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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

The

Telecommunication Journal of Australia

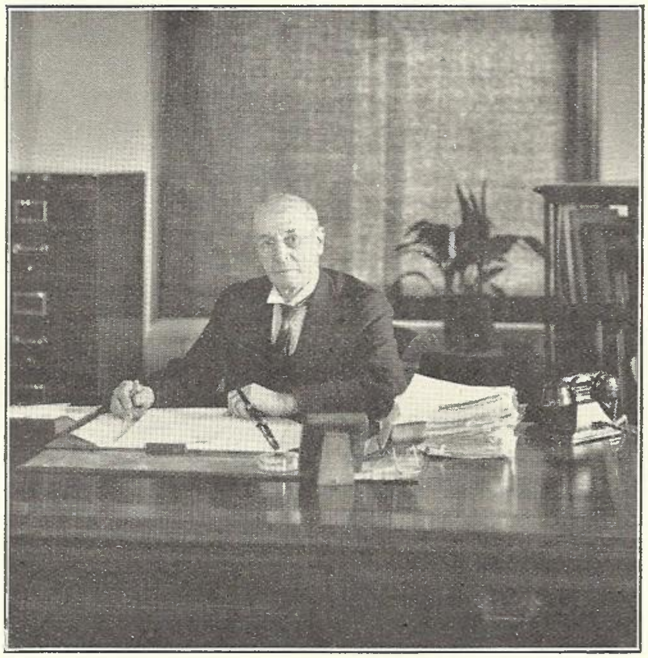
No. 3. *JUNE, 1936*

JOHN MURRAY CRAWFORD

IT is with regret that we say farewell to Mr. J. M. Crawford, our Chief Engineer for the last twelve years. During that time the world has passed through a period of economic stress which, in its reaction on the Engineering Branch, created difficulties and problems which were without precedent. A leader with the courage and the vision to use such a time for building up rather than for breaking down was almost unique, but in "J.M.C.," as he was so universally known, we were fortunate to have had such a Chief. An undaunted believer in the recuperative powers of Australia, he held together his whole organisation and set out to commence development works at the first sign of returning prosperity, with the result that to-day the Department is able to meet a very heavy demand for new services.

His ability to look beyond the present pressing problems to the needs of the future, his unwavering courage in the control of the Engineering Branch, and his scrupulous fairness, will always remain in our memories as his outstanding characteristics. By the force of his personal example he has created a feeling of mutual respect and goodwill in the Engineering Branch, and has earned the personal esteem and loyalty of all who worked under him.

After being educated at Queen's School, Liverpool, Mr. Crawford was employed in the British Post Office for some 20 years; in 1912 he was selected, after a personal interview by the late Mr. J. Hesketh—who was then Chief Electrical Engineer—as his assistant. Later, he occupied the positions of Superintending Engineer in Victoria and in New South Wales, and was appointed Chief Engineer in 1924.



Courtesy of Inst. of Engineers (Aust.)

John Murray Crawford, M.B.E., M.I.E.E., M.I.E. (Aust.)

There have been many outstanding developments during those years of service. The present methods of recruitment and training of Engineers, Mechanics, and Linemen are largely the results of his activities. Mr. Crawford has been intensely interested in the Improvements Board and has been the Chairman since its inception. He has also been particularly interested in the establishment of Postal Institutes in the various capital cities. As Chief Engineer he has been responsible for introducing many major engineering works.

In 1932 Mr. Crawford attended the Paris Electrical Congress, and later in the same year he was delegate for Australia at the Telegraph, Telephone and Radio Conference in Madrid.

Outside his Departmental activities, J.M.C. was keenly interested in the affairs of his profession. Before he came to Australia, he was secretary of the British Post Office Engineers' Society, and later secretary of the Institution of Post Office Engineers, London, and a member of the editorial staff of that Institute's journal. At present he is a member of the Institution of Electrical Engineers, London. In the Institution of Engineers, Australia, Mr. Crawford has served as chairman of the Victorian Division, has been for many years a member of the Council, in 1935 was elected vice-president, and is now senior vice-president. He is also a member of the Council of the Standards Association of Australia.

Mr. Crawford received the Silver Jubilee Medal, and in 1935 was honoured with the membership of the Order of the British Empire. We are honoured that he should have accepted an honorary life membership of our Society.

DEVELOPMENTS IN BROADCASTING AERIALS

A. J. McKenzie, B.E.E.

THE technique of radio broadcasting has developed with amazing rapidity within the last decade or so, and it is natural that the developments in the various sections of the technique, like those in other engineering activities, have not occurred with equal rapidity, sometimes one section and sometimes another being in the ascendency. Thus it has come about that under existing conditions of practice the faithfulness of reproduction generally suffers to a much smaller extent in transmitters than in receivers, the former being more satisfactorily developed from this standpoint than the latter. In the same way it may be stated that the technique of broadcast transmission, the generation and modulation of radio frequency energy, although undoubtedly in a state of considerable flux, is more nearly standardised and has reached a more satisfactory position than that of radiation. In recent years, however, more attention has been paid to the question of broadcasting aerial design, and at the present time large sums of money are being spent by broadcasting administrations in various parts of the world in attempts to develop radiators more closely approaching the ideal. The most noteworthy example of this expenditure occurs in the 1,000-foot mast erected for the Hungarian broadcasting administration. At the other extreme there are the simpler and earlier types of aerial employing a wire cage supported from one or two masts of height 150 or 200 feet. Existing broadcasting aerial practice may indeed be said to be characterised primarily by variety, while the amount of published experimental data on the existing types is not great.

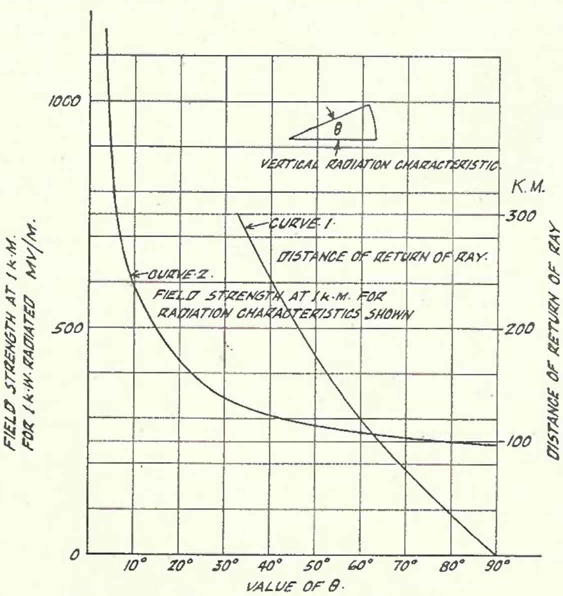


Fig. 1.—Influence of Angle at Radiation.

Before considering any of the developments in the aerial field, it is desirable to recapitulate the main objects in broadcasting aerial design. Obviously the primary consideration, although perhaps not that of primary importance, is the provision at the receiving locations of as large a field strength as possible, for a given power input to the aerial. This consideration may be attained by attention to two points: firstly, the reduction of heating losses in the radiation process, and secondly, the concentration of the radiated energy in useful directions, namely, those inclined at small angles to the horizontal. The second consideration, and in some respects the more important one, is the reduction of fading during the hours of darkness at some distance from the aerial, and the consequent increase of the fading free service area. The cause of fading is well known, its existence being due to interference between the field directly radiated in a horizontal direction, and the indirect field radiated at high angles to the horizontal, and reflected to earth from the ionised region existing at some distance above the surface of the earth. The two waves add vectorially, the resultant varying in magnitude fairly rapidly, owing to variation in phase of the indirect wave consequent upon slight variations in the path length, caused by fluctuation in the state of the ionised region. It will be appreciated that fading is worst at such a distance that the magnitudes of the direct and indirect fields are equal, the magnitude of the resultant field then varying from zero to twice the daylight field. At shorter distances the fading is either negligible or of smaller magnitude, while at longer distances the fading again becomes less severe, although at great distances fading still occurs due to fluctuations in actions of the ionosphere. It is obvious, too, that a reduction in the magnitude of high angle radiation from an aerial will effect an increase in the fading free service area.

The existing fading and indirect ray propagation phenomena are ascribed to the existence of two ionised regions, the "E" or Kennelly-Heaviside region at a height of approximately 100 kM, and the "F" or Appleton region at a height of approximately 250 kM. At broadcast frequencies the bulk of the reflected field is ascribed to the presence of the "E" region. This fact enables us to determine, from the simple geometry of the case, the angle of upward radiation, of a ray returning to earth at a given distance, it being assumed that the ray returns by a simple reflection and that the reflection occurs from a horizontal portion of the region, the assumption applying to average conditions. Figure 1, Curve 1, shows the relation between upward radiation angle and distance from the station at which the ray returns to earth.

Assuming that the worst fading occurs at about 100kM from the station, the field radiated at angles in the vicinity of 65 degrees to the horizontal is seen to be the worst offender,

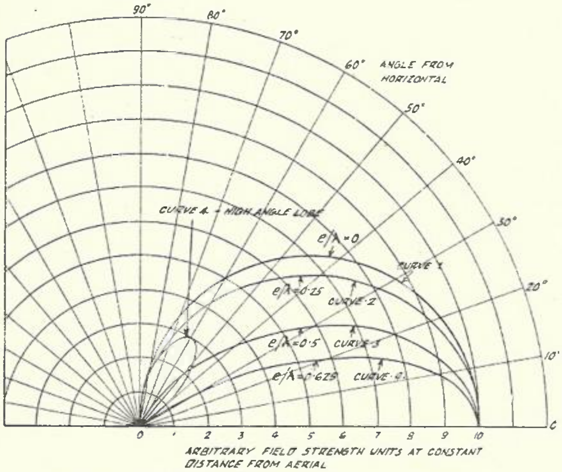


Fig. 2.—Vertical Radiation Characteristics of Vertical Aerials.

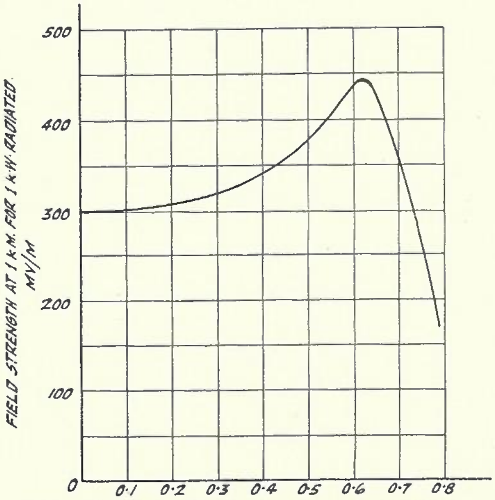
and its reduction by the use of a suitable aerial most desirable. The importance of concentration of radiation of energy at low angles is demonstrated by Figure 1, Curve 2 [1], which shows a curve of the field strength on the ground at 1 kM for 1 kilowatt input against an angle θ for an arbitrary shape of vertical radiation characteristic in which the radiation is constant for any angle from the horizontal below the angle θ, and is zero for higher angles. The vertical polar curve or radiation characteristic of field strength is as shown in the inset. For a low vertical or T aerial, the polar curve of field strength in the vertical plane follows the cosine of the angle from the horizontal as shown in Curve 1 of Figure 2. The field strength at 1 kM for 1 kW radiated from an aerial having such a vertical polar diagram is 300 mV per metre. It will be seen from Figure 1 that if the radiated energy could be concentrated below an angle of 9 degrees from the horizontal the field strength would be twice this value. Thus the improvement effected by replacing a low vertical aerial by such an aerial, neglecting losses in each case, is equivalent to increasing the value of power supplied to the vertical aerial in the ratio of four to one, since the radiated power is proportional to the square of the radiated field intensity.

The concentration of the radiation at such a low angle on broadcasting frequencies has not so far been economically possible, and has been effected only to a limited degree. Stuart Ballantine showed in 1924 [2] that considerable concentration may be effected in the vertical plane by employing an aerial consisting of a straight vertical conductor of height of the order of half a wavelength. He assumed the current distribution in such a conductor to be sinusoidal, that is, zero at the free end and increasing to a maximum value at a point some distance along the conductor. This current distribution is the result of a sinusoidal excitation at the base, producing a wave travelling along the conductor with a velocity approaching that of light. A reflection at the free end produces a standing wave of current and voltage whose length is equal to the velocity of propagation divided by the frequency. The velocity of propagation is in practice about 5 per cent. less than that of light. If we neglect radiation and losses, the current distribution is definitely sinusoidal, but in practice the current does not reach zero at a point half a wavelength from the free end, but changes sign by means of a phase rotation. For calculations of vertical radiation characteristics not much error is introduced by assuming sinusoidal current distribution, and velocity of propagation equal to that of light. Figure 2 shows the vertical polar diagrams for vertical conductors of very small height, of heights 0.5 wavelength and 0.625 wavelength. It will be seen that the vertical radiation characteristic becomes more concentrated at low horizontal angles as the height is increased to one-half a wavelength, above which a high angle lobe of radiation becomes apparent. The field strength on the ground at 1 kilometre from the aerial for 1 kW radiated is plotted in Figure 3 against the height of the vertical aerial expressed as a fraction of a wavelength. It will be seen that the optimum height from the point of view of saving in power is 0.625 of a wavelength, and at this height the field strength is increased by 48 per cent. over that from a low vertical aerial, equivalent to an increase in power input of 120 per cent. Owing to the existence of the high angle lobe in the vertical radiation characteristic for heights above half a wavelength, the optimum height for power saving is not necessarily that for optimum fading reduction. Where the terrain in the service area is of low conductivity and the fading ring is therefore nearer the aerial, the fading is due to radiation at higher angles, and so the lobe should be reduced as far as possible, and the optimum height for fading reduction is reduced to a figure slightly above half a wavelength, whereas for very good terrain the optimum height for fading reduction approaches that for power saving. Ballantine also has given the radiation resistance of a vertical wire of any height, that is, the input resistance of the aerial neglecting losses. The radiation resistance of a vertical wire is greatest when its length is about 0.5 of a wavelength. A high radiation resistance is an advantage since the ratio of power radiated to power loss is

(1) Brown, P.I.R.E., Jan., 1936. (2) P.I.R.E., Dec., 1924.

equal to the ratio of radiation resistance to loss resistance, and a considerable portion of the latter remains reasonably constant. It will be seen that from the point of view of obtaining a high radiation resistance, a high vertical aerial is also desirable.

It will be seen from Figure 2 that the concentration of radiation in the vertical plane at low angles is very small for vertical aerials of height less than one-quarter of a wavelength, so that we may say that for such aerials the vertical polar diagram approximates to the semi-circular



Height of Vertical Aerial Wavelengths.
Fig. 3.—Horizontal Radiation—Vertical Aerial.

form shown in Curve 1, of Figure 2. It may be shown theoretically that the polar diagram for a low T or L aerial of height less than one-quarter wavelength is of the same form, if we neglect radiation from the horizontal portion. Actually some radiation will ocur from this portion, and it is probably greatest at high angles. The vertical polar diagram of a multiple tuned aerial is, neglecting radiation from the horizontal, of the same form, and the radiation from the horizontal portion would probably be slightly greater than that from a T aerial, and less than that from an L aerial. It will be appreciated that theoretically the low aerials are comparatively poor from the point of view of fading and that considerable heights are necessary to obtain much improvement in this connection. Height in such aerials is, however, an important factor in keeping the radiation resistance high, the radiation resistance for heights much less than a quarter wavelength being proportional to the ratio of height to wavelength.

The question of the efficiency rating of an aerial is of considerable importance. The ratio of power radiated to power input is an unsatisfactory rating, firstly because in order to evaluate its magnitude it is necessary to know the vertical polar diagram, necessitating the use of an aeroplane, or else the making of doubtful assumptions, and secondly, because it is not a true measure of the effectiveness of an aerial, since it takes no account of concentration of radiation in the required direction. Actually we are interested primarily in the field strength on the ground. The aerial efficiency is sometimes calculated from ground field strength measurements, assuming the vertical polar diagram to be semi-circular as shown in Curve 1 of Figure 2. In such a case the radiated power is equal to $\frac{E^2d^2}{90}$ watts, where E mV/m is the field strength at a distance d kM from the aerial, and the efficiency is obtained by dividing the above by the power input. The figure so obtained undoubtedly gives a satisfactory relative measure of the aerial's effectiveness from the point of view of horizontal radiation, but has the disadvantage that there is an apparent incongruity in that results higher than 100 per cent. are obtained, when there is considerable concentration in the vertical plane. Perhaps the most satisfactory method of rating is to express a "figure of merit" as the field strength at 1 kM from the aerial at 1 kW input. It is of interest to note here that the theoretical figure for an aerial having no losses, and a semi-circular vertical polar diagram is 300, while that for the optimum vertical aerial of height 0.625 wavelength is 444.

Although Stuart Ballantine had pointed out in 1924 the advantages accruing from the use of a high vertical radiator, some years elapsed before such a radiator was actually constructed for the broadcasting frequencies. The reason for the delay was, of course, primarily economic, since the height of a half-wave radiator is about 1,000 feet for use on 550 kC and about 300 feet on 1,500 kC. The type of radiator developed in America by the Blaw Knox Coy. is a development of the Stuart Ballantine theory and consists of a square lattice steel tower insulated at the base, and guyed at about the middle point, by means of four guys sectionalised into insulated sections. For structural reasons, the tower is made of non-constant cross section, being of largest section at the guying point. This type is usually provided with a section at the top which can be slid vertically from the inside of the mast, providing an adjustment of the height for operation on different frequencies. The mast is guyed, it will be noted, at only one point along its length, the point chosen being near the voltage node, so that the voltage on the insulators is comparatively small. In addition, it is possible that the stray radiation from induced currents in the guys is minimised by this procedure. It has recently been shown by Brown ([3]), who used models on frequencies of the order of 10 megacycles per second, that the current distribu-

(3) P.I.R.E., April, 1935.

tion along this type of mast, owing to the variation in its cross section, departs considerably from the sinusoidal form. The conclusions of Ballantine are based on the assumption that the current distribution is sinusoidal, and while the departure is not necessarily detrimental, yet in

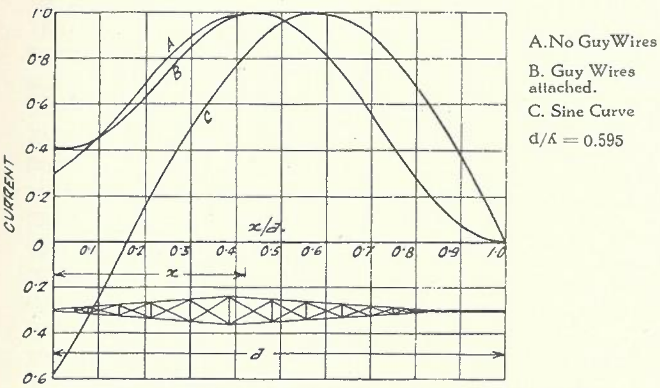


Fig. 4.—Current Distribution—Blaw-Knox Mast.

some cases it is definitely so. Figure 4 shows the measured current distribution on a model of a Blaw-Knox mast employed at Station WCAU, Philadelphia, together with the current distribution on a vertical wire of the same height. It will be seen that for sinusoidal distribution a current node exists some distance above the ground, and that in the measured distribution no current node exists on the mast at all. The polar diagrams calculated by Brown for the measured current distribution, and for the sinusoidal distribution are shown in rectangular co-ordinates, in Figure 5, together with measured points taken by means of an aeroplane. The radiation characteristic for a vertical wire of height only 75 per cent. of the height of this mast is seen to be approximately the same. It will be seen that in this particular case the non-uniformity of cross section has a definitely deleterious effect. For this reason the Blaw Knox Company have developed a mast having constant cross section and guyed only at the one point near the voltage node.

Another aerial of particular interest is that erected by Philips at Hilversum, in Holland. It is a slightly tapered steel mast of triangular cross section, the cross section being greatest at the base, is guyed at four points along its length and is provided with an adjustable top section as in the case of the Blaw Knox masts. Its height is 460 feet, 0.47 of the operating wavelength. It is stated that a current node exists at 20 metres above the base, so that the wavelength of the standing wave existing on the mast must be considerably less than that in free space. The reason for this is not clear, but it is possible that the effect is due to loading produced by the presence of the guys, with consequent equivalent reduced velocity of propagation along the mast.

A type of aerial favoured by the German broadcasting authorities consists of a wooden lattice tower carrying a vertical copper wire, and surmounted by a light copper ring which acts as a self-capacity termination to the vertical wire. The effect of the ring is to produce a considerable amount of current at the top of the vertical wire with consequent saving in height for the same vertical polar diagram as obtained with a simple vertical wire. One of several aerials of this type is in operation at Breslau, its height being 460 feet, 0.43 of the operating wavelength. It is surmounted by a copper ring of cartwheel construction, having a diameter of 30 feet. The German authorities have employed other experimental forms of radiators, such as a wooden tower supporting a vertical dipole (or wire fed at the centre point), having its lower end some distance above ground and some modifications of this type. Still another type consists of a ring of low vertical aerials spaced approximately one-quarter of a wavelength from a central low vertical structure.

Another type employed initially by the British Broadcasting Corporation consists of a single guyed mast, from the top of which are suspended three wires terminating on short poles equi-spaced round the base of the mast and some distance out from it. These wires are fed by means of horizontal wires about ten feet above ground, brought to a point near the base of the mast and commoned there. The lengths of horizontals and upleads are so proportioned that a current node exists near the base of each uplead, and so that the distance from the current node to the feed point is slightly less than one-quarter of a wavelength. Aerials of this type are in operation in Australia at the Regional stations of the National Broadcasting System erected in North Tasmania (7NT), and Gippsland (3GI),

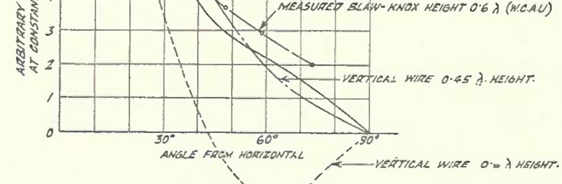


Fig. 5.—Vertical Radiation Characteristics.

and a third will be installed at the North Queensland Regional Station (4QN). They are often referred to as conical or umbrella radiators.

The Department has, of course, been interested in the question of broadcast radiator design for some time, but the question became one of major importance in 1933, when the construction programme for the National Broadcasting Service was recommenced. At that time brief details were available of two types of radiator which appeared to be improvements on those previously used, the so-called Blaw Knox and conical types referred to earlier. For the operating frequencies allocated to the broadcast stations concerned the former type was quite out of the question for economic reasons. The latter type was considered to be quite suitable for the three stations referred to in the previous paragraph, but not for others, the preliminary plans for which were then being prepared. As the whole question was so important and the available information so meagre, the electrical design and performance of radiators at broadcast frequencies was investigated theoretically, particularly from the viewpoint of conditions pertaining in Australia, especially for the National Broadcasting Service. Attention was focussed on the possibility of obtaining satisfactory current distribution in a vertical mast by using top capacity instead of going to the full optimum height necessitated by utilising the Blaw Knox structure. Theoretical conclusions were supplemented by practical tests on a scale model structure erected at the radio transmitting station of the Department's Research Laboratories. The model was operated at 10 m.c. and from these tests sufficient data was obtained to permit of a commencement being made on the development of full-sized radiators. After studying many possibilities the development took the form of a guyed steel structure surmounted by a horizontal steel top or "armature" of cartwheel form. A contract for the supply of a radiator of this type was entered into with Johns & Waygood, of Melbourne, for erection at the Northern Rivers' Regional Station (2NR), near Grafton, N.S.W. This radiator, which is about to be placed in service as this issue of the journal goes to print, is described in some detail in an accompanying article by Mr. R. A. Turner.

Electrically the Northern Rivers' radiator may be regarded as having a top (armature) fed through a loading inductance (tuning coil). The effect of the loading inductance in series with the armature is virtually to increase the capacity of the latter so that, as far as current distribution is concerned, the armature and coil combination acts as a termination equivalent to many feet of mast. The nett effect is a reduction in height necessary to produce a given shape of vertical polar diagram. Theoretically the polar diagram produced by a vertical mast of optimum anti-fading height (0.53 of a wavelength) can be very closely reproduced by a mast thus "loaded" of much less height, say, 0.3 of a wavelength. The reduction in height is, however, accompanied by a reduction in radiation resistance and this reduction, combined with the loss resistance in the loading coil, produces a loss of power, making it undesirable to carry the reduction too far. For this reason it is considered practically undesirable to reduce the height below 0.35 to 0.4 of a wavelength. The Northern Rivers' radiator is 500 feet high, that is, 0.36 of a wavelength, at the operating frequency of 700 kC. It is considered that, as far as anti-fading properties are concerned, the radiator should give a good performance, closely approaching that of a vertical mast of the optimum anti-fading height, namely, 750 feet, for a frequency of 700 kC. The radiation in the horizontal direction for a given power input will be not quite as great as that which could be obtained if the mast were designed for an optimum power efficiency height, but from the point of view of providing primary service coverage for the National Broadcasting Service the former factor is considered to be the more important.

Performance tests on the various types of radiator in use at broadcast stations of the National Broadcast Service have been made from time to time and, of course, are continually in progress. These tests cover field strength measurements from which the "figures of merit" of the various installations may be obtained, night fading measurements and tests from aeroplanes in flight in order to determine vertical polar diagrams. Details of the measuring technique and the results obtained are held over from publication in this issue, but it is intended that they be the subject of an article in the next issue of the Journal.

NORTHERN RIVERS REGIONAL STATION—GRAFTON, N.S.W. RADIATOR—SOME ASPECTS OF DESIGN, CONSTRUCTION AND ERECTION

R. A. Turner

THE electrical theory of radiator design is discussed by Mr. A. McKenzie in this issue of the "Telecommunication Journal." The following matter will give the reader some idea of the structure recently erected in the vicinity of Grafton, N.S.W., for the Northern Rivers Regional Station, which embodies the practice outlined in the aforementioned article. The station is situated near the township of Lawrence, overlooking the Clarence River. The radiator is now an outstanding feature of the landscape.

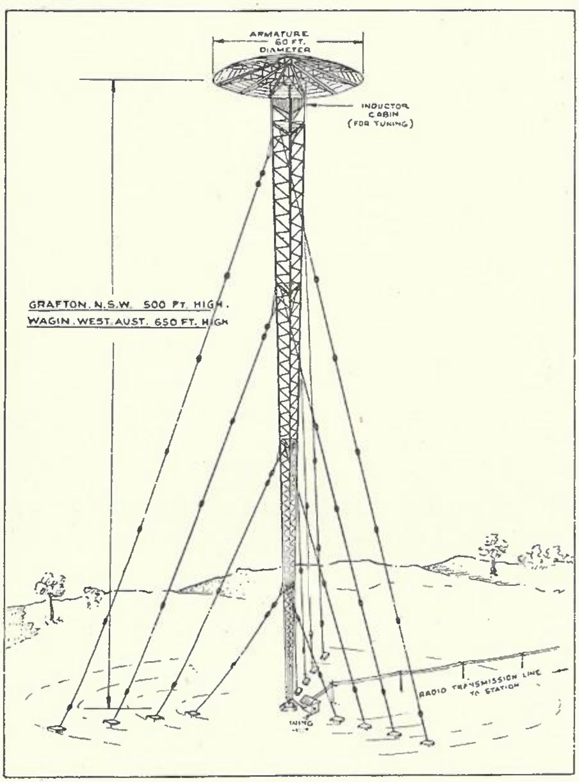
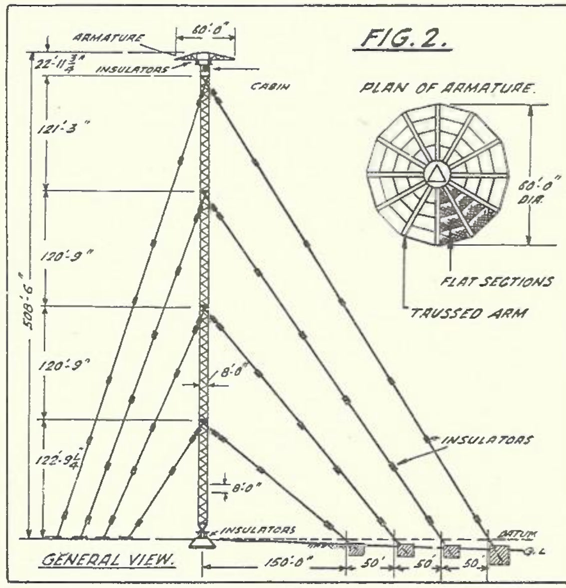


Fig. 1.

The performance of the Grafton Radiator is not within the scope of this description, which is concerned mainly with the structural design and erection.

The Grafton Radiator is of a type not previously constructed in Australia, the main feature being a mast insulated from ground and surmounted by an armature erected on insulators. The structure is in itself the radiator. The mast carries a stranded copper bond clamped to each leg and at intervals of 24 feet there is an encircling copper strap bonded to the vertical cables, the complete bonding carrying the R.F. current, which also passes through a tuning inductor housed in a cabin at the top of the mast. From the inductor the current leads out through an insulator and flows into the armature standing on insulators on top of the mast. It will thus be seen that the radiator is in two sections, coupled together by a tuning inductor. The inductor is fitted with a wiper arm, adjustment of which is made by means of a continuous steel cable extending down one of the mast legs. This permits the adjustment of the position of the current node, from any location throughout the height of the mast during the tuning period.



The mast illustrated in Fig. 1 is 500 feet high, triangular in section and is guyed at four heights in three directions. The structure stands on a group of insulators and the guys are sectionalised throughout their length with insulators. Mounted on top of the mast is the 60-foot diameter armature, supported by a group of stand-off insulators. The general dimensions of the structure are indicated in Fig. 2. The steelwork weighs approximately 50 tons.

The following brief description may indicate some of the problems of design and the main features of the structure:—

Design.

In structures, such as a radiator, where electrical considerations demand the combination of dielectrics and conductors with steel structural members to form the complete unit, great care has to be exercised in design and fabrication. Porcelain is the most satisfactory material available for insulating purposes, but whilst it gives good performance in compression—withstanding a pressure of 7 tons per square inch—its tensile strength is only about 1-7th of the compressive strength, the shear being much less.

In a mast the usual factors of safety for structural steelwork are scaled down, lightness of steel sections being essential to enable great heights to be reached with ordinary stock sizes of structural steel. It should be appreciated that where structural steelwork is combined with masonry, as in buildings, any large flexure of the steel will tend to crack or distort the masonry portion of the construction. In mast work, however, greater deflection of steelwork can be permitted, providing the yield point of the steel is not reached. A general factor of safety of three was used throughout for the steelwork and guy construction. With no external artificial forces, such as an aerial pull, operating on the radiator, only wind pressure and the weight of the structure need to be considered in the design. The horizontal wind pressure on which calculations were based is 20 lbs. per square foot at ground level, increasing by 1 lb. per square foot for each 100 feet of height; this being equivalent to a wind velocity varying from 82 to 91 miles per hour. The pressure was assumed to act on the full projected surface of the mast, normal to the direction of the wind. The armature was designed on the horizontal wind pressure previously indicated, as well as a vertical pressure of 5 lbs. per square foot on its projected area. During erection the armature has to support the weight of a man working in any position over its area, and the live load thereby imposed had to be taken into consideration in design. After the armature is completely assembled in position, the load imposed by a man is negligible compared with the normal stresses the armature has to withstand. An allowance for screening of wind pressure was made in the armature construction owing to the close fabrication of the members. With such a large diameter top, excessive deflection of the mast had to be guarded against, and this was limited to 1 per cent. of the height. Such deflection is calculated with the wind blowing between two sets of windward guys directly on a mast face. This necessitated close consideration of guy construction with their relative sags, since they in turn limit mast deflection. In considering the pulls in the guys, each windward guy was assumed to hold against the pressure of the wind, firstly, its section of the mast; secondly, the wind on the set of guys themselves; and thirdly, the pull of the opposing guys on the lee side of the mast. The top guys were also required to hold the wind pressure on the armature top, which explains the size of the top guy hereinafter mentioned.

Mast Construction.

The mast is constructed of ordinary structural grade steel, galvanised; it is triangular in section with 8-foot sides and of lattice construction, single bracing being used throughout. The base arrangement is illustrated in Fig. 3. The mast is erected on a ball and socket joint formed on a plate standing on a group of six porcelain insulators, bedded in sheet lead top and bottom. The base plate is grouted in the concrete foundation. The mast legs throughout are of 6 inches x 6 inches angle steel, the thickness varying from $\frac{1}{2}$ inch at the top to $\frac{3}{4}$ inch at the bottom. Bracing is of 3 inches x 3 inches angle steel, the

FIG. 3.
CONSTRUCTION AT MAST BASE.

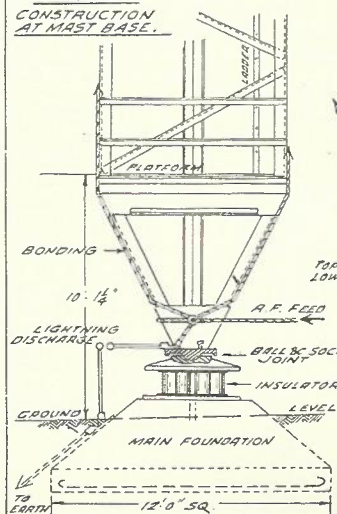
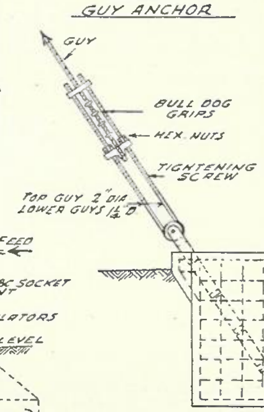


FIG. 4.
GUY ANCHOR



thickness varying from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch according to the shear load. A ladder with safety cage is provided throughout the full height of the mast, rest platforms being fitted at each guying position. At the top of the mast is a cabin 8 feet high, housing the tuning unit. Bolts fitted with steel spring washers are used throughout.

Guy Construction.

Owing to the uneven contour of the site, the length of the guys varies in order to preserve the same angle of pull on the mast of each guy in a set; this necessitates individual anchor blocks.

Guys are of galvanised steel stranded, steel cored, cable, tensile strength 90 tons to the square inch. The top guys are each 1-7/8ths inches diameter and the lower guys 1-1/16th inches diameter, the calculated maximum working loads varying from 27.6 tons in a top guy to 7.6 tons in a lower guy. Each set of guys was tensioned to the maximum working load as they were attached to the structure; which had the threefold purpose of testing the guy insulators, stretching the guy, and imposing a test load on the mast. Care was exercised in accurately fixing the length of each guy in a set, in order to maintain the mast in a vertical position during erection, one guy in each set being tensioned with hydraulic gear attached to the guy close to the anchor block, such tensioning having the effect of equally stressing opposing guys. After imparting the maximum load, guys were set at their initial tension, thus governing the deflection of the mast. To facilitate erection, tensioning and adjustment of guys, each is fitted with a large extension screw. Guy construction at the anchor block is illustrated in Fig. 4.

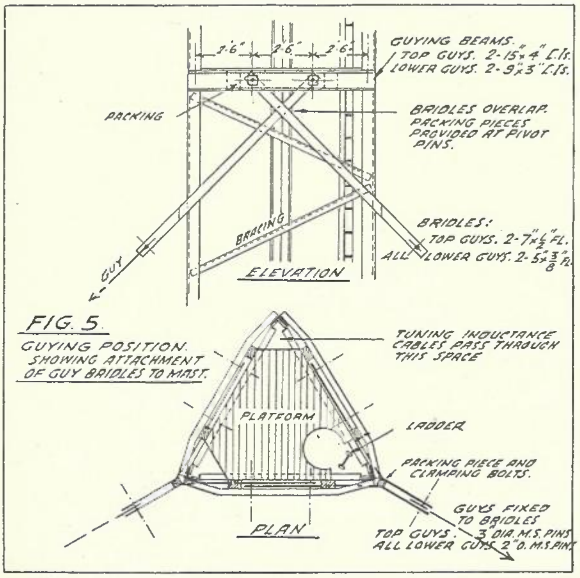


FIG. 5
GUYING POSITION.
SHOWING ATTACHMENT
OF GUY BRIDLES TO MAST.

The vertical component of the guy pulls is distributed equally in the mast legs by means of overlapping bridles (see Fig. 5), by means of which the guys are attached to the mast.

Foundations.

The mast foundation and guy anchor blocks are of reinforced concrete. The mast foundation was designed to take the full thrust of the mast under maximum wind conditions, this being in the vicinity of 131 tons, imparting a load of 1 ton per square foot on the ground formation. The guy anchors each consist of a concrete block with cage reinforcement on all sides, the guy anchor rod being embedded in the concrete with the direction of pull of the guy passing through that point in the anchor block where a line one-third of the height from the bottom crosses a vertical line through the centre of gravity of the block. This construction provides maximum resistance to both vertical and horizontal components of the guy pull. The weight of each anchor block, 1.75 times the vertical component of the guy pull, resists uplift, to which is added the hold in the ground; this offers additional resistance, but is difficult to assess and will vary with the season of the year; hence this resistance is not relied upon in the calculations. The total amount of concrete used in the foundations was 187 cubic yards.

Erection.

Erection problems were complicated by remoteness of the site from the centre of fabrication, while members or units were limited in size owing to transport difficulties. The mast was erected member by member from the base, the first section being temporarily guyed during erection since it balanced only on the ball and socket joint, but after the first guys were fixed and stressed the mast proceeded to the next guying position without any temporary guys. Erection was carried out from an erecting mast travelling up inside the main mast, advancing in stages equal to the length of leg sections. Fig. 6 illustrates the arrangement, the erecting mast being hauled up by a hand winch with the drum in three sections, the cables from the winch passing over sheaves socketed temporarily on the mast legs. When the erecting mast was at its full height for the section being erected, it was supported at the bottom by brackets fixed to the main mast legs. On continuing erection the leg sections were fixed first. The sheaves being in position, the cables were passed over the sheaves and the erecting mast could then be hauled up and the bracing fixed. The erecting mast had a turn-table top with an overhanging cat-head, provided with a sheave over which the lifting rope passed. The lifting rope travelled down inside the mast to an electric winch on the ground near the base, communication between the erecting gang and the winch operator being maintained by telephone. On completion of its work, the erection mast descends to the bottom of the structure, where it is dismantled. The cabin roof and platforms down the mast are placed in position after the erection mast has descended.

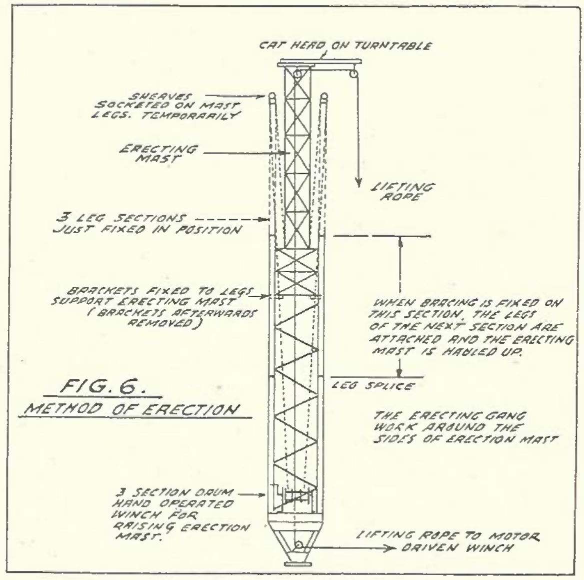


FIG. 6.
METHOD OF ERECTION

Armature.

The armature illustrated in the photograph, Fig. 7, consists of a centre cage or drum mounted on six stand-off insulators fixed to the mast top. Attached to the centre cage are twelve supporting trussed arms, 2 feet in width, radiating from the centre and equally spaced, the areas between them being filled in with flat sections formed of angle-iron frames and covered with 4-inch wire-netting. The arms were assembled on the ground and hauled by the point into position, where the top flange was pivoted on the centre cage, the arms then being lowered into position, and the lower flange bolted to the bottom of the centre cage. Arms were erected in opposing pairs so that the overhanging load was balanced as quickly as possible. With the arms in position, the flat sections were fitted in the intervening spaces, four to each segment. The netting was securely bonded to each frame and all frames and arms bonded together so that the armature forms one complete electrical unit. It may interest some readers to know that the most satisfactory tool for bonding the armature in such an exposed position, 500 feet in the air, is the "Mox" Thermit-heated soldering iron now being used in the Department.

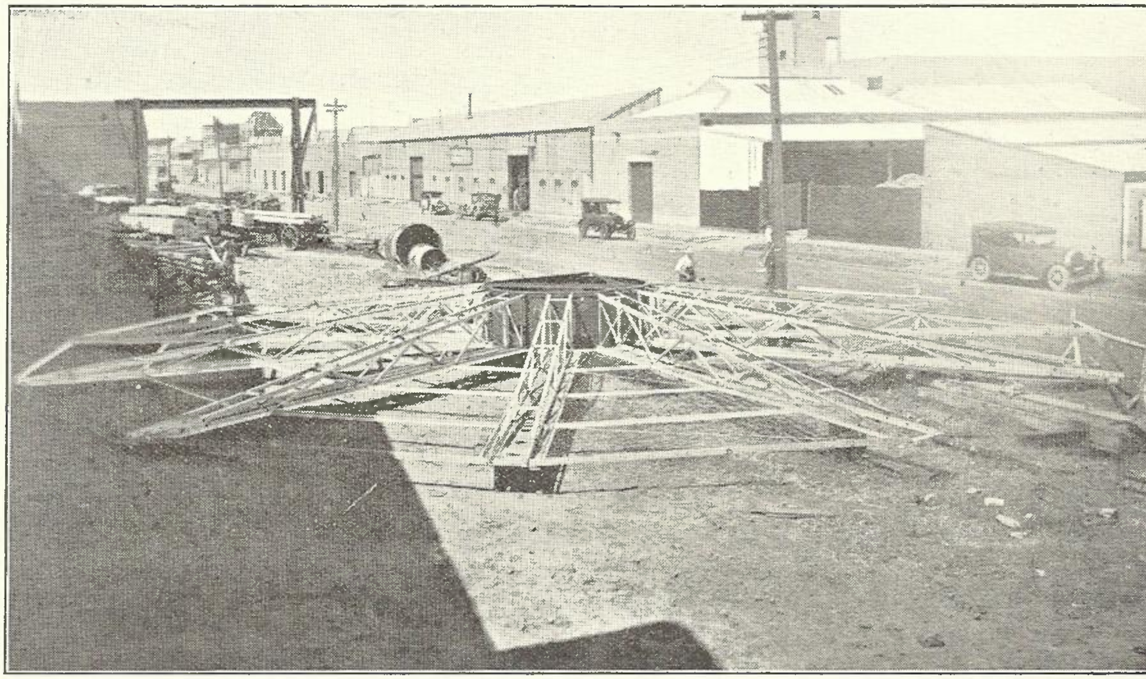


Fig. 7.

Insulators.

Insulators for a structure of this magnitude, as previously indicated, were a problem in themselves, for, apart from electrical performance, they had severe structural loads to carry. Fig. 8 illustrates some of the insulators used in the structure. All insulators were of glazed porcelain.

The base of the mast stands on a group of tubular insulators of ample strength to support the mast. The arrangement of the group ensures that, should an insulator fail by fracture, it will not affect the stability of the structure. Provision is made for the replacement of base insulators. By means of the overhanging plate bearing on the insulators the insertion of three hydraulic jacks with a common feed from a pump is possible, the jacks enabling the mast to be lifted and the insulators replaced.

The guy insulators are of the overlapping metal cage type with the porcelain unit cemented in position, so that whilst the metal cage is in tension the porcelain unit is in compression. They are designed to counteract the pull of the guy and the torsional shear imparted by the twisting of the guy rope under tension. The porcelain unit in the top guys is 6½ inches in diameter.

The stand-off insulators supporting the armature are of tubular type and tapered, the ends being cemented in steel flanges bolted to the armature centre cage and the plate on top of the mast. These insulators are each subjected to a vertical load imparted by the weight of, and downward wind pressure on, the armature, and a bending moment and shear caused by the side wind on the armature under maximum wind conditions.

The lead-in insulator to the cabin at the mast top, whilst not subject to any severe mechanical stress, deserves mention, if only for its size, as it is 16 inches in diameter over the centre flange and 42 inches in length. The connection for R.F. current from the inductor to the armature passes through the longitudinal axis of the lead-in insulator.

The stand-off and lead-in insulators are subject to very high working voltages. They were designed to withstand a proof-test dry flash-over

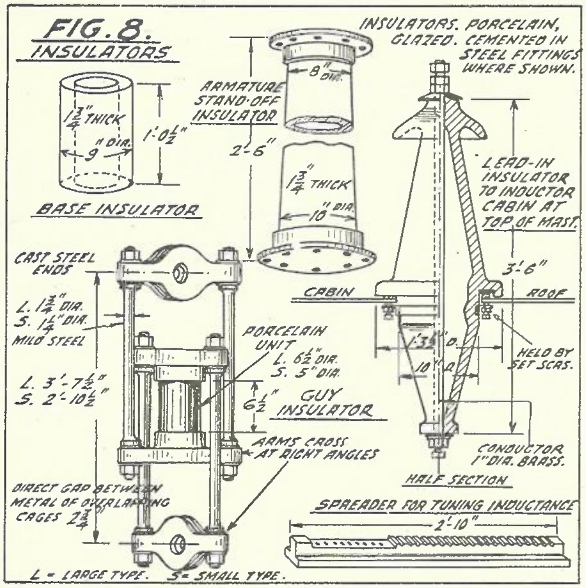


FIG. 8. INSULATORS

voltage at 50 cycles per second of 120,000 volts. When tested, they were found to meet that requirement.

The spreaders for the tuning inductor are also of porcelain, and serve to maintain the spacing of turns in the inductor coil.

The whole of the insulators were manufactured by Sunshine Porcelain Potteries Pty. Ltd., and may be considered an achievement in modern ceramics.

Tuning Inductor.

This item, previously mentioned, is mounted in the cabin at the top of the mast. Associated with it are an ammeter and switch. The inductance has 30 turns, 18 inches diameter, of ½-inch copper tube, the lower 10 turns being fitted with a wiper arm. The arrangement is illustrated in Fig. 9. The wiper arm is controlled by a shaft capable of being locked in position. When free, the wiper shaft can be moved through a sheave by a continuous cable travelling down one of the mast legs through suitable guide pulleys. The lower end of the cable passes round a floating sheave working in guides, the sheave being fitted with weights to prevent undue flapping of the cable and to maintain tautness under all conditions of temperature. The cable is fitted with stops to prevent over-travel of the wiper arm.

Earth System.

The radiator earth system consists of wires spaced at intervals of 2½ degrees, radiating in all directions from the mast to the boundary of the site and varying in length from 525 to 675 feet. The earth wires are of 100-lb. tinned copper wire bonded at the centre to an open loop surrounding the base of the mast. The loop is formed of 19/.072-inch stranded copper cable. The whole of the earth system is buried 6 inches deep in the ground, and the ends of the radiating wires terminate on an earthing rod driven vertically into the ground. A total length of 11 miles of wire was used.

The radiator is also provided with an earth mat at its base; the mat is 24 feet square and consists of woven copper wire fixed to a tubular steel frame. The mat is shaped to cover the top contour of the main foundation and is bonded to the main earth system.

Radiator R.F. Feed.

The R.F. current is fed through an overhead transmission line from the station to the tuning hut at the mast base. From the tuning unit it is connected by stranded copper cable to a bonding stud on the base of the mast.

Lightning Discharge.

A horn gap lightning discharger is provided at the top of the mast. One arm of the horn gap is fixed on the cabin roof and is connected to the mast bonding, the other arm of the horn gap being attached to the armature. The gap is variable from 2 to 12 inches. There is also a lightning discharger at the base of the mast, one leg being bonded to the general earth system.

Aircraft Warning.

Provision is made on the radiator for visual warning to aircraft. The radiator is painted with alternate bands of orange and white, each

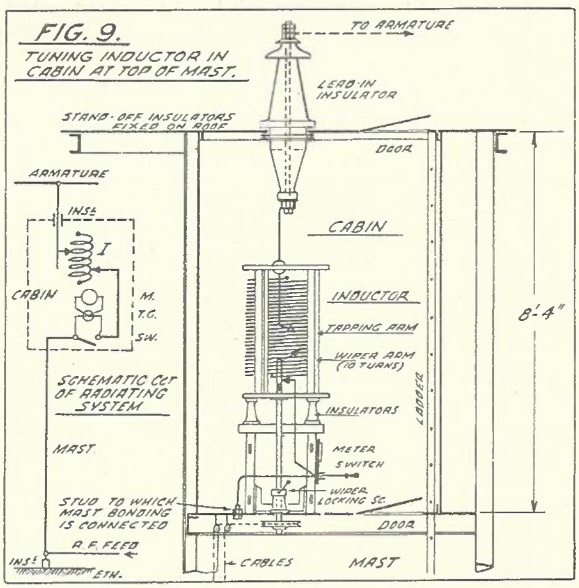


FIG. 9. TUNING INDUCTOR IN CABIN AT TOP OF MAST.

band being 30 feet in length, with the orange above and the white below each of the three top guying points.

At night the radiator is electrically illuminated, current being fed through a special filter unit at the mast base. The warning lights are red, and are mounted on each leg of the mast at the second and third top guying positions and on a standard on the mast top, which passes through, but clears, the armature construction. Each light is provided with two lamps, fed from different circuits, so that the failure of one circuit does not entail the total failure of the mast illumination.

Conclusion.

Whilst this article describes the radiator at Grafton, similar structures are being erected at Wagin (W.A.), Dooen (Vic.), and Cumnock (N.S.W.). With the exception of an additional 150 feet in height in each case and minor details of construction, such as socketed guys, they embody principles of electrical and mechanical design similar to the Grafton radiator. It is also interesting to note that at these stations the R.F. current will be fed from the station to the radiator by a co-axial underground transmission line similar to that provided at 6WF station, Perth.

In a brief article such as this, it is only possible to indicate in outline some of the problems of design and construction met with in a structure of this type. In evolving a combined electrical and mechanical structure of this nature, it will be realised that the ideas and thoughts of many individuals were marshalled together. It serves as an illustration of modern scientific and technical team work. The Department is to be commended for its enterprise in permitting this large-scale experiment to be undertaken, since the design is more or less revolutionary. Great credit is also due to the designing and erecting staff of the contractors, Messrs. Johns & Waygood Ltd., and also to the porcelain manufacturers previously mentioned.

It is pleasing to recall that the work was entirely developed in Australia and carried out with local materials.

SUBSCRIBER'S REGISTER No. 100 TYPE

M. Bowden

A new form of subscriber's register, known as the No. 100 type, will be introduced into the Commonwealth in the near future. It is smaller than the present standard, the dimensions being $3\frac{5}{8}''$ x $1''$ x $1''$ compared with $4\frac{7}{8}''$ x $1\frac{1}{2}''$ x $1\frac{1}{4}''$, and is approximately half the weight of the register in general use. The type 100 register is mounted 100 per plate in five rows of 20 per row. Each plate measures $29\frac{1}{8}''$ x $6\frac{1}{8}''$, and a 200-point test jack to facilitate routine testing is mounted on each plate. Each plate requires a rack space of 178.4 sq. inches, which is considerably less than the space required for mounting 100 registers of the present type. The existing standard register is mounted 10 per plate, which measures $19\frac{1}{4}''$ x $2''$, and 10 such plates for mounting 100 registers require a rack space of 385 sq. inches. From this comparison it will be seen that the introduction of the new register should result in a reduction in the amount of floor space required for the register rack.

Mounting details being entirely different, the new register cannot be mounted readily on existing racks or plates, and for the immediate future at least its use will be restricted to new installations.

The No. 100 type register differs entirely in construction from the familiar pattern. The armature is of the knife-edge type, is of almost the full length of the coil, and is mounted horizontally above and with the knife edge at the mounting-plate end of the coil. The forward end is turned down at right angles, and is attracted by a specially formed extension of the core. The armature is held in the unoperated position by a retractile spring. The number wheels are of the usual form, but of smaller dimensions. The register operates on the reverse action principle, i.e., the operating pawl engages a tooth of the unit's number wheel when the armature is operated to its full extent and registration is effected during the return of the armature to normal. The system of locking pawls is such that when the armature is at rest in the normal position, the number wheels are locked and can be neither advanced nor set back by hand. The principal features are illustrated in Figures 1 and 2.

Although some of the moving parts are of relatively light construction, the register should perform reliably for a lengthy period without readjustment. Acceptance tests for the register are very exacting. It is required to operate 10,000 times without failure, the test current being considerably lower than the normal operating current. Following this test, the register is expected to withstand a life test of 300,000 operations in a circuit simulating practical conditions with no more than five failures.

The register to be introduced here will be of 500 ohms resistance and will be used in R.A.X.'s and in exchanges using positive battery metering. This form of metering differs from existing systems operating in the Commonwealth.

In the Siemens No. 16 system a 3 ohm register is connected in series on the private wire and is operated at the appropriate time by an increase of current in the circuit. In other systems various types of metering circuits have been used.

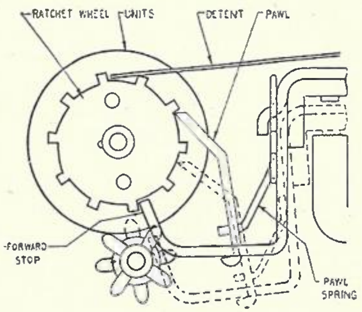


Fig. 1.

In the earliest automatic exchanges a two-winding register is used; one winding being connected directly in one leg of the subscriber's line and the second winding in a purely local circuit. Normally the currents in the two windings are in opposition, but when the called party answers, battery through the line winding is reversed and the register operates. Exchanges which followed are equipped with single coil registers, each wired in a local circuit. Registration is controlled by two relays associated with each trunk outgoing from the primary preselectors. One of the relays is electrically polarised and, one winding being connected in series with the trunk,

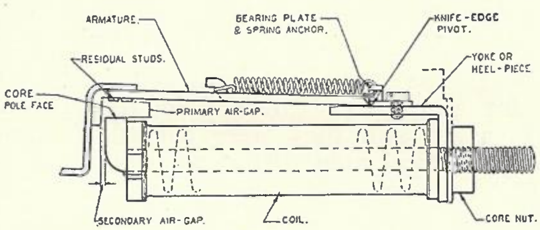


Fig. 2.

operates on battery reversal when the called subscriber answers.

Later exchanges again, which include the most recent installations, are also equipped with single coil registers. This register, however, is connected to the private wire of the subscriber's line circuit and requires an E.M.F. of 90 volts for its operation. A potential of 50 volts normally is applied to the register throughout the duration of a call, but registration is only effected when the voltage is increased to 90 volts by the connection of a "booster" battery for a brief period when the called party answers.

With each of the three systems briefly mentioned, the register, when once operated, is held operated, and the armature is released only when the connection is broken down at the completion of a call.

In the positive battery metering system a single coil register is used, and 50 volts only are required for its operation. In one system the register is connected from the subscriber's private wire to earth through a small metal rectifier so connected that it is non-conducting when the private wire is at negative potential. This is the condition prior to the called party answering. When the called subscriber answers, a 50 volt positive battery is connected to the private wire for a short period, and the register operates, the metal rectifier being conducting under this condition. The register releases immediately the positive potential is removed from the private wire. In another system one rectifier is associated with the private wire of each line finder instead of with each register and the total number of rectifiers required is thereby reduced. The principle of operation, however, is the same as that previously discussed. It is expected that the latter method will be used in the Commonwealth.

The holding of the register operated only for a short period of time is a feature of this system. It renders possible the introduction of multi-fee metering, whereby the register may be operated (and released) a predetermined number of times according to the number of separate metering pulses which may be transmitted in relation to the destination of each call.

In R.A.X.'s the usual practice is to have a "fourth wire" for the metering circuit which is quite separate from the "private wire." This enables the register to be operated by the closure of a circuit to the normal exchange battery and requires no special metering battery.

SUBMARINE TELEPHONE CABLES

A LECTURE DELIVERED BEFORE THE POSTAL ELECTRICAL SOCIETY OF VICTORIA, DECEMBER 12, 1935.

A. Rosen, Ph.D., A.M.I.E.E, (Siemens Brothers & Co. Ltd., London)

Early Cables.

THE earliest submarine cables were, of course, laid for telegraphy, and consisted of a single core insulated with gutta-percha, using the sea as a return path. It was found that there was considerable interference between parallel cables having a common earth return when these were tried for telephony, and consequently the metal-

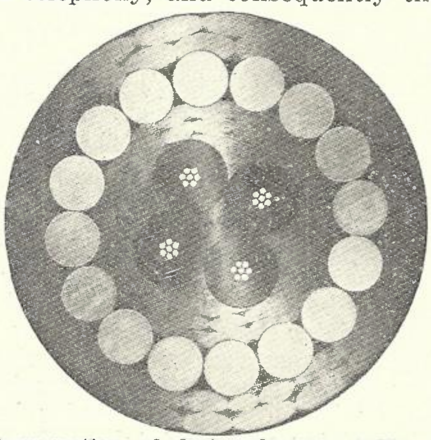


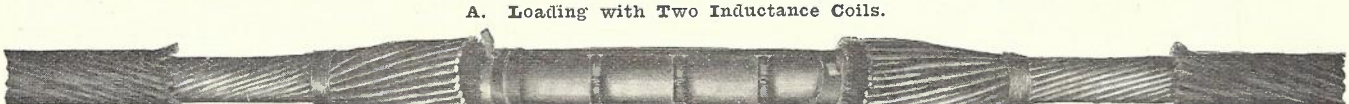
Fig. 1.—Cross-section of first Telephone Cable connecting England with the Continent (1890).

lic circuit was adopted for speech. As four wires can be accommodated in little more space than two, the standard type of early submarine telephone cable contained four conductors, insulated with gutta-percha. Fig. 1 shows a cross-section of the first telephone cable across the Straits of Dover, connecting England with the Continent of Europe in 1890. Each conductor weighed 160 lbs. per naut, and the insulation weighed 300 lbs. per naut. This type was also laid across to Belgium in 1902, a distance of 50 nauts, and gave quite a workable circuit, its attenuation being 25 decibels. Of course, in those days, the decibel and modern methods of transmission measurement were not thought of; the figure given is calculated from the known particulars of these cables.

Loaded Cables.

The advantages of loading apply particularly to submarine cables, on account of the high capacity of the gutta-percha insulation, which is about three times that of a paper insulated cable. Continuous loading, in which a fine iron wire is wrapped in a continuous spiral round the conductor, was tried in the early years of the present century, but the resultant gain in attenuation was small, as the increase in inductance was set off by increased resistance and capacity. However, a few years later, the problem of inserting loading coils into submarine cables was solved, the insertion consisting of a gutta-percha case little larger than the cable, and sheathed in a similar manner to the rest of the cable (Fig. 2). It could, therefore, be handled and laid without undue extra care, and the first such cable was laid across the Straits of Dover in 1910; the conductors were the same size as the older unloaded cable, viz., 160-lb. copper, insulated with 300-lb. G.P., as it was thought that if the loading proved unsuccessful the coils could be cut out, leaving a line of proved efficiency. There were four conductors, and each insertion contained two loading coils, one for each pair. The coil inductance was 80 millihenries, and they were spaced at intervals of one nautical mile. This cable was quite successful, and the following year another coil-loaded cable was laid to Belgium. This differed in some respects from the French cable. Firstly, as the coils had proved efficient, the insulation could be reduced to a more economical size, and its weight was reduced from 300 to 150 lb. per naut. Another improvement was the use for the

A. Loading with Two Inductance Coils.



B. Loading with Four Inductance Coils.

C.—Loading with Eight Inductance Coils.

A. Loading Coil Chamber with Two Inductance Coils showing Method of Insulating with Gutta Percha Envelope filled with Compound.
B. Loading Coil Chamber with Four Inductance Coils for Phantom Circuit Working, showing Method of Protection by means of a Sheathing of Steel Wires.
C. Completed Loading Coil Chamber with the position of Eight Inductance Coils diagrammatically indicated.

Fig. 2.—Coil Loading of Submarine Cables.

first time of balata, which has considerably lower leakance at audio frequencies than gutta-percha, and has since been employed extensively for submarine telephone cables. Further, in this Anglo-Belgian cable the phantom circuit was also loaded; in land practice, it is usual to have one coil for the phantom circuit, which, however, is somewhat larger than the side-circuit coils. In submarine cables it is desirable to have all the coils the same size, and for this reason two coils were used for the phantom circuit, one in each pair; thus there were four coils altogether in each insertion. Fig. 2 shows these insertions, and the method of armouring them. The attenuation of this cable was only 10 decibels, as compared with the 25 of the earlier cable, although it had considerably less insulation. Its cut-off frequency was 2,500 cycles, which is low compared with modern standards; however, the quality was a good deal better than the unloaded cables, and this remained the standard type of cable for about 10 years.

The continuously loaded cable (Fig. 3) had its advocates, and one of this type was laid across the English Channel to France in 1910. It was more expensive than the coil-loaded cable for the same efficiency, as it was not possible, with the loading materials then available, to obtain the high values of inductance provided by coils.

Fig. 3.—Continuously-loaded Cable.

Effect of Repeaters on Design.

The situation was completely changed when repeaters were introduced after the war. It was no longer necessary to have the lowest possible attenuation, as the repeater could make up for the line losses. On the other hand, as these early repeaters were all of the two-wire type, smoothness of impedance was essential, in order to obtain a good balance with the simulating network. This is always possible with the continuously loaded type of cable, for when a repair is needed the new cable is the same as the original, and no appreciable change occurs. It must be realised that when a repair takes place at sea the cable is always lengthened, because it is not possible to insert exactly as much cable as is cut out. It is necessary to raise the cable from the sea bottom, and a loop is formed where the final splice is made. This increase in length is generally small compared with the total length of the cable, and hence the overall attenuation is not seriously affected. However, in the case of the coil-loaded cable, the regularity of the coil spacing is upset by repairs, and large bumps appear in the impedance-frequency curve. This lowers the singing point of the two-wire repeaters, and the efficiency of the circuit is reduced.

Another advantage of the continuously loaded cable is that it is mechanically homogeneous, and can be laid and handled generally in the same way as the ordinary type of unloaded cable; it therefore appeals to maintenance men, who are naturally averse to designs with unfamiliar characteristics.

For these reasons, the continuously loaded cable came into favour, and it is still one of the leading types.

Lead Covered Cables.

A new development that occurred after the war (1923) was the introduction of lead-covered cables for use in tidal waters. The advantages of the paper-insulated lead-covered cable are that it has considerably lower capacity than the gutta-percha insulated type; moreover, nothing like the same thickness of insulation is required for mechanical strength. The lead cable is thus much more suitable for cables containing a large number of conductors; Fig. 4 shows the cross-section of a typical cable having seven quads. A disadvantage is that if the lead is punctured all the circuits are earthed, and consequently the lead-covered cable requires more careful handling to avoid sharp bends and crushing. The risk of pin-holes in the lead sheath was practically eliminated by providing two lead sheaths with a layer of compound between them, and as it is desirable to have as few joints as possible in the lead, these cables are made in long continuous lengths, generally about 10 miles each. It is not feasible to manufacture the core in such long lengths, and, moreover, it may be necessary to introduce crosses in the pairs to reduce cross-talk. The cable is, therefore, made initially in shorter lengths, of the order of half-mile each. These are lead cased in the usual way, and are then jointed together to form the required 10-mile length. The lead sheath is then stripped off

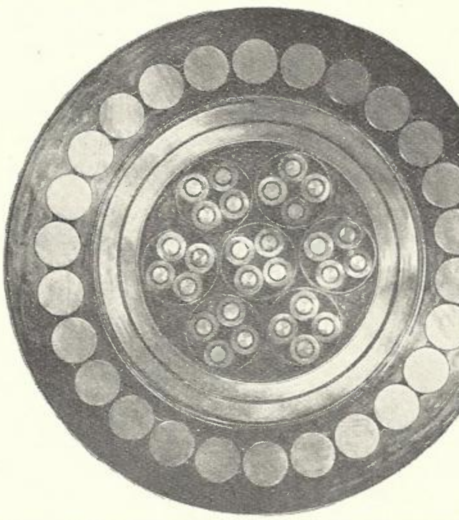


Fig. 4.—Cross-section of typical Lead-covered Cable with 7 quads.

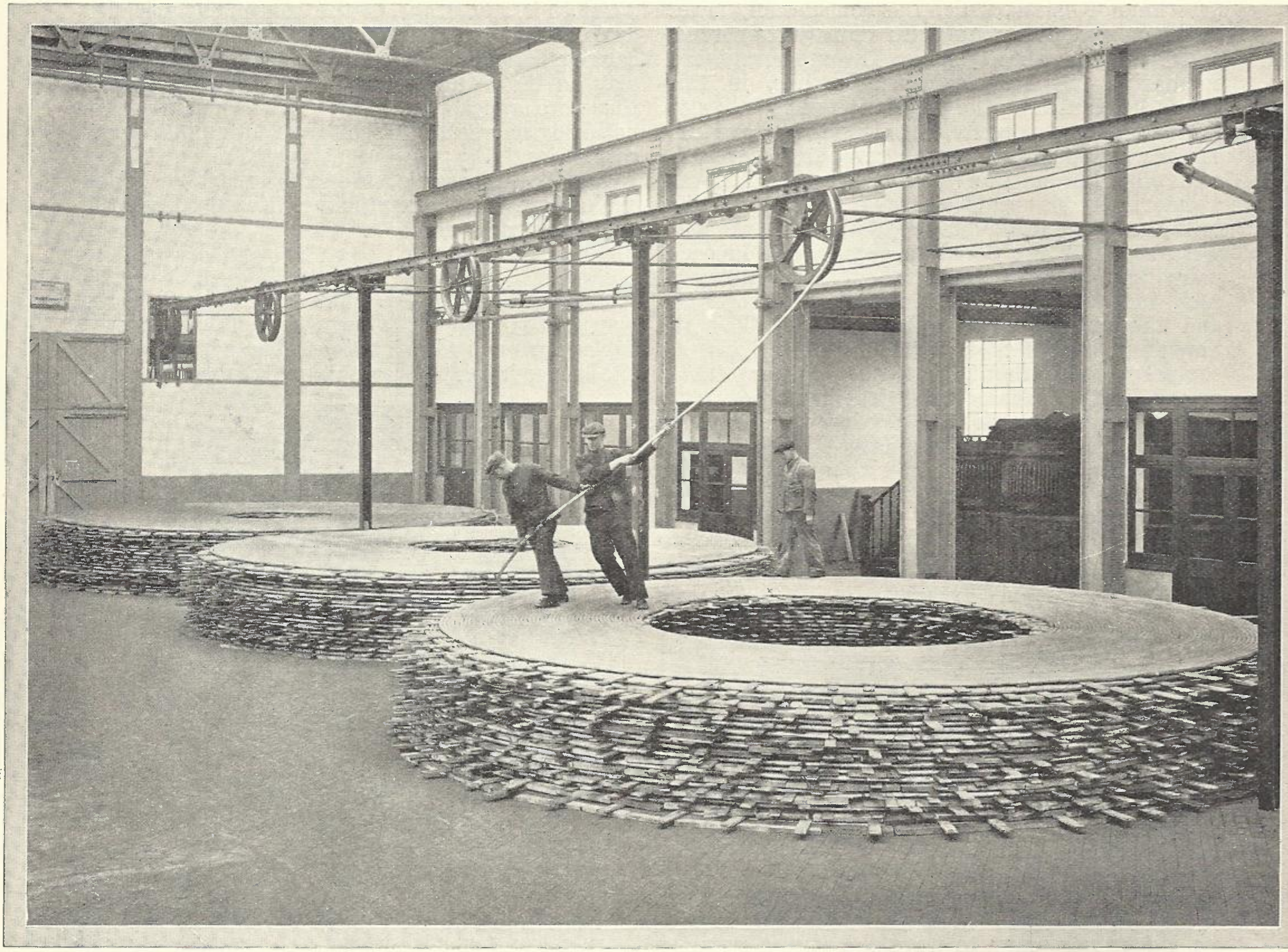


Fig. 5.—Lead-covered Telephone Cables in long continuous lengths.

and the cable is re-sheathed as a continuous length, so that there is no joint in the lead. The operation has to go on for several days, and considerable care and skill are necessary to make sure that no hitch occurs during this time. When the 10-mile length is completed, the cable is put through the lead-press a second time to receive its second sheath; Fig. 5 shows the large coils formed by these 10-mile sections. After armouring, the required number are spliced together, and a continuous length is available for laying.

Thus the pattern that succeeded the balata-insulated coil-loaded cable was the paper-insulated continuously loaded cable, having two lead sheaths. The cable illustrated in Fig. 4, which contained seven quads, provided 14 physical and seven phantom circuits. Similar cables have been laid round the coasts of Britain, and also in other parts of the world. Fig. 6 shows the latest Anglo-Belgian cable, laid in 1932, which contains no less than 120 conductors.

Lead Covered Cables with Rubber Sheaths.

On one of these lead cables it was found that trouble occurred very soon after the cable was laid. The lead sheath developed cracks which admitted the water and the cable failed. The cause was traced to the vibration which resulted from the strong tidal currents sweeping over the cable where it was laid over rocks. Considerable work was undertaken to eliminate the trouble, and a form of lead-alloy was developed which is very much less susceptible to vibration faults; this is an alloy of lead, antimony and cadmium. Further, as an additional precaution, the second lead sheath was replaced by a water-tight covering of india-rubber. This type was used to repair the cable just mentioned, and as no further trouble has since occurred, over a period of eight years, it gives good proof of the soundness of the remedy. Fig. 7 shows a view of a cable having a rubber sheath over the lead, and gives an idea of the general appearance of paper-insulated lead-covered cables.

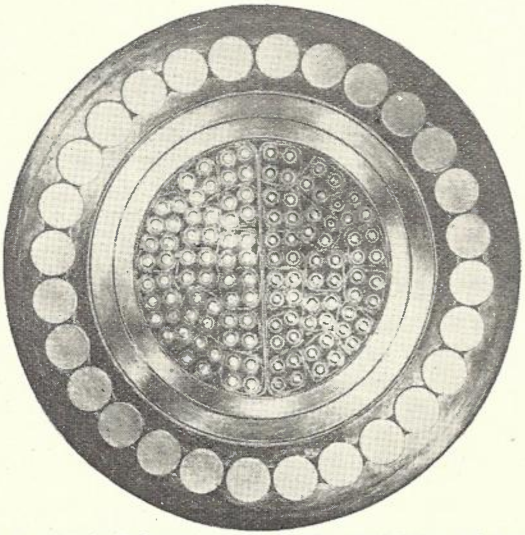


Fig. 6.—Anglo-Belgian (1932) Cable, containing 30 quads.

This combination of lead-alloy and rubber sheath is used now wherever it is desired to obtain the maximum degree of security, and the cable supplied to the Department to connect Rottnest Island with Fremantle, Western Australia, is protected in this way.

At one time it was thought that if a fault were to occur as a result of the lead being punctured the water would penetrate along the whole length of the cable, and that it would all be ruined. This, however, does not happen, as the paper swells up in the vicinity of the damaged place and blocks the entrance of further water. In one case where the cable was left completely severed for more than a week, the water had only penetrated about a hundred yards. In any event, one does not reckon on locating a fault to closer than this degree of accuracy, and a repair which uses only, say, a quarter of a mile of new cable would be considered a very successful operation. Thus the penetration of the water up the cable is not a matter to cause concern.

The chief limitation on the size of lead-covered cables is their weight. The British Post Office sets a limit of 30 tons per nautical mile for their Channel cables, which are laid in about 50 fathoms of water, as this is considered to be the greatest weight that their repairing ships can lift without undue difficulty. The greatest part of this weight is contributed by the lead sheaths, with the iron armouring wires coming a close second. Fig. 8 shows the relative weights of the materials in a typical lead-covered cable, and demonstrates how small is the proportion of "active" material, namely, copper, loading wire and paper.

Modifications Resulting from 4-Wire Working.

As telephone circuits became ever longer it was found that the two-wire type of repeater was unsuitable, more than about six such repeater sections tending to give an unstable circuit. Hence it has become the practice to use four-wire circuits for long-distance work, particularly for international purposes in Europe. Most of the cables landing on the coasts of England are parts of international circuits, and it is now desirable to work such cables as far as possible on a four-wire basis. This has led to further changes in the design of such cables. Firstly, four-wire repeaters can be operated at higher gains, permitting greater attenuations per repeater section than in the case of two-wire circuits. This allows conductors of smaller gauge to be used, which partly makes up for their larger number. Secondly, the need for close balance to the two-wire network disappears and, in consequence, the cable does not require such a smooth impedance-frequency curve, and greater irregularities are permissible in the line characteristics. The chief objection to coil-loading, therefore, no longer exists and a number of such cables have been laid in recent years in the Baltic, which is an inland, tideless sea. The mechanical objection, however, still exists, indeed it is even greater in the case of multi-conductor cables, and coil-loading would not, in general, be considered for such tidal waters as the English Channel or the Bass Strait. Cases may, however, arise in which loading by means of coils is the only electrical solution, and in

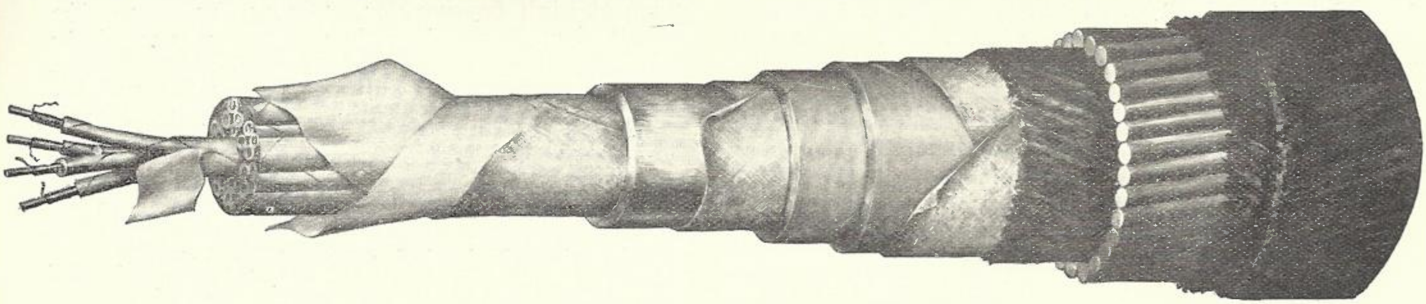


Fig. 7.—Lead-covered Cable with rubber covering.

such instances this objection would not be regarded as insuperable.

Cross-talk.

Cross-talk provides one of the limitations in the design of submarine telephone cables; it is undesirable from the point of view of secrecy, and also considered as an interfering noise. The former sets a stricter limit on the amount of cross-talk, and it is usually considered necessary to have a margin of about 55 decibels between the levels of received speech and intelligible cross-talk. If the cross-talk is unintelligible the margin need not be so great, e.g., where the interference takes place from a carrier channel, and the speech is inverted, a margin of about 50 decibels is sufficient. Near-end cross-talk occurs between circuits when speaker and listener are at the same end of the cable; this condition provides the greatest difference of level between the two circuits and, in practice, near-end cross-talk is generally the most troublesome. Distant-end cross-talk occurs when the speaker and listener are at different ends of the cable, and there is no difference of level betwen the two circuits; this condition is, therefore, easier to fulfil. Where two-wire circuits are concerned, both near-end and distant-end cross-talk have to be considered between each pair of circuits. As just mentioned, near-end is the more difficult to control, and without special precautions a value of about 90 db. is obtainable. As a margin of 55 db. is required, this leaves 35 db. as the limiting value of attenuation. The cross-talk can be improved by shielding the circuits, but this is not generally required, as the attenuation could not be increased above 35 db. on account of the singing of the repeaters. In the case of four-wire circuits, the circuits are divided in two groups, "goes" and "returns"; near-end cross-talk occurs only between circuits going in opposite directions, and hence for these some form of screening is usually adopted. The "goes" and "returns" are usually segregated into two groups separated by a metal screen as in the Anglo-Belgian (1932) cable, Fig. 6, or alternatively, the "go" and its associated "return" may be formed into a quad, and each separate quad screened. By the use of screens the near-end cross-talk attenuation may be raised to about 100 db. which would allow line attenuations of the order of 45 db.

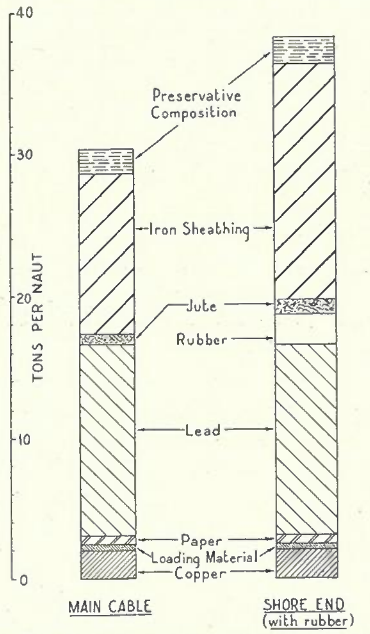


Fig. 8.—Relative Proportions by Weight of Materials Used, in paper-insulated lead-covered Submarine Cable.

Carrier Circuits on Submarine Cables.

As first applied to submarine cables, carrier circuits were somewhat in the nature of a by-product. Those that were obtained were additional to the facilities for which the cable was provided, and were a free gift or bonus from the cable maker to the customer. The cables had been designed for audio frequencies, and consequently the attenuation over the carrier ranges was considerable. Continuously loaded cables proved more suitable than coil-loaded cables in this respect, as there is no definite cut-off frequency. Fig. 9 shows the gradual rise in the attenuation with frequency in a continuously loaded cable, which is due mainly to the losses in the magnetic loading material. The cross-talk limitation in multi-conductor cables is more severe, firstly, on account of the greater attenuation of the carrier circuits, and secondly, because of the greater transfer of energy that takes place at high frequencies. Thus not many extra circuits could be obtained on cables not specially designed for the purpose. The last Anglo-Belgian cable and also the recent Anglo-French cable were both specially screened with a view to reducing carrier cross-talk, and on these a four-wire circuit can be superimposed on each four-wire audio circuit, giving respectively 30 and 19 carrier circuits. Another limitation which arises in loaded cables, both coil and continuous, is due to the non-linear distortion in the loading material which causes inter-modulation between the audio and the superimposed carrier frequency currents. This has been overcome very ingeniously in the "twin-band" system, in which audio frequencies are used for the transmission in one direction and carrier frequencies for the return paths, the "go" and "return" for each conversation taking place over the same pair of wires. Thus audio and carrier are never traversing the same path together, and cross-modulation effects are avoided. This system may also be used to overcome some of the cross-talk difficulties, by transmitting all the "go" paths as audio frequencies and all the "returns" as carriers. The near-end cross-talk that then occurs is between bands at different frequencies, and as reduced by the filters, as well as having greater tolerance through being unintelligible. For this reason the twin-band system offers the only possible solution for certain cases where a number of circuits are required over a considerable distance.

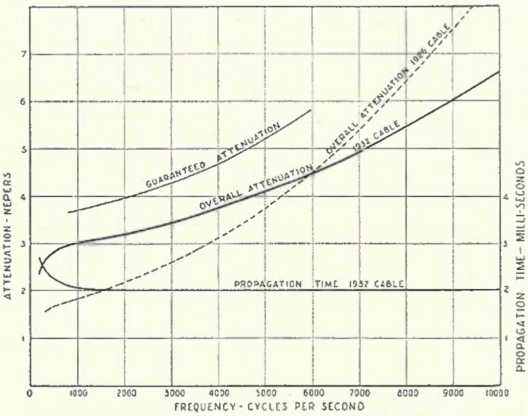


Fig. 9.—Transmission Characteristics of continuously-loaded cables.

Non-loaded Cables.

However, the tendency nowadays is towards non-loaded cables wherever possible, as then non-linear effects are completely avoided and a number of carrier circuits can be superimposed on each other, depending on the attenuation and cross-talk. The latest cross-Channel cable was laid between England and France in 1933 and consisted of 19 quads, each separately screened, with paper insulation, lead sheathing and rubber protection.

Another advantage of the non-loaded cable is its high propagation velocity. On open aerial lines, the electric wave travels with almost the speed of light, i.e., 186,000 miles per second. Where, however, heavily loaded cables with high capacity are concerned the velocity may drop to less than 10 per cent. of this value. For short distances the time taken is inappreciable, but when circuits involving thousands of miles are concerned the delay introduced by loaded cables is of importance. A limit of 250 milli-seconds has been set for the transmission time between international subscribers in Europe, and it is therefore an advantage to have lightly loaded or unloaded circuits wherever possible.

Concentric Cable with Plastic Insulation.

The cables which have been discussed so far have been all of the shallow-water type. Lead-covered cables are not suitable for depths above 50 fathoms without special reinforcement, on account of the crushing action of the water. Plastic insulation does not suffer from this disability, but all multi-core cables (whether with plastic insulation or lead sheaths) get crushed and distorted in passing round sheaves when under a heavy strain, and this limits the use of multi-core cables to one or two hundred fathoms, depending on the weight. Hence the only possible type for greater depths is the single-core cable with plastic insulation, similar to gutta-percha. Before carrier circuits were developed such cables could provide only one conversation each, and if more were desired additional cables had to be laid. For example, three parallel cables were laid between Key West and Havana, in 1921, where the greatest depth is over 1,000 fathoms; each of these was of the single-core continuously loaded type with concentric copper return sheathing and gave one telephone circuit only. It was, therefore, of special interest to apply carrier to single-core deep-sea cables, and it was soon found that it was better to omit the loading; although the attenuation of loaded cables is better at low frequencies, the losses due to eddy currents and hysteresis in the loading material more than outweigh the effects of the added inductance at high frequencies, and the resulting attenuation is greater than that of an unloaded cable.

Another important effect is the loss introduced by the sea return. It is well known that the sea provides a very good conducting path for direct currents and, in fact, it has no appreciable resistance in this case. Alternating currents, however, refuse to return by this easy path, and cling as closely as possible to the cable. They would thus traverse the armouring wires, which, on account of their magnetic nature, would introduce heavy losses at high frequencies. For this reason a copper return path is provided inside the armour, as close as possible to the insulated core. This return need not be insulated from the sea, and the combination behaves to high frequencies as a concentric pair.

Paragutta.

The application of carrier to submarine telephone cables was greatly stimulated by the invention of a new plastic insulator, called paragutta. It had been found that the dielectric losses in balata, which had been so satisfactory for audio frequencies, were quite large at frequencies of the order of 30 kilocycles; in paragutta, dielectric loss has been reduced to the point where it is negligible and, moreover, it has a considerably lower dielectric constant, resulting in a lower capacity. Fig. 10 shows the way the losses are proportioned between the conductor and the dielectric, for the two cases employing balata and paragutta respectively. Both components are lower in the latter case, due to the lower capacity and dielectric losses.

Paragutta consists of a mixture of rubber and balata, each treated in a special manner. The rubber is deprived of its protein matter, which would otherwise provide conducting paths for the water. The balata is deprived of its resin, to which most of the dielectric loss has been traced. To the mixture is added a small proportion of pure hydrocarbon wax, which gives the whole plasticity, and the finished product behaves mechanically in a similar manner to gutta-percha.

Paragutta received its first practical trial in the Key West-Havana cable, which was laid in 1930; it has remained in good condition since, and promises to retain its excellent transmission qualities without deterioration. This cable is very similar to the new Bass Strait cable. It is operated with a three-channel system, using the same frequencies as are employed in land-line carriers, and the attenuation at the highest frequency, viz., 28 kc., is about 80 db.

Bass Strait Cable.

Although this cable is essentially the same as the one that was laid between Key West and Havana five years ago, it presents some important new features. In the first place, the depth across the Bass Strait does not exceed 50 fathoms at any point, so that the situation is quite suitable for a lead-covered cable. This is the first time that concentric type with plastic insulation has been chosen in preference to the multi-core paper-insulated lead cable, and it may be that this marks the beginning of a new phase. There is little to choose between them in cost, when equipment is included, and the paragutta cable does offer the advantage of easier handling during laying and in the event of a repair. Whether the paragutta cable is less liable to faults than the latest type of rubber-covered lead cable is still a debatable point. However, there is no doubt that, where maintenance has to be carried out by people who are familiar only with gutta-percha cables, one with similar properties is to be preferred.

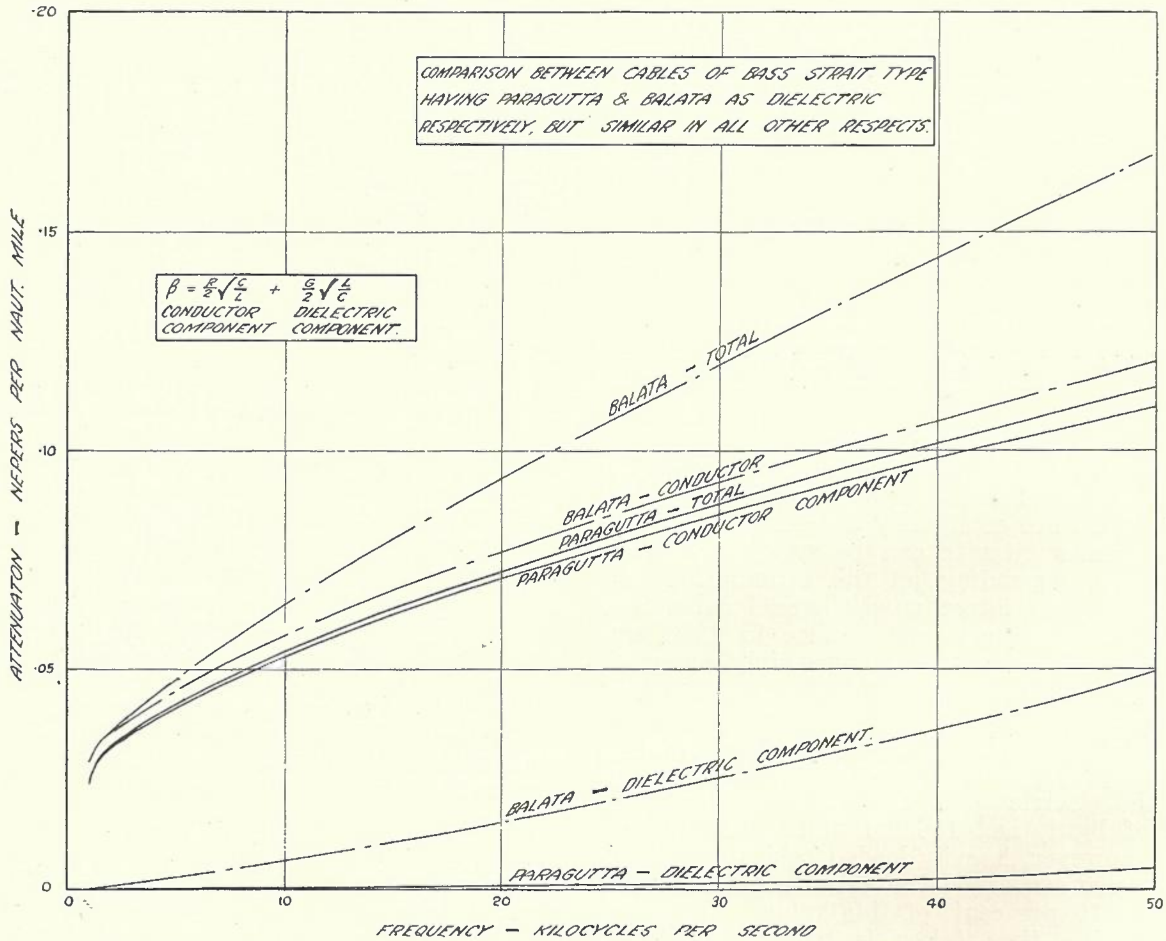


Fig. 10.—Relation between Conductor and Dielectric losses in Balata and Paragutta Cables.

Another notable feature of the new cable is that it will be operated with balanced carrier channels as well as grouped channels. Fig. 11 shows the approximate allocation of the frequency channels. The three lowest bands will be worked as duplex channels, the range of the highest being from 7.0 to 9.6 kilocycles. In order to obtain sufficient stability and to allow for the effect of possible future repairs, a margin of at least 10 decibels was required between the singing point and the line attenuation over this range. The maximum permissible attenuation was 41 db., so that a minimum singing point of 51 db. had to be guaranteed. In order to meet this extremely severe condition, very great care had to be taken in the manufacture of the cable. The utmost uniformity was necessary throughout, both in the raw materials and in the processes of manufacture. As examples of what was done in that respect, all the material for the 190-odd miles of cable was assembled in bulk and then sorted and mixed so that the batches used during the six months that the core was being made would all be the same; further, automatic control was fitted wherever possible to the processes that were repeated day after day, so that the same result would be obtained, irrespective of the external temperature and weather conditions. When the core was made, and was complete with its copper return tapes, it was assembled on wooden drums in lengths of a mile and placed in a large tank to undergo tests for impedance. Over one hundred miles of cable were thus assembled together, and on the results of these tests the lengths were graded and the order of joining up was determined that would give the smoothest impedance-frequency curve; Fig. 12 shows the large iron tank specially constructed for the purpose.

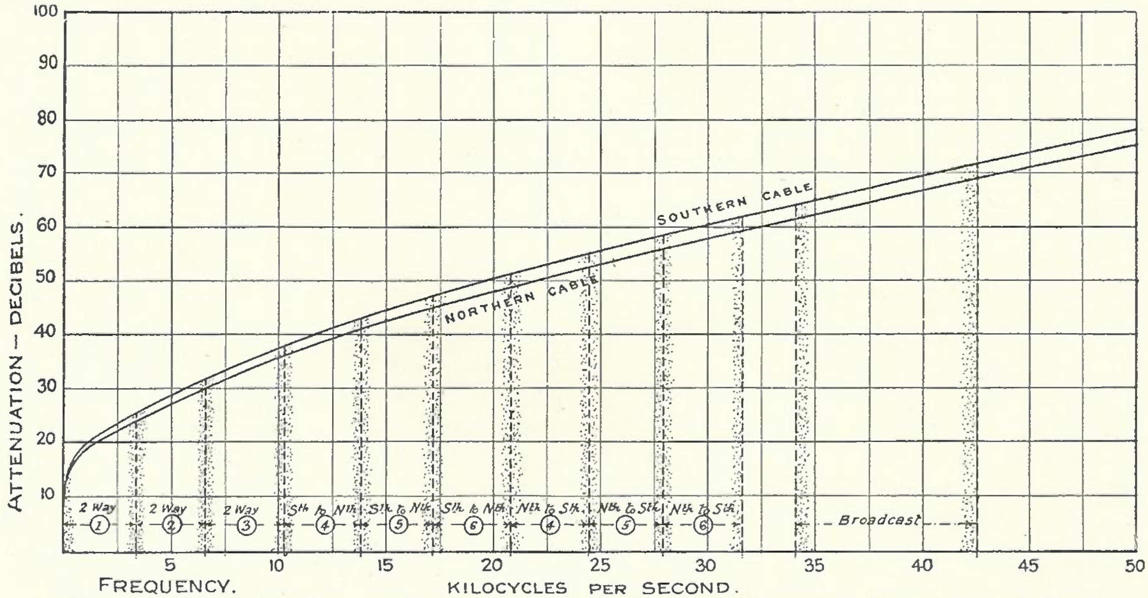


Fig. 11.—Overall attenuation values at various frequencies for each repeater section of Bass Strait Cable, showing the approximate allocation of the carrier channels. Northern section, 78.92 nautical miles. Southern section, 82.05 nautical miles.

Particulars of the Cable.

The central conductor consists of a solid copper wire 138 mils in diameter surrounded by six tapes 15 mils in thickness, forming a total of 168 mils diameter, and weighing 508 lb. per nautical mile. The paragutta weighs 690 lb. and is put on to a diameter of 620 mils. The return consists of six tapes each 18 mils in thickness, weighing 852 lb. per naut, and this is covered by a 4-mil copper tape as a protection against the teredo-boring worm. The armouring varies according to the depth, the main cable weighing $6\frac{3}{4}$ tons, the intermediate type $8\frac{3}{4}$ tons, the shore ends, which have double armouring, 19 tons; the beach cable, which has a lead sheath over the paragutta to prevent access of air, weighs $21\frac{1}{4}$ tons per nautical mile. The external diameters are respectively $1\frac{1}{2}$, 1.6 and $2\frac{1}{4}$ inches (Fig. 13).

Fig. 14 shows the route over which the cables were laid. The Northern cable goes from Apollo Bay, Victoria, to Naracoopa, King Island, and measures 78.92 nautical miles; the southern cable runs from Naracoopa to Perkins Bay, near Stanley, Tasmania, and is 82.05 nautical miles in length.

Tests After Laying.

The performance of the cables after laying is shown in Tables I., II. and III. below. Fig. 15 shows the impedance as measured in the Works' tanks before shipment, and Fig. 11 the attenuation after laying; it is gratifying that there has been very little change in the characteristics as a result of the laying operations, and that in consequence the guarantees have been fulfilled with an ample margin.

TABLE I.—DIRECT CURRENT MEASUREMENTS.

	Northern Cable	Southern Cable
Length, nautical miles	78.92	82.04
Insulation Resistance after 1 minute's electrification, megohms per nautical mile	62,000	40,000
Electrostatic capacity, microfarads per nautical mile	0.199	0.201
Inner Conductor Resistance, ohms per nautical mile	2.27	2.27

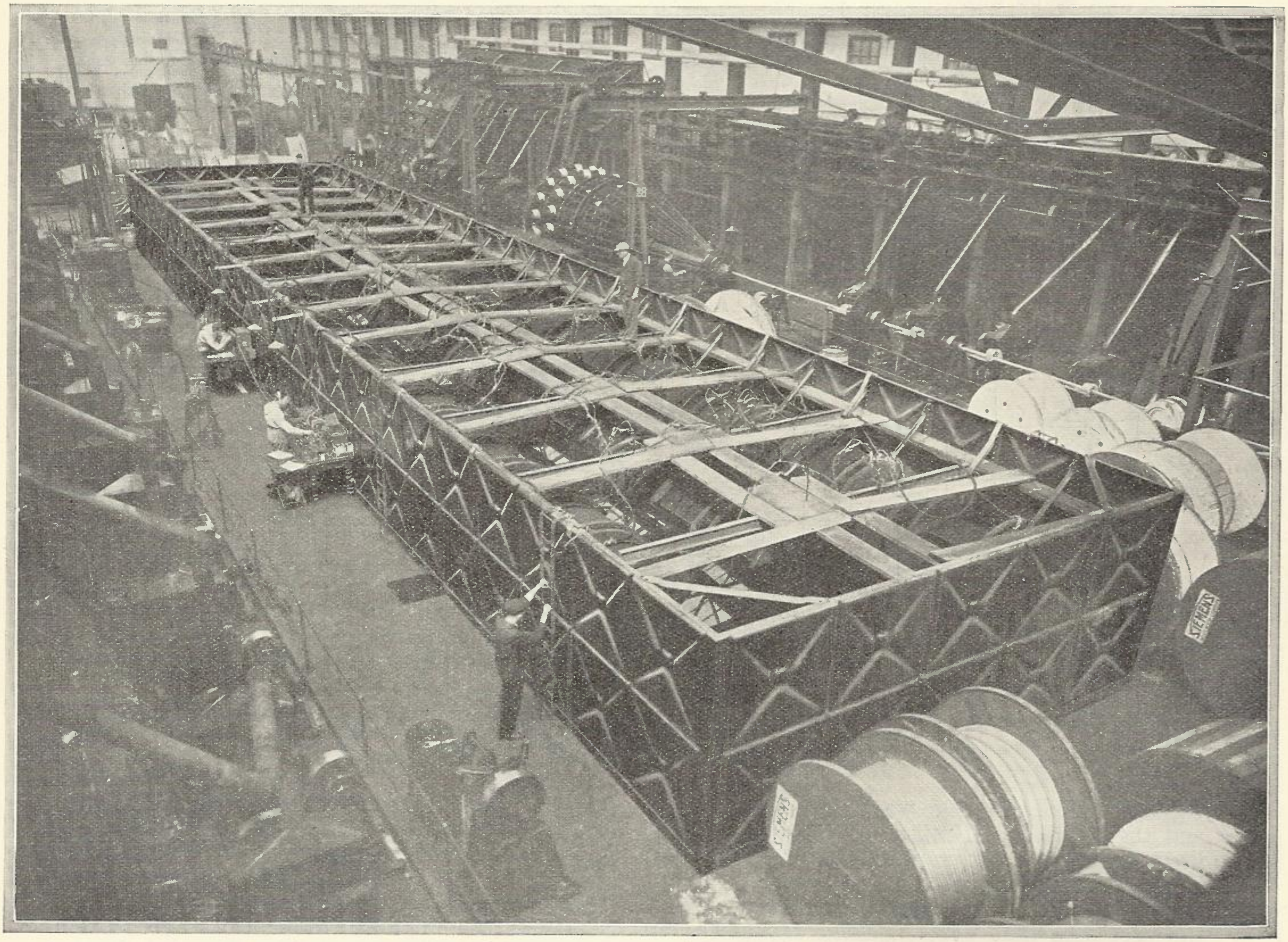
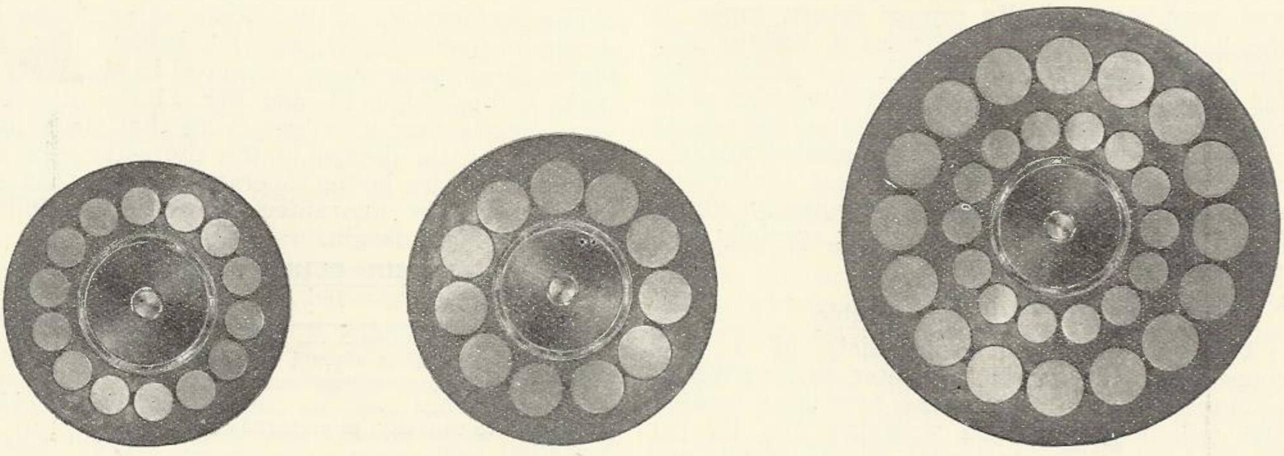


Fig. 12.—Large Tank, built to accommodate drums of cable during the "grading" process.



Main Cable.

Intermediate Cable.

Shore end Cable.

Fig. 13.—Cross-sectional views of Bass Strait Cable (actual size) showing the different types of armour.

TABLE II.—ATTENUATION.

Frequency kilocycles per second	NORTHERN CABLE Overall decibels	NORTHERN CABLE Per n.m. decibels	SOUTHERN CABLE Overall decibels	SOUTHERN CABLE Per n.m. decibels
0.2	11.1	0.141	11.5	0.140
0.4	14.6	0.185	15.2	0.185
0.6	16.5	0.209	17.2	0.210
0.8	17.7	0.224	18.5	0.226
1.0	18.6	0.236	19.4	0.236
1.5	20.0	0.253	21.0	0.256
2.0	21.0	0.266	22.0	0.268
2.5	22.0	0.279	23.0	0.280
3.0	22.9	0.290	24.1	0.294
4.0	24.9	0.316	26.1	0.318
5.0	26.8	0.340	28.2	0.344
6.0	28.7	0.364	30.2	0.368
7.0	30.4	0.385	32.1	0.391
8.0	32.2	0.408	33.9	0.413
9.0	33.8	0.428	35.5	0.433
10	35.4	0.449	37.1	0.452
12	38.2	0.484	40.2	0.490
14	40.8	0.517	42.8	0.522
16	43.2	0.547	45.3	0.552
18	45.5	0.577	47.7	0.581
20	47.6	0.603	50.1	0.611
25	52.6	0.667	55.5	0.677
30	57.4	0.727	60.5	0.737
35	62.1	0.787	65.3	0.796
40	66.3	0.840	69.7	0.850
45	70.4	0.892	73.9	0.901
50	74.0	0.938	78.0	0.951

TABLE III.—IMPEDANCE DEVIATIONS.

Frequency kilocycles per second	DEVIATION Ohms	DEVIATION Per cent.	Singing Point decibels	Line Attn. db.	Margin db.
Northern Cable, Apollo Bay End					
8.16	0.18	0.33	55.6	32.4	23.2
9.6	0.18	0.33	55.5	34.6	20.9
24	0.34	0.63			
37	0.51	0.95			

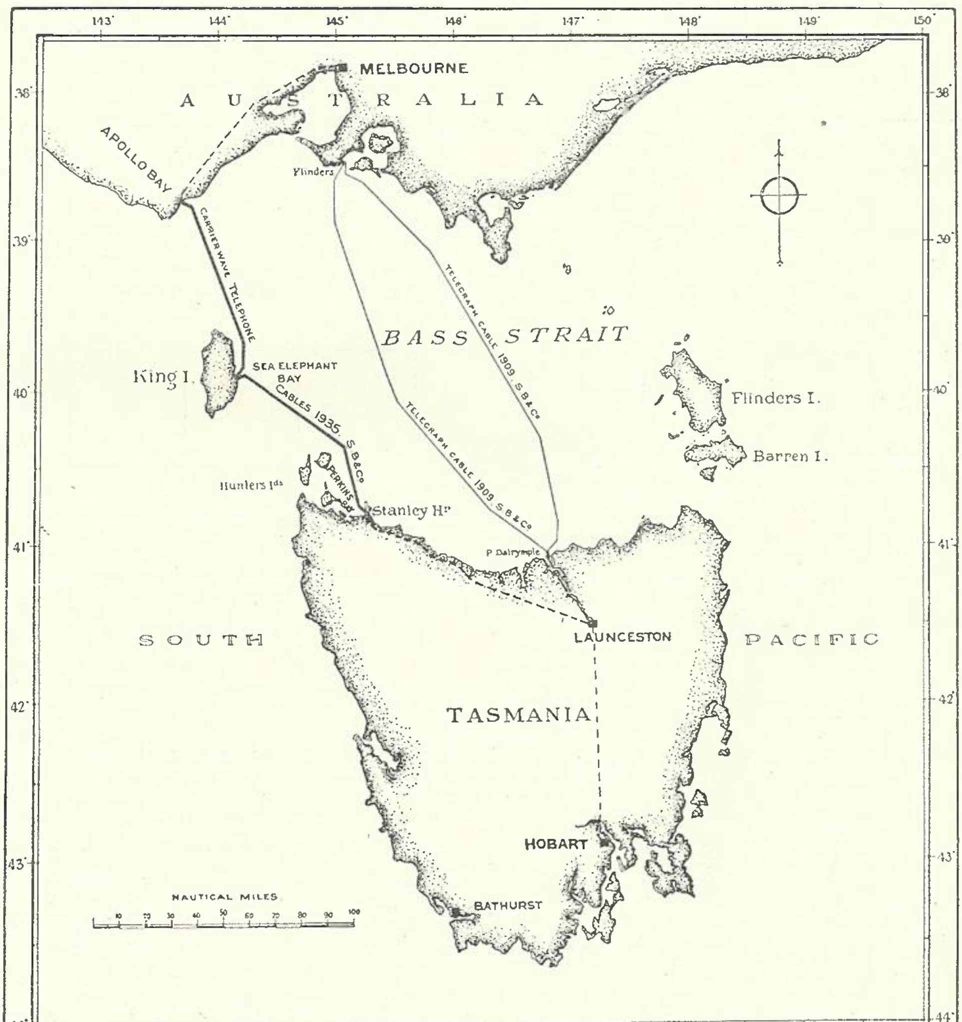


Fig. 14.—Map of Bass Strait, including Tasmania and part of the Victorian Coast. The route of the new cable is shown, also the land line extensions.

Continued from previous page:

Northern Cable, King Island End					
4.2	0.18	0.32			
6.4	0.19	0.35			
6.8	0.16	0.29			
7.3	0.15	0.28	57.1	30.9	26.2
23.5	0.46	0.88			
31.7	0.33	0.64			
Southern Cable, King Island End					
6.5	0.16	0.30			
7.8	0.16	0.30	56.5	33.7	22.8
9.4	0.11	0.21	59.6	36.2	23.4
9.6	0.11	0.21	59.6	36.5	23.1
17.5	0.36	0.68			
33.5	0.40	0.77			
38.0	0.47	0.91			
Southern Cable, Perkins Bay End					
6.0	0.12	0.22			
6.5	0.14	0.26			
6.8	0.16	0.30			
8.4	0.16	0.30	56.5	34.5	22.0
20	0.51	0.97			
22.5	0.45	0.85			
31	0.58	1.10			
42	0.58	1.11			

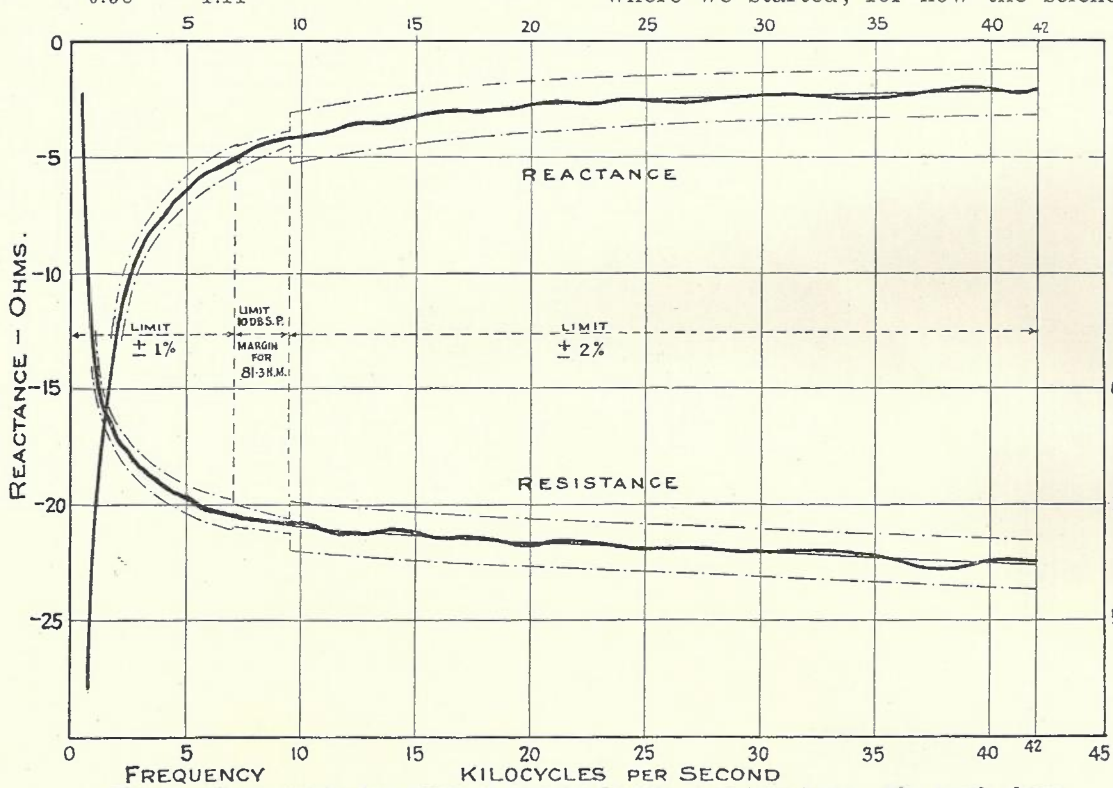


Fig. 15.—Characteristic impedance of completed cable in factory tanks. The graph shows results obtained by tests of the north cable from its northern end. Very similar results were obtained for both cables from both ends.

Cross-talk.

The interference between the North and South cables was measured at King Island, which is the common landing point. It was found to be inappreciable at all frequencies, being above 114 decibels, the limit of measurement.

Noise.

The noise was measured at King Island with the cables terminated at the far end in 52 ohms, and at the near end with a hybrid coil and low and high pass filters, having a cut-off of 3 kc.

Northern Cable: No measurable noise, i.e., less than 1 microvolt.

Southern Cable: Through H.P. filter, no measurable noise.

Through L.P. filter, noise of about 250 cycles, value 4.5 microvolts.

Conclusion.

The last word has not been said regarding the development of submarine telephone cables. Fresh advances in loading materials, insulating materials or method of utilising the cable may radically modify future designs. Nevertheless, it is apparent that the tendency to-day is towards simplification and it is noteworthy that the latest design is a reversion to the earliest type of submarine cable, viz., a single core with plastic insulation and no loading. The cycle of changes has been completed, but we are not back where we started; for now the science of telephone transmission has a firm basis and it is possible to forecast performance with reasonable accuracy. There is a mine of past experience to draw on, and telephone cables of to-day are in every way a "sound engineering job."

The author desires to express his thanks to Messrs. Siemens Brothers & Co. Limited, London, for permission to publish some of the information in this article, and for the loan of blocks for illustrations.

MAINLAND - TASMANIA CABLE

DESCRIPTION OF THE EQUIPMENT

N. W. V. Hayes and C. Anquetil

THIS description covers the equipment installed at the various stations between Melbourne and Hobart to provide the various channels estimated by the Traffic Sections as necessary for requirements for the next twenty years. This estimate was as follows:—

Trunk telephone channels—
2 initially, 5 ultimately.
Telegraph channels—
5 initially, 7 ultimately.
Channel for broadcast programmes—
1 initially, 1 ultimately.

The equipment on the submarine cable section actually provides for the ultimate requirements, but on the landline sections only the equipment necessary to meet immediate requirements has been installed.

On the lines between Melbourne and Apollo Bay and also between Stanley, Launceston and Hobart standard type carrier telephone systems are employed. The lines consist mostly of open wire, but sections of underground cable occur at intervals, and where these cable sections are over 100 yards in length the cables have been loaded.

For the submarine cable section a special carrier and voice frequency system providing a total of six telephone channels has been designed. The broadcast programme channel, which is superimposed, is reversible, and is capable of transmitting a programme from Melbourne to Launceston and Hobart or from any one of those stations to the other two stations. The frequency allocation of the various channels is shown in the following table:—

Channel	Frequency	Type of Channel
	Cycles per second	
No. 1 Telephone	0-3,000	Balanced, i.e., same frequencies used in each direction.
No. 2 Telephone	3,000-6,000	Ditto.
No. 3 Telephone	6,000-9.000	Ditto.
No. 4 Telephone	South to North: 11,000-14,000 North to South: 21,000-24,000	Simplex or 4-wire type, using separate channels for each direction.
No. 5 Telephone	South to North: 14,000-17,000 North to South: 25,000-28,000	Ditto.
No. 6 Telephone	South to North: 17,000-20,000 North to South: 28,000-31,000	Ditto.
Broadcasting Programme Channel	34,000-42,500	Uni-directional but reversible.

N.B.—Any one of the 6 telephone channels can be used for the V.F. Telegraph System.

The equipment which has been installed comprises:—

(a) Six Telephone Channels arranged as follows:
  (i) No. 1 Channel—Melbourne (Victoria) to Stanley (Tasmania), with Currie (King Island) as an intermediate station.
  (ii) Nos. 2 and 3 Channels—Between Melbourne and Launceston.
  (iii) No. 4 Channel—Between Melbourne and Hobart.
  (iv) Nos. 5 and 6 Channels—Between Apollo Bay repeater station and Stanley repeater station.
  (Channels 5 and 6 are not actually in use and ringing equipment has not been provided.)

(b) A Broadcasting Programme Transmission Channel between Melbourne, Launceston and Hobart.

(c) Stand-by V.F. telegraph equipment not actually connected to any channel, but capable of providing over any telephone channel three telegraph channels between Melbourne and Launceston and two channels between Melbourne and Hobart.

At present the five-channel V.F. Telegraph System is wired to jacks and can be patched into any telephone channel between Melbourne and Launceston when required in emergency.

The two Hobart duplexes will be extended from Launceston by special composite circuits.

A telephone channel is lost whilst the V.F. Telegraph System is in operation, as both cannot be operated simultaneously.

The equipment which has been installed at the various offices is shown in block form in Figure 1.

OPEN WIRE LINES.

On the landline sections the Hobart and Launceston telephone channels are provided between Melbourne and Apollo Bay, in Victoria, and between Stanley and Launceston, in Tasmania, by three-channel Type CS. carrier telephone systems superimposed over wires which were in existence previous to the installation.

The open wire lines had, at railway crossings and at other points, several lengths of underground cable which could not be removed. It was necessary, therefore, for carrier operation, to load these intermediate sections of cable so that the impedance of the cable would match the open wire lines and, at the same time, provide a cut-off well above the top frequency of the carrier systems superimposed on the lines, i.e., above 42.5 kC, the top frequency of the programme channel. Loading coils having an inductance of 3.5 millihenries were installed at intervals of 715 feet on the intermediate lengths of cable and, where short cables were involved, they were built out to the equivalent of one loading coil length. In Tasmania, where a length of submarine cable was involved at the Derwent River crossing near Hobart, matching transformers only could be used. This cable is 0.785 of a mile in length, made up of 0.285 submarine and 0.5 mile Multiple Twin.

load the common amplifiers used in the system and, while the distortion introduced is not noticeable on speech, nevertheless, it has been found to be of considerable importance in the operation of the telegraph circuits. The volume limiters used consist of a step-up transformer with the primary winding normally in shunt across the telephone channel, whilst a Neon tube is placed

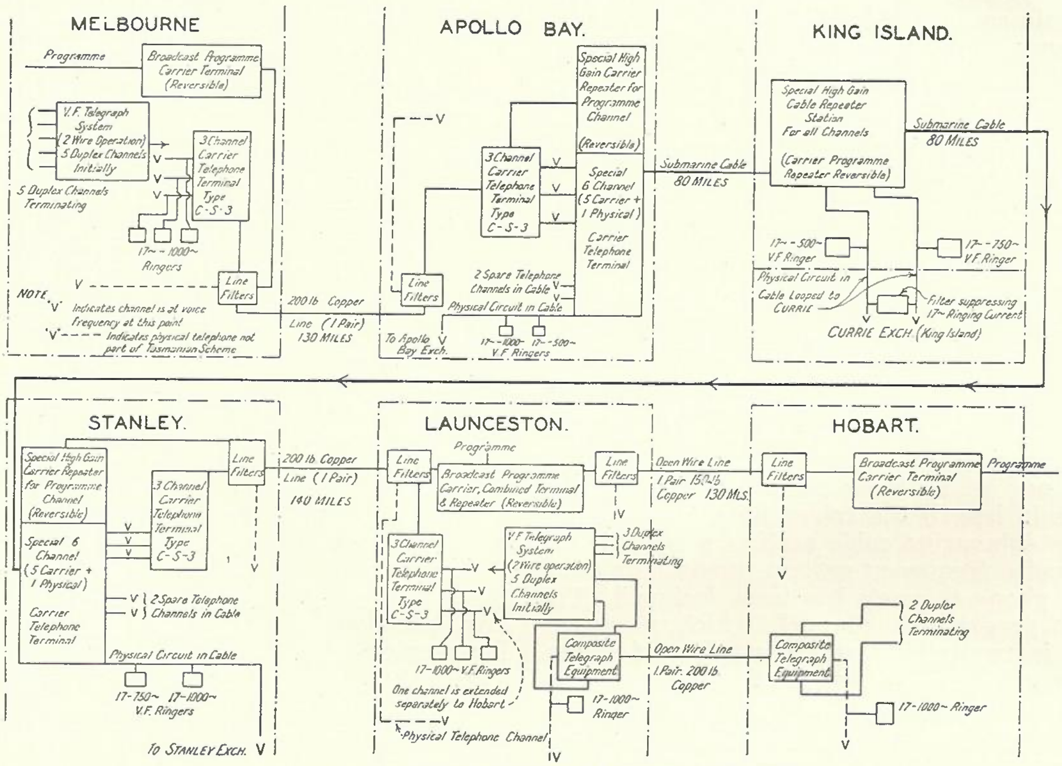


Fig. 1.—General Diagram of Installation.

LANDLINE CARRIER SYSTEMS.

The Type CS. carrier telephone systems which are used to provide the telephone channels are similar to those in use generally on the mainland. The system between Melbourne and Apollo Bay and the system between Stanley and Launceston are each complete systems, i.e., the various channels are brought to voice frequencies at the cable terminal station before they are introduced into the cable system. Pilot channels are provided between Melbourne and Apollo Bay and between Stanley and Launceston to enable the circuits to be maintained at their correct equivalents.

VOLUME LIMITERS.

Each telephone channel is provided with a volume limiter. This has been found necessary where voice frequency carrier telegraph systems are operated over one channel of a three-channel telephone system in order to prevent interference from the peaks of speech on the other channels affecting the telegraph signals. These peaks of speech have been found to momentarily over-

across the terminals of the secondary winding. In the event of a speech peak exceeding a predetermined value, the Neon tube strikes and places a low impedance across the telephone channel during the duration of the peak only.

EQUALISERS.

Equalisers have been provided on each channel so that a good overall quality could be obtained over three systems in tandem. It is not proposed to further describe these carrier systems, as they otherwise offer no unusual features to those already in use in Australia.

CARRIER SYSTEM ON THE CABLE.

In designing equipment for the cable section of the route, it was essential that the methods employed should permit of the fullest possible exploitation of the traffic carrying capacity of the cable. A telephone circuit is necessarily a duplex channel, and when amplifiers are employed in such a channel either the "Go" and "Return" transmission paths must be separated or else special measures must be taken at each point where amplification is required to prevent "singing" of the amplifiers due to feedback. As the cable consists of one transmission path only, this effect must be achieved in one of two ways, i.e., either by separating the directions of transmission by using different frequencies and corresponding filters for each direction or by balancing.

To quote examples of each method, the normal carrier channel employs separate frequency bands for transmission in either direction, giving in effect a 4-wire circuit, while the normal 2-wire repeatered line relies upon the balance of hybrid coils at each voice-frequency repeater where the telephone line is imitated by an artificial network. Speaking in telegraph terms, the arrangement is practically a differential duplex circuit.

The latter method offers the greater advantage, as it uses the same frequency band in each direction and, therefore, requires only half the frequency range of the normal carrier channel. It necessitates, however, the construction of an impedance matching network which will balance that of the line or cable to an extent depending on the amplification required and, hence, on the attenuation of the line. The principle is equally applicable to carrier channels as to the voice frequency channel previously mentioned. It was, therefore, decided to use as many of this type of channel as was practicable.

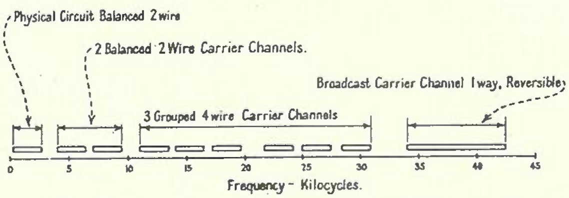


Fig. 2.—Frequency allocation, Submarine section.

In this connection, one property of the cable was of outstanding importance. Experience has shown that a co-axial cable of this type having paragutta insulation does not vary appreciably in its characteristic impedance and, therefore, a network which matches the cable on installation is likely to continue to do so.

The Bass Strait cable had been manufactured to exhibit such an impedance characteristic that it could be accurately matched with a network up to at least 10 kC. In the frequency range up to 10 kC three telephone channels of the balanced type are, therefore, provided, while between 10 kC and approximately 31 kC three further channels of the type using separate frequencies in each direction are provided. In the south to north direction the three channels are grouped and occupy the frequency range between 11 kC and 17kC, while in the north to south direction they occupy the frequency range of 21 kC to 31 kC. The programme transmission channel which also is provided in the cable occupies the band from 34 kC to 42.5 kC.

The frequency allocation is shown in Figure 2.

EQUIPMENT AT TERMINAL AND REPEATER STATIONS.

Altogether the whole installation makes use of 74 racks of equipment, not including three fuse panels since added by the Department. All equipment is mounted on the normal standard racks, 10 feet 6 inches high, and at each office forms a complete self-contained installation, including filter bays, battery supply bays, equipment bays, equaliser and loading coil panels, carrier systems, pilot equipment, Wheatstone bridge trunk test position, oscillator and volume indicator. At the three cable stations special testing equipment for accurate cable measurements is installed also.

Terminal Stations.

Commencing with the terminal stations, it is now proposed to briefly describe the equipment at each point.

Melbourne Terminal.

At the Melbourne terminal is all the equipment terminating the Melbourne-Apollo Bay landline section, apart from filters, protectors, etc. This equipment includes:—

- 3-channel carrier terminal;
- Broadcast carrier terminal;
- 3-channel pilot channel;
- Broadcast pilot channel;
- 5-channel Voice Frequency Telegraph System;
- Volume Indicator, and
- Heterodyne Oscillator;
- Associated Battery Supply Bays and Fuse Panels.

As already mentioned, the 3-channel carrier system is similar to those already installed on various main trunk routes. In addition, it is fitted with volume limiters and equalisers, and has an interesting variation in the ringing circuit.

The original project arranged for a telephone circuit between Melbourne, King Island and Launceston, with Stanley, Apollo Bay and King Island repeater stations connected to a special signalling circuit. So that communication could be established between any two of the three offices concerned, a multi-frequency ringing scheme was adopted involving the use of two ringing frequencies at each point. Two jacks wired to separate ringers were provided at each switchboard so that, on plugging into the correct jack, the operator could ring whichever of the other stations was required by sending out the correct ringing frequency. The frequency allocation was as under:—

Melbourne-Launceston—1,000 cycles;
Melbourne-King Island (Currie)—500 cycles;
Launceston-Currie—750 cycles;
these frequencies applying in both directions.

Under the present arrangement, Stanley takes the place of Launceston, but, otherwise the arrangement is unaltered.

Hence, if Stanley desires to call Melbourne, the telephonist plugs into the jack designated "Melbourne" and rings with the ordinary 17 cycles. This ring would be transmitted over a special pair of wires to Stanley repeater station, where it would be converted into interrupted 1,000 cycles and sent to line. The ringers at King Island, being tuned to 750 and 500 cycles, would not respond, so that Currie would not be called in unnecessarily. If Stanley had required Currie, a 17-cycle ring would have been sent out on the pair of wires connected to the 750-cycle ringer at Stanley repeater station, and Currie would have been signalled with interrupted 750 cycles, without disturbing Melbourne.

Similarly, Melbourne could raise Stanley alone by sending out 1,000 cycles, or Currie alone by sending out 500 cycles interrupted. A drop indicator is associated with each calling station.

To prevent any possibility of the 17-cycle current once reproduced at Currie again operating the opposite ringer and ringing an unwanted station, a special 17-cycle filter suppresser was installed between ringers.

Calling In Facility.

Bridged across the voice frequency line at each repeater station is a special calling-in circuit which will operate on either of the frequencies allotted to that station. By means of a special code ring a chain of relays is caused to operate, which brings in an alarm circuit and attracts the attention of the repeater attendant.

Reverting to the general installation, a schematic circuit of the Melbourne terminal is shown in Figure 3.

Bearing in mind that both the 3-channel system and the broadcast carrier are operated over the same physical wires, the circuit can be readily traced from the line terminal.

The physical line first comes through a compensator which introduces inductance to compensate for the effects of capacity in the office cabling. Then comes a normal high and low pass filter group having a 3,000-cycle cut-off, where the physical circuit is taken off to the switchboard via the low pass section. The excluded carrier frequencies have a free path through the high pass section, after which they encounter another pair of filters having a cut-off point at approximately 32 kC. The low pass section of this group allows the passage of all frequencies below 32 kC, and to the drop side of this filter is connected the 3-channel system terminal equipment comprising the usual directional filters for separating the transmitting and receiving frequencies and the associated amplifiers, modulators, demodulators, etc. (The special equalisers previously mentioned are connected between the hybrid coil and the modulator of each channel.)

The high pass section of the second group admits frequencies of 32 kC upwards, and to the drop side of this filter is connected the broadcast carrier terminal equipment. This system is almost identical with those already installed on main routes. It operates on a carrier frequency of 42.5 kC and synchronises both sending and receiving oscillators by means of the transmitted pilot frequency of 34 kC. A variation from the earlier systems is that the pilot oscillator in this installation has two outputs fed through separate tubes to supply line and local pilot current.

The broadcast channel uses ¼ ampere tubes throughout and the filament current is controlled by ballast lamps as hitherto.

The terminal being one-way reversible, the transmitting and receiving sides of the circuit are brought out to a key which switches either one or the other to the line filter. The key is actually a group of keys coupled mechanically, and also makes the necessary local circuit changes with respect to modulator and demodulator, etc.

With the key thrown to "TRANSMIT" the voice frequency line bearing the studio programme is connected to the modulator, to which also is supplied carrier from the local carrier oscillator. The carrier oscillator is kept on its frequency by a 34 kC pilot obtained from one output of the local pilot oscillator. The other output from the pilot oscillator transmits the same frequency to line to synchronise the receiving terminal carrier. The modulated carrier passes through the modulator and crystal filters to line, via the transmitting amplifier.

The pilot indicator at the sending end is disconnected during transmission.

With the key thrown to "RECEIVE" the line filter is connected to the receiving amplifier, which amplifies both programme and pilot received from the other end. The received pilot is filtered out and amplified and fed into the local carrier oscillator, and thus controls its frequency. The pilot indicator is bridged across the output of the pilot amplifier to indicate the incoming level. The local pilot oscillator is disconnected. The output of the carrier oscillator is switched over to the local demodulator, which also receives the incoming programme via the crystal filter group, and the demodulator output or, in other words, the actual programme is switched to the V.F. line.

It is interesting to note that the crystal filter group, consisting of the modulator filter, auxiliary modulator filter and crystal filter, are in circuit in both directions.

Voice Frequency Telegraph System.

A voice frequency telegraph system is installed at Melbourne, but is not yet actually connected to any particular circuit.

As this equipment will be made the subject of a later paper, no attempt will be made to describe it here other than to say that it is somewhat similar in operation to the well-known Type "B" telegraph carrier. It employs band filters in place of the familiar tuned circuits and includes an automatic volume control in its receiving circuit. The initial provision is for five duplex channels, capable of extension to nine, for operation on any one of the Tasmanian cable telephone channels. If, however, its use is restricted to the directional type of channel its capacity can be increased to 18 duplex channels. The equipment is compact and panel-mounted on both sides of the racks. It has the new aluminium finish.

The Melbourne terminal is supplied with a multi-frequency alternator which, from a series of armatures, produces the sending carrier frequencies. The system is not connected to any particular channel of the cable system, but can be patched in readily when required.

Associated with the voice frequency telegraph system is special distortion measuring equipment, by which a visual measurement of the signal distortion can be obtained on the screen of a cathode ray tube.

Transmission Measuring Equipment.

Also provided at Melbourne is a volume indicator, mainly to measure the level of the programme received from the studio or interstate relays, and a heterodyne oscillator for measurements within the voice frequency range. The frequency is continuously variable and is controlled by a single dial. Calibration is effected at 50 and 500 cycles by observation of the vibration of reeds tuned to those frequencies. The reeds are fitted to an ordinary gramophone pickup head which is connected to the oscillator output.

LAUNCESTON TERMINAL.

The equipment at Launceston is very similar to that at Melbourne, but the broadcast carrier terminal is more complicated owing to the fact that Launceston has also to function as a repeater in either direction. The testing equipment is identical with that at Melbourne.

The line and filter arrangements at Launceston are similar to those at Melbourne, and the 3-channel system terminal being practically identical further comment will not be made.

With regard to the broadcast channel, however, this is the first unit of this type installed in the Commonwealth, as it combines with the functions of a receiving repeater those of a branching transmitter, one of the requirements of the Launceston equipment being that it shall be able to transmit a Launceston programme to both Melbourne and Hobart simultaneously.

So far as the components of the Launceston equipment are concerned, these are like those at Hobart and Melbourne. The arrangement of switching keys, however, is somewhat different. The directional key, i.e., A-B and B-A, is mechanically separate from the "TRANSMIT and RECEIVE" keys, as it will be seen that the necessity may often arise for a reversal of direction of the station, whilst it continues to function as a repeater. To operate as a repeater the station "TRANSMIT and RECEIVE" key must be in the "RECEIVE" position. It will be seen, by reference to Figure 4, that the equipment includes two transmitting amplifiers.

Perhaps it would be preferable to first trace the circuit of the Launceston equipment when it is being used as a repeater in the Melbourne-Hobart direction.

Broadcast carrier frequencies will pass through the 32 kC high pass filter, through the directional key in the B-A direction, through the usual line equalisers to the receiving amplifier. Ignoring the local demodulating path for the moment, these currents now pass through a pad to Transmitting Amplifier No. 1 via a spring of the "RECEIVE" key. From Transmitting Amplifier No. 1 the carrier frequencies pass through the B-A key again, through another high pass filter to the physical circuit leading to Hobart via the normal line filter group. (In this case the physical line is also composited, as two duplex telegraph circuits are required to extend the voice frequency telegraph system to Hobart.)

With the directional keys thrown in the opposite direction it will be seen that the repeated current will pass through exactly the same apparatus as previously. Transmitting Amplifier No. 2 is only used when Launceston is transmitting.

Now take the case when Launceston is repeating, but also demodulating. At the output of the receiving amplifier are two parallel paths, one through the pilot filter to the pilot amplifier, and the other through the crystal filter group. The received pilot frequency having passed through the pilot filter, is amplified and used to synchronise the local carrier oscillator in the usual way. This, in turn, supplies carrier frequency to the demodulator, which also receives broadcast carrier sideband current via the crystal filter. The output of the demodulator is switched to the studio or V.F. line. These conditions are exactly the same in both directions of transmission, Hobart-Melbourne or Melbourne-Hobart.

Next take the case when Launceston is required to transmit to the other stations. The "TRANSMIT and RECEIVE" key is thrown to "TRANSMIT." This immediately supplies pilot oscillator output of 34 kC to the local carrier oscillator, and also to the output side of each of the transmitting amplifiers, so that the Launceston pilot oscillator now synchronises the carrier oscillators at all three stations. The crystal filter group is swung over to the output of the modulator and the carrier frequency is fed to the modulator instead of the demodulator. The V.F. circuit or studio is connected to the input of the modulator. Modulated 42.5 kC carrier is, therefore, transmitted via the modulator filter, auxiliary filter and crystal filter by the appropriate springs of the transmitting key to the centre point of the two transmitting amplifiers, and is thus transmitted to Hobart and Melbourne. The A-B keys play no part in the transmission other than that of interchanging the transmission lines with the two amplifiers. In either position both Hobart and Melbourne will receive Launceston's programme.

Voice Frequency Telegraph System.

The voice frequency telegraph equipment at Launceston is similar to that at Melbourne, with the exception that, instead of the multi-frequency generator supplying all carrier frequencies, we have separate oscillators for each sending channel. The distortion measuring equipment is electrically identical with that of Melbourne, but made up into portable form.

Extended Circuits.

On reference to the Launceston schematic, it will be noticed that Channel 1 of the 3-channel system, Launceston-Stanley, is cross-connected to the Type FA single channel carrier system going to Hobart. It will be seen that both ends of the hybrid coils are connected in the so-called "Tail-chasing" connection. This arrangement avoids the loss of half the energy in each of the hybrid coils. A reversal is put in one side of the "Tail-chasing" connection to preserve the correct phase relationship. It will also be noticed that the physical circuit carrying the Hobart-Launceston section of the broadcast carrier is also composited. The composite leg will carry the special telegraph duplex circuit by which channels of the voice frequency telegraph system will be extended to Hobart.

The duplex telegraph equipment is panel-mounted on standard panels and includes transmitting and sending relays, together with balancing equipment, cross-fire balancing equipment and a transmitting filter on each sending leg. These measures will contribute largely to the successful operation of the comparatively high-speed telegraphy over the composite channel.

The total number of bays of equipment installed at Launceston is 12, not including a fuse panel and a relay adjusting table. An interesting feature of the Launceston installation is that the battery charging plant consists entirely of copper oxide rectifiers instead of motor-generators. This move was necessary because of space limitations and maintenance considerations.

HOBART EQUIPMENT.

At Hobart is installed the broadcast carrier terminal, the telegraph duplex equipment and, as at the other stations, a heterodyne oscillator and a volume indicator. These various equipments have already been mentioned in connection with the other stations, so further comment need not be made.

REPEATER STATIONS.

Apollo Bay.

The equipment at the repeater stations differs somewhat to that at the terminal stations. At Stanley and Apollo Bay the racks are arranged in two rows facing each other, the landline equipment in one group and that directly associated with the cable itself in the other group. Figure 5 shows the cable and landline equipment at Apollo Bay.

At this station, as also at Stanley, the landline telephone channels are demodulated to voice frequency and connected to the cable equipment, where they are again modulated for transmission through the cable at slightly different carrier frequencies. The broadcast channel is not demodulated at the cable terminal and, consequently, Apollo Bay, King Island and Stanley stations all function as repeaters only. Figure 6 shows the interconnection of the land and cable channels at the cable terminal stations.

It will be noticed that Cable Channels 1, 2, 3 are not connected consecutively to Landline Channels 1, 2 and 3. The change-over is due, partly, to the fact of the physical circuit, i.e., Channel 1 of the cable being originally installed as an Apollo Bay-Stanley trunk, and partly because of the improvement possible in overall quality by placing three selected channels in tandem. It will be noticed that Channel 1 has been taken into King Island to provide Currie with a telephone circuit. Channel 1 is the only channel operating throughout at voice frequency, as all other channels have been transposed to carrier frequencies. Consequently, to bring out any of the other channels at King Island would have meant fitting demodulators and modulators at that station, together with a more complex filter arrangement.

All the telephone channels are led, at voice frequency, into the hybrid coils of what may be regarded as a special 6-channel system connected to the cable. The physical channel is handled by a special 4-wire voice frequency repeater and the other five channels are connected to modulators and demodulators. Channels 2 and 3 operate on the same carrier frequency in each direction and rely upon the accuracy of the cable balance for their operation. The other three channels transmit separate frequencies in each direction and are, therefore, stabilised or prevented from singing by the use of directional filters.

It will be seen, therefore, that the filter arrangement will need to be such that all frequencies up to 9 kC are transmitted in both sending and receiving directions, whilst the "grouped" or directional frequencies must only be transmitted in the proper direction, i.e., frequencies from 9 to 20 kC in the Stanley-Apollo Bay direction, and from 21 to approximately 31 kC in the opposite direction. The band between 9 and 20 kC must be eliminated in the Apollo Bay-Stanley direction. Figure 7 shows a schematic circuit of the Apollo Bay station.

A 20 kC low pass filter is used in the A-B direction and a band eliminating filter 9 to 20 kC in the B-A direction. All six telephone channels are combined at their outputs on the transmitting side and fed into a common transmitting amplifier leading into the cable.

On the receiving side the frequencies of all channels incoming from the cable are amplified by common amplifiers before the six channels are separated as physical and carrier circuits. Amplification given on the receiving side is by means of two amplifiers in tandem offering, if necessary, a total gain of approximately 100 db. The second amplifier is specially designed to deliver a high output power level. Filters and equalisers are introduced to overcome variations in attenuation at the different frequencies, and to limit the frequencies to be handled by the amplifier so that those serving no purpose may be eliminated. The modulators and demodulators of the cable system are connected to the hybrid coils in the usual way and the hybrid coils of the cable system are connected by the "Tail-chasing" method to those of the landline systems.

The hybrid coil connected to the cable itself performs a similar function to the hybrid coil in a voice frequency repeater, and it is in the accuracy with which the balance network imitates the cable characteristics that the stability of the system depends. Very special precautions have been taken in the design and manufacture of the hybrid coil, even the wires leading to testing jacks being disconnected until they are actually required, when they are joined up by means of special U links.

The cable balance network is of a 3-stage type, containing three sections of resistance and capacity. The characteristic impedance of the cable is approximately 52 ohms, but as the equipment is designed to 600 ohm terminations matching is effected by means of suitable transformers.

Broadcasting Repeating.

It will be seen that adjacent to the cable are filter groups which enable the broadcast carrier to be separated from the carrier telephone frequencies. The amplification provided on the broadcast carrier consist of two amplifiers in cascade, together with the necessary pads and equalisers. By means of the switching keys provided the chain of amplifiers and equalisers can be switched in either direction, and the correct amount of equalisation adjusted by special keys on the equalisers themselves. The amplifiers are identical with those used for the telephone carrier frequencies. As there are broadcast filters on both transmitting and receiving sides of the cable, and only one of these will be used at a time, switching keys are arranged so that the unused filter will be terminated in 600 ohms.

Bridged across the centre point of the two broadcast amplifiers is the pilot indicator. This is adjusted to show a normal deflection when the correct level is being transmitted.

Testing Equipment.

At Apollo Bay, King Island and Stanley sensitive testing sets comprising Bridges and Reflecting Galvanometers are installed, so that accurate measurements can be made on the cable itself. Regular routine tests are carried out, so that any variation in the characteristics of the cable can be detected promptly.

Stanley.

The equipment at Stanley is practically identical with that at Apollo Bay. The opposite directional groups of frequencies will be transmitted and received, resulting in changed filter groupings, but in other respects there is no alteration. The physical channel is brought out to the pair of special ringers. Two loops are employed between the repeater station and the P.O., so that Stanley Post Office may signal Currie or Melbourne at will. In this respect the arrangement differs from that at Apollo Bay, where the circuit is now joined straight through to a physical circuit and carrier to Melbourne. Special ringing units, having two loops to the switchboard, are installed at Melbourne, as already described.

Testing equipment at Stanley is identical with that at Apollo Bay.

King Island.

King Island presents the simplest arrangement of the three cable stations. It differs from Apollo Bay and Stanley, firstly, in that it has no modulating or demodulating equipment and, secondly, that each side of the office is terminated in a submarine cable. King Island is approximately at the electrical centre of the cable, the variation on each side being only very slight. Figure 8 shows a schematic of King Island office.

The equipment immediately adjacent to the cable is similar to that at Apollo Bay and Stanley. A filter group separates the broadcast carrier which is amplified by a similar pair of amplifiers in series and having the usual arrangement for reversing the direction. The pilot

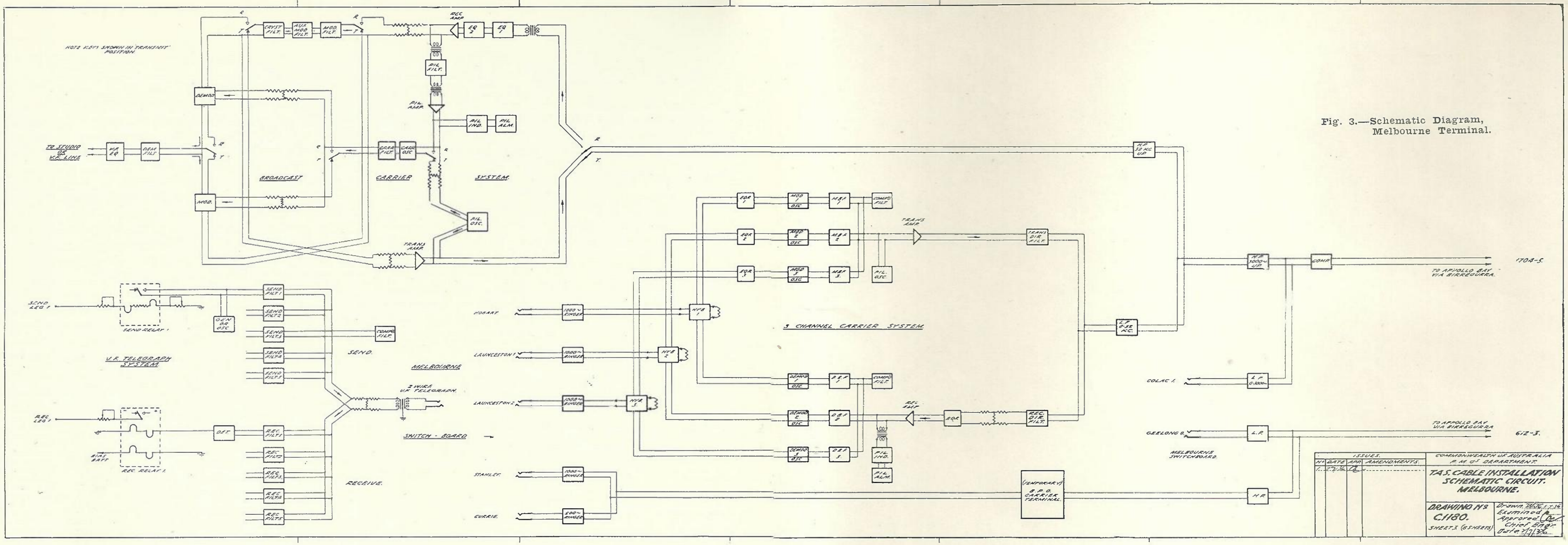


Fig. 3.—Schematic Diagram, Melbourne Terminal.

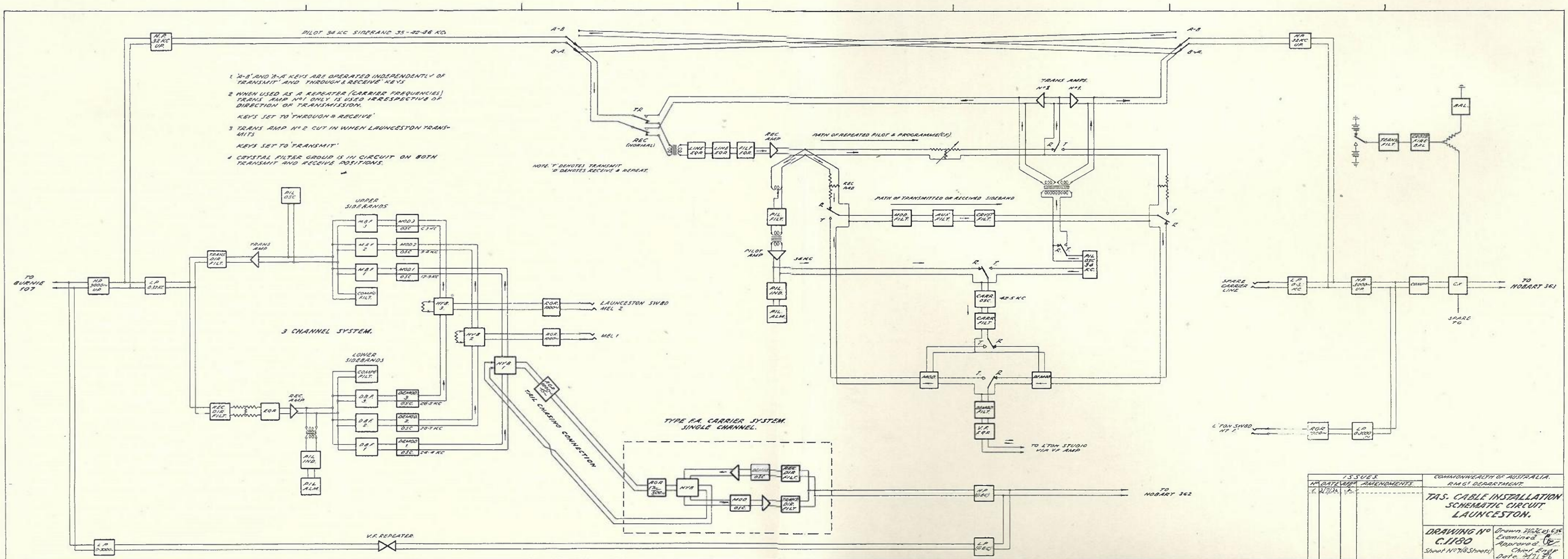


Fig. 4.—Schematic Diagram, Launceston Equipment, excluding V.F. Telegraph.

indicator is connected in the normal manner.

It will be seen that on the telephone side a normal low pass filter separates the physical channel from the carrier channels, which are separately amplified. The filter groups show the same discrimination in the A-B and B-A direction as at the terminal station. The 4-wire repeater for the physical circuit is similar, and the physical circuit having once been filtered out, is sent to Currie and back from the Naracoopa repeater station over two separate loops. At Currie special provision at the switchboard, which is not shown in full on the schematic diagram, arranges for proper terminations on either side of the circuit when speaking to the opposite side. Volume limiters and the special 17-cycle suppresser already mentioned are fitted at the Currie switchboard. The same ringers which are used to signal to and from Currie are also employed to operate the mechanic's calling-in device which, as mentioned in previous paragraphs, operates on a code ring. As at the other stations, a heterodyne oscillator is supplied, together with a trunk test board fitted with Wheatstone Bridge, as well as the special cable test set.

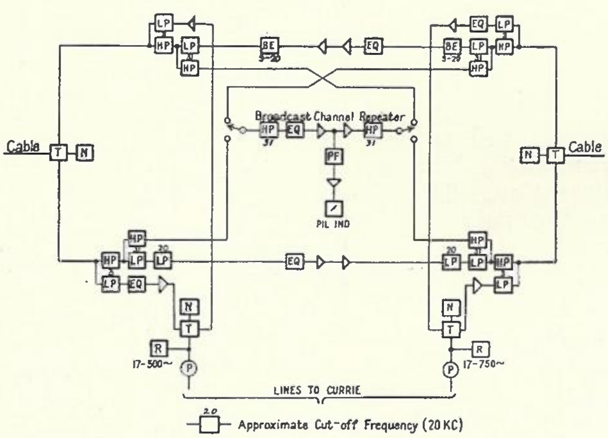


Fig. 8.—Schematic King Island Repeater Station.

Any further description of the various equipments at the cable stations does not come within the scope of this paper, but a brief description of the power plant should prove interesting.

Power Plant.

In the main, standard voltages, i.e., 24 Volts negative for the filament and 130 Volts positive for the plate current, are used to operate all the equipment associated with the Tasmanian cable. At Melbourne, Launceston and Hobart the existing power plant has been suitably increased to meet the demands, whilst at Apollo Bay, King Island and Stanley complete new battery installations have been carried out. At King Island and Apollo Bay the entire charging is done by petrol-driven generator sets, the 4-cylinder petrol engines driving direct coupled plate and filament generators. A 24-gallon reserve tank provides the gravity feed to the petrol engine, whilst storage for 500 gallons is provided in an underground tank outside the building. Large galvanised tanks are provided to cool the circulating water.

At Stanley a special three-phase main was run to the repeater station from the Hydro-Electric Supply, and charging is normally carried out by the motor generator set. An emergency petrol engine, however, is installed, and this is similar to those at Apollo Bay. Adequate spare parts are also held to cater for any normal breakdown.

The power plant at Launceston is of particular interest, as this station, by reason of the heavily congested floor space, has to be operated entirely from copper oxide rectifiers. New batteries were installed simultaneously with the rectifiers, which are built integral with the associated power board installation. The power equipment at Launceston is operated practically on an unattended basis, and the whole installation, comprising copper oxide charging units, meters and switching gear for 24-Volt, 8-Volt, and 130-Volt batteries, only occupies a space of approximately 10 feet x 2 feet. (The 8-Volt battery is used for metering in the C.B. Exchange.) The 24-Volt rectifier uses groups of 20-Amp. plates, air cooled by means of a fan, and gives an output of 120-130 Amps. The 130-Volt section employs naturally cooled disc elements and delivers a maximum output of 10 Amps.

Conclusion.

The equipment which has been described was supplied by Messrs. Standard Telephones and Cables Ltd. and was installed by Departmental labour under the supervision of Installing Engineers of that company, and the authors desire to take this opportunity of expressing their appreciation to those gentlemen for their courtesy and co-operation.

Thanks are also due to the publishers of "The Electrical Engineer and Merchandiser" for the loan of blocks used in this article.

LINES AND NETWORKS OF THE NORTH-WEST COAST

C. F. Cook

THE long coastline of north-west Australia is served by a number of important ports spaced roughly two to three hundred miles apart. Named from the west, these townships are Onslow, Cossack (the port for Roebourne), Port Hedland (which serves the Marble Bar district), Broome, Derby, and Wyndham. Of these ports, Broome is the most important. Though many Government officials are stationed there, it really depends on pearl fishing, or rather pearl shell, as good pearls are rare finds. In fact, the very mention of the name of Broome conjures up in one's mind thoughts of pearling lugger fleets, divers and heaps of pearl shell. However, in common with the other ports mentioned, it provides an outlet for the cattle and sheep stations which take up most of the extensive but sparsely inhabited inland area. Almost all the business of the north-west country is transacted with distant parts and goes through the coastal towns, so that efficient communications are essential.

Practically all food is brought from the south by boat, and the ordering and transportation of perishable goods present special difficulties which cannot always be satisfactorily dealt with by the normal mail, and even the speedy and regular Air Mail Service is sometimes not fast enough to satisfy urgent requests for supply of commodities required to be forwarded by the first boat. Hence the telegraph is relied upon for all kinds of business, varying from the order of an immediate supply of a bag of cabbages to deals involving tons of mother-of-pearl shell. Independent telephone circuits between the ports are at present hardly justified, but a condenser circuit is superimposed on the telegraph line. This is, of course, only a low-grade service and often is scarcely workable.

Telegraph Circuits.

The main telegraph line between Perth and Wyndham is, perhaps, the longest direct line in the Commonwealth. The total length is about 2,000 miles.

It is worked duplex from Perth to Broome and extended as a simplex line from Broome to Wyndham.

Repeaters are situated at Mullewa, Marble Bar and Broome. The pole route comes overland from Perth almost to Broome before it reaches the coast.

Another line from Perth follows the coast to Port Hedland and connects with the inland line at Marble Bar with repeaters at Geraldton, Carnarvon and Roebourne. It is duplexed and provides an alternative route to the northern ports if necessary. This line suffers from the effects of the moist salt-laden air on the coast.

In the north-west the difficulties of erecting and maintaining a line are very great.

Owing to the ravages of white ants in wooden poles the use of iron poles is absolutely necessary, and these are generally of tubular construction, 16 or 18 ft. long. Often for hundreds of miles the line consists of only a single wire.

Unique Maintenance Difficulties.

It may be of interest to refer to the faults which occur on these lines. The most common is low insulation, especially on the coast line, where the moisture deposited from the damp air gives a leak to earth at each insulator. The duplex line sometimes has to work at the low value of three milliamps of received current, with consequent difficulties of balance and relay adjustment.

In some districts large flocks of parrots will settle on the line, and the combined weight of a span full of them is sufficient to break a wire of light gauge.

Parrots have been known to swing around on their beaks on a line, and the nick made in the wire has subsequently caused a break. A V.I.R. insulated wire also excites the curiosity of parrots, and this particularly applies to tame ones should they escape from captivity, for, by stripping the insulation from the wires, they cause unexpected troubles.

The insulator seems to have a special attraction for a species of wasp which is inconsiderate enough to build its nest of mud inside the skirt of the insulator, and, to add insult to injury, exudes an acid which corrodes the iron spindle, so that it may be reduced gradually until it finally breaks off.

A fault giving low insulation was caused on one occasion by a hawk leaving the remains of a snake over an insulator. On the Christmas Eve of 1934, when the traffic was just beginning to accumulate, the line between Broome and Derby failed completely, due to an open circuit. A car was sent out from Broome and it was found that the line had been cut by a swagman who had used this means of calling attention to his need of a lift into Derby.

In addition to these and other general faults, there is the liability of widespread damage from the severe storms which occur in that part of the Commonwealth. From December till March there is always the likelihood of a cyclone striking the coast and doing damage to anything in its path. There are two types of storms, known locally as "willy-willy" and "cock-eye." The

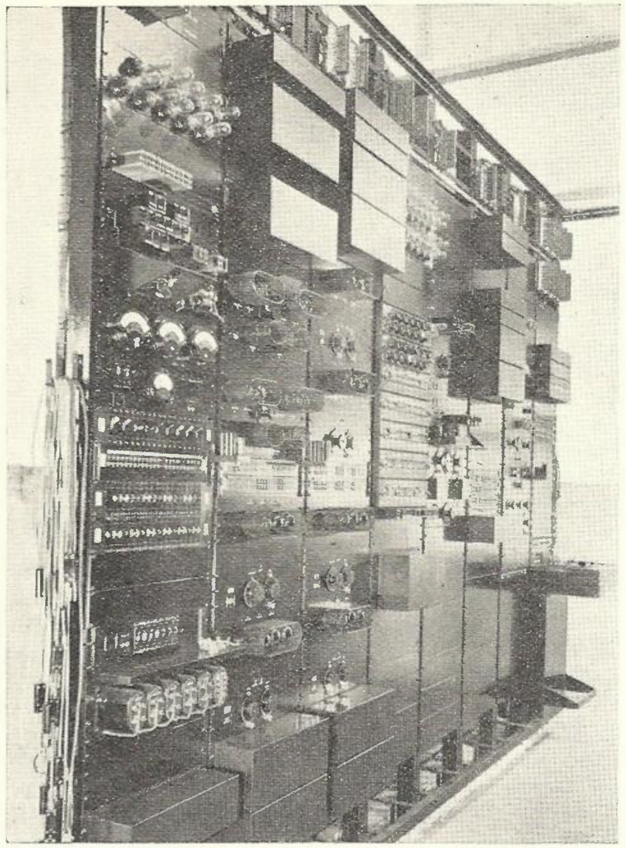


Fig. 5.—Cable Equipment at Apollo Bay.

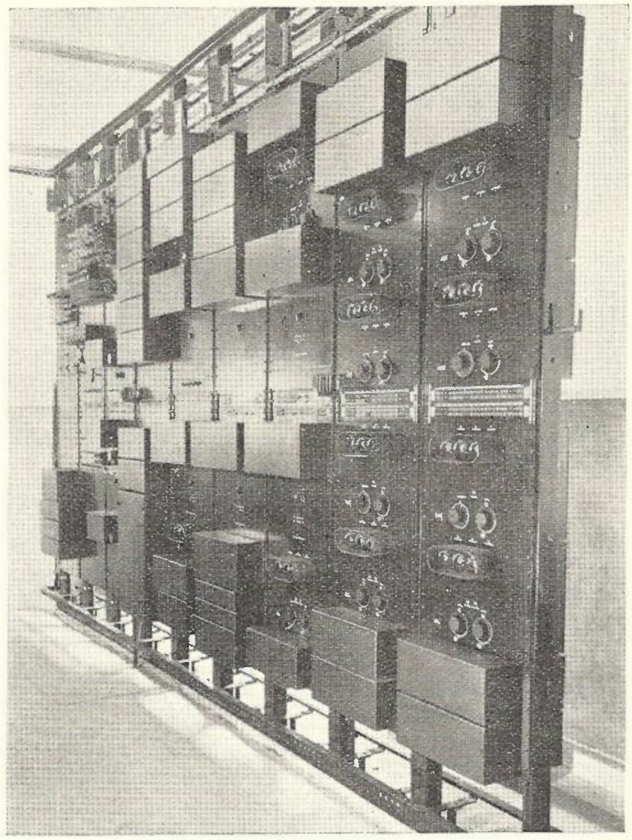


Fig. 5.—Landline Equipment at Apollo Bay.

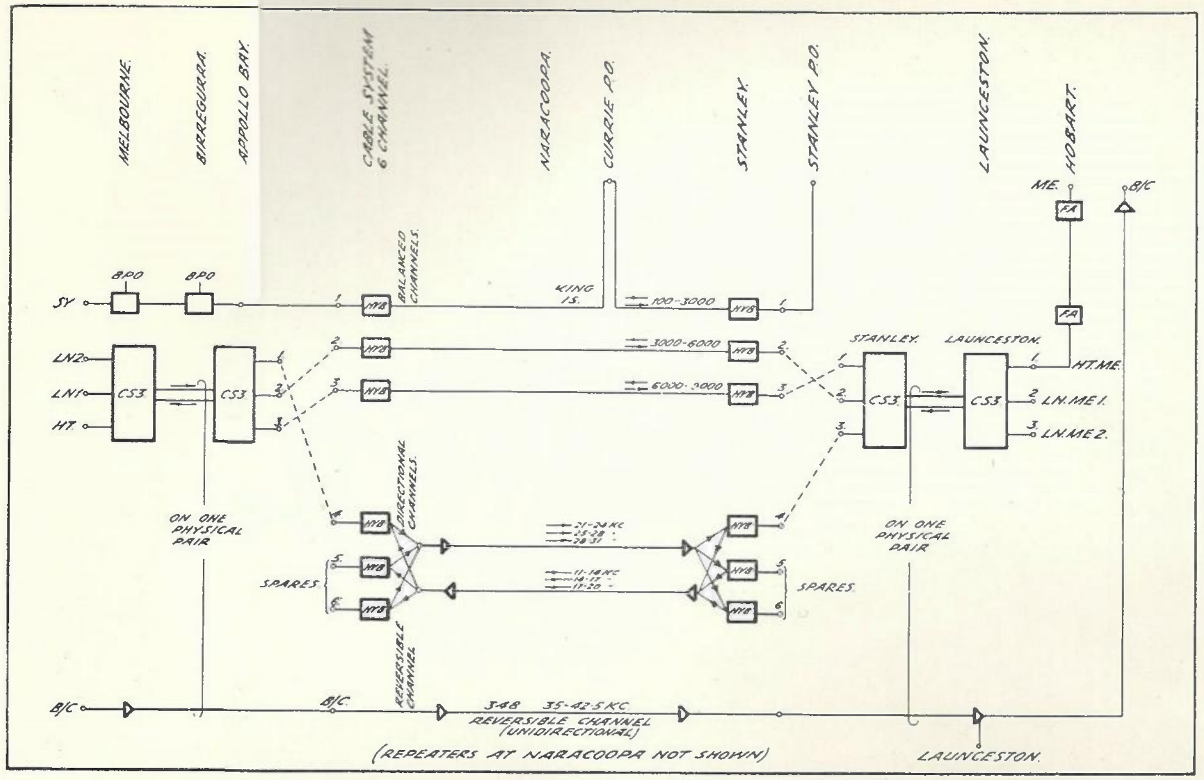


Fig. 6.—Interconnection of Channels—Landline and Cable Systems.

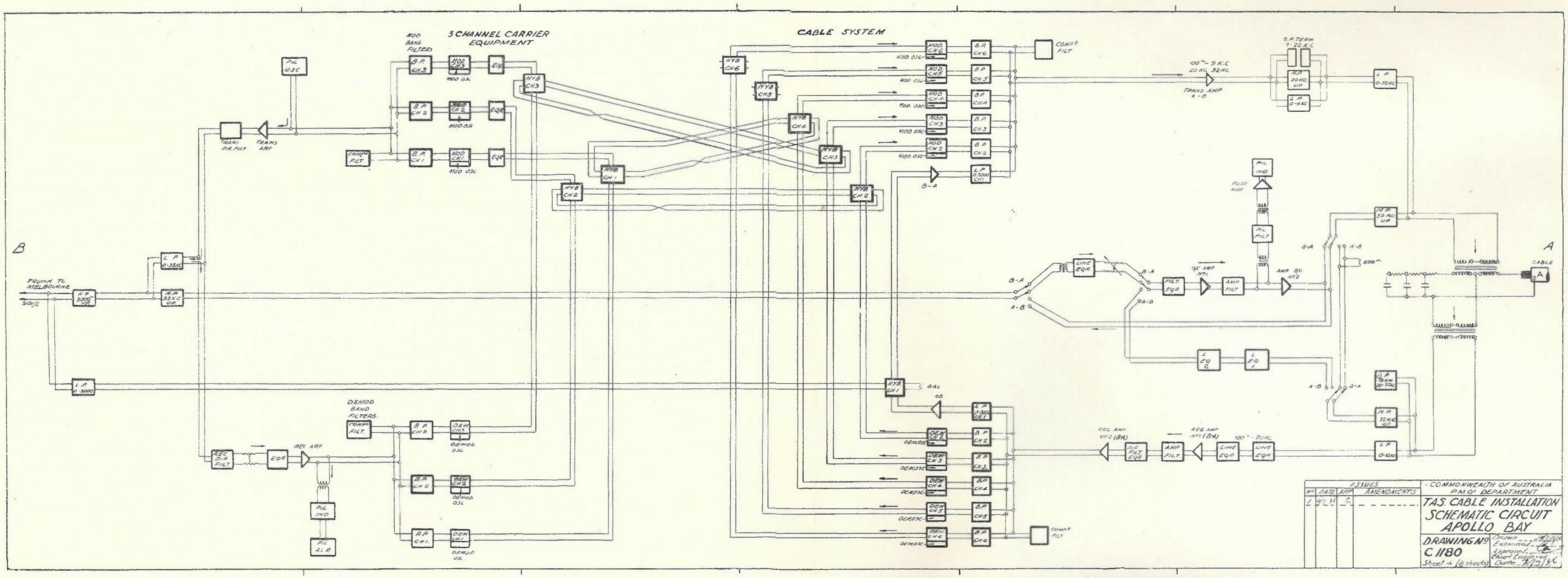


Fig. 7.—Schematic Apollo Bay Repeater Station.

willy-willy is really a cyclone, and is indicated in its approach by a falling barometer. The wind rises to hurricane force till it is impossible to walk against it. In the towns debris is blown along the streets and collects in heaps against the fences. Trees are uprooted and roofs of houses lifted, and everyone has to stay indoors till the storm is over. Not content with causing so much inconvenience, it usually finishes by raining for a day or two. A "cock-eye" is a local thunderstorm, and is indicated by a bank of fleecy clouds inland, which gradually spreads overhead. There is little wind at first, but with a sighing sound the wind rapidly increases in intensity and comes in gusts to the accompaniment of terrific thunder and lightning. These storms do not last long.

In January last the poles of the telegraph line near La Grange were blown down for miles by a willy-willy and were lying in two feet of water, whilst the lineman at Wyndham had to travel 140 miles to reach a fault which was only 10 miles away in a direct line.

In these parts rivers are marked by the sandy or rocky beds, perhaps 200 yards wide, and in other places with banks 20 or 30 feet high. Normally the small stream or series of pools occupies the centre of these courses, and if a line crosses on poles placed in the bed there is plenty of clearance. However, with the advent of rain inland, the river rises out of all proportion to its normal height, and it is not unknown for a telegraph line to be covered with flood waters even with the poles upright.

The arrangements now made for the line to cross at these places is to erect on each bank a 60-foot tower, and the long span between the two will, even with the sag, be out of the reach of flood waters.

Travelling Along the Line.

It is necessary for the lineman, every month or so, to make regular inspections of the lines under his care. When this journey is made over the route, the lineman usually takes a horse and cart to allow him to carry the necessary equipment for the maintenance of the line and also for camping each night. The tracks are often very poor, and sometimes impassable in the wet season, so that devious routes have to be taken to reach certain sections. In some districts run-about cars are being used, which results in greater efficiency in clearing faults.

The lineman at Broome, when on inspection trips, is usually accompanied by an aboriginal helper named Joe. This particular aboriginal is a faithful old fellow who has been associated with the Post Office for many years. He shares the duties of the inspection of the line, and is useful for such jobs as keeping the fire pot alight and guarding the bottom of the ladder. In addition, he is a useful companion in case of emergency or sickness. Sometimes, however, his attention is distracted by the possibility of the capture of a large goanna, which would provide a treat for his friends on his return.

There are aboriginal helpers at other linemen's stations, who are kept in food and clothing and given a few pence a day in return for their services; but often they are not worth the trouble of looking after them. The photograph, Fig. 1, shows the Onslow lineman with his outfit.

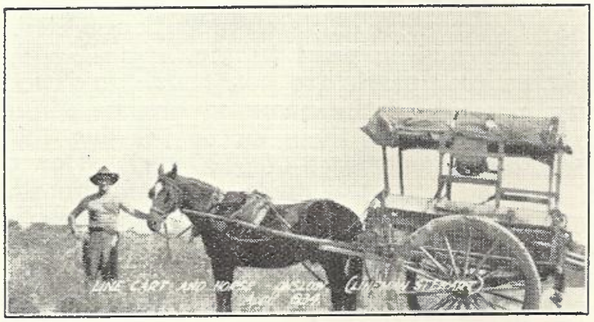


Fig. 1.

The subscribers' network in Broome is interesting because of the unusual type of poles used. In the main streets the wires are supported by double poles—iron, of course—one on each side of the footpath, and 17 way arms between them. The wires are thus directly above the footpath. At cross streets four poles are used with arms on each side of the square so formed.

The cosmopolitan population of Broome uses many languages, and this adds to the difficulties of the manual magneto system which is installed. The number of subscribers has fallen off considerably during the last few years, due mainly to the drop in price of pearl shell. At present the number connected is about 75. Whilst the mechanic's duties may not be very exacting technically, they are made arduous by the vast area to be covered. An inspection of the apparatus at the various offices is made annually, or more often if necessary. The regular boat service is used to get to the various ports, but owing to the variations in the tides it is often necessary to wait almost a fortnight for the next boat.

The care of the telegraph lines and apparatus occupies a considerable proportion of his attention, but each port or township has its local exchange, which is inspected and overhauled.

If you have any doubt about the difficulties with which an officer has to contend when carrying out even the ordinary duties on the North-West Coast, perhaps the following will help to convince you that sometimes there are unique experiences to be had. A report of an inspection by Lineman L. N. Stewart, of Onslow, has been made available for inclusion here, and it gives first-hand information which should be of interest:—

"As we had fine weather and the roads were dry, I left Onslow at 8 a.m., Monday, on an inspection trip of the South Section with one horse in the cart. The camp was pitched on the bank of the Ashburton River, 20 miles out from Onslow. During the night a 'cock-eyed bob' blew the tent over, and approximately one inch of rain fell, wetting everything.

"Leaving at 8 a.m., I travelled along the line to the section end on the bank of the Ashburton River, 29 miles out, and put in a test point. It

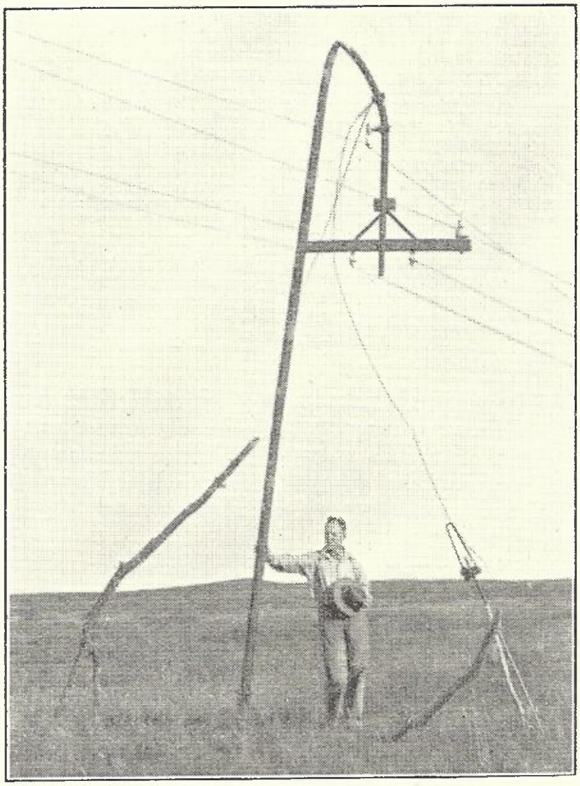


Fig. 2.

started raining at 1.30 p.m., and the camp was set up at 6.30 p.m. It rained approximately eight inches during the night, and at 5 a.m. blew the camp over. The wind was freshening all the time, so I packed up everything and stowed it in the cart and tied it down, turned the back of the cart to the wind, chained both wheels and put a log through the under-cart, and tied the axle to a tree with a piece of 200-lb. wire. The river was running a banker, 30 feet high, and a stream of water one mile wide was coming down parallel with it. At 8 a.m. the hood of the cart blew off and, as the position was becoming desperate, I took the horse and waded with him through water waist deep for two miles to a sandhill. The wind was coming with hurricane force from the south. I was forced to let the horse go on the sandhill, and the last I saw he was being driven before the wind in a stream of water a mile wide, heading towards the river. There are several sandy rises before the river is reached, and it is possible he may have got to one of these. Stones, bushes, sand, Spinifex bushes, etc., were flying through the air and making it impossible to see even 50 yards. The wind had now turned to the east and was blowing a hurricane. As it had been impossible to light a fire the night before or that morning, I had had no hot food, and as all the food was in the cart I had had no breakfast. It was impossible to return to the cart, even if it was still there, so I decided to attempt to reach Onslow, about 20 miles away, or at least get to high ground before the main body of the water became too deep. Travelling along the line to the transformer box—18 miles out—I crawled, swam, was blown or ran from pole to pole. The willy-willy was howling, and all the country, with the exception of the top of a few sand rises, was from one to five feet under water. Practically

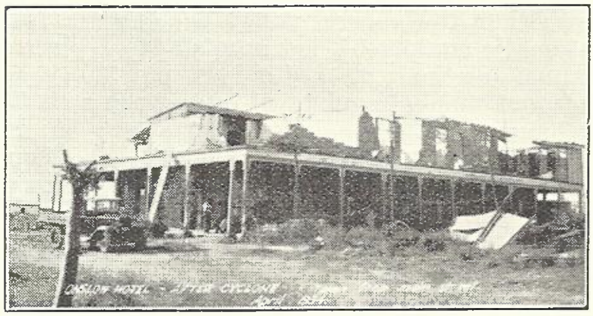


Fig. 3.

every pole was lying over from east to west, but as this section of six miles is of beam or 18-inch pipe poles, none were broken; some were bent. Arms, wire, etc., were all intact, as far as could be seen at this time. As the water was rushing past them, three feet deep for miles, some poles are probably washed clean out.

"I reached the junction pole—11 miles from Onslow—at 3 p.m., when the willy-willy had just about blown itself out, but it was still raining hard. I should reckon approximately 12 inches fell during the day. From the junction pole to Onslow, approximately 11 miles, practically every pole was either broken off at the base, or the base itself was broken. Pipe poles were bent over and telescope poles near road crossings were bent over above the stays. As practically every pole head, arms, wire, etc., were under water, it was impossible to gauge the damage.

"I reached Onslow at approximately 7.30 p.m. All camp equipment, tools, harness, personal belongings, etc., in cart. Fate of the horse and cart is unknown at present."

The photographs, Figs. 2 and 3, show the effect of the storm on the line and the buildings in Onslow.

AUTOMATIC TELEPHONE SWITCHING.

APPLICATION OF RECENT DEVELOPMENTS TO THE COMMONWEALTH SYSTEM.

R. V. McKay, A.M.I.E. (Aust).

INTRODUCTION.

In recent years, important fundamental changes have been occurring in automatic telephony. It is, therefore, intended to make some reference to those developments which have a present bearing on the automatic switching system used in the Commonwealth. It is also intended that these notes shall be supplemented by a series of later contributions, describing in further detail particular phases of the new developments.

GROWTH OF THE AUTOMATIC SYSTEM IN AUSTRALIA.

Following the trial of a 100-line automatic unit at the G.P.O., Sydney, in 1911, the first automatic exchange in Australia was installed at Geelong (Victoria) in 1912, capacity 1,100 lines. Since then the general policy has been to install automatic equipment, not specially to replace the manual method of switching, but to replace worn-out manual equipment or to open additional exchanges. The main problems are in New South Wales and Victoria. The following figures show the growth in the number of automatic telephones in these two States and the Commonwealth, in periods of four years since 1914. It is interesting to notice the halt during the depression years and the rate at which the automatic total is overhauling the manual total, although so many of the manual telephones are in the country, where automatic switching has been introduced to a very limited extent owing to the special difficulties involved.

Year	New South Wales Auto.	New South Wales Manual	Victoria Auto.	Victoria Manual	Commonwealth Auto.	Commonwealth Manual	Commonwealth Total
1914	3,150	53,452	2,506	39,836	10,136	132,590	142,726
1918	13,308	68,535	3,336	53,636	22,747	174,863	197,610
1922	26,140	82,796	12,282	68,897	49,305	220,703	270,008
1926	59,318	101,106	28,728	104,490	111,201	313,241	424,442
1930	92,020	106,987	56,284	104,097	207,510	312,659	520,169
1934	94,285	94,309	55,875	101,927	208,778	292,624	501,402
1936	113,930	101,873	68,043	109,354	249,984	312,884	562,868

Year	Metropolitan (All States) Auto.	Metropolitan (All States) Manual	Country (All States) Auto.	Country (All States) Manual	Total (Commonwealth) Auto.	Total (Commonwealth) Manual	Total (Commonwealth) Total
1914	8,931	82,082	1,205	50,508	10,136	132,590	142,726
1936	242,938	92,218	7,046	220,666	244,984	312,884	562,868

EXISTING AUTOMATIC EQUIPMENT.

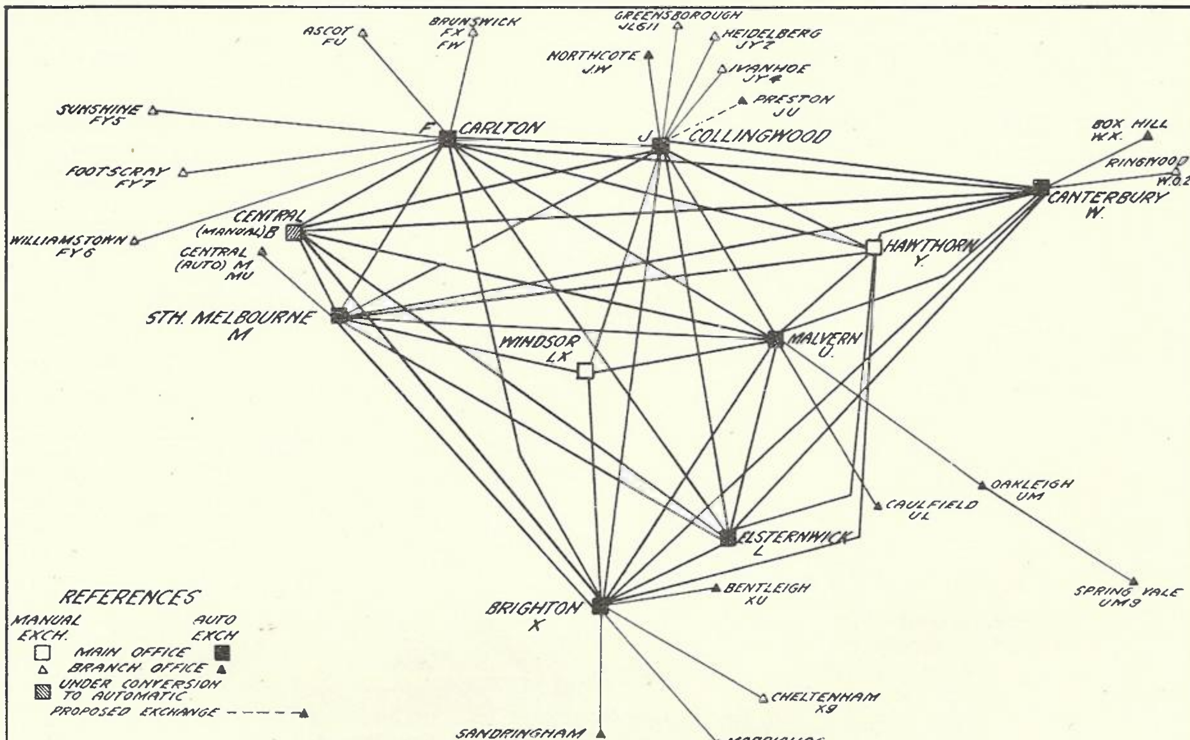
Some reference to the type and distribution of the existing equipment will be given because the extension of this equipment, in order to meet the growth of the service, is an ever-present problem and it becomes more difficult when newly developed types of equipment are to be considered for introduction into existing networks, where several different types are already in service. In the space available, only a very general classification can be given. The figures for lines and telephones are for June, 1935.

Type	Exchanges		Lines	Telephones
Automatic Electric Co., Chicago (Keith)	Geelong	1	71,388	101,542
	Melbourne	7		
	Perth	1		
	Sydney	10		
Automatic Electric Co., Chicago (uniselector)	Melbourne	5	29,639	35,304
	Perth	2		
	Sydney	10		
Automatic Electric Co., Liverpool (uniselector)	Canberra	1	26,974	40,165
	Melbourne	4		
	Perth	1		
	Sydney	3		
General Electric Co. (uniselector)	Adelaide	8	11,047	13,826
	Cairns	1		
	Hobart	2		
Siemens (uniselector, No. 16)	Brisbane	10	18,624	25,511
Standard Telephones & Cables (uniselector)	Adelaide	2	13,298	14,797
	Sydney	4		

Up to the present, it may be said that a mixture of more than one type in any one exchange has been avoided, except in some of the Keith type exchanges, where extensions have been made with uniselectors of Chicago or Liverpool type.

RECENT DEVELOPMENTS.

Automatic exchange equipment is on order for new exchanges at City West (Melbourne), North (Sydney), and Tamworth (N.S.W.). In each case line finders using the new selector mechanism type 2000 and the 3000 type relay have been specified, single-sided racks are to be supplied, ballast resistances and low resistance battery feeds are to be included in the final selectors and repeaters; repeaters, group selectors and final selectors will be of the latest type, i.e., the selectors will be type 2000 and the repeaters will include the latest type of mounting and the type 3000 relay. In addition, the type 100 meter is specified. Equipment is also on order and will shortly be delivered for a new exchange at Brunswick (Melbourne), but as some of the new developments were not available at the time the orders were placed it was not practicable to fully incorporate them, although line finders using the type 2000 switch and type 3000 relays will be used throughout the exchange. Ballast resistances and low resistance battery feeds are included, and single-sided racks will be used. Repeaters, group selectors and final selectors are, however, of Siemens 51 type.



MELBOURNE AUTOMATIC NETWORK NUMBERING SCHEME

The following notes give some details of each of these developments:—

SINGLE-SIDED RACKS.

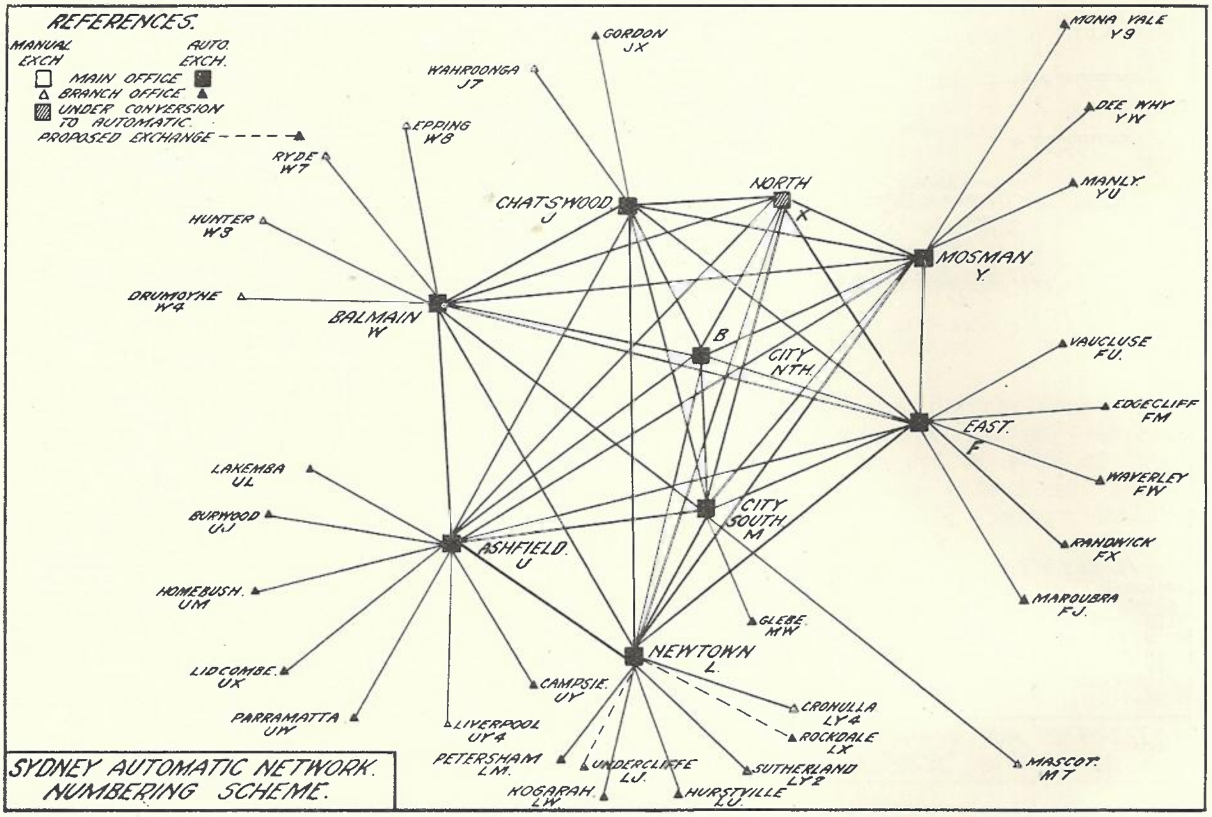
This type of rack is used in the Brisbane exchanges, where the automatic equipment is wholly of Siemens No. 16 type. The advantages of single-sided racks have been recognised, but it has not been practicable to introduce them into existing layouts, so far, in this country, as the design of the exchange layout and runways has been based on the use of the 100-line units combining uniselectors on one side with final selectors on the other side. In most of these cases it is convenient to continue the original arrangements until existing suites of racks are occupied or until the building space is occupied to the point where a new section of equipment can be commenced. In the latter case it is intended to give full consideration to the use of single-sided racks, but it will not be always advantageous to use them. They will be specified for new installations. The main advantages are: economy of floor space, uniformity of height and size, cabling facilities and uniformity of method with overseas standards. The racks are 10 ft. 6 ins. high, 4 ft. 6 ins. wide, 1 ft. 2 ins. deep, erected in parallel rows back to back with a wiring aisle 1 ft. 6¾ ins. wide and a general aisle space 2 ft. 5¾ ins. wide. It is necessary to use travelling ladders in conjunction with racks of this height.

Single-sided racks have been standard with the British Post Office both for uniselector and line-finder installations, but some modification of the rack design has been necessary to make provision for the British Post Office 2000 type selector. This modified rack will be used in the several exchanges mentioned. The selector mechanism and line-finder mechanism are both designed for standard mountings and racks.

USE OF LINE FINDERS.

Except in a few rural automatic and private automatic branch exchanges, line finders are not used in existing Commonwealth exchanges. Their use, however, has been found economical in overseas exchanges. They offer undoubted economies over uniselectors for ordinary services and they are also used for P.B.X. services, as a uniform installation of line finders is a better proposition than one having uniselectors for ordinary services and line finders for P.B.X. services. In the equipment on order for new exchanges, line finders have been specified, and their use is also proposed in future exchanges.

Line finders may be of the uniselector type or the two-motion type. Several types of uniselector have been developed and used as finders and although two separate finder installations, each employing a different type of uniselector, have been made in recent years, most of the line finders installed in the British Isles employ a two-motion selector as a line finder. Although there were inherent limitations with line finders of the two-motion selector type, the advantages offered, particularly with the use of a standard mechanism for both finders and selectors, caused concentration on the production of a two-motion selector designed to overcome these limitations, although the two-motion selector installations are giving good service. These efforts culminated in the standardisation by the British Post Office of the type 2000 two-motion selector switch, for use as a line finder, group selector and final selector.



SYDNEY AUTOMATIC NETWORK. NUMBERING SCHEME.

ADVANTAGES OF THE TYPE 2000 SWITCH.

The operation of a selector often depends vitally upon precision of mechanical adjustment and where this cannot be definitely specified, but varies within fairly wide limits, faulty operation occurs. Constant improvement has taken place, but it was necessary to re-design the switch for purposes of further improvement and standardisation. Selectors, as manufactured by different companies, incorporate fairly wide differences of design and there is lack of uniformity in piece parts. These differences constitute a serious disadvantage in practice, affecting costs, stocks, adjustment instructions and staffing.

An important feature of the type 2000 switch is its fast operation. An improvement in speed was necessary for finder operation. A stepping rate of 50 per second is obtainable on both vertical and rotary movements. In the case of a line finder having 200-point banks, the time waiting for dialling tone is reduced from 1 second to 0.5 second. It is important that this waiting time should be reduced as much as practicable. It is worth mentioning that some uniselectors have been constructed with greatly increased hunting speed—even speeds of 200 per second having been attained. A uniselector must have a greater hunting speed than a two-motion selector, for line-finder purposes, as it has only a single-motion search. The total finding time of the type 2000 two-motion selector at 50 steps per second is less than that of a uniselector at 200 steps per second.

The main advantages of the type 2000 selector, in addition to operating speed, are:—

Reduced dimensions. Due to smaller vertical and rotary magnets and absence of a separate release magnet.

Reduced weight. Due to the reduction in dimensions and the use of a frame which is 90 per cent. aluminium, strengthened by a back piece. In the existing types the frame is cast iron.

Reduced cost. The two features just mentioned cheapen the construction processes. Reduced dimensions also increase rack capacity, saving racks and building space.

Vertical and rotary operation improved. The vertical and rotary magnets are of the single-coil type, with cores of generous dimensions and of "H" formation. The armature is parallel to the axis of the core and carries a heavy auxiliary plate, to give rapidly a high flux density.

Reduced number of piece parts. Mechanical details of the same design are employed wherever possible, thereby reducing the number of piece parts and permitting the application of the same adjustments for several items.

Uniform spring assemblies. All mechanically operated spring assemblies contain a uniform type of contact spring, bracket, insulator, and clamping plate. They are arranged across the top of the selector frame, and each assembly is secured by one screw and a locating slot. The soldering tags project at the rear and thus the spring sets are readily accessible and the tags are conveniently related to the wiring forms which serve the relays. Twin silver or twin platinum contacts, as required by the circuit conditions, are used. Flexibility for circuit design purposes is furnished, as the number of springs available is greater than with the existing type selector.

Easy removal of mechanism is made possible for cleaning and lubricating bank contacts. The mechanism is independent of the banks which are supported by a cradle fitted to the shelf. The mechanism readily jacks into the cradle.

Increased bank capacity. Rigid construction of the banks and the design of the shaft, together with increased magnet efficiency, enable the switch to operate satisfactorily with almost any desired number of banks.

Adjustment in position. As a result of its design, all adjustments can be made from the front of the switch while it is in position on the shelf.

Standard relays used. In the existing switches there is a considerable difference in the type of relays used by the several manufacturers, but in the new switch the standard type 3000 relay is used.

200 OUTLET SWITCHES.

For line finders, group and final selectors, either 100 outlet switches or 200 outlet switches can be used according to the trunking requirements, but the latter size is being applied to an increasing extent, especially for large groups of equipment. With the 200 outlet switch the traffic capacity is increased 20 per cent. The 200 outlets are provided by a 600-point bank, consisting of three 200-point bank units. One unit provides the private for 200 lines, the second unit is the line bank for the odd hundred, and the third unit is the line bank for the even hundred.

The construction of the 200-point bank for the type 2000 switch is essentially the same as that of existing banks, but the bank units are closer together and are not disturbed by the removal or replacement of the switch. This should tend to reduce faults due to banks and bank wiring.

TYPE 3000 RELAY.

This relay is included in the new switch, type 2000. Its development overcomes the difficulty caused by different operation of a given circuit with relays of different manufacture. Circuit design, development and standardisation will be facilitated by the general use of a standard relay, some of the advantages being as follows:—

Reliability and uniformity are secured by careful design data used in common by the various manufacturers.

Reduced fault liability and ease of adjustment are secured by mounting the springs at the side and a definite process of adjustment is provided. The previous methods of gauging travel and also checking and adjusting tension to "operate" or "non-operate" fixed only the total break contact pressure and did not control the pressures at individual contacts. In the new relay, a buffer block is placed between the two spring sets. The adjustment process is simplified and is to tension all make and break springs against the block, tension moving springs to lift break springs from the block with relay de-energised, check correctness of armature travel and check that make springs are lifted away from the block when relay is operated.

High magnetic efficiency has been secured. This enables heavy contact pressure to be used, decreasing contact failure, and it also enables increased air gaps to be used, decreasing release failure due to residual magnetism.

TYPE 600 RELAY.

The type 3000 relay is classified as a major type relay, but for cases where it is important to substantially save space or the operating margin need not be as exact, a minor type relay, type 600, has been developed. One particular use is for line and cut-off relays.

BALLAST RESISTANCE IN TRANSMISSION BRIDGES.

The majority of existing switches employ 200 + 200 ohm relays in transmission bridges. High impedance is necessary to limit bridging loss to small value, and low direct current resistance is necessary to ensure that an effective supply of current is provided for the telephone transmitter.

Relays have been developed having windings of only 50 + 50 ohms, while their impedance is as effective as the 200 + 200 type, and the direct current resistance is adjusted by the addition of ballast resistance. On a short line the resistance of the ballast increases, but on a long line the ballast resistance remains low and the transmitter receives the benefit of increased current supply due to the low resistance of the 50 ohm windings of the relay.

This development is described in greater detail in Journal No. 2. Ballasts and low resistance feed relays will be included in all final selectors and all repeaters in the new exchanges on order, also in repeaters which have been purchased for general supply. On account of the transmission difficulties in our networks it is advantageous to have this feature on all levels for which repeaters are provided.

TYPE 100 METER.

This type of meter is referred to elsewhere in this issue, and it is sufficient to say here that the type has been ordered for City West (Melbourne) and North (Sydney), also that it is proposed to use it for future new exchanges.

RURAL AUTOMATIC EXCHANGES.

Following experimental installations of several locally developed units, 26 complete units were purchased, which conform to general standards, but contain some modifications to meet local conditions. The installations are all giving reasonably satisfactory results, and 52 additional units have been ordered for installation during 1936-37, bringing the total rural automatic lines to approximately 3,300.

PRIVATE AUTOMATIC BRANCH EXCHANGE INSTALLATIONS.

In general, P.A.B.X. installations have been provided by the adaptation of switching equipment as used for major exchanges. For services with a low calling rate line-finder systems employing 25-point uniselectors have been developed, whilst for busy services 100-line units, combining uniselectors with final selectors, are used. For two- and three-figure systems final selector repeaters and selector repeaters have been developed. Single-sided racks have been designed for accommodating major switches and relay sets, and a single-sided type of distributing frame has been standardised for the termination of cables. A manual switchboard is used for filtering calls incoming from the public exchange, whilst outgoing exchange calls are dialled direct from the extension telephones or, if desired, reverted through the manual switchboard. The associated relays are rack mounted; 50-volt systems are standard and one battery only is provided and controlled automatically by the voltage variation. This class of service is developing rapidly; the present position as to installations is as follows:—

P.A.B.X.'s working or being installed	Lines connected: Exchange	Extension
64	1,480	11,900

EXISTING NETWORKS AND DEVELOPMENT STUDIES.

The following table gives a general idea of networks in the capital cities excepting Canberra, which is served by a single automatic exchange, and including Newcastle (N.S.W.).

Network	Radius Miles	Number of Exchanges included	Statistics at 1/1/1936: Population	Number of Telephones
Sydney	15	43	1,254,780	128,628
Newcastle	5	5	105,341	5,389
Melbourne	15	54	1,008,300	111,622
Brisbane	10	16	306,154	29,126
Adelaide	10	17	315,130	30,445
Perth	10	12	210,365	18,394
Hobart	10	13	60,900	5,838

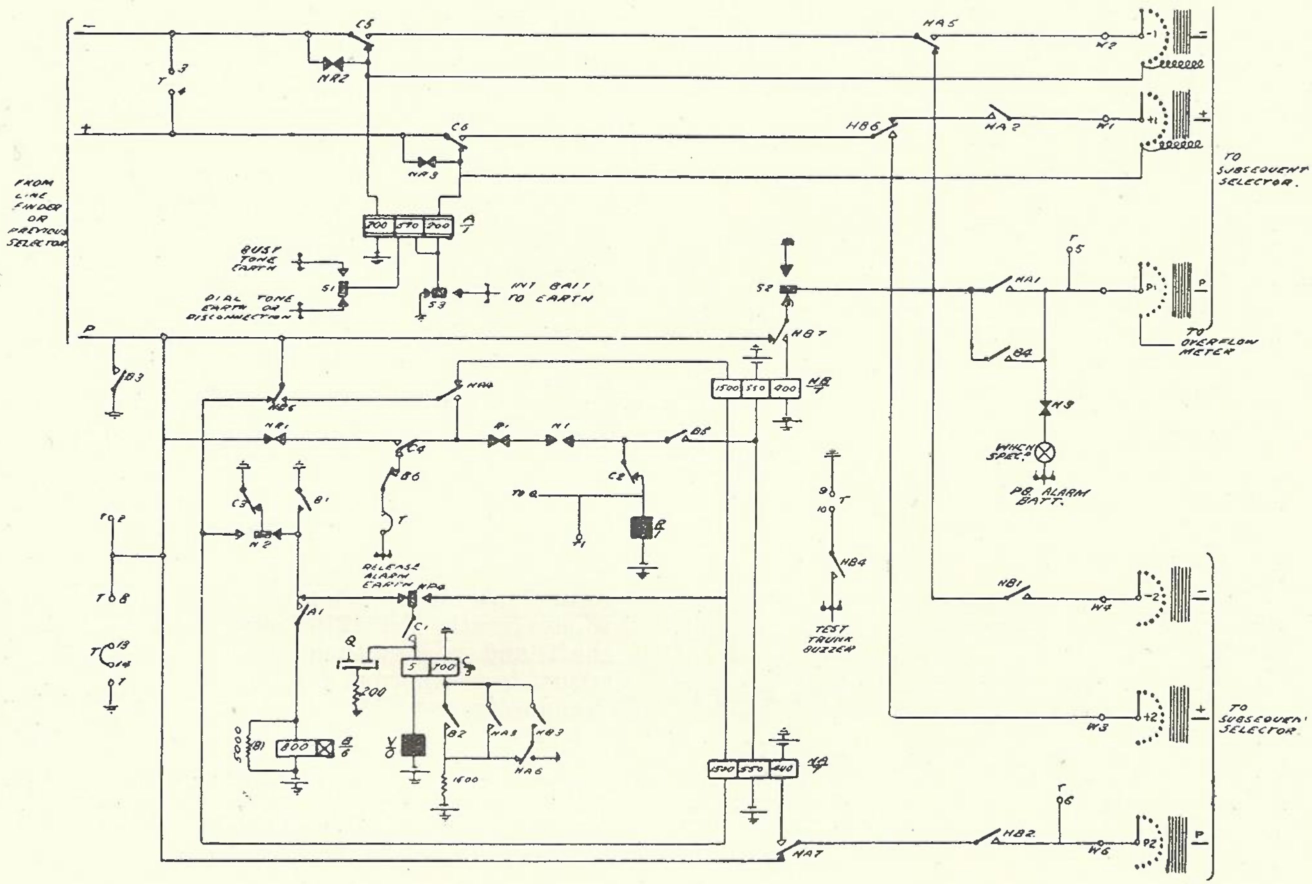
The main problems are in the Melbourne and Sydney networks, which are schematically illustrated in Figures 1 and 2. Some of the small exchanges on the fringe of the networks are included in the table but not shown in the diagrams.

The problems include the conversion of manual exchanges to automatic and the difficulties due to the age of some automatic equipment. At the same time, it has been necessary to make extensive additions and alterations in order to meet development and changes in the numbering scheme are involved, but these must await a later description.

THE 200 OUTLET GROUP SELECTOR
(B.P.O. 2000 TYPE)

F. J. Ryan, B.Sc.

AUTOMATIC switching equipment of the B.P.O. 2000 type is now being manufactured for City West, Victoria, by the General Electric Co. Ltd., Telephone Works, Coventry. In view of the general interest being taken in the 2000 type equipment, a series of articles describing the apparatus and circuits employed will be published in subsequent issues. A copy of the circuit and circuit description supplied by the G.E. Co. for a 200 outlet group selector is given hereunder. The block for the circuit diagram has been made available through the courtesy of "The Electrical Engineer and Mechandiser."



The 200 outlet group selector is stepped vertically under the control of the dial to any one of 10 levels. It then cuts in on the level dialled and steps around the bank, testing two outlets at each rotary step. A total of 20 outlets is tested in 10 rotary steps. If all outlets on the level are busy, the switch steps to the 11th contact, and a busy signal is given.

On release the rotary circuit is again completed and the switch is stepped to the 12th contact, where it drops vertically at the right-hand side of the bank and restores to the normal position at the bottom of the bank.

Circuit Description.

Relay A operates from the subscriber's loop.
A1—operates relay B.
Dial tone is connected to the 3rd winding of relay A and is transformed on to the two line windings and thus out to the subscriber.
B2—operates relay C.
B3—connects guarding earth to the P wire.
B4—lights the PG lamp.
B5—prepares a circuit for HA and HB.
B6—disconnects the release circuit.
C1—prepares the vertical magnet stepping circuit.
C2—disconnects the rotary magnet circuit until after vertical stepping.
C3—disconnects the original operating circuit for relay B and prepares release guard circuit.
Subscriber dials.
Relay A responds to the dialling and spring A1 pulses the vertical magnet to the required level.
Vertical off normal springs (N) operate when the switch makes the first vertical step.

N1—operates relay HA and HB from earth at B3.
N3—disconnects the P.G. lamp.
HA1—prepares the testing circuit for relay HB.
HA4—holds relays HA and HB operated after relay C releases at the end of the dialling.
HA6—short circuits the second winding of relay C, making it slow to release so as to hold during dialling.
HA7—prepares the testing circuit for relay HA.
HB2—closes the testing circuit for relay HA.
HB3—with HA6 short circuits relay C.
HB5—with HA4 holds relays HA and HB.
HB7—closes the testing circuit for relay HB.
At the end of dialling relay A remains operated.
Relay C releases.
C1—disconnects the vertical magnet circuit.
C2—energises the rotary magnet from earth at B3 via N1.
C4—disconnects the original operating circuit for relays HA and HB.
Rotary magnet is operated and the wipers move on to the 1st contacts of the banks.
Rotary off normal springs (NR) operate.
NR2 and NR3—make relay A dependent on contacts C5 and 6.

When the rotary magnet operates springs R1 open, disconnect the rotary magnet which releases, reclosing springs R1. The switch wipers are driven round by this self-interrupting action until they arrive at a free outlet. During this time relays HA and HB hold on the 400 ohm windings to earth on the busy P1 and P2 contacts.

If contact P1 is free and P2 busy, relay HB will release when springs R1 open, HA being maintained operated to the earth on P2.

HB3—removes the short circuit from relay C which re-operates.

HB5—prepares holding circuit for relay HA.

HB7—connects earth to the P1 contact.

C1—closes the holding circuit for relay HA via the vertical magnet.

C5 and 6—release relay A and connect the incoming negative and positive wires via contacts HA5 and HA2 to the subsequent selector.

HA1—maintains the P1 circuit independent of B4.

HA3—holds relay C operated.

Relay B releases.

If contact P2 is free and P1 busy, relay HA will release when R1 springs open.

HA4—prepares the holding circuit of relay HB.
HA6—removes the short circuit from relay C.
HA7—connects earth to the P2 contact.
C1—holds relay HB.
C5 and 6—release relay A as before.
If both contacts P1 and P2 are free, both relays HA and HB will release when R springs open.
HB3 and HA6 allow relay C to operate.
HB5—operates relay HA.
HB7—connects earth to the P1 contact.
If all outlets are busy, the selector will rotate until the 11th row is reached.
S springs operate when the wipers step to the 11th contact.
S1—connects busy tone to the A relay.
S2—connects earth via the P1 wiper to the traffic meter.
S3—connects interrupted battery and earth to the positive line to give flashing signal and holds relay A.
On completion of a call earth will be removed from P wire and relay HA or HB will release, allowing relay C to release.
C2 and 4—connect the release circuit to the rotary magnet which self-interrupts until the wipers reach the 12th rotary position. The shaft and wipers then release vertically and return to the normal position.
C3—connects earth to the P wire, maintaining the selector guarded until the normal position is reached.
N springs restore to normal and N2 disconnects the earth from C3, the selector then being free to be seized again.

NEW FEATURE

Commencing with the December issue, it is proposed to include as a regular feature, typical answers to questions in Examinations which are held from time to time for promotions to Mechanic, Senior Mechanic and Engineer.

Power Plant for Automatic Telephone Exchanges.

A. R. Gourley

It is the purpose of this article to describe the principles underlying the design and operation of power plant in Automatic Exchanges and Private Automatic Branch Exchanges (P.A.B.X.'s).

The floating system is standard practice, and although various types of floating systems have been in service for many years it may be desirable, for the sake of completeness, to restate the advantages over the charge and discharge method. These are:—

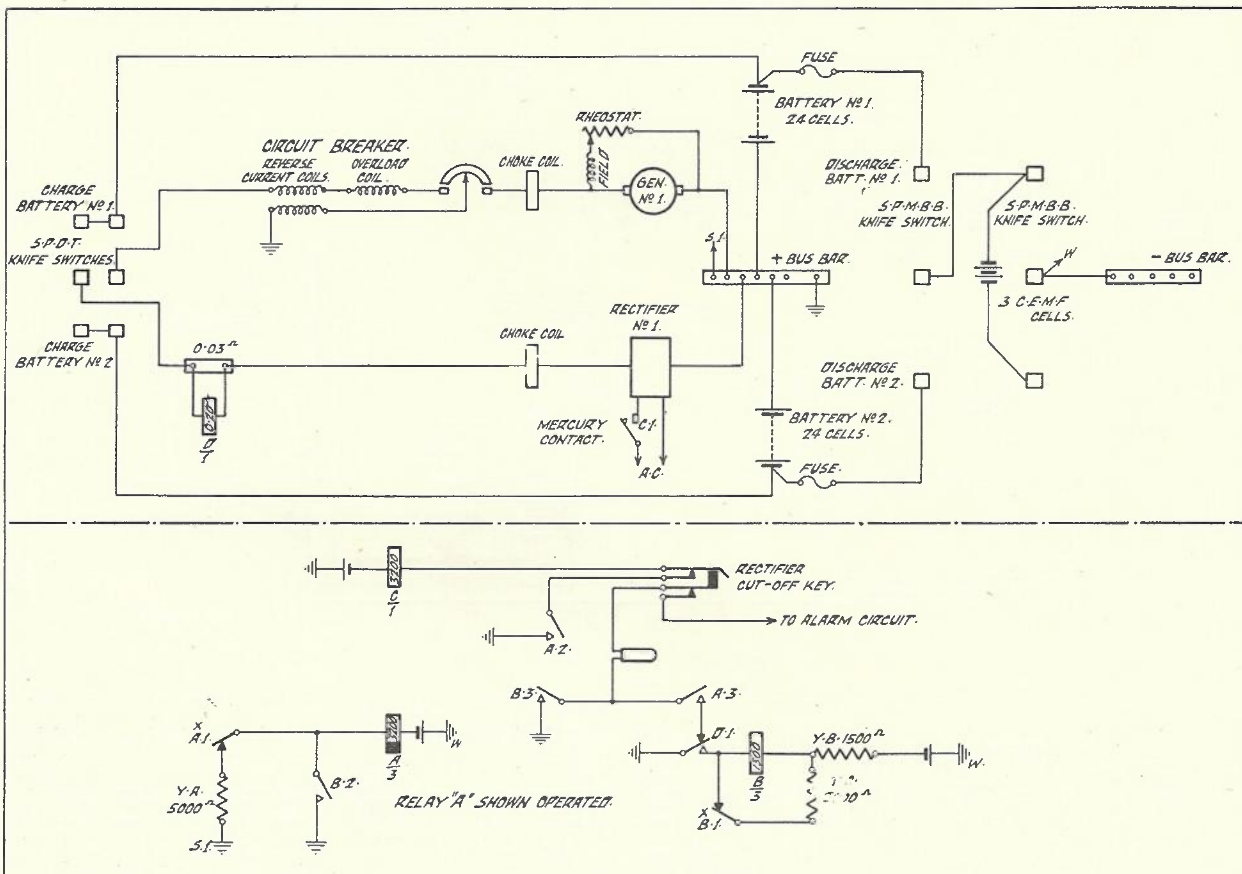


FIG. 1.

(1) The total battery capacity required is half that necessary for charge and discharge working, because in the event of a power failure the total battery capacity is available.

(2) As energy is supplied direct from the machines to the exchange busbars, losses are reduced.

(3) The average life of the battery plates is increased from five to seven years for charge-discharge working to ten to fourteen years. The elimination of regular charges and discharges obviates the wear on the plates caused by gassing during charging, and the mechanical stresses resulting from the expansion and contraction of the active material.

(4) As gassing is reduced considerably, less distilled water is used.

The reliability of modern commercial power supply systems is such that a total battery capacity sufficient to provide for a 12-hour reserve (which is equivalent to from three to four busy hours), will in general provide ample safeguard against dislocations in the telephone system. Other general considerations, such as ease in replating, the retention of a minimum reserve of one-half of the total battery capacity, and the use of smaller cells than would be necessary otherwise, render it desirable to install two batteries in each exchange.

For P.A.B.X.'s, excepting installations of relatively small capacity located in areas in which the power supply is D.C., a single battery is usually provided. In general, a three- to six-hour battery reserve is sufficient. Where the power supply is D.C. and a resistance employed, two batteries are installed and operated on an automatically controlled charge-discharge basis. Owing to the possibility of getting the full mains' voltage across the telephone equipment, it is not desirable to connect the power supply via a resistance to a battery serving the exchange. As the positive busbar of the P.A.B.X. is grounded, this also introduces complications in floating with a resistance.

be installed initially, and the other as justified by the growth of the exchange. The elements of the power circuit are shown in Figure 1. The motor generator is provided to cater for the initial charge and periodical overcharges. It is also used in emergencies to charge the battery. The C.E.M.F. cells are normally not in circuit, but their use permits the battery to be given a full charge without the busbar voltage being increased beyond 52 volts. Normally the rectifier is connected to the exchange busbars with

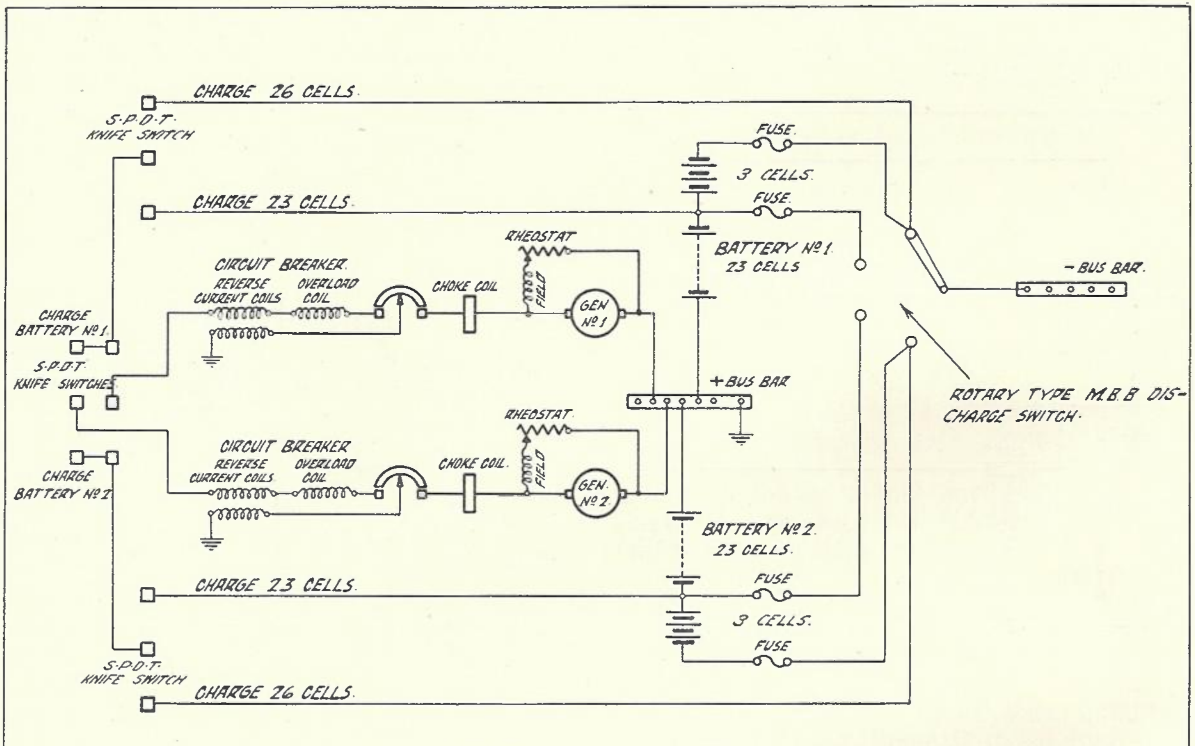


FIG. 2.

In major exchanges two or more motor generators are provided. The total output of the machines is sufficient to fully charge the batteries in not more than eight hours at the 20-year period. The outputs of the various machines are designed to permit of the operation of one or more machines at maximum efficiency to supply the exchange load.

In small exchange installations both a motor generator and a rectifier are provided, whilst in P.A.B.X.'s either a motor generator or a rectifier meets requirements.

Power Circuit for Exchanges of up to 3,000 Lines' Ultimate Capacity.

In these cases the total battery capacity required at the 20-year date will be not more than 500 to 1,000 A.h., and where the number of lines to be connected at the cutover date is small comparatively (say, 300 to 500) one battery may

the battery floating, and is controlled automatically by the voltage variations of the battery. To maintain a reserve in case of emergency, the battery is operated normally between the limits of 48 and 52 volts. The output of the rectifier is adjusted to supply the normal load during the period when there is an appreciable demand on the exchange—e.g., from 9 a.m. to 9 p.m. That is, the battery will be floated at approximately 50 volts and frequent stopping and starting of the rectifier will be avoided. The circuit conditions detailed in Figure 1 show a battery on discharge and the charge cut off. The contact of relay C is of the mercury tube type. On the battery voltage dropping to 48 volts, relay A releases and operates C, which connects the A.C. supply at C1. The rectifier functions and current flows through the battery via relay D and the low resistance shunt. Relay D opens the alarm circuit and completes the circuit of B, which, however, does not operate at this stage. When the battery voltage reaches 52, relay B operates and operates relay A, which in turn releases relay C and opens the A.C. mains. Relay A also open-circuits relay B and opens the alarm circuit. Relay A holds via contact A1 and YA5000. The supervisory circuit is so designed that an urgent alarm is gradually, but is restored by an overcharge, which will be necessary every four to eight weeks, depending on the particular installation.

Power Circuit for Exchanges of over 3,000 Lines' Ultimate Capacity.

Two batteries, each of 23 main cells and three end cells, are provided, and each battery is con-

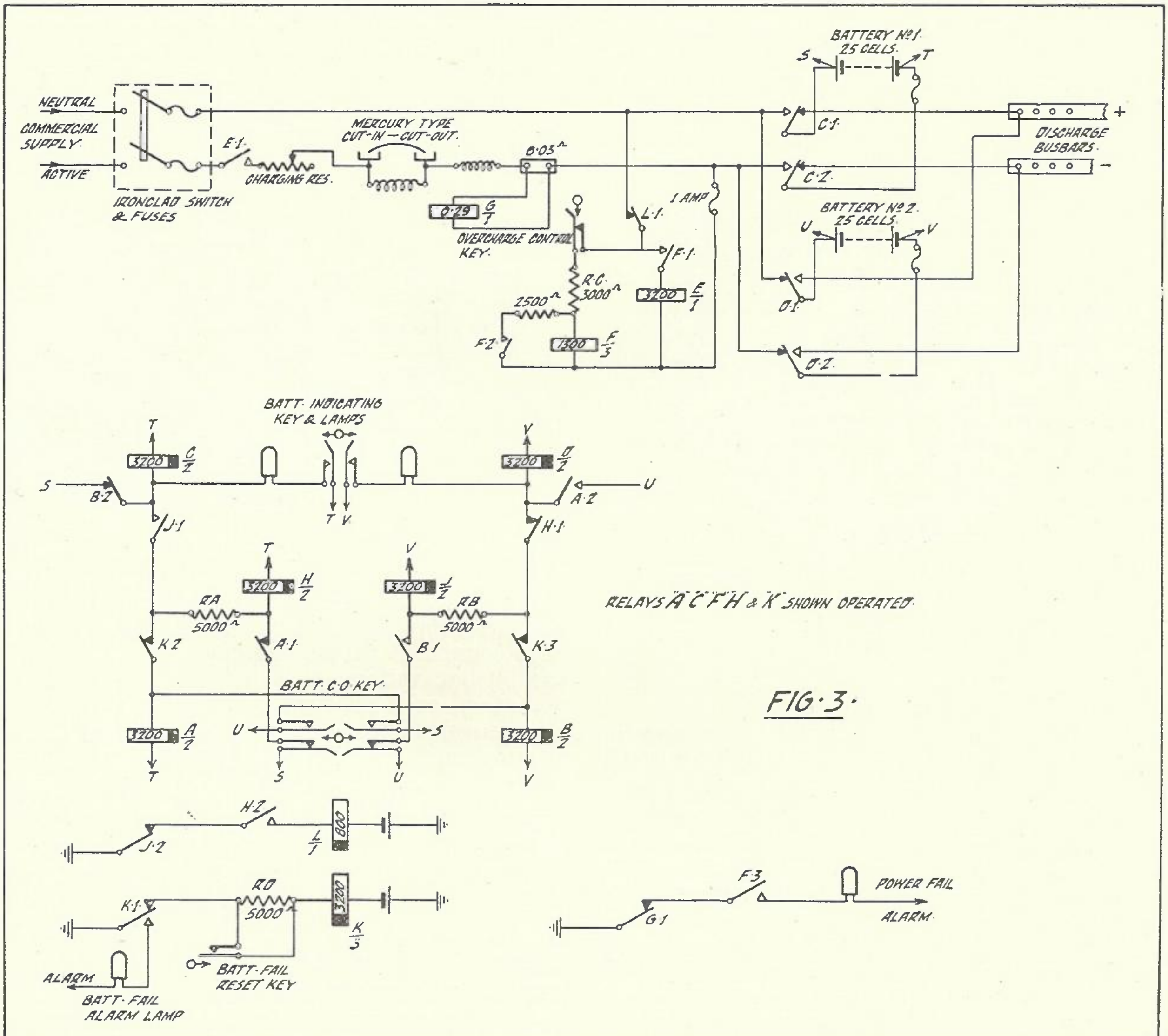


FIG. 3.

transmitted to the parent exchange should the commercial supply fail, the rectifier cease to function, or the control equipment function incorrectly. Relays A and B are fitted with micrometer adjustments and are described in "Features of Private Automatic Branch Exchange Installations," L. Paddock (T.J. No. 1). The "X" contacts on relays A and B provide for definite operation immediately the relay armatures commence to move. When operated in this manner the specific gravity of a battery falls nected across the exchange busbars on alternate weeks. The circuit elements are shown in Figure 2. The method of operation is as follows:—

When the load is insufficient to warrant the operation of the charging equipment, the end cells are switched in and the battery operates on a discharge basis. When the charging equipment is used again, it is connected across the 26 cells and the exchange connected across 23 cells only. When the end cells are charged, the generator is connected across the exchange busbars with the 23-cell battery floating. This condition maintains during the major portion of the day. After a week the second battery is switched on load and the first battery overcharged to even up the specific gravity in all cells. It is then held in reserve.

In the Melbourne City West Exchange a charging procedure similar to that described above will be adopted, but an automatic voltage regulator will be provided to maintain the busbar voltage between the limits of 50.5 and 51.75 volts. As desired, the automatic voltage regulator can be cut out and the machine regulated by hand. When two or more machines are operating in parallel, one machine will be controlled by the automatic regulator and the remainder of the machines allowed to trail.

P.A.B.X. Power Circuit—Rectifier Charging.

The circuit is similar to that shown in Figure 1, with the exception that a rectifier and one 24-cell battery without end or C.E.M.F. cells is provided. The description of the operation of the rectifier and control equipment applies also. In most installations the premises are closed over the week-end and the battery can be switched off load and, when necessary, given an overcharge during this period. In these circumstances no difficulties will arise from a high battery voltage. When this is not practicable an overcharge is given at a low charging rate.

P.A.B.X. Power Circuit—Motor Generator Charging.

A 24-cell battery without C.E.M.F. or end cells is provided in a power circuit of this type. The circuit is similar in fundamentals to the rectifier portion of Figure 1, but the contact of relay C operates an automatic starter which controls the motor. When the motor rotates at full speed, the generator voltage builds up beyond the battery voltage and a circuit breaker of the mercury, cut-in-cut-out type operates and connects the machine to the busbars. The circuit breaker is connected in the charging leads between the generator and the battery. When the battery voltage reaches 52, the control relays function as described previously, relay C trips the automatic starter and the motor generator slows down and stops. The generator voltage falls below the battery voltage and the mercury cut-in-cut-out releases and so prevents the battery feeding back into the generator.

P.A.B.X. Power Circuit—Resistance Charging.

Two 25-cell batteries are provided. The circuit (Figure 3) provides for automatic charge and changeover facilities, and a brief description may be of interest. On relays C, D and E mercury tube contacts are employed. The circuit conditions show battery No. 1 on discharge and battery No. 2 fully charged with the charge cut off. When the voltage of battery No. 1 falls to 49, relay A releases; A1 opens the locking circuit of H, whilst A2 completes the circuits of relays B and D. Prior to the release of H, relay B operates and locks, thus opening the circuit of C, which releases and connects battery No. 1 to the charging leads. Relay D operates and connects battery No. 2 to the discharge busbars. During the release of C both batteries are in parallel on discharge. J operates from V via B1, and at J1 prepares a circuit for the next operation of A. J2, in conjunction with H2 (during the slow release of H), controls L, which is operated during the release of H, thus controlling the release of F and preventing the premature operation of E. Charging is not commenced until the discharged battery is connected to the charge leads. Relays L and F release and complete a circuit for E, which operates and closes the charge circuit. The circuit breaker, which is of the mercury cut-in-cut-out type, operates and closes the circuit of G, which operates and opens the alarm circuit at G1. When the No. 1 battery voltage reaches 62 volts, relay F operates and holds, and at F1 releases relay E and cuts off the charge. Relay K is connected across the discharge busbars. If the busbar voltage fails because of faulty relay operation, or if an open circuit occurs during the changeover K releases and locks, K1 completes the alarm circuit, whilst K2 and K3 open-circuit relays A and B and place both batteries in parallel across the discharge busbars. The consequential release of relays H and J operates relay L, which prevents the connection of the charging current. Relay K can be restored only by depressing the reset key. Either battery may be switched on load by operating the battery changeover key. To determine the battery on discharge at any time, a battery indicating key is operated and the relative lamp glows. Overcharges are controlled by operating the overcharge control key, which open-circuits relay F.

TELEPRINTER SERVICE FOR SYDNEY STOCK EXCHANGE

F. E. Moore, M.B.E.

IN these days competition in business demands time savings in all spheres of activity, and high-speed communications are indispensable to modern enterprise. As a central telegraph office is the nerve centre of a city, so a Ticker service is the main artery of the stock exchange, where members require the latest stock information immediately it becomes available. Intelligence must be communicated to members instantly variations occur in the prices on 'change, and transactions involving large sums of money may depend on the very second that the stock price is available to brokers.

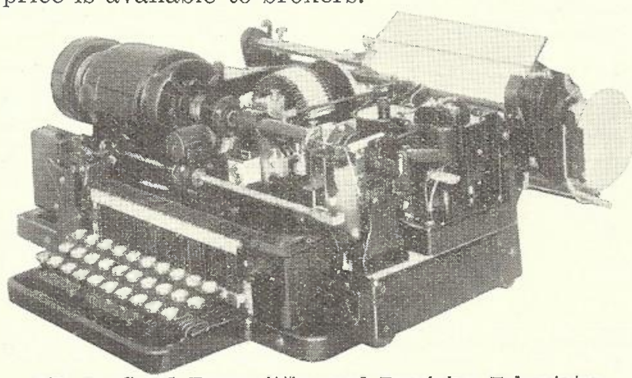


Fig. 1.—Creed Transmitting and Receiving Teleprinter.

The provision of communication services is a responsibility of the Postmaster-General, so the department has undertaken the provision and maintenance of a ticker service for the Stock Exchange in Sydney. A ticker service in broad outline consists of a transmitting station at one centre, sending to many receiving stations at other locations. The transmitting machine is installed in the call room of the stock exchange, and details of transactions and market quotations are transmitted from the stock exchange to the offices of the various subscribers to the service.

The manipulation of the typewriter keyboard on the transmitting machine automatically effects transmission to all subscribers' machines. The sharebrokers, therefore, are kept in very close touch with all stock movements. Messages are sent in the form of trains of electrical impulses at a speed of 60 words per min., and these signals are automatically received and recorded in typewritten form on each subscriber's machine. No operating attendance is necessary at the receiving machine; all that the subscriber need do is to read the incoming message, and then act as thought desirable should he be interested in the quotations just scrutinised.

The chief requirement of a ticker service from the department's viewpoint is to provide a plant capable of passing the traffic speedily and accurately, and reproducing at reception points a visible record of the transmission in the form of printed characters. The received record may be in the form of a continuous tape marked as the characters are received, or, on the other hand, the received matter may be printed in page form as an ordinary typewritten sheet. The service in Sydney has been provided with page reception at the request of the exchange authorities.

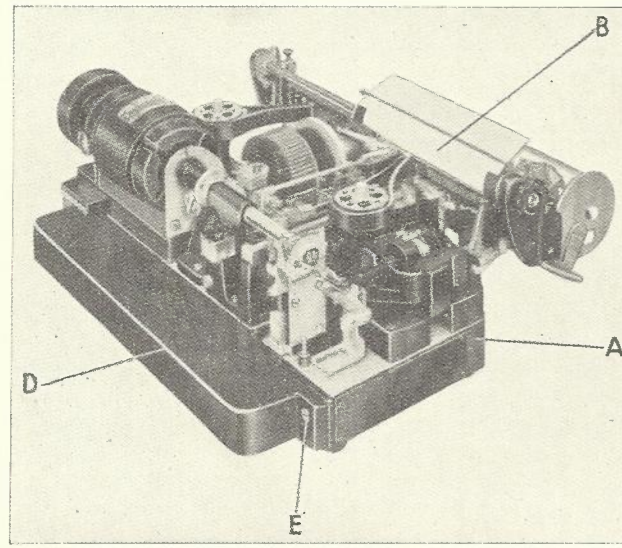


Fig. 2.—Creed Receiving Teleprinter.

Developments in the art of machine printing telegraphy, based on the five-unit code and the use of trains of signal permutations, have rendered obsolete the older ticker devices. Start-stop machines, like the Teletype and the Creed Teleprinter, are now provided for ticker services, and these telegraph machines function on the Murray code adapted for start-stop practice. The word "ticker" has survived from the early installations, and the name is now applied to stock exchange systems, irrespective of the kind of telegraph machine used.

The Sydney system, which was brought into operation in March, 1936, uses Creed teleprinters, Model 7C (Fig. 1), for the sending machine, and Model 8C (Fig. 2), for the receiving units. The Creed Teleprinter in service usage is similar to the Teletype machine, insofar as both function on the so-called "start-stop" principle. In any fast speed system of printing telegraphy, transmitting by means of a series of signal permutations for each character, it is necessary for the sending and receiving devices to be revolving continuously and kept in exact synchronism with delicate mechanism controlled by correction signals over the line. A later development in the art was the Teletype machine working on the start-stop principle. In start-stop working no special synchronism impulse is sent over the line, but the receiving device begins to function upon receiving the "start" impulse preceding the train of five signal impulses, and after the transmission of five signal impulses, the reception of the "stop" impulse restores the device to the normal position of rest, ready for the next letter or character. Provided the motors of the machine at each end are running at reasonably equal

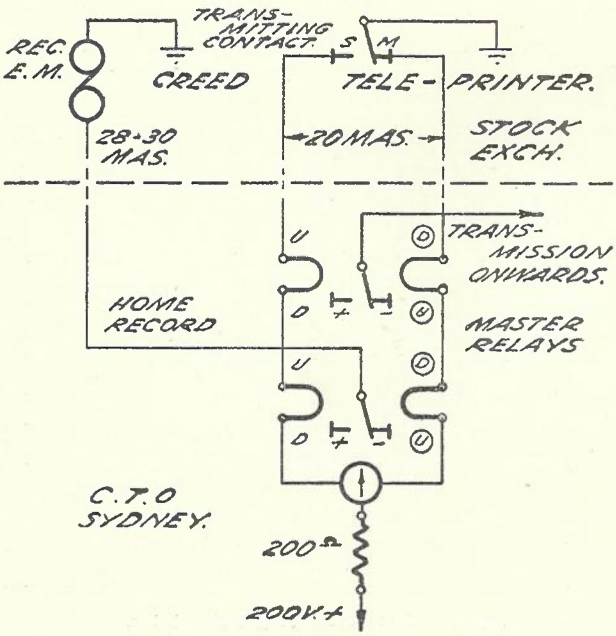


Fig. 3.—Master Relay Circuit.

speeds, the synchronism of the sets is accurate enough during one cam revolution or period between the "start" and "stop" impulses. In other words, the start-stop principle ensures that there is not any harmful degree of out of synchronism during the period between start and stop impulses. These two controlling impulses prevent any differences of speed becoming cumulative, as would happen in the case of two independent devices revolving continuously at about the same speed.

The Creed Teleprinter is quite different from the Teletype machine of U.S.A., in mchanical design, although both function upon the same principle of telegraph working. Among ticker services using the Creed Teleprinter are Reuters service in London and the Johannesburg stock exchange system in South Africa. The Sydney service has 35 subscribers connected at the outset, but it is thought that there will be considerable growth as the advantages of the service become more evident to exchange members after observing the system in every-day use.

The central equipment for the installation is located at the G.P.O., which is some distance from the Stock Exchange. The two transmitting Creed Teleprinters, one a stand-by machine, are located adjacent to the Call room of the stock exchange, and the receiving units are located in members' offices within the city. The sending machines are fitted with direct keyboard transmission, and the keyboard layout is similar to that of an ordinary typewriter. Infrequently used fractional signs are not normally provided on the teleprinter, but in a ticker service it is necessary to make special provision in the keyboard, and in the receiving printer, for a more complete set of fractional characters. The following fractions have been specially fitted to the machines, and each fractional sign is printed when one corresponding key of the keyboard is depressed: $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$.

Provision is made on the transmitting machines for a home record of all transmission to be visible in front of the operator. Transmission throughout the system is "double current," and the transmitting unit, either of two machines as switched into service, controls over underground wires the multiple sending equipment at the central telegraph office. Battery supply is applied at the central plant, and the sending teleprinter tongue places earth on the spacing or marking contact in accordance with the signal permutations.

Referring to Fig. 3, the transmitter contacts of the sending teleprinter are extended to the spacing and marking windings of the master relay set on the central equipment, the central point or split of the polarised relay windings having battery potential applied. The windings of the two relays of the master relay set are in series; one tongue repeats the signals onward whilst the tongue of the second relay returns to the stock exchange machine a facsimile of the outward impulses to operate the receiving portion of the Call room teleprinter and provide the home record. This method of connecting the transmitter was adopted in order to obviate a positive and negative signal battery supply at the stock exchange building.

Another method of operation, also using earth only at the stock exchange, could have been used. This necessitates the use of a polarised relay winding with battery permanently connected to the split and energising the marking coils of the relay to earth. The tongue of the transmitter, which is connected to the spacing winding, when moved to the spacing contact connected with earth, completes circuit through the spacing winding, and the latter assumes control, being energised at double the current value that is passing through the marking winding. When the teleprinter tongue moves to marking, the spacing winding is opened, and the marking winding regains control.

This arrangement, owing to some degree of inherent bias, was not considered as suitable for the stock exchange service as the circuit adopted, although it is very suitable in other ways for ordinary point-to-point services. It was considered unwise to include any feature in the circuit that might tend to reduce the working margin.

Fig. 4 shows the rack mounted equipment for serving 45 subscribers. A schematic circuit of the arrangements is shown in Fig. 5. The master relay tongue passes the signals to one set of nine group relays, which are connected in three parallel branches, each containing three relays in series. Each group relay passes the signals to five receiving teleprinters. The first bay, A^1, houses the master relays, jack field, fuse and alarm panels and testing apparatus. The second bay, B^1, houses the group relays, current limiting resistances, the shunted condensers, and an I.D.F. When the service expands, the second bay will be duplicated, and a further set of nine group relays will receive an input from the original master relays through "control" relays. The first bay, A^1, caters for 90 subscribers, and, if this figure be exceeded, a second testing bay would be installed. It will be seen that the master relay, likened to the apex of a pyramid, can serve, through a few control relays and several sets of group relays, numerous receiving teleprinters. The central plant can expand, therefore, in uniform and easy steps in accordance with service demands.

Like all machine printing telegraph systems, the need for accuracy of transmission is paramount. Accuracy is perhaps more important in a ticker service than in a teleprinter point-to-point service, as any faulty signal combination from the one sending centre causes faulty reception at numerous receiving points. Particular care has been exercised in arranging the circuit so that shunted condenser values and other devices throughout the circuit are correct for preserving the required wave form, and also for ensuring sparkless operation at relay contacts. The number of subscribers' machines commoned to one group relay tongue has been limited to five, as the necessary total current of 140 to 150 ma. is quite considerable for rapidly breaking telegraph relay contacts, and any tendency for sparking must be eliminated to maintain successful working. Laboratory tests with the aid of an oscillograph showed that the values chosen for the several parts of the circuit are quite the most satisfactory for those conditions.

Telegraph relays, of course, must be strictly neutral and bias free to ensure accuracy in any modern printing telegraph system. Provision has been made to transmit 25-cycle bias free signals to the system relays for observing on a milliammeter neutrality of output from individual parts of the circuit or over the entire system. Jacks are provided before and after the different relay groups for enabling tests such as these to be easily conducted. In addition, before service each morning the relays are tested separately on a relay test bench and adjusted to be strictly neutral in output.

The general testing arrangements include a monitoring teleprinter keyboard sender, a teleprinter receiver and a separate test relay. By means of jacks and cords, these components can

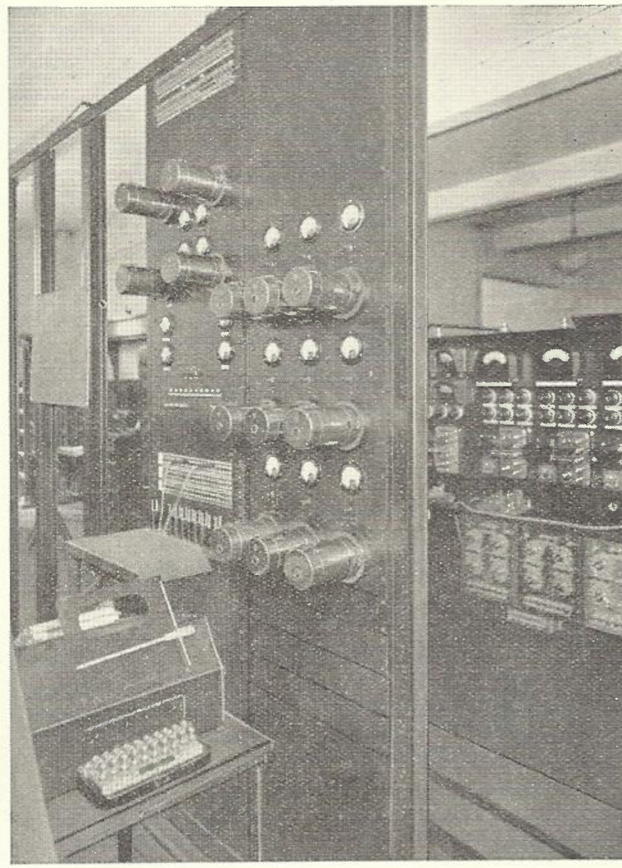


Fig. 4.—Central Equipment for Stock Exchange Ticker Service.

be interchanged with other similar service equipment in the circuit. The test teleprinter keyboard can be substituted for the Call room machine and the output applied to individual or multiple paths of the circuit. The outputs of various parts of the circuit can be received on the monitoring receiving teleprinter. In addition, the normal working of the service can be observed by connecting at any desired part of the circuit a leak relay functioning through a high resistance, the relay tongue operating an observation receiving teleprinter. The accuracy of response and general performance of the system can be readily and closely supervised. The condition of subscribers' receiving machines can be tested by passing to each, as desired, standard transmission from the monitoring teleprinter keyboard through the system relays or through a special relay previously tested and known to repeat accurately.

As the machines at members' offices are receiving units only, provision has been made to enable the visiting maintenance mechanic to report the result of test transmissions to the C.T.O. officer, by means of a portable telephone

which caused actual service stoppages was 2.25 per week, with an average duration of 32 min. per fault. This amounts to approximately 2.2 minutes' lost time per subscriber per week.

A rough check of the traffic shows that approximately 40,000 symbols are transmitted from the control machine in one day. These symbols being received on 35 machines necessi-

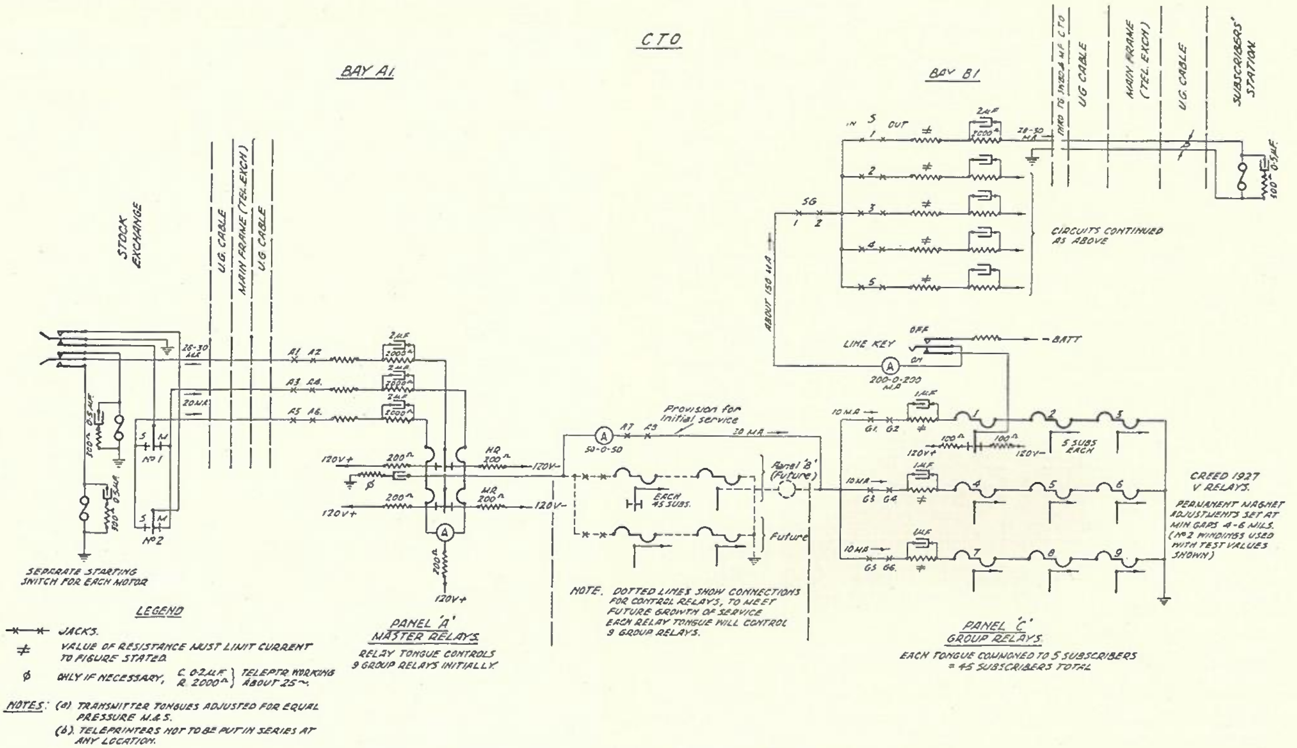


Fig. 5.—Schematic of Stock Exchange Ticker Service.

plugged into a jack mounted on each subscriber's teleprinter table. The speaking wires are commoned into groups and are connected to jacks, calling lamps and answering equipment located at the C.T.O. ticker rack.

In order that maintenance testing shall be uniform and of a high standard in method, a rigorous line-up and maintenance procedure has been issued for the assistance of the maintenance officers. This sets out the order and details of tests to be made prior to opening for service each morning. As an indication of the reliability of the plant, it might be mentioned that during the month of April the average number of faults

tate 1,400,000 printer operations per day. Each printer operation is controlled by a train of seven electrical impulses, making 280,000 impulses per day per receiving machine, or a total of 9,800,000 impulses per day from the central equipment.

The Creed Teleprinters were supplied to the department by Standard Telephones and Cables (A/sia) Ltd., and the service was designed and arranged by engineers of the department, the rack equipment being manufactured in Sydney. It is desired to acknowledge the courtesy of "The Electrical Engineer and Merchandiser" for the loan of blocks for illustrations.

WOODEN POLE REPLACEMENTS

A NEW ECONOMICAL METHOD

B. McMahon, A.M.I.E. (Aust.)

The Postmaster-General's Department has approximately 2¼ million wooden poles in Australia. Assuming an average pole life of 25 years, 90,000 poles will have to be replaced each year. The cost of renewal varies over a wide range: short poles carrying only one or two wires may be replaced at little more than the cost of the pole, say at £1. On main interstate trunk routes, some of the poles reach a height of 70 feet and carry 80 or more wires. On a heavy trunk route in the vicinity of a capital city, a fairly normal condition might be a 40 ft. pole, with 70 or 80 wires. In the renewal of such a pole, the cost of the new pole is but a small part of the total cost of the work. The pole to be renewed will probably have been in position for 15 to 25 years, the crossarms will probably be equally old, and some of the bolts may be rusted in position. The process of replacing such a pole necessitates the fitting of new arms to a new pole, erecting it close to the old pole and then transferring to the crossarms on the new pole all the spindles, insulators and wires.

These arms, spindles and insulators would probably give no trouble for many years if allowed to remain undisturbed on the pole. The process of changing them, however, involves the withdrawal of rusted bolts, and unscrewing of insulators, the withdrawal of spindles and the untying of copper tapes and binding wires. This transfer causes defects which would not have occurred had the material remained undisturbed, and it is found necessary to replace many bolts, spindles, insulators, tapes and ties when transferring to the new pole.

As trunk routes carry important circuits, and there may be a number of speech or telegraph channels on one physical circuit, the changing of the wires must be done very carefully to prevent interruptions to traffic. This necessarily lengthens the time of the operations, and it may easily occur that the renewal of a straight line pole may cost £25, while in the case of an angle, junction or thwart arm pole, the cost may be as high as £50.

Even when the utmost care is taken in carrying out this work, it is rarely that it can be completed entirely without interruption to service. Short circuits and contacts can occur by adjacent wires touching each other, or they may be caused indirectly by workmen handling copper tapes and binding wire, or by the wires touching a brace or combiner. The delay to traffic occasioned by momentary contacts of an intermittent nature may be very serious.

In an effort to reduce the cost of this replacement work and to minimise the risk of circuit interruption, consideration has been given to the factors leading up to the necessity for replacement of the wooden pole. Experience has shown that under average conditions, especially in the southern half of the continent, the damage to the wooden pole occurs mostly at and about the ground line. This damage is caused mainly by rot and, to a lesser extent, by termites (white ants). What is referred to as "rot" is

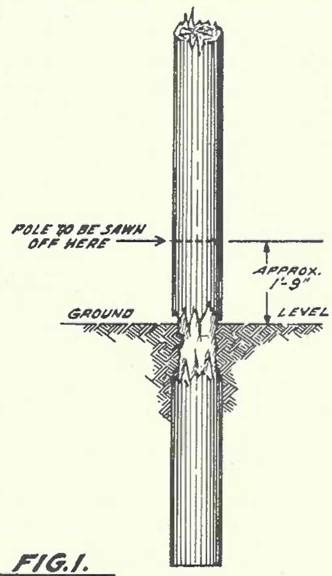


FIG. 1.
POLE SHOWING USUAL LOCATION OF DEFECTIVE WOOD.

the cause of much the greater part of the renewals. An examination of many replaced poles showed that the rot or decay seldom extended seriously for more than 12 to 18 inches above the ground line. Figure 1 shows the usual location of the defective part in a wooden pole. In the great majority of cases, the wood above 18 inches from the ground line is found to be perfectly sound.

For many years it has been the practice to replace defective poles completely with new poles, though the proportion of the replaced pole which was defective was comparatively small. It was realised that if the sound portion of the pole could be retained in position it would be unnecessary to renew the arms, spindles and insulators and to change the wires. This would cut out the greater portion of the cost of renewal of heavily loaded poles and would minimise the risk of interruption to working circuits.

For some years a method has been used, in suitable cases, of transferring the existing arms to a new pole. The arms with all fittings in situ are held together with combiners. The bolts are removed from the pole and the arm assembly supported with jacks and pikes, derrick, gantry or such like. The old pole is removed and a new one erected in its place. This requires very careful work in accurate spacing of the crossarm joggles and boring of bolt holes, and it is not easy to effect the transfer without straining the ties and injuring the wires. The method involves much work at the top of the pole amongst the wires, tending to circuit interruptions, and difficulty has been experienced also in removing the bolts to release the arms from the old pole. On the whole, this method has not found great favour.

During the last year, experimental work has been carried out with a method in which it is not necessary to touch the top of the pole. The defective portion of the wooden pole is replaced by a steel butt which projects 18 inches to 2 feet above ground level. Around the steel butt is fitted a steel sleeve about 4 ft. 6 ins. in length. This sleeve fits very snugly on the butt, on which it can be moved telescopically (see Fig. 2).

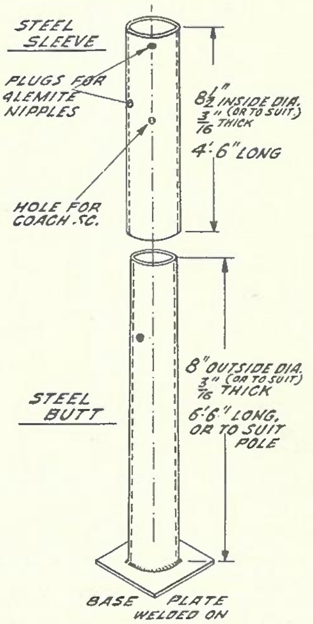


FIG. 2.

STEEL BUTT & SLEEVE.

In practice the pole is held in position with a tripod, each leg consisting of two steel tubes fitted telescopically. At the lower end a square-threaded screw is fitted for the purpose of making the final adjustment of height when the tripod has been fitted in position on the pole. It is rarely necessary to work these screws more than 2 inches. Figure 3 shows how the pole is held with the tripod. First the clamp or collar is fitted round the pole at a suitable height, after which each leg is fitted separately in one of the three sockets provided on the collar. The collar grips the pole tightly by means of six screws, and once in position does not move.

When the pole has been thus secured, a trimming or shaving machine is fitted to the lower portion in such a position that the trimming of the pole will be commenced at a point 18 inches or more above ground level and continued upwards for about 27 inches. The point at which to commence the trimming and the length of the trimmed portion will depend, of course, on the condition and size of the pole.

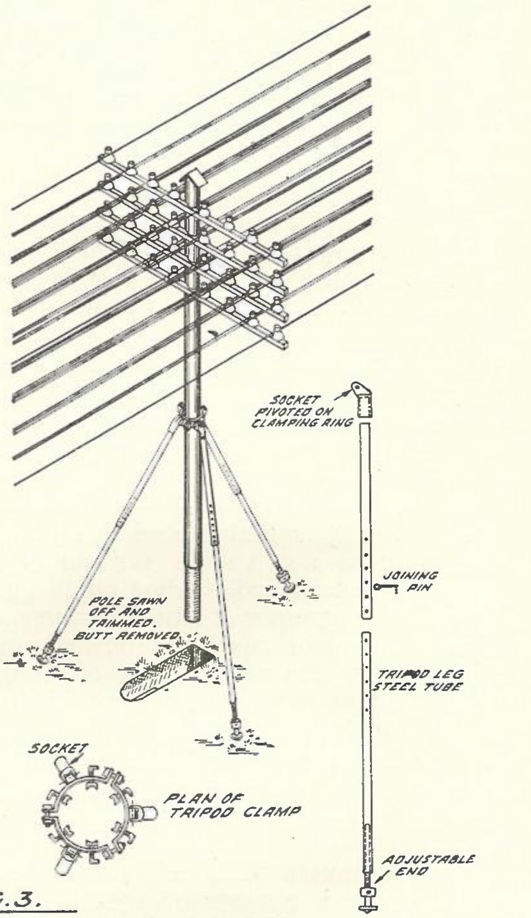


FIG. 3.

POLE SUPPORTED BY TRIPOD AND TRIMMED FOR SLEEVE.

All of the defective butt must be removed.

The trimming machine is illustrated in Fig. 6. The lower support "A", made in two halves hinged at one side and bolted at the other to facilitate fitting and dismantling, is first fitted on the pole by means of four screw clamps. A frame "C", carrying a cutter "D", is then placed on support "A." This frame also is made in two halves. On top of this frame is placed the upper support "B", which is adjusted in position by four screw clamps. This upper support carries a handle "E", turning a bevel gear engaging with the rack at the top of support "C." When the handle is operated, the whole frame "C", carrying the cutter, moves round between the two supports "A" and "B." As the frame revolves, the cutter support "D" is moved downwards half-an-inch per revolution of frame "C", by means of the lead screw which is propelled through a bevel gear by one of the bearing wheels in the bottom of frame "C." When a deeper cut is required, the cutting tool is fed inwards by the slide attachment shown at "D."

This machine was developed in the Melbourne Postal Workshops and the writer wishes to express his thanks to the staff, especially Messrs. J. Marks and L. Davidson, for their contribution to the finished design. While the machine in its present form lacks the refinement which can be included when this method of pole renewal is extended, it trims the bottom of the sound portion of the pole to a perfect cylinder, about 27 inches in length and of such diameter that it will fit tightly inside the steel sleeve (see Fig. 4). The cutting tool is so shaped that small ridges are left round the wood: this corrugated surface assists retention of creosote.

On completion of the trimming, when the correct diameter has been gauged, the upper support "B" is unbolted and removed, followed by the frame "C", and the lower support "A." If necessary, guy wires are then run between the pole and the legs of the tripod, to prevent lateral movement of the pole.

The whole weight of the pole is then taken on the tripod by operating the screws in each leg. The ground is opened out at one side of the pole, which is then sawn through at the bottom of the trimmed portion and the defective butt removed, the pole being left suspended, as in Fig. 3. Into the hole is then placed the steel butt with the sleeve around it. The top of the butt is adjusted to come within an inch or two of the trimmed portion of the pole. The trimmed pole is treated with creosote and a pad of pine heavily impregnated with creosote is placed on top of the steel butt. This pad is about one inch thick and nearly fills the gap between the steel butt and the pole. The steel sleeve is then forced up around the trimmed portion of the pole. The screws in the legs of the tripod are eased, allowing the steel butt to take the weight of the pole, and the steel sleeve is then fixed to the wooden pole by means of two coach screws or bolts. At this stage the hole can be filled in and the tripod withdrawn.

The trimming of the wooden pole is carried to such an extent that when the sleeve is fitted the untrimmed portion above the sleeve overhangs the sleeve a quarter of an inch or more all around. This has the effect of shedding water. In addition, a bituminous sealing compound is pasted in between the top of the sleeve and the adjacent wood. This, with the overhang of wood above the sleeve, is designed to prevent the ingress of water which would favour the development of rot in the enclosed wood. This is not the only precaution: at four places in the steel sleeve there are fitted tapered threaded holes, fitted with small brass plugs which, when withdrawn, allow the insertion of a grease nipple of the "alemite" type. A grease gun is then used to force heavy creosote to fill completely the space between the sleeve and the trimmed wood. An injection of creosote at each annual inspection will ensure that the trimmed portion

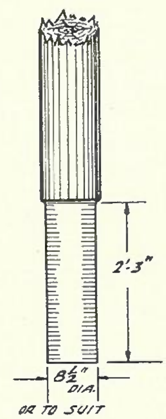


FIG. 4.

TRIMMED END OF SOUND PORTION OF POLE.

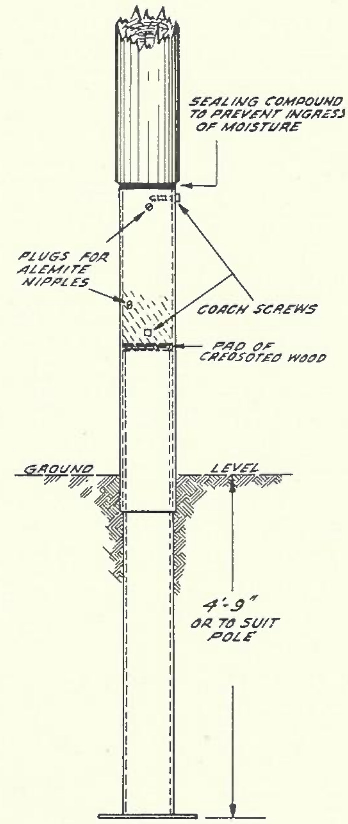


FIG. 5.

RECONSTRUCTED POLE IN POSITION

of the pole is always in a bath of creosote. This should effectively prevent attack by fungus or termites.

The pole then consists of a steel butt for at least 18 inches above ground and sound wood for the upper portion (see Fig. 5). In addition, the steel sleeve extends about 27 inches above the top of the steel butt, and downwards to about 9 inches below ground level, giving a double thickness of steel at the point of maximum bending moment. There is no wood within 18 inches of ground level, and provided suitable action is taken to prevent deterioration of the steel butt in bad soil, such a pole should have a long life.

Twenty poles were recently treated by this method on the main Sydney trunk route in the vicinity of Melbourne. As this work was the first of its kind, the time taken was necessarily somewhat longer than would be the case under normal circumstances after experience had been gained in the work. A further factor was the necessity for shifting fences close alongside the line in order to permit operation of the pole trimming machine, which at the time was fitted with a capstan handle to turn the frame. Despite these factors, the time taken averaged less than one day per pole for the 4-man party engaged. The poles were 40 feet in length and carried 80 wires on 11-9 ft. crossarms. On some poles 50 per cent. of the wires were transposed.

A comparison of the cost of treating these twenty poles with the cost of replacing poles on the same route by the ordinary method, indicated a saving of £12 per pole.

The method would be applied only in the case of poles carrying heavy or medium loads or special fittings or wiring, the transfer of which would involve heavy labour costs. For small lightly loaded poles it would be at least as economical to replace the pole completely. Main interstate trunk routes carry fairly heavily loaded poles throughout, and many intrastate routes are also very heavily loaded. There are probably 60,000 heavily loaded wooden poles on main interstate trunk routes and probably a greater number on intrastate routes throughout the Commonwealth. These figures suggest the magnitude of possible savings.

The new method would be particularly applicable to routes in regard to which the future is undecided; for example, where consideration is being given to the installation of trunk cable. It may be necessary to ensure the stability of the route for a few more years until cable can be installed. This could be done with the new method at a cost much lower than that of completely replacing the defective poles.

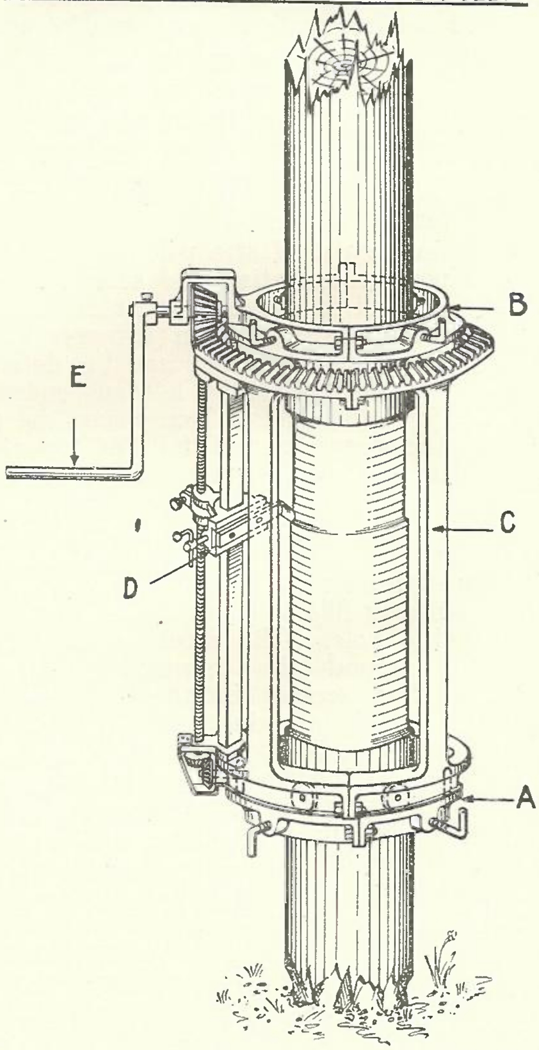
In all the trials to date it has not been necessary for the workmen to touch any of the wires, and no interruptions or wire contacts have been experienced.

Another economical application would be in fitting angle poles carrying subscribers' wires, or poles carrying cable or transformer boxes, where the cost of rewiring or transferring the equipment would be high. Poles in difficult situations (e.g., through verandahs) could be treated without disturbing the upper portion, and a particularly advantageous feature is that steel butts can be concreted in position without damage to the pole, whereas placing concrete around wooden poles in the ground hastens decay of the timber.

The economy of the method having been demonstrated by the recent trials, it now remains to further improve the trimming machine and pole lifting device and to develop a specialised operating technique. In practice, it would probably prove economical for two men to proceed along a trunk route examining the poles, selecting those suitable for treatment and trimming the butts to a suitable size for steel sleeves. The steel butts and sleeves could then be ordered to size, and after delivery on the job, erected by a separate party of two or three men.

The new method can be used with wooden poles of practically any size or shape of cross section. For economy, no greater length of steel butt should be used than is necessary to replace the defective wood, but there is no practical objection to the use of a steel butt extending out of the ground to any desired height. This would be an easy method of increasing or decreasing the height of poles, for raising or lowering wires or fittings.

FIG. 6.
MACHINE TRIMMING A DEFECTIVE POLE.



The experiments so far have been in the replacement of defective poles only. The principle is now being extended to new poles—the lower portion, where wood is especially vulnerable, being of steel, and the upper portion, where wood has the advantage of being easily cut, sawn or bored, being of wood treated full length with a suitable timber preservative.

CABLE AND CONDUIT PLANS FOR THE MELBOURNE NETWORK

W. Banks

The object of this article is to outline briefly the nature of the plans which are in use or in process of preparation as part of the system for recording the Melbourne underground cable plant.

The Melbourne Metropolitan area is defined by a 15 miles radius from the General Post Office and contains approximately 600 square miles, excluding portion of the bay. This area is served by 54 exchanges, and the inner part of this area (approximately 150 square miles) is served by an underground cable system, radiating from and connecting the main metropolitan exchanges.

The underground plant consists mainly of approximately—

500,000 single wire miles of cable,
2,000 duct miles of conduits,
2.2 miles of telephone cable tunnel,

and is the result of an ordered development conforming to the growth of the city and the telephonic demands made on the Department, and the plans recording this plant have been divided into three main divisions:

(1) Street plans,
(2) Conduit plans,
(3) Cable plans.

The details shown are the essential requirements found by experience to be necessary to facilitate maintenance and repairs, and may be summarized as follows:

(1) A record of the plant in situ,
(2) A basis for the study of development and extension of existing plant,
(3) Instructions relative to distribution and allotment of pairs,
(4) Working drawings for the maintenance and repair of plant.

The street plans available and suited to the requirements of the Department are the 10 chain map of Melbourne and suburbs compiled by the Lands Department and the 160 ft. plan of the Melbourne sewerage area compiled by the Melbourne and Metropolitan Board of Works. From the 10 chain plans, 5 chain plans were compiled by the Drafting Section, and though they are still used extensively by the Department, the 160 ft. Board plans were found to be more suitable for plotting the newer forms of underground cable distribution in the congested areas. To improve the co-ordination of the associated cable and conduit plans, the 160 ft. plans were divided into uniform sized sheets, defined by ordinates extending over that portion of the metropolitan area served or likely to be served by underground cable. These will be the standard street plans, and in this form will simplify the recording of cable and conduit details.

The M.M.B.W. plans are supplied in the form of litho copies, showing the streets defined by their building lines with the survey bench marks shown on them. The Board of Works granted permission to use the standard distances and bearings of their bench marks to define our ordinates, which were plotted by triangulation from the bench marks. These ordinates being the boundaries of the plans, some permanent physical point was required as a datum. The G.P.O. and Central Exchange were considered, but finally the axis of the transit telescope at the Melbourne Observatory defining the fundamental meridian was adopted for the principal north and south ordinate, the lateral axis of the instrument defining the principal lateral ordinate, and the intersection of the principal ordinates being regarded as datum. Incidentally, this method defines the ordinates geographically, the meridian being 9 hours, 39 minutes, 53.6 seconds east of Greenwich. This datum being selected, the ordinates were projected by triangulation from bench mark No. 98 in St. Kilda Road, as shown in Fig. 1. A correction of 8° 24′ E. was found necessary to orient the standard plans to conform to the general practice of plotting maps of Melbourne approximately magnetic north.

In addition to defining the ordinates, the bench marks are plotted to correct the errors of shrinkage and warping in the litho plans.

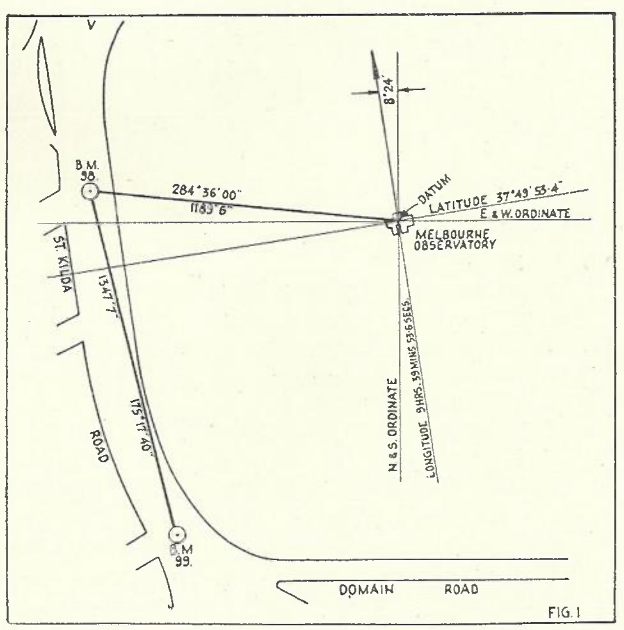


FIG. 1

This involves a considerable amount of computation, but a big saving in time has been effected by the use of an adding machine.

As the standard plans are completed, two true to scale copies of them are taken on tracing linen to form the basic conduit and cable plans.

The basic conduit plans are now being prepared by transfer of details from the existing plans, and by the addition of current construction to the true to scale copy of the standard street plans. They will show:

(1) The position of the duct line in roadway or footpath, with offset measurements to surveyed building line or other permanent position.
(2) The depth, size, type and number of ducts.
(3) Position and type of manhole with distance from cover to cover.
(4) The subdivision or allotment with house number or name to indentify position of pairs on cable plan when cable is taken into subscribers' premises.
(5) The route distance calculated from the cable well by the addition of the distances from manhole to manhole.

In addition to the basic conduit plans are separate plans of multiple duct runs, showing:

(1) Position of duct line in roadway or footpath with offset measurements to building lines.
(2) Section of ducts showing number and size, type and depth below surface.
(3) Position, type, size and depth of manhole with drainage and ventilation details.
(4) Distance from cover to cover.

Other plans are prepared to show the position of conduits into blocks of flats, hospitals, factories, abbatoirs, dockyards, racecourses and similar places. Considerable accuracy is required in plotting these plans to prevent loss or damage by excavations or extensions of buildings, and they are usually plotted on architects' or similar plans to a suitable scale.

Cable plans in general use may be subdivided as:

(1) Individual cable plans,
(2) Assembly cable plans,
(3) Pillar plans,
(4) Section plans.

The cable record plans have developed from simple diagrams of small cables serving to lead open wire into exchanges to plans of the existing network, now including 1,200 pair star quad cables into City West.

This network from the subscribers' premises to the main frame is now almost completely underground and the main function of the cable plans is to show the availability of the cable pairs, through the jointing, from the main frame to the cable termination.

As the conduit plan defines the position of the cables in the roadway, the cable plan, whilst adhering generally to the selected scale may be drawn diagrammatically to show the cable details without the restriction of street alignments or measurement. This allows a comprehensive plan of the entire cable to be drawn to a reasonable size, and no difficulty is found in associating the joints of the cable with the correct manholes or the conduit plans.

The principal details shown on the plan may be summarized as:

(1) Position of cable in duct run.
(2) Size and weight of conductors.
(3) Position and details of joints.
(4) Position, designation and multiplying of pairs, termination and yardage of distributing points, including pillars.
(5) Pairs and house numbers of cable used as direct leads.
(6) Cross connections for fire alarms and other services.
(7) Diagrams showing any departure from straight jointing or jointing to other cables to prevent loss of pairs.

CABLE ASSEMBLY.

These plans have been compiled to show principally the total cable in situ in main runs and the association of various cables with each other. They show:

(1) The total number, size and class of cables in situ.
(2) Route.
(3) Position and size of laterals.
(4) Any details that may be necessary to indicate the association of various cables.
(5) The route distance at appropriate places.

PILLAR PLANS.

The plans form the record of cable in the distribution side of the pillar and show the allotment of the distributing pairs to the subscribers' premises, together with the main pairs from the exchange and the link pairs to other pillars. They are not yet drawn to scale but conform to the basic conduit plans in regard to residential allotments. This arrangement allows the pillar plans to be drawn diagrammatically to allow other details to be shown whilst the conduit plan provides the essential scale measurements.

The section plans are used to indicate the position of cable distributing points and their distributing areas. These points and areas are being eliminated by direct leads, but until the old system has been entirely superseded by the newer forms of distribution, the section plans are maintained and show the new pillar areas. This arrangement indicates to the cable recorder the distributing areas that have been replaced by pillar areas and enables correct allotment of pairs to be made.

Obviously, limitations of space do not permit a detailed description of all these plans, but it is hoped that the brief summary given will enable the reader to obtain an idea of the nature and form of cable records necessary in a complete telephone network.

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