amplitudes. It states that the human voice practically never contains two such high frequencies simultaneously with equal amplitudes.

ITALY

Large installations of 50-cycle dialling were in use before the war over the trunk cable networks used for most of the important trunk traffic. In Italy installations had been made of early type 4-frequency dialling systems, and some of these were later converted to 2-frequency systems using 600 and 750 cycles per second.

EUROPEAN PRACTICE—C.C.I.F.

The original recommendations of the C.C.I. were based on the use of 600 and 750 cycles per second through a simple frequency 2 V.F. system, and they have laid down the general limits covering the frequency limits and levels and other main features of a desirable system. It seems clear, however, from published information that many of the European telephone administrations and manufacturing companies were not satisfied that a design satisfactory from all points of view could be achieved using simple frequencies of 600 and 750 cycles per second. It was considered by these investigators that better results could be achieved by using a compound signalling system in addition to the simple frequency signals. The compound frequency was suggested as a simultaneous transmission of 600 and 750 cycles per second, levels of the two components being maintained within 3db. of each other.

JAPAN

It appears from information published in the Nippon Communication Engineering Journal that the Japanese use 2,300 cycles per second for voice frequency signalling purposes. This frequency has been chosen because of the fact that interference from voice is much less at the higher frequencies in the voice range than at the lower frequencies.

AUSTRALIA

Victoria.—Siemens 2 V.F. Equipment: A large installation of Siemens Bros. 2 V.F. equipment dialling into Melbourne has been installed, the present number of lines equipped being in the vicinity of 300. This installation has aroused a good deal of interest throughout the world, particularly in view of the fact that the war has retarded development and interfered with installations which were contemplated in other countries. The system represents a noteworthy step forward in modern trunk line switching. The Australian Post-office has made a substantial contribution to world progress in this general subject through its introduction of this large and unique State-wide installation. The facilities provided are generally in accordance with the recommendations of the C.C.I.F., but it includes many completely novel features which have been described in various journals as mentioned in the attached list of references. The following information is intended to give only a very general outline of features pertinent to this general survey. This system utilizes two frequencies, 600 and 750 cycles per second, transmitted separately on all occasions, so that the system is a simple frequency system; 750 cycles is used generally for setting up a connection; 600 cycles is used to release the connection, speaking in very broad terms. The 600 cycle frequency is used extensively for supervisory signals, and the equipment provided by Siemens Bros. gives a full range of standard lamp signals between the originating manual operator and the automatic subscriber at the end of the channel or between two manual operators where manual tandem working is necessary. The system utilizes 600 and 750 cycles per second because these two frequencies had been recommended by the C.C.I.F. and adopted by the B.P.O. Signals are transmitted over trunk channels in the form of short or long pulses of either frequency. The selective sections of the receivers provide reasonable immunity from false operation of the V.F. signalling relays by voice, and protection against occasional fleeting operation from this source is provided for by relay circuits which prevent response to anything except sustained operation. It is therefore practically impossible to cause irregular operation by means of the voice. Important signals which may be masked by voice due to the operation of the guard circuit are repeated in the form of successive pulses from one end of the trunk channel to the other until they are properly registered at the receiving end and an acknowledgment pulse of signal is sent back to the originating end. This important principle of repeating a signal until it is acknowledged avoids many theoretical difficulties with a system of signalling which depends on pulses of signal only being transmitted. The guard circuit in the Siemens receiver operates over a band of frequencies whose mid point is 340 cycles per second. This guard frequently is chosen so that harmonics of voice components at about this frequency will not be likely to cause false operation of the receiver. The first stage valve in the receiver is an amplitude limiter, and the circuit arrangement is such that harmonics are freely generated. A frequency component of voice at 300 cycles per second will generate a harmonic at 600 in the limiter and excite the tuned circuit in the second half of the receiver. Similarly, a frequency of 375 in the voice will generate a harmonic at 750. The 340 cycles per second is a compromise between the two frequencies required, and the band-width of the guard circuit is adequately wide so that the guard circuit is completely effective in suppressing the effects from harmonics mentioned. A guard circuit operating at this comparatively low frequency is particularly liable to interference by automatic tones and switching clicks, etc. When the Victorian equipment was designed it was not considered necessary to provide standard dial tone to be transmitted from the city end automatic exchange equipment to the country telephonist who was dialling in. The difficulties which might have arisen from the dial tone interfering with the low frequency guard circuit have therefore not arisen in practice. The guard circuit is sensitive to busy tone at nominal 400 cycles per second, and also N.U. tone, which is usually of the same frequency as busy tone. Busy tone is always interrupted at regular intervals, and no difficulty has arisen in practice since the releasing signal from the country end is always long enough to over-ride gaps in the busy tone. Difficulty with the N.U. tone has been avoided by altering it from its uninterrupted form to give a half-second interruption every five seconds, and there is provision for the releasing signal (2 secs.) to be extended until the half second period of interruption is reached—this may be a maximum of six seconds. However, in the case of country magneto switchboards such arrangement was limited to discrimination between effective and ineffective calls, and the maximum signal of six seconds is sent on all ineffective calls, whether N.U. or otherwise.

This wait of six seconds for the country operator before she can make a call succeeding an ineffective call may recur often enough, particularly in very busy traffic periods, to become rather annoying to the operator. The operator at the country end must operate a dial key before dialling, and this is arranged to disconnect the operator's talking circuit from the trunk channel while dialling. This means that she hears nothing from the channel until she has dialled the full number of digits and then restored the dial key. If she then hears busy tone she has no means of telling whether it means a subscriber's line is busy or whether she has encountered group congestion at some stage of the setting up of the call. She must then unplug and wait the full six seconds before plugging in and trying again. If, on the other hand, she plugs in and throws the dial key, dials the digits, restores the dial key, and then hears nothing on the line she has no ready means of ascertaining whether the line itself is in good order. In systems in which the operator can plug in and hear dial tone transmitted back to her she has the reassuring feeling that the line is in normal condition. When she dials successive digits and is able to hear any tone encountered at the end of each digit I suggest she is in a much better position to handle traffic under busy hour conditions where group congestion is by no means uncommon.

The circuits are designed to operate within $\pm$ 22.5 cycles per second on either side of the nominal frequencies, these being the limits specified by the C.C.I.F. It is necessary to ensure, therefore, that the carrier systems over which the system may operate are maintained in reasonable synchronism.

The trunk channels in Victoria are all utilized at present on a both-way working basis in order to give the extra efficiency of 2-way working in the case of comparatively small groups of lines.

South Australia.—2,200 Cycle Equipment: This simple type equipment was first installed some years ago before any published information was available on other systems. It was intended to be used mainly to give urgently needed relief to the manual trunk switchboard at Adelaide. The equipment provides for both-way working to take advantage of the increased efficiency when working circuits in small groups. The original installation provides facilities for dialling into the city automatic exchange from the country and for manual ring-down working in the opposite direction. It can, however, be readily altered for both-way dialling operation. At the present time there is no automatic exchange in country areas in South Australia, which has to be reached by dialling from the city, and therefore this facility has not been used to date. The range of signals is naturally not as extensive as that provided in other systems, for example, in the Siemens 2 V.F. equipment in Victoria, since it is not practicable to provide a complete range of signals with only a single frequency in each direction. The system, however, meets present needs very well, and has the advantage of being comparatively simple in design and low in price. The pick-up or seizing signal is short, being about 50 to 100 milliseconds, the same as is used in Victoria with the Siemens 2 V.F. equipment. (On very early installations in South Australia the pick-up signal was two seconds, but this was modified subsequently.) The clearing signal from the originating end is two seconds on all calls, effective or ineffective. The general operation is as follows:—

The country end operator plugs into the line, throws the listening key, hears dial tone, and then dials (without utilizing any dialling key). She hears any tone which may occur at any stage of the dialling, and on completion of the call releases in not more than two seconds. In the later installations the country operator receives a flashing supervisory signal on a lamp above the trunk jack when the automatic subscriber in the city answers. She extinguishes this lamp by throwing her listening key (if, as generally happens, she has her listening key already thrown waiting for him to answer, the lamp does not flash). When the automatic subscriber clears, the supervisory lamp flashes again. She again extinguishes this by throwing the listening key, which she does in order to challenge the line before disconnecting. On an outgoing call from Adelaide manual trunk exchange the supervisory signal in the cord circuit flashes when the country end operator answers. This supervisory lamp is extinguished by the Adelaide telephonist throwing her listening key. The supervisory lamp flashes again when the country end operator clears first. It is again extinguished by throwing the listening key at Adelaide. This flashing supervisory signal has been found much more effective than the older method in which the supervisory lamp glows when the circuit is first set up, goes out when the distant end answers, and lights again when they clear. This latter sequence of lamp signals is satisfactory between the manual trunk operator and subscribers in the metropolitan area, but to ensure prompt attention on the costly trunk lines it is found preferable to use a flashing signal since this tends to bring the operator into the circuit at once, whereupon she either clears or establishes a successive call. The signals provided in South Australia appear to be adequate for the present conditions, particularly bearing in mind the advantage of avoiding elaborate relay sets in country towns with small switchboards. The 2,200 cycle frequency was adopted to take advantage of the lower energy content in voice at that frequency, and to simplify the design of the receiver by utilizing tuned circuit components which are reasonably satisfactory at this frequency. It is usually very difficult (on the local market) to obtain filter components giving good performance at the lower voice frequencies. Reliance is placed on a guard circuit which operates at all frequencies below 2,200 cycles per second as well as a time delay feature which is brought in during conversation.

Just over 100 circuits are operating in South Australia at the present time using this simple frequency 2,200 cycle equipment. All of the major towns have been converted to direct dialling on this system.

New South Wales.—2,200 Cycle Equipment: In this case there are about 30 circuits working, and these are all one-way dialling lines into Sydney. The system is very similar to that used in South Australia, but the V.F. receivers differ somewhat in detail.

N.S.W.—Carrier Dialling System: There is an extensive installation on the Sydney-Newcastle-Maitland route provided by Communication Engineering Pty. Ltd. It makes use of the principle described earlier in which the carrier on an individual channel is deliberately transmitted to line when it is required to send a signal. The installation on this route is in conjunction with a large four-wire carrier on cable system in which 9- and 17-channel systems are equipped using frequencies up to 72 kC/s. The carrier systems proper are equipped with signalling bays which contain sending relays to control the transmission of carrier current on each channel and carrier frequency receivers which are bridged across the demodulator band filter of each channel, and are arranged to respond to the incoming carrier current and to operate a receiving relay. These receivers utilize the heterodyne method of reception described earlier. The signalling leads from these carrier signalling bays are extended as required to manual or automatic exchanges, depending on the traffic facilities necessary. A signal control wire coming in to the carrier signalling bay controls the sending relay proper, and in the reverse direction the receiving relay of the carrier signal receiver extends an earth on a control wire going away to the distant equipment, in a manual or automatic exchange. As the carrier current can be transmitted to line only in the form of pulses and not, of course, during conversation, it is necessary to use a system of pulse transmission similar to the V.F. system. It is necessary, therefore, to provide relay sets which convert the ordinary signal conditions from the manual or automatic exchanges into the necessary sequence of pulses to suit the carrier system proper. There are various relay sets to provide for one-way dialling into Sydney, both-way dialling between Sydney and Newcastle, dialling in and manual out to other towns, and so on. The system, of course, is free from voice interference effects, and is not affected by automatic exchange tones, so that dial tone and standard automatic tones can be given without change. The system as provided at present is more or less confined to the terminal towns of the carrier system, but it is, of course, possible to extend individual channels beyond Newcastle to a country town provided a signalling path is available between that town and Newcastle. So far as the carrier signalling equipment itself is concerned, it is merely necessary to provide the required signals to and from the carrier signalling bay over the two control wires referred to.

FUTURE DEVELOPMENT IN A.C. AND V.F. DIALLING

In the existing V.F. dialling systems, it has been necessary to design the receiver to respond only to a very narrow band of frequencies, and to provide guard circuits and time delays in order to ensure that there is no interference by voice, automatic exchange tones, switching clicks, etc. The use of a narrow band receiver imposes strict requirements on the oscillator frequencies at the distant end, and requires carrier telephone systems, etc., to be maintained in fairly close synchronism. The use of the guard circuit makes it difficult to receive a genuine signal in the presence of automatic exchange tones, line noise, or voice. The guard circuit is also extremely suspectible to sharp impulse disturbances, such as inductive kicks in various automatic exchange switching operations. The use of time delays in the relay set requires that genuine signals be transmitted for a definite minimum time. This naturally slows down the rate at which signals can be transmitted. Faced with these difficulties, the designer has to resort to a number of expedients in order to ensure reliable signalling. To guard against the possibility of signals being masked by various interfering signals, recourse is often had to the principle of repeating the signals in the form of pulses until they accomplish their object at the receiving end, whereupon an acknowledgment pulse or pulses are transmitted back to stop the transmission of further pulses from the originating end. These expedients require generally that the parties at each end of the trunk channel must be cut off from the channel during the transmission of these signals, and this sometimes leads to disconcerting intervals of silence, which would be better avoided.

It is to be expected that difficulties of the type mentioned will be gradually overcome. Some of the minor uncertainties will be swept aside by general developments of a fundamental type. As an instance of this, consider the previous reference to the value of dialling tone. The provision of dial tone is considered to have substantial operating advantages in present circumstances, but, as has been pointed out, there is some difficulty in its inclusion in some sytems. Already we know of the use of the recorded voice to replace tones in automatic exchanges, and the application of this system to long trunk lines would overcome the problems associated with dial tone, and also those related to N.U. tone.

Where large groups of trunks are likely to exist in the future, it is fairly certain that key-set senders will be used at the originating end. With key-set senders it is, of course, not usual for telephonists to wait for dial tone before key sending, nor do they listen for busy tone, N.U. tone, etc., at intermediate stages. So far as large groups of lines are concerned, it is quite likely that V.E.S. (Visual Engaged Signal) or F.L.S. (Free Line Signal) circuits would be employed on the outgoing trunk multiple jacks into which the originating telephonist plugs before either dialling or key sending. When these types of lamp signalling circuits are provided with direct current signalling methods, the existence of the correct lamp signal is a positive indication to the telephonist that she can go ahead and dial or key send with full confidence that the distant equipment is ready to receive her signals. With V.F. or similar systems in which all signals are transmitted in the form of pulses, however, it is much more difficult to ensure that the state of the circuit at the distant end is correctly indicated to the originating telephonist by V.E.S. or F.L.S. methods.

In view of the difficult technical problems involved, and reviewing the rather wide range of systems already in use in various parts of the world to provide long-distance dialling, it seems fairly clear that the future developments are likely to remain rather obscure for a time. The diversion of laboratory staffs on to war work in practically all countries has necessarily retarded developments which otherwise would have taken place, but, on the other hand, many new developments for war purposes may have application in peace time to this problem of dialling over trunk lines. It would be most unwise to set any limits to the technical developments which are likely in this regard. There are several possible applications of phase or frequency modulation which may have a bearing on trunk line dialling problems. Although at the present time frequency modulation is thought of as being more appropriate to very high frequency systems, much attention is being paid to the application of frequency modulation for carrier systems over power transmission lines, the frequencies in some cases being as low as 70 kC/s. It may well be that future development will bring frequency modulation methods into the range of frequencies at present employed for carrier systems over telephone lines, and possibly the signalling methods may also make use of this form of modulation. Some experiments were carried out in South Australia on the idea of a frequency modulated V.F. system that were not taken to finality, as pressure of work in other directions prevented full development of the ideas. It was thought that a receiver arranged to respond to a signal consisting of 1,000 cycles per second, frequency modulated between the limits of 300 and 1,700 cycles per second, would be reasonably immune from voice. A limiter in the first stage of the receiver removed all amplitude peaks, and the discriminator portion of the receiver was similar to the conventional F.M. receivers for radio frequency receivers. A somewhat similar discriminator for use at voice frequencies on a carrier telegraph system is in use by the Western Union Telegraph Company in America. Some of the results obtained were favourable, and it is possible that, with sufficient attention to detail and proper choice of operating frequencies, it would be possible to obtain a receiver which would respond to such a frequency modulated V.F. tone while ignoring voice.

Australian conditions are radically different from conditions in England, and in many respects are different from those in America. So far as is known, V.F. dialling is used in America only between comparatively large cities having very dense telephone traffic, and in these cases the dialling is generally carried out on key-board senders, or special types of dials operating at 20 steps per second, which necessarily must operate into storage registers. In England and in the cases mentioned in America, comparatively high capital expenditure is justified in the signalling equipment. In Australia, on the other hand, with three or four exceptions, practically all existing trunk routes into capital cities are confined to groups of 1 to 6 channels. The originating country exchanges in many cases are extremely small, many of them having only 100 or 200 line switchboards. The necessity for V.F. dialling, however, is very apparent, since the trunk channels are extremely costly in Australia because of the long distances involved and the relatively small number of channels on each route. Any device which will improve the trunk handling capacity of the trunk channel is, therefore, of vital interest to Australia.

In V.F. systems recourse must necessarily be had to the transmission of all signals in the form of pulses. This differs radically from conventional automatic exchange practice, where relays operate more or less in well-defined sequence, and it is possible to reproduce the conditions almost at will for testing purposes. Where series of pulses only are transmitted and reliance is made on discrimination between long and short pulses, etc., it is rather difficult to observe the operation of the relay circuits. This necessarily means that the country mechanic is given a more difficult task in diagnosing and clearing faults. Naturally, the use of automatic routine test circuits and the provision of spare sets of relays can go a long way towards helping in this direction. It seems, however, that simplicity of equipment and circuit design is much more important at isolated country towns than would be the case in large cities, where constant attention is available.

Facilities, which not long ago seemed like fantasies, are gradually being added to one system or the other. The wishful thinking of progress of long-distance service in one country is being applied in some other country where conditions have been more favourable. Design and production have kept pace with progress, and have been able to meet requirements wherever an administration has made up its mind what facilities it will provide.

Reference has been made to the anticipated expansion of multi-channel carrier systems and the application of U.H.F. radio links. Attention has been directed to the notable advance in the use of toll ticketing machines and the potentialities in the application of 150-cycle dialling from a zone centre to local exchanges, while V.F. is used from the capital city to the zone centre. Wider use may be made of the transmission of carrier for dialling, and development may be expected along the lines of independent channels for signalling, which has special application in certain circumstances. There have already been remarkable achievements in this field, and the many ingenious methods applied are detailed in the articles appropriate to each particular system —references to which are given in the attached bibliography.

That there is a big future with the application of V.F. systems can hardly be doubted. Whatever uncertainties exist about the best system of frequencies to be used may be gradually cleared for each country, but for others the uncertainty should not extend beyond the time when the C.C.I.F. is re-established and continues its work of standardisation.

The success of our communication engineering work is determined largely by the facilities given on trunk lines inter-linking our far-flung cities. The trunk network must be forever spreading, and the traffic will grow as facilities are available. The extent to which the public uses the telephone for keeping in touch with distant parts will, in turn, depend on how we develop a speedy and reliable service.

This development can best be promoted by the extension of automatic switching of trunk lines, and in solving the problems presented by the special conditions in this country there is the opportunity for Australia to make an outstanding contribution to the progress of trunkline service.

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AN INTERESTING CONTACT FAULT

H. T. Wright

Reports received from P.A.B.X. subscribers connected to a City automatic exchange that false rings were being received, led to an investigation which showed that, in some instances, calls could be completed in all respects except for the transmission of ringing tone to the calling subscriber. The caller would hang up on the assumption that the call had failed. Meanwhile, the ringing current on the called P.A.B.X. line had operated the line relay and the lamp at the manual board. The telephonist answering the call would find there was no calling party on the line and would conclude that it was a false ring.

The failure in the ringing tone circuit was traced to the F4, J2, or G3 relay contacts in the final selector circuit at the main exchange (see Fig. 1). These contacts were found to be intermittently open to ringing tone, although they appeared to be making, and sometimes the trouble would suddenly disappear after the fault had been in evidence for a minute or so. The relay springs were in correct tension. It was observed that a slight jar or vibration would sometimes clear the fault, and at other times

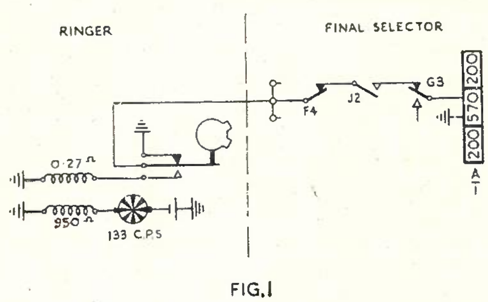


FIG.1

bring on the trouble. As shown in Fig. 1, the circuit for the 133-cycle A.C. is completed from earth to earth over the relay contacts. There is only a small current flowing and there is no D.C. in the circuit.

Some of the contacts were found to be discoloured, and as a first step in dealing with the trouble they were carefully cleaned on all final selectors. This reduced the number of faults located during routine tests from approximately 140 to 40 per month, but did not eliminate the trouble. No further improvement was obtained by ordinary methods, but it was observed that in the Melbourne trunk exchange, similar circuit conditions had been avoided by placing high resistance shunts (100,000 ohms) across condensers to give a definite potential difference across relay contacts. This is known as "wetting" the contacts.

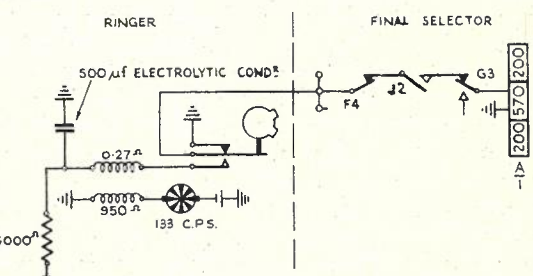


FIG.2

Based on this practice, the ringing tone circuit was altered as shown in Fig. 2. A 50-volt D.C. potential was applied via a limiting resistance of 5,000 ohms. A low impedance path for the A.C. is given through a 500 microfarad electrolytic type condenser. This circuit proved to be satisfactory, faults of the type mentioned being practically eliminated.

As comparable conditions exist on the busy tone circuit, this was treated similarly, and has proved satisfactory. The information regarding the need for "wetting" of contacts is apparently not applied in all circuits, and the experience given above may be of value in dealing with similar circuits in other installations. The need for "wetting" of contacts is, of course, not a new development. Two overseas references are of interest—one from the British Post Office and one from the German Post Office. The following extract from a B.P.O. report throws some light on the matter, although it is not conclusive:

"**Coherer Action:** A doubtful contact is obtained under certain conditions with contacts having small P.D.'s between them, due to 'Coherer Action.' This effect has been investigated by Lodge, Branly, and others, chiefly with reference to its application to radio detectors.

"The effect as it applies to relay contacts is as follows: When the voltage between two contacts subject to coherer action is increased from zero, the current passing is at first only a minute fraction of that current to be expected from the E and R values of the circuit. Increasing the voltage further the current also increases, but still remains practically negligible. When, however, the increasing voltage reaches a certain point, the contacts cohere and the current jumps to its full E/R value. On reducing the voltage after cohesion the current decreases proportionately with the voltage unless the contact be subjected to a jar or vibration, when 'decohesion' takes place and the current drops to a negligible value.

"It appears that no exact explanation covering all cases of this phenomenon has been given, but authorities are agreed that thermal effects introducing back E.M.F.'s at the contacts predominate.

"The effect has been found to exist, for example, between two slightly oxidised steel needles or copper wires resting in light contact or between an oxidised or sulphided iron wire touching a clean or oxidised iron plate."

The German report simply states the observed effects of the phenomenon, but does not offer any theoretical explanation. The process of "wetting" the contacts is known to the Germans as "fritting."

In each case a certain definite P.D. is recommended to overcome the difficulty.

The British figure is 0.2V., and the German report states that "the current from a voltage of at least 10 volts, measured at the open contact, when applied to a contact, will bring the contact resistance back again to a low value. This effect is almost independent of the current, and depends almost entirely on the effective voltage, so that a very small current may be sufficient to bring about an improvement."

It is interesting to note that the voltage and current in the circuit shown in Fig. 2 vary from 50 V. and 0.28 V. and 8.9 mA.-0.51 mA. respectively when the demand on the ringing tone varies between one and twenty simultaneous circuits. In each case the voltage was measured across the open F.4 contacts.

In speech circuits it is desirable that the "wetting" current be kept as low as possible, otherwise the circuit may become noisy due to variations in resistance at the contacts. The German report advocates a current of 0.1 mA. or less without dropping below the specified minimum voltage. In the circuit under discussion, no particular effort has been made to keep the "wetting" current to a minimum, as the circuit does not carry speech.

The German report stresses the influence of humidity on contact troubles of this nature, and states that the relative humidity should not be allowed to fall below 60 per cent. In Melbourne the relative humidity in exchanges falls to a very low value, particularly in winter, but so far no definite evidence can be produced to support the German contention. The theory, however, is of great interest and worthy of investigation.

Reference:

(1) B.P.O. Research Laboratory Report No. 4031.

(2) "Causes of Noise from Switching Equipment in Connections in Telephone Exchanges," M. Langer. Telegraphen, Fernsprech, Funk und Fernsch Technik, 1941.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART IV.: EXCAVATION (Contd.)

Excavation in Water-logged Soil: If the trench has to be dug below the ground water level, water will flow into the trench, giving rise to difficult working conditions, and necessitating careful timbering to support the walls of the trench. The poling boards (see Part III., Fig. 20) should be driven well below the bottom of the trench; this is particularly necessary in sand, as quicksand may be formed and flow into the trench, undermining the sides.

Under such conditions it will frequently be necessary to lower the level of the water to permit the work to proceed; manhole construction particularly being difficult in water-logged soil. A frequently used method is to dig a sump either inside the excavation or closely adjacent to the excavation and pump the accumulated water away. This method suffers from the objection that sand as well as water is carried away by the pump, with a consequent danger of subsidence of the soil.

This disadvantage is reported to have been overcome by the use of "wellpoints." A wellpoint consists essentially of a 2-inch diameter iron pipe, the lower end of which is fitted with a fine mesh gauze screen. Wellpoints are driven into the ground at various points around the excavation and the water drawn off by means of a pump. The gauze, together with sand or gravel compacted around the well-point, adequately prevents the movement of fine particles of sand. The method is more fully described by S. J. Mayo and J. A. Hart in the P.O.E.E. Journal, Volume 35, Part I., Page 1.

Tunnelling: The necessity to use tunnels for the laying of conduits does not often occur under Australian conditions, although tunnels may be used at times to pass under obstructions such as a busy road or tram lines, where an open cut would not be practicable or economical. Tunnelling is an expensive process on account of the following factors:—

1. The work is necessarily slow on account of the restricted conditions and the limited staff that can be employed at the working face.
2. Greater handling of spoil is involved, particularly so if space for surface operations is restricted, preventing storage of spoil in the vicinity.
3. Expensive timbering is generally required, and usually this cannot be recovered as the tunnel is filled in.
4. Conduit laying in a tunnel is more difficult and more expensive.
5. Special care is necessary in filling in, to ensure that the refilled soil is sufficiently consolidated to take its share of the weight above the tunnel, and so avoid subsequent subsidence.
6. Specially skilled workmen are necessary.

On account of the above factors, any proposal to drive a tunnel requires close consideration, together with full examination of alternative methods of construction.

Tunnels are driven from trenches or shafts provided at suitable locations, and should only be of sufficient size to enable the work to proceed and to enable the conduits to be laid. A minimum head room of 4 feet is generally considered necessary. To ensure that the tunnel is driven in the correct direction, it is necessary to transfer the centre line of the tunnel from the surface to the workings. The centre line is first marked out on the surface and two plumb-

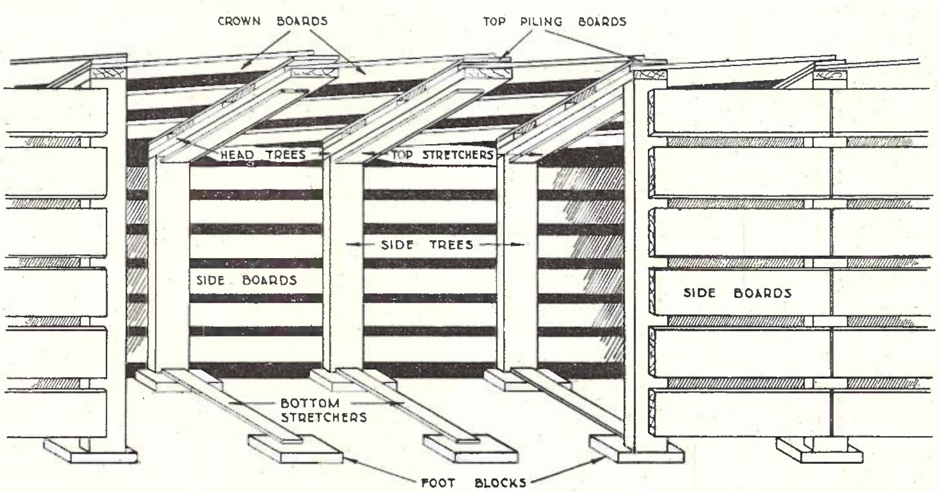


Fig. 24.—Timbering of Tunnel.

bobs set up in the working shaft on this line. The line is then sighted on to a candle held at the working face and the centre line marked by means of a nail on the timber. If there is any tendency for the plumb-bobs to swing, they can be steadied by immersion in a bucket of water at the bottom of the shaft.

The method of timbering a tunnel is illustrated in Fig. 24. The frame, consisting of side-trees, head-tree, top and bottom stretcher, and top piling board, is first placed in position. The "crown boards" are placed in position between the head-tree and the top piling board, and are forced forward as the work proceeds. Additional frames are added as required and the side boards placed in position as each frame is installed. The spacing of the side boards will depend upon soil conditions, open spacing for firm soils and close spacing for wet or unstable soils. Frames are usually spaced 3 to 4 feet apart.

Where tunnels are driven in solid rock, it may be permissible to dispense with the timbering.

Filling-in of tunnels must proceed simultaneously with the conduit laying, and the completed work must conform to exacting requirements, viz.:

(1) The refilled material should hold the conduits secure against movement.

(2) The refilled material should take a share in supporting the soil, etc., above the tunnel.

(3) Voids, etc., which may form watercourses along the run of the tunnel should not be permitted in the refilled material.

These requirements can generally best be met by refilling over and around the conduits with blown concrete. Although more expensive than other forms of filling, the extra cost is not great in relation to the total cost of the work. In addition, the conditions under which conduits are laid in tunnels are generally such as to require the best possible class of construction.

For further details on tunnelling the reader is referred to "Tunnelling Work in Underground Line Construction," by A. T. Soons, P.O.E.E. Journal, Volume 30, Part II., Page 94.

Headings: Headings are generally regarded as short lengths of tunnel only a few feet in length and are frequently employed in passing under small obstructions, such as gutters, drains, etc. No special difficulty is usually encountered in such cases provided the soil is reasonably firm.

The "Alternate Heading" method of excavation is sometimes employed in particular under expensive pavements, so as to limit the reinstatement costs. Sections of trench 6 to 8 feet long are opened up to the required depth and connected with headings about 6 feet in length. The heading should only be of sufficient size to provide working room. In good firm soils no timbering may be necessary in the heading if the top is arched, otherwise a simple support as shown in Fig. 25 will generally suffice.

Filling-in: Refilling of the trenches is much more than a matter of returning as much as possible of the excavated soil to the trench. To ensure stability of the conduits and to avoid subsidence of the soil, it is necessary that the refilled soil be well consolidated.

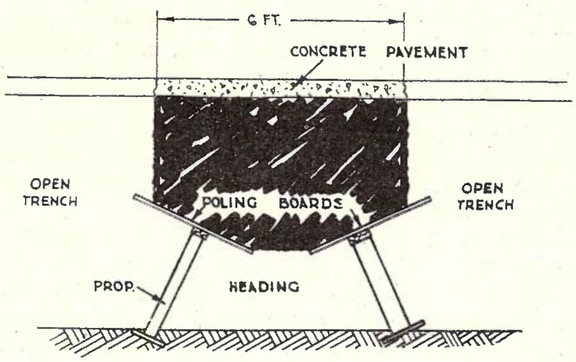


Fig. 25.—Timbering Short Heading.

Backfilling should be commenced as soon as possible after the conduits are laid. Fine soil free from stones and gravel should be used for the first refill up to 6 inches above the conduits, and should be well tamped under, around, and over the conduits, with even pressure on both sides to avoid disturbing the alignment of the conduits. Close attention to ramming of the soil around the ducts is of utmost importance, as otherwise a watercourse will probably form along the run of conduits, with consequent undermining of the whole of the refilled soil. In the case of conduits which are several ways high, the consolidation of the soil along the sides of the ducts is liable to be tedious, but none the less essential. Ramming of the soil at higher levels in the trench will have a negligible effect on the consolidation of the soil alongside the ducts. At this stage, care is required in dropping the soil into the trench, particularly in the case of deep trenches, to avoid injuring the conduits. If suitable fine soil is not available from the excavated soil, it is desirable to cart suitable soil to the job. A fine loam which compacts well is most suitable, while sand is to be avoided, as it does not compact under ramming.

After the initial refill, the balance of the soil may be refilled relatively quickly, provided it is replaced in layers not more than 6 inches thick, and each layer is well tamped before the next is added. The amount of time spent on ramming will to a large extent depend upon the location of the trench in regard to road traffic. Obviously a trench alongside the fence of a country road would not justify the same time spent on consolidation as would a trench crossing a busy street carrying heavy traffic. In the latter, earliest possible reinstatement of the road surface is usually desired by the Road or Municipal Authorities, and to permit of this and to avoid later subsidence of the trench, it is essential that the trench be very well rammed. A measure of the degree of consolidation of a trench is the amount of spoil remaining to be disposed of after completion of work. If the refilled soil has been well consolidated, there should be comparatively little spoil remaining, although space has been taken up in the trench with conduits. The British Post Office, to ensure proper consolidation of trenches, has adopted a rule restricting the number of shovellers to one to each three rammers.

Water is frequently used to assist in the consolidation of the trench, but it should be judiciously applied. Sandy soils can be "washed" into the trench, but this is not practicable with other soils. In such cases a light watering of the soil may be helpful.

Recovery of Timber from Timbered Trenches: Timber can be recovered from close or open timbered trenches (see Part III., Figs. 20 and 21) in the following manner:—

First the trench is filled and rammed to a point just below the bottom stringers, then the bottom stringers and struts removed, the poling boards being held in position by the refilled soil. Backfilling of the trench then proceeds and further stringers removed if necessary until the soil is within 12 to 18 inches of the top stringer. The first poling board is levered out of position and a chain with hook and eye secured around the board, when is then lifted out to within 3 inches of the filled-in surface by means of a lever (bar and block of wood) or lifting jack. After raising the remaining boards similarly, the filling and ramming of the trench then continues and the timber removed as the trench is filled. Fig. 26 illustrates the method of withdrawing timber.

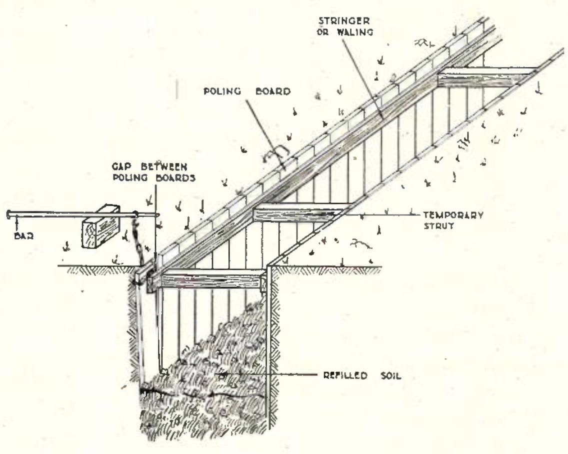


Fig. 26.—Recovery of Timber (Close Timbering).

In the case of timbering in accordance with Fig. 22, the earth is filled and rammed up to the lowest stringer. Temporary struts are then placed across the upper stringers as shown in Fig. 27. The main struts are then knocked out and the poling boards and lowest stringers removed. The filling in of the trench may then proceed, the remaining stringers and struts being progressively removed.

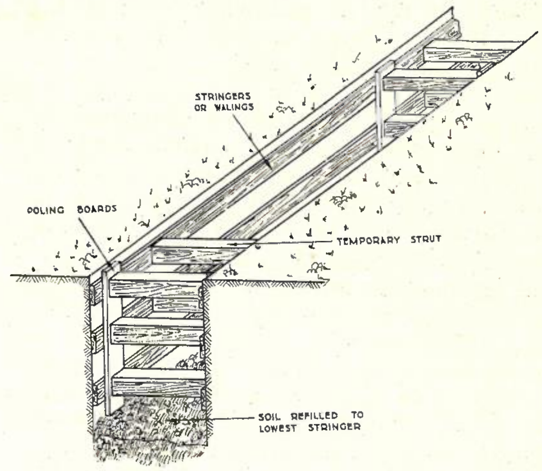


Fig. 27.—Recovery of Timber (Open Timbering).

Erosion of Trenches: The danger of erosion taking place on completed trench work is one which has to be guarded against, and in special cases preventative measures taken. In undulating or hilly country, water running off the hills after heavy rain may be diverted and follow along the trench, scouring out the soft refilled soil. It is possible for long sections of trench to be scoured out to the bottom, and the conduits to be disturbed from their alignment and grade, necessitating relaying the conduits and cartage of spoil for filling. Erosion is more likely to be troublesome in open country than built-up areas.

Careful selection of the route will help in avoiding these conditions, but often it is impracticable to obtain a route entirely free from the danger of erosion, and it will be necessary to apply preventive measures when the trench is filled in. The objective in such measures is to divert the flow of water across the trench rather than along the trench. This is accomplished by placing at intervals obstructions across the trench to prevent the build-up of a flow of water along the trench and divert it down the hillside.

A block of wood 6 to 12 inches longer than the width of the trench, and 6 to 9 inches in diameter placed across the trench and sunk several inches into the soil, as shown in Fig. 28, is a convenient and effective "diverter." The soil at this point requires to be well rammed; a few flat stones on the uphill side will help to avoid water undermining the timber, which should be well packed with soil on the downhill side. Such diverters will be required at intervals of 20 to 40 feet, depending on conditions. Obviously, other materials, such as stones, bricks, or concrete could be used in lieu of timber if economical or convenient.

Reinstatement of Pavement Surface: The final reinstatement of the pavement surface will usually be carried out by the Municipal or other authority controlling the roadway; arrangements for reinstatement will, therefore, be a matter for discussion with the authority concerned.

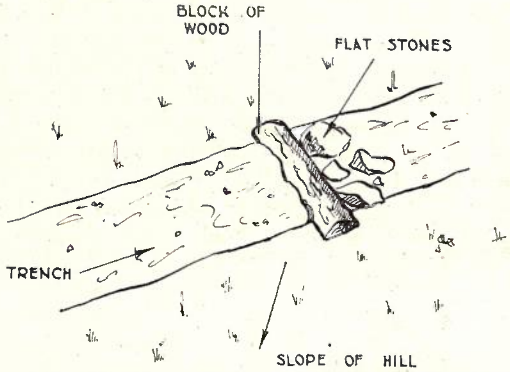


Fig. 28.—Prevention of Erosion of Trench.

In some cases, particularly in busy streets, it will be desired to carry out permanent reinstatement of the pavement with as little delay as possible. In such cases the importance of properly consolidating the trench cannot be too highly stressed, if subsequent subsidence of the pavement is to be avoided. On the other hand, the final reinstatement may be deferred for a short period to allow of the natural consolidation of the soil to occur before repairing the pavement. It will then be necessary temporarily to finish off the surface in such a manner as not to cause inconvenience or danger to traffic. If the material of the original pavement is suitable, it may be used for the purpose, otherwise gravel, screenings, or cinders may be used according to conditions and availability.

It is frequently the practice to leave a mound of soil over the trench when refilling to allow for sinking of the soil. Such mounds should not be too high or too severely rounded, otherwise they may constitute a danger to foot or vehicle traffic. Care needs also to be exercised to avoid interference with drainage when such mounds are provided. The alternative to the provision of a mound is to finish off the trench flush with the surface, in which case sinking of the trench following rain will probably leave a dangerous hollow. Therefore, taking all factors into account, the preferable arrangement is to ram the soil as well as possible during backfilling and leave a slight mound only.

Mechanical Aids in Excavating Work: As in other works involving the moving of earth, there is considerable scope for the use of mechanical equipment in excavating for conduit work. Increasing attention has been given in recent years to the application and development of mechanical methods of excavating, and there are now available a variety of machines suitable for conduit work. The chief advantages of the use of mechanical equipment are:—

1. The work is speeded up.
2. Savings in labour, and therefore in overall costs, are affected.
3. Much of the laborious work is avoided.

On the other hand, no single item of equipment satisfactorily meets all ordinary conditions (although some have very wide application), and consequently different machines are required for different purposes; frequently it is necessary to associate two or more different types of machine on the one job.

In considering the application of mechanical equipment to any particular work and selecting suitable plant, the following aspects will need to be taken into account:—

1. Size of job.
2. Location, geographically and climatically.
3. Nature of soil involved — loam, clay, gravel, rock, etc.
4. Nature of surface—paved or unpaved.
5. Time for completion.
6. Cost and availability of labour.
7. Transportation facilities available, particularly for handling heavy equipment.
8. Presence of obstructions which may hinder the use of particular types of equipment.
9. Operating costs of mechanical equipment, including drivers' or operators' wages, fuel, oil, repairs, etc.
10. Availability of various types of plant.

All of the above factors are important, and require to be carefully assessed in each instance. Owing to the wide range of conditions under which conduit work is carried out, it is not practicable to lay down any set rules regarding the application of mechanical aids in any particular case, each work requires to be considered in the light of the conditions applying. These notes indicate the main purpose and range of application of typical mechanical aids.

In conduit excavating work, mechanical aids can be considered in relation to the following operations:—

1. Breaking down the material to be excavated, whether soil, clay, rock, etc.
2. Removal of the material from the trench.
3. Backfilling of the trench.
4. Removal of surplus spoil.

Obviously, where two or more of these operations can be performed by the one machine, substantial economies can be effected. Logically, Items 1 and 2 appear suitable for association together, and several machines of the trench-digging type are available which simultaneously break down the soil and remove it from the trench, a typical example being the Barber Greene ditcher. Within the limits of their sphere of application, machines of this type provide what is generally the most economical method of excavation.

For breaking down the soil, rock, etc., preparatory to removal from the trench by other means, there are available a number of types of equipment, each of which has specific application according to conditions. The following are the more generally used types:—

1. Pneumatic excavating tools (pavement breakers, picks, clay diggers, etc.), and associated air compressor.
2. Petrol-driven excavating tools (similar to pneumatic tools, but driven by a self-contained petrol engine).
3. Plows—horse or tractor driven.
4. Machines of the Roto-tiller type.

The first two find application where trenching machines cannot be used, but they may be adjuncts to such machines. The remainder are equipments of the less expensive type, and are of use where more expensive type of equipment cannot be made available.

Except where trenching machines combine the breaking down with the removal of soil from the trench, the latter operation is usually performed by hand, even where machines are employed for the former. This arises from the successful development of trenching machines and consequently limited application for soil-removing machines, and also by virtue of the fact that for conduit work the soil can be removed from the trench reasonably economically by hand labour once the ground is broken down. There would probably be some application for a machine to remove soil from trenches in association with, say, pneumatic tools, in cases where trenching machines cannot be used. Such machines could be in the form of a modified scoop or scrape, or alternatively an adaptation of one of the various types of "Loaders" available.

For backfilling trenches, machines of the bulldozer or road grader type can be used. These will, of course, only restore the soil to the trench, the soil being rammed by hand or by a mechanical rammer, several types of which are available, including pneumatic and petrol driven types. Reference is made in "Telephony" of April 25, 1942, to a tractor-mounted machine which can both fill in and tamp a trench; the machine apparently includes a scraper and a tamping device which provides repeated blows by a heavy weight. Road rollers can also be used for consolidating purposes. Mechanical loaders and tipping trucks when used in conjunction are very suitable for handling of surplus spoil.

The application and operation of all machines referred to above are necessarily subject to some discrimination, and care and incorrect use of mechanical equipment will produce unsatisfactory results, such as damage to equipment, badly formed trenches, or uneconomical working.

A general description of the principal types of mechanical aids, together with their functions and method of use, will be given in the next part.

A CALL QUEUEING LINE FINDER ENQUIRY SYSTEM

R. Treloar

Extension equipment to a P.A.B.X. installation was recently provided to enable a group of attendants to handle enquiries from the public relating to train services, etc. The subscriber required that all such calls should be switched by the operators on the P.A.B.X. manual position to this group of attendants, who would take such calls on telephones in the sequence of arrival. Each call would be connected in its appropriate order when any one of the attendants lifted the receiver of her set.

The incoming traffic to the enquiry positions is subject to daily and seasonal fluctuations, and the number of attendants would be varied, within limits, according to these fluctuations. Provision had to be made so that the Supervisor could observe the waiting calls and be able to adjust the number of attendants accordingly to prevent excessive waiting time of the calling party.

The following requirements were considered in designing the installation:

(1) Full availability of all lines to each attendant.
(2) A minimum ineffective operator's time.
(3) Absorption of traffic peaks by call queueing.
(4) Means of readily observing the traffic flow.

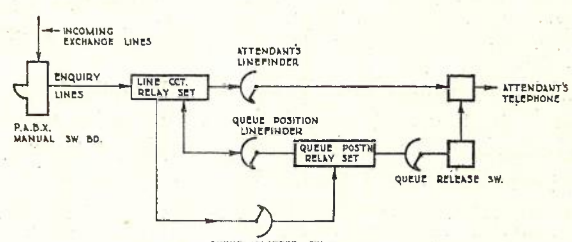


Fig. 1.

The trunking scheme (Fig. 1) shows the general call routing arrangement. The incoming exchange lines terminate on the associated P.A.B.X. manual positions, and calls for "enquiries" are switched in the usual manner to the equipment associated with the attendants' positions. There are 24 jacks on the manual position leading to the enquiry system, which provides for a maximum of 16 telephones and 8 positions in the queue. The enquiry line relay sets are arranged for ring down signalling so that, if required, they may be converted to direct exchange lines in the future, which would avoid handling by two operators, as at present. When an incoming call is switched by the operator to the enquiry system, it enters the queue and is stored, if necessary, until taken by an attendant's line finder. Each position is equipped with a type 332 telephone modified for lamp signalling, the subscriber preferring this arrangement to the use of head and breast sets. In addition, each telephone has a hold and call feature terminating in the P.A.B.X. When the enquiry attendant lifts the receiver her line is connected to the next call in the queue.

The queue consists of eight queue positions, each comprising a line finder uniselector and its associated relays. These queue positions appear on the bank contacts of two independent non-homing uniselectors, the Allotter and Release switches, so that No. 1 queue position is connected to the first bank contact and so on. An incoming call is signalled on to the common start lead, which is directed by the allotter wipers to a vacant queue position. This start signal causes the queue position line finder, on which the allotter is standing, to hunt for and seize the incoming call. When this is done, the allotter steps on to the next adjacent queue position into which the start signal of a subsequent call will operate. In this manner the start lead is directed into each queue position in turn as the allotter steps once after each call is set up in the queue.

The release uniselector steps in the same direction as the allotter, and is always standing on the queue position from which the next call will be released. When a searching operator's finder withdraws a call from the queue, the release switch steps on to the next adjacent queue position from which the next call must be released. Thus the allotter and release switches move in single steps in the same direction over the queue positions, the allotter always leading the release switch.

This arrangement may be described as a rotating queue in as much as the calls are accepted, stored, and released progressively around a continuous train of queue positions. This establishes correct answering sequence in accordance with the order in which the calls enter the system.

The traffic indicator, shown in Fig. 2, is essentially three light columns. The centre column is connected to the queue, and thus indicates the number of calls waiting. The two outer columns are in parallel to give a balanced appearance, and are connected to the attendants' relay sets to indicate the number of calls in progress.

This presents to the observer a continuous indication of the traffic situation and has proved very effective for supervision and as a basis for staffing arrangements.

Circuit Operation (Fig. 3): An incoming call from the switchboard operates relay L in the line circuit, L locks, and marks the queue A bank, and earths the common start lead at L1. The start lead is directed into a vacant queue

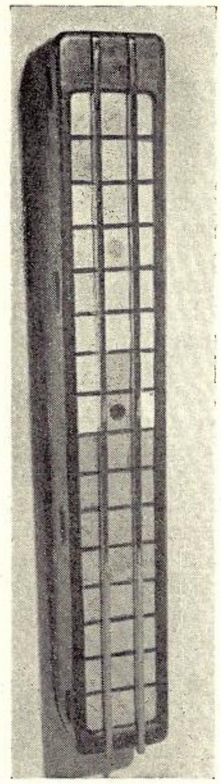


Fig. 2.

position via B bank of allotter, H relay, YD, battery. H relay operates and closes the queue position finder drive circuit. The switch hunts and when marked line is found relay G operates and locks to YC and battery.

G2 busies queue A bank contact.
G3 operates common W relay and marks release switch B bank.
G4 maintains H relay operated after removing it from start lead.
G5 earths associated relay in call waiting relay set.
G6 earths allotter D.M. and allotter steps.
G7 prepares chain circuit.
G8 operates K relay in line circuit.
K1 extends attendant's line finder P bank to G8 earth.
K2 opens start lead.
K3 opens L relay which restores.
W1 earths call lamp common and lamps on attendant's telephones glow.
W2 earths A relay operate common.
W3 opens N.U. tone lead.
W4 closes release switch D.M. and switch drives to marked queue position.
W5 short-circuits H relay which restores.
H3 removes G8 earth from attendant's finder P bank, thus marking this contact.

The call is now ready to be taken out of the queue. The attendant lifts the handset and switch-hook contacts complete a circuit for A relay, which operates and locks at A3.

A1 and A2 close the line finder drive circuit and the switch hunts. When the marked contact is found B relay operates. B1 earths P wire to short-circuit G relay and maintain K relay. G restores. B2 and B3 switch line to attendant and the ring is tripped. B4 opens the call waiting lamp. B5 closes associated "call in progress" indicator relay.

The call waiting and call in progress relay sets are similar and are arranged to concentrate a constantly changing order of signals, into a uniform display on the traffic indicator. All of the common equipment is duplicated on to change-over keys, to permit substitution in the event of failure or for maintenance purposes.

This installation has been in operation for 62 weeks, and in that time has handled 1 million calls satisfactorily.

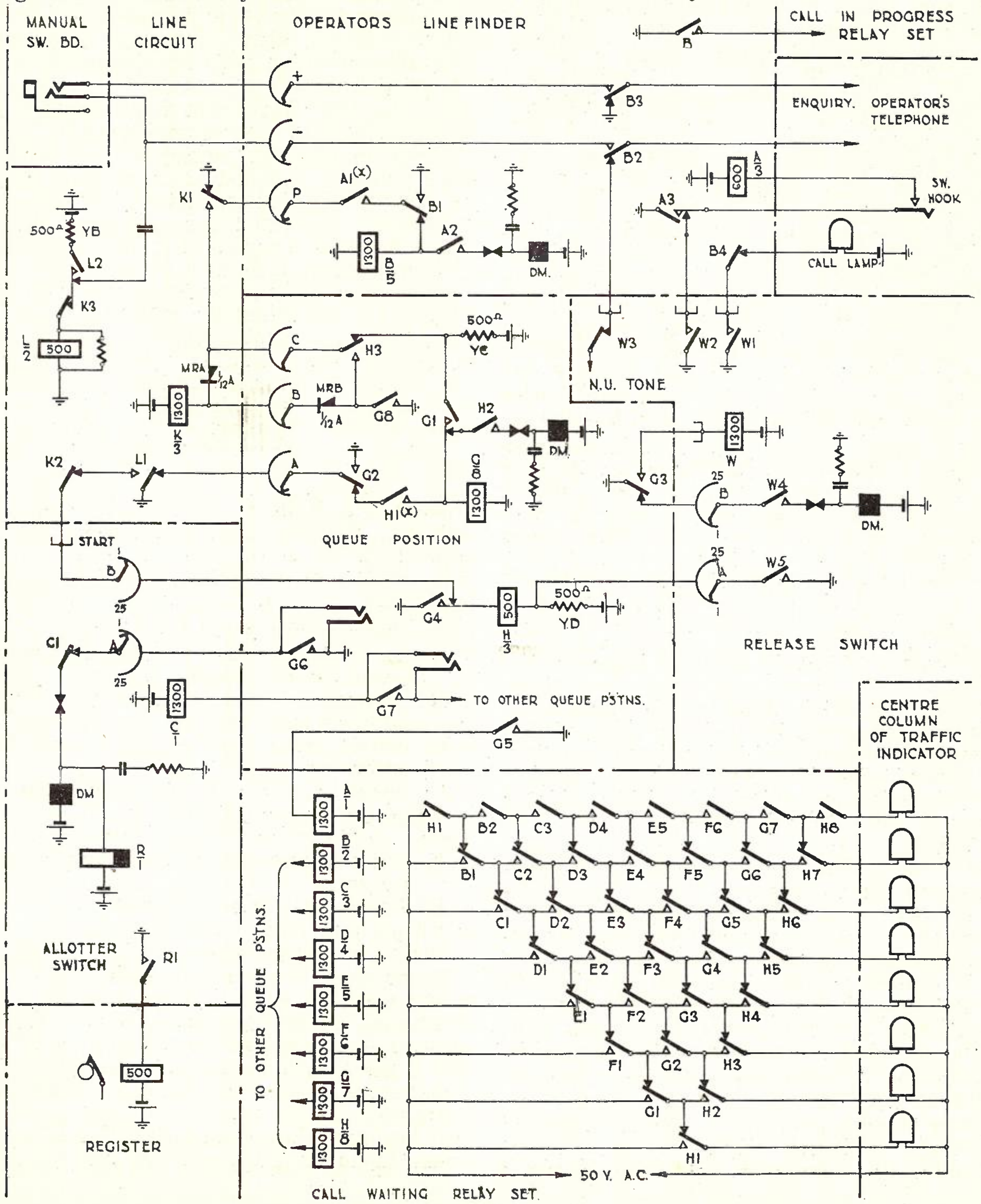


Fig. 3.

AN OUTLINE OF THE DEVELOPMEMT OF TELECOMMUNICATION SERVICES BETWEEN AUSTRALIA AND PLACES OVERSEAS—PART 2

J. C. Harrison

RADIO-TELEGRAPH SERVICES (Continued)

Three years passed before the direct radio-telegraph service between Australia and the United Kingdom was inaugurated on 8th April, 1927. During this period, remarkable improvements were made in radio-communication technique. In this connection it is interesting to observe that in the "Notes of the Proceedings" of the Parliamentary Select Committee referred to above, it was indicated that the speed of operation on the long-wave, high-powered radio services Java-Amsterdam, Honolulu-Japan, New York-Nauen (Germany), then in use, the speed of operation ranged from 10 to 23 words per minute, it being necessary for traffic to be transmitted twice under unfavourable conditions. The utilisation of the short-wave directional beam system, however, since 1927 not only permits direct services to be operated between Australia, the United Kingdom, and certain other places, but transmission may be effected at high speed, e.g., 200 words per minute, and even higher speeds.

The tariff approved by the Government for messages routed via Beam between Australia and places overseas was substantially lower than the charges applicable at the time for telegrams circulated via cable, representing in the case of messages from Australia to the United Kingdom 1/8 via Beam and 2/ via cable. This differential rate in favour of the Beam service quite naturally resulted in a very substantial proportion of the overseas loads being diverted to the wireless routes. On the introduction of the Empire flat rate scheme on 25th April, 1938, however, the disparity in the beam and cable rates disappeared. So far as telegrams to and from Empire points are concerned the uniform rate of 1/3 per word for messages of the ordinary category, with correspondingly lower rates for telegrams of other categories, is applicable to either cable or beam messages within the Empire.

In November, 1927, a further agreement was made between the Commonwealth and Amalgamated Wireless (A/asia) Ltd., it being designed to clarify a number of important issues relative to the Commonwealth's control. It declares, among other things, that while the Company is entitled, subject to certain conditions, to establish and operate commercial wireless services between Australia and ships at sea; with aircraft; between Australia and its Territories; and between Australia and other countries, the Commonwealth, however, shall have the right to determine whether or not any such services are necessary in the public interest. It also provides that the fixation of all rates for traffic be charged by the Company in respect of such services shall be subject to the approval of the Commonwealth. This covenant contains a stipulation that no Department of the Commonwealth shall carry on a commercial wireless service in competition with the Company. The Commonwealth, however, is not bound to refuse a licence to any other Company to conduct a service in competition with Amalgamated Wireless (A/asia) Ltd.

By the 1927 Agreement the Company undertook to pay to the Commonwealth terminal charges on overseas messages dealt with over the Beam system. Legal advice given to the Commonwealth indicated that under the International Telegraph Convention the Company must pay these terminal charges, as it was impossible to give preferential treatment to wireless communications over messages routed via cable. The Company was advised by eminent counsel, however, that it was not liable to pay such charges under the 1922 and 1924 Agreements. The issue was settled, however, in the 1927 Agreement, but not without a very substantial concession being made to the Company, as the Commonwealth undertook to contribute £45,000 annually towards the maintenance of the coastal radio stations subject to the Company paying to the Commonwealth 30 per cent. of the revenue derived from the continuance of the services which were carried on by the stations at the time of the original agreement. The average annual loss over the last five years of Government control represented approximately £34,300. It was estimated that the nett payment to the Company would be in the vicinity of £34,000 annually. The terminal payments by the Company to the Commonwealth during the past five financial years were £47,840, £56,600, £54,600, £85,300, and £119,900 respectively.

As mentioned above the submarine cable between Bundaberg and Noumea became interrupted in 1923, and from that time onward traffic has been moved exclusively by radio, utilising, in Australia, the coast stations of A.W.A. Ltd. During periods of interruption to the cable in earlier years, radio links had been used temporarily for this purpose also.

Under the agreement between the Commonwealth and A.W.A. Ltd., dated 28/3/22, a direct short-wave radiotelegraph service was opened between Australia and Canada on June 16, 1928, and a direct radiotelegraph service between Australia and Fiji was inaugurated on September 16, 1929.

Following on the outbreak of hostilities between Japan on the one hand and the British

Empire and the United States of America on the other, a direct radiotelegraph service was established between Australia and the United States on December 26, 1941, to provide an alternative means of communication between the two countries, thus ensuring continuity of service in the event of the existing cable channels becoming interrupted. The American terminal of the service is controlled by the Radio Corporation of America, while the Australian terminal is operated by Amalgamated Wireless (A/asia) Ltd. as an agent of the Commonwealth. A second radio service with U.S.A. was brought into operation on 13th April, 1942, the operation of the American terminal being undertaken by the Mackay Radio Company and the Australian end by A.W.A. Ltd., as an agent of the Commonwealth Government. For similar reasons, direct radiotelegraph services were established between Australia and China on 20/1/1942, Australia and India on 10/2/1942; and between Australia and Java on 19/1/1942 until occupation by Japanese forces. These radio services were introduced as for the duration of the war. The Australian terminal in each case is being operated by Amalgamated Wireless (A/asia) Ltd. as an agent of the Commonwealth. The tariffs applied are identical with the charges for messages routed via cable to the points concerned.

The overseas Beam services utilise the Wheatstone system of operation at speeds of up to 200 words per minute, and even higher speeds. Keyboard perforators of the Kleinschmidt and Creed types, similar to those formerly used in the Commonwealth telegraph service, are employed in the preparation of the requisite combinations of perforations on a paper tape, so that when the tape is passed through an automatic transmitter, the appropriate signalling impulses conveying the intelligence to be transmitted are sent out over the radio channel. At the receiving end, the demodulated signals are recorded on a paper tape in the form of variations in a continuous ink line above a zero by means of an instrument known as an "Undulator." The signals on the tape are subsequently transcribed by telegraphists, utilising typewriters for the purpose. The form of a typical Undulator signal was shown in Fig. 2 accompanying the first part of this article (Vol. 5, No. 2, Oct., 1944).

During the year ended 30/6/1928 the total load moved over the Beam system to and from Australia represented 8,567,000 words, or approximately 35 per cent. of the total overseas load of 28,103,000 words circulated over all routes. The load dealt with over the Beam system during the year ended 30/6/1939 expanded to 13,011,000 words, or 41.6 per cent. of the total overseas load. Under wartime conditions the international load has developed at a remarkable rate, the total load dealt with during the 12 months ended 30/6/43 representing 89,836,000 words, or an increase of 189.7 per cent. on the 1938-39 load. During the 1942-43 fiscal period, 42.4 per cent. of the total overseas load was circulated over Beam channels.

MERGER OF CABLE AND WIRELESS UNDERTAKINGS

On establishment of the Beam services between England, Australia, and a number of other Empire points, a substantial proportion of the traffic loads previously circulated over the extensive submarine networks of the British cable companies was diverted to the radio channels, in view of the lower tariffs applicable to the wireless services.

The British cable companies at this time owned 164,000 nautical miles of submarine links, or approximately 50 per cent. of the total submarine cable network of the entire world.

In Great Britain, the Beam radiotelegraph stations at the outset were owned and operated by the British Post-office, the installations having been constructed by the Marconi Company under contract with the Government. In Canada, Australia, South Africa, and India the terminals were operated by companies under licence from the Governments.

In view of the very severe effect of the operation of the Beam services on the cable undertakings, because of the lower rates applied to messages routed via radio, and the necessity for the retention of the cable services not only on strategic grounds but also because radio services are subject to fading and occasional prolonged interruptions, an Imperial Wireless and Cable Conference was held at London in 1928 to examine the position. Arising out of the consideration given to the problem, a Merger Company, now known as Cable and Wireless Limited, was formed to take over the operation of all the British cable undertakings, including the Eastern Extension, Australasia, and China Telegraph Company Limited, as well as the Pacific Cable Board, and the Beam stations of the British Post-office. The Pacific Cable undertaking was sold as a going concern to the Merger Company while the British terminals of the Beam services were leased to the company for a period of 25 years for an annual rental of £250,000. The capital of the Merger Company was set down at £30,000,000. This arrangement was authorised by the Imperial Telegraphs Act 1929.

The conditions associated with the establishment of the Merger Company, the sale of the Pacific cable, and the transfer of the British Beam terminals to the Merger Company are set out in a series of agreements dated 29th May, 1929, between the British and Dominion Governments and the other parties concerned. Among other things, provision was made for the establishment of the Imperial Communications Advisory Committee, consisting of representatives of each of the Partner Governments and one representative of the Colonies and Protectorates, the Merger Company being required to consult the committee before taking action in certain matters.

The operations of the Pacific Cable Board in this country were taken over by the Eastern Extension Company in 1929, the latter representing Cable and Wireless Ltd. in Australia until 30/9/1942. From the latter date the name of the Eastern Extension Australasia and China Telegraph Company, which had been a familiar one in Australia for nearly 70 years, was changed to that of Cable and Wireless Ltd. throughout the Commonwealth. So far as Australian telegraph users were concerned, only a change in the name of the company was involved. Some years previously the use of the separate routing indicators "via Pacific" and "via Eastern" had been abandoned and senders who desire their telegrams to be routed by cable merely insert the indicator "via cable" as distinct from messages intended for transmission by radio, in which case the indicator "via Beam" is used.

Unfortunately, shortly after the merger became effective, the world-wide depression occurred, and for some years the company did not earn the revenues which had been anticipated. As a result of an undertaking by the Merger Company during the discussions associated with the Imperial Rates Conference of 1937 to drastically reduce Empire telegraphic rates, the British Government agreed, among other things, to cancel the annual rental of £250,000 payable by the Merger Company and to sell to the company the British Beam stations for 2,260,000 shares valued at £1 each. The sale was authorised by the "Imperial Telegraphs Act, 1938."

EMPIRE RATES CONFERENCE 1937

The Empire Rates Conference of 1937 made a comprehensive survey of the rate structure of the Imperial communication system and with the approval of all the Empire Governments, a plan providing for substantial reductions in the tariffs for telegrams between all British countries was agreed to.

The scheme provided for the equalisation of cable and wireless charges in respect of telegrams circulated between the Commonwealth and other Empire countries and for a reduction in the tariff for ordinary telegrams to 1/3 (sterling) per word over all Empire routes where the existing rate exceeded that sum, with appropriate lower rates for other classifications of traffic, except press. The charges for press and deferred press telegrams via cable were brought down to the Beam level, however, which resulted in a reduction from 6d. to 4d. a word for press messages and from 4½d. to 3d. a word in the case of deferred press telegrams routed via cable.

Owing to the depreciation of Australian currency below sterling, application of the 1/3 (sterling) rate would have required senders in the Commonwealth to pay 1/7 a word for ordinary telegrams, while users in other countries would be charged only 1/3. Prolonged and difficult negotiations therefore took place with the object of overcoming this anomaly, and in order to ensure that the maximum benefit of the plan might be conferred on Australian users, an agreement was reached stipulating that telegrams originating in the Commonwealth would be charged for on the basis of Australian currency. As a contribution towards the loss on exchange suffered by the cable and wireless companies, the Commonwealth Government undertook to make a payment of £15,000 (Aust.) annually for a period of five years, as from the date of the inauguration of the flat rate scheme.

Introduction of the plan was contingent on all Empire countries reducing their terminal charges, and the sacrifice of revenue so far as the Commonwealth was concerned represented £29,000 annually on the basis of 1936 traffic loads, while the resultant savings to Australian senders was estimated at £80,000 per annum. The cost to the Merger Company in terms of reduction in revenues from traffic was set down at £400,000 a year.

COMMONWEALTH TELEGRAPH CONFERENCE

An important gathering of representatives of British Governments took place in Australia during December, 1942, the object of the conference being to review the Empire telecommunication system. A number of important recommendations were made by the conference to the Empire Governments, and subsequently were approved. As a result of this conference, the constitution of the Imperial Communications Advisory Committee was varied, and the name changed to the Commonwealth Communications Council, the first meeting of which was held in London during April, 1944.

REDUCTIONS IN RATES SINCE 1900

Since 1900, the rates for telegrams between Australia and places overseas have been drastically reduced, although costs in Australia have generally risen in the intervening years. It would be wearisome to indicate in detail all the changes that have been made, but the more remarkable reductions are indicated hereunder.

The tariff per word for ordinary telegrams between the Commonwealth and the United Kingdom was reduced from 4/ to 3/6 in 1901; to 3/ in 1902; to 2/6 in 1924; to 2/ in 1927; and to 1/3 in 1938. The volume of traffic circulated between Australia and the United Kingdom during the year ended 31/12/1911 represented 2,459,000 words, or 46.53 per cent. of the total overseas load originating and terminating in the Commonwealth while in the 1938-39 fiscal year the Australia-United Kingdom load had increased to 13,588,000 words, or 43.8 per cent. of the total load.

The introduction of the Empire flat rate scheme as from 25/4/1938 not only resulted in a substantial reduction in rates for telegrams between Australia and the United Kingdom but also drastic cuts in the charges for messages between the Commonwealth and many other British countries. The following examples indicate the extent of the concessions:

Until 1/3/1927 telegrams between Tasmania and certain countries overseas were subject to a surcharge, in addition to the tariff applicable between other parts of Australia and such places, this arrangement being a continuation of the practice which had been in existence during the time the Eastern Extension Company had operated cables across Bass Strait. The surcharge represented 3d. per word on ordinary messages, with lower fees for other categories, except Government telegrams.

Between Australia and—	Rate Per Word for Ordinary Telegrams		
	Prior to 25/4/1938		As from 25/4/1938
	Via Cable	Via Beam	Via Cable and Via Beam
	s. d.	s. d.	s. d.
Great Britain	2 0	1 8	1 3
India and Ceylon	2 6	*	1 3
Union of South Africa	1 8	*	1 3
Canada proper and British Columbia	1 7 to 2 0	1 5½ to 1 10	1 3
Sierra Leone	4 6 to 4 8	*	1 3
British Guiana	3 10 to 4 3	3 5½ to 3 10½	1 3
Falkland Islands	5 0	5 0	1 3
Jamaica	4 1	3 8½	1 3

* Service not available via Beam.

The rates for messages between European countries and Australia were identical with those for messages between Great Britain and the Commonwealth, with certain exceptions, until 1924, when the Australia-United Kingdom rate for ordinary telegrams was reduced to 2/6, the charge for telegrams between Australia and a number of European points, including Belgium, Germany, Norway, Italy, Sweden, and Russia, was also reduced to the same level, with slightly higher charges to certain other countries, e.g., 2/7 in the case of France and 2/6½ as regards Denmark, and these rates have continued in operation so far as messages routed via cable are concerned. When the Beam service was introduced between Australia and the United Kingdom in 1927 the tariffs applied to messages routed by radio to and from places in Europe ranged from 2/0½ to 2/5½ per word.

For ordinary messages between Australia and the United States of America, the charges vary according to the zone of destination or origin in America. In 1902 the rates ranged from 4/ to 6/7 per word, and these charges were substantially lowered in 1910, the new rate varying from 2/4 to 2/8. The tariffs for messages routed via Beam were fixed in 1927 at rates ranging from 2/0½ to 2/5½ per word. As from June 1, 1942, the rates for messages routed via cable were reduced to the same level as those for messages via Beam to the United States.

SPECIAL CATEGORIES

Press Telegrams: As early as 1886, special rates were applied to press telegrams. In that year a rate of 2/8 per word was applied to such messages between Australia and the United Kingdom, a reduction of 71 per cent. on the charge for ordinary telegrams. The press rate was further reduced to 1/10 a word in 1891, this representing 46 per cent. of the tariff for ordinary telegrams. As from January 1, 1901, a further reduction to 1/4 a word was effected. Since the establishment of the Commonwealth, the tariff per word for press telegrams between Australia and the United Kingdom has been progressively reduced to 1/ in 1902; 9d. in 1909; 7½d. in 1912; 6d. in 1925; and when the Beam service was introduced a rate of 4d. per word was applied to messages transiting the radio link. The tariff for press messages via cable and Beam was equalised on the basis of 4d. per word as from 25/4/1938. The rate for press telegrams between Australia and Canada represented 9d. per word in 1902; 5½d. as from 1/7/1910; 5d. as from 1/1/1912; 4d. as from 1/8/1925; 3¾d. as from 10/8/1925; and 3½d. as from 1/4/1933. Substantial reductions have been applied to press telegrams between the Commonwealth and most other countries, but relatively small loads have been exchanged between Australia and places other than those mentioned.

An inter-Empire flat rate of 2¼d. for press telegrams was introduced as from April 15, 1939, the flat rate replacing the rates previously applied to press and deferred press messages between the Commonwealth and the United Kingdom of 4d. and 3d. per word respectively, as well as the rates varying up to 7½d. a word for telegrams between Australia and other Empire points. Concurrently the deferred press service previously in existence between Australia, Great Britain and Canada was abolished. Where the existing press rate was already below 2¼d. a word no change was made. The rate of 2¼d. represents a reduction of 85 per cent. on the tariff for ordinary messages. The charge for press telegrams between Empire countries was further reduced to 1d. per word as from 1st October, 1941, for the duration of the war.

The charges for press telegrams between Australia and the United States of America vary according to the American zone concerned, and represented from 1/5 to 1/9 per word in 1902; from 6d. to 8d. in 1910; and from 5½d. to 7½d. as from 1933. In order to develop a wider coverage of Australian news in the United States, as a wartime measure, the Commonwealth Government introduced a plan which enables correspondents in Australia of newspapers in U.S.A. to lodge press telegrams for their newspapers at 1d. per word, the difference between that amount and the approved tariff being made good by the Government. As from May 1, 1944, the Australia-U.S.A. press rates were reduced, the tariff now ranging from 2½d. to 4½d. a word.

During the year ended 30/6/39, the volume of press traffic transmitted between Australia and other countries represented 4,946,000 words, or approximately 16 per cent. of the total load. The press load inward to Australia via Beam during that year represented 2,303,000 words, or 35 per cent. of the total incoming load via Beam. Under wartime conditions there has been a phenomenal increase in the volume of press traffic to and from overseas countries, and during the 1942/43 fiscal year 19,405,000 words of this category were transmitted to and from Australia. Of this total 15,886,000 words were circulated over the Beam system, representing no less than 41.7 per cent. of the total Beam load.

Urgent Rate Press Telegrams: In accordance with the International Telegraph Regulations as adopted by the International Telecommunication Conference of Madrid in 1932, urgent press telegrams may be lodged for transmission at rates equivalent to the tariff for ordinary rate telegrams. On the outbreak of war, urgent telegrams were suspended. Arrangements were made, however, to introduce, as from September 27, 1939, a special urgent press telegram facility between Empire countries at a tariff equivalent to 50 per cent. of the ordinary full rate telegram charges. These urgent rate press messages are accorded precedence in transmission after the three higher categories of British Government telegrams. An urgent press telegram service was introduced specially between Australia and U.S.A. on June 1, 1942, the tariff applied in this case being based on the charge for ordinary telegrams between the offices of origin and destination.

Government Telegrams: Provision was made in the agreement dated 6/5/1879 between the Eastern Extension Company and the State Governments for preferential tariffs to be applied to British and Colonial Government telegrams, the concession representing 50 per cent. In subsequent arrangements, British Government telegrams have enjoyed a reduction in the normal tariff, but it was not uniformly a cut of 50 per cent. Under the Empire flat rate scheme the tariff for British Government telegrams between places within the Empire is 7½d. a word, i.e., 50 per cent. of the tariff for ordinary telegrams. Government telegrams drawn up in five-letter code words also enjoy the benefit of a further cut. Concession tariffs are also extended to certain foreign Government telegrams, as regards messages between the Commonwealth and particular countries overseas. In accordance with the International Telegraph Regulations, Government telegrams also enjoy precedence in transmission over other messages. During the year ended 31/12/1911, the volume of Government traffic originating and terminating in the Commonwealth represented 182,000 words, or 3.4 per cent. of the total overseas load dealt with in the Commonwealth. In the 1938/39 financial year, the volume of traffic of the Government category approximated 809,000 words, or 2.6 per cent. of the total overseas load. Under wartime conditions, however, the Government component of the load has considerably expanded, and during the 12 months ended 30/6/1943 the number of words dealt with in this category was 25,013,000, or 27.8 per cent. of the total load.

Deferred Telegrams: A deferred telegram service between Australia, the United Kingdom, all British possessions, and many other countries, including Austria, Belgium, Denmark, Egypt, France, Germany, Greece, Hungary, Italy, Norway, Portugal, Spain, Sweden, Switzerland, and the United States of America, was introduced on January 1, 1912, by special arrangements, which provided that 50 per cent. of the ordinary rate would be applicable to messages of this category, subject to the telegrams being expressed in plain language. Messages were accepted for transmission in this category conditionally on their being transmitted after ordinary and press telegrams, but deferred messages which had not reached their destination in 24 hours from the time of lodgment were transmitted in turn with messages charged for at ordinary rate. The fundamental reason for the introduction of this arrangement was to develop a better loading factor for the costly undersea telecommunication plant, i.e., it was an attempt to keep the submarine cables occupied during the 24-hour cycle of each day. During the year ended December 31, 1912, the volume of deferred telegrams originating and terminating in the Commonwealth represented 423,000 words, or 5.8 per cent. of the total load as compared with 10,551,000 words, or 34 per cent. of the total load during the 1938-39 financial year, and 7,752,000 words during 1942/43.

The deferred telegram service is admitted by most countries throughout the world, the conditions applicable to this category having been incorporated in the International Telegraph Regulations, as an optional service, in 1925.

Daily Letter Telegrams: A Daily Letter Telegram service between Australia, the United Kingdom, the United States of America, Canada, South Africa, India, and certain other places was introduced in 1923, by special arrangement. Messages in this category were accepted at rates representing only 25 per cent. of the tariff for ordinary rate telegrams, subject to a minimum charge as for 20 words, the sender being required to express his message in plain language. These messages were subject to a minimum delay of 48 hours from the time of lodgment. The tariff for this class of message was not adjusted to 25 per cent. of that applicable to ordinary telegrams when the rates for the latter were reduced in 1924. The International Telecommunication Conference held at Madrid in 1932 decided to incorporate in the International Telegraph Regulations the conditions applicable to this category, as an optional service, the tariff being fixed uniformly at one-third of the rate for ordinary telegrams between the offices of origin and destination, with a minimum charge as for 25 words. These messages are now deliverable on the morning of the second day following that of lodgment. During the financial year ended 30/6/1939, 5,407,000 words were dealt with in this category, representing 17 per cent. of the total overseas load outgoing from and incoming to this country.

Week-end Letter Telegrams: A week-end letter telegram service was introduced on January 4, 1913, between the Commonwealth and the United Kingdom at a tariff equivalent to 25 per cent. of the charge for ordinary telegrams, i.e., 9d. per word, with a minimum charge of 18/. The conditions of acceptance required that the messages be written entirely in plain language and be lodged by midnight on Saturday to ensure delivery on the following Tuesday morning. During the year ended December 31, 1913, the volume of this traffic represented 490,000 words, or 6 per cent. of the total load. This facility was subsequently extended to a number of other countries, including South Africa, India, Burma, and Portugal, Denmark and Germany, but the service was withdrawn as from April 1, 1933, as a result of a decision reached at the International Telecommunication Conference held at Madrid in 1932. During the year ended 30/6/1932, the volume of this traffic reached 3,925,000 words, or 17 per cent. of the total overseas load between Australia and other countries.

Night Letter Telegrams: A night letter telegram service was established between Australia and New Zealand in 1924 by special arrangements, the rates representing two-fifths of the tariff for ordinary telegrams, with a minimum charge of 3/ as for 20 words. The tariff was modified as from 1/1/1934 to 3/9 as for a mimimum of 25 words. The service was extended to Fiji, the Straits Settlements, and the Dutch East Indies subsequently.

The conditions in respect of Night Letter Telegrams were incorporated in the International Telegraph Regulations by the International Telecommunication Convention, held at Madrid in 1932, on the understanding that the service is an optional one. The conditions include a stipulation that these messages enjoy a tariff equivalent to one-third of that applicable to ordinary telegrams, subject to a minimum charge as for 25 words. The tariff applied to messages between Australia, the Straits Settlements, and the Dutch East Indies was fixed on this basis. The charges on such messages to and from New Zealand and Fiji have been fixed specially. During the year ended 30/6/1939, the volume of traffic falling within this category represented 3,267,000 words, or approximately 10 per cent. of the total load moved inward to and outward from the Commonwealth.

Christmas and New Year Greeting Telegrams: A Christmas and New Year Greeting telegram service at reduced rates was introduced in December, 1926, by special arrangement, the tariff for such messages between Australia and the United Kingdom being fixed at 5/ as for a minimum of ten words and 6d. for each additional word. The charge for Greeting telegrams between Australia and New Zealand was fixed at 1/6 as for a minimum of 10 words, with 2d. for each additional word.

The conditions relating to this service were incorporated in the International Telegraph Regulations as a result of a discussion at the International Telecommunication Convention of Madrid. A minimum charge as for 10 words is still specified, but the actual tariff is the subject of special arrangement.

This service was extended to most Empire points, and to many other countries. In Empire relations, however, the Christmas and New Year Greeting Telegram service was withdrawn in 1939, from which time the Social Telegram service replaced it. The Social Telegram facility, however, is available throughout the whole year. The Christmas and New Year Greeting telegram service has been suspended for the duration of the war.

Social Telegrams: The Social Telegram service between Australia and all other Empire countries, except Canada, India, and Burma, was introduced on 1st May, 1939. The occasion was marked in a most unusual way, each member of the public being permitted to send one free message, not exceeding twelve words, on the opening day. Many thousands of people in Australia took advantage of this concession. The tariff applicable to this service is based on a minimum charge as for 12 words and 5d. for each additional word, except as regards messages to and from New Zealand and certain other places, in which cases the rates are lower. This facility is confined to messages relating solely to social matters, i.e., greetings, family news, or non-commercial personal affairs, and as a cheap rate service, messages of this category are subject to deferred delivery. This service was subsequently extended to all Empire points.

De Luxe Telegrams: On 1/1/1937 a de luxe telegram service was introduced between Australia and certain countries overseas, a surcharge of 6d. per message being made, irrespective of category, to secure delivery on special de luxe stationery. Prior to the outbreak of war this service had been extended to 38 countries altogether, including the United Kingdom and a number of other British points as well as certain European countries. This service has been suspended for the duration of the war.

EFM Telegrams: A special telegram service to and from members of H.M. Army and Air Force abroad was established on 9/2/1940 under very attractive rate conditions, the tariff being fixed on the basis of 5d. per word for the text and signature only, with a minimum charge as for 2/6, no charge being made for the words included in the address or for the indicator EFM. At the outset it was necessary for the messages to be expressed in plain language. The scheme was later modified by introducing standard texts, represented by numbers, a maximum of three authorised phrases being permitted in each telegram. A service under similar conditions, but requiring the use of plain language exclusively, was extended to members of the Navy as from 1st January, 1941. During the year ended 30/6/42, the total EFM load incoming to and outgoing from this country was equivalent to 4,839,000 words. The service was extended to U.S.A. on 16th November, 1942.

Free Telegram Service Between Evacuated Children in Australia and Their Parents in Great Britain: A free telegram service was introduced in 1941 between evacuated children in Australia and their parents in Great Britain. The arrangements provide for each family to send one free telegram in each direction every month, by means of standard texts, which provide news regarding safe arrival, health, receipt of letters and parcels, birthday greetings, requests to write often, and indications such as "Miss you a lot but very happy here."

TERMINAL RATES

Article 26 of the Telegraph Regulations annexed to the International Telecommunication Convention provides that the tariff for the telegraphic or radio-electric transmission of international telegrams is made up:

(a) Of the terminal rates of the Administrations of origin and destination;

(b) Of the transit rates of intermediate Administrations in cases where the territory, installations, or channels of communication of those Administrations are used for the transmission of correspondence; and

(c) Where the case arises, of the transit rate of each of two stations performing a radio-electric transmission or of cables used for submarine transmission.

Somewhat similar declarations were embodied in the International Telegraph Convention of St. Petersburg (1875).

From the time the first overseas telegraph service was established between Australia and places overseas, the Governments of the Australian States required the payment to them of a proportion of the charges collected on telegrams to and from their States, for the work performed by them in circulating traffic over their respective systems, this principle being an important feature of the International Telegraph Convention. The Australian States formally joined the International Telegraph Union on the following dates: South Australia, 27/5/1878; Victoria, 1/7/1880; New South Wales, 25/2/1884; Tasmania, 8/7/1885; Western Australia, 1/1/1894; and Queensland, 9/4/1896. The Commonwealth formally adhered to the International Telegraph Convention on 1st January, 1903, and is a signatory to the International Telecommunication Convention, which replaced the Telegraph and Radiotelegraph Conventions as from 1st January, 1934. The agreement between the Government of South Australia and the British Australian Telegraph Company Limited, dated 29/8/1871, provided that the Government would promptly transmit all messages that were delivered at either terminus of the overland telegraph line at such rates as shall be agreed upon between the Superintendent of Telegraphs in South Australia and the Company's Manager in Australia.

Substantial reductions have been made in the Australian terminal charges since 1900. For example, the terminal rates per word on ordinary telegrams between Australia and Europe in 1900 were as follow: New South Wales, 9d.; Victoria, 8d.; Queensland, 11d.; South Australia and Western Australia, 5d.; and Tasmania, 7d. A uniform terminal rate of 5d. per word was applied throughout the Commonwealth, excluding messages to New Zealand, Norfolk Island, and Fiji, as from 1st June, 1902. In 1924, concurrently with the reduction in the charges for ordinary telegrams between Australia and the United

Kingdom, as well as Europe and certain other countries, to and from which the traffic transited Europe, the Commonweatlh terminal rate in these cases was reduced to 4d. per word. When the charges for telegrams between Australia and the United Kingdom and Canada were further reduced in 1927, the Commonwealth terminal rate on ordinary telegrams to and from those countries was lowered to 2d. per word. On the Empire flat rate scheme being introduced on 25/4/38, the Commonwealth terminal rate on ordinary telegrams to and from Empire countries was reduced to 1½d. per word.

The terminal rates applied to press telegrams by the State Governments varied from 3d. to 6d. per word in 1900. Today the Commonwealth terminal rate in respect of press telegrams to and from places within the Empire represents only one-tenth of a penny.

So far as Deferred telegrams, Letter telegrams, and Urgent telegrams are concerned, the terminal fees are respectively one-half, one-third, and double those applicable to the ordinary category.

The drastic cuts in the Commonwealth terminal rates have naturally resulted in severe losses to the telegraph revenue account. In the 1919-20 fiscal period, the revenue from terminal rates represented £276,000 as compared with £134,000 during the year ended 30/6/1939, notwithstanding a substantial rise in the load, as indicated in the following table:

	Total overseas load to and from Australia (in words)	Revenue from terminal rates £
1913	8,118,000	98,789
1917/18	19,355,000	210,346
1919/20	17,166,000	276,236
1924/25	22,608,000	235,776
1929/30	29,449,000	205,700
1934/35	28,317,000	153,987
1938/39	31,003,000	133,657
1941/42	69,635,000	272,000
1942/43	89,836,000	304,956

It will be noted that the total load dealt with during the year ended 30/6/43, represented an increase of 423 per cent. on that dealt with during 1919/20, while the revenue from terminal charges increased by only 10.4 per cent. During this period the terminal revenue has been reduced from an average of 3.8d. to 0.81d. per word, equivalent to a reduction of 78.7 per cent.

International telegrams are accepted at and delivered from any of the 10,000 telegraph offices of the Postmaster-General's Department, and during the year ended 30th June, 1939, about 28 per cent. of the 1,462,000 overseas telegrams originating and terminating in the Commonwealth were handled by the Post Office. The percentage of the overseas traffic dealt with by the Commonwealth telegraph staff during the year ended 30th June, 1943, however, represented approximately 65.6 per cent. of the total incoming and outgoing load, which amounted to 2,965,000 telegrams. In conformity with a proviso to the Memorandum of Conclusions to the Empire Rates Conference of 1937, the Commonwealth undertook to take over without charge to Cable and Wireless Limited the work of acceptance and delivery of cable messages being carried out by the Company in Perth, Adelaide, Melbourne, and Sydney.

The negotiations concerning this matter were opened in 1939, but finality has not yet been reached in regard to the proposal.

The Growth of the Overseas Telegraph Load: The following table gives particulars of the development in the overseas telegraph load since 1873. These figures include the Australia-New Zealand component; during the year ended 30/6/1939, the volume of this traffic represented 7,468,000 words, or 24 per cent. of the total load. In the same period the Australia-United Kingdom proportion represented 43.8 per cent. of the total load.

Volume of Overseas Traffic Originating and Terminating in Australia

Year ended 31st December,	Number of of Words	Number of Messages
1873	—	9,000
1890	827,000	58,000
1895	1,949,000	107,000
1900	—	170,000
1905	—	366,000
1910	4,706,000	496,000
30th June,		
1915	13,460,000	641,000
1920	17,093,000	981,000
1925	22,608,000	1,259,000
1930	16,813,000	1,500,000
1939	31,003,000	1,462,000
1940	40,892,000	1,420,000
1941	48,683,000	1,727,000
1942	69,635,000	2,475,000
1943	89,836,000	2,965,000
1944	84,725,000	2,462,000

Phototelegram Services: With the approval of the Postmaster-General, Amalgamated Wireless (A/asia) Ltd. inaugurated a phototelegram service between Melbourne and England on 16th October, 1934, the British terminal being operated by Cable and Wireless Limited. The charge for each phototelegram accepted for transmission in either direction was fixed at 3/3 per square centimetre, with a minimum charge of £16/5/ as for 100 square centimetres, the plant being capable of transmitting a phototelegram of a maximum size of 10 inches by 9 inches. Phototelegrams to and from New York and San Francisco were accepted for circulation over this system, the rates representing 5/ and 5/8 per square centimetre respectively. A very substantial reduction in the tariff for phototelegrams between Australia and Great Britain became effective on 1/1/1940, since which date the charge represents 1/4 per square centimetre, with a minimum charge as for 150 square centimetres.

The system employed at the outset was the constant frequency variable dot arrangement; when the picture for transmission was scanned, a series of dots were transmitted at constant amplitude, but the dots were varied in length according to whether light or dark tones were being transmitted; i.e., the dark tones were built up of long dots joining each other, and the light tones of short dots. Facsimiles received by this method incorporated a screen effect. The time involved in the transmission of an average size picture over the Beam channels between London and Melbourne represented about 35 minutes with this method.

In September, 1941, a new system of transmission was introduced, eliminating the screen effect and offering a substantial improvement in the quality of the facsimile reproduced at the reception end, as well as reducing the time of transmission by about 66 2-3 per cent., an average size picture involving only 12 minutes. This system is based on developments in Great Britain, America, and Continental countries during the preceding months. The new system utilises frequency modulation, the value of light at the receiving end being varied in accordance with the frequency being transmitted at a particular instant. The frequency modulation is effected by a sub-carrier.

With the new method, which is known as the sub-carrier frequency modulation method, a carrier wave is continuously radiated, but is modulated by a tone which varies between 1,600 and 2,000 cycles per second, according to the density of the tones of the picture to be transmitted. At the scanning end, the light which is reflected back from the picture is chopped up at the rate of 2,600 times per second. The density of light, of course, varies with the tones in the picture. The variation is amplified and is caused to act on a reactance tube, which varies the frequency of an oscillating system to the extent indicated, thus producing a tone which modulates the carrier wave. At the receiving end, the carrier is suppressed and the tone is applied, after amplification, to a discriminator. The function of the latter is to convert the frequency change, within the limits mentioned, to an amplitude change, which is applied to vary a glow tube, which in turn records on a sensitised paper. Much of the equipment used with the earlier system has been incorporated in the new apparatus; the principal components used in the new system are the oscillator, the reactance tube, and the discriminator.

In February, 1942, a direct phototelegram service was established between Australia and the United States of America, the Australian terminal being operated by Amalgamated Wireless (A/sia) Ltd. at Sydney, and the American terminal by the Radio Corporation of America at San Francisco. The tariff for the transmission of phototelegrams from Australia to San Francisco is based on 1/8 per square centimetre, and in the opposite direction 40 cents (the par equivalent of 1/8) per square centimetre, with a minimum charge as for 150 square centimetres. Where transmission beyond San Francisco through the American internal phototelegram service is required, additional charges are applicable.

Under wartime conditions and with the improved quality of reproduction, the volume of the phototelegraphic traffic has shown a remarkable expansion. During the month of July, 1943, 21 phototelegrams were transmitted between Australia and the United Kingdom, and 8 between the Commonwealth and the United States of America.

Overseas Radiotelephone Services: A commercial telephone service was first established between Australia and th United Kingdom on 30th April, 1930, utilising radio channels. At the English terminal the radio equipment is installed and maintained by the British Post Office, and at the Australian end Amalgamated Wireless (A/asia) Ltd. provides the radio equipment. The Post Office, however, controls and operates the Australian terminal. The service was inaugurated formally by a conversation between the Prime Minister of Great Britain, the Hon. Ramsay McDonald, and the Prime Minister of Australia, the Hon. J. Scullin.

Direct radiotelephone services were inaugurated between Australia and New Zealand on 25/10/30; between Australia and Java on 23/12/30; and between Australia and Rabaul on 18/10/37. A direct service between Australia and the United States of America was introduced on 21st December, 1938, and further direct services were opened with the Philippine Islands on 10/7/40 and Port Moresby on 14/7/41.

Owing to wartime conditions, the radiotelephone services between the Commonwealth, the United Kingdom, New Zealand, Rabaul, Papua, Netherlands East Indies, and the Philippines have been suspended. The service with the United States of America is, however, being used subject to certain conditions.

Prior to the outbreak of war it was practicable for telephone subscribers in Australia to communicate with 52 countries by means of these radiotelephone channels, thus having access to 34,500,000 other telephone subscribers, representing 93 per cent. of the total telephones of the world.

During the period from 30th April, 1930, to 30th June, 1931, 2083 calls were completed over the overseas radiotelephone service, of which 1,383 were originated by subscribers in Australia. The number of calls completed during the twelve months ended 30th June, 1939, represented 5,983, of which 3,293 were originated in the Commonwealth.

The charges for telephone calls between Australia and the United Kingdom were fixed originally at £2 a minute, with a minimum of £6 for the first 3 minutes. In December, 1933, a reduced rate of £1 per minute with a minimum charge of £3 as for the first 3 minutes was applied to calls made on Saturdays. In June, 1935, the normal tariff was reduced to £1/10/ per minute, with a minimum charge of £4/10/ for the first 3 minutes. The Saturday rate remained unchanged.

The tariffs for calls between Australia and the United States of America vary according to the American zone concerned. Prior to the establishment of the direct Australia-U.S.A. channel, a service was given via London, and the rates ranged from £3 a minute, with a minimum charge of £9 for the first 3 minutes, for calls to and from the 1st zone, to £4 a minute with a minimum charge of £12 for the first 3 minutes in respect of calls to and from the 6th zone. On the introduction of the direct Australia-U.S.A. service in 1938, substantially lower rates were applied to calls to and from zones 1, 2, 3, and 4, ranging from £1/15/ per minute with a minimum charge of £5/5/ as for 3 minutes as regards calls to and from the 1st zone on week days, and £1/5/ per minute with a minimum charge of £3/15/ on Sundays, up to £2/6/3 per minute and a minimum charge of £6/18/9 in respect of calls to and from zone 4. The charges in respect of zones 5 and 6 were unaltered.

Restrictions on Telecommunication Services during the War Period: On the outbreak of war, all telecommunication services with enemy countries and enemy occupied territories were entirely suspended, and a censorship of telegrams to and from all places overseas was established. Except as regards British Government telegrams, senders of overseas telegrams are required to write their communications in plain English, French, Spanish, or Portuguese: the messages are accepted at the risk of the senders, and subject to censorship by the Commonwealth authorities; that is, they may be stopped, delayed, or otherwise dealt with in all respects at the direction of those authorities, and without notice to the senders; and no claims are entertained for the reimbursement of the sums paid for transmission or otherwise. The sender's name is required in each case. Registered telegraphic code addresses are not accepted either as addresses or names of senders. Urgent telegrams are not admitted. Moreover, the overseas radiotelephone services are suspended, except as indicated above.

THE FUTURE

The introduction of the Empire Flat Rate scheme in 1938 suggests the possibility that we may yet see a uniform tariff applied to telegrams to and from foreign countries, a principle that was established in the sphere of postal communications many years ago. The rate for telegrams to and from foreign points may perhaps be somewhat higher than for messages between British countries, in order to afford some measure of favourable treatment to Empire communications, as is done in the postal service.

The present war has demonstrated the value of the submarine network in the expeditious circulation of the most vital and secret communications between Empire and Allied countries. The Beam wireless services have also been instrumental in moving large volumes of telegraph traffic which could not perhaps have been transmitted over the undersea links available, taking into account the loss of certain routes by enemy action (e.g., occupation of Singapore by the Japanese forces). The total load moved to and from the Commonwealth during the year ended 30/6/1943 represented an increase of approximately 190 per cent. on that dealt with in the year before the outbreak of war, and the coexistence of the cable and beam channels has enabled the greatly expanded volume of traffic to be treated expeditiously. It has been suggested in past years that great expenditures on the laying of further submarine channels could not be envisaged, bearing in mind that radio-electric services may be established much more economically. One can imagine, however, that, as a result of developments in recent years, moves will be made to lay additional submarine lines of communication between certain points, and particularly to and from places which are at present either not connected to the cable network or are inadequately served by this method.

AN EMERGENCY MOBILE TANDEM EXCHANGE

M. J. Power

A very important part of the war activities of this Department has been the action taken to safeguard essential communications and the preparation of emergency arrangements which could be brought into use to restore essential services speedily in the event of serious damage to exchange equipment. One of the most important units in the emergency scheme was the mobile automatic tandem exchange designed for the switching of calls incoming to Branch Exchanges in a Main Exchange group in the event of serious damage to the Main Automatic Exchange for that group.

The essential features considered in the design of the tandem exchange were:—

(1) Mobility and transport arrangements.
(2) Flexible trunking facilities to enable it to be suitable for use in any exchange area in a particular network.
(3) Provision of adequate switching equipment with due regard to limitations in space and weight.
(4) Facilities for ready connection to U.G. cables.
(5) Power plant independent of Commercial Electricity Supply.
(6) Regular maintenance of batteries when not in service.
(7) Artificial lighting.
(8) Testing of equipment.
(9) Provision for maintenance tools and spare parts.
(10) Organisation and training of emergency staff.

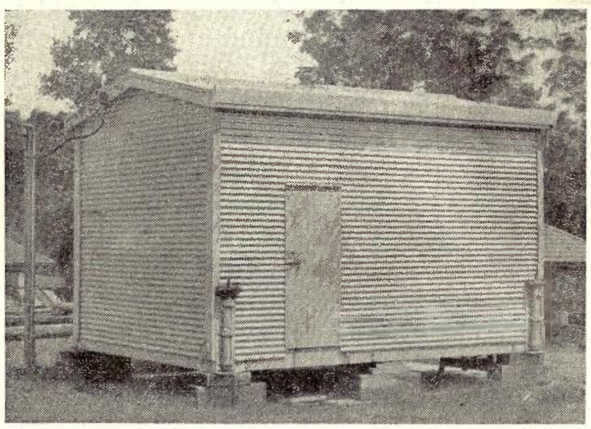


Fig. 1.

The portable building, which is shown in Fig. 1, was specially designed for the purpose. The base is of welded channel iron with galvanised iron walls and roof. No windows were provided, as it was necessary to cater for blackout conditions. Special care was taken throughout the whole construction to ensure against any distortion during movement. In addition, the selector trunk boards were stayed to the bottom frame to prevent movement in relation to the building. An adjustable lifting jack was provided at each corner of the structure to make it possible to compensate for levels in the event of an uneven location being chosen for its erection. These jacks did not take the weight during storing, a concrete bed being constructed and the whole structure supported on wooden piers.

To anticipate transport difficulties, a survey was made of the available trailers in Sydney, a list prepared, and details as to heights and widths of bridges obtained, to ascertain the routes over which the exchange could be transported. All such information was suitably recorded and held for use as necessary.

As space had to be reduced to a minimum, special consideration was given to the design of the M.D.F., which was fitted to the wall at one end of the building, and the batteries were placed on a stand beneath the frame.

In view of the necessary limitations imposed on the trunking scheme, arrangements were made in advance for the immediate disconnection of non-essential subscribers throughout the entire metropolitan network in the event of the loss of a main automatic exchange, to prevent the tandem being hopelessly overloaded to the exclusion of essential calls.

No attempt was made to provide service in the tandem to subscribers' lines connected to the damaged main exchange, nor was any provision made for junctions incoming from the Branches as portion of the latter could have been diverted to other exchanges. The sole object of the tandem was to distribute junction traffic incoming to branches of the damaged main, and, due to the limited availability of switching plant, the grade of service on junction routes incoming to the tandem was also to be considerably reduced. Trunking diagrams and grading charts were prepared for the different selector level conditions, as estimated for each main exchange the tandem may have been called upon to replace. If, in any particular instance, repeater shelf space was not required for the levels originally allotted, it was possible, by means of a system of U-links, to re-allot readily the shelf space as required. The switching scheme was planned during the design period and operational instructions were made as simple as possible.

Obviously, complete duplication of any existing main exchange junction plant was out of the question, and it was decided to give restricted junction switching service by installing two pre-

2000 type selector trunk boards equipped with selectors and repeaters, together with the associated batteries, power plant, and M.D.F.

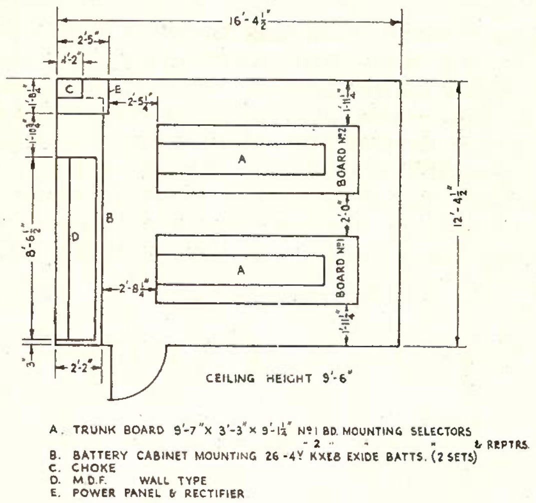


Fig. 2.

The floor layout of the apparatus is shown in Fig. 2 and a photograph showing part of the equipment in Fig. 3. The trunk boards were equipped with selectors and repeaters of the pre-2000 type, which were allotted for use as incoming second selectors from other main exchanges, with outlets graded to the repeaters, which were to be trunked to incoming third selectors in the branch exchanges of the damaged main exchange being replaced by the tandem.

The S.I.L.C. cable was terminated on the M.D.F., and a considerable length provided for connection to underground cables. The spare cable was supported and protected beneath the floor of the exchange, so that damage would not occur during transportation. The proposed junction cable pairs were allotted in advance, and the M.D.F. jumpering carried out in the tandem exchange, so that all that was required to connect the exchange was the jointing of the street cable.

Two batteries and two rectifiers with a single-panel power board designed for the purpose were provided. The batteries were of the 210 A.H. at the 10 hour rate home lighting enclosed type, having 3-16 in. plates. This type of cell was considered more suitable for the purpose than the motor-car type. A weatherproof plug and socket was fitted on the outside of the unit to permit the speedy connection of 3-phase commercial supply, or, alternatively, a portable Diesel-alternator set. Liberal internal lighting was provided, and in view of the restrictions in space, the fittings were mounted flush with the walls and ceiling.

Apart from the normal testing and adjusting of the equipment, actual working tests were carried out with main and branch exchanges. The latter included exchanges of the manual type, for which special repeaters were employed. These were wired in advance and held in reserve in case of damage to Drummoyne exchange, which is the only main having manual branches. In the case of group selectors and auto.-auto. repeaters, it was not possible to adjust and reserve special equipment owing to the shortage of these items. However, as non-essential subscribers were to be disconnected in the event of the tandem being required, the reduced traffic resulting therefrom rendered it practicable to allot and designate working switches in selected exchanges for use in the tandem.

A similar type of unit has been provided in Melbourne, and it is understood that the building

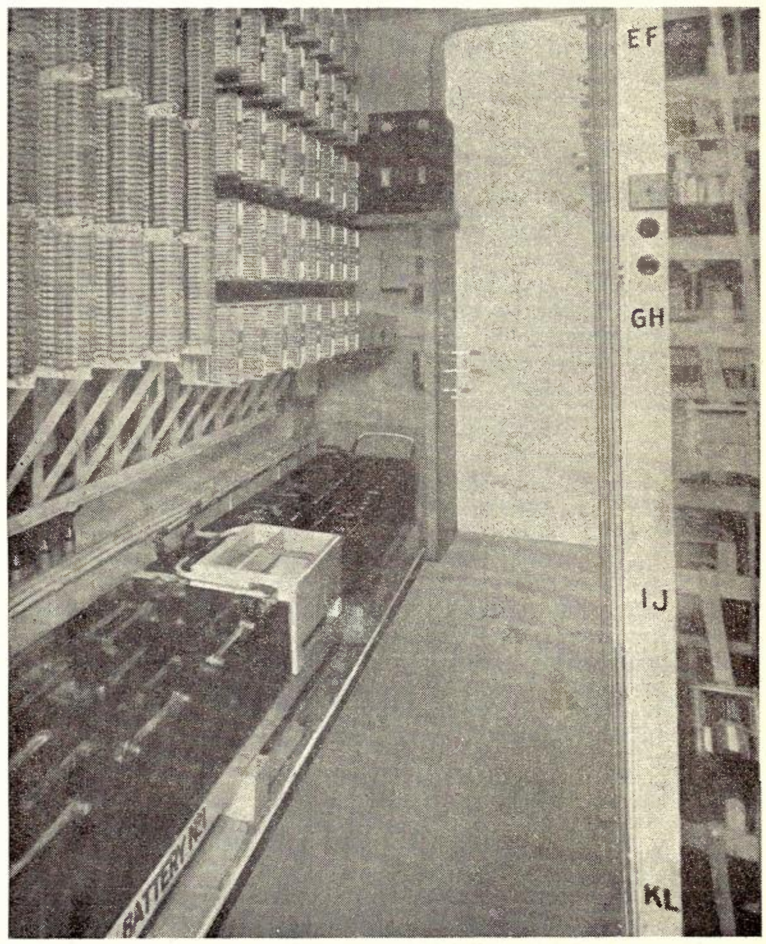


Fig. 3.

was constructed in the form of a caravan, with solid rubber tyres to guard against the possibility of puncture. In this case, switching selector repeaters were employed, so that all the switching equipment could be mounted on one trunk board, which contained rack space for 200 switching selector repeaters and 40 automatic-manual repeaters. The required degree of switching flexibility was obtained by the installation of a patch panel at one end of the trunk board. The switches were packed in separate boxes and individually marked and adjusted for particular positions in the racks. The power plant, consisting of a 50-volt battery, rectifier unit and petrol engine generator, was housed in a separate hut designed to fit on the truck chosen to haul the trailer. Arrangements were made for 230 volt or 50 volt lighting.

The organisation for placing the portable tandem exchange into service, apart from its local connections, included a prearranged plan for the restriction of outgoing junctions from each main exchange to the tandem exchange. Trunking drawings were prepared showing the method to be adopted in reducing the outlets from any main exchange to approximately 10 per cent. of the normal quantity. This enabled the dispersion of traffic into the reduced junction groups to be planned, and the cable pairs for the junctions nominated to be tentatively allotted. Jumpers were run in main distributing frames but not terminated.

A comprehensive set of instructions for the emergency scheme covering both subscribers' junction and trunk lines was issued, covering the progressive stages of work required to implement the emergency measures according to the extent and location of damage sustained.

ANSWERS TO EXAMINATION PAPERS

The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and as such might be given by any student capable of securing high marks.

EXAMINATION No. 2473. — ENGINEER — TRANSMISSION THEORY AND MEASUREMENTS

H. W. Chamberlain, B.Sc.

Q. 1.—(a) Describe the purpose, indicate the location in the circuit, and the usual values of the cut-off frequency point or points of the following items of filter equipment:—

(i) Line filter set for a 3-channel carrier system.

(ii) Line filter set for a carrier programme system.

(iii) Voice frequency repeater low pass filter.

(iv) Directional filters for a 3-channel carrier system.

(v) Channel band filters for a 3-channel carrier system.

(b) With carrier programme systems operating at frequencies above the range of 3-channel systems, it is necessary to use crystal filters to secure certain results. Describe the principle of operation of a crystal filter and explain why such a filter is incorporated in a programme carrier system.

A.—(a) (i) The line filter set for a 3-channel carrier system separates the voice frequency currents from the carrier frequency currents, so that they may pass to their respective sets of equipment. The set consists of a high pass and a low pass filter.

The usual nominal cut-off frequency points of both high pass and low pass filters making up the set are either 3 kc or 5.6 kc. The 3 kc filter set is used on ordinary circuits, while the 5.6 kc set is used where the physical line is required for programme transmissions up to 5 kc.

(ii) The carrier broadcast system which is in general use in Australia is of the single side-band, suppressed carrier type, using the lower sideband of a carrier frequency of 42.5 kc. In order to separate the channel in which the lowest frequency of 34 kc is transmitted corresponding to the pilot frequency, carrier line filter sets cutting off at approximately 32 kc are used—the high pass filter passes frequencies in excess of 32.4 kc, whilst the low pass filter will pass all frequencies up to 31.9 kc.

(iii) The successful operation of a two-wire voice frequency repeater on a long trunk circuit depends on how closely the balance network simulates the actual line impedance on each side of the repeater. It is necessary to transmit a range of frequencies 200 to 2600 cycles in order to pass commercial speech over a channel, and to prevent singing at a frequency outside this range a low pass filter is introduced in front of the amplifiers to attenuate the unwanted high frequencies. This, of course, simplifies the task of designing a balance network to match the line. The filters generally supplied with the repeaters have a cut-off frequency of 2600 to 2800 cycles.

(iv) The directional filters of a 3-channel system are used for separating the high and low groups of sidebands for each direction of transmission. The directional filter group is a high and low pass filter combination, and typical cut-off frequencies for 3-channel systems employing "S" and "T" type frequency allocations are:—

"S" type, 16,700 cycles; "T" type, 17,800 cycles.

(v) The channel modulator and demodulator band filters are used respectively at terminal stations for separating the sideband required for transmission from the other modulation products and for segregation of the different sidebands into their appropriate demodulator units.

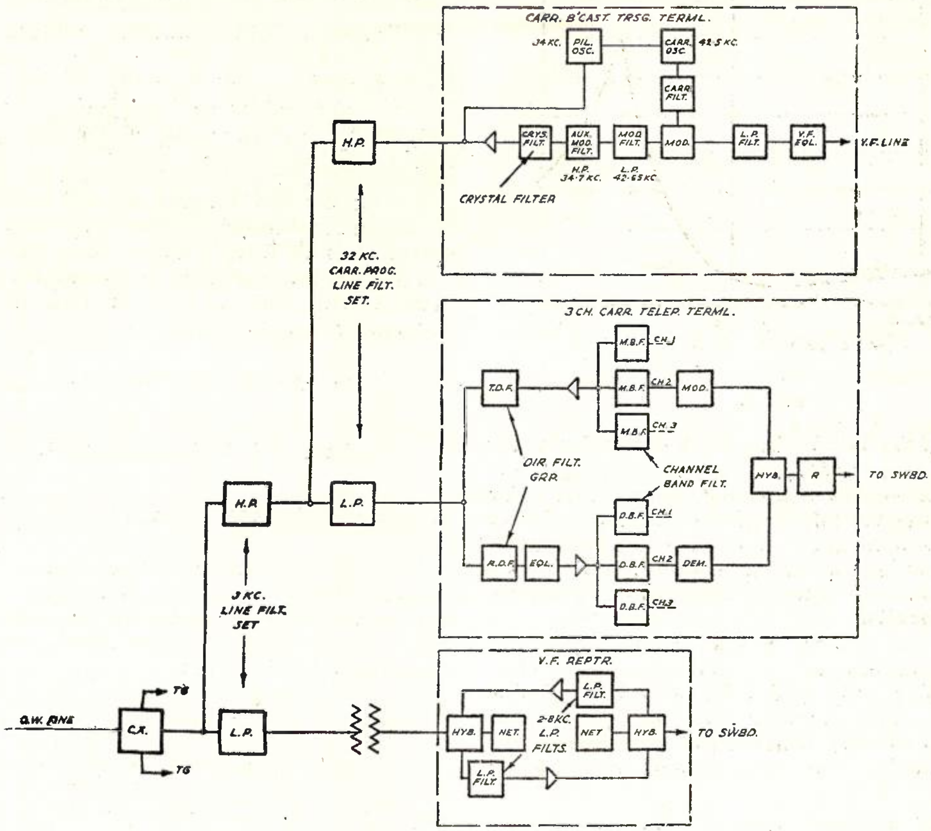
The channel band pass filters have cut-off frequencies which are each about 200 to 2,800 cycles distant from the carrier oscillator frequency of each channel. Typical values of the channel band pass frequencies would be those of a CS or SOS type system, which are:—

(a) In the low frequency direction, 6.5 to 9.1 kc; 9.6 to 12.2 kc; and 13.1 to 15.7 kc, while

(b) In the high frequency direction, they are 17.9 to 20.5 kc; 21.6 to 24.2 kc; and 25.6 to 28.2 kc.

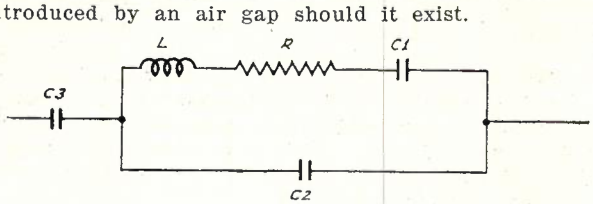
Typical locations of the above filters in the equipment with which they are associated are shown in Fig. 1.

(b) If a flat plate of quartz or other piezo-electric material is freely mounted between two electrodes and then subjected to an electrostatic field, the combination reacts upon any electrical circuit into which it may be inserted as if it were replaced by the electrical networks shown in Fig. 2. L, R, and C1 are



Q. 1, Fig. 1.

constants depending on the crystal itself. C2, which is large in comparison with C1, is the capacitance between the electrodes with the quartz dielectric, provided that there is no air gap between the electrodes and the crystal. C3 is the effective series capacitance introduced by an air gap should it exist.

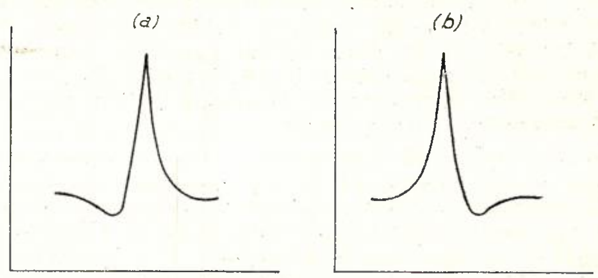


Q. 1, Fig. 2.

The circuit will have a resonant and an anti-resonant frequency. Due to the high value of C2/C1, the two frequencies will be very close together. When a single crystal is inserted in series or in parallel with pure resistances, and included in a suitable electrical circuit, the resulting attenuation v. frequency characteristics of the combinations are as shown in Fig. 3 (a) and (b) respectively. The combinations thus behave as narrow-band elimination filters having a very steep cut-off.

The carrier broadcast system in general use provides a transmission band from 35 to 7500 cycles, the lower sideband of a carrier frequency of 42.5 kc being used. Since the two sidebands corresponding to a voice frequency 35 cycles are only 70 cycles apart, their separation is practically impossible by filter structures of the coil and condenser type.

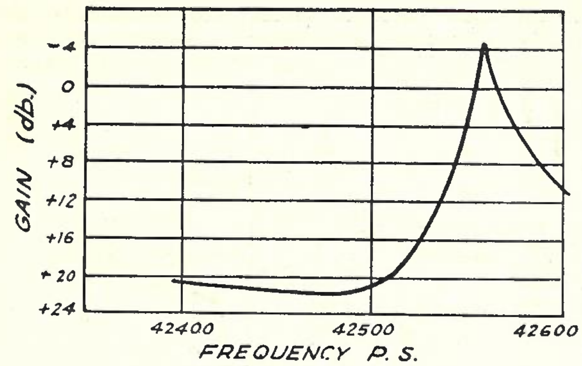
The discrimination must be such that the attenuation of the unwanted sideband is of the order of 25-30 db, if the resulting undulation in the overall lower frequency characteristic due to phase differences of the two sidebands is to remain negligible.



Q. 1, Fig. 3.

The above difficulty of transmission is overcome by means of a quartz-crystal filter used in conjunction with a low pass filter of normal construction, having a cut-off frequency of 42.65 kc. The crystal is operated in series between substantially pure resistances of about 50,000 ohms between the stages of a two-valve resistance coupled amplifier. The attenuation characteristic of the filter as shown in Fig. 4 rises rapidly between the resonant and anti-resonant frequency.

An identical crystal filter is also inserted directly in front of the demodulator unit in the receiving terminal, and further assists in providing the necessary sideband discrimination.



Q. 1, Fig. 4.

Q. 2.—(i) Explain briefly (a) the reasons for using loading coils in long underground cable circuits, and (b) how the transmission equivalent, the characteristic impedance, and the cut-off frequency of a loaded line depends upon the inductance of the loading coils used, and their distances apart, and how the values of each of these characteristics affect transmission of speech over the cable circuits.

(ii) (a) Since in general a low overall equivalent in a circuit is desirable, and an increase in the inductance of the loading coils used reduces the transmission equivalent of the cable, are there, in your opinion, any reasons why coils of very heavy inductance should not be used to secure a very low overall transmission equivalent?

(b) In applying a certain value of added inductance per mile to a cable to secure a specified overall attenuation, would there be any objections against using coils having inductance values heavier than normal, but spacing them proportionally wider apart, so as to save expense by reducing the number of loading pots and loading chambers?

A.—(i) (a) It is well known that the transmission characteristics of an unloaded cable circuit are decidedly inferior to those for an open-wire line, both in respect to magnitude and variation with frequency.

From the expression for the propagation constant $[P = a + jb = \sqrt{(R + j\omega L)\ (G + j\omega C)}]$ it may be deduced that if RC = LG, then a, the attenuation constant, V, the velocity of wave propagation, and Z_0, the characteristic impedance, are each independent of frequency, resulting in a line which possesses "distortionless" characteristic. All components of a complex wave, consisting of a fundamental frequency and a number of harmonics, such as a voice-frequency signal, are thus transmitted with the same velocity, all are attenuated by the same amount, and all meet the same impedance. The received signal, except for a slight phase shift between component waves, which is indiscernible for a line of average length, is, therefore, a replica of the sent signal.

In practice the condition for distortionless transmission cannot be achieved, because of the necessity of maintaining a reasonably high wave velocity and cut-off voice frequency for reasons indicated later, but it is closely approximated by the introduction of inductance coils spaced at regular intervals in the circuit.

The transmission characteristics of a cable circuit are affected by the addition of loading coils as follow:—

(a) The attenuation constant and velocity of propagation are both reduced, provided the ratio $\frac{R}{2L}$ is less than ω. This limitation is approached only at very low frequencies outside the range considered necessary for speech transmission.

(b) Increases the characteristic impedance, and therefore the efficiency of the circuit.

(c) Makes the attenuation, velocity, and impedance substantially independent of frequency over the range where R is small in comparison with ωL.

(i) (b) Approximate expressions for the electrical characteristics of a uniform line having distributed inductance are as follow:—

$$\text{a, attenuation constant} = \frac{R}{2}\sqrt{\frac{C}{L}} \quad \ldots \ldots (1)$$

$$Z_0\text{, characteristic impedance} = \sqrt{\frac{L}{C}} \quad \ldots \ldots \ldots (2)$$

$$\text{V, velocity of wave propagation} = \frac{1}{\sqrt{LC}} \quad \ldots \ldots \ldots (3)$$

$$\text{b, wave-length constant} = \omega\sqrt{LC} \quad \ldots \ldots \ldots (4)$$

In addition, due to the added series inductance and the capacity of the cable circuit, each loading section will behave as a low-pass filter, whose cut-off frequency, f_c, is given by:

$$f_c = \frac{1}{\pi\sqrt{L_1 SC}}$$

where L_1 = coil inductance
S = coil spacing
C = line capacitance per unit length.

From (1) any increase in L, for a given spacing, causes a corresponding reduction in a. The greater the spacing for a given inductance coil, the less will be the inductance per mile of circuit, and consequently the higher the attenuation. Less attenuation results in a better overall transmission equivalent, and the higher the volume of the received speech.

From (2) the characteristic impedance increases with an increased value of L. The effect of an increase in Z_0 is to cause greater reflection at the sending and receiving ends of the circuit, resulting in increased attenuation, and, if the circuit is long enough, produce undesirable echoes which are assisted by the low speed of transmission. Difficulties also arise in providing suitable balance networks for two-wire voice-frequency repeater operation.

For a given spacing, an increase in the value of the inductance of the loading coil results in a lowering of the cut-off frequency. Also, for a given inductance coil value, an increase in the spacing will again result in a lowering of the cut-off frequency, and vice versa. The greater the effective band-width of speech frequencies transmitted, the better is the quality of the received speech.

(ii) (a) In i. (b) above, it was shown that any increase in the value of the loading coil inductance for a given spacing results in a decrease in the attenuation constant of the circuit and a corresponding decrease in the cut-off frequency. It is highly desirable to receive as large a volume of sound as possible, but along with this it is just as essential that the quality be such as to render the reproduction easily intelligible. Therefore, there is a limit to the value of inductance which can be added. As the length of circuit is increased, involving as it does the addition of repeaters and consequently a low overall circuit loss, other effects become important, viz., echoes and velocity distortion. The heavier the loading, the lower is the velocity of wave propagation. Should there be an impedance irregularity in the circuit, the time of transmission from the point of reflection to the receiving end is appreciable, and there will be echo effects.

As the frequency approaches the cut-off frequency for the loaded circuit, the departure of the velocity of wave propagation from that of the corresponding smooth line increases rapidly. The waves of higher frequency are delayed more than those of lower frequency, giving rise to transient distortion.

A low velocity can give rise to a transmission delay time which, when added to the normal time elapsing between question and response, is apt to cause confusion psychologically.

A high velocity of transmission with a high cut-off frequency is, therefore, essential on long loaded cable circuits, and this can only be achieved by restricting the coil inductances to relatively light or medium values, depending on the length of the circuit.

(ii) (b) The only characteristic among the five enumerated in (i) (b) above which would be affected by a variation in coil spacing using coils such that the inductance per unit length remains constant, is the cut-off frequency for the circuit. The expression for f_c may be re-written:

$$\frac{1}{\pi S \sqrt{La\ C}}$$

where La is the added inductance per mile
and $L_1 = La\ S$

Now La remains constant within each loading section in order to preserve the secondary line characteristics, but if the distance apart of the coils is increased, then the cut-off frequency is decreased in the same ratio. The effect is therefore to produce a circuit which is inferior in quality to the one provided by the basic loading system.

Q. 3.—In examining a long trunk line to determine whether it is suitable for the superimposition of a 3-channel telephone system, there is evidence of an impedance irregularity existing at some point along the line. This is to be located by alternating current bridge measurements. Give details of the apparatus required to carry out suitable measurements for this purpose, describe the measurements that would be made, and how, from the results of the measurements, the location of the irregularity is determined.

A.—For the measurement of the impedance of an open-wire line at carrier frequencies lying in the range 3 to 30 kC/sec., the following equipment, connected as shown in Fig. 1, will be required:

(a) An oscillator, whose frequency is capable of being varied continuously or in intervals of 100 cycles. Suitable oscillators for the purpose are the 17B, 10B, or 8A types.

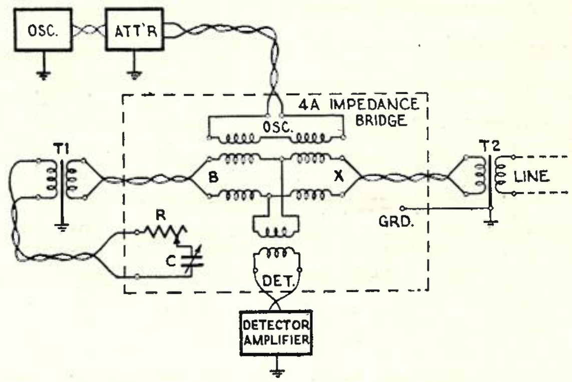
(b) An impedance bridge of the balanced hybrid-coil type—the 4A or 5A.

(c) A detector amplifier, types 1A or 3A.

(d) An attenuator, S.T.C. type 1A, or Muirhead type 4B.

(e) Two 600/600 ohm accurately matched carrier transformers.

As a preliminary to the impedance measurements, the open-wire line should be checked to ensure that conditions are normal—the usual tests applied involve measurements of the insulation resistance between the wires and each wire to ground, loop resistance, and resistance unbalance, and finally a speech test, as a check on the line equivalent and freedom from noise.



Q. 3, Fig. 1.

The line to be tested should be terminated in its characteristic impedance, which is determined approximately by carrying out impedance measurements at a number of frequencies in the range 3-30 kC/sec., viz., at 3, 8, 16, and 30 kC/sec., first with the distant end of the circuit open-circuited, and then short-circuited. The characteristic impedance, Z_o, at each of these frequencies is then obtained from the expression $Z_o = \sqrt{Z_{oc}\ Z_{sc}}$

The mean of the four computed values of Z_o is taken as the characteristic impedance of the circuit, and the distant end is then terminated in a non-inductive resistance equal to the modulus of this value of Z_o.

Impedance measurements are then carried out, commencing at 3 kC and proceeding in steps of 0.5 kC to 30 kC. The values of resistance and reactance are then recorded and plotted on a graph. The curves so obtained indicate the variation of the resistance and reactance with frequency.

On a line which is free from impedance irregularities the curves will be smooth, but where an irregularity is encountered at some point along the line, reflection occurs, the effects of which are exhibited as peaks occurring at regular intervals. The greater the degree of reflection and the less the attenuation between the reflection point and the sending end, the greater will be the magnitude of the impedance variation. It may easily be proved that the impedance of a line with partial reflection will pass through maximum and minimum values at the quarter wave length points as the reflected wave is alternately in and out of phase with the initial wave.

Let f_1 and f_2 be the frequencies corresponding to two adjacent maximum or minimum impedance points on the curves for R, X, or Z, and d the distance from the testing station to the irregularity in miles. The difference between f_1 and f_2 corresponds to a change in electrical length of one-half wave length.

Then $d = a\ \lambda_1 = a\ V_1/f_1$, where a λ_1 is the number of wave lengths for frequency f_1 to the reflection point.

Also $d = (a + \frac{1}{2})\ \lambda_2 = (a + \frac{1}{2})\ V_2/f_2$,

substituting df_1/V_1 for a in the last equation.

We have $d = (df_1/V_1 + \frac{1}{2})\ V_2/f_2$,

from which $d = \dfrac{V_1 V_2}{2(V_1 f_2 - V_2 f_1)}$.

For an open-wire line the velocity of propagation is practically constant over the carrier frequency range.

It also approaches the speed of light, which is 186,000 miles per sec., but for computation purposes it is more exact to take 180,000 miles per sec. as the representative speed. Therefore, the above equation with $V_1 = V_2$ reduces to $d = \dfrac{180{,}000}{2S}$ miles, where S is the separation in cycles per sec. between two adjacent like peaks.

The calculated distance to the irregularity is only approximately correct. The actual location of the trouble is obtained by repeating the test with the line terminated at the point determined by calculation. Generally speaking, with open-wire lines, the irregularity is caused by the introduction of a short length of unloaded cable, or loaded cable in which there is a defective loading coil.

It will be observed that the frequency intervals were taken as 0.5 kC during the impedance run. After plotting the curve the approximate frequencies corresponding to the peak points are easily determined, and in order to ensure greater accuracy in locating the distance to the irregularity, it would be worth while repeating the tests in the vicinity of each of these frequencies, but at frequencies, say, 100 cycles apart.

EXAMINATION No. 2473—ENGINEER—NATURAL SCIENCE

E. H. Palfreyman, B.Sc., B.E.

Q. 1.—State in words the rule for finding the derivative with respect to "x" of the function, $y = (ax + b)^n$. Differentiate the following with respect to "x":—

$$\text{(i)}\quad y = \sqrt{x^3} + \frac{2}{x} - \frac{3}{x^2} + \frac{4}{\sqrt{x^5}}$$

$$\text{(ii)}\quad y = \frac{1}{(2x + 3)^2}$$

A.—If $y = (ax + b)^n$ then $dy/dx = na\,(ax + b)^{n-1}$. Thus the derivative of the n^{th} power of the linear function $(ax + b)$ equals "n" times the coefficient "a," multiplied by the $(n\text{-}1)^{th}$ power of the linear function.

(i) $y = x^{3/2} + 2x^{-1} - 3x^{-2} + 4x^{-5/2}$

$\therefore\ dy/dx = 3\sqrt{x}/2 - 2/x^2 + 6/x^3 - 10/\sqrt{x^7}$

(ii) $y = 1/(2x + 3)^2 = (2x + 3)^{-2}$

$\therefore\ dy/dx = (-2) \cdot 2 \cdot (2x + 3)^{-3} = -4/(2x + 3)^3$.

Q. 2.—Using partial fractions integrate the following function of "x":—

$$y = \frac{5x - 7}{(x + 1)\,.\,(2x - 1)}$$

A.—

$$y = \frac{5x - 7}{(x + 1)\ (2x - 1)} = \frac{A}{x + 1} + \frac{B}{2x - 1}, \text{ say.}$$

To find A multiply throughout by $x + 1$ obtaining

$$\frac{5x - 7}{2x - 1} = A + \frac{B}{2x - 1}(x + 1)$$

and then put $x + 1 = 0$, i.e., put $x = -1$ to obtain

$$\frac{-5-7}{-2-1} = A + B.0, \therefore A = 4.$$

To find B multiply throughout by $2x + 1$ and then put $2x + 1 = 0$ to obtain $B = -3$.

$$\text{Thus } y = \frac{5x - 7}{(x + 1)(2x - 1)}$$

$$= \frac{4}{x + 1} - \frac{3}{2x - 1}$$

$$\text{hence} \int y\,dx = \int \left(\frac{4}{x + 1} - \frac{3}{2x - 1} \right) dx$$

$$= 4 \log (x + 1) - \frac{3}{2} \log (2x - 1) + C.$$

Q. 3.—By means of exponential identities, derive the hyperbolic equivalents of sin x, cos x and tan x. Prove that $\cosh^2 x - \sinh^2 x = 1$.

A.—

$$\text{Sin } x = \frac{e^{jx} - e^{-jx}}{2j} = \frac{1}{j}\,\frac{e^{jx} - e^{-jx}}{2}$$

$$= -j \sinh jx$$

$$\text{Cos } x = \frac{e^{jx} + e^{-jx}}{2} = \cosh jx$$

$$\text{Tan } x = \frac{\sin x}{\cos x} = \frac{-j \sinh jx}{\cosh jx} = -j \tanh jx.$$

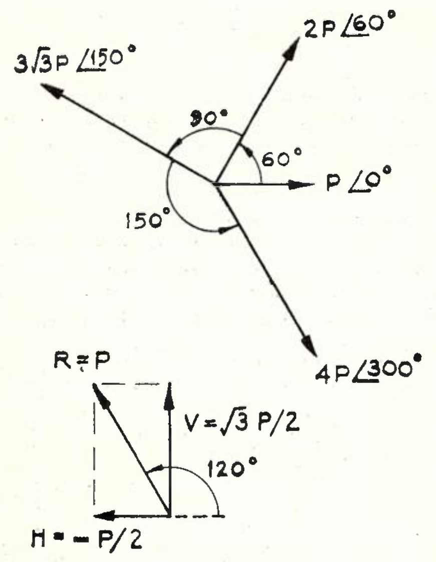
$$\text{L.H.S.} = \cosh^2 x - \sinh^2 x$$

$$= (\cosh x - \sinh x)\ (\cosh x + \sinh x)$$

$$= (e^{-x})\ \ (e^{x}) = 1 = \text{R.H.S.}$$

Q. 4.—A particle is acted upon by forces in one plane represented by P, 2P, $3\sqrt{3}$P and 4P; the angles between the first and second, the second and third, and the third and fourth are 60°, 90°, and 150° respectively. Show that the resultant is a force P in a direction inclined at an angle of 120° to that of the first force.

A.—Assume that the first force is horizontal, then the remaining forces will have the magnitudes and directions shown in Fig. 1.



Q. 4, Fig. 1.

If H and V are the horizontal and vertical components of the resultant R, then

$$H = P \cos 0° + 2P \cos 60°$$

$$+\ 3\sqrt{3}\ P \cos 150° + 4P \cos 300°$$

$$= P\ (1) + 2P\ (1/2) + 3\sqrt{3}\ P\ (-\sqrt{3}/2)$$

$$+\ 4P\ (1/2).$$

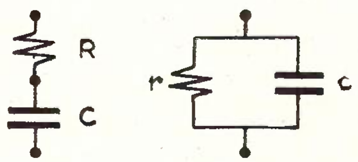
$$= -P/2.$$

$$V = P \sin 0° + 2P \sin 60° + 3\sqrt{3}\, P \sin 150° + 4P \sin 300°$$
$$= P\,(0) + 2P\,(\sqrt{3}/2) + 3\sqrt{3}\, P\,(1/2) + 4P\,(-\sqrt{3}/2)$$
$$= \sqrt{3}\, P/2.$$
$$\therefore R = H + jV = \sqrt{H^2 + V^2}\ /\tan^{-1} V/H$$
$$= \sqrt{(-P/2)^2 + (\sqrt{3}\,P/2)^2}\ /\tan^{-1} (\sqrt{3}\,P/2)/(-P/2)$$
$$= \sqrt{P^2/4 + 3P^2/4}\ /\tan^{-1} (\sqrt{3})/(-1)$$
$$= P\ /120°.$$

Q. 5.—The losses in a condenser can be represented by either a series or a shunt resistance. Deduce an expression for the relationship between the two equivalent resistances.

If the product of the equivalent series resistance and capacitance of a condenser at a certain frequency is 20 × 10^{-10} and the power factor is 0.001, at what frequency was the measurement made?

A.—(i) The two circuits shown in Fig. 1 have identical impedances.



Q. 5, Fig. 1.

$$\text{Thus } R + 1/j\omega C = \frac{1}{1/r + j\omega c}$$

Cross multiplying gives
$$R/r + Rj\omega c + 1/r\, j\omega C + c/C = 1.$$

Equate imaginary parts to obtain
$$R\omega c - 1/r\omega C = 0$$
$$\therefore Rr = 1/\omega^2 Cc$$
$$= 1/\omega^2 C^2 \text{ if power factor small.}$$

(ii) Power factor $= R/Z \div R/X$ very approx.
$$= R \Big/ \frac{1}{\omega C} = R\omega C.$$
$$\text{Thus } R\omega C = 10^{-3}$$
$$\text{and } RC = 20.10^{-10}$$
$$\therefore \omega = 10^{-3}/20.10^{-10} = 10^{7}/20$$
$$\therefore f = \omega/2\pi = 10^{7}/40\pi$$
$$= 79{,}600 \text{ c/s.}$$

Q. 6.—List four of the six major effects present in a high-frequency circuit embracing dielectric and magnetic materials, which cause loss additional to the d.c. loss.

The d.c. resistance of a copper wire, 0.01 cm. diameter, is 10 ohms. Calculate the high-frequency resistance of the wire at 10 megacycles per second, given that $(R_{HF}/R_{DC})^2$ is directly proportional to the area, the permeability and the frequency (in cycles per second) and inversely proportional to the volume resistivity which may be taken as 2 × 10^{-6} ohms per cm. cube. The constant of proportionality is π.

A.—(a) The major effects at H.F. are—

(1) **Eddy Current Loss.** Currents induced in neighbouring masses of conducting material by varying magnetic fields.

(2) **Hysteresis Loss.** Energy lost in subjecting magnetic material to magnetization cycles.

(3) **Dielectric Loss.** Dissipation of energy within dielectric material due to alternating electric stress.

(4) **Radiation Loss.** Energy emitted in the form of electro-magnetic waves.

(5) **Skin Effect.** Increase in effective resistance due to greater current density near surface of conductor.

(6) **Proximity Effect.** Increase in effective resistance due to currents induced in neighbouring conductors.

(b)—

$(R_{HF}/R_{DC})^2 = \pi.A.\ \mu.f./\rho$ (quantities in abs. units).

$$\text{In this case } A = \pi \times 0.01^2/4$$
$$\mu = 1$$
$$f = 10^7 \text{ c/s.}$$
$$\rho = 2 \times 10^{-6}\ \Omega/\text{cm cube}$$
$$= 2 \times 10^{3} \text{ ab-ohms/cm cube.}$$
$$\text{Hence } (R_{HF}/R_{DC})^2 = \frac{\pi^2 \times 0.01^2 \times 1 \times 10^7}{4 \times 2 \times 10^3} = \frac{\pi^2}{8}$$
$$\therefore R_{HF}/R_{DC} = \pi/\sqrt{8} = 1.11.$$
$$\therefore R_{HF} = 1.11 \times R_{DC} = 1.11 \times 10$$
$$= 11.1 \text{ ohms.}$$

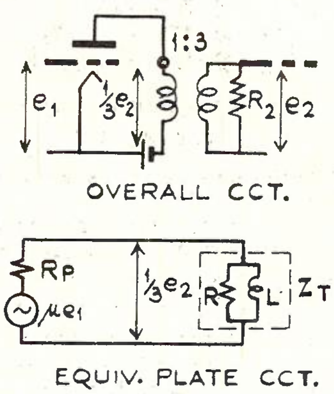
Q. 7.—In an audio-frequency amplifier the tube has an anode-cathode dynamic resistance (R_p) of 30,000 ohms, and an amplification factor (μ) of 40. It is coupled to the succeeding stage by a transformer having a ratio 1 : 3 and a primary inductance of 40 henries. The secondary load is a resistance of 0.9 megohms. Calculate the overall amplification for frequencies, f_1 and f_2 such that—

(i) $2\pi f_1$ = 1,000 radians/second.

(ii) $2\pi f_2$ = 50,000 radians/second.

The internal capacitance of the tube, the self-capacitance, resistance and leakage of the transformer may be neglected.

A.—The overall circuit and the equivalent plate circuit are shown in Fig. 1 and it will be seen that the overall amplification equals e_2/e_1.



Q. 7, Fig. 1.

In the equivalent plate circuit the generator has e.m.f. of μe_1, and internal impedance R_p = 30,000 Ω, whilst the load is a zero-loss transformer, terminated in R_2 = 900,000 Ω which is equivalent to Z_T, the primary inductance L of transformer paralleled by $R_1 = R_2/3^2$ = 100,000 Ω.

In the plate cct we will have—
$$e_2/3 = \mu e_1 \times \frac{Z_T}{Z_T + R_P}$$
$$\text{Thus } \frac{e_2}{e_1} = 3\mu \times \frac{1}{1 + R_P/Z_T} \text{ (vectorially)}$$

But $1/Z_T = 1/R_1 + 1/j\omega L$

Hence $\dfrac{e_2}{e_1} = 3\mu \times \dfrac{1}{1 + R_p\ (1/R_1 + 1/j\omega L)}$

$$= \frac{3\mu}{(1 + R_p/R_1) - j\ R_p/\omega L}$$

thus $\dfrac{e_2}{e_1} = \dfrac{3\mu}{\sqrt{(1 + R_p/R_1)^2 + (R_p/\omega L)^2}}$
(Magnitude only).

At $\omega = 1000 \quad \omega L = 40{,}000.$

$$\therefore \frac{e_2}{e_1} = \frac{3 \times 40}{\sqrt{\left(1 + \frac{30{,}000}{100{,}000}\right)^2 + \left(\frac{30{,}000}{40{,}000}\right)^2}}$$

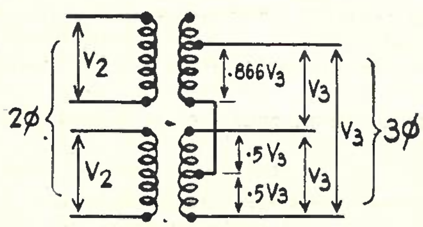
$$= \frac{120}{\sqrt{1.3^2 + 0.75^2}} = \frac{120}{1.50} = 80.$$

At $\omega = 50{,}000,\ \omega L = 2{,}000{,}000.$

$$\therefore \frac{e_2}{e_1} = \frac{120}{\sqrt{\left(1 + \frac{30{,}000}{100{,}000}\right)^2 + \left(\frac{30{,}000}{2{,}000{,}000}\right)^2}}$$

$$= \frac{120}{\sqrt{1.3^2 + 0.015^2}} = \frac{120}{1.3} = 92.4.$$

Q. 8.—A 50 horse-power 440-volt three-phase motor is operated through a Scott-connected transformer group from a 2,200 volt, two-phase power line. If the efficiency of the motor is 90 per cent. and the power factor 0.88, and neglecting transformer losses, calculate the two-phase and three-phase line currents.



SCOTT CONNECTION

Q. 8, Fig. 1.

A.—The transformer circuit is as shown in Fig. 1.

Motor output $= 50$ H.P.
$= 50 \times 746 = 37{,}200$ watts.
Motor input $= 37{,}200/.9 = 41{,}400$ watts.
3-Phase power $= 3 \times (E_3/\sqrt{3}) \times I_3 \cos\theta$
$= \sqrt{3} \times 440 \times I_3 \times 0.88 = 41{,}400.$
$\therefore I_3 = 41{,}400/\sqrt{3} \times 440 \times 0.88$
$= 41{,}400/670 = 62$ amp.
2-Phase power $= 2 \times E_2 \times I_2 \times \cos\theta$
$= 2 \times 2200 \times I_2 \times 0.88 = 41{,}400$
$\therefore I_2 = 41{,}400/2 \times 2200 \times 0.88$
$= 41{,}400/3870 = 10.7$ Amp.

Q. 9.—Ten litres of oxygen are collected over water at a pressure of 750 m.m. and a temperature of 15°C., being saturated with water vapour. Find the mass of dry oxygen and of water vapour, having given that the density of hydrogen at 0°C. and 760 m.m. is of 0.0896 grams per litre and that the specific gravities of oxygen and of water vapour referred to hydrogen are 16 and 9 respectively. The saturation pressure of water vapour at 15°C. is 12.7 m.m.

A.—(i) **For Water Vapour.**
Volume is 10 litres when the pressure is 12.7 m.m. Hg. and Temperature is 15°C.
Hence Volume at NTP $= 10 \times 2.7/760 \times 273/288$
$= 0.337$
and mass $=$ Volume $\times 9 \times 0.0896.$
$= 0.128$ gms. . . . (i).

(ii) **For Oxygen.**
Volume is 10 litres when the pressure is 750-12.7 = 737.3 m.m. Hg. and Temperature is 15°C.
Hence Volume at NTP $= 10 \times 737.3/760 \times 273/288$
$= 9.20$
and mass $=$ Volume $\times 16 \times 0.0896.$
$= 13.2$ gms. . . . (ii).

Q. 10.—Given that the velocity of sound in air at 0°C. is 330 metres per second, calculate the velocity at 20° C. What is the effect on the velocity of sound in air, of change of pressure and of increase of the amount of water vapour present?

A.—(i) The velocity of sound in a gas at temperature t°C., relative to its value at 0°C. is given by

$$v_t = v_o \sqrt{(273 + t)/273}$$

Hence $v_{20} = 330 \sqrt{293/273} = 342$ metres/sec.

(ii) If the temperature is constant, then $v = \sqrt{Kp/d}$ where p = pressure, d = density and K = ratio if specific heats (constant). Now in any gas p/d = a constant, for variations in p and thus v is unaltered with variation in pressure.

(iii) If water vapour is present in air, then the gaseous mixture will have a lower density at NTP, hence the velocity of sound will increase slightly.

Q. 11.—(i) Name two kinds of rays which are emitted by radio-active elements and indicate three of the properties possessed by these rays.

(ii) According to modern theory, four different kinds of particles may be found within the structure of the atom. Name two of them, indicating qualitatively the amount of mass and electric charge (if any) possessed by each of them.

A.—(i) The rays emitted from radio active elements are "alpha," "beta" and "gamma" rays and these have the following properties (respectively):—

(a) Can penetrate metals—very low, low, high.
(b) Are deflected by electric and magnetic fields—slightly, strongly, not at all.
(c) Produce fluorescent effects in certain substances—brilliant flashes, weak flashes, continuous glow.
(d) Ionize gases—all.
(e) Affect photographic plates—all.

(ii)—
(a) Electron—small mass and small negative charge.
(b) Proton—large mass and small positive charge.
(c) Positron—small mass and small positive charge.
(d) Neutron—large mass and no charge.

Q. 12.—Fifty grams of Manganese Dioxide is heated with an excess of Hydrochloric Acid. Show by the chemical equation the reaction which takes place and calculate the volume of Chlorine produced at 0°C. and 760 m.m. pressure.

Mn = 55, O = 16, H = 1, Cl = 36.

A.—$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$
Mol. wt. of $MnO_2 = 55 + (2 \times 16) = 87.$
Thus, 1 gm. mol. of MnO_2 is needed to yield 1 gm.

mol. of Cl_2, i.e., 87 gm. of MnO_2 yields 22.4 litres of Cl_2 at NTP.

Hence 50 gms. yields $22.4 \times \frac{50}{87}$ litres.

Thus Chlorine produced = 12.9 litres.

EXAMINATION 2473—ENGINEER—TELEGRAPH SECTION 2

R. C. Henry.

Q.1.—Explain how two multiplex systems are brought into synchronism ready for the disposal of traffic, assuming that the correction segments are fixed at both stations.

Q.2.—(a) Discuss the correct adjustments for satisfactory operation of the correcting mechanisms of a Murray Multiplex installation. (b) What are the normal indications that the adjustments are wrong?

Information covering the answers to these two questions is contained in the short article on p. 52 of the June, 1944, issue of this Journal.

Q.3.—An 18-channel V.F. system has been provided between two centres. Twelve of the channels are to be extended at one centre to physical lines for the operation of four Morse Simplex, four Manual Duplex, and four Teleprinter Services. Describe the facilities required at this Telegraph Centre, and furnish a schematic sketch of the circuit arrangements for each type of service.

A.—It would be necessary to provide relay sets to extend the V.F. channels to the physical circuits. These relay sets would be rack mounted, and would be assembled on panels as follow:—

(a) **To Extend to Morse Simplex Lines:** Four panels in accordance with Fig. 1 would be required for this purpose. These panels are of the half duplex type, with a dry metal rectifier in the morse line circuit. The relay A is operated direct from the carrier receive relay tongue. When this relay is on the marking contact, the morse physical line current of 30 milliamps operates the relay B to marking against the 15 mA current through the bias winding which tends to operate the relay to spacing.

When the morse key is opened at the distant end of the simplex physical line, the bias current operates the relay B to spacing passing the signals to the static modulator of the V.F. channel.

With the physical line closed, when the carrier receive relay is operated to spacing under the control of the operator at the distant V.F. terminal, the rectifier in the physical line prevents the flow of current in the physical line. The current through the bias winding is now reversed, and as Relay B is of the polarised type, this relay is retained on the Marking contact.

By this means the morse signals are repeated from the simplex line to the V.F. channel, and in the reverse direction.

(b) **To Repeat to the Physical Duplex Lines:** Four panels would be required for this purpose. The panels would be in accordance with Fig. 2.

As the artificial line network AL is balanced to simulate the line characteristics, the signals received on the carrier receive relay are repeated into the physical line without affecting the physical line relay. This relay, however, under the control of the key at the distant end of the physical circuit, repeats signals to the static modulator, both transmissions taking place simultaneously.

(c) **To Extend to Teleprinters:** It is assumed that the teleprinters are connected to the telegraph office by means of local loops. Four panels with circuit in accordance with Fig. 3 would be installed.

When the circuit is at rest, the local relays CS and HR are held on the marking contact by 15 mA current flowing through the bias winding. The teleprinter is held to marking by the negative potential passed to its electro-magnet via the M contact of the home record relay HR. When signals are received from the distant terminal, they are extended to the local machine over this circuit.

When the local machine is operated to space, the local relays CS and HR are operated to space by the 30 milliamps current flowing through the local loop circuit. Relay CS controls the static modulator at the carrier terminal, and thereby repeats the signals to the distant V.F. carrier telegraph terminal. The home record relay HR is also operated, and as the relay CR is maintained on the M contact under the control of the distant machine at this time, the local teleprinter receives its home record signals under the control of its own transmitter.

General: The following general equipment would be provided. The test equipment listed would be connected to plugs at the switchboard:—

(i) **Switchboard:** The jacks shown in the diagrams would be assembled in a common switchboard for patching and testing.

(ii) **Teleprinter Observation:** A test teleprinter would be provided with an associated panel to permit of observation and monitoring of the teleprinter circuits.

(iii) **Morse Monitoring Set:** A double current morse monitoring set would be provided to speak on any V.F. channel or on the duplex physical lines.

(iv) **Carrier Test Set:** This set would be used to test V.F. carrier telegraph channels. Equipped with send and receive loop meters it would be capable of transmitting continuous mark, continuous space and reversals. Sets iii. and iv. may be combined.

(v) **Simplex Morse Set:** This set would be used to monitor the morse simplex to carrier repeaters by inserting its associated plugs in the jacks of the simplex line under test.

(vi) **Reversal Generator:** To supply reversals for carrier and relay tests.

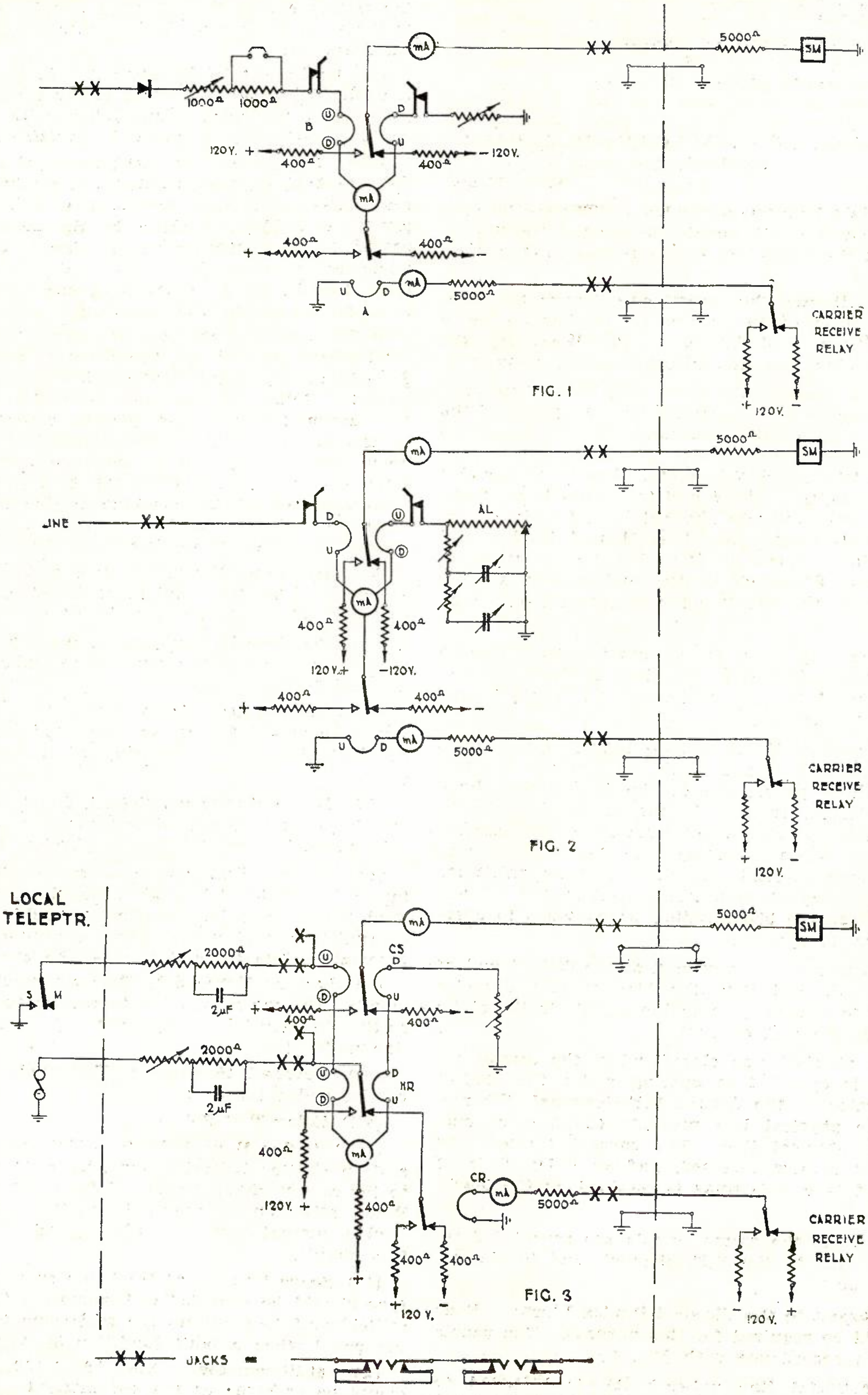
(vii) **Relay Test Set.**

(viii) **Order Wire Indicator:** This would consist of a drop shutter indicator normally connected via jacks to the carrier channel reserved for order wire purposes. When attention is required on the order wire, the double current morse monitoring set is plugged into this circuit.

(ix) **Spare Panels:** At least one spare panel of each type should be provided and connected to jacks at the switchboard to facilitate the replacement of any working panel when a fault condition is suspected.

(x) **Milliammeter:** One 100-0-100 milliammeter would be provided at the switchboard.

(xi) **Voltmeter:** 0-200 voltmeter would be similarly provided.



Q. 3, Figs. 1, 2 and 3.

SECTION 3

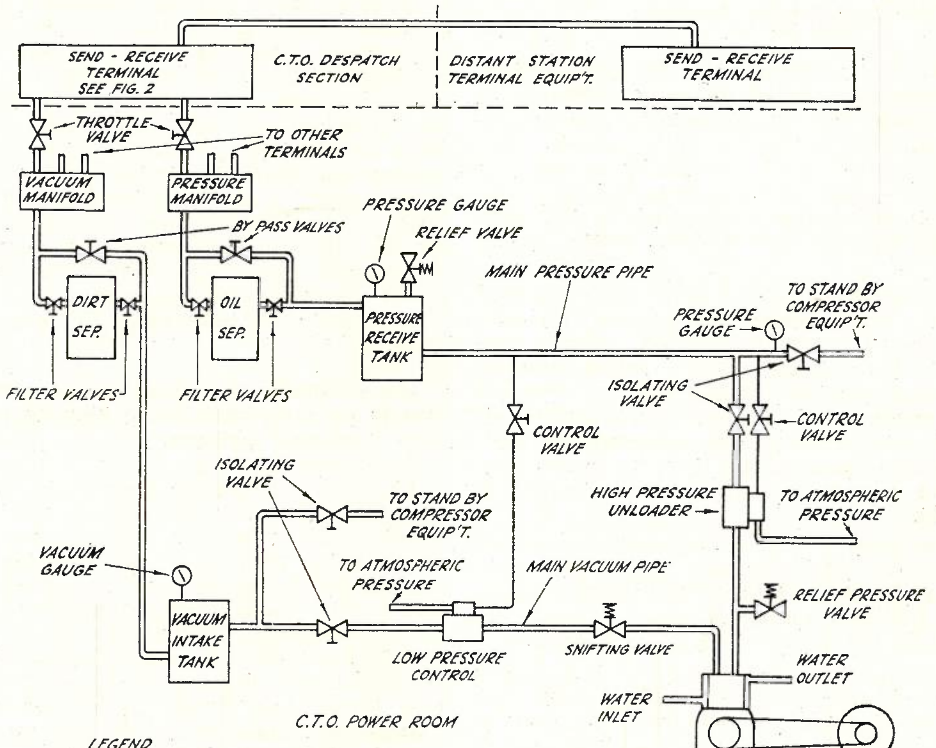
Q.1.—Three single pneumatic tubes to Telegraph Branch Offices are to be connected to a Central Telegraph Office. The lengths of the tube are 2,000 feet, 1,200 feet, and 700 feet respectively, and two-way operation is required in each case:—

(a) Discuss generally, with the aid of a sketch, all the equipment and power plant necessary at each terminal and at the Central Telegraph Office.

(b) What is the desired standard speed of travel of the carriers in each direction?

(c) What pressures above and below atmospheric pressure would you suggest as being necessary to obtain the desired standard speeds in each direction?

A.—General: Single pneumatic tube systems operate on a two-way basis, i.e., one tube suffices for the transmission of a carrier, containing the message form, between two stations. The associated power plant is situated at the main office. When a carrier is despatched, it is forced through the pneumatic tube to the distant office by compressed air, whose terminal pressure is maintained at approximately 10lb. per square inch above that of the atmosphere. On the return trip the carrier is propelled by atmospheric pressure against a vacuum ranging between 8 to 10 inches of mercury. The average speed of carrier travel, in either direction, is 30 feet per second.



General Layout of Equipment.
Q. 1, Fig. 1.

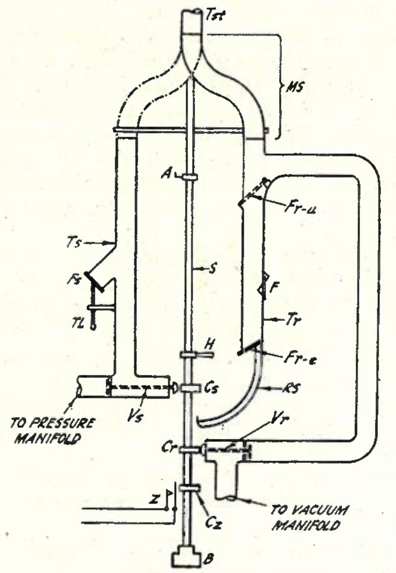
Power Plant: In a typical installation the air compressor is a single cylinder, one stage, water cooled unit, capable of displacing 85 x 3 = 255 cubic feet of free air per minute. The compressor is driven by multiple Vee rubber belt from an electric motor of 25 b.h.p. When A.C. service mains are available, the motor would be a 400 volt, 3 phase, induction type machine, with star-delta starting equipment.

Safety Features: On the pressure side, a safety valve is fitted in the delivery pipe and adjusted to operate when the air pressure exceeds 12lb. per square inch. It should be placed close to the compressor to safeguard the installation in the event of an isolating valve being shut while the machine is running, also, an additional safety valve is fitted to the air receiver. The pressure unloader is air controlled, and allows the compressor to discharge directly to atmosphere should the working air pressure rise above a pre-determined figure dependent upon average operating conditions. Thus the driving motor average power consumption is reduced.

On the vacuum side the compressor intake pipe is normally connected to the vacuum tank, but in the event of subnormal air pressure in the main pressure pipe, the air controlled low pressure unloader causes the compressor intake to be connected to the atmosphere, with resultant increase in volumetric efficiency and the rapid restoration of normal working pressures.

The snifting valve performs a somewhat similar function as the low pressure control unloader, except its operation serves to admit air, at atmospheric pressure, to the main intake pipe should the vacuum therein exceed 10 inches of mercury.

Despatch: (Fig. 2.) The despatch officer inserts the carrier, containing the message form, in the send tube (Ts) and then seals the tube inlet with send flap (Fs) by operating toggle lever (TL). Next, shaft (S) is partly rotated by means of handle (H) to connect the send and street tubes (Ts and Tst respectively) by means of the movable section (MS), the final positioning of which is arranged to take place prior to the operation of the send valve (Vs) by send cam (Cs), to prevent damage to the carrier should it strike the movable section before its final setting is reached.



C.T.O. Send-Receive Terminal.
Q. 1, Fig. 2.

The operation of handle (H) to its send position allows the curved extension of its outer extremity to lock toggle handle (TL) to prevent its release by manual operation while a carrier is in transit, also, shaft (S) is held in the send position by means of a latch (not shown), which engages with the shaft arm (A). Thus compressed air is admitted to the send tube to propel the inserted carrier to the distant station terminal.

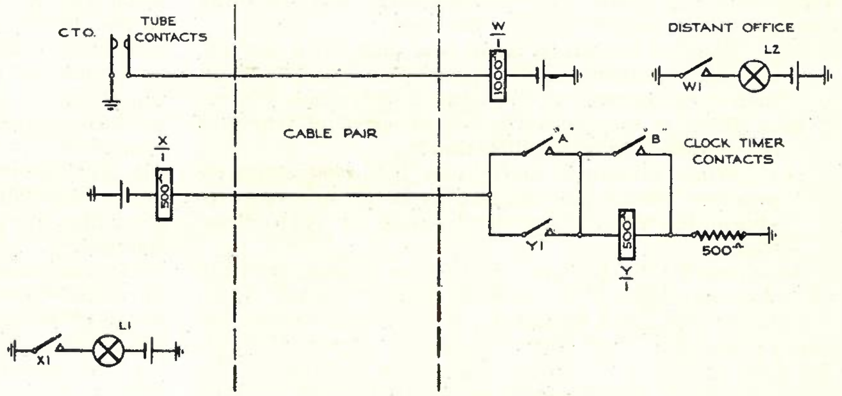
When air was admitted to the send tube it caused the operation of a timing device (not shown), the purpose of which is to unlatch arm (A) after a predetermined interval of time plus a safety margin, equal to the period elapsing between the despatch and receipt of the carrier. When shaft (S) is unlatched, it automatically returns to its normal (receive) position, thereby causing receive cam (Cr) to operate receive valve (Vr) and connect the street tube to the vacuum manifold.

Receipt: When shaft (S) is in its receive (normal) position, receive cam (Cr) operates the receive valve (Vr) to connect the street tube to the vacuum manifold. Thus the incoming carrier is pushed towards the C.T.O. terminal by the pressure of the atmosphere.

On leaving the movable section (MS) the carrier continues its downward course to strike receive flap (Fr-a) and cause it to move away from its seat so that the second receive flap (Fr-e) will be held against its seat by atmospheric pressure. In this manner, therefore, the pressure on either side of the receive flap (Fr-a) is equalised, and hence it opens fully to allow the carrier to continue its downward course and strike finger (F).

The operation of finger (F) allows sufficient air, at atmospheric pressure, to enter to permit the second receive flap (Fr-e) to open easily on impact by the incoming carrier, whose momentum is finally arrested by receive section (RS).

At the **distant terminal** the open-ended tube has an "S" bend, designed to decrease the momentum of an incoming carrier before it is ejected into the delivery tray.



Q. 1, Fig. 3.

Signalling Circuit. Fig. 3: A signalling circuit is provided between stations to indicate to either the C.T.O. circulation officer or the distant attendant the despatch of a carrier.

Contacts Z shown in Fig. 2 are closed when shaft S is in the send position, therefore, relay W operates to cause warning lamp L2 to light when a carrier is despatched from the C.T.O. Lamp L2 will remain alight until shaft S restores to its normal position. When a carrier is despatched from the distant station, the attendant operates a clockwork timer (Serial 17, Item 1), thereby causing the timer contacts "A" to momentarily close the circuit of relays X and Y. Relay Y locks via Y1, and warning lamp L1 lights at C.T.O. After an interval of time, dependent upon the length of the tube, timer contacts "B" close to momentarily short-circuit relay Y and restore the circuit to normal.

(b) and (c)—See first para.

Information is also given in Journal 2, December, 1935, p. 51.

Q.2.—Explain the functioning, with the aid of a sketch, of a through Morse Simplex repeater equipped with calling-in facilities.

A.—General:

Fig. 1 is a schematic diagram of a Simplex to Simplex Toye Repeater for use on single current Morse circuits. The "Call In" arrangements provide a means whereby the services of the Repeater Attendant may be obtained by simply opening the line circuit at either terminal by means of the Morse Key.

The telegraph Transmitters TR.W. and TR.E. are the Stearns pattern, whose special feature is their "make" before "break" contacts. The Repeating Relays RR.W. and RR.E. are of the Morse pony type (Serial 123, Item 19A); in this case, however, they have back as well as front contacts.

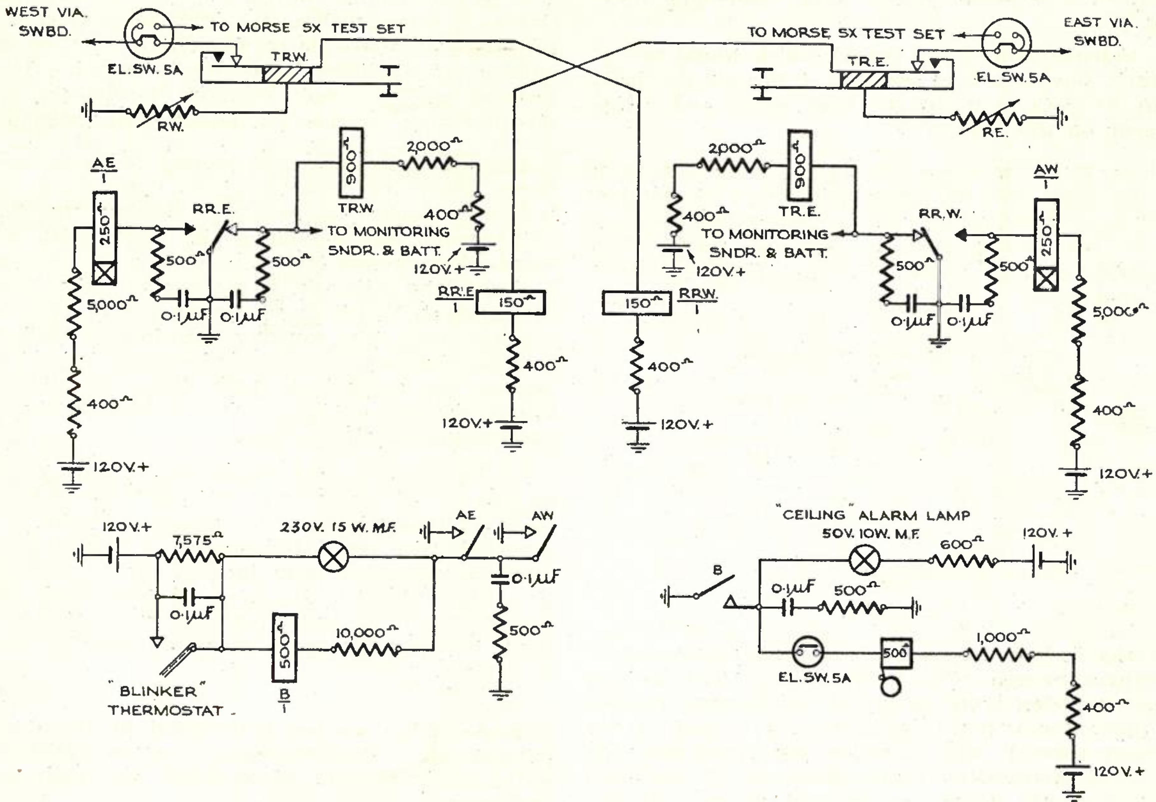
The time delay thermostat is a commercial product distinguished by the trade name of "Blinker." Its operation depends upon the unequal linear expansion of the metals forming its bimetallic strip so that when subjected to the heating effect of its operating current through the 7,575 ohm winding, it will close a pair of contacts in about two minutes.

Repeater Operation Description:

With the circuit in the normal condition, i.e., both of the terminal Morse keys closed and with battery applied to the circuit, let the East terminal Morse key be opened in a manner as during the transmission of Morse signals. Consequently, the circuit of Repeater Relay RR.E. will be opened, thereby causing its armature to open the operating circuit of Transmitter TR.W.

the lamp filament, but Relay B will not operate due to insufficient current flowing through its winding.

After a period of approximately two minutes the bimetallic strip of the thermostat will close its contacts and short circuit its heating winding of 7,575



Q. 2, Fig. 1.

On the Transmitter restoring to its unoperated position, its "make" before "break" contacts will open the West line and provide a circuit to hold Repeater Relay RR.W. steadily operated without any appreciable change in its working current value by virtue of Resistance RW being adjusted to equal the ohmic resistance of the West line. When the East terminal closes its Morse key, the circuit is again restored to its normal condition. Thus, the signals transmitted by the East terminal are repeated to the West terminal equipment.

For satisfactory operation the adjustment of resistances RW and RE should be maintained within close limits to the ohmic resistance of the lines they represent, since any variation of current through the repeating relay tends to set up a chattering condition.

Should the West terminal Morse key be opened and closed, the same relative circuit operation will ensue in the West to East direction.

Call-in Circuit Description:

When the East terminal Morse key is opened, Repeater Relay RR.E. becomes de-energised, and hence its armature on falling back closes a circuit for Telephone Relay AE. During the transmission of Morse signals, Relay AE does not operate, since it is slugged at its armature end. However, should the open circuit line condition persist, Relay AE will operate and close the thermostat circuit, under which condition only a small voltage is developed across the filament of the 230 volt lamp. Telephone Relay B, in series with the 10,000 ohm resistance, is connected across

ohms, thus applying 120 volts across the lamp filament and thereby allowing Relay B to operate and close the visual and audible alarm circuits. The thermostat contacts remain closed for several seconds, during which time, of course, the alarm signals are maintained. When the bimetallic strip cools sufficiently, its contacts will open, thus causing the armature of Relay B to fall back and open the alarm circuits.

In the event of the open-circuited line condition being maintained, the abovementioned cycle is repeated. Relative circuit operation is similar, should the West terminal Morse key be opened for the necessary period of time.

Q.3.—(a) State the advantages and disadvantages of single and double current working as applied to telegraph signalling.

(b) Which system would you recommend, and briefly state your reasons, for the following circuits:

(i) An omnibus morse channel 300 miles in length.

(ii) A busy composite channel superimposed on a trunk line with a number of intermediate telephone offices. The telegraph facility is only required between the two terminal stations.

A.—See Vol. 4, No. 1, p. 62, for answer to this question. From this information the recommended systems of working would be:—

(b) (i) Single current working would be more satisfactory.

(b) (ii) The composite circuit is highly capacitative, and, therefore, as in the case of submarine cable, double current working would be preferable.

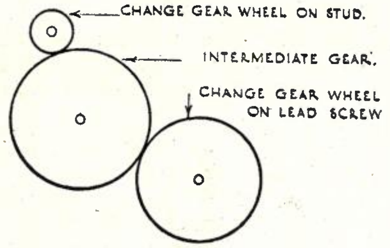
EXAMINATION No. 2559.—TECHNICIAN—ENGINEERING WORKSHOPS—MACHINE SECTION

G. W. Smith

Q. 1.—(a) Explain, with the aid of simple sketches, the difference between simple and compound lathe gearing.

(b) Calculate the screw thread which would be cut by a lathe, having a lead screw of 4 threads per inch, with an 84-tooth gear on the lead screw and a 24-tooth gear on the stud.

A.—(a) When a screw thread is being cut in a lathe, the main spindle, on which the work rotates, and the lead screw, which moves the cutting tool, are connected together through a train of gears. The arrangement of gear wheels shown in Fig. 1 forms a simple gear train.



Q. 1, Fig. 1.

For example, if it is required to cut a screw thread, having 12 threads per inch, on a lathe with a lead screw of 4 threads per inch, the work must revolve three times for every revolution of the lead screw. Two change gears (one of which has three times as many teeth as the other) are therefore selected, the large gear being placed on the lead screw, and the small gear on the spindle stud. The intermediate gear may have any convenient number of teeth, as required to mesh with the change gears.

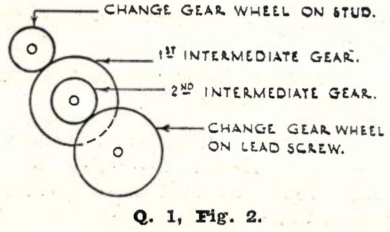
In compound gearing, two gear wheels, having a definite reduction ratio one to the other, and keyed together on an intermediate stud, are interposed in the train between the change gears on the spindle stud and the lead screw, in order to either increase or decrease the relative motion between the work and the lead screw. Compound gearing is used when the set of change gears provided with the lathe does not include the gears necessary to cut the desired thread with a simple gear train. Fig. 2 shows the arrangement of a compound train.

(b) Assuming the lathe is geared 1 to 1, then—

$$\frac{\text{Threads/inch of lead screw}}{\text{Threads/inch cut}} = \frac{\text{Teeth on stud gear}}{\text{Teeth on lead-screw gear}}$$

$$\therefore \frac{4}{\text{Threads/inch cut}} = \frac{24}{84}$$

The thread cut will have 14 T.P.I.



Q. 1, Fig. 2.

Q. 2.—Give a brief description of the various types of lathes with which you are familiar, and mention the class of work for which each class of lathe is particularly adapted.

A. — The engine lathe is used for miscellaneous classes of work, such as turning, facing, boring, thread cutting, etc., particularly when only one, or a small number of duplicate parts are required. The main features are the bed, carriage, headstock, tailstock, thread cutting mechanism, and feeding mechanism.

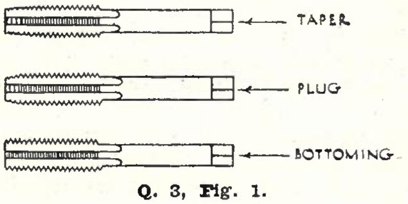
The turret lathe is used in preference to the engine lathe, when the number of duplicate parts required is large enough to warrant making the necessary adjustments, and equipping the turret with whatever standard or special tools may be needed. On this type of lathe, the tailstock of the engine lathe is replaced by a turret, which is so arranged that tools may be brought into the working position by indexing or rotating the turret. In many instances it is also necessary to use other tools held in a cross slide for the initial shaping of the work, cutting off the finished part, knurling, etc.

If the number of duplicate parts is very large, an automatic lathe may be used in preference to a hand-operated turret lathe. The automatic lathe is usually provided with special mechanisms for automatically locating successive tools in the correct working position, the automatic changing of feeds and speeds to secure economical operation, and automatic feeding of stock to the tools for a repeated series of machining operations.

Q. 3.—What do you understand by the terms: (a) tapping, (b) counterboring, (c) centre drilling? Describe, with the aid of sketches, the tools used for each operation.

A.—(a) Tapping is the operation of cutting an internal thread in a hole, either by hand or power machine. A tap is a cylindrical bar of steel with threads formed around it, and grooves or flutes running lengthwise in it, intersecting with the threads to form cutting edges.

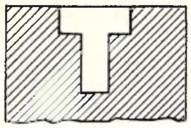
The tools used for hand work are usually made in sets of three, as shown in Fig. 1.



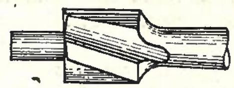
Q. 3, Fig. 1.

It is common practice to turn the taper tap clear through the work, but for deep holes the taper and plug taps are frequently used alternately to relieve the long cut made by the taper tap. The taper and plug taps are followed by the bottoming tap when a full thread is required to the bottom of a blind hole.

(b) Counterboring is the operation of machining a larger hole on the same centre line as a hole previously drilled, as in Fig. 2. The tool used is shown in Fig. 3, and is known as a counterbore.

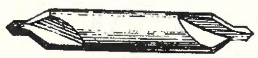


Q. 3, Fig. 2.



Q. 3, Fig. 3.

(c) Centre drilling is the operation of forming centre holes in the ends of parts which have to be machined whilst held between lathe centres. It is usually performed with a combination drill and countersink (Fig. 4), sharpened to the correct angle of 60deg. The tool also drills a clearance hole for the ends of the lathe centres. This clearance hole provides an oil reservoir for lubrication purposes.



Q. 3, Fig. 4.

Q. 4.—(a) How would you check a $\frac{3}{8}$-in. Whitworth screw thread for accurate dimensions?

(b) State the included angles of the Whitworth and B.A. screw threads.

A.—(a) The dimensions of a $\frac{3}{8}$-in. Whitworth screw thread can be checked most accurately by gauging with a bench comparator, i.e., by comparing an enlarged shadow of the thread against a scaled chart, or by direct measurement of the shadow.

Alternatively, the various dimensions may be checked as follow:—

Pitch Diameter. With a screw thread micrometer, or by the three-wire method, using three wires having a suitable and equal diameter in conjunction with an outside micrometer.

Pitch. Use a steel rule or a screw pitch gauge to check the correct number of 16 threads per inch.

Included Angle. With a 55 deg. thread gauge tool, or an accurately cut screw pitch gauge.

Outside Diameter. With an outside micrometer.

(b) The included angle of the Whitworth thread is 55 deg. and that of a B.A. thread 47½ deg.

Q. 5.—Describe briefly the main parts and functions of a Vertical Spindle Drilling Machine, and the usual methods adopted for holding the drill.

A.—This machine is equipped with a variable speed drill spindle fitted in a vertical position, and may be used for individual or repetition drilling, tapping, reaming, countersinking, counterboring, or spot-facing operations.

The main features are a base or stand supporting a solid frame or pillar, on which are mounted a drill head and a work table. The head supports the vertical spindle and encloses the spindle driving and vertical feed mechanisms. Within definite limits, the work table is adjustable in height. A hand wheel or lever controls the vertical movement of the drill spindle, as an alternative to machine feed. In the sensitive type of machine, used for light and high-speed work, the drill spindle is fed towards the work by means of a hand-operated lever.

There are three general methods adopted for holding drills in the vertical spindle:

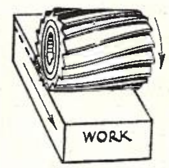
(1) By inserting the tapered drill shank directly into a tapered hole in the spindle.

(2) Inserting the drill shank in a socket or sleeve which is held by the drill spindle.

(3) By using some form of adjustable self-centreing drill chuck.

Q. 6.—Sketch and name four types of milling cutters in common use. Describe the class of work on which each may be used.

A.—(1) The slab milling cutter, Fig. 1, with cutting teeth only on the cylindrical surface, is used for milling plane surfaces parallel to the axis of rotation.

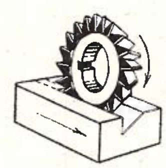


Q. 6, Fig. 1.

(2) The end mill, Fig. 2, with end cutting teeth as well as cutting teeth along the cylindrical body, is mainly used for milling surfaces at right angles to the axis of rotation.

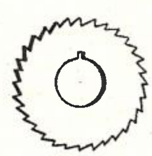
Q. 6, Fig. 2.

(3) The single angle cutter, Fig. 3, is used for cutting surfaces at an angle to the axis of rotation of the cutter.



Q. 6, Fig. 3.

(4) The slitting saw, Fig. 4, is used for cutting thin slots, or for cutting off sections of metal as required.



Q. 6, Fig. 4.

Q. 7.—(a) What are the essential differences between carbon steel, high speed, and carbide tipped lathe tools?

(b) How would you harden and temper carbon steel tools for brass turning?

A.—(a) Carbon steel lathe tools, usually forged in one piece from high carbon tool steel, are subject to definite cutting speed and feed limits, since the hardness of the cutting edges is drawn at comparatively low temperatures.

High speed steel tools are formed from high speed steel, containing alloying elements, such as tungsten, nickel, chromium, etc., in addition to carbon and iron. These tools retain their hardness at temperatures considerably in excess of those which readily soften tools made from carbon steel. They may be used at speeds, feeds, and cuts which raise their cutting ends to a red heat, without rapid deterioration of the cutting edges.

Carbide tipped tools consist of a cutting tip cast from various non-ferrous alloys, fitted and firmly held in a steel tool holder, or welded to a steel shank. These tools are especially adapted for machining materials which would quickly dull steel tools by their abrasive action, and for higher cutting speeds than can be used with high speed steel tools.

(b) Heat the cutting end of the tool to a cherry red, and quench the part to be hardened and tempered in water or oil. Clean the cooled part of the tool, and watch the flow of colours as the heat remaining in the body of the tool warms up the hardened cutting end. When the tip becomes a light straw colour, quench the entire tool.

Q. 8.—(a) Describe in some detail three methods of producing tapers on a lathe.

(b) How far should the tailstock be set over to turn a taper, 6 in. in length, on one end of a 14 in. shaft? The small and large diameters of the taper are to be $1\frac{9}{16}$ in. and $1\frac{3}{4}$ in. respectively.

A.—(a) Tapers may be produced in a lathe by:

(1) Offsetting the tailstock.

(2) Using a taper attachment.

(3) Setting the tool slide at the required angle and feeding the tool by hand.

When both headstock and tailstock centres are in line, the movement of the carriage and cutting tool is parallel to the axis of the work, and a cylindrical surface is produced. If the tailstock is set out of alignment, a taper is produced, since the movement of the cutting tool is at an angle to the axis of the work. If the taper extends along the entire length of the part to be turned, the tailstock is offset from its central position by an amount equal to one-half the difference between the large and small end diameters.

When using a taper attachment, the tail stock centre remains in a central position as for cylindrical turning. The function of the taper attachment is to move the cross slide and cutting tool across the lathe bed whilst the carriage moves parallel to the axis of the work. The rate or extent of the lateral movement of the cross slide for a given lengthwise movement of the carriage determines the amount of taper.

For relatively short and abrupt tapers, the carriage is clamped to the bed, whilst the tool slide is swivelled and clamped at the required angle to the axis of the work. The tool slide is operated by hand at an angle across the work, which may or may not be supported between the lathe centres. If supported between centres, these should be set in line.

In all cases, it is most important that the cutting edge of the tool be at the same height as the centre or axis of the work.

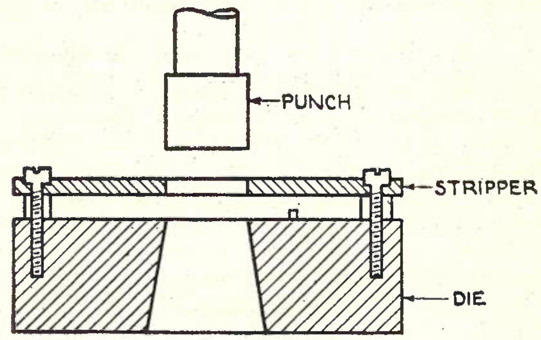
$$\text{(b) Offset} = \frac{\text{Length of shaft}}{\text{Length of taper}} \times \frac{\text{Large Diameter} - \text{Small Diameter}}{2}$$

$$= \frac{14}{6} \times \frac{1\frac{3}{4} - 1\frac{9}{16}}{2} = \frac{7''}{32}$$

Q. 9.—(a) Sketch and name three types of punch and die used in press work.

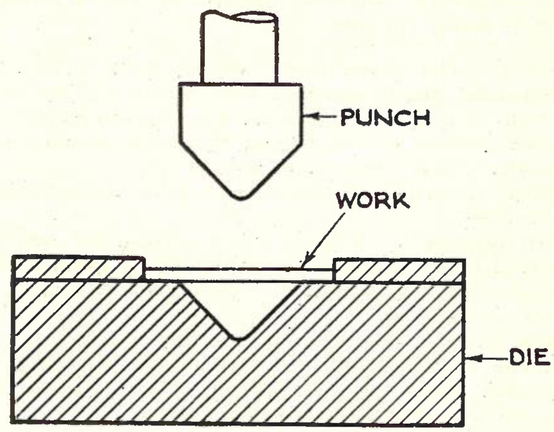
(b) How would you arrive at the correct allowance for clearance between a punch and die for a blanking operation?

A.—(a) **Blanking Die.**



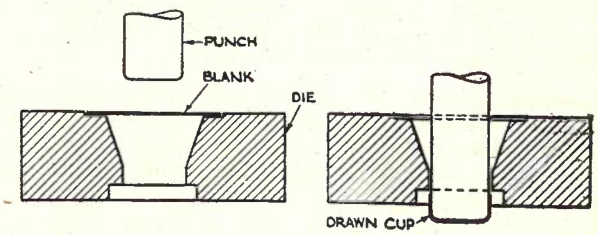
Q. 9, Fig. 1.

Bending Die.



Q. 9, Fig. 2.

Drawing Die.



Q. 9, Fig. 3.

(b) As a general rule, make the size of the punch less than the size of the die by an amount between 5 and 8 per cent. of the thickness of the stock to be blanked. The allowance will vary according to the thickness and the type of metal being worked.

Q. 10.—Under what circumstances would you use soft iron and steel in magnetic circuits? State your reasons.

A.—Soft iron is used for the cores of electromagnets, transformers, relays, etc., since it possesses (a) high permeability or relative magnetic conductivity, and (b) low coercive force or retentivity of magnetism. For efficient operation, it is essential that changes in the magnetising current shall quickly produce corresponding changes in the magnetic flux density in the core. Steel is used in the manufacture of permanent magnets for telephone receivers, magneto generators, bells, etc., on account of its high cœrcivity, or ability to retain magnetism when in the hardened condition.

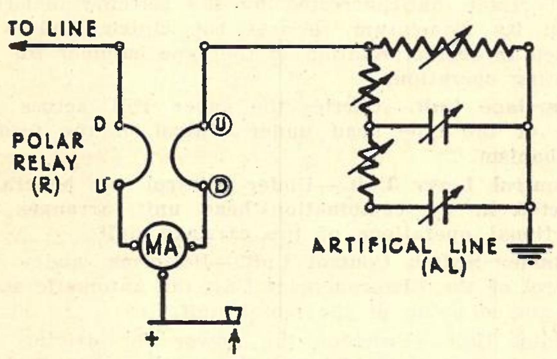
EXAMINATION No. 2490.—TECHNICIAN—TELEGRAPH

A. R. Glendinning

Q. 1.—Why are "timing" resistances provided in a telegraph artificial line box? Draw a circuit in which an artificial line is used and explain the functioning of the circuit.

A.—On physical telegraph lines, where simultaneous two-way working is possible by means of differentially wound relays, it is necessary to have equal electrical conditions set up in both windings to maintain balance, i.e., to prevent the transmitted signal from distorting the received signal. The electrical conditions of the circuit to which the line winding of the relay is subject are simulated in the other relay winding by connecting it to earth through the artificial line. This unit is usually contained in one box, and contains elements which provide the main characteristics of a physical line: resistance, capacity, and a timing element. It has been established that about 2-3rds of the line capacity discharges back through the sending end relay. Thus the total capacity used is 2-3rds of the total line capacity. To keep this charge and discharge in phase with that of the line circuit, it is necessary to time these operations in the artificial line. It is found that 0.4227 of the total line resistance is required for this purpose. As these line characteristics are not lumped in the external circuit, the capacity and timing resistance values are divided into sections depending on the type of circuit and the capacity thereof. The conductor resistance of the line is matched by means of an adjustable resistance in the artificial line box. The capacity and timing resistances are shunted across that resistance.

In Fig. 1, a schematic of a duplex set is shown.



Q. 1, Fig. 1.

Note.—D and U in circles are shown as D′ and U′ in text.

This set consists essentially of a polarised relay R, an artificial line AL, a key for reversing the battery for signalling, and a milliameter MA. This set would be working into a similar set at the distant end. The set is balanced by operating the home key and adjusting the resistance in the artificial line until the home relay tongue is unaffected by the current reversals at the home station. This can be observed visually on the milliameter, the needle of which should remain steady when balance is obtained. Now, with the distant and home keys normal, positive battery is applied to line at both ends, and no current will flow in the line winding U D of relay R. But current flows from battery through the other relay coil from D′ to U′, and the artificial line to earth. This current holds the relay tongue to space. Should the home key be closed and negative battery be applied to the split of the relay, current flows from line to battery and earth, passing through the line relay coil from D to U. This current will be double that flowing from earth through AL and relay coil in direction U′ to D′. This lesser current tends to drive the tongue to mark, but is overwhelmed by the heavier line current, which is in the spacing direction. The sending end relay remains unoperated. Should the distant station close his key, there will now be no current in the line, and the U′ D′ coil takes control, and the home relay changes to mark. Now, if the home key changes over to spacing, the positive current from D′ to U′ of the home relay, which tends to space, is overborne by the heavier current now flowing in the line winding from U to D, and the relay remains on mark as long as the distant key remains closed.

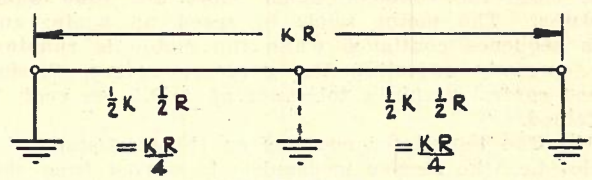
Q. 2.—What are the effects upon the speed of telegraph signals over a line with a large increase of (a) resistance, (b) capacity. How are these conditions overcome?

A.—The speed of telegraph signals over a line is a function of the capacity and resistance of that line. This KR or "time constant" of the circuit is a product of the capacity and resistance in farads and ohms respectively. The formula which has been derived for signalling speed on physical lines is:

Telegraph signalling speed in w.p.m. $= \frac{a}{KR}$, in which "a" is a constant that differs for each type of wire used.

It is seen that large values of one or both of the quantities K and R have detrimental effects on the working speed.

High resistance alone might be offset by increasing the applied voltage to provide the required working current, but this is limited in application by the danger of high voltages to equipment and personnel, and the severe inductive action set up in neighbouring circuits. High capacity increases the time required for the line to charge and discharge on application of battery to the line. The use of double current working will improve the signalling speed in this and the high resistance case. In the high capacity circuit the reversals of current tend to assist the charge and discharge of the line. In the high resistance case the relay depends for its operation on reversals of current, and not so much on current strength, and is thus more sensitive to smaller currents.



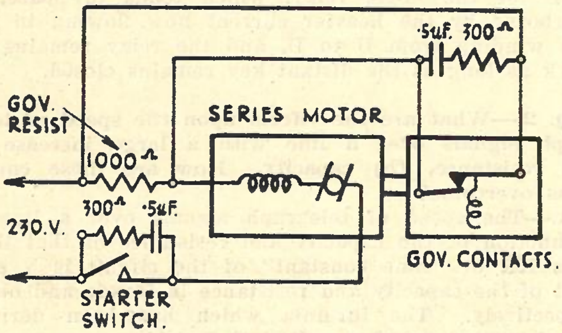
Q. 2, Fig. 1.

The most effective way of increasing signalling speed, however, is to divide the line and instal a repeater, Fig. 1 shows the effect on the KR of dividing the circuit. If the KR of the whole circuit be represented as 1, then the comparative value of each half is $\frac{KR}{4}$.

Owing to limitations of electro-mechanical repeaters due to the inertia of moving parts, the theoretical speed over one of the divided sections is never achieved over the circuit as a whole.

Q. 3.—Explain with the aid of a diagram how the speed of a teleprinter is maintained at a constant rate. Why is it necessary for the speeds of two units working together to be approximately equal?

A.—(a) The circuit shown in Figure 1 gives the arrangement for series motor governing and a somewhat similar circuit may be used for shunt motor governing. In the teleprinter the governor is mounted directly on the motor shaft and the electrical connections to it are made through slip rings.



Q. 3, Fig. 1.

The motor is connected to the power mains in series with a 1000 ohms resistor, across which are connected the governor contacts. The normal speed of the motor is 3000 r.p.m., and at rest, due to the tension of the governor spring, the governor contacts are making. This short on the resistor under the control of the spring permits the motor to attain its normal speed as quickly as possible after being switched on. When the motor speed reaches 3000 r.p.m. or a little above this figure, the centrifugal force developed on the movable governor contact arm overcomes the tension of the governor spring and the contacts open. This action removes the short from the resistor, which is then in series with the motor, and the torque is reduced, with a consequent reduction in speed. The governor contacts remain open until the speed falls sufficiently for the governor spring to resume control and close the contacts which short the 1000 ohms resistor. The motor tends to speed up again, and this sequence continues while the motor is running. By correctly adjusting the governor spring, tension speed control within a tolerance of ± 0.5 per cent. is obtained.

(b) The teleprinter operates on the start-stop principle; i.e., the receive mechanism is started from rest for each group of received code signals, and it is necessary that the receive cam of the receiving teleprinter and the transmitting cam of the sending teleprinter rotate approximately in synchronism for one revolution each time the receiving cam has been released by the reception of the start signal. The teleprinter electromagnet is controlled from the sending teleprinter. Thus, it is necessary to maintain the speed of the two teleprinter motors within about 1 per cent. of normal in order that the vertical movements imparted to the striker blade under the control of the electromagnet will bear their correct relation to the horizontal movements of the striker blade. These horizontal movements are controlled from the relative cam track on the receiving cam sleeve, which is driven through gearing from the main motor shaft of the receiving teleprinter. Should the receive cam gain on the transmitting cam due to speed differences, wrong translation will occur and probably letter R would, for example, be received as letter G.

If the receive cam runs more slowly than the transmitting cam, similar wrong translations would result. This latter, of course, is the condition when transmission takes place in the opposite direction to that described in the preceding paragraph.

Q. 4.—Name the main components of a teleprinter and explain in general terms the functions of the component units.

A.—The main components of a teleprinter unit and their functions are as follow:—

Keyboard Unit.—Converts letters selected on the keyboard into trains of code impulses and transmits these to line.

Electromagnetic Unit.—Receives the impulses from the line and transfers them to the Receiving Cam Unit.

Receiving Cam Unit.—Translates the received signals into mechanical motions to set up the Combination Head Unit and performs in correct sequence the mechanical operations necessary for printing the character, feeding the carriage, the paper roll, and the ribbon.

Combination Head Unit.—Selects the bellcranks corresponding to the letter to be printed or the function to be performed.

Type Head Unit.—This is the unit in which the type is carried. It is rotated under the control of the type head clutch until arrested by the selected bellcrank when its momentum releases the clutch, and it is locked in correct relation to the type hammer for the printing operation.

Carriage Unit.—Carries the paper roll across the face of the type head under control of the feeding mechanism.

Control Lever Unit.—Under control of bellcranks selected in the combination head unit, arranges the functional operations of the carriage unit.

Starter Switch Control Unit.—Performs under the control of the Electromagnet Unit the automatic starting and stopping of the motor unit.

Motor Unit.—Provides the power for driving the main shaft, from which all the motions are derived. The governor is mounted directly on the motor shaft, and the operation of its contacts under centrifugal force maintains the speed of the motor within the desired limits.

Answer Back Unit.—Provides an automatic signal to the calling teleprinter which indicates that the called teleprinter is switched on and ready for reception.

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