The
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CONTENTS

	Page
Mr. G. T. Chippindall, C.B.E.	1
Picture Telegraphy R. D. KERR	2
The Use of Guides in Cable Hauling C. M. ROGERS, B.E.(Mech.).	11
Outline of Television—Part I N. S. SMITH, A.M.I.R.E.(Aust.).	15
C.B. Manual Exchanges for Country Centres R. W. TURNBULL, A.S.T.C. A. W. McPHERSON, A.M.I.E.(Aust.), M.I.R.E.(Aust.).	32
Manual C.B. Multiple Exchanges and Sleeve Control Trunk Switchboards R. W. TURNBULL, A.S.T.C. A. W. McPHERSON, A.M.I.E.(Aust.), M.I.R.E.(Aust.).	36
The Silica Dust Hazard in Departmental Excavations P. R. BRETT, B.Sc.	42
Recent Developments in Metal Rectifiers for Telecommunication Purposes D. ASHBY, B.Sc.(Eng.), M.I.E.E., A.M.I.Mech.E.	51
Tight Corners for P.A.B.X. Racks E. G. WORMALD	55
Answers to Examination Papers	57

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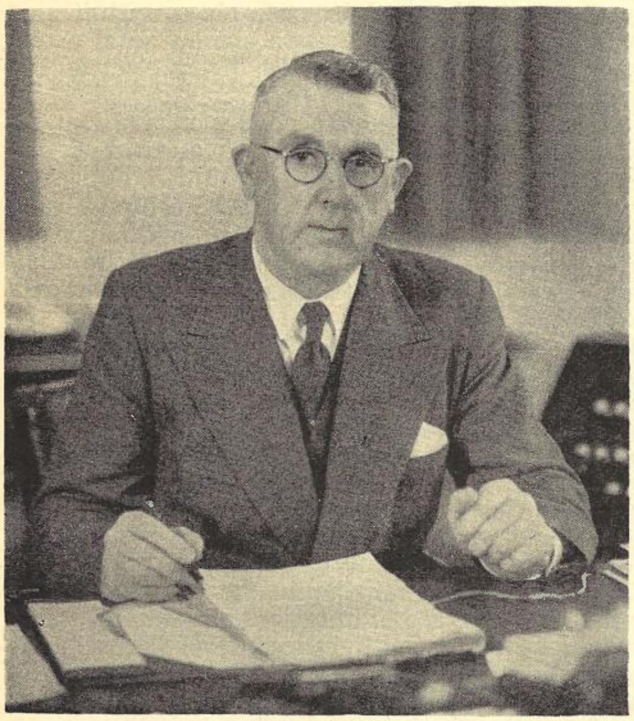
The
Telecommunication Journal of Australia

Vol. 8, No. 1 *June, 1950*

MR. G. T. CHIPPINDALL, C.B.E.



The well-deserved honour of Commander of the British Empire, conferred upon our Patron, Mr. G. T. Chippindall, Director-General, Posts and Telegraphs, in the Birthday Honours List has caused gratification to members of the Postal Electrical Society of Victoria and subscribers to this journal.

Mr. Chippindall's career in the Post Office has been marked throughout by his outstanding organising ability. In 1908 he commenced duty in the Post Office as a telegraph messenger, and was later employed on mail and telephone traffic work. He was associated with the formation of the Telephone and Personnel Branches and was subsequently appointed the first Chief Inspector of the latter branch.

Soon after the outbreak of war in 1939, Mr. Chippindall temporarily left the Post Office and occupied many important positions in other departments. These included Director-General of War Organisation of Industry, Chief Executive Officer of the Economic Cabinet, Secretary of the Department of Supply and Shipping, Chairman of the Australian Shipping Board, and Chairman of the Disposals Commission. He returned to the Post Office in 1946 as Assistant Director-General, Posts and Telegraphs, and when, in March, 1949, he was promoted to the important position of Director-General, the appointment was welcomed in all quarters.

Mr. Chippindall has been an inspiring leader to the Post Office in the difficult period now being experienced, when acute shortages of materials, labour and equipment and delays in providing suitable buildings for Telephone and Exchanges and Post Offices are creating difficult problems.

Insofar as the Post Office is concerned, it is felt that the honour bestowed upon him is of double significance; it is a fitting tribute to one whose many and varied activities have done much to increase the prestige enjoyed by the Postmaster-General's Department, and at the same time it gives recognition to the services rendered by the Department to the community.

All members of the Postal Electrical Society of Victoria and subscribers to this journal offer Mr. Chippindall their sincere congratulations on this overdue recognition of his services.

PICTURE TELEGRAPHY

R. D. Kerr

General

For several years before the recent war the Post Office operated a picture telegraph service between Sydney and Melbourne. The equipment used was of the Siemens Karolus type and because of war-time maintenance difficulties with spare parts the service was discontinued in 1942. As part of the Post Office's plans for the post-war period a new picture telegraph service between all the Australian capital cities and Newcastle, N.S.W., was proposed. It was, furthermore, planned that the new installations should be capable of operation in conjunction with the Overseas Telecommunication Commission's radio links, so that direct reception and transmission of overseas picturegrams would apply throughout the Commonwealth.

The new service has been opened between Sydney, Melbourne, Brisbane and Adelaide and will shortly be extended to Perth, Hobart and Newcastle, using Muirhead Jarvis picture telegraph equipment throughout. In addition to fixed transmitting and receiving installations at these points, two portable transmitter units which may work to any of the receivers are available. The internal picture telegraph service is provided over the trunk telephone networks while overseas service is provided by extension of the O.T.C's radio links, at Melbourne, into the Post Office land line system.

Principles

The fundamental principles of the Muirhead Jarvis picture telegraph system are indicated in Fig. 1. The picture to be transmitted is clipped around a drum. A small area of the picture is illuminated by a projection lamp and a photo-electric cell is focussed through an optical system (not shown) on a small rectangular section of the picture, or scanning spot, in the illuminated area. The current flowing in the photo-electric cell varies with the light reflected from the scanning spot, a greater current flowing for a white spot and less for the darker spots.

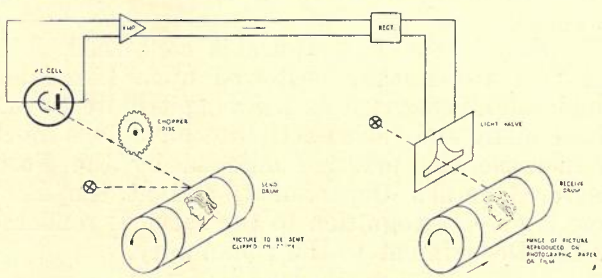


Fig. 1.—Principles of Picture Transmission.

By rotating the drum continuously and arranging for it to be moved axially by the width of the scanning spot with each revolution, the picture is scanned in successive strips, each the width of the scanning spot. The current flowing in the photo-electric cell is amplified and transmitted over a line to receiving equipment and there controls a light valve. The receiving equipment has a drum similar to that at the sending terminal and around this a sheet of photo-sensitive film or paper is clipped in the same way as the transmitted picture. A projection lamp illuminates a small spot on the receiving film, an optical system (not shown) focussing the light beam through the light valve on to the spot which has the same size as the send scanning spot. The light valve under the control of the received current permits a greater or lesser exposure of the receive scanning spot to the light from the projection lamp. By rotating the receive drum continuously at the same rate as the send drum, in phase with it, and by giving the receive drum a similar axial movement to the send drum the photo-electric cell currents controlling the receiver light valve in turn control the exposure of the receive film reproducing the details of the sent picture as viewed by the send scanning spot.

The current in the photo electric cell may vary very slowly if, for instance, a strip of the picture of unchanging shade is being scanned. The problem of amplifying and transmitting such currents over lines is a difficult one. To avoid this the picture signal to the photo-electric cell is transformed to a signal superimposed, by amplitude modulation, on a carrier wave. This is achieved by interposing a rotating toothed wheel, or "chopper disc" in the light beam between the send scanning spot and the photo-electric cell. As the light beam is being continually "chopped" by the toothed wheel the signal reproduced by the photo-electric cell will be a pulsating current whose frequency depends on the number of teeth in the wheel and its rate of rotation, and whose amplitude depends on the lightness or darkness of the scanning spot on the picture—in effect a carrier wave of the "chopping" frequency, amplitude modulated with the picture signal. With a suitable choice of carrier frequency such a signal may be conveniently transmitted over telephone channels, amplified, translated, and the original picture intelligence recovered by rectification of the carrier signal at the receiving equipment. The rectified signal may then be used to control the light valve of the receiver.

The drums at each end are rotated by phonic motors fed from sources of A.C. of high frequency stability, the phonic motor shaft being coupled to the drum shaft through 10 : 1 gearing. The drum and its carriage are moved axially by a lead screw which engages in a nut fixed to the supporting ways of the carriage. An eccentric, on the drum shaft, at each revolution engages a pawl in a ratchet wheel on the lead screw so producing the longitudinal motion. The mechanical arrangement is generally analogous to a screw cutting lathe, the fixed light spot tracing out a path like a helix on the constantly rotating and longitudinally moving drum.

In the Muirhead Jarvis equipment, to facilitate handling of the photo-sensitive material, the receive drum is normally encased in a light-tight metal box. A drum may be loaded in the darkroom, carried out in the box, fitted into place on the receive carriage and rotated inside the box by shafts extended through the ends of the box. A long slot in the rear of the box faces the receive optical system but is normally closed by a light-tight shutter which is only opened when the box is placed on the receive carriage, the receive console lid closed, and locked.

A series of standards to cover each of these functions has been formulated by the International Telegraph Consultative Committee in its Recommendation No. 681. This specifies that the drum diameter should be 66 m.m. or 88 m.m., the width of the scanning spot and, consequently, the scanning pitches should then be 3/16 m.m. (i.e., $5^1/_3$ lines per m.m.) or $\frac{1}{4}$ m.m. (i.e., 4 lines per m.m.) respectively, the normal speed of rotation of the drum should be 1 r.p.s. and the carrier frequency 1300 c/s. In the Muirhead equipment the 4 lines per m.m. scanning pitch has been translated into the more convenient (for British purposes) 100 lines per inch and the drum slightly enlarged to 3.52 inches (90 m.m.) diameter and 11 inches circumference. The relationship between the width and the length of a picture will be directly equivalent to the relationship between the drum diameter and the number of lines required to scan it. It is possible for picture telegraph work to express this relationship as the product of drum diameter and number of lines per unit length, this product being called the "Index of Co-operation." If different equipments have the same Index of Co-operation the relationship between width and length of a picture will be preserved when working from one equipment to another even though the drums differ in size. Thus when sending from the 66 m.m. drum to an 88 m.m. drum the reproduction of each scanning line is lengthened by $^1/_3$ but its width is correspondingly increased by $^1/_3$ from 3/16 m.m. to $\frac{1}{4}$ m.m., the reproduced picture being "scaled up" by $^1/_3$ with respect to the original. For all of these sizes the Index of Co-operation is 352, the implication of the 90 m.m. drum of the Muirhead Jarvis equipment being only a very slight increase or decrease of picture size when working from or to a standard 88 m.m. drum.

The portable picture transmitters, for compactness, have the smaller 66 m.m. drum and $5^1/_3$ lines per m.m. (135.4 lines per inch) scanning density so that pictures sent from these units to the fixed receivers are scaled up by $^1/_3$. For the Muirhead Jarvis equipment the 100 lines per inch scanning density implies that the scanning spot should be 10 mils wide and that the minimum detail of the picture which can be adequately recognised is of, at least, 10 mils dimensions. This corresponds to the resolving power of the naked human eye at normal reading distance, so that no appreciable advantage would be gained, in practice, by a finer scanning pitch. Incidentally, since picture telegraphy is mostly used for Press work, this scanning pitch is quite adequate, the normal half-tone newspaper blocks being prepared with screens of the order of 80-100 lines per inch.

The mechanical design of the equipment readily permits the provision of an alternative scanning pitch, and to meet the possibility of a suggested 125 lines per inch (Index of Co-operation 440) scanning density, this is provided as the second choice. The changeover of pitch is simply effected by arranging for the feed pawl to normally feed five teeth at a time on the 250 tooth ratchet wheel of the lead screw but to feed only four teeth at a time for the alternative scanning pitch.

Naturally one of the chief questions must be how to keep two drums, widely separated and driven by motors fed from two different sources, running in phase with one another and at the same speed for a considerable time. This has been achieved by using phonic motors which are of the single phase A.C. type and will only run at a synchronous speed, and supplying these with A.C. controlled by very stable oscillators. The oscillators are of the tuning fork controlled type, the forks being made of perminvar, a magnetic alloy of very low temperature co-efficient. The fork frequency is 1020 c/s and is adjustable over a range of $\pm$ 0.2 c/s. by varying the coupling between the coils and the tines of the tuning fork. Any difference in the speeds of the two drums results in the original rectangular picture being reproduced as a parallelogram. To reproduce the maximum size of picture, 11 in. x 10 in., without more than $\frac{1}{8}$ in. skewing of the rectangle requires a stability of rotational speed of $\pm$ 1 in 100,000, and the tuning fork oscillators must consequently be capable of maintaining this over the period of some 20 minutes required for the running of the picture. Actually the oscillators appear to be capable of maintaining this order of accuracy for several weeks, notwithstanding appreciable day-to-day variations of room temperature.

Phasing of the two drums is effected by sending a special phasing signal before transmission of a picture. This consists of a 30 milliseconds pulse of tone sent to line during each revolution of the send drum as the gap between the two clipped edges of the picture passes the send optical system. This phasing impulse is received, rectified, and operates a relay, which in turn engages the clutch between the receive motor and drum. The sending and receiving drums are marked to indicate where the gaps between the clipped edges of the original picture and receiving film respectively should be placed. The send drum has a one-tooth clutch which will engage at only one point while the receive drum lies with the gap between the clipped edges of the film opposite the receive optical system until the phasing impulse engages the receive clutch. A neon lamp stroboscope is also provided, a continuous succession of transmitted phasing impulses flashing the lamp over arrows on the tailstock of the receive carriage and on the receive drum. These two arrows are in line when the send and receive drums are in phase and any error in phasing is indicated directly by the misalignment of the arrow heads. The time of transmission of a picture, from the fixed equipment, is 100 seconds for each inch to be scanned along the drum at 1 r.p.s. Thus the time for a normal 10 in. x 8 in. picture is $12^1/_3$ minutes, and for the maximum sized 11 in. x 10 in. picture is $16^2/_3$ minutes.

A.M. Operation

The actual functioning of the equipment for A.M. transmission is shown in Fig. 2. The area around the send scanning spot is illuminated by two projection lamps so arranged that the images of their filaments are crossed on the lighted area. This is done to ensure even illumination of the scanning spot and avoid the possibility of shadows being cast by unevenness of the original picture surface. Light reflected from the scanning spot

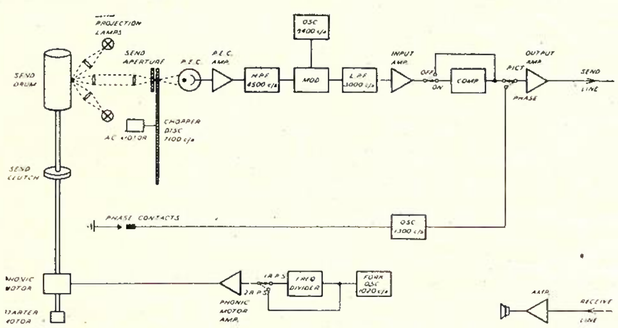


Fig. 2.—Muirhead Jarvis A.M. Transmitter.

passes through the send optical system, the send scanning aperture of rectangular form, and the chopper disc to the photo-electric cell. The choper disc gives a chopping frequency of 7100 c/s and is driven by a constant speed, single phase 50 c/s A.C. motor. The output from the photo-electric cell is a 7100 c/s carrier, amplitude modulated with the picture signal, which passes to a two stage amplifier. This amplifier is mounted in the back of the send console but all other electronic equipment is rack-mounted. The photo-electric cell amplifier magnifies the very low signal level from the photo-electric cell and avoids the possibility of the signal being affected by interference picked up in the wiring between the console and the rack.

Since the smallest sized detail which may be recognised when scanning is 10 mils, the maximum picture intelligence frequency is that when scanning a succession of such fine details, alternately of light and dark shade. With the 11 inch scanning strip around the circumference of the drum rotating at 1 r.p.s. 1100 such details, alternately light and dark, will be scanned each second and the picture intelligence frequency will thus be 550 c/s. With a drum speed of 2 r.p.s. this increases to 1100 c/s. The 7100 c/s carrier is consequently amplitude modulated with picture signals up to 1100 c/s at the higher speed. Since the slots in the chopper disc are rectangular, the carrier wave so produced will be saw-toothed in form comprising a fundamental frequency of 7,100 c/s and its odd harmonics each being modulated by the picture signal.

This composite signal passes through a high-pass filter of cut-frequency 4,500 c/s, preventing the actual picture signal frequency from passing to later stages, thence to a frequency changer stage which is also fed from a 8400 c/s oscillator. The lower product of modulation will be a 1300 c/s carrier amplitude modulated with 1100 c/s picture signals, while the input frequencies and higher modulation products are suppressed in the following low-pass filter of 3000 c/s cut-off frequency.

The indirect method of producing the 1300 c/s carrier has been adopted by the designers as the simplest method of producing a sinusoidal carrier. It will be appreciated that chopping directly at 1300 c/s would produce harmonics of the carrier such that the lower side bands of modulation of the harmonics would fall in the same frequency range as the upper side bands of modulation of the fundamental carrier, that such harmonics and their side bands could not in this case be suppressed by filters and may prejudice the received picture if their velocities of propagation over the line differ from that of the fundamental carrier.

The 1300 c/s amplitude modulated carrier is amplified in the input amplifier to the compensation stage, passes through this stage, which may be by-passed if not required, and through the output amplifier to the send line. Since the maximum current flows in the photo electric cell for the white scanning spot, the carrier wave has its greatest amplitude for "picture white" and its least for "picture black" which is actually 32 db. below white. The compensation stage compresses this range to 14 db., 1 milliwatt normally being sent to line for white and —14dbm. for black with compensation, or —32dbm. without compensation. This stage consists of a variable T attenuator having two fixed series resistors, and the plate to cathode resistance of a 6H6 diode as the shunt resistor. With a low voltage across the diode its resistance is high but this decreases with increasing voltage across the electrodes. The two diode elements of the 6H6 are used, one functioning on positive and the other on negative half cycles. The high level white signals are thus attenuated to a greater extent than the lower level greys and blacks.

The phonic motor is fed from the 1020 c/s tuning fork oscillator, a 2 : 1 frequency divider stage and the phonic motor amplifier. The speed of the phonic motor with 510 c/s supply is 10 r.p.s. and through the 10 : 1 reduction gearing the drum speed is 1 r.p.s. With the frequency divider stage by-passed the 1020 c/s supply causes the phonic motor to rotate at 20 r.p.s. with a drum speed of 2 r.p.s. The output stage of the phonic motor amplifier consists of four 6L6G beam tetrodes in parallel push-pull providing some 30 watts of power to drive the motor. Since the phonic motor is not self-starting a small auxiliary D.C. motor is provided for this purpose. The starter motor is belt-coupled to the phonic motor through a centrifugal clutch which engages the latter motor shaft only when the starter motor is running.

The input to the final amplifier may be switched from the picture signal to a 1300 c/s oscillator, the output of which is keyed by a relay controlled by cam-operated contacts mounted on the drum shaft. These contacts close once each revolution and provide the phasing impulse to line as a 30 millisecond pulse of 1300 c/s tone, in effect a short "white" impulse in a "black" background. This phasing signal is, by consequence, commonly called "phase white."

The normal picture circuit is a true four-wire one, the picture transmitter being connected to the "out-going" line with the receiver connected to this line at the other end. The "in-coming" line at the transmitter is connected through an amplifier to a loud-speaker and provides a "talk-back" circuit during sending of a picture. A telephone transmitter (not shown) may be connected to the send line in place of the picture transmitter and the four-wire circuit used for speech.

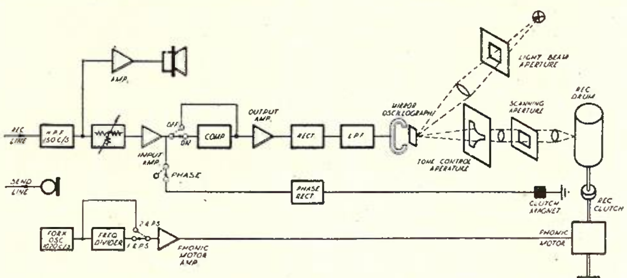


Fig. 3.—Muirhead Jarvis A.M. Receiver.
New figure eliminating error in phase impulse pick-up circuit.

A.M. Receiver: The actual functioning of the equipment for A.M. reception is shown in Fig. 3. The incoming 1300 c/s carrier signal passes from the "receive" line through a 150 c/s high-pass filter to the input level control. This filter is included to suppress low frequency interference from such things as D.C. telegraph circuits, dial impulsing, and ringing currents. The input level control is a key-switched attenuator having 0, 10 and 20 db. settings and a continuously variable 0—20 db. attenuator. This controls the level to the input amplifier which feeds the compensation stage, this being switched in or out of circuit as required. Compensation is effected in the same way as in the transmitter, the signal passing to the final amplifier, whose output is rectified in a full wave metal rectifier network. The carrier ripple frequency is suppressed by the final low pass filter and the rectified current, which follows the intensity of light reflected from the scanning spot of the original picture, flows through a Muirhead Dudell mirror oscillograph.

This unit consists simply of two parallel wires between, and parallel to, the pole pieces of a strong permanent magnet. On the wires a small mirror, approximately 1 m.m. x 0.5 m.m., is mounted. Current flowing in the wires causes them to move in the magnetic field. By passing the current in one direction through one wire and the reverse in the other the mirror will be deflected by the complementary movements of its supporting strings. Since the whole movement is very light it is capable of following very rapid fluctuations of current in the wires. The whole movement is immersed in paraffin to damp the motion, and, with a given alternating current in the strings, deflection is independent of frequency up to some 500 c/s after which it decreases slowly. Undamped, the movement exhibits a resonance at about 700 c/s. Such a movement is capable of following the variations of current due to the smallest recognisable details of the picture at 1 r.p.s. drum speed and with only slight infidelity may follow the smallest detail at 2 r.p.s.

The receive optical system consists of a projection lamp whose light passes through a rectangular aperture to a lens which focusses the beam on the mirror of the oscillograph. The reflected light beam falls on the shaped tone control aperture, passes through it to the receive scanning aperture, which with the lens focusses it on to a 10 mils scanning spot on the receive drum. The reflected light beam from the oscillograph falls evenly on the tone control aperture for picture white and light passes through all parts of the aperture. With less current the oscillograph deflects the beam towards the tapered end of the tone control aperture and less light passes through the aperture, in the limiting case of picture black, the beam being deflected off all but the edge of the aperture. Electrically, the changeover from negative to positive reception is made by a key which reverses the connections to the oscillograph.

The fork oscillator, frequency divider, phonic motor and starter motor of the receiver are the same as those on the transmitter. Across the incoming line, an amplifier and loud speaker are bridged permanently. For phasing, an anode bend detector may be bridged across the input to the compensation stage, this rectifier operating a relay in its plate circuit when tone is incoming in the "phase white" signal. The relay closes circuit to the controlling electromagnet of the receive drum clutch which engages. A telephone transmitter may be connected to the out-going line which is used as a "talk-back" circuit during preparation to transmit a picture.

Compensation and Tone Control: The essential requirement of a picture telegraph system is that it should be capable of reproducing, as accurately as possible, the original picture. This implies not only fidelity of proportion and detail, but fidelity of shade reproduction. In this regard the variations of signal level with the variations of shade of the original picture, the shaping of the tone control aperture in the receiving optical system, and the photographic characteristics of the receiving film or paper are closely inter-related.

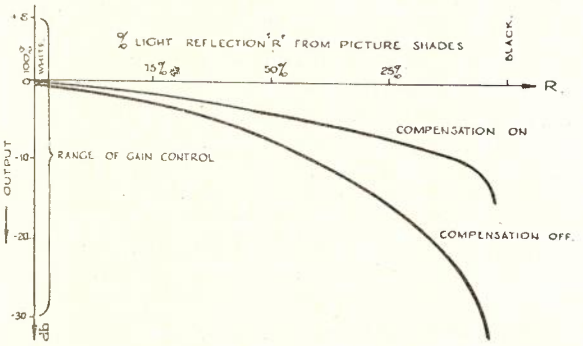


Fig. 4.—Send Amplifier—A.M. operation output level versus % light reflection "R" from send picture shades white to black. [Input for shade white adjusted to 230 μA compensation current indication and output to zero level on 600Ω]

The output characteristic of the photo electric cell is shown in the lower curve of Fig. 4 and the effect of compensation is clearly shown in the upper curve.

The tone reproduction characteristics of photographic materials may be defined in logarithmic terms, which is the way in which light affects the human eye. This is similar to the common engineering practice with sound. Any given shade on photographic paper may be defined as the $\log_{10} L_O/L_R$ where L_O is the light reflected from an unexposed portion of the paper and L_R is the light reflected from the shade under consideration. This quantity is called the "Density Co-efficient" and for ordinary photographic papers has a range from 0, for picture white, to 1.3-1.6 for picture black. In a similar way any shade in photographic film may be defined as the $\log_{10} L_O/L_T$ where L_O is the light transmitted through an unexposed portion of the film and L_T is the light transmitted through the shade under consideration. Films also have a certain minimum density due to a slight fog which appears even in unexposed and developed material. For all papers and films a series of curves may be drawn for a range of conditions of development showing Density co-efficient against log. exposure and these are of the form shown in Fig. 5. The effect of variation of developing time and temperature is to alter the slope of the straight portion (which is measured in terms of the tangent, "gamma," of the angle between the straight position of the curve and the X axis) and to shift the curve to and fro along the X axis. By using these char-

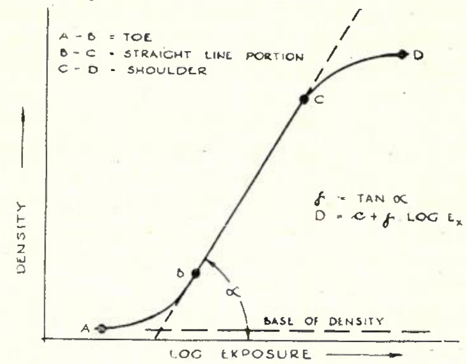


Fig. 5.—Characteristic D-Log.E. Curve of Photographic Materials.

acteristics the experienced photographer is able to use photographic materials to best advantage.

The length of the straight portion is a measure of the material's ability to recognise a large number of intermediate shades of light and its ability to reproduce fine details. The shorter and steeper the straight position the fewer will be the number of intermediate shades which may be recognised and the greater the tendency for all lighter

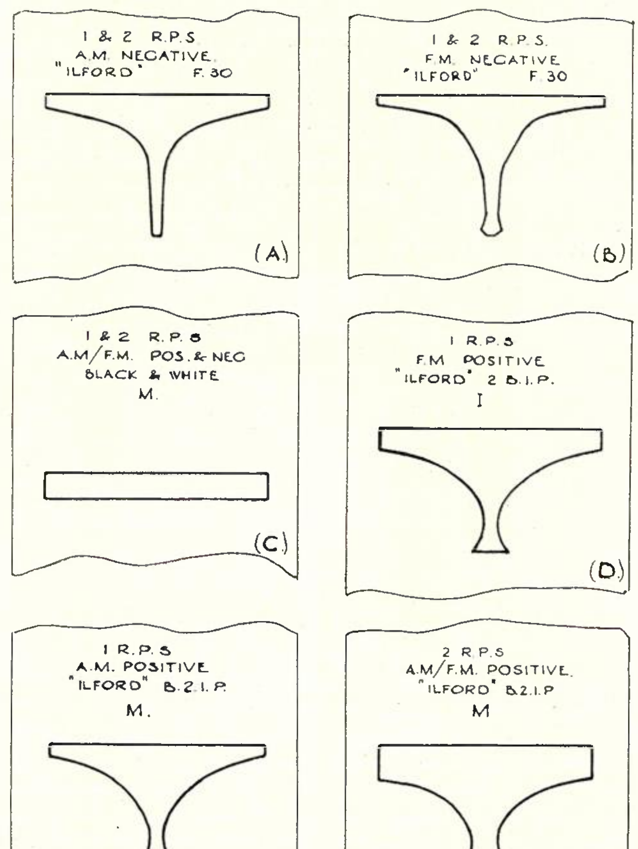


Fig. 6.—Shape of Tone Control Apertures for Negative and Positive Reception.

shades and all darker shades to be merged with the whites and blacks respectively at the curved ends of the characteristic. "Hard" or "contrasting" films and papers have steep characteristics, while "softer" materials have longer and more sloping characteristics, giving better intermediate shade reproduction and better detail, but produce exposures of the receiving material as closely following the tones of the original as possible. To simplify the design requirements part of the controlling has been done electrically by the compensation stage and the remainder done within the aperture. Since the characteristics of the various photographic materials differ, a

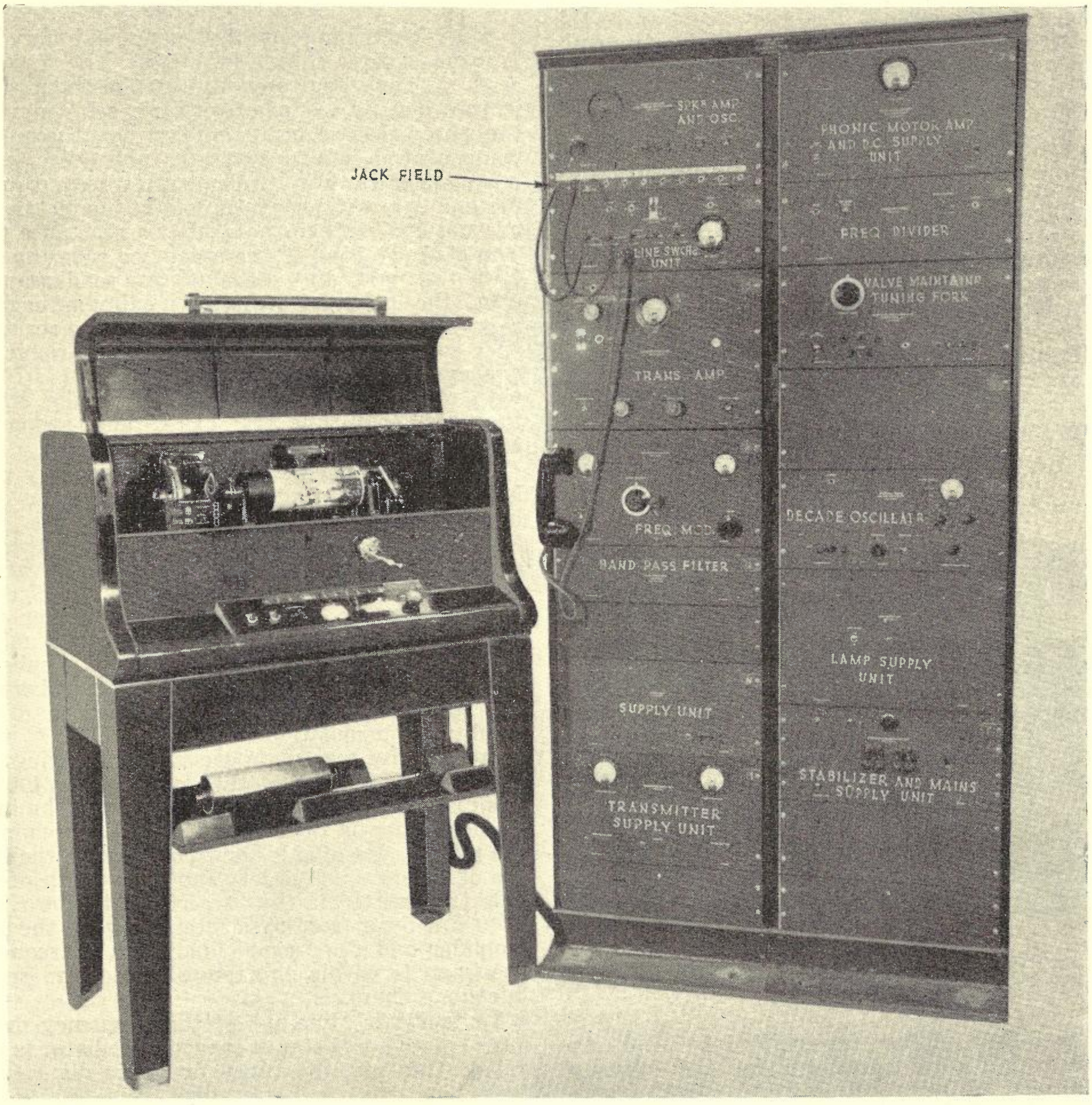


Fig. 7.—Transmitting Rack and Console.

generally with less range between blacks and whites. Negative film materials have much longer straight portions to their curves than the positive papers and, consequently, negatives may always have a wider range of shades than may be reproduced from them on printing paper.

The purpose of the tone control aperture is to special aperture is required for each material, and since the electrical effects of F.M. operation differ from those for A.M., different apertures may be needed for the same material in each case. Typical apertures are shown in Fig. 6. That marked C is of interest since in transmitting a black and white original there is no need to reproduce intermediate shades of grey and, consequently, a rectangular slot only is required, permitting the light beam to pass through for white and blocking it for all lower signal levels.

It is the practice to use compensation at the transmitter and not at the receiver, it being advantageous that the amplitude range is compressed to 14db. in the presence of possible interference on the circuit. The sole exception to this practice is operation from the portable transmitters which, in the interests of simplicity, have no compensation and this must necessarily be provided at the fixed receiver.

Fig. 7 is a general view of the racks and console of the transmitter unit. The picture drum may be seen on its carriage in the console, the open lid protruding on top. The left hand rack contains the picture signal electronic equipment and its power supply, while the right hand rack contains the lamp and phonic motor supplies. The receiving racks and console are very similar in appearance to the transmitter, with the receiver drum in the same relative position but enclosed in its cassette. The shutter of the cassette is to the rear and is not opened until the receiver lid is closed and locked.

Both transmitter and receiver are powered directly from the A.C. mains, the power consumption in each case being some 500 watts.

Fig. 8.—A.M. picture. The left-hand section is seen as "lined-up," the next with 1500 c/s interfering tone 17db below picture white, the next with 3db increase in level and the right-hand section with 3db decrease in level.

Fig. 8 is a picture transmitted by A.M., the extreme left-hand portion under the "line-up" conditions, the next section with a slight drop in level and a 1500 c/s interfering tone 17 db below "picture white," the next section with an increase of 3 db in level over "line-up" and the right-hand section with a decrease of 3 db in level below "line-up." This illustrates the limitations of A.M. picture transmissions with interference and changes in level. Actually an interfering tone 40 db below picture black (i.e., 54 db below white with compensated transmission) may be recognised on a picture and the minimum recognisable change of level is $\pm$ 0.5 db. Consequently, very quiet and stable circuits are required for A.M. picture transmission. Such a method of transmission is not suitable for long range high frequency radio transmission, and for this purpose the frequency modulated sub-carrier system was developed.

F.M. Operation

The functioning of the equipment for F.M. transmission is shown in Fig. 9. The 7100 c/s A.M. carrier signal produced by the chopper disc is recorded by the photo-electric cell, passes to the photo-electric cell amplifier, input amplifier, compensation stage which is not used at the transmitter for F.M. transmissions, output amplifier and to a rectifier which detects the picture signal and applies it to the grid of a reactance tube. The grid potential of the reactance tube thus follows the light and shade of the send scanning spot, the potential being a maximum negative for white and a minimum for black. The reactance tube controls the tuning circuit of a variable frequency oscillator which oscillates at 113,070 c/s with minimum negative potential on the grid of the reactance tube for black, and swings to 113,870 c/s for white.

The output from the variable frequency oscillator is modulated with the signal from an oscillator of a fixed frequency of 115,370 c/s. The lower sideband of modulation is passed through a filter and is an audio frequency signal varying from 1500 c/s for white to 2300 c/s for black. It is customary to define these limits rather than the mid frequency which represents a middle shade of grey. The shift in frequency is substantially linear, i.e., the shift in frequency between the specified limits is a linear function of the amplitude modulation voltage. With 1 r.p.s. operation the maximum picture modulating frequency is 550 c/s and the deviation $\pm$ 400 c/s from the mean frequency of 1900 c/s. The index of modulation is then only 0.72 and consequently the magnitudes of side bands, other than the first, are of a very small order. The band-width of signals transmitted is thus restricted to 800 c/s to 2800 c/s by a band-pass filter between the final amplifier and the "send" line. Such a frequency spectrum is within the range of modern carrier telephone channels.

To facilitate "line-up" of the frequency modulator a decade resistance capacity oscillator is provided. This may be tuned on three dials (unit, tens, hundreds) in 1 c/s steps from 1400 c/s to 2399 c/s. A 2300 c/s output from this unit is beaten with the output from the frequency modulator, the input to the reactance tube rectifier being cut-off and the variable frequency oscillator tuned to have 2300 c/s difference from the fixed frequency oscillator. A picture white signal is then passed to the reactance tube and the level of this signal adjusted so that there is 1500 c/s difference between variable and fixed frequency oscillators, this being indicated by beating the

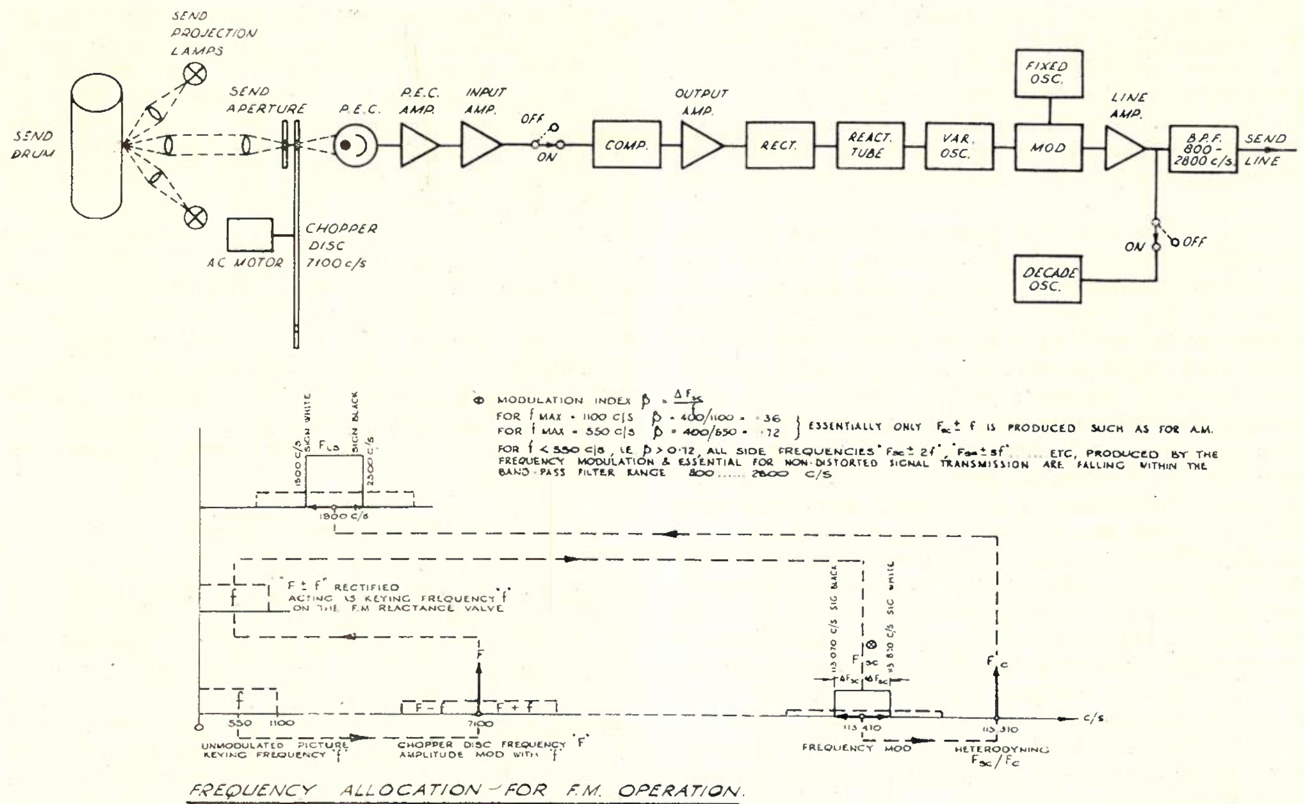


Fig. 9.—Muirhead Jarvis F.M. Transmitter.

frequency modulator output with a 1500 c/s tone from the decade oscillator.

The additional equipment for F.M. operation is mounted on the transmitter rack, the changeover from A.M. to F.M. being effected by throwing two keys.

F.M. Reception: The principles of F.M. reception are shown in Fig. 10. The F.M. receiver

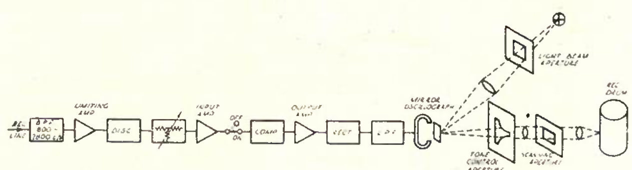


Fig. 10.—Muirhead Jarvis F.M. Receiver.
New figure eliminating error in B.P.F. figures.

follows conventional lines. An input band-pass filter eliminates noise and spurious frequencies outside the picture signal frequency range of 800 c/s-2800 c/s. A limiting amplifier accepts the varying level F.M. sub-carrier, and provides a constant level output for inputs not less than —30 dbm. The constant level, varying frequency, signal is then applied to a discriminator network, comprising resistors and capacitors arranged to present an attenuation of 18 db to the 1500 c/s white signal and rising to an attenuation of 50 db for the 2300 c/s black signal. The attenuation/frequency characteristic of the discriminator is arranged to be similar to the output/light shade characteristic of the photo-electric cell amplifier shown in Fig. 4. The output of the discriminator is thus an amplitude modulated, varying frequency, carrier wave with a 32 db difference between white and black corresponding to the level relationships of the original amplitude modulated carrier. This signal is then amplified, compensated and rectified in the same manner as the normal 1300 c/s A.M. carrier signal.

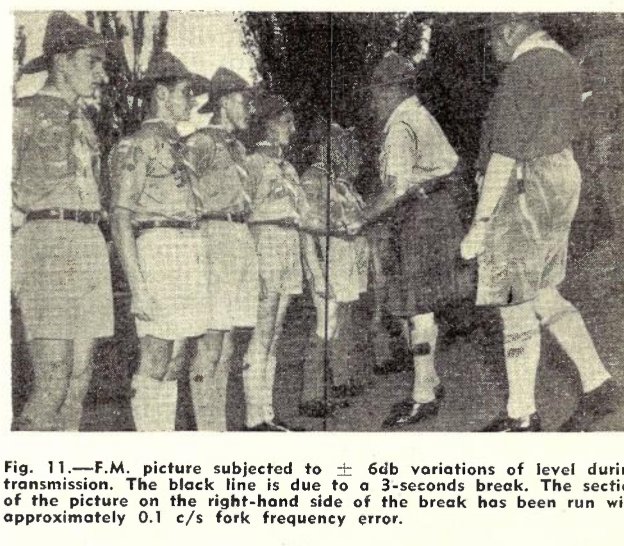


Fig. 11.—F.M. picture subjected to ± 6db variations of level during transmission. The black line is due to a 3-seconds break. The section of the picture on the right-hand side of the break has been run with approximately 0.1 c/s fork frequency error.

By virtue of the limiting amplifier the F.M. sub-carrier transmission will be unaffected by wide variations of input level; there is some 14 db improvement in tolerable noise level, still 40 db below signal level, but this is now unchanged for black or white, and such an audio signal may be conveniently transmitted over modern line telephone channels or any double sideband or single sideband high frequency radio telephone channel.

Fig. 11 is a test F.M. transmission and has been subjected to ± 6 db variations in level without variation in shade of the received picture. Because of this fact the performance with F.M. operation on land lines is very much better than with A.M. and, notwithstanding widely varying conditions on overseas H.F. radio circuits, good commercial pictures may be reliably received. The system is still not immune to fleeting interruptions of the circuit and the disastrous effects of a 3-second break in the circuit and three repetitions of the word "Hullo" may be seen in the middle of the picture. F.M. operation has, however, solved the otherwise almost impossible problem of avoiding change in level with A.M. which the pilot regulation of the modern carrier telephone systems, not being instantaneous in action, does not reduce to close enough limits for perfect A.M. picture transmission. Incidentally, the right hand portion of the picture from the break has been run with approximately 0.1 c/s difference in fork frequencies.

The frequency limits for F.M. transmission conform to the recent recommendations (No. 25 of 1948 at Stockholm) of the International Radio Consultative Committee and the stability required therein—instantaneous 8 c/s, during 15 minutes 16 c/s—is provided by the equipment. It is interesting to note that the choice of frequency limits was based on the necessity to make the uppermost frequency less than twice the lower frequency. The strong harmonics produced by selective fading on the radio circuit could then be eliminated by band-pass filters at the receiver, the limitation being that the second harmonic of the lower limit frequency should be above the upper limit of the transmission band. It is, however, desirable that the limits be as far apart as practicable so that the tolerance of frequency instability of the sub-carrier is a maximum, with the limitation that 800 c/s is the greatest difference beyond which trouble may possibly occur due to appreciable variations in propagation time for the black and white limit frequencies. It will be seen that the 1900 c/s carrier with deviations of $\pm$ 400 c/s and a maximum modulating frequency of 550 c/s meets these diverse requirements.

Fork Frequency

The high precision of the tuning fork oscillators has a point of interest. It is desirable that these be checked periodically, a weekly routine check back to a reference station being the practice. This is done by sending fork tone from one station to the next over the line. However, since the telephone channels used are generally of the single side-band suppressed carrier type, the difference between the sending and receiving carrier oscillators may be appreciable. An error due to this cause is avoided by modulating the 1300 c/s artificial white tone with 1020 c/s fork tone and sending this carrier and both side-bands over the telephone channel simultaneously. This is rectified at the receiving station, the 1020 c/s recovered and used for comparison with the local fork frequency. For example, if there should be a 2 c/s difference in the carrier telephone oscillators the input frequencies would be 1300 c/s, lower side-band 280 c/s, and upper side-band 2320 c/s. The output frequencies would be, say, 1302 c/s, 282 c/s and 2322 c/s, which is a 1302 c/s carrier with upper and lower sidebands of modulation by 1020 c/s, which latter frequency may be recovered by rectification.

Operational Aspects

The normal land-line picture circuits are carrier telephone channels, these being used on a true four-wire basis. The "go" path is used for the picture transmission, or speech during line-up, and the "return" path is used for the "talk-back" circuit. If traffic requirements warrant, it is practicable to use both transmitter and receiver at two stations and operate a duplex picture telegraph service, pictures being transmitted in both directions simultaneously.

The requirements of "broadcast" transmissions —i.e., one station sending to several receivers simultaneously—are rather more complicated, and the case of an overseas transmission incoming through the Overseas Telecommunications Commission, Melbourne, to a number of Australian

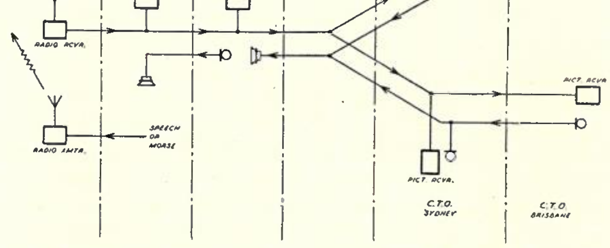


Fig. 12.—Circuit Arrangements—Automatic Relay of Overseas Picturegrams.

cities simultaneously is shown in Fig. 12. The radio signal is received at the O.T.C. receiving station, at Rockbank, and passed by land line to the O.T.C. operating centre in Melbourne, where a monitor copy is taken of the picture. This is delivered to a Melbourne addressee should there be one. The picture signal is also passed to Melbourne C.T.O. and a monitor copy is taken here. The Melbourne picturegram operator has the responsibility of ordering the land-line channels and, if there is likely to be delay in providing any circuit, of deciding if it be necessary to use the Melbourne monitor copy for a re-run to that circuit later. The circuit is then extended to the Long Line Equipment Terminal at City West, and the signal branched to those circuits concerned. If further branching is required, as, for instance, shown at Sydney, this will be done at the Long Line Equipment centre. The return sides of the channels are commoned back to a monitoring loudspeaker at Melbourne C.T.O., providing a "talkback" circuit to this station controlling the land line network. An order wire circuit terminated on a loud speaker is provided between the Melbourne C.T.O. and O.T.C. The O.T.C. picture telegraph operator passes any requests, at line-up, from receiving stations, back to the originating radio station either by morse or speech as is most expedient, it being generally necessary to take a radio traffic circuit for this purpose. The overseas radio picture telegraph stations with which O.T.C. operates are at London, San Francisco, Montreal and Wellington. Through these stations pictures may be passed to Australia from practically every part of the world.

It will be appreciated that the administrative complications of providing such a network, on demand, are quite appreciable, requiring as it does the close co-operation in releasing telephone channels from traffic, of Telegraph and Telephone Traffic Branches, the Long Line Equipment Section, Engineering Branch, in setting up the network, and the Overseas Telecommunications Commission. The provision and maintenance of the equipment and the service is the responsibility of the Telegraph Equipment Section, Engineering Branch, and the operation of the service is done by the Telegraph Traffic Branch.

The great bulk of picture traffic is for the Press and since a negative is more flexible, from the photographer's viewpoint, than a positive reception of a negative is the rule, this being passed, after processing, to the addressee. However, where one picture is sent to several addressees in the same city, prints are taken from the negative and one forwarded to each addressee.

The provision of the picture telegraph service has involved the concerted efforts of several Sections and many individuals. The author would, however, like to express his thanks to Mr. F. Ruf, of the Research Section, Engineering Branch, for his work of quantitive analysis of the electrical and photographic performance of the system, which has been invaluable in establishing the service on a sound basis.

THE USE OF GUIDES IN CABLE HAULING

C. M. Rogers, B.E. (Mech.)

Introduction

The location of the new Franklin Exchange, Adelaide, in the rear of Engineering Buildings, Franklin Street, introduced some rather unusual features in conduit and cable construction. The position of the exchange cable well, adjoining buildings, lanes, etc., made it necessary to construct three right angle turns in the main conduit route within the first 115 yards. Using normal cable hauling methods it was anticipated that at least one intermediate joint in each cable would be necessary, and as ten 1200 pair cables and one 300-pair cable were required initially it was estimated that a large amount of jointers' time would be required for this purpose. Consideration was given, therefore, to the practicability of drawing cables around three 90° bends over the 115 yard length without flattening or damage to the lead sheath or excessive strain to the conductors. Fig. 1 illustrates the layout of the Franklin exchange cable well, conduit run, and manholes on the route to Bentham Street.

Various types of guides were considered, the main requirements being:—

(a) Diameter of bend to be not less than the core diameter of the largest cable drum used (approximately 5′ 0″ for a 1200-pair cable).
(b) Guide should not permit the cable to flatten or kink.
(c) Low friction loss with minimum increase in strain.
(d) Guides should be strong, capable of being fitted rigidly in any manhole and occupy as little space as possible.
(e) Guide to turn the cable through 90° and provide a smooth curve from duct to duct.

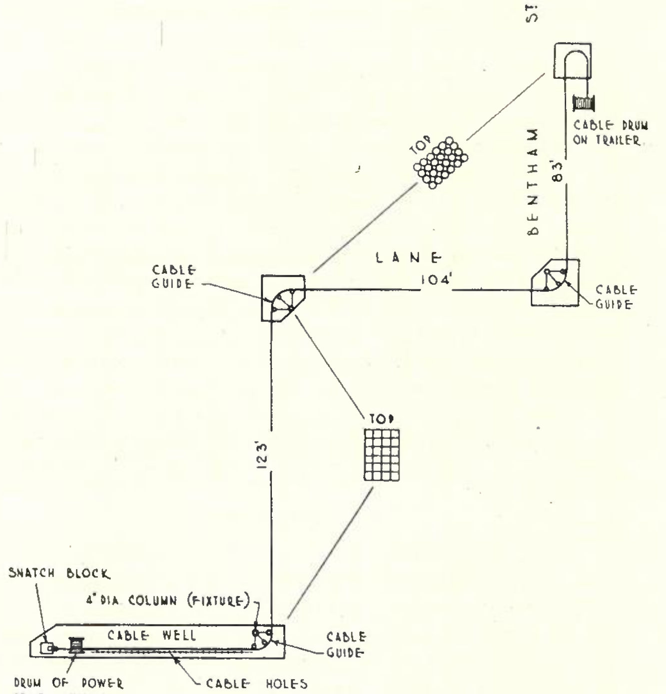


Fig. 1.—Layout of duct run at Franklin Exchange.

Guides were made up as illustrated in Fig. 2 and fulfilled the above conditions. Three-inch water-pipe 54″ long was cut in halves longitudinally with an oxy-torch and bent carefully into a quadrant of a circle of 6 feet diameter. The ends of each guide were splayed and rounded to ensure

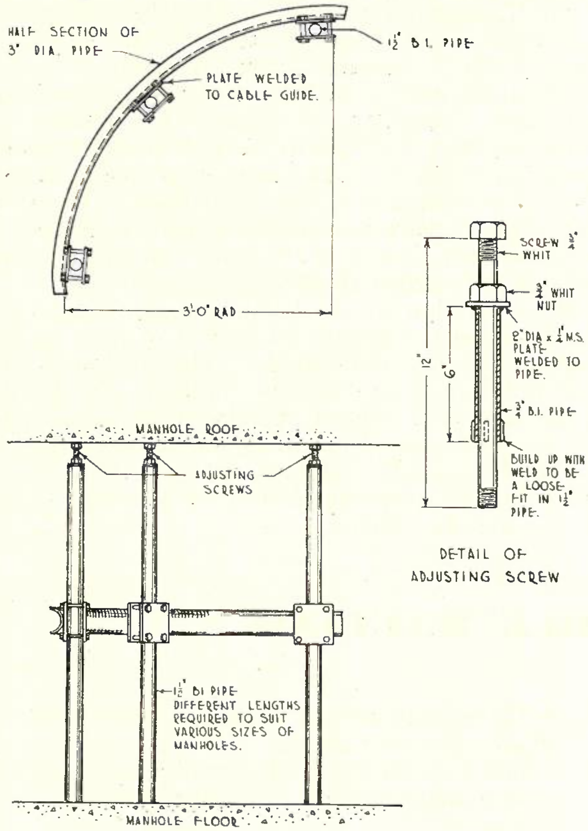


Fig. 2.—Detailed arrangement of cable guides.

that the cable or the cable grip would not be caught or damaged at these points. Heating was necessary to prevent flattening. Steel plates were arc-welded to the back of each guide to provide for bolting to vertical supports. These supports consisted of 1½″ diameter pipe cut to lengths of 3″ less than the normal height of manholes from floor to ceiling. A ¾″ diameter bolt 12″ long was threaded for its full length and dropped into the end of the 1½″ pipe. This bolt was extended by tightening the nut until the head contacted the manhole roof and further tightened until a rigid support for the guide was provided in any desired position. Supports were used also in a horizontal plane and attached to vertical pipes by U-bolts and cover plates. By varying the supporting arrangements guides may be placed in any desired intermediate plane.

Procedure for Pulling in Cable

The power-driven winch was set up directly above an opening in the exchange cable well and the steel wire rope fed through a snatch-block attached to a permanent fitting on the end wall. The wire rope was then carried along the full length of the well and fed around the first cable guide into the selected duct. The wire was drawn around guides in the two succeeding manholes and attached to the cable grip on the end of the cable in the usual way. Positions of all guides were checked to ascertain that the wire rope lay at a tangent to the cable guide at both ends. All vertical supports were then tightened and horizontal supports clamped in position.

An efficient means of communication between all manholes and the winch operator was essential, and as these positions were not in line of vision or within hearing range a loud speaker system was provided with microphone and speaker for each station.

The party leader took up his station near the cable drum, and, having checked that everything was ready, gave the order for the winch operator to start hauling. He then moved to the next manhole and watched the movement of the cable around the guide, taking particular care to see that the cable grip and the leading edge of the cable did not foul the guide or the edges of the ducts. Similar checks were made in each manhole, adjustments to positions of guides being made, if necessary. The party leader then proceeded to the exchange cable well and hauling was continued until sufficient cable had been provided for termination at the correct vertical.

The cable was tested immediately by the application of gas pressure and withstood 15 lbs./sq. inch overnight. Tests for insulation and conductivity showed no defects due to overstrain. A total of six 1200-pair 6½ lb., one 300-pair 20 lb. and two 1200-pair 10 lb. conductor cables have already been

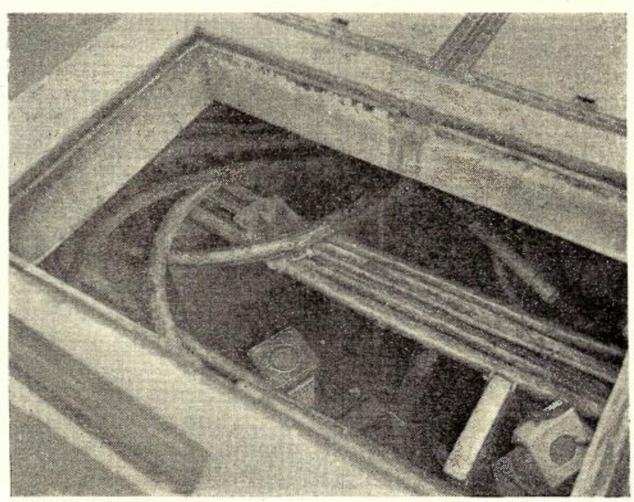


Fig. 3.—Cable being pulled through intermediate manhole. Loud speaker for communication purposes shown in lower right-hand corner.

drawn in over the route shown in Fig. 1. The multiple ducts nearest the exchange cable well consisted of 4 sets of six-way conduits (3¼″ square). Cables were drawn in towards the exchange and all cables, including the 1200-pair 10 lb. cable with a nominal diameter of 2.8 inches, negotiated the two right-angled bends and the section of 3¼" square ducts without difficulty. Figs. 3, 4 and 5 are photographs showing the work in progress.

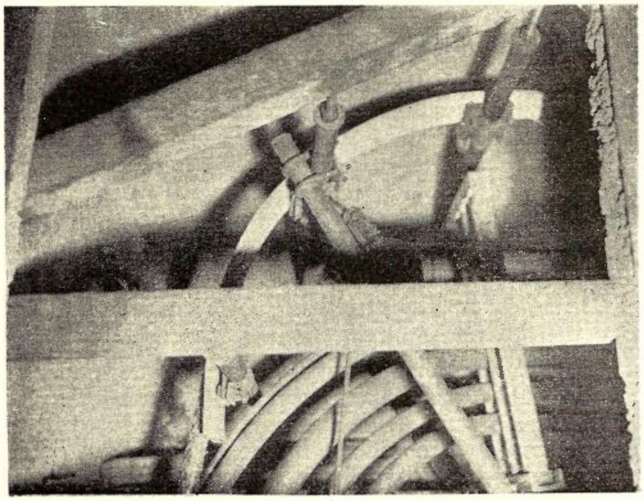


Fig. 4.—Looking into manhole, showing guides in position during progress of work.

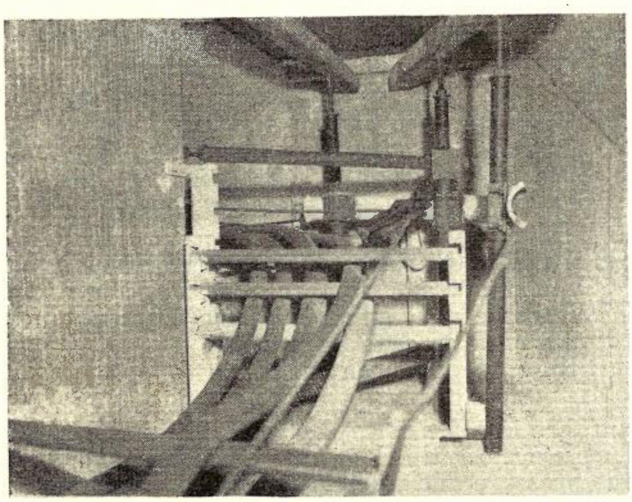


Fig. 5.—General view of entrance to cable well, showing cable guides in position.

The guides have also been used extensively on other work when hauling through manholes where duct positions changed in alignment and in level. In these cases shorter guides were found to be more convenient and pieces of three-inch pipe (30" long) were split and bent as before, but provided with two supports instead of three. Figs. 6 and 7 illustrate the set-up of short guides for change of alignment or level. Both can be accommodated by suitably placing guides. A feature of this method has been the good appearance of cables in intermediate manholes, the cables retaining a smooth curve from duct to duct.

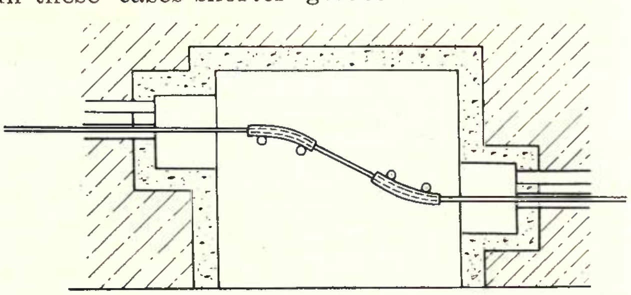


Fig. 6.—Elevation of manhole, showing change of level using short guides. Supports fitted horizontally.

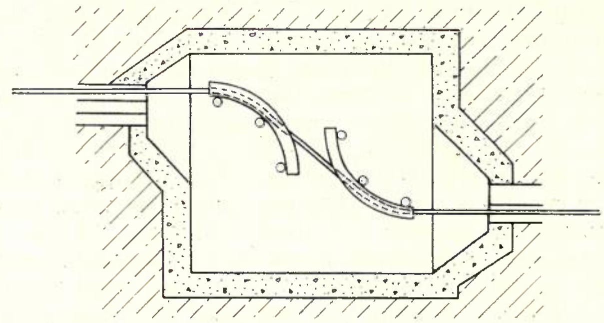


Fig. 7.—Plan of manhole, showing change of position using long guides. Supports fitted vertically.

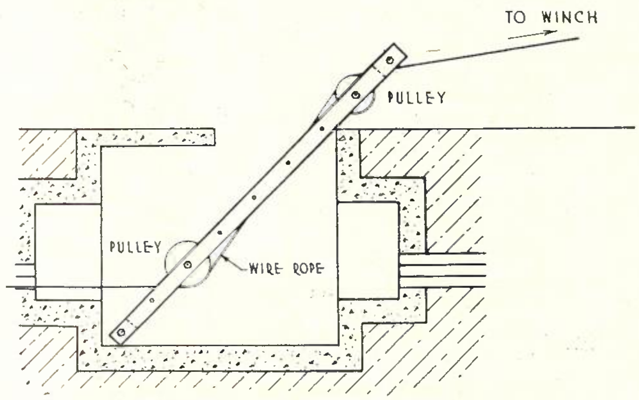


Fig. 8.—Standard arrangement of fittings in manhole for pulling in cable.

An interesting amendment has been made to the standard fitting for cable hauling which is illustrated in Fig. 8. This fitting has been useful but if cables are drawn around the lower roller they are subjected to a rather severe bend. This

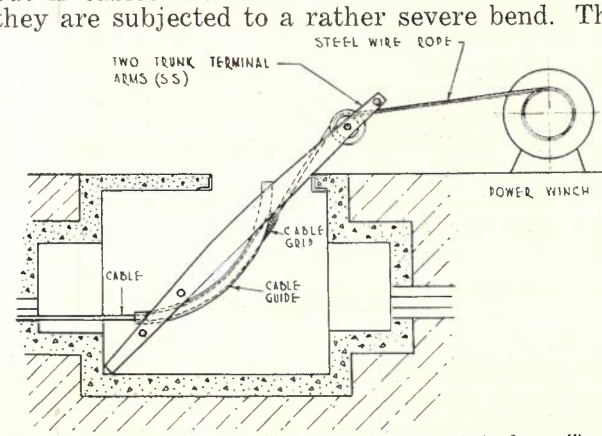


Fig. 9.—Amended arrangement of fittings in manhole for pulling in cable. Lower pulley replaced by cable guide.

has been improved by replacing the lower roller with one of the long cable guides (see Fig. 9). This permits sufficient length of cable to be drawn around the lower guide for jointing and does not introduce any severe bends. With this improvement this fitting has been found the quickest and easiest method of transferring the pull on the wire rope from the winch to duct level, the position of the guide being readily adjusted to suit varying levels and positions. The fitting used in this case was made from two trunk terminal type crossarms (bored for steel spindles), three $\frac{5}{8}''$ bolts, one cable guide, a six inch roller, and spacing pieces as required. This was easily constructed from standard material and has given good service.

The Use of Guides for Withdrawing Cables

Cable guides have also been used for withdrawing disused cables from conduit. Fig. 10 indicates the position of the power winch, the cable drum on a trailer and the cable being withdrawn with the aid of the cable guide. Fittings attached to the side of an empty cable drum by cable drum bolts and coach screws (see Fig. 11) are used to hold the coils of wire rope from the winch and provide an effective power drive to the cable drum.

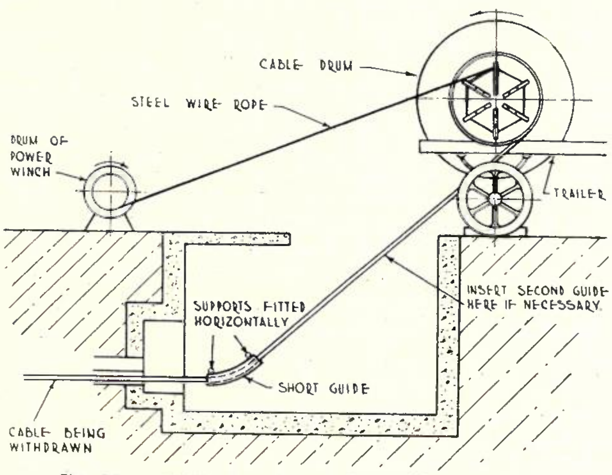


Fig. 10.—Layout of equipment for withdrawing cable.

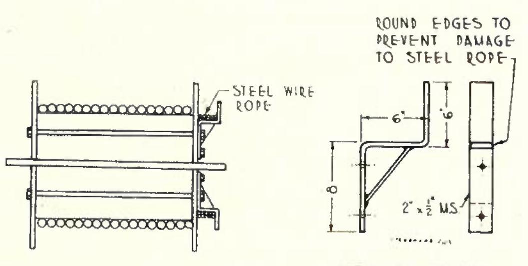


Fig. 11.—Additional fittings attached to cable drum for use when withdrawing cable.

As illustrated in Fig. 10, the location of the cable drum and trailer with respect to the cable guide is important in order to prevent reverse bends in the cable. The procedure for hauling out cable is as follows:—

(a) Mount the guide in the manhole to provide a smooth curve from the duct to the opening at ground level.

(b) Place the cable trailer and cable drum in position.

(c) Mount the power winch and run the wire over the wooden battens of the drum. Attach it to the end of the cable with a standard cable grip.

(d) Withdraw sufficient cable for about three turns around the cable drum (leave end free for the present).

(e) Uncouple the steel wire rope from the cable grip and wind sufficient turns around the fittings on the side of the drum to withdraw the length of cable lying in the duct. Hook the free end of the wire rope to one of the fittings. (The number of turns is not critical, as a few additional turns can be slipped around the fittings later if found insufficient.)

(f) Bend the free end of the cable around the drum the required number of turns and pass the end through the hole in the side and fasten it with a light piece of rope.

(g) Take up the slack of the steel wire rope, start the engine and commence winding slowly, being careful to guide the cable into its correct sequence in each layer and continue until all the cable has been withdrawn.

There is a tendency for cable to flatten on the first layer, but this has not proved detrimental on gas pressure and electrical tests. The time taken to withdraw approximately 150 yards was twenty-five minutes, including stops for attention to the cable. The time for setting up the gear was approximately one hour, with a cable hauling team of six men. The condition of the cable recovered was very good, except for the flattening of the first layer, and better than cables withdrawn by means of split grip and a series of short pulls. This method also represented considerable savings in time and handling.

Conclusion

The guides and fittings have proved a very useful addition to the cable hauling party's kit for use in awkward places, for changes in level, etc., at intermediate manholes and for hauling around corners. Time has been saved by the cable hauling party itself and by cable jointers, because of the reduction in the numbers of intermediate joints.

OUTLINE OF TELEVISION

N. S. Smith, A.M.I.R.E.(Aust.)

PART I—GENERATION AND TRANSMISSION OF THE SIGNAL

Introduction

As the first step towards the introduction of television in Australia, technical standards of the type of service to be provided have been adopted recently, and plans for the establishment of the first stations are proceeding. It is the intention of this article to outline the general principles involved in a television system so that future developments may be appreciated. The first section covers the generation and transmission of television signals, and a second section covering receivers will appear in the next issue of this journal. Fuller information on specific developments when they occur will, no doubt, be given in future articles.

Historical

Pictures have been transmitted over telegraph circuits for many years, using both line and radio, but the process is relatively slow, and at the receiving end the picture is not visible until after development of the photographic paper on which it is received. The principles employed in picture transmission are described fully in a companion article in this journal (1). Television, on the other hand, is the simultaneous transmission and reception of complete pictures in rapid succession, conveying the illusion of movement as in the case of the cinematograph.

The first practical demonstration of picture transmission was made about 1881 by Bidwell, who focussed light through a transparent picture on to a selenium cell. The picture was moved in a regular manner across the cell, producing currents varying in accordance with the density of the picture. These varying currents were used to operate a pointer which traced on a specially coated paper the lights and shades of the original picture, the value of the current governing the degree of a chemical reaction which resulted in various amounts of discolouration of the paper.

In 1883 Nipkow introduced the first device for scanning a stationary picture. This was a thin disc pierced with a number of spirally arranged holes. Rotation of the disc caused light passing through these holes to scan the picture, and a suitable arrangement of photocells converted light reflected by the scanning action into electric currents. The receiver used a similar rotating disc arrangement. Another method employed a cylindrical drum provided with a series of mirrors around its periphery. A source of light was projected on to the mirrors, reflected off them and focussed on to the subject to be scanned. Rotation of the drum caused the spot to move radially as required, and the successive mirrors were staggered slightly so that the successive spots of light traced out linear paths adjacent to one another. A modification of this was the arrangement of mirrors in a spiral or screw form. These mechanical methods had many limitations, although J. L. Baird gave a successful television demonstration in 1926, using Nipkow discs.

About 1906 attention was given to the possibility of using a crude form of cathode-ray tube for reproducing the pictures, but it required the advent of the thermionic valve amplifier to enable developments along this line to take place. Since the introduction of wholly electronic methods of scanning, television development has been rapid, and the earlier mechanical systems have been entirely superseded.

Cathode-Ray Tube

Although the cathode-ray tube is a familiar piece of apparatus to most telecommunication engineers, its importance in television warrants a brief review of the operating principles. Fuller details have been given in a previous article in this journal (2). A cathode-ray tube is an evacuated conical-shaped glass tube containing a cathodic source of electrons and several electrodes, one of which has a small hole in the centre and causes emitted electrons to form a beam or ray. In modern practice this electrode is called the control grid, since it functions to control the number of electrons forming the beam. The remaining electrodes serve to accelerate the beam, and, in conjunction with other means, assist in focussing the electron stream into a narrow beam. The wide end of the tube is slightly dished and coated internally with a special fluorescent film, which glows under the impact of the electron beam, the degree of fluorescence depending on the intensity of the beam. A typical arrangement is illustrated in Fig. 1. The picture

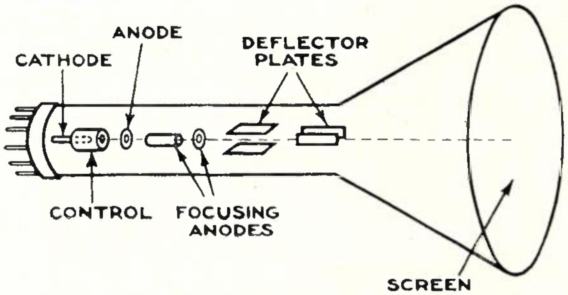


Fig. 1.—Elements of Cathode-ray Tube.

signal is applied to the control electrode and varies the brilliancy of the spot in accordance with the variations in the signal currents, which variations were originally due to the lights and shades of the picture being transmitted.

Movement of the beam over the screen is controlled by sets of deflecting plates within the tube, or by external magnetic coils. Four plates or coils are used in two pairs, one pair vertical and one horizontal. Potentials applied to the vertical plates will cause the beam to move horizontally, and to the horizontal plates, vertically. Potentials applied to each pair of plates simultaneously will cause simultaneous movements in each direction proportional to the relative values of the potentials. The rate of movement of the beam is dependent on the frequency of the applied potentials and their wave form. This operation is dealt with in more detail in the section on receivers.

The use of the cathode-ray principle in a television system will be appreciated from the following brief description of the operational sequence of transmission. At the originating end (studio or out-door), a cathode ray is caused to travel across the picture in the television camera in a regular manner. Electric currents of strength varying according to the degree of light and shade are generated and caused to modulate the transmitter. The received currents are amplified and used to control the intensity of the beam of a cathode ray tube, on the screen of which is thus reproduced the varying shades of light and dark of which the original picture was composed. These processes are known as "scanning" and are explained under the appropriate heading.

Elements of a Television System

The elements of a television system are illustrated in Fig. 2, and are:—

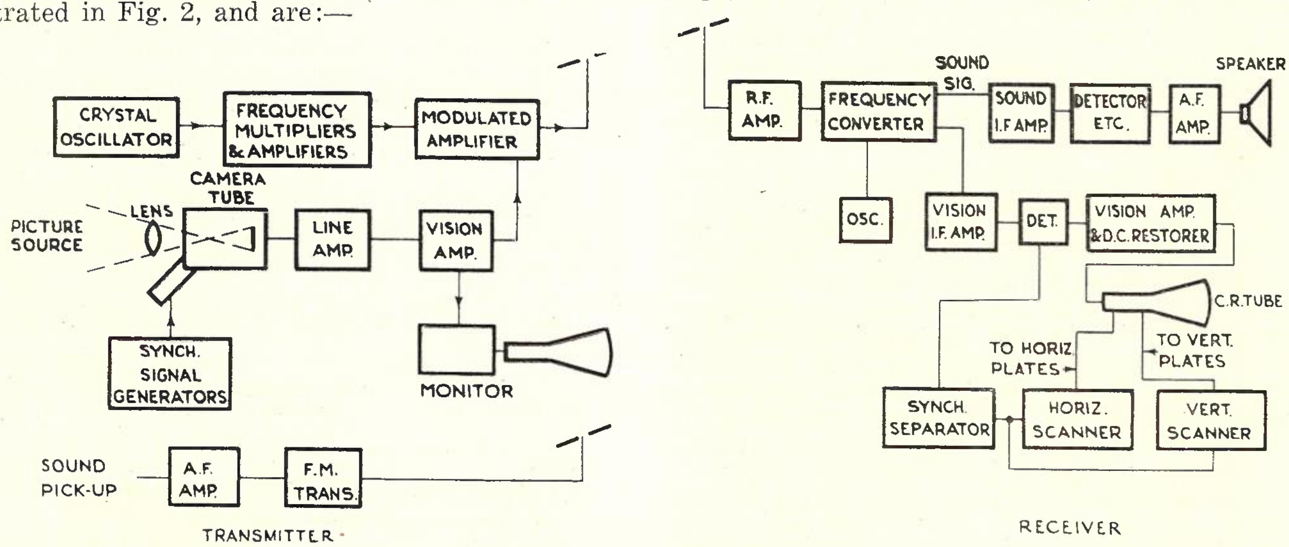


Fig. 2.—Television System Block Diagram.

- Pick-up camera unit.
- Synchronising signal generators.
- Transmitter.
- Receiving amplifiers and frequency changers.
- D.C. restoring circuit.
- Synchronising signal separator.
- Cathode ray tube and control circuits.
- Accompanying sound transmitter and reception circuits.

In this paper the sound transmission system will not be discussed. Both amplitude and frequency modulated systems are used, and design in general follows high-fidelity principles.

Television Cameras

The pick-up camera, being the first unit in a television system, controls the resultant quality and fidelity of the reproduced picture, assuming high fidelity design of the rest of the equipment. Television quality depends on the faithfulness with which the elements of light and shade of the picture are converted into electrical currents, and a great deal of ingenuity has been applied to the development of photo-electric eyes, and many electron principles have been put into use for this important item of the television system. Despite the fact that the various tubes are based on different principles, all pick-up tubes have one fundamental characteristic in common: they depend for operation on the conversion of an optical image, in which the light intensity varies from picture element to picture element, into an electrical image in which the charge varies from element to element and which is created by the agency of the photo-electric effect.

Monoscope: There is one type of electrical picture-generator which does not depend upon an optical image. These generators are termed pattern generators, and were created for the purpose of generating a fixed pattern with which to test a television system. Typical of these is the "Monoscope," which consists essentially of a glass envelope containing an electron gun at one end and a metal plate at the other end. Suitable patterns, usually including the station call-sign, are etched in black on the bright metal plate.

The operation of the monoscope depends on the emission of secondary electrons from the pattern surface. This surface is scanned by an electron beam generated in the electron gun. Scanning is by means of magnetic fields in the high-resolution tube, the deflection coils being similar to those used for magnetic deflection of an ordinary C.R. tube. The electron beam is focussed on the target plate, from the bright portions of which it knocks out secondary electrons. Each primary electron generates several secondary electrons on these bright areas. The secondary electrons flow to the second anode so that the bright areas of the pattern are charged positively. The secondary emission of the carbonised portion of the pattern is less than unity, so that the electron beam when it strikes these dark areas charges them negatively. It is general practice to ground the pattern plate through a load resistor, and the voltage developed across this resistor is applied to the grid of an amplifier as shown in Fig. 3. The direction of electron flow is such as to make "black" negative on the grid of the first amplifier.

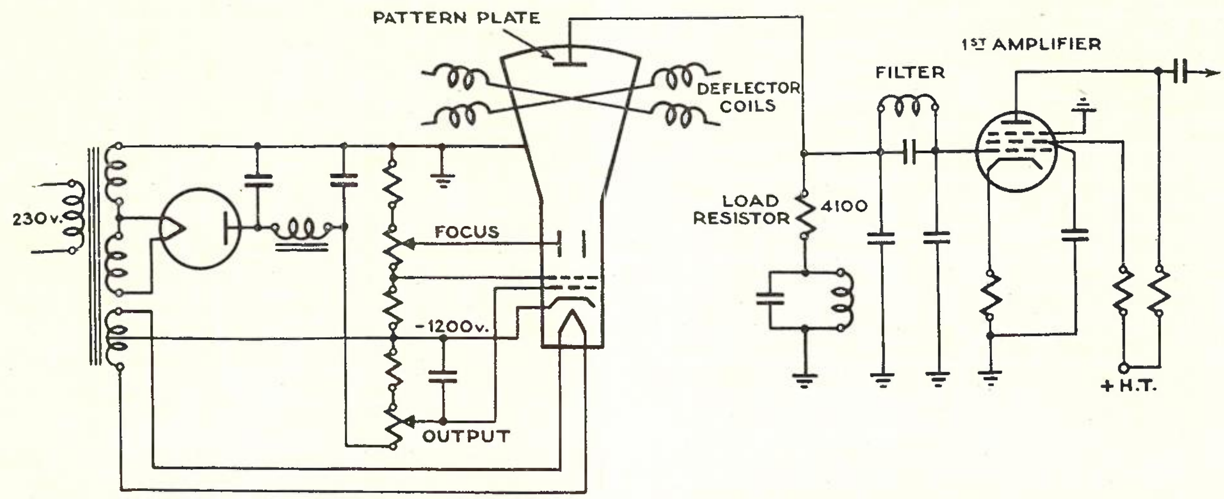


Fig. 3.—Monoscope.

The Iconoscope Camera: This camera, illustrated in Figs. 4 and 5, corresponds to the microphone in sound broadcasting, and consists essentially of a camera-shaped box fitted with a lens which focusses the scene to be televised on the plate of a large glass tube mounted in the box. This plate is mounted inside the glass tube and generally consists of a thin sheet of mica with a metallic back plate. On the front of the mica and thus insulated from each other and the metal plate are millions of tiny specks of silver coated by a film of caesium, forming a "mosaic." These silver caesium cells emit electrons when subject to light rays, and thus possess the properties of photo-electric cells. The number of electrons emitted from each silver cell depends on the amount of light falling on it, and the emitted electrons are attracted to a positively charged electrode also in the tube. It is important to note that each photo-electric cell also forms with the metal back plate, which is common to all, a microscopically-sized condenser. When electrons are emitted from each cell the insulated plate of the condenser is deficient in negative electricity or, in other words, the insulated plate of each small condenser has a positive charge. As previously stated, the scene to be televised is focussed by camera lenses on this plate, and thus the electrical charges on the cells of the sensitised plate correspond to the lights and shadows of the scene to be transmitted. The function of this plate, which should really be called an image plate, is to change an optical image into an electrical impression of the image and to divide this electrical impression into a number of extremely small sec-

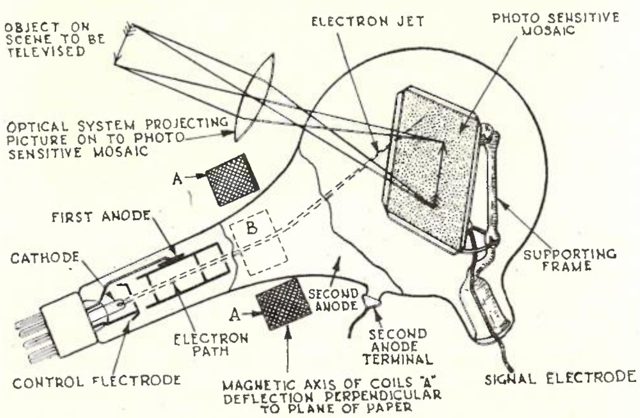


Fig. 4.—Illustrating the principle of the "Iconoscope" Camera.

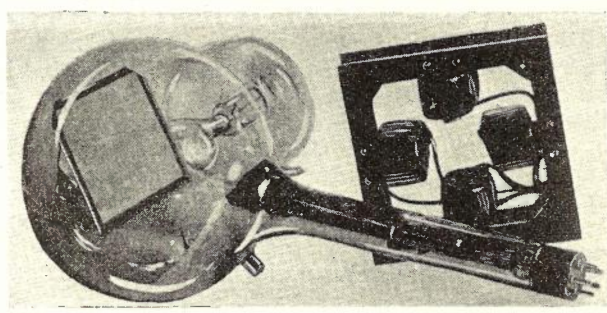


Fig. 5.—The Iconoscope, which combines the advantages of the Cathode-ray tube and the photo cell.

tions. Included in this tube is a means of developing an electron beam which is methodically directed to each section of the plate. The beam originates in the cathode, which is made from a special electron emissive material. When the cathode is heated by a current, electrons are drawn through a cylindrically-shaped anode in the form of a fine beam and strike the image plate.

The electron beam is moved horizontally over the plate from side to side until it has contacted the entire plate. The movement of the beam may be controlled and directed by magnetic fields generated in coils outside the glass tube. After each horizontal movement, the beam strikes the image in a slightly lower position than on the previous line and thus the plate is scanned.

As the electron beam strikes each silver cell it replaces the electrons which were emitted by the action of the light rays. The variation of electronic replacement on the front of the image plate corresponds to the values of light and shade on the scene focussed on the image plate and, as the beam moves across the front of the plate, corresponding electrical impulses are transmitted from the metal back of the plate. The back of the plate is connected to the external apparatus, and the currents flowing from the plate with the charge and discharge of each microscopic condenser are amplified and used to control the television transmitter aerial current.

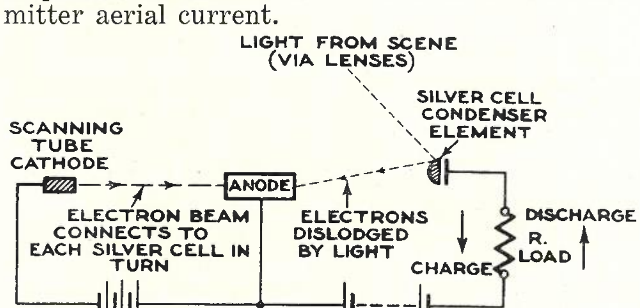


Fig. 6.—Photo-cell Action of Iconoscope.

The equivalent circuit of one cell of the mosaic is shown in Fig. 6. Light from the focussed scene falls on the silver cells of the image plate and each cell emits electrons according to the intensity of the reflected light. These electrons are collected by the anode and thus bridge the space between the silver cell and the anode and allow the condenser to be charged. When the electron beam on its scanning journey contacts this particular cell it replaces the emitted electrons. This electron replacement flow is in the opposite direction to the charging electron flow. The condenser is thus wholly or partially discharged. The discharge current depends on the charge of the silver cell condenser element and, therefore, on the light intensity at that particular element. The discharge currents of the condenser are transformed into signal voltages across the resistance R and passed to the amplifiers.

This method of converting light variations into electrical variations has the advantage that each silver cell "stores" charge in the intervals between visits from the electron beam. The trade name of "Iconoscope" has been given to this type of television picture transmitting tube.

Image Dissector Tube: The image dissector type of tube was formerly used for film scanning and is included as it illustrates some principles employed in other types of camera tube. It has less sensitivity than the storage type tubes such as the iconoscope and image-orthicon, but possesses very good linearity of response and freedom from electronic shading.

The image dissector may be considered as an instantaneous scanner, because storage of energy is not involved, and is illustrated in Figs. 7 and 8.

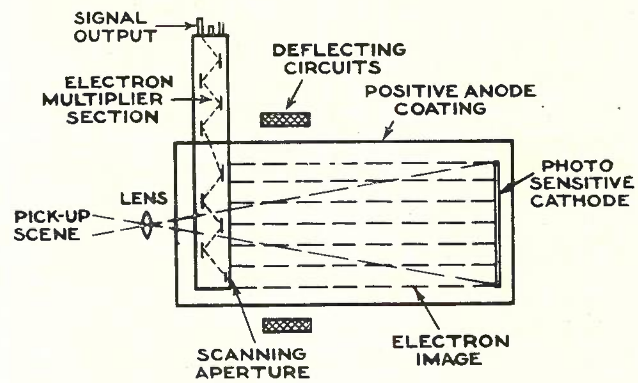


Fig. 7.—Image Dissector Tube.

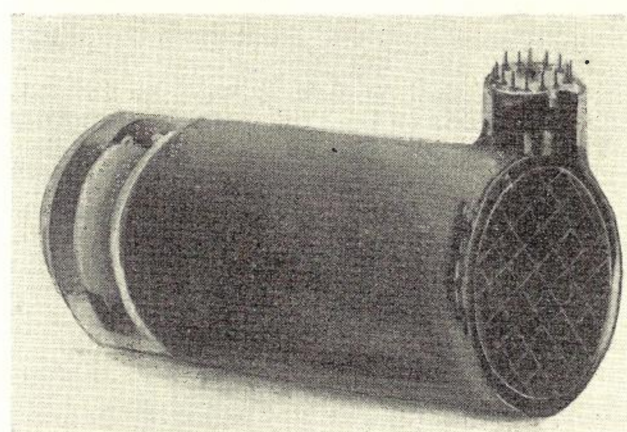


Fig. 8.—Image dissector tube.

It consists of a flat photo-sensitive cathode located at one end of the tube. The scene to be televised is focussed on this cathode by means of a lens system located outside the opposite end of the tube. When the light reaches the cathode, electrons are emitted proportionally to the amount of light striking any one point. Thus the electron emission density of the cathode is equivalent to the light flux density of the picture focussed by the lens. This electron cloud is forced to move down the tube by high voltages applied to attracting electrodes situated at the other end of the tube. A fixed scanning aperture is also located at this end of the tube, and deflecting coils move the electron cloud past this aperture in a regular manner, until the whole of the electron picture has been moved past the aperture. This occurs at about 25 times per second. (Note the difference from the iconoscope in which the picture is stationary while the scanning beam moves.) After the electrons enter the scanning aperture in turn, they pass through an electron-multiplier of about 9 to 11 times, which builds up the output to a relatively large current. This electron-multiplier principle is illustrated in Fig. 9. Electrons emitted from the cathode are

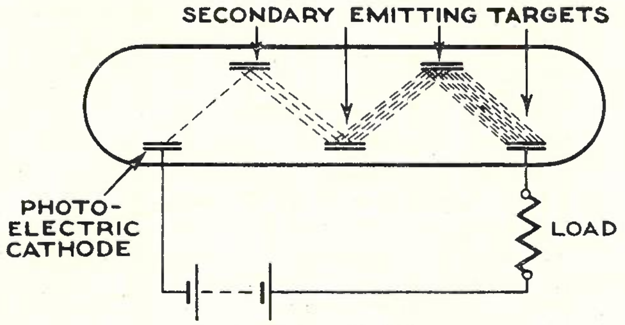


Fig. 9.—Electron Multiplier.

focussed on a plate which is designed to give high secondary electron emission. This means that if it is struck by electrons moving with sufficient rapidity it will in turn emit electrons of its own, in the proportion of perhaps five or ten electrons for each one that strikes it. Since the circuit contains no coupling impedances or subsidiary source of emission, the signal to noise ratio is very high and very weak illuminations on the photo-cell cathode are capable of giving some milliamps emission at the far end.

Image Orthicon: This is a storage type tube which incorporates an electron-multiplying section, and thus possesses relatively high sensitivity, which gives it two advantages, the ability to televise scenes under very poor lighting condi-

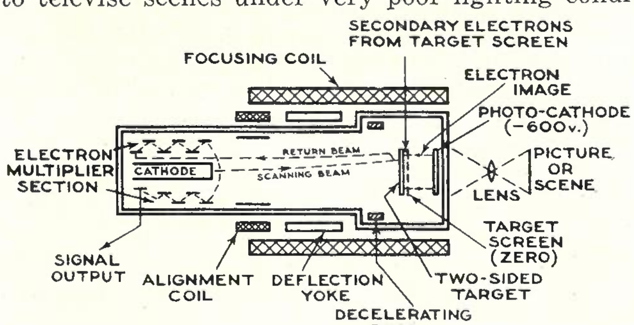


Fig. 10.—Elements of Image Orthicon Tube.

sions, and secondly, a lens system may be used to give a greater depth of field, permitting the inclusion of background that otherwise would appear blurred on the receiver.

This tube is illustrated in Figs. 10 and 11, and consists essentially of three sections, firstly, the image section, where the equivalent distribution of charge over a photosensitive surface is formed; secondly, a scanning section, consisting of the electron gun, the scanning beam and deflecting coils, and, finally, an electron-multiplying section.

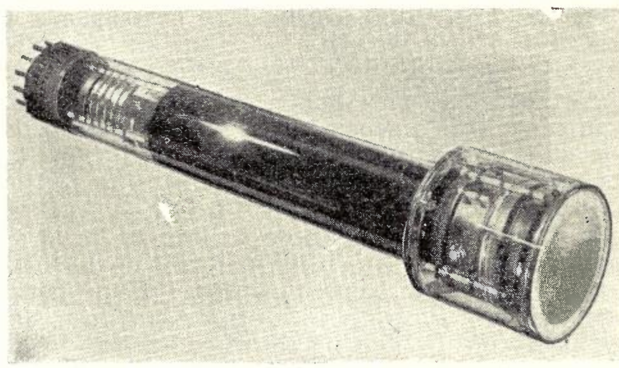


Fig. 11.—Image Orthicon.

In this tube the picture is focussed on to a semi-transparent photo-cathode to produce an electron image on the further side. This image is, in its turn, focussed magnetically and with unity magnification on to a target electrode which consists of a very thin glass plate, faced on its input side with a metallic screen of extremely fine mesh. The electron image builds up a "picture" on the target in terms of charge distribution. This is done by means of secondary emission from the target, and the whites of the original scene correspond to areas of most positive charge, that is, areas most deficient in electrons.

The target is scanned on the other side by a low velocity electron beam. It is of such low velocity that electrons will not reach an uncharged area of the target and the beam returns towards its starting point. Positively charged areas, however, attract sufficient electrons to neutralise the charge and the returned beam is then deficient in electrons by the number accepted by the target. In this way the return beam is modulated in intensity according to the intensity of the light and dark shades of the picture.

The return beam is induced by a "persuader" electrode to enter a five-stage electron multiplier which produces an output current, in a typical case, of 40 micro-amperes for an illumination of 0.3 ft. candle on the photo-cathode. Subsequent amplification incorporated in the body of the camera brings the output up to about 0.5 volts in 50 ohms. In the other cameras discussed the voltage generated by the unit was directly proportional to the charge on the photo-cells of the mosaic, prior to electron multiplication. In this case the voltage is reduced from its steady value by an amount proportional to the intensity of the charged area. To illustrate this more clearly, let the intensity of a charged area be 1000 units. In the iconoscope type of camera 1000 units would be released by the scanning beam to develop the output voltage. In the image orthicon type let the intensity of the low velocity beam be 6000 units, then the intensity of the returning beam will be 6000 — 1000 = 5000 units. Since a bright area constitutes a relatively highly charged area, the return beam will be of less intensity than the forward beam; conversely a dark area will have little effect on the return beam. This corresponds to negative phase polarity of the signal, since brighter areas give less current than dark areas.

An electronic view-finder is used; in portable equipment it is a separate unit which clips to the top of the camera. Like the camera, it contains its own time bases. The diagonal of the picture on the photo-cathode is only 1.6 inches. As a result, the optical lenses do not need to be large, and it is possible to employ standard double-cine-frame miniature camera lenses. Four lenses mounted in a turret head are used and focussing is carried out by moving the tube relative to the lens. Pre-set adjustments on the lens mountings can be provided, however, so that all four can be pre-set to need substantially the same setting of the operator's control.

For mobile use, the associated camera units comprise a synchronising generator in two units, camera control and pre-view monitor units, and power supply units. In addition, a vision-switching and communication unit, which can handle the output of six cameras, is needed. One type of camera-unit is shown in Fig. 12.

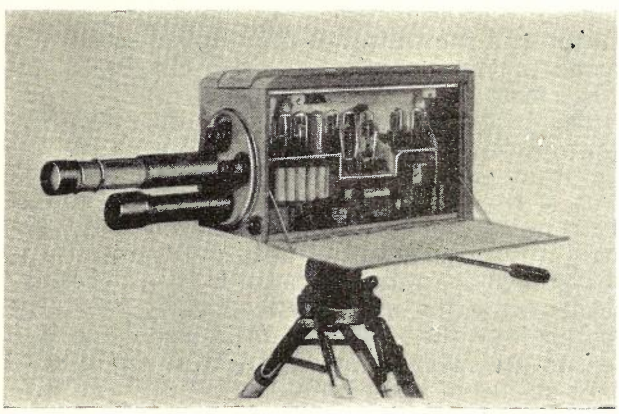


Fig. 12.—A typical pick-up camera unit.

Scanning: Insofar as the transmission side is concerned, scanning is a most important process, as the quality of the picture depends on the fidelity with which it is translated into electric currents. As has been seen previously, scanning consists of causing an electron beam to travel across the picture area in a regular manner under the control of two sweep circuits, one controlling the vertical travel and the other the horizontal. The rate of travel along the horizontal line is much more rapid that that in the vertical direction. The cathode beam, having a definite width or cross-section, traverses the picture in a series of steps or lines, as shown in Fig. 13 and returns to the start at A after each scan.

The number of lines per picture will determine the amount of detail that can be transmitted, but, among other things, the diameter of the scanning beam places a limit on this number. If the width of the beam is appreciably wider than the distance between two lines, lack of definition will occur, due to over-lapping pick-up. The number of lines per picture varies from 405 to over 800,

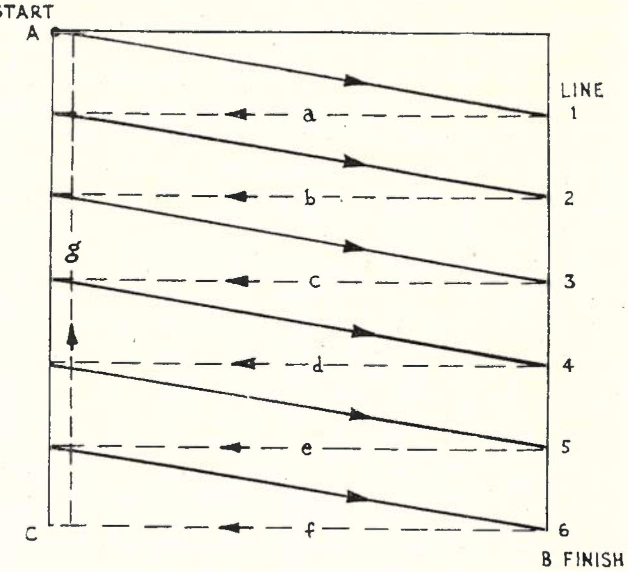


Fig. 13.—Path of beam in sequential scanning.

and 625 is being adopted as standard for the proposed Australian service.

In order to provide the illusion of smooth movement, at least 24 pictures per second need to be transmitted, as in the movies. The number of pictures per second is termed the "frame frequency," and thus we have two different sweep frequencies for the camera tube at the transmitter and also for the cathode-ray tube at the receiver.

In order to reduce flicker effect, a modified form of scanning has been introduced, which is known as "interlaced" scanning. In this, the odd lines are first scanned and then the even lines. Thus two scans are required to cover the picture completely.

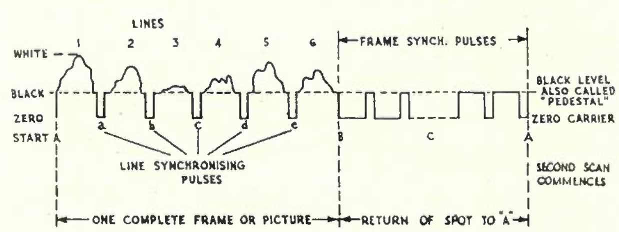


Fig. 14.—Typical Signal—Sequential Scanning.

Fig. 13 illustrates "sequential" scanning, in which each line of the picture is scanned consecutively. The approximate effect of scanning is shown in Fig. 14, and it will be seen that each line scan is followed by a line synchronising pulse to return the spot to the left-hand side of the frame. At the end of the frame a "frame" synchronising pulse returns the spot to the beginning point A, and another scan is commenced. The scan commences at A and follows the arrows to point B, horizontal synchronising pulses occurring at a, b, c, etc. At point B the frame synchronising pulse takes charge and returns the spot to A. The spot does not travel straight from B to A, but rather as shown in Fig. 15. This point will be further discussed when explaining the synchronising frequencies.

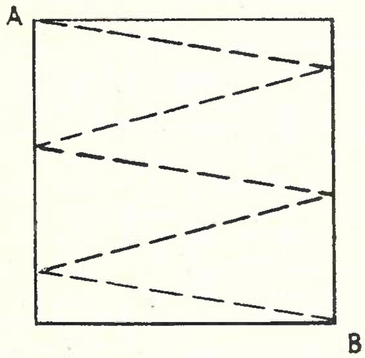


Fig. 15.—Path of return spot.

Interlaced scanning is illustrated in Figs. 16 and 17. The spot starts at A and follows the heavy odd numbered lines to B, where it is returned to C, and then scans the even numbered lines to D, finally returning to A. The approximate wave form is shown in Fig. 17. In this case also the return paths are similar to that shown in Fig. 15. It should be noted in this figure that points B and C are halfway across a line, and that is why the first scan finishes at $11\frac{1}{2}$ lines in the diagram, and the second scan commences half a line earlier than the first. This is a simple way to locate the spot midway between the odd lines for the alternate scans.

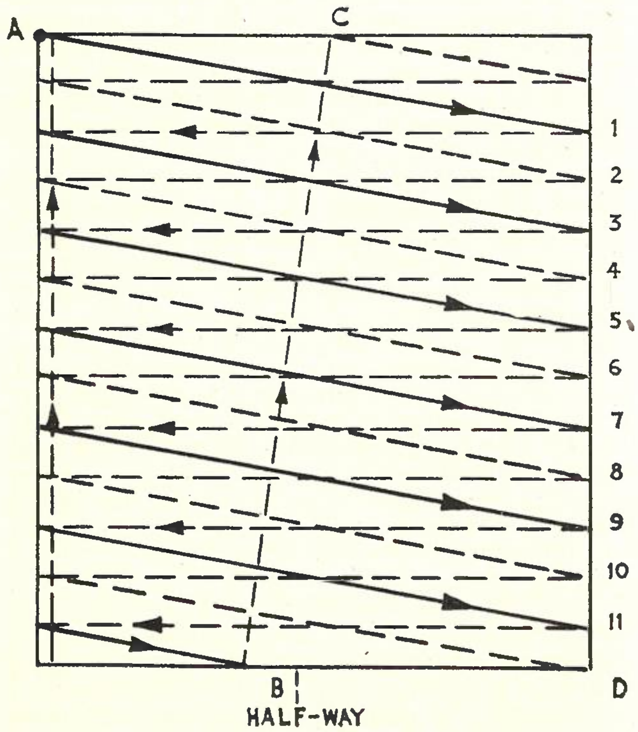


Fig. 16.—Beam Path in Interlaced Scanning.

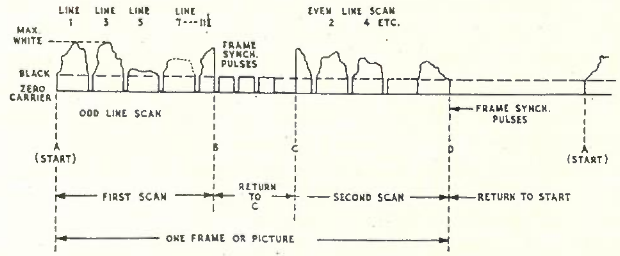


Fig. 17.—Interlaced Scanning Signal.

Determination of Bandwidth: The bandwidth required for a television service is determined from a consideration of the number of lines and the frame frequency. The number of lines, as referred to, means the number of horizontal lines from top to bottom of the picture, and these lines have a finite width. If we divide the picture with vertical lines of the same width as the horizontal lines, we will then have a picture made up of squares. The greatest amount of detail would occur when the picture was made up of alternate squares of black and white, like a draughtboard, these squares having a length and width equal to the width of the line as shown in Fig. 18.

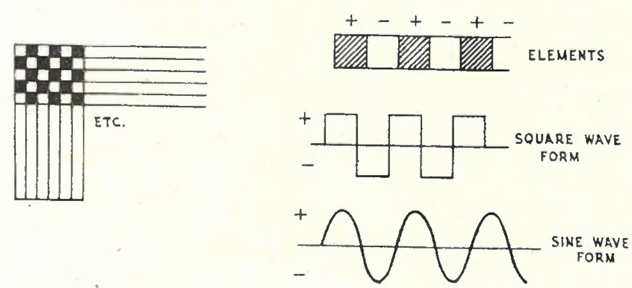


Fig. 18.—Translation of light elements into electrical elements.

For the fundamental frequency, one black and one white square or element could be considered as constituting one cycle. The total number of squares would be equal to the product of the number vertically and the number horizontally. The number horizontally is usually greater than the number vertically because the pictures are not square, 4 x 3 being the proportion proposed for Australia. Thus, if there are 625 lines vertically, there will be 625 x 4/3 = 2500/3 = 833 lines horizontally. The ratio 4/3 = ratio of width to height is termed **the aspect ratio** of the picture.

Therefore, total number of squares for the above is 625 x 833, and since two of these are equivalent to 1 cycle the number of cycles per picture is 625 x 833/2 or 260,417 c/s.

At 25 pictures per second, the fundamental frequency will be 260,417 x 25 = 6,510,400 c/s or 6.51 mc/s.

It will be appreciated from the above that the number of lines directly affects the required bandwidth, and was one of the arguments in favour of keeping the line frequency at a lower value. It is found in practice, however, that a bandwidth less than that calculated above can be tolerated as the effective number of active picture elements in a vertical direction is less than the maximum determined from Fig. 18. It has been estimated that about 65% to 70% of the total picture elements are fully effective, so that the above bandwidth could be reduced from 6.51 mc/s to 4.5 mc/s without impairing quality appreciably, thus simplifying design.

While discussing frequencies, it might be as well to determine the sweep frequencies for the synchronising circuits before dealing with these circuits in detail. For a sequential scanning system using 25 frames per second and 625 line transmission, the line sweep frequency = lines x frame frequency = 625 x 25 = 15,625 c/s.

For an interlaced scanning system, the field frequency = 2 x frame frequency = 50 c/s.

As only half the number of lines are scanned each time, but the frame frequency is doubled, the line sweep frequency = $312\frac{1}{2}$ x 50 = 15,625 c/s, which is the same as for sequential scanning.

Thus there is no difference in either case, and picture definition would be the same for either type of scanning.

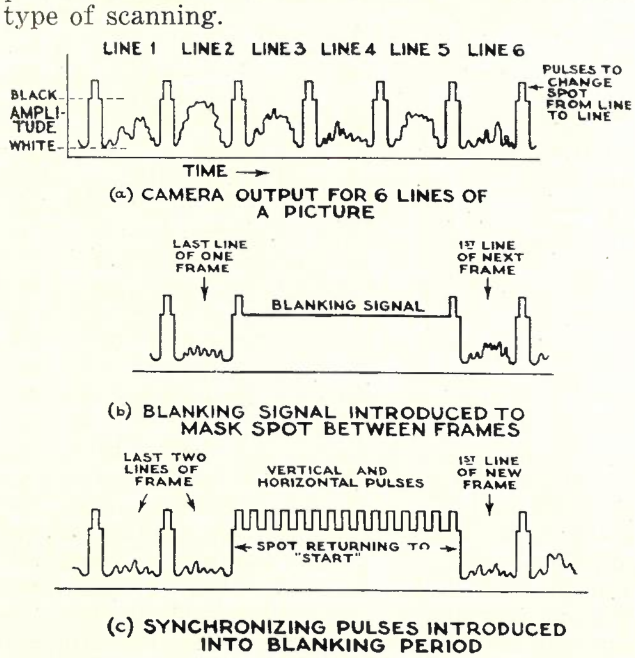


Fig. 19.—Camera output signals.

Generation of Synchronising Signals: In a television channel, correct presentation of the image at the receiver output is dependent on the light spot of the receiver C.R. tube keeping in exact step with the scanning spot of the transmitter. This is done by including synchronising pulses in the picture signal at the appropriate instants, filtering these out at the receiver and applying them to the vertical and horizontal control circuits of the cathode-ray tube as required. After each horizontal line and after each vertical frame of the picture the electron beam travels back to its original position, to the left-hand side of the picture and to the upper left-hand corner respectively. The back sweep or fly-back takes place at greatly increased speed. Notwithstanding this speed, the beam's path, nevertheless, would produce a signal and mar the received picture. To nullify this effect, a "blanking" signal is transmitted at the end of each line and of each frame. This blanking signal is a pulse which corresponds to "black" and, therefore, has no effect on the cathode-ray screen of receiver.

Fig. 19 illustrates the output of a pick-up camera after scanning 6 lines, no allowance being made for returning the spot in this case. In (b) is shown the addition of a blanking signal to mask the return of the spot from the bottom of the frame to the beginning. In (c) is illustrated the manner in which the synchronising pulses may be introduced into the blanking period without interfering with the blanking effect. The synchronising pulses, being in the blacker than "black" region, keep the spot extinguished.

The actual form of these signals, or rather pulses, depends on whether they are for horizontal or vertical synchronising, and also whether they follow the odd line or even line scans. It is more convenient to discuss these pulses in connection with the receiver and the output cathode-ray tube. So far as the transmitter is concerned, inter-locked master-signal generators produce the 25/50 c/s vertical synchronising pulses and the 15,625 c/s horizontal synchronising pulses. These pulses control the saw-tooth sweep generators, which will be dealt with more fully in a later section, and which feed into the deflecting circuits of the pick-up camera.

These synchronising pulses are added to the signal which is to be radiated, and together they form the modulating wave. The pulse sources are interlocked so that any frequency drift will affect both sweep circuits proportionately and maintain their ratio constant. The time duration of each pulse is also highly important since this affords the differentiation between the vertical and horizontal synchronising signals. Some systems use the power line frequency as the control frequency. In other systems it is preferred to start with a highly-stabilised crystal oscillator of 100 kc/s or so, and reduce this by de-multiplication to the two frequencies required.

Television Transmitters

General: An outline diagram of a television transmitter is shown in Fig. 20. Apart from the synchronising pulses, the action in a television transmitter is entirely analogous to the corresponding action in a sound transmitter. In one, the object is to transform audio vibrations in the surrounding air to equivalent electrical variations. A microphone accomplishes this simply. In the other, light rays are changed into equivalent electrical variations, and a camera tube is employed. In either case, once the currents have been formed essentially the same procedure is followed to form the final amplitude-modulated R.F. signal. It is well to keep the correspondence between the purpose of the microphone and the camera tube in mind, for this will aid in visualising the overall operation of television transmitters.

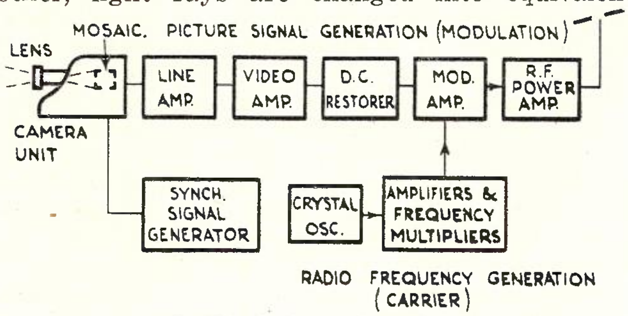


Fig. 20.—Television Transmitter.

The speech and music associated with the scene to be televised are kept separate from the video (or vision) electrical currents. The sound frequencies pass into a separate transmitter. Either amplitude or frequency modulation may be employed and the transmitter frequency lies close to the edge of the band of frequencies utilised by the vision signals. Thus, so far as the transmitters are concerned, two separate units are necessary, one for the sound, and one for the picture.

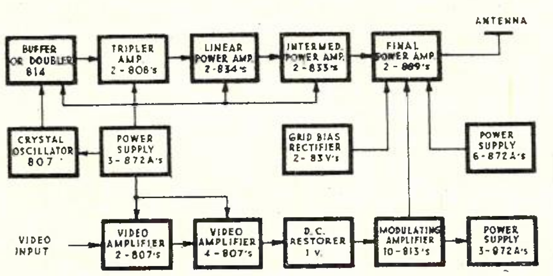


Fig. 21.—Block diagram of T.V. Transmitter.

We now have the televised picture reduced to electrical terms, an extremely rapid succession of minute electric impulses. These must now be amplified, without distortion or disarrangement, many millions of times. The first stage or stages of this amplification are in the so-called pre-amplifier, which is housed within the metal casing of the electron camera. Sometimes, instead of the grid-controlled amplifier tube, an electron-multiplier tube is first employed in this pre-amplifier. But even with the electron-multiplier, one or more stages of tube amplification are necessary before the video signals are sufficiently strong to be piped through the flexible coaxial conductor from camera to the studio amplifying equipment and monitor control board.

Figure 21 is a block diagram of an early type of 1 kilowatt television transmitter illustrated in Fig. 22. The upper portion of Fig. 21 shows carrier generation commencing with the 807 crystal oscillator, and the lower the video amplifier, whose input is from the camera pick-up unit. Designs naturally vary, and the following is merely illustrative of one type.


Fig. 22.—1 Kilowatt Television Transmitter.

The Video Amplifier: The video frequency amplifier stages must be designed to have essentially uniform frequency response over the entire range up to about 4.5 mc/s. Resistance-capacity coupled amplifier stages are used for this purpose. But this type of coupling introduces a reactance which varies with frequency, causing a phase delay that varies with the frequency of the signal. This in turn necessitates compensation, or correction, which in turn involves a sacrifice in amplifier gain, which calls for more stages of amplification.

Before successful modulation of the ultra-high frequency oscillation generator, by means of this amplified video current, can take place, the television signal must be converted into an acceptable direct-current form, so that "information" concerning the general background of the scene can be transmitted automatically to control the general brilliance of the screen at the receiver. This characteristic is obtained by inserting into the signal a D.C. component which supplies the necessary datum level. The D.C. component may be introduced by one of several circuits and this function is treated at greater length later.

As to modulation of the ultra high frequency carrier currents by the amplified and corrected television signals, the Heising modulation used often in an audio frequency or broadcasting transmitter cannot be employed successfully in a television picture transmitter as the constant-current choke will not maintain a constant reactance over the wide range of frequencies being handled. Therefore, it is necessary to employ "electronic injection" of the picture signal into the carrier signal. This usually is accomplished by means of the control grid feed, although screen grid or suppressor grid feed, or a combination of the two, might be employed.

Generating the Carrier Current: An accurate master oscillator is required for generation of the carrier or radiated frequency. This frequency is generally above 50 megacycles. A carrier signal, adequately constant in frequency, can be generated by a self-oscillating circuit employing for its tuned circuit a transmission line or resonant coaxial cable constructed with material which remains essentially constant in physical dimensions despite variations in temperature. With this arrangement the master oscillator can be operated at a high level, eliminating the need for a large number of intermediate stages of power amplification.

The next step in the television broadcasting process is the low-loss coaxial cable to conduct the modulated radio frequency carrier from the television station to the radiating system. This antenna usually consists of doublet elements resonant to the carrier frequency. But in order to secure a wide-frequency response and thereby ensure uniform signal intensity for all side-band frequencies as well as the carrier frequency, these doublets are often given a special shape.

Horizontal transmitting doublets are employed in order that the radiated electric fields will be horizontally polarised, the usual form of vision transmission. When the radiating doublets are located essentially in free space, high above all objects, two doublets positioned at right angles to each other will normally give adequate coverage of the service area in all directions. But when the doublets are mounted on a tower which is itself conductive, it is advisable to employ four sets of doublets arranged 90° apart around the tower. A "turnstile" comprising six such sets, each one a half-wavelength above the other, will give a considerably increased radiated signal. The transmitter used for the sound portion of a television programme is entirely conventional in design, and need not be considered here.

Although a coaxial cable is normally employed for feeding the picture signal from the studio to the transmitter, when either a temporary or permanent programme source is at some distance from the studio and transmitter an ultra high frequency radio relay link may be required. This remote pick-up equipment is generally installed in trucks or trailers. Either a telephone line or another radio relay link is used for the associated sound signals. Careful tests must be made prior to each remote pickup to make sure that no distortion is introduced by the radio relay link.

Resistance-capacitance coupled amplifiers are used between the camera output and the radio-frequency modulator, and the direct current component is usually inserted into the picture signal at the final video frequency amplifier stage, just prior to modulation.

The radio-frequency section of a typical television picture transmitter will have a master oscillator for generating the carrier signal, followed by a buffer stage, an intermediate power amplifier, and the final power output amplifier. Modulation may be accomplished by feeding the television picture signal into the grid circuit of the power output stage.

Modulation: Modulation in television achieves the same result as in normal broadcasting, that is, imparting to the radio-frequency wave the intelligence it is desired to transmit, in this case the varying currents resulting from scanning the picture elements.

If the brightest portions of the picture cause the least amount of current flow, or the lowest voltage, the modulation is said to be negative, or of negative polarity. This is illustrated in Fig. 23, where it is seen that black is represented by

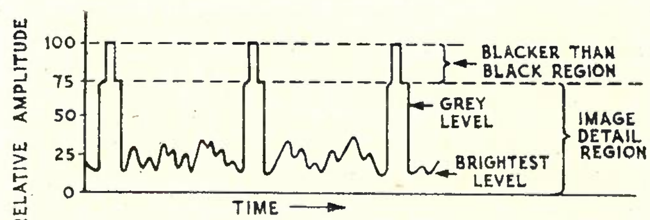


Fig. 23.—"Negative" modulation.

75% modulation, and white by less than 20%.

If the brightest portions cause an increase in current or voltage, the modulation is said to be of positive polarity or positive modulation. This is illustrated in Fig. 24.

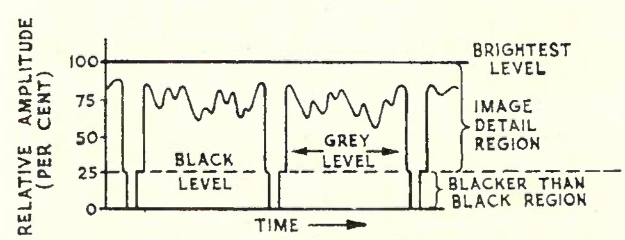


Fig. 24.—"Positive" modulation.

English systems use positive modulation, American negative, and the latter has been adopted for the proposed Australian service. In both systems it will be noted that the synchronising pulses are located in the "blacker than black" region.

It is common practice to employ grid-circuit modulation in television transmitters, since to obtain sufficient video voltage and power for plate-circuit modulation costs much more than the improvement warrants. A fairly linear modulation curve from grid voltage to R.F. output can usually be obtained, but linearity is perhaps the least problem of all in modulation, since non-linearity can be corrected in the preceding video amplifier stages. The principal problem is that of obtaining high values of video voltage for modulation purposes. With existing high-power modulating amplifier tubes of the water-cooled variety, the tube capacitances are so high that flat response over a 4.5 Mc/s bandwidth can be obtained only with very low values of plate load impedance, actually below 1000 ohms in typical cases. New tubes now in development show promise of improving the situation however. When the modulation occurs at low level the above difficulty is not so serious since the modulating amplifier tubes then have smaller internal capacitances. In this case the R.F. amplifiers following the modulated stage must be extremely linear.

One interesting aspect of modulation in television transmitters is the necessity of maintaining a "D.C." reference level in the R.F. carrier envelope. It is convenient to visualise the operation of the transmitter as if it were a telegraph transmitter operating normally at peak power output, with maximum carrier level. The composite video signal, containing both picture and sync impulses, operates to reduce the carrier below maximum level, in effect "chopping holes" in the carrier envelope. With negative transmission proposed for this country, the peak carrier amplitude corresponds to the tips of the sync pulses. This level must be fixed by the bias value applied to the modulated amplifier tubes.

Another reference level which must be maintained in the modulation envelope is the "black level." In the case of negative modulation, this may be standardised at from 75 to 80 per cent. of the peak carrier level. The sync pulses are extended higher than this level, and the picture signals are below it. If the black level is fixed, the average level of the picture signal, relative to the black level, corresponds to the average brightness of the scene transmitted. Consequently to transmit average brightness it is necessary to establish the black level independent of changes in the

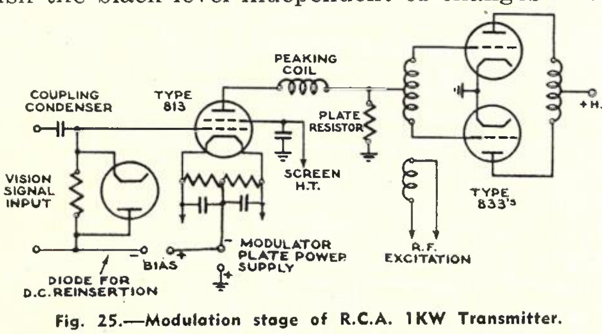


Fig. 25.—Modulation stage of R.C.A. 1KW Transmitter.

average level of the picture signal. This function is accomplished, in the transmitter just referred to, by the method shown in Fig. 25. The video signal is fed to the modulator and to a diode rectifier and load resistor. The diode rectifies the video signal, and the average direct component of voltage across the load resistor remains constant and corresponds to the peak of the video signal. This direct voltage is a part of the bias of the modulator stage, and the polarity is such that the black level falls near the lower bend of the i_p-e_g characteristic of the tubes used in that stage. The sync signals then extend further in the negative direction, as required, while the picture signals extend into the upper portion of the operating characteristic curve. Maximum modulating current flows for correspondingly maximum points of brightness in the scanned line. This arrangement not only establishes the black level ("re-inserts the D.C. component") but also makes the best possible use of the i_p-e_g characteristic of the modulator tube.

It will be noted that the modulator tubes are direct-coupled to the modulated R.F. amplifier stage. This ensures that the D.C. levels established in the grid circuit of the modulator tubes shall produce corresponding levels in the R.F. carrier envelope. In the R.C.A. transmitter arrangement, shown in Fig. 25, the direct-coupled arrangement is obtained by operating the plates of the modulator tubes at PA bias potential, and the cathode at a high negative potential. The bias control of the modulator tube is thus directly effective in controlling the peak R.F. carrier level.

Wave Propagation and the Television Antenna

General: Antennas for television receivers require much more attention and care, especially with regard to placement, than those used with the ordinary sound receivers. In order to obtain a clear, well-formed image on the cathode-ray screen, it is absolutely necessary that the maximum signal strength be developed at the antenna, that the signal be received from one source, not several, and that the antenna be placed well away from man-made sources of interference.

In ordinary sound receivers, a certain amount of interference and distortion is permissible. If not excessive, reception of the broadcast is satisfactory. For television, however, the standards are more severe, and added precautions must be taken to guard against almost every type of interference and distortion. Hence, the need for more elaborate antenna receiving systems.

The position of the antenna must be chosen carefully, not only for additional signal strength but also because of the appearance of so-called "ghosts" on the image screen which are due to the simultaneous reception of the same signal from two or more directions. For an explanation of this form of interference, refer to Fig. 26, in which a television dipole antenna is receiving one signal directly from the transmitting tower, while another ray strikes the same antenna after following a longer, indirect path. Reflection from a building or other large object could cause the indirect ray to reach the antenna. Because of the longer distance the reflected ray travels, it will arrive at some small fraction of a second later than the direct ray. In sound receivers, the ear does not detect the difference. On a television screen, the scanning beam has travelled a small

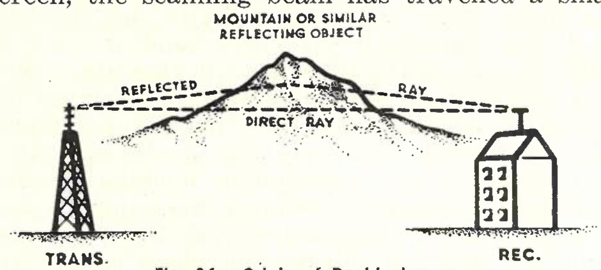


Fig. 26.—Origin of Double Image.

distance by the time the reflected ray arrives at the receiver. Hence the image contained in the reflected ray appears on the screen displaced some small distance from the similar image contained in the direct ray. When the effect is pronounced, a complete double image is obtained and the picture appears blurred. To correct this condition, it is necessary to change the position of the antenna until only the direct ray is received. The antenna should not generally be turned to favour the reflected ray, because the action of reflecting surfaces changes almost daily and there is no certainty that a good signal will always be received. The placement of the antenna is generally the most difficult operation of a television installation. To obtain maximum results, it is necessary for the radio serviceman or other person erecting the receiving antenna to have a good knowledge of the behaviour of radio waves at the high frequencies.

Line of Sight Distance: At the frequencies employed for television, reception is possible only when the receiver antenna directly intercepts the

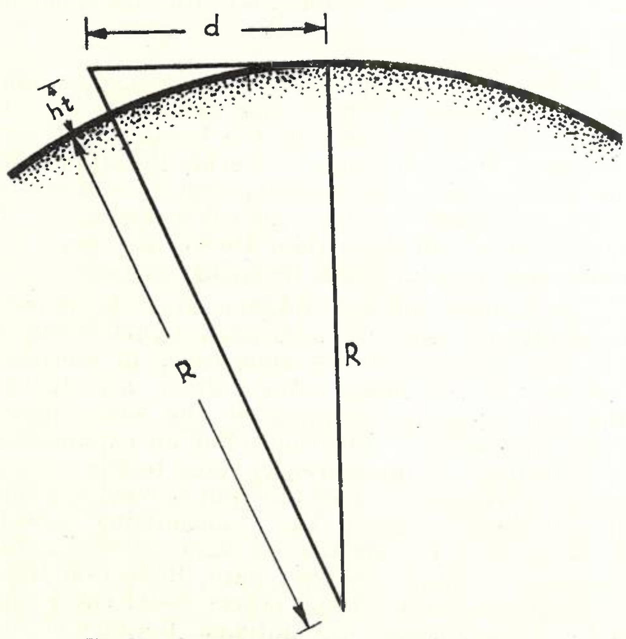


Fig. 27.—Computing the distance to the horizon.

signals as they travel away from the transmitter. These electromagnetic waves travel in essentially straight lines, and the problem resolves itself into finding the maximum distance at which the receiver can be placed from the transmitter and still have its antenna intercept the rays. This distance may be computed as follows. In Fig. 27, let the height of the transmitting antenna be called h_t, the radius of the earth R, and the distance from the top of the antenna to the horizon d. The triangle will be right-angled, so that from elementary geometry, $(R + h_t)^2 = R^2 + d^2$. Expanding we have $R^2 + 2Rh_t + h_t^2 = R^2 + d^2$. h_t is very small compared with the radius of the earth and the h_t^2 term may be neglected. This leaves $d^2 = 2Rh_t$. The value of R is approximately 4000 miles. Substituting this value in the above equation, and changing h_t from units of miles to feet, we obtain $d = 1.23\sqrt{h_t}$, where d is in miles, h_t in feet. The relationship between d and h_t for various values of h_t has been put into graph form in Fig. 28. The coverage for any transmit-

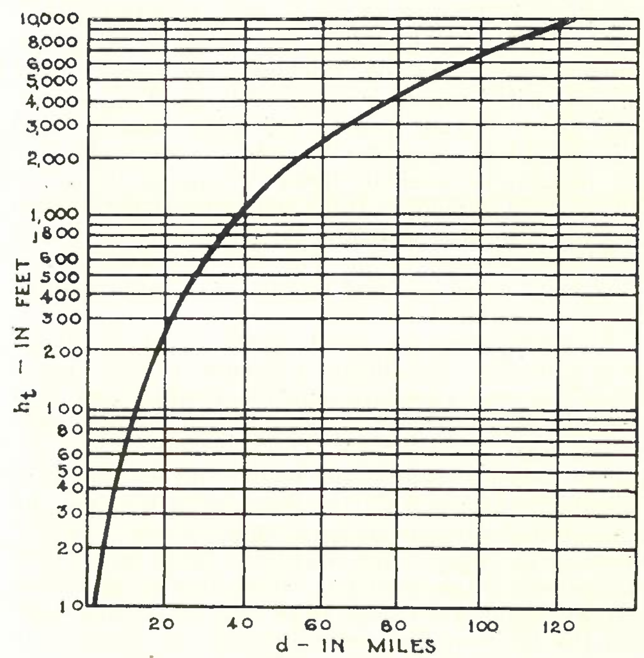


Fig. 28.—Relation between d and h_t where

d = distance to horizon.
h_t = height of antenna above sea level.

ting antenna will increase with its height. The number of receivers capable of receiving the signals would likewise increase. This accounts for the placement of television antennas atop tall buildings, for example, the Empire State Building, and on high plateaux.

The signal range thus computed is from the top of the transmitting antenna to the horizon at ground level. By placing the receiving antenna at some distance in the air, it should be possible to cover a greater distance before the curvature of the earth again interferes with the direct ray. Such a situation is depicted in Fig. 29. By means of simple geometrical reasoning, the maximum distance between the two antennas now becomes $d = 1.23 (\sqrt{h_t} + \sqrt{h_r})$ where h_r is the receiving antenna height in feet.

Unwanted Signal Paths: While the foregoing computed distances apply to the direct ray, there

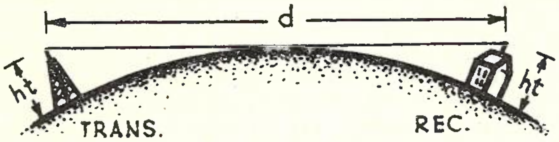


Fig. 29.—Effect of height at each end of circuit.

are other paths that waves may follow from the transmitting to the receiving antennas. Each of these other rays is undesirable as they tend to distort and interfere with the direct-ray image on the screen. One method, by reflection from surrounding objects, has already been discussed. Another ray may arrive at the receiver by reflection from the surface of the earth. This path is shown in Fig. 30. At the point where the re-

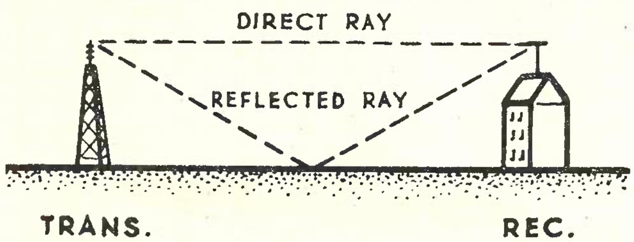


Fig. 30.—Earth Reflected Ray.

flected ray impinges on the earth, phase reversals up to 180° have been found to occur. This phase shift thus places a wave at the receiving antenna which generally acts against the direct ray, and the overall effect is a general lowering of the resultant signal level.

However, there are compensating conditions acting against the decrease due to the ground reflected ray. One is the weakening of the wave strength by the absorption at the point where it grazes the earth. The other results from the added phase change arising from the fact that the length of the path of the reflected ray is longer than the direct ray path. Thus there is a ground phase shift plus whatever else may have been added because of the longer distance.

It has further been observed that the received signal strength increases with the height of either or both antennas. At the same time, a decrease in noise pick-up occurs. For television signals, this is most important. Placement of the antenna and utilisation of its directive properties will help in decreasing, and many times eliminating, all but the desired direct wave.

Tuned Antennas: The need for good signal strength at the antenna has led to the general use of tuned antenna systems. A tuned antenna, which is a wire cut to the necessary length, is equivalent in its properties to any resonant circuit. The radio waves, passing by the antenna, will induce voltages along the wire. For equally powered radio waves, the maximum voltage is developed in the antenna when its resonant frequency is equal to that of the passing wave. A large signal at the antenna means a greater input to the receiver.

Half-Wave Antennas: An ungrounded wire, cut to one-half the wave length of the signal to be received, represents the smallest length of wire that can be made to resonate at that frequency. The half-wave-length antenna is the most widely used since it represents the smallest antenna for its frequency and, consequently, requires the least amount of space. In troublesome areas it may be necessary to erect more elaborate arrays possessing greater gain and directivity than the simple half-wave antenna. They are, however, more costly and more difficult to install. A simple half wave antenna is erected and supported as indicated in Fig. 31. Metallic rods are used for the antenna itself, mounted on the supporting structure and, for horizontally polarised signals, placed in a horizontal position. Each of the rods is one-quarter of a wave-length long, the total equal to the necessary half wave-length. In this arrangement, which is also known as a dipole antenna, the transmission lead-in wire is connected to the rods, one wire of the line to each rod. The line is then extended to the receiver.

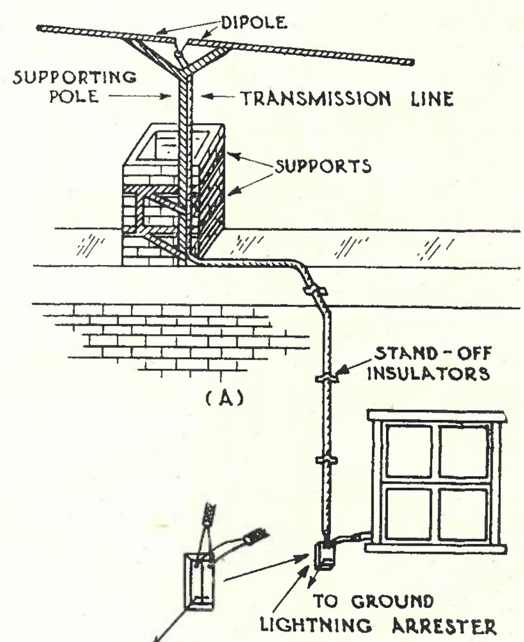


Fig. 31.—Typical Aerial System.

Half-Wave Dipole with Reflector: The simple half-wave system provides satisfactory reception in most locations within reasonable distances of the transmitter. However, the signals reaching receivers situated in outlying areas are correspondingly weaker, and noise and interference have a greater distorting effect on the image. For these locations more elaborate arrays must be constructed, systems that have greater gain and directivity and provide better discrimination against interference. A simple, yet effective, sys-

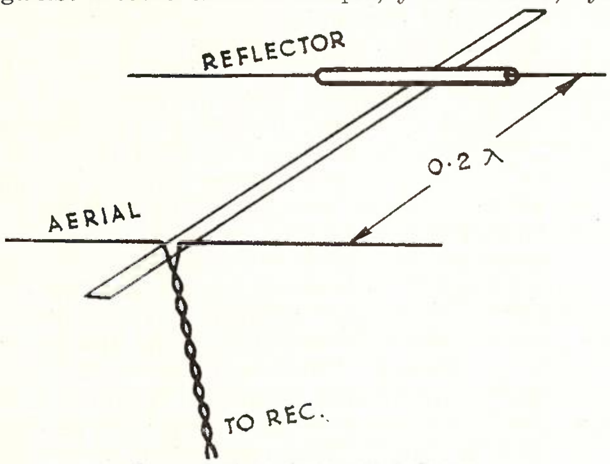


Fig. 32.—Dipole Aerial with Reflector.

tem is shown in Fig. 32. The two rods are mounted parallel to each other and spaced about .2 of a wave-length apart. The action of the second wire, which is not connected, is twofold. First, because of its position, it tends to concentrate signals reaching the front wire. Second, it shields the front antenna from waves coming from the rear. The gain of the array is generally 5 db greater than that from a single half-wave antenna. Besides the additional gain that is observed with this two-wire system, the angle at which a strong signal may be received now is narrower. This is also advantageous in reducing the number of reflected rays that can affect the antenna. Finally, partial or complete discrimination is possible against interference, man-made or otherwise. The method of erecting the antenna is similar to that of the half wave dipole, although the adjustments of the position of the wires is more critical. A small displacement, one way or another, alters the strength of the received signal appreciably. Many commercial antenna kits do not provide adjustment of the spacing distance between the two wires. However, if an adjustment is possible, the spacing may be

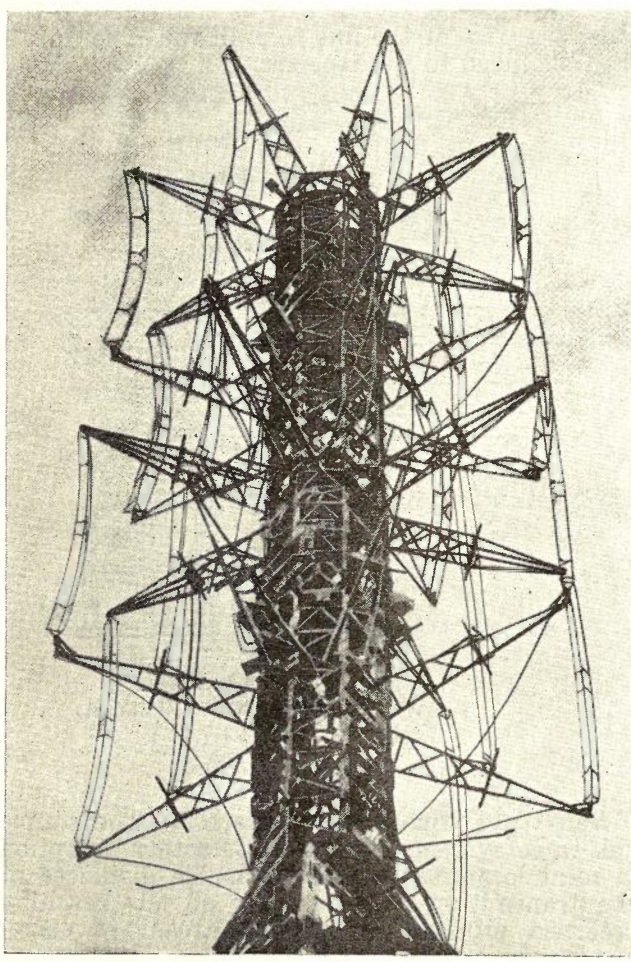


Fig. 33.—T.V. aerials at Alexandra Palace, London.

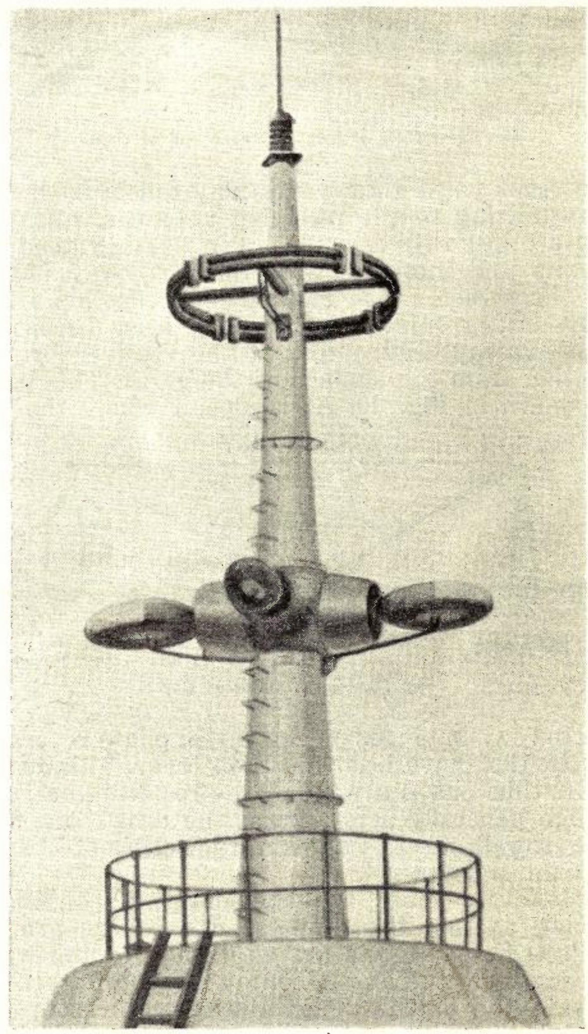


Fig. 34.—Two types of American design.

altered if experimentation indicates that it would result in better reception.

Transmitting Antennas: Transmitting antennas are of more elaborate design, the aim being to obtain high gain in all directions. Two types are illustrated in Figs. 33 and 34, Fig. 33 showing the vision (upper) and sound (lower) aerials at Alexandra Palace, London, and Fig. 34 two types of American design.

Studio Technique

In order to obtain an idea of the studio technique required for television, a recent article describing a visit to a television studio is quoted in an abridged form:—

"We enter the studio—it is almost time for the final dress rehearsal before the broadcast, or telecast, as it will be called to distinguish it from radio. The room is not large, but literally packed with the mechanical apparatus and scenery necessary for one television production.

"The studio is thoroughly sound-proofed, the walls covered with perforated material for acoustic perfection. Overhead is a network of wires and pipes, from which are suspended batteries of lights, and here and there a microphone hung on a wire or on a long boom, near the sets but out of range of the cameras.

"Around the sides of the room are three or four stage settings. In one corner is a living-room scene—a chair, a lamp, and a radio. Across the end of the room is a garden with a bench. The deepest background of the scene is painted, but the bench and the closer flowers and shrubs are real. Next to the garden, in the other corner, is a restaurant table set for a meal, with chairs, and in the background a real door. Painted doors used in stage productions will not suffice in television performances, because, as the television camera moves, the natural highlights in the scenery should appear to move also. Painted ones would remain stationary, and the realistic effect would be destroyed.

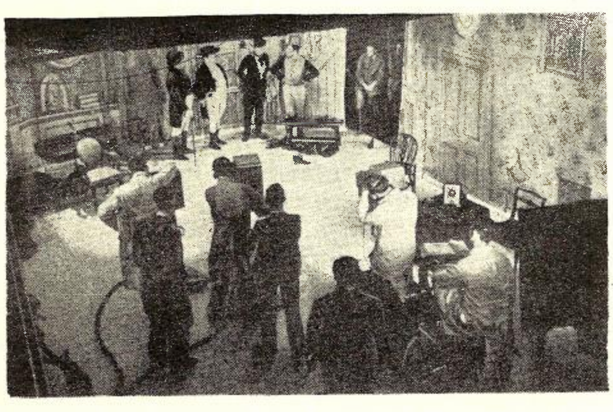


Fig. 35.—Typical scene in television studio.

"All background scenery and properties are painted in shades of grey, because most television cameras do not yet register colour, and only the contrast of light and shade is recorded. Dead white, which would reflect the lights glaringly into the camera lens, is never used. All properties and scenery are of extremely light-weight material, and portable, to make scene changing quiet and rapid. If more scenes are needed than can be set up in the studio at one time, they must be changed while the performance is in progress. When the cameras have moved away from the first set it is quietly taken down and another put in its place, for any noise would register on the sound transmitter.

"A typical studio scene is shown in the photo of Fig. 35. Since the television audience will not want delays, the new scene must be ready for use when the cameras have finished with the last of the series, and this necessitates great speed in shifting from one to another. On the floor of the studio in front of the stage settings stand three of four box-like cameras on rolling platforms, floor lights, and a platform supporting a fishing-rod structure called the microphone boom, with the microphone hanging at the end of the long rod. Cameras are mounted on standards so that they may swing easily and silently in all directions, and motors regulated with push-buttons elevate and lower the camera boxes to any desired height. The boom is hinged, with a crank to move it back and forth, and a swivel on which it swings in an arc from side to side.

"At the opposite end of the room from the stage setting is a long window, behind which can be seen a row of receiver tubes and control boards. This is the control-room, where engineers observe the final results of the broadcast on the screens in front of them and give directions by telephone to the technicians in the studio.

"It is now time for the final dress rehearsal before the actual production. The actors, directors and technicians already have rehearsed from 20 to 40 hours for this one hour of television broadcasting, as compared with four to ten hours of rehearsal for each hour of sound radio. There can be no re-takes in television, as in motion pictures. Every move of actors and cameras must be perfect, and intricately mapped out beforehand. Any error in the broadcasting speeds out into space and is caught by thousands of viewers on home receivers almost before the actor or director can detect it.

"First the technicians enter the studio and take their places at the equipment. One man mounts the platform of the microphone boom and adjusts the crank and swivel so that the microphone hangs over the first set. Other men take their stations at the cameras and arrange them for the first shot. All cameramen are skilled in framing the pictures and focussing the cameras, under the supervision of the production director in the control room. One camera, rolling on its own wheels, is placed at some distance from the set, for long shots. The close up camera stands on a low, rubber-wheeled platform. The cameraman stands on the platform, while his assistant on the floor pushes the camera "dolly" wherever it is needed. Other cameras are either on wheels or platforms, and are trained on the first set.

"Lighting engineers are ready at switches and floor light. The silently rolling floor units are hinged so that their angle may be changed at will to augment the ceiling lights or spotlight certain portions of the scene. Property men, scene-shifters, and special men for the title machines take their places in the studio.

"In the control room the production director, the video engineer, the audio engineer, and assistants take their seats at the control boards and television receivers and don head-phones. The assistant production director and actors enter the studio and the rehearsal is ready to begin.

"During rehearsal the director on the studio floor gives directions through a public-address system. The exact timing of the scenes is worked out and co-ordinated with the camera movements. Each cameraman and pusher must know his exact route, at what moment he must move, and the way the camera must be pointed for each change of viewing angle. In addition to their lines the actors must know when to move to another scene, and to their exact positions, so that no time may be lost when the programme is on the air.

"The time arrives for the broadcast. All sound ceases in the studio. The public-address system is shut off, and from now on all directions must be given from the control room through the headphones to the assistant production director on the floor, who may communicate with the actors and technicians only by gestures. No sound must be heard other than the voices of the actors and the sound effects, which are usually produced in a different room and added electrically to the sound coming from the studio.

"The television broadcast is opened with an announcement, or with a printed title describing the play or other entertainment to follow. One camera picks up the title from a board, or sometimes a "windmill" machine which can be turned to expose one title after another. Appropriate music is turned on in the sound-effects room and blended into the title. A miniature stage is photographed in the effects room, curtains draw aside, and the miniature setting fades into the full-sized stage in the studio.

"Although all the acting takes place in the studio. the production director in charge of the programme sits in the control room and gives instructions through the telephone system by wires and headphones to the assistant production director on the floor, who relays them to the technicians and actors.

"During the progress of a scene cameras are busy switching from one angle to another, on an average of once every twenty seconds. One camera is photographing the scene for actual broadcast; three more are trained for different shots, ready to be switched into the circuit as soon as a signal is given from the control room. When the first camera is finished with its particular shot the second camera is cut in. The first camera then is moved to a different angle and awaits its turn to shoot as soon as the fourth one is finished. In this way the viewing angles can be quickly and easily shifted with no delay or confusion. The three or four cameras are usually placed at various distances from the stage, for long shots, intermediate, and close-ups. The broadcasted picture then may be easily changed back and forth from close-ups to long distance and vice versa. All switching from one camera to another in the transmitter is handled in the control room, and while more than one camera in the studio may be picking up its special scene only one at a time will be linked to the sending station.

"Next to the production director sits the video engineer, who observes the broadcast results on his receiver, or kinescope monitor, and gives instructions to the cameraman on the floor. From his position he can see faults in the picture not apparent to the cameraman, and can see through the window what change of camera angle or distance from the stage will correct the error. The video engineer selects all the shots, instructs the cameramen on the floor in switching and focussing, and gives cues for turning the cameras on and off the outgoing channel. In motion-picture production the video engineer's counterpart is the editor and the film processing laboratory, but in television all editing must take place on the spot.

"On the other side of the production director sits the audio control engineer. He is responsible for the sound effects, hears them as they come over the radio receiver, and communicates by telephone with the man on the microphone boom. The microphone follows the action, always as close as possible to the speakers without coming within the camera range. All of the sound portion of the broadcast is monitored through an individual circuit and broadcast on a radio channel, separate from that of the video signals.

"The production director in the control room, through the video and audio engineers, co-ordinates the microphones and the camera with the lighting effects, and sees that the complete effect is satisfactory.

"In the studio the assistant production director is the only medium between the actors and the production director. Receiving instructions through his headphones, he directs by gestures the timing of the printed titles, the moving of scenery, and supervises the acting as best he can.

"The acting should be perfected before the broadcast, because the actors cannot watch the director, nor can they be prompted. They must memorise their lines perfectly, since use of script is taboo in television. Because the camera apertures are large, focussing is limited, and the actors must learn to keep within this focus, limited, usually, to about six feet. It is the frequent changes of camera-viewing angle which compensate for the possible monotony of this narrow range of action.

"The small acting range also limits the number of persons photographed at one time. For a close-up shot, not more than three actors can be conveniently included at one time. A long-distance picture can cover nine or ten, but more than that would be crowded to the edges of the scene, and the limit of focus would tend to blur those on the outside. If a close-up is desired of some particular property on the stage during a multi-character scene, it is necessary to narrow the picture down to a portion of the characters in order to focus on the object. The background scenery must be within three feet of the actors in order to photograph properly."

Summary of Proposed Australian Standards.

Most of the standards proposed for the Australian television service have been mentioned previously in this article. Summarised, the standards are:—

Carrier frequency range—178-200 mc/s.
Channel width—7 mc/s.
Number of lines—625, interlaced 2:1.
Vision modulation polarity—Negative.
Polarisation of vision radiation—Horizontal.
Frame frequency—25 pictures per second.
Aspect ratio (width : height)—4 : 3.
Type of emission—Vestigial side-band.
System of sound transmission—Frequency-modulated.

In vestigial side-band transmission, the carrier, one complete side-band, and a vestige of the other side-band are transmitted. This latter is really an extension of the band-width to ensure that no mutilation of the carrier or other side-band frequencies occurs due to the inclusion of the suppression filters. The total channel width of 7 mc/s with this system of transmission is shown in Fig. 36.

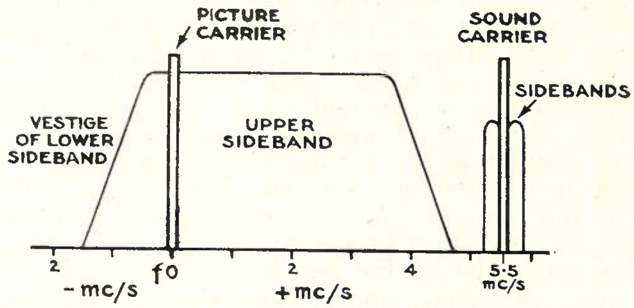


Fig. 36.—Channel Spectrum.

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POSTAL ELECTRICAL SOCIETY OF VICTORIA ANNUAL REPORT, 1949-50

A bi-monthly lecture programme was arranged for 1949-50 and the Society was fortunate in being able to arrange for talks by Mr. B. Hensler, Circuit Design Engineer from Siemens Pty. Ltd., England, and Mr. D. Ashby, Rectifier Engineer of Westinghouse Brake & Signal Co., England, who were visiting Melbourne.

Appreciation for the delivery of lectures during the year is expressed to Messrs. B. Hensler, R. C. Lamb, D. A. Gray, D. Ashby, and R. D. Kerr. The committee also thanks the State Electricity Commission for the loan of a sound film on the Yallourn-Kiewa schemes. The lectures were held in the Radio Theatre, Melbourne Technical College, by the courtesy of the Principal, Mr. F. Ellis, M.A., B.E., and Mr. R. R. Mackay, M.I.R.E.(Aust.), and we are indebted to them and Messrs. P. Permewan, A.M.I.R.E.(Aust.) and H. Power for the material assistance they are rendering the Society.

The Society lost a very good friend in the sudden death of Mr. N. W. V. Hayes, Acting Chief Engineer and former President. Mr. Hayes had always taken a keen interest in this Society and was ever ready to help in any capacity.

The resignation of Mr. S. T. Webster from the Board of Editors on account of ill-health was received with regret and the Committee is most appreciative of the help which Mr. Webster gave as Editor to the Journal, and wishes him a speedy recovery. Mr. N. M. Macdonald has been appointed Editor in place of Mr. Webster.

At the request of the Board of Editors the Committee appointed Mr. C. R. Anderson, of Brisbane, and Mr. C. J. Prosser, of Melbourne, as Sub-Editors, to assist in obtaining and editing articles from Queensland and Victoria.

The Board of Editors and Committee regret the late publication of recent issues of the Journal, which was primarily due to the difficulty in obtaining suitable articles. The position has now improved, but it would be appreciated if any member willing to contribute an article would communicate with one of the Sub-Editors or Editors.

The number of members and subscribers at 30/4/50 was 2595.

Appreciation is expressed to Miss Wright for the valuable services rendered as Distribution Manager during the current year. It is desired to express thanks to the authors, members of the drafting staff and typists who have given freely of their time in preparing articles and illustrations for the Journal.

C.B. MANUAL EXCHANGES FOR COUNTRY CENTRES

R. W. Turnbull, A.S.T.C., A. W. McPherson, A.M.I.E.(Aust.), M.I.R.E.(Aust.)

Introduction

At the conclusion of the war, the Australian Post Office was faced with an unprecedented demand for new telephone services. To the arrears of the war years were added the growing requirements for industrial development Economic conditions generally were favourable for expansion, and a high rate of applications has continued to the present time. Similar development problems also arose in other countries, with the result that the normal pre-war output of the telephone industry was not sufficient to cater for the demand. As with other essential needs of the community, there was a time lag in raising production to the new level of requirements.

On 30th June, 1950, there were 793,077 exchange lines in service throughout the Commonwealth, and of these 309,190 were connected to country exchanges. The net development of exchange lines in the country areas is shown graphically in Fig. 1, Graph A, in which the net connections as at 30th June each year are given for the period 1930-1950 inclusive.

The high rate of applications received in recent years can be seen from Graph B, which shows the number of deferred applications. It will be seen from Fig. 2 that the net annual rate of growth has increased from 5127 lines in 1938-39, the year immediately preceding the war, to 22,805 lines in 1949-50, and at 30th June, 1950, there were 24,442 deferred applications for exchange lines.

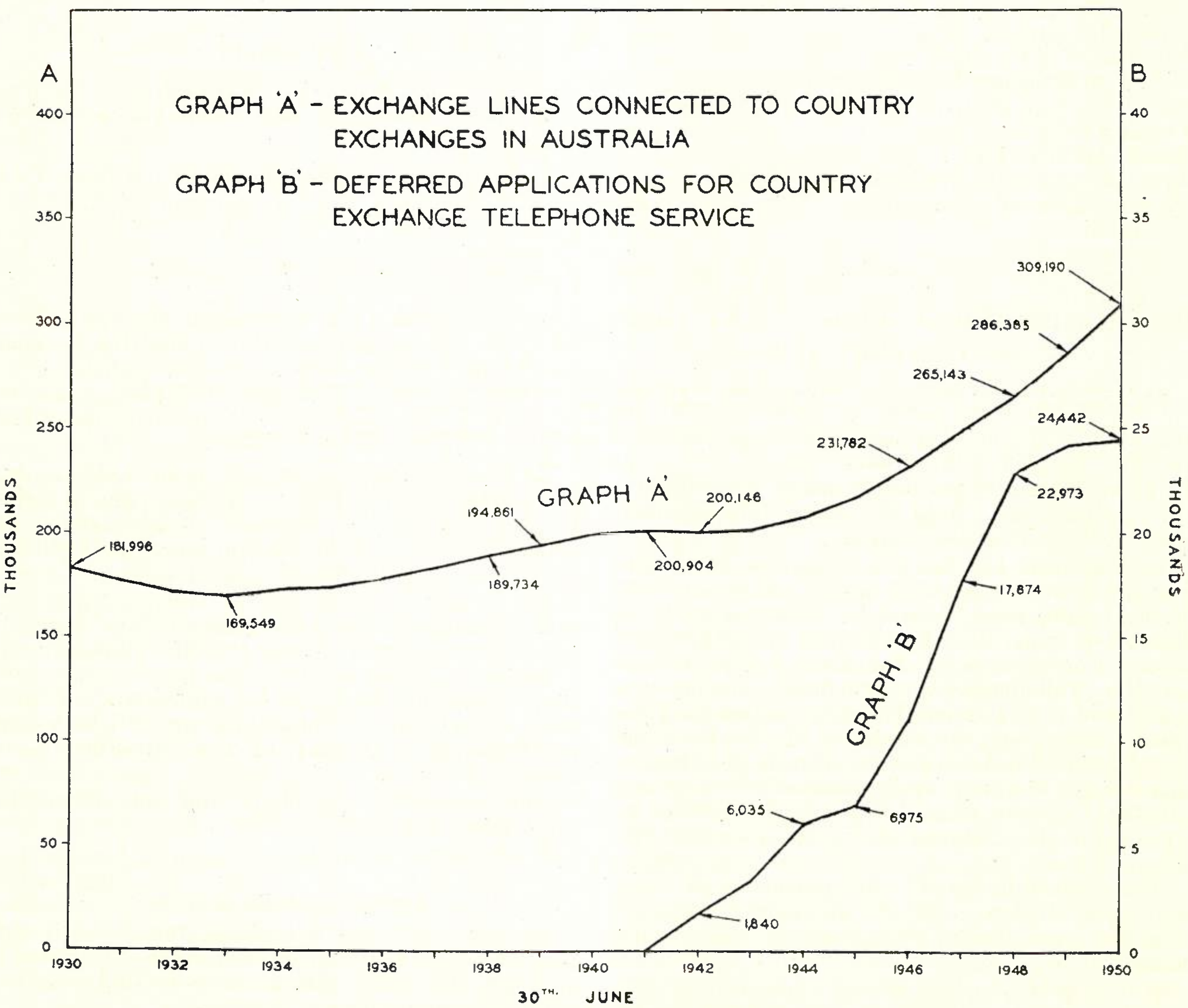

Fig. 1.—Exchange Lines connected to Country Exchanges and Deferred Applications for Telephone Service.

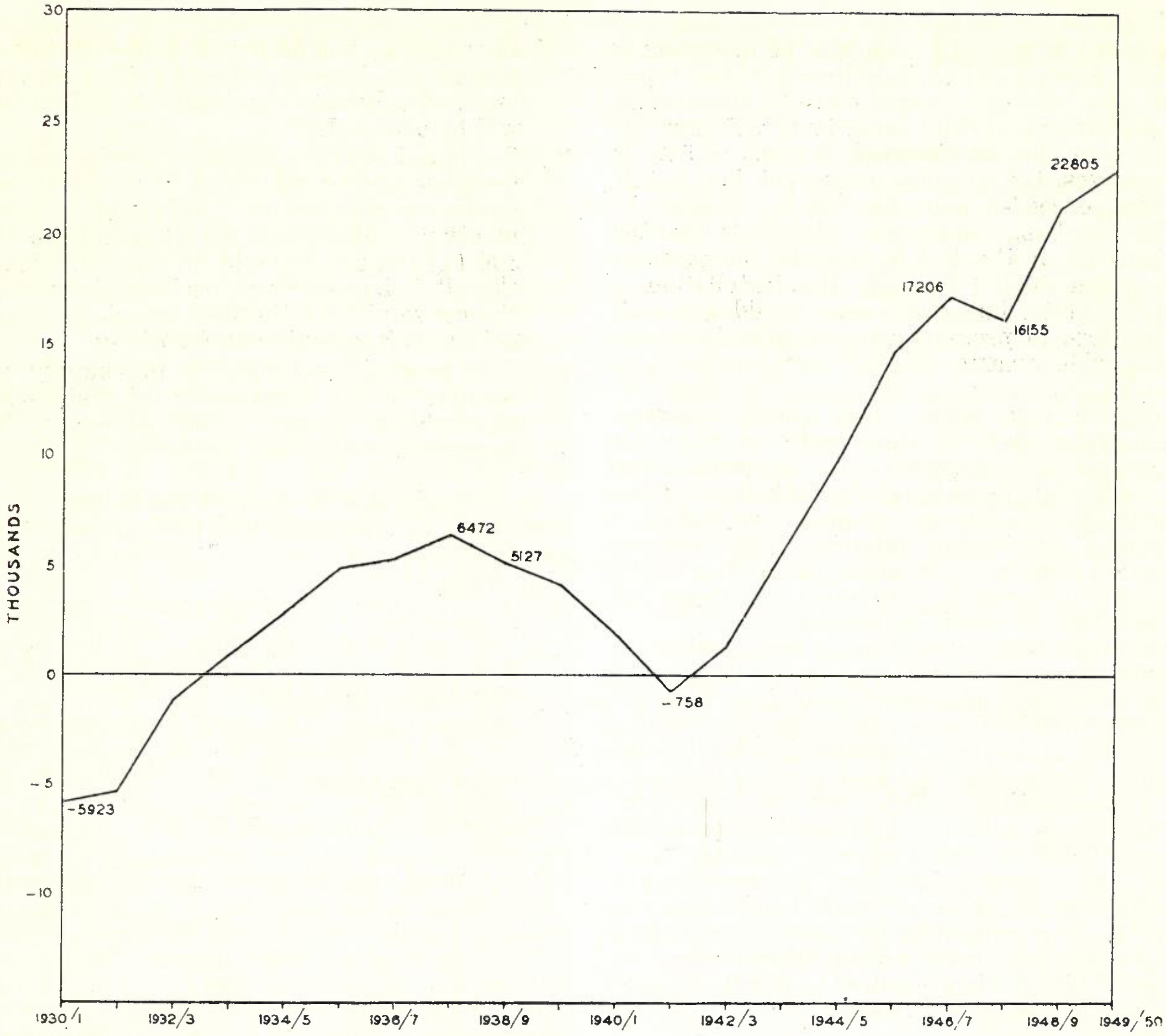

Fig. 2.—Nett annual rate of growth of Exchange Lines connected to Country Exchanges.

Long Range Plans for Country Networks

In extending the capacity of the exchange network serving country districts, the provision of new buildings, telephone and carrier equipment and subscribers, junction and trunk lines is proceeding on a large scale in accordance with co-ordinated plans to ensure that a satisfactory standard of service is maintained during the expansion. The plans for the future envisage ultimately the complete conversion of the whole of the country exchanges to automatic. The extent of the work entailed in reaching this objective can be appreciated from the large number of exchanges involved. At 30th June, 1950, there were 6494 exchanges in service outside the State capital city areas. These comprise 15 automatic exchanges, 228 rural automatic exchanges, and 6251 manual exchanges. Nearly all these manual exchanges are equipped with magneto type switchboards.

It would be impossible to undertake a programme of works catering for the early conversion of all country exchanges from magneto to automatic, and at the same time provide for development both in the country and the metropolitan areas. It is, therefore, necessary to proceed in stages, and the most important single step is the introduction of common battery manual exchange switchboards, which will supersede the magneto equipment used so extensively to date. The purpose of this article is to set out the reasons for the development of the common battery and sleeve control equipment which has been adopted as standard, and the principles governing its use, as a preliminary to descriptions of the various types of switchboards and associated apparatus, which will be dealt with later in this and subsequent issues.

Implementation of Plan

In small centres, the installation of a large number of rural automatic exchanges is proceeding. The locations are determined from service considerations such as availability of operators and hours of attendance and from the engineering standpoint in which economy of line plant is a major factor. The R.A.X. units are of two types, the smaller having a capacity for 40 subscribers, and the larger an initial capacity of 50 lines capable of extension to 200 lines in steps of 50. In some centres, the capacity of the 200 line R.A.X. has been exceeded and the R.A.X. replaced by standard exchange equipment. In other localities the capacity of the R.A.X. may be increased to a maximum of 400 lines by the installation of extension units, but such cases would generally not be those in proximity to metropolitan areas or in seaside resorts where heavy traffic is experienced.

There are also some large country centres in Australia where the early introduction of automatic equipment is essential, and these will be considered individually. When complete conversion of manual exchanges is undertaken, it is the intention that priority will be given to exchanges exceeding 2000 lines capacity, where permanent buildings are available for automatic equipment.

Meanwhile, the introduction of common battery manual exchanges and sub-station equipment will enable a better standard of service to be given than is available from existing magneto equipment. Such equipment, in association with trunk positions of the sleeve control type, will provide improved operating facilities for local and trunk line traffic and facilitate the extended application of long distance signalling and dialling equipment. At the appropriate time, automatic equipment for the switching of trunk traffic may also be added. The application of automatic switching methods to trunk traffic will in future reduce the number of telephonists required to handle through traffic and increase the efficiency of the trunk line service.

Under the procedure envisaged, it is planned to meet development in selected country centres by replacing the magneto equipment with common battery and sleeve control trunk switchboards. Such areas are those where it is apparent that automatic exchange equipment cannot be provided for some considerable time and the capacity of existing equipment cannot be extended. Apart from improved service to the public, which is a dominant consideration, the following advantages are expected from this course of action:—

(1) Trunk exchanges of modern type and suitable for use with automatic trunk switching equipment will facilitate the development and extension of trunk line services.

(2) The purchase of further supplies of magneto type switchboards and telephone instruments may be progressively reduced and finally discontinued.

(3) Purchases of dry cells, involving the use of large quantities of zinc, as well as raw materials, such as carbon and manganese, which are not produced in Australia, will be minimised.

(4) The gradual deterioration of transmission efficiency of magneto telephones during the life of the dry cell batteries, too frequently renewed only after complaints by subscribers, will be obviated.

(5) Common battery subscribers' equipment may be subsequently converted to automatic with minimum expenditure. It is appropriate to mention that the universal telephone type 300 (1) and developed in the Chief Engineer's Circuit Laboratory was designed to facilitate the conversion of the instrument from magneto to C.B. or automatic working.

(6) The general improvement in country subscribers' lines necessary for automatic operation will be brought about gradually, thus conserving manpower resources.

Types of C.B. Manual Exchanges

In order to proceed on the lines described, two standard types of C.B. manual exchanges have been designed:—

(a) A multiple type switchboard consisting of "A" and trunk positions suitable for exchanges having a maximum capacity of 2000 subscribers' lines, and

(b) A non-multiple type single position switchboard for combined "A" and trunk working, having a maximum capacity of 200 subscribers' lines.

Orders have been placed for C.B. equipment of these types to a total capacity of approximately 100,000 lines, and deliveries are now proceeding.

The Department has also taken advantage of offers from the British General Electric Co. and British Automatic Telephone and Electric Pty. Ltd. for the supply of multiple type C.B. "A" positions of United Kingdom manufacture. In the former case, B.P.O. C.B. No. 10 switchboard positions are being supplied, and in the latter the Australian standard circuits are incorporated in switchboards developed by Automatic Telephone and Electric Co. Ltd., and having a maximum capacity of 3000 lines.

The A.P.O. standard C.B. multiple exchange, with associated sleeve control trunk positions, is in accordance with Drawings CE-360, CE-366, CE-371 and CE-550. Multiple type C.B. "A" positions are provided for local subscribers' services, and there are two types of trunk positions known as "terminating" and "through" types respectively. The terminating trunk position is equipped with both subscribers' and trunk multiple fields, and is used for incoming and outgoing trunk traffic for local subscribers. Each pair of cords contains one cord for C.B. operation of the subscribers' lines and one cord for sleeve control operation of trunk line circuits. In sleeve control circuits, as the name implies, the signalling and supervisory circuits are operated over a third or sleeve wire, as distinct from the bridge control method of operation used for subscribers' lines connected to "A" position switchboards. The "through" type of trunk position is equipped with a trunk multiple field and is designed for the handling of 2-wire or 4-wire through connections with sleeve control cord circuits.

The standard non-multiple type exchange switchboard is designed as a combined "A" and trunk position. Details are given in Drawings CE-522 and CE-523. These switchboards will replace as a standard the 100-line and 200-line magneto floor pattern switchboards. The capacity of the C.B. non-multiple type position is 200 subscribers' line circuits and 18 two-wire magneto trunks.

Application of Various Types of Equipment

It has been decided to adopt the following general procedure for manual exchanges in country districts:—

(i) Install the standard C.B. multiple and sleeve control switchboards in large centres where major extensions to or replacement of existing magneto exchange installations are required and an automatic installation cannot be provided immediately. With centres over 2000 lines, conversion to automatic would be given priority. The minimum size of a multiple installation is determined by the number of operating positions required to handle the traffic, and whether the installation of functional type positions is justified, rather than by a specific number of subscribers' lines.

(ii) Install the standard C.B. non-multiple switchboards in country exchanges where, during the life of the exchange, not more than 2 operating positions will be needed. In special cases, 3 positions have been permitted.

(iii) Extend exchanges which are too small for the provision of standard C.B. multiple switchboards and too large for C.B. non-multiple equipment by installing new or recovered magneto switchboards.

In addition, floor type magneto P.B.X. switchboards in subscribers' premises will be replaced by C.B. switchboards as opportunity offers, and all new P.B.X's will be of C.B. type. This procedure was adopted more than 10 years ago and applies to all areas, irrespective of the type of public exchange in use. Progress has been impeded by supply difficulties, but shortages have now been largely overcome, and the general use of C.B. P.B.X. switchboards is being arranged as soon as practicable.

Detailed descriptions of the standard C.B. and sleeve control multiple switchboards and the G.E.C. and A.T. & E. Co. C.B. multiple equipment and of the standard non-multiple switchboards will be given in a series of articles, the first of which is contained in this issue of the Journal.

Acknowledgments

Acknowledgments are due to many of the staff within the Engineering and Telephone Branches of the Postmaster-General's Department, and to representatives of the Telephone Manufacturers for valuable assistance given during the development of the standard designs and the manufacture and assembly of proto-type exchanges to the new standards.

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MANUAL C.B. MULTIPLE EXCHANGES AND SLEEVE CONTROL TRUNK SWITCHBOARDS

R. W. Turnbull, A.S.T.C., A. W. McPherson, A.M.I.E.(Aust.), M.I.R.E.(Aust.)

PART I—PHYSICAL DESIGN AND CONSTRUCTION

Introduction

A combined manual C.B. local exchange and sleeve control trunk exchange consists of operating positions of the following functional types:—

"A" Positions. These positions cater for the handling of all calls originated by local subscribers and for the completion of all connections within the local network. When the local subscriber requires trunk service, the telephonist on the "A" position connects to the "terminating" trunk position via a junction or transfer circuit which is released when the "terminating" trunk telephonist completes the call via the subscribers' multiple.

The "A" positions are equipped with a combined local and multiple field, with a multiple appearance of every subscriber's line occurring every five panels. Lamps are inserted at one appearance only.

"Terminating" Trunk Positions. The "terminating" trunk positions are equipped with both subscribers' and trunk multiple fields, and are used for the completion of all trunk traffic which involves connection to and from local subscribers. The subscribers' multiple field over the "terminating" trunk positions consists of jacks only. Each pair of switching cords contains one cord for C.B. operation of the subscribers' lines, and one cord for sleeve control operation of the trunk line circuits. All incoming trunk traffic is first dealt with by the telephonist at the "terminating" trunk position, but when "through" connections to other trunk lines are necessary the calls are passed over to the telephonist at the "through" trunk position. This is done by a circuit arrangement which, under the control of the "terminating" trunk telephonist, operates a call transfer lamp in the trunk multiple over the "through" trunk positions.

"Through" Trunk Positions: "Through" trunk traffic is handled at the "through" trunk positions which are equipped with a trunk multiple field and are designed for the handling of 2-wire or 4-wire "through" connections.

The operating positions are associated with equipment racks on which are mounted subscribers' line and cut-off (L. & K.) relays, trunk line relay set terminations and other miscellaneous equipment.

All relay sets directly associated with the functional nature of the operating positions are mounted on relay bases which are jacked in to the rear of the positions. These relay sets contain equipment for cord circuits, cord test circuits, position circuits and time check circuits.

This article, i.e., Part 1, describes the development of the physical design of the operating positions and the main equipment racks. The circuits will be described in Part 2, and in a later article in the series a typical installation will be described.

Design of Operating Positions

The design and construction of standard operating positions for multiple working were influenced by many factors, the principal among which were:—

(1) Operating requirements.
(2) Accessibility for installation and maintenance.
(3) Cabling arrangements.
(4) The existence of a multiple type switchboard position adapted for universal use in 1938.
(5) The necessity to obtain supplies quickly to provide early relief to important country centres.
(6) Maximum degree of standardisation to facilitate manufacture, delivery, installation, and subsequent extensions.
(7) General appearance.
(8) Durability.

The need for large scale provision of this type of equipment developed with such rapidity, due to the heavy public demand for new telephone services which followed the war years, that the time element became the main consideration in planning and obtaining supplies. Although some purchases of this class of equipment had been made prior to 1947, the scale of operations then contemplated was only of relatively small magnitude. Much of the circuit developmental work had been completed before and during 1947 and, therefore, in taking stock of the situation early in that year, the main points requiring quick action were the determination of a suitable physical design of an operating position having a subscribers' line capacity of 2,000 lines on a five-panel multiple basis, and deciding the most suitable means of purchasing all of the various items forming part of a complete exchange.

The purchase of the exchanges as complete working units for specified locations was considered, but this arrangement would not give the degree of interchangeability required, as it would be necessary to nominate the locations at the time of placing the order. Superficially this arrangement may appear to have great advantages, but during the period between the placing of the order and actual delivery, priorities are likely to change, with the result that equipment specially assembled by the manufacturer for a particular location may have to be diverted to another location, either within the same State or in another State and suitably modified to meet a different set of conditions. Another important factor in determining the method of purchase was that, as a long term plan, overall requirements would be met earlier by obtaining the various parts, comprising an exchange from a group of manufacturers specialising in particular items. Thus the arrangement which suggested itself was that, apart from the separate purchase of relay sets, racks, etc., the operating positions would be supplied without any jack field, so that when delivered they would be capable of being used to form any part of a built-up installation, or to extend an existing installation without undoing any of the work already done by the manufacturer.

chassis already in existence, which had been adapted in 1938 from the design of a similar position used by the British Post Office at that time. It was decided therefore to use this design as the basic prototype with suitable modifications to meet requirements. The main points requiring attention are enumerated briefly as follow:—

(a) It was necessary to increase the multiple capacity from about 1200 lines to 2000 lines.

(b) The prototype was designed for strip mounted relay equipment for cord circuits, position circuits, etc., whereas jacked-in equipment was considered to be an essential requirement for manufacture, transport, installation and maintenance. Jacked-in equipment was used for the first time in Australia on switchboard positions in a C.B. Lamp Signalling P.B.X. (1). Field experience with these switchboards has proved the value of this facility.

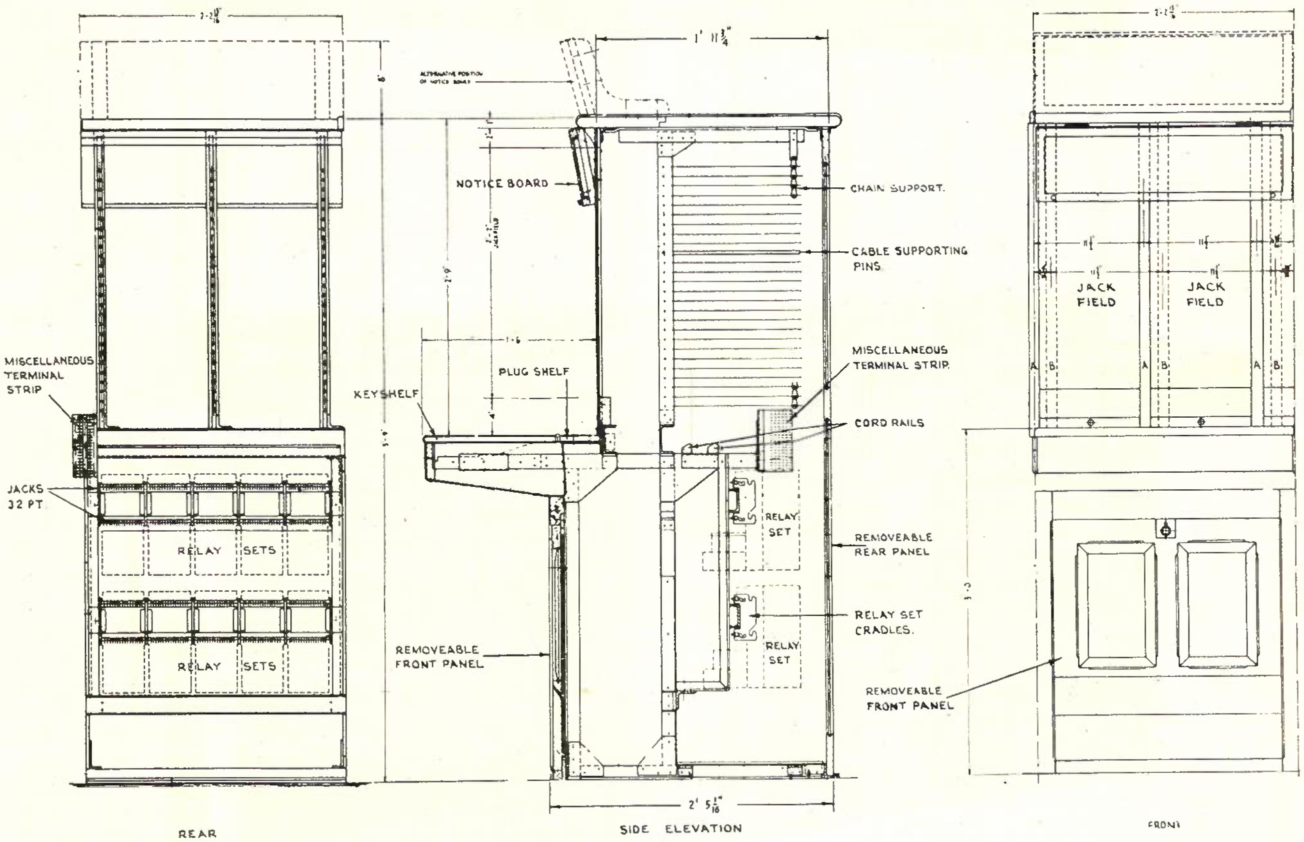

Fig. 1.—Standard Single Position Framework.

(c) Universal drillings on the plugshelf and keyboard of the prototype were unsuitable for the present need.

Normally the logical developmental process for such a project would have been to construct a series of models and finalise drawings from the resultant prototype. This process is, of course, time consuming in the initial stages, and even with an accelerated effort it is doubtful whether completion would have been reached inside 12 months. At the time this matter was under review the situation throughout the country demanded the immediate issue of a tender schedule for the purchase of operating positions and left no time for a normal developmental process. As mentioned previously, there was a multiple switchboard position with a steel frame

From the standpoint of manufacture and general standardisation, it was necessary that each of the three types of position, viz., "A," "terminating" trunk, and "through" trunk, should be identical in physical design and construction as far as possible. Therefore, so far as (a) above was concerned the height of the upper structure of the position to accommodate a full subscribers' combined local and multiple field over the "A" position also determined the height of the trunk positions whose jack fields require less space than that of the "A" position. A considerable amount of modification to the prototype was necessary in the case of (b) but again a universal arrangement was possible. In fact, this requirement was met in all respects for the framework, the only exception being the drillings and arrangement on the plug shelf and keyboard mentioned in (c). It is quite possible to have universal drillings on the plugshelf and keyboard to meet the triple purpose, and, indeed, this had been done earlier for a dual requirement but, as would be expected, it was necessary to drill many holes which may not be used during the life of the exchange. It is quite normal practice to plug unused holes with phenol formaldehyde stops, but in such cases the extra drillings are usually confined to those for which some use can be foreseen. The matter thus resolved itself into a chassis of universal design with a plug shelf and keyboard to suit the specific functional needs of each of the operating positions.

Fig. 1 shows a front and rear view and side elevation of a standard single position framework. The essential dimensions are included. As distinct from a P.B.X. or other completely self-contained non-multiple switchboard, the operating position for a multiple suite does not cater for the termination of subscribers' lines or trunk lines on terminal strips at the rear of the switchboard, because the cables are brought in from an I.D.F. or a multiple connecting frame and wired direct to the jack and lamp field. The terminal

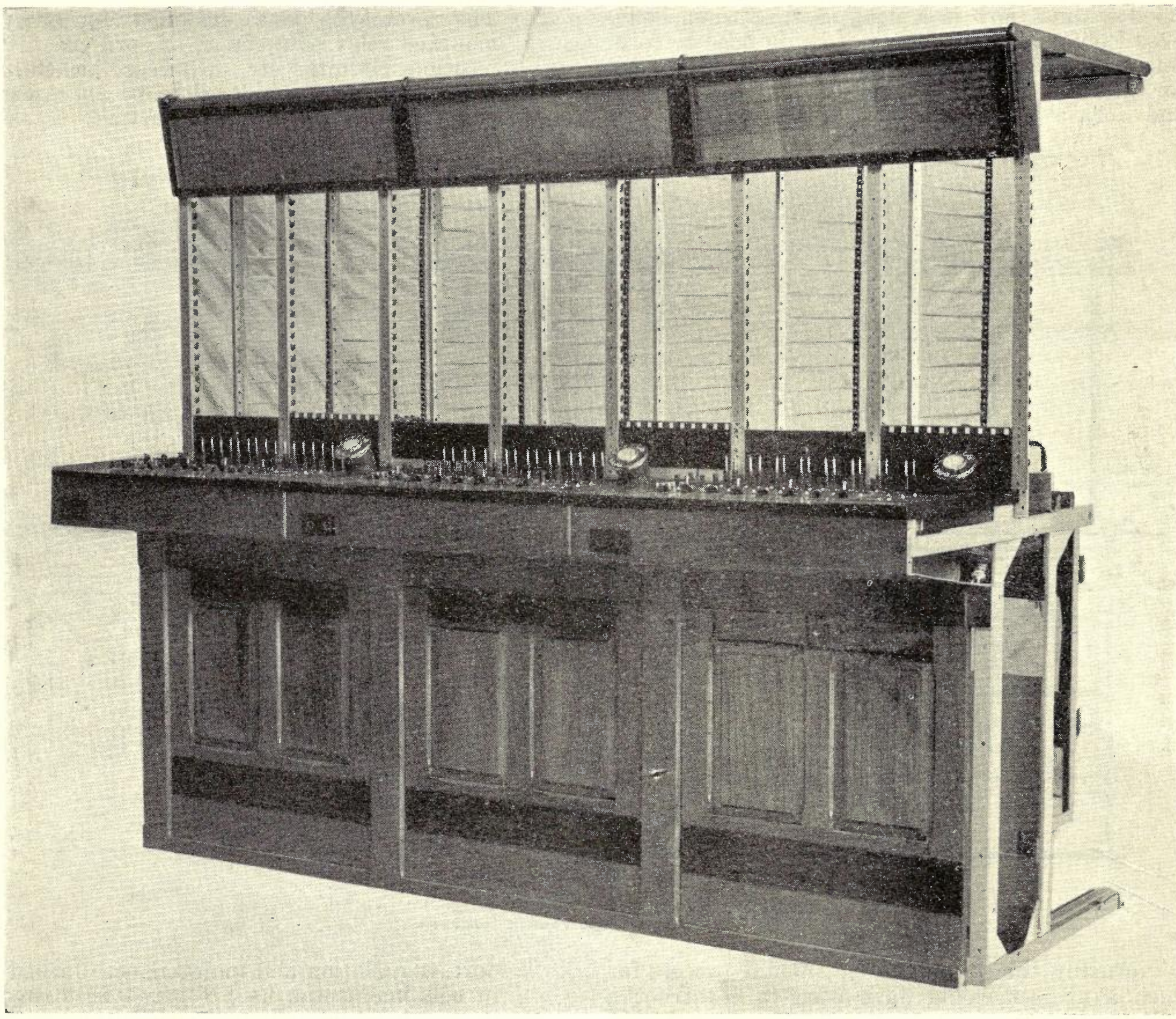

Fig. 2.—Section of multiple suite showing seven panels over three positions.

strip shown in Fig. 1 is used for the termination of miscellaneous circuits such as cord test, time check, and order wires. Consideration was given to the provision of fuse mountings on each position for fusing the battery leads to the cord circuit and position circuit relay sets, etc., but any advantages to be gained by this provision were more than offset by the difficulties envisaged in having extensive fuse equipment in the manual switch room, where accessibility is gained by the removal of panels instead of the more conventional and successfully operated C.B. practice of having a centralised fuse panel in the equipment room. The choice of the latter arrangement involves a separate battery feed from each fuse in the equipment room to the associated relay set in the switch room, but in general is better than having individual fuse equipment mounted at the rear of each position. It is fully recognised, of course, that circumstances may exist which justify individual fusing at certain locations, and in such cases 2000 type fuse mountings can be fitted without great difficulty. In general, however, it is intended that this arrangement should be the exception rather than the rule.

The arrangement of the jack field panels shown in Fig. 1 is for a single position switchboard, but the design of the framework caters for the placing of all vertical upper members in any of three other positions to meet the needs of a multiple suite. Fig. 2 shows the front panel section of a multiple suite extending over three positions, which provides for a complete seven panel section without overlap at each end. The design of the universal framework allows for any unit delivered by the manufacturer to occupy positions No. 1, 2 or 3 in a suite by simply re-arranging the upper vertical members which are secured by screws and bolts. This in itself raised a practical question in respect of the holding of stocks of the items. At first thought it may appear advisable to nominate the numbers of left, right and middle positions to the manufacturer, but this course does not permit full flexibility and would entail twelve separate stock items in lieu of three. The arrangement of the panels represents only a small item in the subsequent assembly of a multiple suite and therefore it was hardly worthwhile calling for separate assemblies when they may not be used as such when received. The best compromise in the interests of flexibility and simplicity was to order all the positions as balanced two-panel sections in the arrangement shown in Fig. 1. It may be argued and, indeed with considerable logic, that further time would be saved and greater flexibility gained if the top structure were not assembled by the manufacturer, but supplied as a separate parcel of steel and wooden pieces ready for assembly. However, this arrangement has the disadvantage that not only is it necessary to sort the various sections, but they have not been previously fitted. Both of these aspects are quite important and tend to minimise any advantages which might be gained. Although the arrangement chosen was regarded as the most suitable compromise offering at the time it is recognised that a change may be desirable at a later date in the light of practical experience gained.

The layout of the relay sets at the rear of each of the three positions is shown in Fig. 3. The

ASSEMBLY 'A' ('A' POSITION)	UPPER	CORD CCTS. 1 - 2	CORD CCTS 3 - 4	CORD CCT. 5 - 6	CORD CCTS 7 - 8	CORD CCTS 9 - 10
	LOWER	CORD CCTS 11 - 12	CORD CCTS 13 - 14	CORD CCTS 15 - 16	CORD CCTS 17 - 18 (IF REQUIRED)	POSN CCTS
ASSEMBLY 'B' (THROUGH POSITION)	UPPER	CORD CCTS. 1 - 2	CORD CCTS 3 - 4	CORD CCTS 5 - 6	CORD CCTS 7 - 8	NET CORD CCTS. 1 - 4
	LOWER	POSN CCT.	TEL'ST. CCT.	TIME CHECK RS1 1 - 8	TIME CHECK RS 2 1, 3, 5 & 7	TIME CHECK RS2 2, 4, 6 & 8
ASSEMBLY 'C' (TERMIN'G. POSITION)	UPPER	CORD CCTS 1 - 2	CORD CCT 3 - 4	CORD CCTS. 5 - 6	CORD CCTS 7 - 8	
	LOWER	POSN CCT.	TEL'ST. CCT.	TIME CHECK RS1 1 - 8	TIME CHECK RS 2 1, 3, 5 & 7	TIME CHECK RS 2 2, 4, 6 & 8

Fig. 3.—Layout of Relay Sets.

allocation of the switch jacks and the wiring of the relay sets have been designed so that a "through" trunk position may be converted into a "terminating" trunk position by an interchange of relay sets and suitable alterations to the multiple fields. This will greatly facilitate subsequent growth of an exchange and will result in economies in the provision of additional positions.

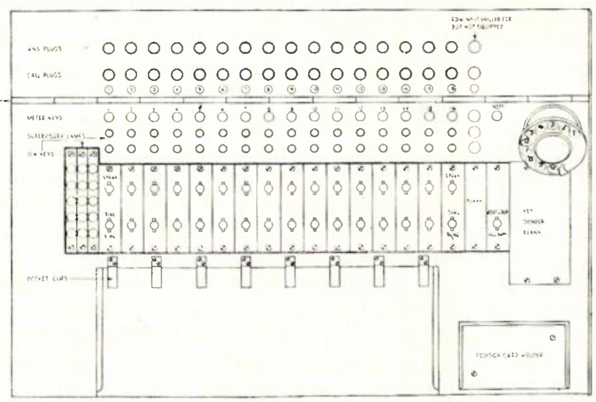

Fig. 4.—"A" Position, Plug Shelf and Keyboard.

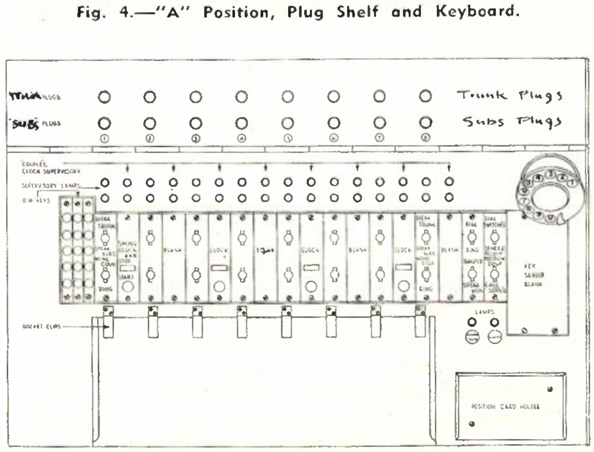

Fig. 5.—"Terminating" Trunk Position, Plug Shelf and Keyboard.

The facility is also of great value in permitting the convenient installation of, say, two "through" cord circuits on a "terminating" trunk position at locations where it is not desired to staff the "through" trunk position during slack periods.

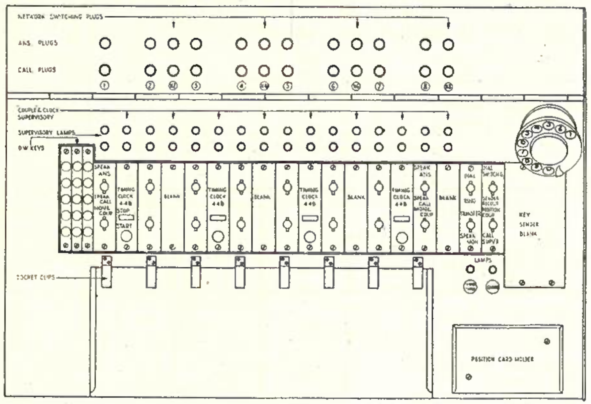

Fig. 6.—"Through" Trunk Position, Plug Shelf and Keyboard.

Figures 4, 5 and 6 show the layout of the plug shelf and keyboard for the "A," "terminating" trunk, and "through" trunk positions respectively. On the "A" position the conventional C.B. practice of press button metering is used. Consideration was given in the early design stages to the use of automatic metering, but it was felt that the advantages to be gained over press button metering were not sufficient to justify the additional circuit complexity and the risk of possible delay in delivery. This consideration also applied to automatic ringing facilities on all positions. Four-wire switching on the "through" trunk positions was in the same category, and, in the interests of economy, simplicity, and conservation of materials, manual four-wire switching of the line and network jacks is employed. On the trunk positions, four B.P.O. type timing clocks are installed initially, but wiring is provided for eight circuits. At first thought it may appear that timing facilities are not required on the "through" trunk position, but it is necessary to cater for the timing of calls at the "through" trunk positions in cases where traffic originates from non-official offices without timing facilities. Order wire keys have been provided on a liberal basis and should be adequate for all normal requirements.

The first order for standard positions was placed on the Superintending Engineer, Melbourne, on 9/1/48, and since then further orders have been placed with Amalgamated Wireless (A'asia) Pty. Ltd., Ericsson Telephone Manufacturing Co., England, and Standard Telephones and Cables Pty. Ltd., England. The total quantities ordered from these combined sources as at 30th June, 1950, was 1224 made up as follow:—

"A" position	337
"Terminating" trunk position	596
"Through" trunk position	291

"L" & "K" Relay Set Racks

In arriving at a suitable design for the "L" and "K" relay set rack, it was first necessary to determine its capacity. In this connection, some racks having capacity for approximately 800 lines had been purchased early in the war years, but it was found that these racks were rather bulky and presented handling difficulties. The capacity finally decided upon was 500 straight subscribers' lines plus 40 party lines. The general assembly of the relay rack is shown in Fig. 7. Flange type relay mountings were chosen as being the most suitable because tools were already available in Australia for this type of mounting. Twenty pairs of relays per strip have been used to simplify cabling to the terminal blocks. A rather interesting comparison is made as follows between the early racks which were 4′ 6″ wide overall and the present rack of 3′ 6″ in width.

No. of straight subscribers' lines	Floor space occupied	
	Previous rack	Standard rack
500	4′ 6″	3′ 6″
1,000	9′	7′
1,500	9′	10′ 6″
2,000	13′ 6″	14′

In the early stages the question arose whether the connections for the external cables should be brought out to terminal strips associated with the rack, or whether the cables should be taken straight to the relays at the time of installation. The main argument in favour of direct cabling to relays is what appears on the surface to be a saving in space, manpower and materials, but again a practical consideration became the dominant factor and rendered it necessary to use terminal strips. The considered opinions of experienced Installation Engineers were obtained, and they were unanimous on the point that the provision of terminal strips on the relay set rack would simplify installation in country areas and thus effect worthwhile economies.

Trunk Line and Miscellaneous Relay Set Racks.

In catering for the mounting of trunk line terminations, junction circuits and miscellaneous relay sets, it was considered advisable to make provision for two different shelf arrangements, viz.:—

Rack No. 1.—9 shelves each arranged to accommodate 10 relay sets of 16 relays.

Rack No. 2.—2 shelves each accommodating 10 relay sets of 12 relays, and 4 shelves each accommodating 10 relay sets of 26 relays.

The racks have been actually purchased in this form, but it is likely that other more desirable arrangements may present themselves when the installation programme has had an opportunity to gain momentum.

Meter Racks

These are standard racks as used in automatic exchanges, accommodating 1,200 meters.

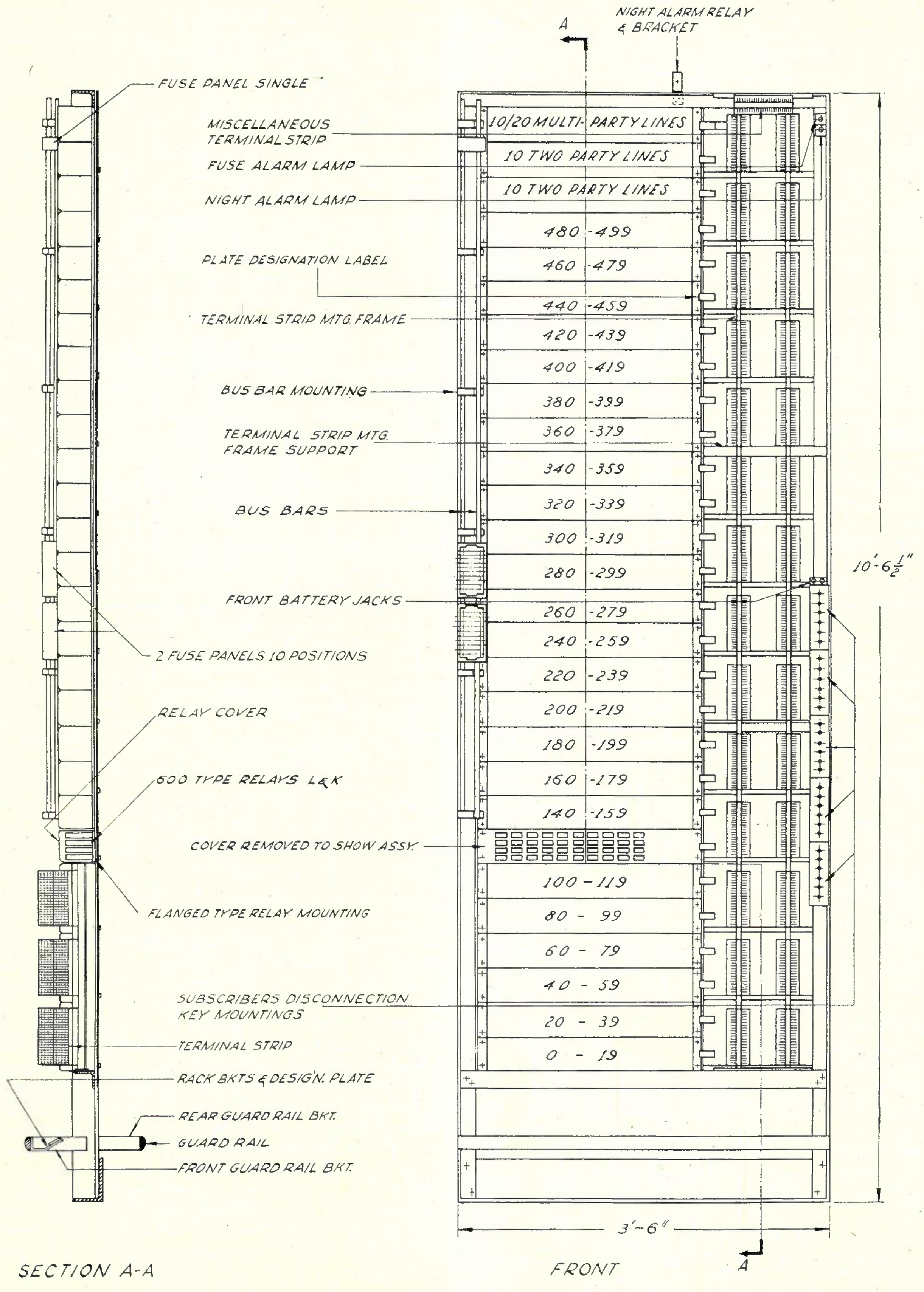

Fig. 7.—L. and K. Relay Rack.

Cable Turning Section

On installations where the "A" positions and trunk positions are in the same row in the switch room, it is necessary to provide a dummy operating position to allow for the entrance and turning of the multiple cables. This is known as a cable turning section (C.T.S.), and consists basically of an iron framework. In view of the varying nature of the buildings in which the exchanges will be installed throughout the Commonwealth, each with its own particular problems, it was felt that a standardised cable turning section may introduce difficulties, and, for the present, arrangements are made locally for the construction of a suitable cable turning section to meet the particular requirements.

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THE SILICA DUST HAZARD IN DEPARTMENTAL EXCAVATIONS

P. R. Brett, B.Sc.

Introduction

For many years air-borne dust of any type has constituted a problem in industrial hygiene because of the unpleasant effect that the dust has on working conditions. In addition to the general problem of the effect of high concentration of any form of dust, there are certain types which have a much more serious action in the lungs and give rise to lung complaints known by the general term Pneumokoniosis. In recent months attention has been refocussed on the question by the Third International Conference of experts on Pneumokoniosis arranged by the International Labour Organisation and held in Sydney from 28/2/50-11/3/50. This conference, which was attended chiefly by medical experts, covered the medical and compensation aspects of all types of the complaint and served to emphasise the seriousness with which the various governments connected with the International Labour Organisation view air-borne dust as a problem of industrial hygiene.

The most widespread form of Pneumokoniosis is that resulting from the inhalation of minute particles of silica and is known as silicosis. It occurs in individuals who have been engaged in gold mining, sandstone tunnelling and quarrying and other industries where there is exposure to siliceous dust. If no steps are taken to control dust it is probable that stonemasons, quarrymen or miners working in sandstone with the usual mechanical tools will begin to show symptoms of silicosis after periods of several years. If the disease is not detected in the early stages and exposure to high dust concentration continues, then disability rapidly increases and the victim becomes subject to severe respiratory complaints, such as bronchitis and tuberculosis. Early death is often a consequence. (See Bibliography 1 and 2.)

The silicosis hazard is so severe that it has been recognised as a compensatable disease in most civilised countries, and many industrial awards provide for periodical X-ray and medical examinations in order that the onset of the complaint can be detected in its earliest stages. In addition, dust standards have been laid down, either by legislation or by industrial awards, and working conditions are required to be in conformity with these standards.

The attention of the Department was drawn to the possible silicosis hazard in conduit excavations when the Amalgamated Postal Workers' Union made application to the Public Service Arbitrator for a variation of the Conduit Workers' Determination (No. 28 of 1926). The Union claimed that a reduction of hours was justified where men were working in trenches or tunnels in rock because of the cramped nature of the work and the injurious effect of the dust on the health of the men.

In dealing with the application the Arbitrator dealt at some length with the health hazards arising from air-borne dust in excavations in sandstone and other types of rock, using as a basis for his remarks the finding of Mr. Justice Ferguson, who dealt with a somewhat similar case in the N.S.W. Arbitration Court. In Mr. Justice Ferguson's finding permissible standards of dust concentration are laid down for various types of excavations and the Arbitrator suggested that similar standards should apply in departmental workings. No data on the dust conditions was available and, consequently, the Arbitrator deferred consideration of permissible dust standards for a period of several months, during which time data could be collected. In order to obtain information to act as a factual basis for subsequent discussions with the Arbitrator an investigation of the general problem, and in particular of the dust concentration in sandstone excavations in the Sydney Metropolitan Area, was carried out by officers of the Research Laboratories during the latter part of 1949. This work (5) is the first that has been carried out on the dust problem in the Department and the information obtained during the investigation may prove of interest to the readers of the Journal.

Conditions in tunnels and mines have been the subject of many reports and investigations, but very little work appears to have been done on the conditions in open excavations. The only references available were to a series of articles (6, 7, 8) describing investigations made in 1929-1932 into dust conditions in excavations in New York. Much of the strata that must be removed for building foundations, etc., is sandstone, and work is done with rotary rock drills and pneumatic picks. Medical investigations showed that of 72 men who had worked only in open excavations about 32 had developed silicosis beyond the primary stages. Dust counts showed that the dust concentration varied between about 50 and 15,000 particles per cubic centimetre on different occasions.

The greatest source of dust was the dry rotary drills and on this occasion the problem was partially overcome by the use of a cup-shaped hood that fitted over the hole—the drill passing through a hole in the top. The dust blown out of the hole is trapped by the hood and exhausted from the cup-shaped cavity by a powerful exhaust system. This method was effective but somewhat cumbersome, and has been largely superseded by the use of axial feed water drills. Among the recommendations arising from this work were the following points:—

(1) Face masks are not satisfactory for this class of work.
(2) Adequate ventilation is necessary for tunnel work.
(3) Workmen using percussion equipment, and others engaged in removing spoil, etc., should be so spaced that maximum advantage is taken of natural ventilation and dust dispersion.

Dust Standards

In dealing with permissible standards of dust concentration (2, 4) it must be remembered that knowledge of dust diseases is still incomplete and any standards adopted should be regarded as tentative. The achievement of a certain standard must not be considered as a solution to the problem, but the aim should be to reduce the dust concentration to the lowest figure possible. With the design and introduction of more efficient devices for eliminating dust it should be possible to adopt progressively lowering standards until the air being breathed by the workmen employed in excavations is comparable with that encountered in other classes of work that are free from the silicosis hazard.

The Arbitrator was of the opinion that if the dust concentration in the air was injurious to the health of the men, then it was of little value to reduce the daily hours of labour as the only effect of this would be to postpone the incidence of silicosis. His opinion, which was endorsed by all attending the discussions, was that the correct approach to the problem was to stipulate that conditions should be such that there was no silicosis hazard. The achievement of these conditions was the responsibility of the engineering staff and work should cease if the dust concentration rose above standard.

The standards suggested by the Arbitrator were dependent on the class of rock being worked. Three main classes were involved, and these were as follows:—

(a) Sandstone, indurated shale, conglomerate, quartz, quartzite, cherts and any other rock containing more than 50% of free silica.
(b) Granite, porphyry, gneiss, schist, slate and any other rock containing 50% or more of silica (as opposed to free silica) and more than 20% of free silica.
(c) Rocks containing less than 50% of silica and less than 20% of free silica.

Two standards of dust concentration were adopted and some doubt existed as to whether rocks in class (b) should be associated with class (a) or class (c). Pending further investigations class (b) was grouped with class (a).

The maximum permissible dust concentration for working in rocks in classes (a) and (b) was a count of 200 particles of dust, not smoke, less than 10 microns in size per cubic centimetre of air measured, using the Owen Jet Dust Counter or other satisfactory dust counter, and for rocks in class (c) a count of 400 particles of dust, not smoke, less than 10 microns in size, per cubic centimetre of air. It is important to associate the instrument used for the measurements with the maximum permissible dust concentration, as these limits are related to the pre-determined efficiency of the instrument specified. Where these standards are exceeded then it might be provided that work should cease until the atmosphere was cleared, the employees being paid while standing by.

The standards outlined in the foregoing are those adopted by Mr. Justice Ferguson, and are based on a great deal of work that has been done in the N.S.W. Department of Public Health, Industrial Hygiene Division, during the past 20-30 years. In 1924 a standard of 200 particles per cubic centimetre of not more than 10 microns diameter was adopted for the Sydney sandstone industries and subsequent experience has shown that this standard can easily be bettered in all well-ventilated tunnel working and that no engineering difficulties are encountered in achieving the standard. A micron is 1×10^{-4}cm.

The standard of 200 particles per cubic centimetre is in substantial agreement with that adopted in U.S.A. and Canada, namely, 5×10^6 particles per cubic foot, for work in rocks containing more than 50 per cent. of free silica. The American standard is based on measurements made with instruments of the Greenburg-Smith impinger type and the figure of 5×10^6 particles per cubic foot is equivalent to a count of 175 particles per cubic centimetre obtained with the Owen Jet Dust Counter.

For an air-borne dust to be injurious, the particle size must be such that the dust, when inhaled, is trapped within the pulmonary bronchioles and alveoli so that the processes leading to dust fibrosis can be initiated. It is believed that only particles smaller than 10 microns in diameter are retained in the lungs, larger particles being caught in the respiratory tract and removed by physiological mechanisms. Examination of the lungs of silicosis victims has shown that the most dangerous particles are those ranging in size from 5 to 0.3 microns, and that particles greater than 10 microns are found very rarely. In other words, the greatest hazards are associated with the very minute particles, and experience has shown that a concentration of over 400 such particles per cubic centimetre, as determined by the Owen Jet Dust Counter, is necessary before the dust can be perceived as a cloud in the dimly illuminated conditions in a tunnel.

As mentioned earlier the particles that give rise to silicosis are free silica particles, i.e., particles having the composition SiO_2. Combined silica might also be present as a silicate, but this does not present a severe hazard. The rocks in classes (a) and (b) represent those containing a higher percentage of free silica, and these can be expected to give rise to a dust consisting chiefly of free silica. The rocks in class (c) contain a lower percentage of free silica and a dust cloud arising from them can be expected to contain other materials in addition to silica. For this reason a higher count of dust particles is permissible.

Method of Determining Dust Concentration

There are a number of different instruments which can be used to measure dust concentration (2, 10). Of these, the best known and most commonly employed are the Greenburg-Smith impinger and variations, the Owen Jet Dust Counter, konimeters of various types, and the thermal precipitator. In the Greenburg-Smith impinger and similar instruments, the air under test is drawn through a glass tube and allowed to impinge at high velocity on a glass plate immersed in water. The dust is retained in the water and counts are made of the dust in the collecting water.

The Owen Jet Dust Counter (which is described in greater detail later) can be more correctly described as a nuclei counter, as the operation depends on the dust particles forming the nuclei for the condensation of water vapour to droplets. The water droplets are impinged on a glass plate where they adhere. The water evaporates and leaves the dust adhering to the plate. The dust sample is then counted using a high power microscope.

The principle of operation of the various types of konimeter depends on the dust being precipitated by being impinged at high velocity on a sticky glass plate. The adherent dust particles are then counted, using a microscope. The thermal precipitator is an instrument in which the dust-laden air moves slowly past two heated wires and is deprived of the dust, which is precipitated on glass plates by thermal repulsion where it forms a deposit of suitable intensity for microscopic counting with high power.

None of these instruments is 100 per cent. efficient, i.e., they measure only a percentage of the total dust, and, because of the different principles on which they depend, the efficiency of the various types varies somewhat. For example, the overall efficiency of the Owen Jet Dust Counter is about 40 per cent., the efficiency for particles in the range 1.5 to 5 microns being less than 25 per cent., and for particles below this size range it increases rapidly, being 100 per cent. for particles about 0.2 microns in size. Thermal precipitators can have an efficiency of the order of 90 per cent., konimeters 30-60 per cent., and Greenburg-Smith impingers about 40 per cent.

The two instruments best suited to the routine field measurements envisaged in the Department are the Owen Jet Dust Counter and the konimeter. Of these the Owen Jet Dust Counter has been adopted by most authorities in Australia for routine dust measurement. The efficiency is constant to within a few per cent. and the instrument is simple and convenient to use. The konimeter is probably more convenient than the Owen Counter, but has the disadvantage that the efficiency varies widely in the same instrument, and careful observers may get widely different results in testing the same dust conditions.

Method of Operation of the Owen Jet Dust Counter

The general appearance of the Owen Jet Dust Counter can be seen from Figs. 1 and 2, and the internal construction is illustrated diagrammatically in Fig. 3. The apparatus consists of a brass

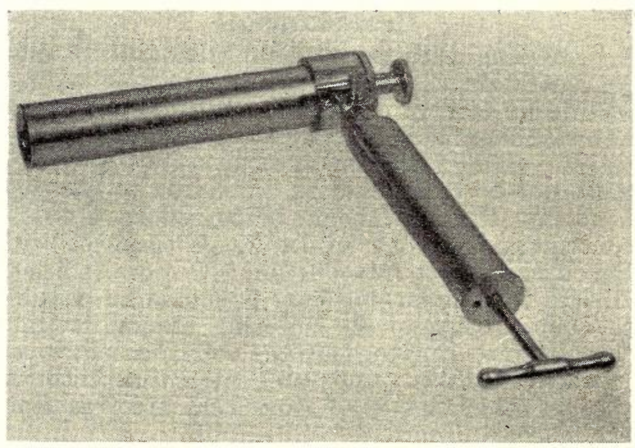

Fig. 1.—Owen Jet Dust Counter.

sleeve B open at the top and bottom and screwed internally for the reception of a piece K, which is perforated by a central hole for admitting the air to a narrow slot A, formed diametrically across the hole by means of two semi-circular metallic plates held in position by a ring R attached to plug K. Into the upper opening of the sleeve B fits a screwed plug C, which is provided with an attachment which carries a plate O into which a microscope cover glass is fitted. The position of the cover glass relative to the slot A can be varied by rotating the external head J.

Inside the sleeve B, and surrounding the cover glass, is an annular recess which communicates

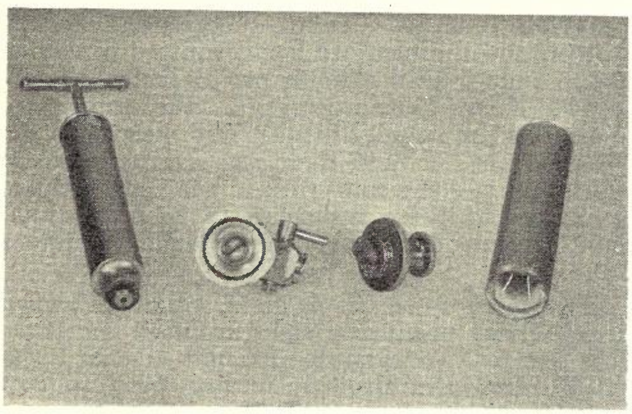

Fig. 2.—Owen Jet Dust Counter, showing component parts.

with a connection E for attachment to the 50 cubic centimetre pump. The damping chamber T screws into plug B, and is lined with blotting paper which is wetted before the instrument is used. By means of the cock the slit can be bypassed while air is being drawn into the damping chamber.

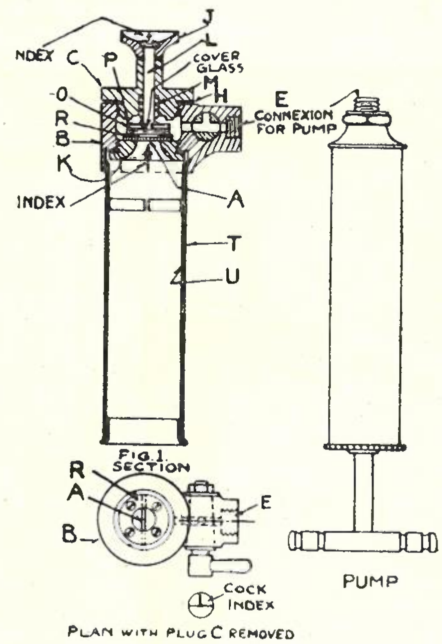

Fig. 3.—Owen Jet Dust Counter—Diagrammatic.

To operate the unit the blotting paper is first moistened with water, and with the cock in the bypass position a sample of the air to be tested is drawn into the damping chamber and allowed to remain for 10-15 seconds to saturate with moisture. A volume of air, measured by the number of strokes of the 50 cubic centimetre pump, is then drawn through the slot. The adiabatic expansion thus produced results in a fall in temperature of the air and moisture condenses on the dust particles. The moisture droplets and dust impinge on the microscope cover glass, which is held about 1mm. to the rear of the slot, where the moisture immediately evaporates leaving the dust deposit, which appears as a fine ribbon having approximately the same shape and dimensions as the slot.

The cover glasses are then mounted on 3″ x 1″ microscope slides and the number of dust particles in the deposit is counted, using a high power microscope. As particles down to at least 0.3 microns in diameter are dangerous, it is necessary that the microscope resolving power be as good as possible. The theoretical limit of resolving power for an optical microscope is of the order of 0.2-0.3 microns, and consequently the highest quality optical equipment is necessary. An oil immersion objective is essential, and a binocular eyepiece is very desirable if large numbers of samples are to be counted. A calibrated graticule in the eyepiece is used to determine the size of the particles being counted, although, in practice, the number of particles larger than 10 microns in diameter is negligible.

It is, of course, not practicable to count all the particles in a deposit and the method adopted is to count the number of particles in a known fraction of the area of the specimen. The area counted consists of four strips of known width extending right across the ribbon and equally spaced along the length of the ribbon. In this way a reasonable estimate of the number of particles in the ribbon is obtained and from this the dust count per cubic centimetre can be calculated.

The chief weakness of the Owen Jet Dust Counter is that it takes a grab sample, and the count obtained is a measure only of the conditions at the moment of taking the test. This objection is not so serious in the case of a tunnel, as the conditions are independent of external influences such as wind gusts, etc., and are dependent only on the type of operation being performed and the ventilation system. Dust conditions can be expected to be reasonably steady over long periods, and by adopting a system of measurement whereby samples are taken at fixed time intervals—say every two or three minutes for a period of half an hour—the average of the counts obtained can be taken as an accurate indication of the amount of dust present.

With a surface excavation such as a deep trench or a manhole, the dust conditions are greatly influenced by the wind speed and direction, and because of the rapid changes that are produced by gusts, a grab sample is not necessarily a true indication of the amount of dust present. In order to completely overcome variable conditions, some form of continuous sampling device would be necessary. Such devices, however, require more elaborate field equipment and are not altogether suited to routine measurements. In the investigations which have been carried out, and which are discussed later in this report, the problem has been overcome, to a certain extent, by adopting the system mentioned above, viz., by taking samples every two minutes regardless of the operation in progress in the excavation and by taking not less than eight samples and preferably more. Although this method cannot be said to give a precise indication of the dust present, it is felt that the average value obtained is a reasonable indication of conditions. In this connection, the value of obtaining a precise value of concentration during any one period, of say, half a day, is somewhat reduced by the fact that the wind conditions might be entirely different on the following day. Because of the impossibility of reproducing conditions it is felt that the figures obtained using the Owen Jet Dust Counter, as described above, are as valuable as those that would be obtained by a more precise method.

The aim, of course, in determining dust conditions at a location using the Owen Jet Dust Counter must be to take as many samples as possible at as short an interval as possible, and to adhere strictly to the time interval, provided that there are no exceptional circumstances causing abnormal interruption of work. The limiting factor on the number of samples taken is the time required to carry out the counting of the specimens. The maximum number of slides that can be counted per day is in the range 25-35, depending on the density of dust deposit. In spite of the length of time involved, it is felt that not less than eight samples, and preferably more, should be taken at any one location.

Methods of Dust Control Adopted by Other Authorities

Discussions were held with the N.S.W. Railways Department and the Metropolitan Water Sewerage and Drainage Board in Sydney. Both of these authorities have had considerable experience in tunnelling in sandstone and the methods adopted are of some interest. It is the practice for both authorities to carry out regular dust measurements, using the Owen Jet Dust Counter, at each working face in tunnels and during each operation at the face. The dust counts obtained are recorded and scrutinised by the responsible officers in the authority concerned and copies are also submitted to the appropriate Union and to the Department of Health. The counts obtained are always available on the morning following the taking of the samples. It is the practice to have the counts checked periodically by the Department of Health.

The methods adopted to control the dust are by the use of axial feed wet rock drills and by forced exhaust ventilating systems. The inlet to the exhaust pipe line is always carried as near to the working face as is possible. This distance is limited by the risk of damage by blasting operations. Full face working is adopted in preference to small cross-section drives wherever possible. Axial feed rock drills have a hole along the axis of the drill through which water is fed right to the cutting rose on the drill. This water has the effect of clearing the spoil from the drill hole as a slurry, and also of preventing dust from rising during the drilling operation. Blasting is the operation which gives rise to the greatest amount of dust, and the men are not permitted to return to the tunnel until after a period which experience has shown to be necessary for the atmosphere to clear to the standard value. Dry rock drills are not used and, in fact, their use is prohibited by legislation in some countries. It has been possible by means of these measures to keep the dust count at considerably below the standard value of 200.

In cleaning down the walls of a tunnel (known as scabbling) pneumatic picks are used and these give rise to a considerable amount of dust. The N.S.W. Railways Department has been experimenting with a fine water spray welded to the body of the pick and directed so that the area surrounding the point of the pick is kept drenched with water. This has given a substantial improvement.

In coal mines the same methods are adopted to control coal dust and, in addition, small hand-picks which have built-in water attachments are now available (see Fig. 4). In the type illustrated the

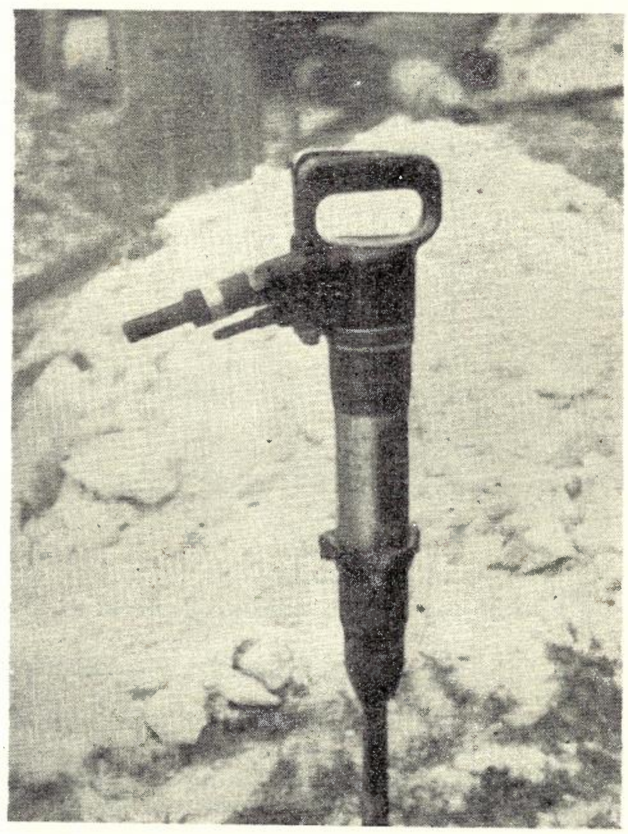

Fig. 4.—Coal Pick with built-in Water Sprays.

water supply is controlled by a valve which is operated by the same lever as the air valve. The water emerges as a spray from three nozzles on the bottom of the pick barrel. The unit is rather light for rock working, but indicates that manufacturers of rock breaking equipment are becoming more conscious of the dust problem and it should be possible to obtain heavier pneumatic picks with built-in water sprays.

Another type of machine, known as the "Rock Burster," is available and would probably be adaptable to trench excavations. The "Burster" is inserted into a hole bored with an axial feed rock drill and exerts a steady lateral pressure on the side of the hole. Provided a suitable face is available, large quantities of rock can be broken away without giving rise to very much dust.

Dust Investigations Carried Out in Departmental Excavations in Sydney Metropolitan Area

General.—In co-operation with officers of the Central Office Lines Section and the N.S.W. Lines Section, a series of tests have been carried out in excavations in sandstone in the Sydney Metropolitan Area. The control and measurement of dust in departmental excavations is complicated by several factors.

(1) The workings are usually comparatively small and numerous, and from the point of view of plant economy the installation of expensive exhaust equipment is to be avoided wherever possible.

(2) Workings are usually in built-up areas and blasting is usually not possible because of the danger to persons and property.

(3) In general, open excavations are made and because of variable wind conditions caution must be exercised in carrying out and interpreting dust counts.

The impossibility of carrying out blasting operations means that all rock breaking is done either with rock drills and wedges or with pneumatic picks or pavement breakers. Because of the nature of a pick and the necessity for frequent re-sharpening of the tool, it is not possible to use an axial water feed, and, in any case, this would be of little value because of the fact that a pick can cause rock to fracture over an area extending from the point of the pick, and if dust is to be prevented then the whole of this surface must be quickly wetted. For this reason, spray attachments must be so designed that the water wets an area extending radially approximately six inches around the point of the pick.

Preliminary Survey.—In September, a visit was made to Sydney to carry out a preliminary survey of dust conditions. Sydney was chosen for this survey because of the large amount of work which is being carried out in sandstone in that area. The reason for the preliminary survey was to ascertain whether the dust problem really existed in open excavations. As far as was known, no other authorities took steps to control dust in open excavations, and it was felt that because of the freedom of air movement the dust conditions might never exceed a count of 200.

A limited series of tests was carried out in several excavations in solid sandstone, and, although the measurements were not carried out strictly as described in the foregoing, the results obtained were sufficient to indicate that dust conditions often did exceed the permissible standard and that further measurements and experiments to reduce dust were necessary. These measurements indicated that in a small excavation, such as an opening in a road between tram lines, the dust count might be as high as 800 and in an open trench the count could be of the order of 200-400. The practice of splashing water from a bucket on to the rock caused a slight reduction in count, but the method is too haphazard to be really effective. As a result of this survey it was decided to carry out a further series of measurements under more rigorous conditions, in which the effect of various preventive devices could be ascertained.

Tests Using Dust Preventive Devices.—The most promising methods of preventing dust appeared to be the use of water sprays and exhaust systems. In order to determine the effective-

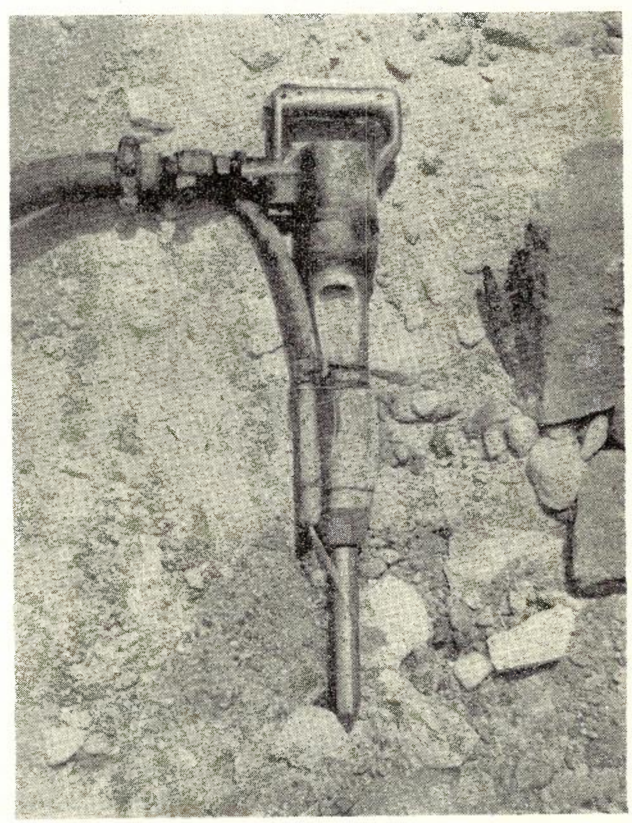

Fig. 5.—Pneumatic Pick with improvised spray attachment.

ness of these two methods, it was desirable to reduce the effects of external variations as much as possible, and for this reason the bulk of the measurements carried out were done in the one excavation. In addition, in order to obtain as wide a picture as possible in the limited time available a number of other tests were carried out in other locations. The results of some of these tests, together with other relevant data, are listed in tables 1 and 2.

a manner that the rate and direction can be controlled and the spray covers the desired area around the pick point. Two or three spray nozzles directed at the pick point from different sides would probably be an advantage, as this would ensure more efficient wetting of all fresh rock surfaces with a minimum of delay.

The exhaust system used in these tests was a truck-mounted unit driven by a small petrol engine. The capacity of the fan, measured without conduits attached, is in excess of 3000 cubic feet per minute, but the resistance to the air flow introduced by the bends and joints in the conduit reduces this considerably. Best results are obtained with large diameter conduits and smooth bends of large radius. Several photographs illustrating the tests are shown in Figs. 6, 7 and 8.

Table 1.

Tests carried out in manhole excavation in solid sandstone in Bickle Road, Mosman
Excavation approximately 4′ x 8′ x 4′ deep

Test Series No.	Date	Spray	Wind (M.p.h.)	Position of test	Dust count
1	7/11/49	Nil	1-2 with gusts	Head of pick operator	115
2	7/11/49	1 pint/min.	1-2 with gusts	,,	30
3	8/11/49	Nil	5-7	,,	212
4	8/11/49	0.25 pint/min.	5-7	,,	70
5	8/11/49	3 pints/min.	5-7	,,	30
6	9/11/49	Nil	1-2 with gusts	,,	86
7	9/11/49	0.75 pint/min.	1-2 with gusts	,,	33
8	9/11/49	1 pint/min.	1-2 with gusts	,,	25
9	10/11/49	Nil	5-10	Head of boodler (Note 2)	150
10	10/11/49	0.75 pint/min.	5-10	,,	44

Note 1.—The tests bracketed represent series of tests carried out consecutively with an interval of not more than a few minutes between the end of one series and the commencement of the next.
Note 2.—Boodler is term given to man clearing spoil with shovel.

Table 2.

Tests carried out in tunnel under concrete road at Bickle Road, Mosman.
Tunnel 4′ high x 3′ wide, and about 10′ under the road. Formation in tunnel consists of about 2′ of solid sandstone and 2′ of road filling. All measurements were made when operations were being carried out in the solid sandstone. The experiments were intended to test the efficiency of the exhaust unit in reducing the dust.

Test No.	Date	Spray	Ventilation	Dust Count	Remarks
1	6/12/49	Nil	Nil	4,600	
2	6/12/49	1 pint/min.	Nil	1,350	
3	7/12/49	Nil	Nil	8,000	
4	7/12/49	1 pint/min.	Nil	340	Inlet to fan 4′ from face and on bottom of tunnel.
5	7/12/49	1 pint/min.	Exhaust at rate of 1450 cub. ft./min.	212	
6	8/12/49	Nil	Nil	6,000	
7	8/12/49	Nil	Exhaust at rate of 1500 cub. ft./min.	1,050	Inlet to fan 4′ from face and 2′ above bottom of tunnel.
8	8/12/49	1 pint/min.	Exhaust at rate of 1500 cub. ft./min.	280	

Note 1.—The tests bracketed represent series of tests carried out consecutively with an interval of not more than a few minutes between the end of one series and the commencement of the next.

The water sprays consisted of simple spray units which directed a spray of water on to and around the pick point. A pick with a spray attachment is illustrated in Fig. 5. It is probable that any type of spray would be equally effective provided that it can be attached to the pick in such

Results Obtained

In the course of the tests 43 series of samples were obtained on various occasions in sandstone and shale excavations and tunnels in the Sydney metropolitan area. These represented about 450 individual dust samples. It is unnecessary to tabulate the complete details of these measurements, but as a matter of interest Tables 1 and 2 are tabulations of a number of the measurements which were made in a manhole excavation and an under-street crossing in Bickle Road, Mosman, N.S.W. Work at this site was in solid sandstone and was carried out by one pneumatic pick operator and one boodler or shoveller.

Fig. 6.—Dust sample being taken at manhole excavation, Bickle Road, Mosman, N.S.W.

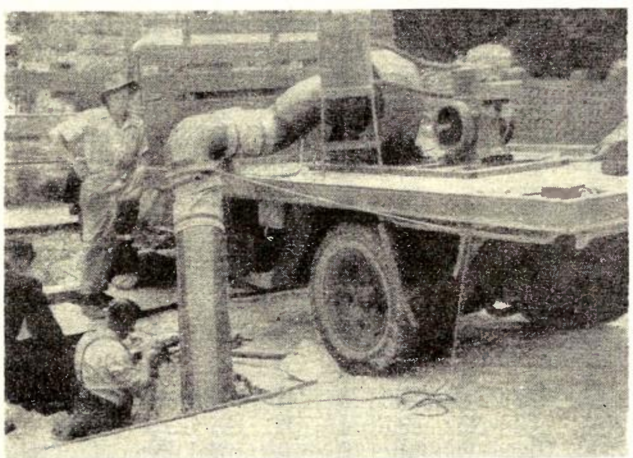

Fig. 7.—View of Truck-mounted Exhaust Unit working at Under Street Crossing.

The results in Table 1 illustrate that, in general, in open excavations the use of a fine spray of water directed on to the area of rock around the end of the pick will reduce the dust count to about one-third of that under dry conditions. Experience at this test site and also at other open excavations which were tested, indicates that under average conditions the use of water sprays will reduce the dust count to considerably less than the maximum allowable value of 200.

The measurements given in Table 2 show that a very serious dust hazard exists in under-street crossings and similar tunnels in sandstone and that the combined effects of water sprays and a forced ventilation system were necessary to reduce the dust count to near the standard value. Even then the dust count was in excess of 200, and it appears that the preventive measures taken at the time of these tests were not sufficiently effective. It is probable that a higher capacity exhaust system or, alternatively, the provision of a supply of fresh air at the working face by a blower system rather than an exhaust system would provide a solution to the problem.

Fig. 8.—View showing Exhaust Unit working in open excavation.

An interesting effect was observed in an open trench, about 3 feet deep, in Argyle Place, North Sydney, where there was a strong wind blowing along the trench. Three parties were working in the trench with about 30-40 feet between each party. The rock being worked was solid, fine-grained, white sandstone. In almost all cases mentioned the dust count obtained at the party on the windward side was less than 120, whereas at the second and third parties the count was much higher, varying on different occasions between about 200 and 600. The location of this job was peculiar in that there was always a fairly strong wind along the trench. In a case such as this it might be necessary to increase the distance between parties or use deflecting screens to shield downwind parties from dust created by those on the windward side.

Use of Dust Masks

In this investigation the use of masks has not been considered. The work performed by men in excavations is arduous, and to a certain extent uncomfortable, and the use of masks would add considerably to the discomfort, in addition to reducing the efficiency of employees. As soon as the visible dust cloud has disappeared workmen will remove their masks, although experience has shown that the dust count might still be as high as several times the permissible value. It is felt that the achievement of conditions of the required standard presents no insurmountable engineering difficulties, and that men should not be asked to wear masks except perhaps in very exceptional circumstances.

It might be mentioned in passing that at the International Dust Conference in Sydney a new type of dust mask, invented in Denmark, was described. In this mask the mouth, nose and eyes are uncovered and the protection comes from a veil of fresh air which is blown down in front of the face from a slit in a brim or an eyeshade in front of the forehead of the operator. The device is attached to the head and compressed air is brought to the unit by a tube. The veil of fresh air in front of the face prevents dust particles from reaching the face and the workman inhales pure air from external sources. The effectiveness of the unit is said to be very high, but as far as is known it has not been tried in excavation work nor is the unit available from commercial sources in Australia.

Dust from Rocks Containing Low Percentages of Free Silica

Up to date all measurements have been made in excavations in Sydney sandstone, which contains 60-90 per cent. free silica. Other types of rock, such as basalt, granite, etc., which contain comparatively low percentages of free silica, are encountered in some capital cities, and because of their hard nature are likely to give rise to considerable quantities of dust. In Melbourne quantities of basalt are encountered in the western suburbs, and it is the practice to drill and blast wherever possible. The dust concentration may be considerable, especially when dry drills are used. The hazard associated with this dust has been disregarded because of the negligible free silica content of the basalt. However, several of the experts attending the conference at Sydney have expressed the opinion that any dust, no matter how innocuous in small concentrations, will, in large enough quantity, eventually overwhelm the defences of the lungs and accumulate in such amounts as to impair their function (11). It is not a difficult engineering problem to control the dust, and the workmen can reasonably expect that all measures will be taken to make their working conditions as safe as possible. Investigations are now being carried out on excavations in and around Melbourne, and if it is found to be necessary dust preventive measures will be adopted.

Conclusion

The investigations have shown that the dust conditions in open excavations in sandstone are often below standard, and that a silicosis hazard exists. The Department has a responsibility to its staff to ensure that the conditions are such that the health hazard is eliminated. By making the use of water sprays on pneumatic picks compulsory in such excavations it is probable that satisfactory conditions will be achieved, but routine checks must be carried out as it may be necessary to adopt special precautions in unfavourable locations.

It may be that, after further measurements extending over a lengthy period and covering all types of excavations and rocks, sufficient experience will be gained to enable an estimate of likely dust conditions to be made as soon as the type of strata has been ascertained. It may be possible, in some cases, to dispense with the sprays but this should be done only after full investigation.

In tunnels in sandstone the dust conditions with dry working are exceedingly bad and water sprays and forced ventilation must be employed and a close check on conditions must be kept.

In the experiments described in the foregoing the water sprays have been improvised attachments which are wired on to the bodies of the picks. The Department is now arranging for the purchase of pneumatic percussion-type tools with built-in water spray facilities, as well as external water spray attachments for fitting to the heavier types of dry pneumatic picks, and with properly designed units the efficiency of the sprays will probably be increased.

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RECENT DEVELOPMENTS IN METAL RECTIFIERS FOR TELECOMMUNICATION PURPOSES

*D. Ashby, B.Sc.(Eng.), M.I.E.E., A.M.I.Mech.E.**

During the two years following the manufacture of the first copper-oxide rectifier in England in 1925, the possible markets other than in the realm of railway signalling were investigated and an exhibition was arranged at which rectifiers for many commercial applications were demonstrated. This introduction to the public by an entirely novel method of AC/DC conversion, having such overwhelming advantages over the then existing alternatives, resulted in a rapid expansion. Within six more years copper-oxide rectifiers had been constructed giving outputs ranging from 12,000 amps. at 5 volts for electroplating, to 400,000 volts at 10 mA for X-ray work.

A selenium rectifier from Germany appeared in the early 1930's, which had many potential advantages over the copper-oxide rectifier, but some examples proved to be unreliable. This new rectifier operated at 2 to 3 times the voltage per element possible with copper-oxide, and could be run at a higher temperature, so was considerably smaller. The reverse resistance in some examples fell to a very low value if the rectifier were not used for several weeks, while considerable variations in the forward resistance were noted between individual elements.

With a view to overcoming these two deficiencies, research was started by the Westinghouse Brake and Signal Co. Ltd. in London, which resulted in the production in 1939 of an improved selenium-compound rectifier for which the trade name "Westalite" was registered. Not only were the problems of shelf life and consistent forward resistance overcome, but the rectifier was more efficient than others.

During the war, further developments of the greatest importance led to the introduction of a selenium rectifier capable of operating at double the normal voltage stress, hence the number of elements in series for a given input voltage was halved. As the forward resistance of each element was increased only by 10% or so, overall efficiency was increased and a reduction in size and weight resulted. This double-voltage Westalite rectifier, together with the original type, which is preferable for low-voltage circuits, are shortly to be manufactured in Australia and have been assembled from elements imported from England for some years (See Fig. 1).

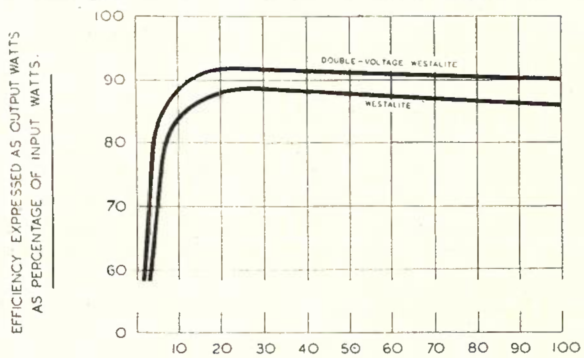

Fig. 1.—Efficiency of single and double voltage Westalite rectifiers operating at optimum voltage.

Voltage-Current Characteristics

Both the copper-oxide and the various types of selenium rectifier exhibit the same non-linearity in the shape of the forward characteristic, as illustrated in Fig 2, the resistance of the copper-oxide element being lower than that of the selenium equivalent. There is a substantial difference in the reverse characteristics, influenced by there being a tendency for the leakage current to increase with time in the case of copper-oxide and to drop with time in the case of selenium. This phenomenon of "creep," as it is called, stabilises within a few minutes with copper-oxide and a matter of seconds with selenium.

It will be seen that as there is a distinct "knee" in the reverse characteristic of the selenium

*Rectifier Engineer, Westinghouse Brake & Signal Co. Ltd., London.

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rectifier, which is actually a scaled-up reproduction of the forward characteristic, that it is safe to operate the rectifier almost up to the point where the leakage current increases rapidly—as the twelfth power of the applied voltage. In the case of the single-voltage Westalite rectifier the

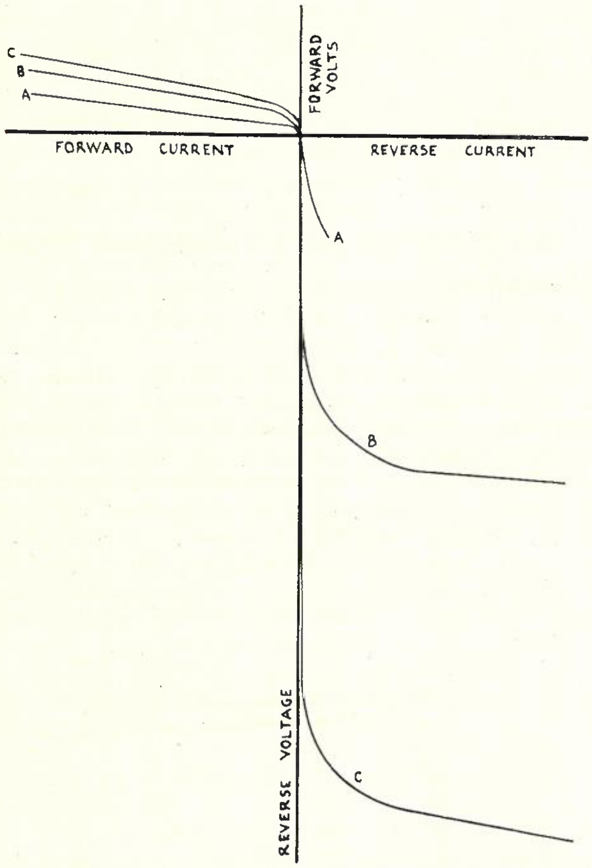


Fig. 2.—Voltage-current characteristics of Copper Oxide and Selenium Rectifiers.
A—Copper Oxide.
B—Selenium, Single Voltage.
C—Selenium, Double Voltage.

knee corresponds to about 35 volts per element, but the working voltage is normally restricted to 26 volts peak reverse, which allows something in hand for variations in the A.C. supply pressure. Choke-ballasted battery chargers may be operated at a higher peak voltage, applicable only if the battery is disconnected as the choke prevents the rapid rise of leakage current which would otherwise take place towards the peak of the wave. In D.C. circuits the reverse voltage should be restricted to 15 for all sizes of single-voltage type Westalite rectifier, regardless of the ambient temperature. The corresponding figures for the double-voltage Westalite rectifier are 42 volts peak working in A.C. circuits, and 25 volts in D.C. circuits. Comparison with the more gradual increase in current with voltage applied to the copper-oxide rectifier shows that it must be worked at a substantially lower voltage—about 4.5 volts D.C. being a maximum.

An examination of these characteristics will show that caution must be exercised when replacing a copper-oxide rectifier by what is apparently the equivalent selenium type, particularly in D.C. circuits. Although the selenium rectifier selected may be suitable for withstanding the steady reverse stress and passing the forward current, usually with a lower voltage drop, the leakage current through the selenium rectifier under surge conditions produced by a relay being switched out of circuit, may rise to such a value that a relay blocked by the selenium rectifier may operate falsely.

Recent Developments as Surge Arrester

The use of the asymmetrical property of a rectifier to absorb the inductive energy from a relay across which the rectifier is connected is well-known, and the slugging action produced by the low resistance circuits provided by the forward resistance of the rectifier is often a serious disadvantage. This problem has been studied by the Westinghouse Brake and Signal Co. Ltd. in England, and improvements have been made which reduce the slugging action and the size of the rectifier, thereby cheapening it.

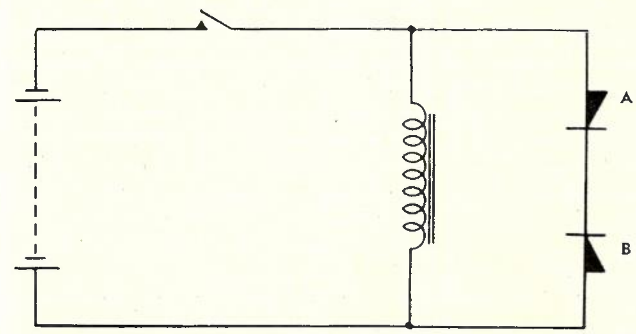


Fig. 3.—Surge Arrester Circuit based on reverse characteristic of Selenium Rectifier.

The first development makes use of the reverse characteristic of the selenium rectifier, which is built up with discs arranged in pairs, in opposition. Two double-voltage Westalite elements A, $\frac{5}{8}''$ dia., mounted on a No. 4 BA bolt, are used to withstand the nominal 50-volt battery voltage applied to a uniselector, shown in Fig. 3, while another pair B are connected in series opposition. The rectifiers A normally withstand the battery voltage, when the switch is opened the voltage across the relay winding rises until the reverse resistance of the rectifiers B becomes very low, at about 80 volts, when the energy is transferred to the rectifier as heat. It is clear that the rectifier assembly must be capable of dissipating the energy absorbed from the relay, which depends on the frequency of switching and the following rest period. The performance of the rectifier has been most promising, and it is thought that it will be cheaper than alternative methods, such as non-linear materials and condensers.

A better method, applicable only where there is a positive battery, is shown in Fig. 4, wherein the energy in the relay is employed to charge the positive battery. The rectifier, while having to withstand the voltage of the two batteries in series, may use smaller elements, because it does not have to absorb the energy in the relay, but only the heat produced by the passage of the surge current through its forward resistance.

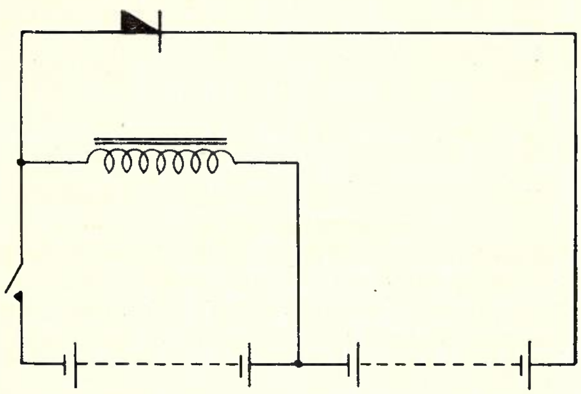


Fig. 4.—Surge Arrester Circuit in which the energy is transferred to charging the positive battery.

If there is no positive battery, the polarity of the inductive surge may be reversed by adding a secondary winding to the relay when the surge may be used to charge the battery normally supplying power to the relay, again the rectifier is small as it handles only the charge current.

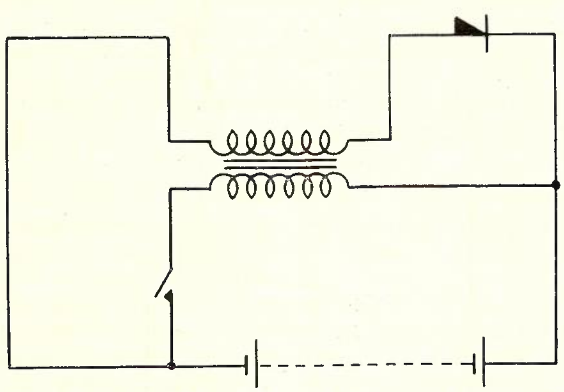


Fig. 5.—Surge Arrester Circuit in which the energy is transferred to charge the battery by means of a secondary winding on the relay.

Applications to Telephone and Telegraph Power Plant

A very large rectifier installation is now being built in London for handling the filament and anode current for repeaters; the rectifiers now installed supply 12,000 amps. at 24 volts nominal, while the ultimate demand is expected to be 16,000 amps. for floating, with a further 8,000 amperes for charging. Forced oil-cooled, double-voltage Westalite rectifiers are employed, giving an overall efficiency from the power supply to the float bars of over 75%. To simplify smoothing, the three phases of the incoming supply have been balanced to within ± 1 volt in 400. This permits the use of a 12-phase rectifier, which has a small ripple component which can be effectively filtered by chokes and condensers, employing the orthodox T filter with a capacity of 160,000 mF per 4,000 ampere rectifier. The layout of the connections to the condensers has been carefully studied with a view to minimising inductance.

Moving-coil voltage regulators are connected between the balanced supply and the main transformer of each rectifier, which may be used either for floating or charging. A current balance circuit has been developed to ensure that the load is evenly shared between the rectifiers connected in parallel. Each 24-volt battery consists of sixteen 5,000 A.H. pasted plate lead cells in parallel and is being floated at about 2.10 volts per cell. Close control of the rectifier voltage is necessary to ensure a healthy charged battery and to limit changes in current due to variations in the A.C. supply pressure.

Air-cooled rectifiers are being considered for 50-volt exchanges with currents up to 2,000 amperes; a 250 and 500 ampere unit will probably be adopted, thereby allowing flexibility and ease of installation. A 1500 ampere equipment under construction is controlled by a contact voltmeter which actuates, through a chain of relays, a motor-driven regulator in which contact with the desired secondary turn of an auto-transformer is made by a carbon wheel rolling over the coil surface from which the insulation has been removed. These regulators have been operating in England for 12 years and have given trouble-free service; the transformer and its contact is oil-immersed, so no lubrication is necessary and the contact wheel is well-cooled. These regulators are now made to carry line currents of 300 amperes at 400 volts 3-phase, and thus can be used for operating the largest rectifiers.

Development work is well-advanced on a system of control which is particularly suited for rectifiers for exchange operation, from the smaller sizes upwards. Saturable reactors will be used for the control of the voltage level, which will be referred to a permanent magnet as a standard of reference in a novel manner. The voltage at which the battery floats may be adjusted by means of a potentiometer knob and provision will be made for change-over to manual control for recharge purposes, for which another control knob will be provided.

Largest Economic Size of Selenium Rectifier

The selenium rectifier element produces individually a relatively low-power output, so a number of elements are generally employed in each installation to build up to the desired circuit, while the voltage and current required may necessitate the use of more than one element in series, or in parallel. The cost per kW is, therefore, substantially constant, but is affected by the cost of the connections or of insulators when heavy currents or high voltages are involved. With other forms of power converter, such as the motor generator and the mercury-arc rectifier, the cost per kW tends to fall with increasing output because the components are produced to some extent in larger sizes rather than employing a multiplicity of smaller components. The efficiency of a rectifier, on the other hand, benefits by the use of a multiplicity of elements, because high efficiency is possible at low output voltages where one element alone is sufficient to withstand the voltage stress. This advantage is not enjoyed by the mercury-arc rectifier, which has a constant voltage drop around 15-20 volts, so is inefficient at low output voltages.

At voltages of up to 20 or so, there is no practical limit to the output obtainable from a rectifier which will have a better efficiency than a motor generator, while dispensing with the cost of brush replacements and commutator maintenance. A 50,000 ampere plant is in operation, while a 32-volt 24,000 ampere Westalite rectifier is being installed. Thus, the rectifier stands supreme for the power supply for electroplating where the voltage required is usually about 7 volts, for which overall efficiencies of 80% are expected.

The demand for heavy currents for voltages above those encountered in electrodeposition is restricted to the application to telephone exchanges, which has already been referred to, and to electrolytic processes where the installation comprises a number of cells connected in series. Up to 64 volts D.C. obtainable from two double-voltage Westalite elements in series, the rectifier can still compete with the machine. A 3000 ampere plant is in use for hydrogen production, while a 12,000 ampere plant is under construction. Thereafter the motor generator is often the cheaper alternative for outputs of 50 kW and over, while the mercury-arc rectifier comes into the picture at voltages of 200 and higher. The selenium rectifier has a temporary advantage at voltages around 400-500, where a small auto-transformer may be used to adjust the three-phase power supply voltage to that required to give the necessary D.C. voltage, while the transformer for the mercury-arc rectifier must, of necessity, be more elaborate and expensive.

There is the important application of anode power supplies for transmitters where the selenium rectifier is being increasingly employed, and a 9,000-volt 1.3 ampere installation for this purpose has recently been built for the British Post Office. However, it is for 24-hour continuous duty, day after day, in the realm of electrostatic precipitation that the advantages of the rectifier over the valve are so very prominent, handling a voltage of 30 to 60 kV at a low current, but with frequent short circuits, for which the selenium rectifier is well suited. Higher voltages are used for surge generators for impulse testing of insulators, for which a 210 kV selenium rectifier is now under construction.

Intermittent Duty

While a selenium rectifier will be undamaged by short-circuiting the D.C. terminals, if the fault continues damage may occur through overheating; as the thermal mass of the rectifier is low it will heat up rapidly, but will cool slowly as the permissible temperature rise is small. Advantage of an increased current rating is, therefore, possible only when the time on load is measured in seconds, while the subsequent cooling period is a matter of minutes. This, however, allows the rectifier to be up-rated in current to about ten times when used for supplying the power to the solenoid for closing heavy-duty switchgear, when the time on load may be up to 20 seconds and the rest period as many minutes. The power delivered by the rectifier is about six times the continuous output as the D.C. voltage falls to nearly half the normal output; nevertheless, a rectifier 6″ square and 15″ long, weighing some 12 lb., will give an intermittent output of 10kW.

Conclusion

Much has been achieved in the development of the selenium rectifier during the last four years. The resultant increase in capacity has brought up many new problems in the control of the rectifier and many interesting developments are taking place in the perfection of automatic means of controlling rectifier equipment to eliminate manual control of processes and to obtain closer limits of control than have been available hitherto.

TIGHT CORNERS FOR P.A.B.X. RACKS

E. G. Wormald

The installation of P.A.B.X. equipment in a subscriber's premises often presents problems in securing an access route with sufficient clearance at doorways and other openings for the passage of the more bulky items of equipment. The convenience of ceiling-height catheads and double doors opening directly on to the roadway or cart dock, so usual in public exchanges, is very seldom available for P.A.B.X. work, and the equipment is largely manhandled from the point of unloading from motor transport, usually in the street, to its final position in the P.A.B.X. room. Almost the only aids to this type of work are the small four-wheel "dolly" which is inserted under the equipment before trundling along to the P.A.B.X. room, and jute bagging which is used for protective purposes where the equipment is likely to come into contact with terazzo or polished floors, partitions and other finished surfaces.

The largest items of P.A.B.X. equipment, and consequently those most difficult to handle, are "C" and "A" type units, the manual switchboard and the linefinder rack. The "C" and "A" type units are approximately 2′ 0″ wide, 1′ 8″ deep and 6′ 11″ high, their weight of approximately 5 cwt. usually presenting the only difficulty in installing them in any desired location.

The manual switchboard in use in N.S.W. has a wooden-cased steel-framed carcase constructed on a unit-position basis, bolted together as required. Each position is approximately 2′ 2″ wide, 5′ 0″ high and 3′ 3″ from the front of the keyshelf to the rear of the switchboard, and consequently can be manoeuvred easily through any doorway giving 2′ 4″ clearance or more (2′ 8″ is usual). The linefinder rack weighs about 6 cwt. and consists essentially of a welded angle-steel framework 4′ 6″ wide and 8′ 6″ high, with feet consisting of two 14″ lengths of 6″ x 4″ angle-iron welded thereto at right angles to the main plane of the rack. Turned on its side, this rack, too, is usually easily manoeuvred into position, unless the P.A.B.X. room is so situated that the only route to it passes through a narrow passageway by means of adjacent doors set in one wall or by means of a door set in the side of a short annexe to the passageway, in which case the handling problem assumes some likeness to a Chinese puzzle. Preliminary investigation of the proposed route with a light framework of wooden slats nailed together to form a dummy of the same overall dimensions as the P.A.B.X. rack usually indicates the best method of handling the equipment in difficult situations such as these.

Other difficulties arise when the P.A.B.X. is to be installed on a floor of the building to which access can only be gained by lift or stairs. Most "goods" lifts are large enough for a line-finder rack turned on its side, and many modern passenger lifts will accommodate this rack also, either turned on its side or leaning diagonally from wall to wall, although in the latter case some difficulty may be experienced in accommodating an operator in the space remaining in the lift.

Sometimes when these methods are inapplicable, a section of the roof of a lift can be raised to allow the rack to stand upright on the floor and project upwards into the lift-shaft. In other cases it is practicable to hoist the rack by lowering the lift so that the top comes to floor level, then loading and securing the rack in an upright position on the roof of the lift. This procedure is impracticable if the lift is suspended from the hoisting cables by a pulley arrangement, if the roof structure of the lift is structurally weak or awkward or if, as appears to be the modern tendency, the roof of the lift is already utilised for the accommodation of auxiliary apparatus such as door-closing motors and their control gear, lights, fans, floor-levelling aids and safety gear. In any case, before a lift is used in this manner the organisation responsible for its operation and maintenance should be consulted.

Sometimes there is no lift in the building, or the use of a lift is impracticable, in which case every effort is made to seek a situation on or near the ground floor for the installation of the P.A.B.X. This, of course, cannot always be arranged and it then becomes a matter of brute-strength to carry the equipment up a stairway. Mechanical handling aids available at present appear to have little or no application here.

Very occasionally methods more drastic than those described above are justified. In one instance a P.A.B.X. was required by a subscriber who leased only the 4th, 5th and 6th floors of a building equipped with lifts and stairways that were small and arranged so as to preclude the passage of the linefinder rack by any of the foregoing methods. This problem was solved by cutting through the angle-steel uprights of the rack about two feet from the top, i.e., between the two final selector shelves (taking care not to damage any wiring) and folding the upper section of the rack (complete with final selector shelf and banks, terminal blocks, fuse panel and wiring) down behind the lower final selector shelf, thus temporarily reducing the height of the rack from 8 ft. 6 ins. to 6 ft. 6 ins. The folded section was supported by means of transverse slats bolted into holes drilled in the sides of the uprights, see Fig. 1, and with wooden blocks (not visible in the photographs) spacing the folded section from the remainder of the rack to prevent damage to the banks and wiring. Fig. 2 shows how it was then possible to load the folded rack into the lift in an upright position for hoisting to the required floor.

In the P.A.B.X. room the rack was "unfolded" and the two halves rigidly joined in their original

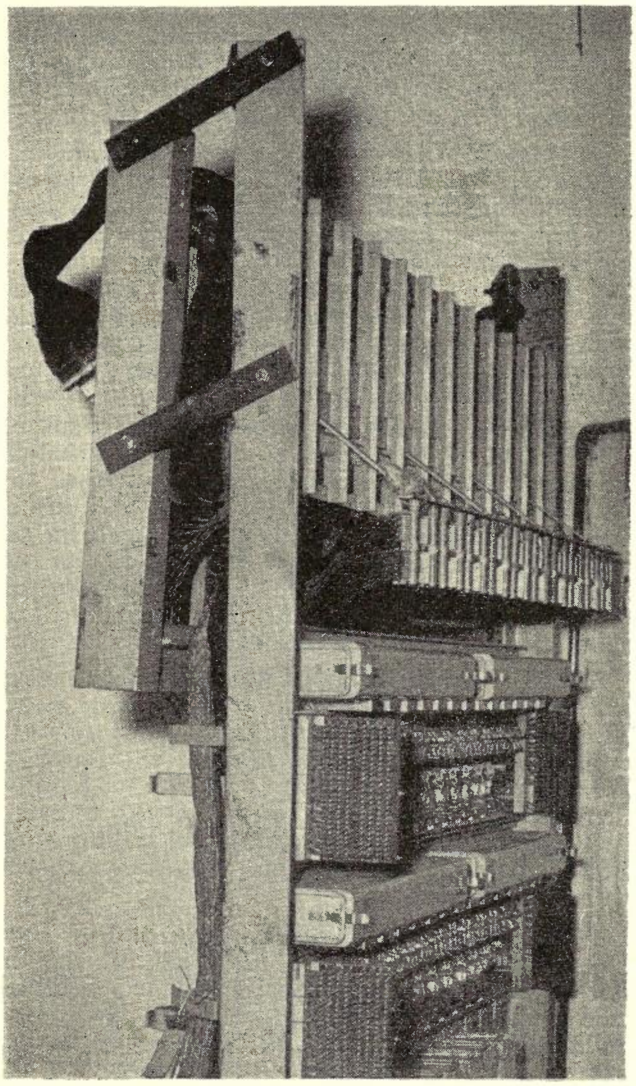


Fig. 1.—"Folding" at top section of line finder rack.

relative positions by means of "fish-plates" of angle steel fitting in the internal corners of the rack uprights and bolted thereto. The bolt-holes, which were also used for fastening the temporary spacing slats to the uprights, were drilled through the uprights and fishplates with the fishplates in position before the uprights were cut through.

In the instance of the P.A.B.X. installed for a large motor vehicle assembly plant, the only suitable space available for the installation was on the mezzanine floor of the office section of the building, access to which was obtainable only by means of twin stairways, one at each end. These stairways were only about 3 ft. wide from wall to wall, quite steep, with only 7 ft. headroom, and with a right-angle turn halfway up. Investigation with a dummy disclosed that it was quite impossible to manoeuvre the linefinder rack around the right-angle turn, and so the assistance of the subscriber was sought. By means of the oxy-cutting process the rack uprights were each severed between the rack-foot and the lowest equipment (line relays) on the rack, and the rack was then carried upstairs, where the pieces were made whole by means of a portable welding outfit.

It is possible, of course, that more difficult access problems than these will be presented by future installations, but judging by achievements to date almost any such problem can be solved provided the subscriber is willing to bear the expense of the additional work involved in dismantling and reassembling the P.A.B.X. equipment when a location with difficult access is unavoidable.

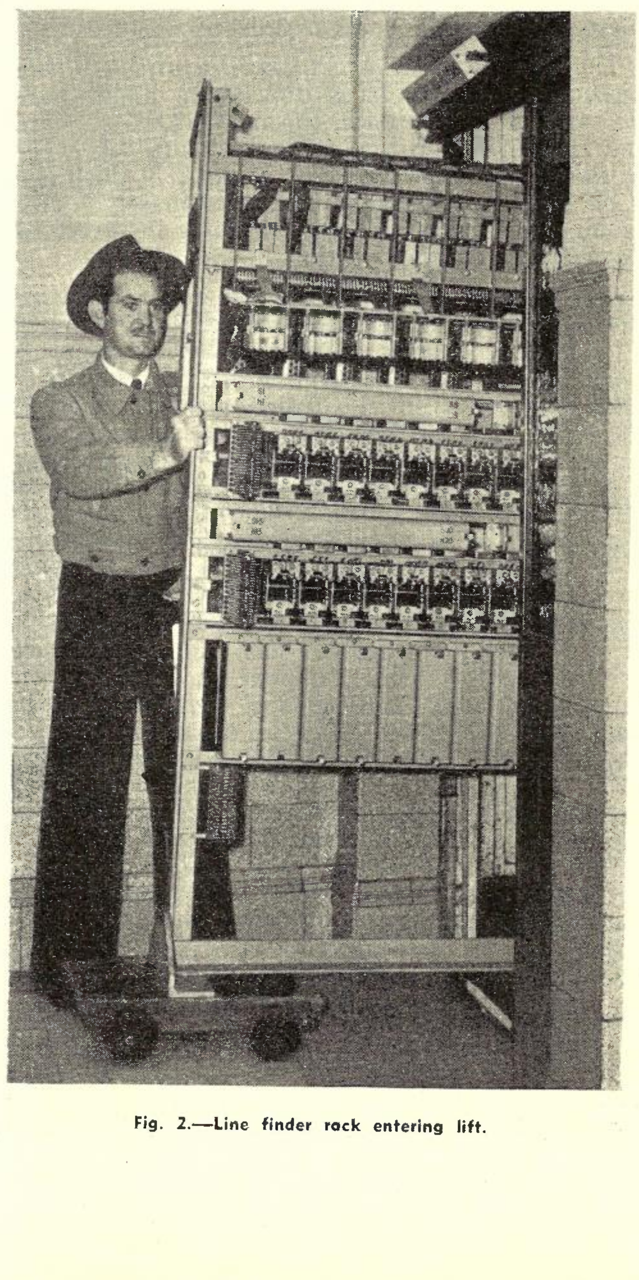


Fig. 2.—Line finder rack entering lift.

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

EXAMINATIONS Nos. 2860 AND 2861—TECHNICIAN, BROADCASTING

SECTION B

N. S. Smith, A.M.I.R.E.

Q.6.—A tuning coil having an inductance of 100 microhenries and a resistance of 5 ohms is connected in series with a condenser having a capacitance of 300 micro-micro farads and negligible resistance. What is the resonant frequency of the circuit and what would be the current flowing in the circuit at resonance if the applied voltage is 200 Volts R.M.S.?

What would this current be if the frequency of the applied voltage was 1 megacycle?

A.—(a) Resonant frequency $f = 1/(2\pi\sqrt{LC})$

$$f = 1/(2 \times 3.14\sqrt{100 \times 10^{-6} \times 300 \times 10^{-12}})$$
$$= 10^9/(6.28\sqrt{3} \times 10^4) = 920\text{kc/s}.$$

Impedance at resonance = R = 5 ohms, current = 200/5 = 40 amp.

(b) The impedance of a series circuit is given by—

$$Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$$

where R = resistance,
ωL = inductive reactance,
ωC = capacitive reactance
$\omega = 2\pi f$.

In the problem—

$$\omega = 2 \times 3.14 \times 10^6$$
$$R = 5$$
$$\omega L = 6.28 \times 10^6 \times 100 \times 10^{-6} = 628 \text{ ohms}$$
$$1/\omega c = 1/(6.28 \times 10^6 \times 300 \times 10^{-12})$$
$$= 10^6/1884 = 530 \text{ ohms}$$
$$\omega L - \frac{1}{\omega C} = 628 - 530 = 98 \text{ ohms}$$
$$Z = \sqrt{5^2 + 98^2} = 98.2 \text{ ohms.}$$
$$\text{Current at 1 megacycle} = \frac{200}{98.2} = 2.04 \text{ amps.}$$

Answer: (a) 40 amps., (b) 2.04 amps.

SECTION C

Q.7.—(i) Describe briefly the following methods of coupling tubes in a multi-stage audio frequency amplifier:—

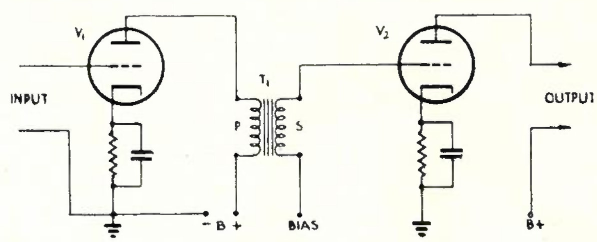
(a) Transformer coupling.

(b) Resistance-capacity coupling.

(c) Choke-capacity coupling.

(ii) The output stage of an audio-frequency amplifier consists of a single triode having a plate impedance of 1000 ohms and an amplification factor of 3. If the impedance of the load is 2000 ohms, calculate the power output when a sine-wave audio frequency voltage of 28 volts peak value is fed to the grid of the tube.

A.—(i) (a) Q.7, Fig. 1, illustrates transformer coupling.

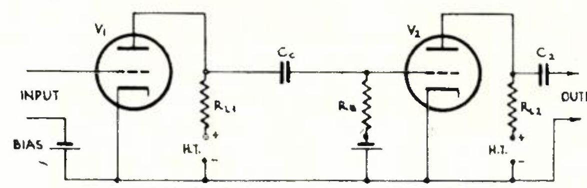


TRANSFORMER COUPLING

Q. 7, Fig. 1.

The valve V1 is coupled to V2 through a high quality transformer T1. This should be so designed that the primary presents the correct load to V1, and the secondary the correct grid load for V2. Also the primary inductance should be high, leakage inductance low, and distributed capacitance small. The frequency response should be reasonably flat over the particular range desired.

(b) Q.7, Fig. 2, illustrates the basic resistance-capacity coupled amplifier.



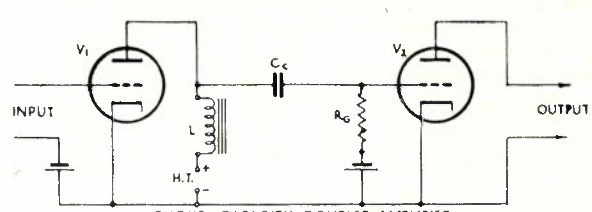
RESISTANCE-CAPACITY COUPLED AMPLIFIER.

Q. 7, Fig. 2.

In this amplifier a voltage developed across load resistor R_{L1} of valve V1 is applied to V2 through the coupling Condenser Cc. The output voltage is developed across load resistance R_{L2}.

Rg. is the grid return resistance of the input circuit of V2. The coupling condenser Cc should be large enough to offer a low reactance to the lowest frequency to be amplified. The coupling or load resistance R_L should be as high as possible consistent with good frequency response. Rg. should not exceed that recommended for the type of valve used as V2.

(c) Q.7, Fig. 3, shows choke-capacity coupling.

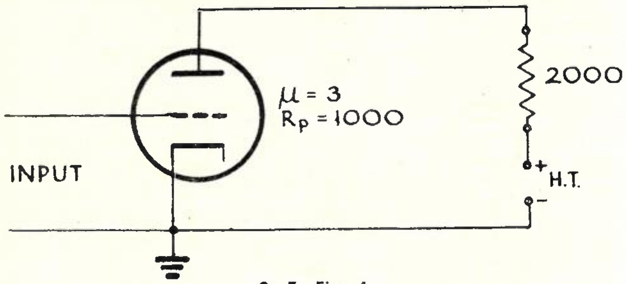


CHOKE-CAPACITY COUPLED AMPLIFIER.

Q. 7, Fig. 3.

In this the voltage developed across the choke "L" is applied through the coupling condenser Cc to the following valve V2. The choke should possess at least 5 times the circuit impedance of lowest frequency to be transmitted.

An advantage of this over resistance coupling is that the D.C. resistance of the choke is much less than the resistance R_{L1} in Q.7, Fig. 2, and will thus introduce less voltage drop in the circuit.



Q. 7, Fig. 4.

Drawing Q.7, Fig. 4, shows the condition.

28 volts peak = 19.8 volts R.M.S.

Voltage output = μ Eg Rl/(Rp + Rl)

where μ = amplification factor of tube

Eg. = applied voltage of input

Rl = load impedance

Rp = valve impedance

Substituting—

Voltage output = (3 × 19.8 × 2000)/3000

= 39.6 volts.

Power = E^2/R = (39.6 × 39.6)/2000

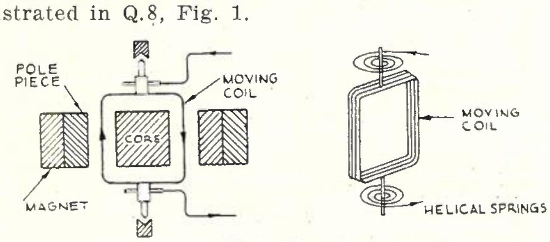
= 780 milliwatts (approx.).

Q.8.—Describe briefly with the aid of diagrams the principle of operation of—

(a) a moving coil D.C. voltmeter,

(b) a valve voltmeter.

A.—The principles of a moving coil voltmeter are illustrated in Q.8, Fig. 1.



Q. 8, Fig. 1.

(a) A permanent magnet has a coil of wire wound on a light aluminium former mounted on pivots between the pole faces, which are designed to have a minimum clearance from the coil. Helical springs govern the movement of the coil. When the current to be measured flows through the coil a field is set up around the coil having such polarity with reference to the permanent magnet that the coil and pointer move and take up a position where the magnetic fields balance.

The deflection of the pointer is proportional to the quantity being measured (voltage in this case) and this results in a linear scale.

Moving coil meters possess high sensitivity.

(b) A valve voltmeter is essentially an ordinary detector tube in which the change in d-c plate current that takes place with the application of a signal voltage is used to measure this voltage.

Q. 8, Fig. 2 illustrates the principle of operation. In this the curvature of the plate-current grid-voltage characteristic of the valve causes the d-c plate current to change by an amount according to the magnitude of the applied signal. This change in plate current is read by means of the milliammeter in the plate circuit, which must be thoroughly by-passed to all alternating currents. The use of a moving-coil meter provides for good sensitivity, and the meter calibration is in volts, several ranges being usually provided. The resistor "R" and battery "C" are used to balance out the steady plate current present when no signal is applied, so that the full range of the meter is available.

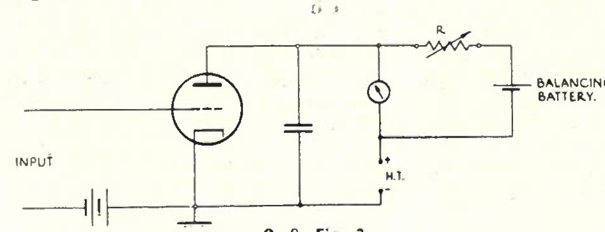
Some advantages of this type of instrument are:—

(1) May be calibrated at low frequencies and used up to very high frequencies.

(2) Consumes negligible power from circuit being measured.

(3) Has low input capacity.

Many other circuits, including the use of diodes, are in practical use.

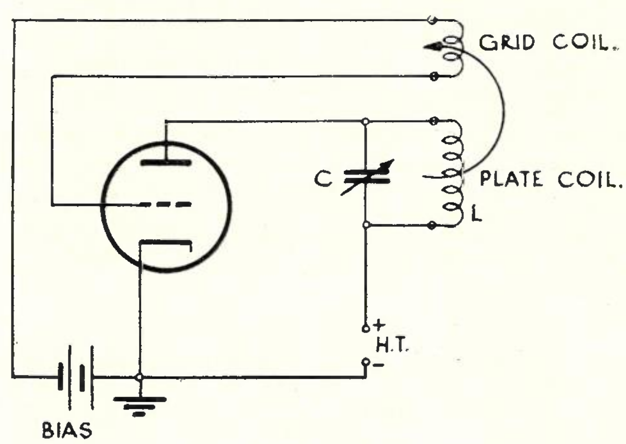


Q. 8, Fig. 2.

Q.9.—Describe with diagrams the principle of operation of a radio frequency valve oscillator. What are the main causes of frequency instability in such a device?

Describe how the piezo-electric effect of quartz can be used to stabilize the frequency.

A.—Q.9, Fig. 1, illustrates a tuned-plate oscillator of the feed-back type.



Q. 9, Fig. 1.

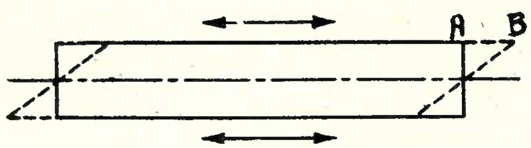
An oscillator consists essentially of an amplifier in which coupling is introduced between the output and input circuits. The magnitude of the feedback is determined by the degree of coupling, and the frequency of the oscillatory circuit by the values of inductance and capacity in the circuit. (L and C in Q.9, Fig. 1.)

Oscillations are started in the circuit by either the transient disturbance associated with the initial application of anode voltage and/or thermal noise in the tuned circuit. They then increase in amplitude until limited by a reduction in amplifier gain due either to an increase in grid current, in bias or to overloading of plate circuit. The valve itself does not oscillate but merely amplifies the electrical impulses impressed on its grid from the oscillatory circuit. The amplifier action is important since without it the circuit losses would gradually cause the oscillations to cease, but the amplifier enables sufficient energy to be generated to overcome these losses.

Frequency instability may be caused by the following:—

(i) Variations of inductance and capacitance with temperature.
(ii) Variation of electrode voltages.
(iii) Generation of harmonics.
(iv) Variation of load impedance.
(v) Overloading. An oscillator should be lightly loaded.
(vi) Vibration.
(vii) Draughts.
(viii) Variation of ambient temperature, etc.

Certain types of quartz possess the characteristic of generating voltages across their faces when subject to mechanical strain, conversely the application of voltages across their faces subjects them to mechanical strain. (Piezo-electric effect.) The degree of strain is dependent (among other factors) upon the applied voltage, the type of crystal, and the dimensions of the crystal plate. Thus the application of an alternating voltage to a crystal will subject it to a varying mechanical strain, first in one direction and then in the other. One mode of operation is shown in Q.9, Fig. 2, "a" and "b" being

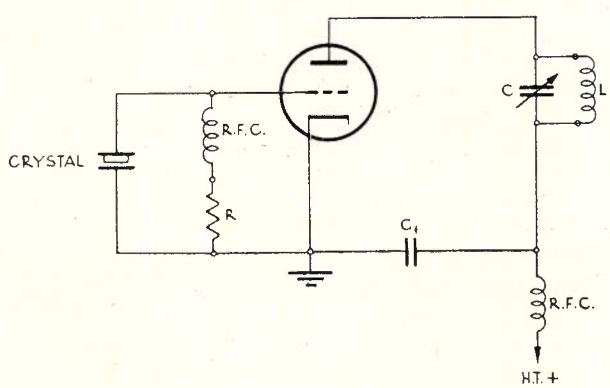


Q. 9, Fig. 2.

the limits of the sideways motion. It so happens that the crystal will respond in this manner only over a relatively narrow band of frequencies. By suitably dimensioning it, it can be made to function at any frequency between about 100 Kc/s and 10 megacycles/sec.

Consequently a crystal may be used to control the frequency generated by an oscillator and maintain this frequency within a few cycles over long periods.

The actual characteristics are variable by altering the manner in which the crystal plate is cut from the mother crystal. A typical circuit is shown in Q.9, Fig. 3.



Q. 9, Fig. 3.

EXAMINATION No. 2817—ENGINEER—TELEGRAPH EQUIPMENT

A. F. Hall

Q.1.—(a) Explain what is meant by "Orientation" as applied to a model 15 teletype and explain the functioning of the device to achieve the desired orientation.

(b) Assuming orient readings were being taken, what type of bias distortion would be indicated if—

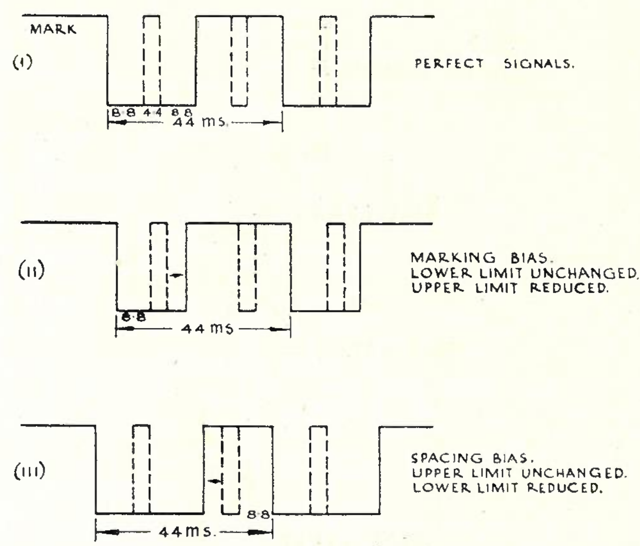
(i) The lower limit were unchanged from normal and the upper limit were reduced?

(ii) Upper limit unchanged from normal and the lower limit reduced?

(iii) Both limits altered in the same direction on the scale?

Give reasons for your answers.

A.—(a) The selecting mechanism of a model 15 teletype is so arranged that, with no signal distortion present, it can be adjusted to operate only during the central portion of the received signal impulse and it requires about 20% of the unit signal interval for its operation. The term "Orientation" is applied to the process of adjusting the receiving mechanism so that the portion of the received signal selected for use will be most favourable for the operation of the printer. Q.1, Fig. 1 (1), indicates the selected portions of the received pulses for the letter Y.



Q. 1, Fig. 1.

The device which is used for "Orientation" is termed the "range finder." It consists of the following parts:—

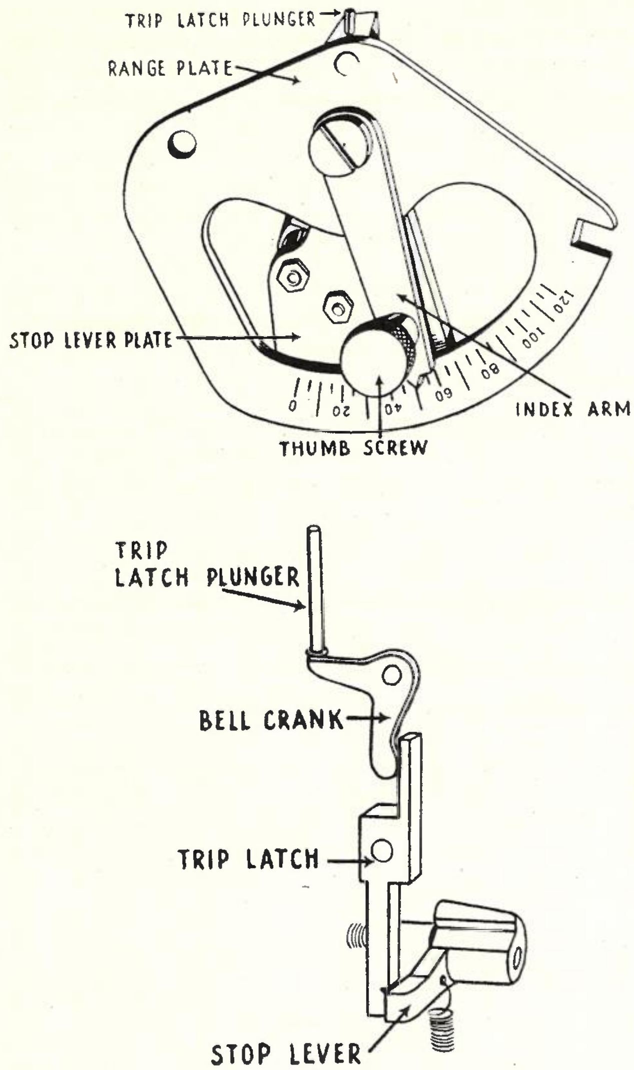
(i) A quadrant plate graduated from 0 to 120.

(ii) An index arm capable of moving in an arc over the graduated scale and to which is attached the latch assembly which arrests the stop arm of the printer.

(iii) A thumb screw to lock the index arm and latch assembly at any selected position.

Q.1, Fig. 2, shows a front view of the range plate and the several components of the latch assembly.

Operation: The stop arm referred to in (ii) above is secured to the selector cam sleeve assembly. An incoming start signal causes the stop arm to be released. By varying the position of the stop arm the selector cam assembly may be shifted with respect to the start signal over a distance greater than a unit signal element which is equivalent to 100 divisions on the range scale. Thus may be simulated the effect of a start signal, early or late, with respect to the remaining elements of the signal train. The mechanism also provides a means of measuring the distortion on received signals. To measure the total nett effect of all kinds of systematic distortion on received signals the range finder is moved in one direction until errors appear in the copy, and is



Q. 1, Fig. 2.

then moved back slowly until these errors are just eliminated. Similarly, the range finder is moved the maximum distance before errors occur in the opposite direction. These two scale readings then give the operating margin of the signals under test and the pointer is secured midway between these values. Since the effective received signal will occupy 20% of the total range perfect signals should give a margin of 10 to 90 if the machine is in adjustment.

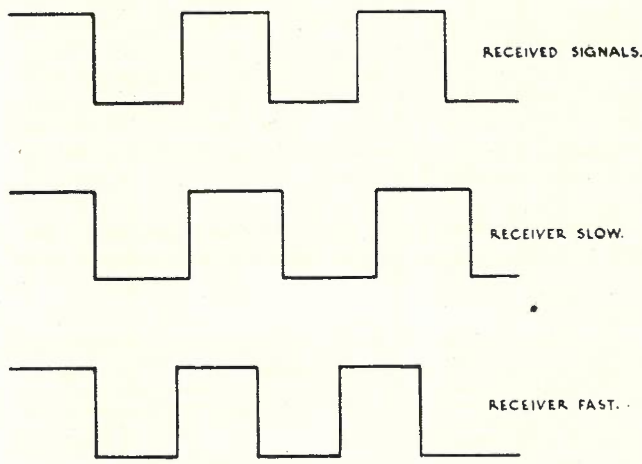
(b) (i) Marking bias is indicated. The start signal occurs with the M-S transition which also determines the displacement from normal in a downward direction of the effective part of the signal. No alteration in the downward direction will occur therefore. Under this condition, however, the S-M transition will occur early giving a reduction in the permissible displacement of the effective part of the signal up the scale.

(ii) Spacing bias is indicated. The S-M transition occurs late, reducing the permissible displacement of the effective part of the signal down the scale.

Q.1, Fig. 1, indicates the effects in (ii) and (iii).

(iii) From the above it will be seen that where both limits are displaced in the same direction a progressive drift is indicated. This is inconsistent with bias distortion effects but commonly indicates speed variation between the sender and receiver. If the receiver is slower than the sender the limits will be displaced down the scale. If the receiver is faster than the sender the limits will be displaced in an upward direction.

Q.1, Fig. 3, indicates these effects.



Q. 1, Fig. 3.

Q. 2—(a) Discuss what connection there is between the speed of telegraph transmission and the frequency band width of a V.F. telegraph channel required to pass the signals.

(b) What is the transmitted line frequency in Bauds of a double, triple and quadruple multiplex system respectively, each running at 270 r.p.m.

(c) Comment on the practicability of operating a double channel multiplex system (270 r.p.m.) over three channels in series, each from 18-channel V.F. systems.

A.—(a) The student is referred to the answer given to question 6 (a), Examination 2721, Telecommunication Journal, Vol. 7, No. 2.

(b) In each case the direction of the shortest signal element would be represented by the time occupied by the send brush in traversing one segment. The number of segments on the send ring is:—

Double multiplex	$2 \times 5 + 2 = 12$ segments.
Triple multiplex	$3 \times 5 + 2 = 17$ segments.
Quadruple multiplex	$4 \times 5 + 2 = 22$ segments.

$$\text{A speed of 270 r.p.m.} = \frac{270}{60} = 4.5 \text{ r.p.s.}$$

Therefore, the maximum number of signal elements transmitted per second and the speed in bauds in each case is:—

Double multiplex	$12 \times 4.5 = 54$ bauds
Triple multiplex	$17 \times 4.5 = 76.5$ bauds
Quadruple multiplex	$22 \times 4.5 = 99$ bauds

(c) A double multiplex channel has an operating speed of 54 bauds, which is well within the capabilities of the

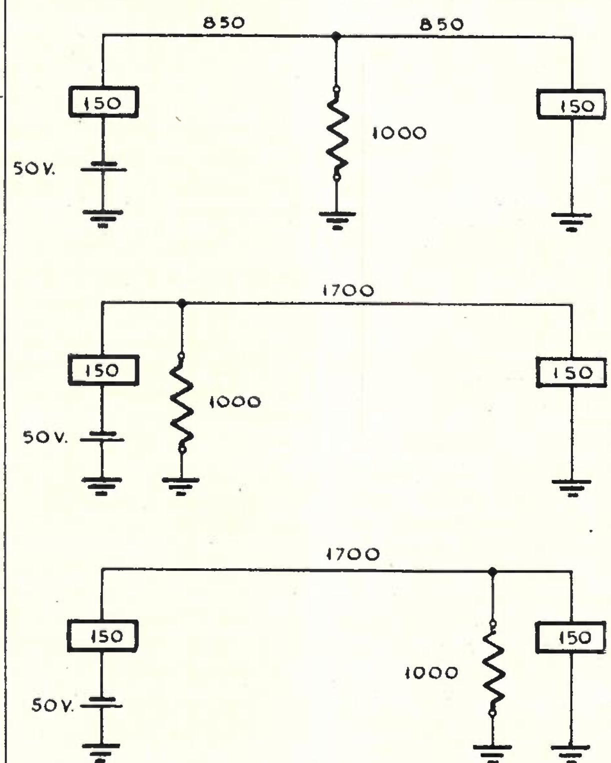
18-channel V.F. carrier telegraph system. One V.F. channel as a single link may introduce 10-12% distortion. The effect of adding a channel in tandem is to increase the distortion beyond that introduced by either channel as a single link, but not necessarily the sum of the two. Thus, three links may introduce 20-22%. This amount of distortion would not render working impossible on a double multiplex system. The Morkrum printer may operate satisfactorily with up to 40% distortion, since only portion of the signal element is employed for selection. It would be found in practice, however, that frequent interruptions to service would occur under the conditions stated. Carrier distortion does not remain constant at all times. Furthermore, deterioration must occur in adjustment of transmitting and receiving equipment. The latter factor would further impair the operating margins already severely restricted by the cumulative carrier distortion.

Q. 3.—A long omnibus morse physical channel is subject to heavy leakage and is supplied with battery from the C.T.O. only. No further improvements can be effected regarding the construction of the line. What steps would you take to improve the operation of the channel? Give supporting reasons for the action you propose.

A.—If we assume a total resistance of line plus equipment of 2000 ohms, the working margin of the relay at A or B will be 25 — 0 = 25 m.a.

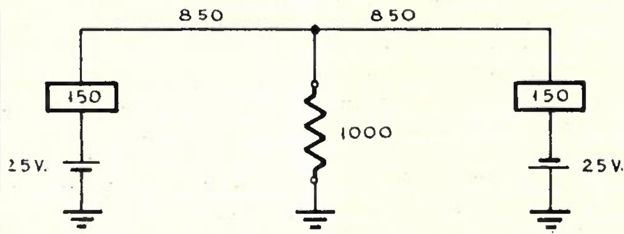
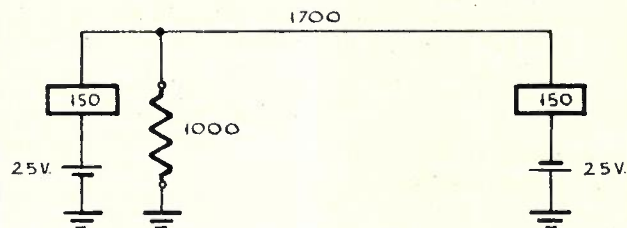
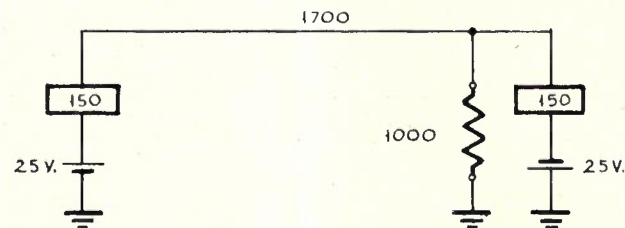
Considering a leakage condition with a joint resistance of leakage paths equal to 1000 ohms. the conditions will vary according to the disposition of the leakage with respect to A and B.

The following three conditions may be considered for the purpose of explanation, assuming leakage concentrated in the positions shown and one battery only provided.

Current via Relay A—Station A				Station B—Current via Relay B		
Keys A & B closed	Key B open	Margin		Keys A & B closed	Key A open	Margin
33.3	25	8.3		16.6	0	16.6
62.5	43.5	19		21.9	0	21.9
25.2	17.5	7.7		21.9	0	21.9

Since the potential applied to the line is a factor in determining the insulation resistance of the line it is important to note that reduction of line potential would greatly improve the insulation values. This reduction can be effected by dividing the battery and locating half the potential at A and half at B.

Under the no leakage condition the working margin for relay A or relay B will again be 25—0 = 25 m.a. considering leakage conditions as before.

Current via Relay A—Station A				Station B—Current via Relay B		
Keys A & B closed	Key B open	Margin		Keys A & B closed	Key A open	Margin
25	12.5	12.5		25	12.5	12.5
42.25	21.8	20.4		23.6	8.8	14.8
23.6	8.8	14.8		42.25	21.8	20.4

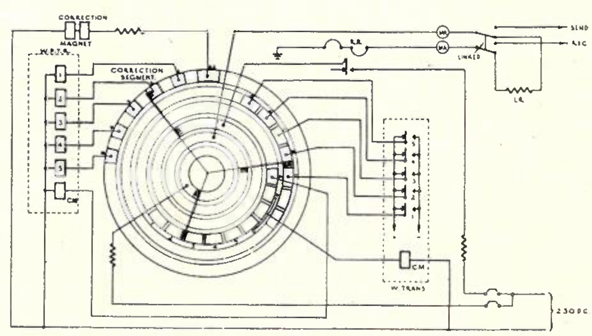
It will be seen that the margins have been improved for relay A and, although somewhat reduced for relay B, are comparable for both ends. Furthermore, the reduction in line potential would permit greater deterioration in insulation resistance before the circuit proved unworkable.

An alternative method which would improve the operation of the channel would be to divide the line and instal a simplex to simplex repeater at the intermediate station. This method would necessitate battery provision at this station and may introduce maintenance problems. A trained operator would also be desirable at this station since, under leakage conditions, the resistance associated with the transmitter should approximate that of the main line to prevent relay "chatter."

Q. 4.—(a) Describe with the aid of sketches the operation of a quadruple Murray multiplex system. Show the allocation of distributor rings and segments.

(b) Enumerate the chief parts of the equipments that require regular maintenance attention.

A.—(a) It is assumed that a discussion of the principle of operation of the Murray multiplex is not required and only the operation of the quadruple multiplex will be described. Q. 4, Fig. 1, indicates the general arrangement of the Murray quadruple plateau. One plateau is installed at each terminal of the system and the sending and receiving channels are connected to the plateaux as indicated in the figure which shows the connections for W. channel only. Three pairs of brushes, rigidly connected and spaced at 120°, connect solid and segmented rings of the plateaux as is also indicated in the figure. The brushes, driven at constant speed by a phonic motor at each end, establish the orderly transmission and reception of the signals.



GUARD RING NOT SHOWN.

Q. 4, Fig. 1.

Maintenance of Synchronism.—The stipulated speed of rotation of the phonic motors in Australia is 270 r.p.m. Very little departure from synchronism can be tolerated between the two phonic motors on any system. To achieve this close regulation the vibrator which governs the speed of the particular phonic motor at one terminal, known as the "corrected" end, is set to drive its phonic motor at approximately $\frac{3}{4}$ r.p.m. faster than the speed of the motor at the "correcting" end. From segment 21 on the send ring a negative pulse and from the adjacent segment 22 a positive pulse are transmitted every revolution. The negative pulse is called the "correction signal" and the two pulses make up the "correction cycle." When the two motors are in synchronism the correction signal, transmitted by the correcting station, reaches the corrected station when the receive brush at that end is traversing the space between segments 20 and 22 shown in Q. 4, Fig. 1. An electro magnet, termed the correction magnet, is connected to receive segment 22 at the corrected end. Due to the speed difference the correction signal will ultimately be applied by the receive brush to segment 22 so as to operate the correction magnet. The phonic motor and its shaft carrying the brushes are coupled together through a gear train which responds to the operation of the correction magnet and causes the brushes to be set back $1\frac{1}{2}$ degrees with reference to the motor to re-establish synchronism. The action of drift and correction continues during the whole time the plant is running.

Transmission of Signals.—Each transmitter is allotted five adjacent segments on the associated send ring. The potential, whether mark or space, applied to each segment by the transmitter is determined by the transmitting tape which is perforated in accordance with the five unit code and which is prepared by the operator in the Murray keyboard perforator.

Reception of Signals.—Each printer is allotted five adjacent segments on the associated receive ring and each segment is connected to its associated single current printer selector magnet. Should the receive relay be operated to mark when the receive brush is traversing a particular receive segment the associated selector magnet will be operated but the magnet will otherwise remain unoperated. The selection of the character to be printed or an operational function of the printer is determined by the relative position of the five selector magnets at the time at which the printing operation of the machine is initiated.

Due to the slight drift back and forth of the receive brushes under control of the correction magnet the points of application and cut-off of the received signals will correspondingly drift with relation to their corresponding receive segments. In order to prevent the overlap of received signals to adjacent segments the receive segments are reduced to half the possible length by removing the first and last quarters. The space between adjacent segments is occupied by projections of the guard ring in order to provide for smooth operation of the receive brushes.

Cadence.—In order that the printers and transmitters will perform their respective functions at the correct time, certain segments on the third or cadence ring are arranged to supply functional pulses to transmitters and printers. In the case of the transmitter this pulse steps on the transmitter immediately after each signal train has been transmitted. In the case of the printer the appropriate pulse initiates the operation of the printer after selection has been effected.

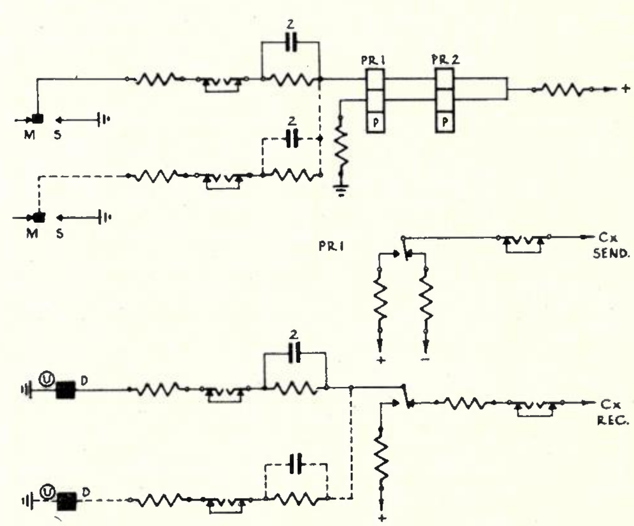
The allocation of all plateau segments in a typical quadruple Murray multiplex is as follows:—

Receive Ring	Send Ring	Cadence Ring
W Printer segs. 1-5	W Transmitter segs. 1-5	W Transmitter segs. 6, 7, 8.
X Printer segs. 6-10	X Transmitter segs. 6-10	W Printer seg. 9.
Y Printer segs. 11-15	Y Transmitter segs. 11-15	X Transmitter segs. 11, 12, 13.
Z Printer segs. 16-20	Z Transmitter segs. 16-20	X Printer seg. 14.
	Mark seg. 21	Y Transmitter segs. 16, 17, 18.
Correction Magnet seg. 22	Space seg. 22	Y Printer seg. 19.
		Z Transmitter segs. 21, 22, 1.
		Z Printer seg. 2.
		Extension Restore seg. 3.
		Unallotted segs. 45, 10, 15, 20.

(b) The chief parts requiring regular maintenance attention are Perforator, Transmitter, Printer, Phonic Motor, Plateau Face, Brushes, Plugs, Vibrator, Receive Relay, Jacks, wiring and connections.

Q. 5.—(a) It is desired that two teleprinters in one centre operate simultaneously over a carrier channel with a teleprinter located at a distant centre "B" so that each lessee will be able to communicate with the others. Give a diagram showing the connections.

(b) What alterations would require to be made to enable the service to function if the only machines avail-

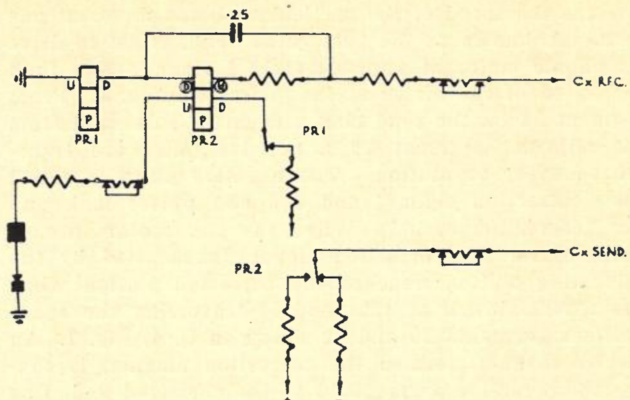


Q. 5, Fig. 1.

able for use at "B" were teletype model 15 units? Neglect secondary character differences.

A.—(a) The diagrammatic connections for a long distance teleprinter point to point panel with one subscriber are indicated by full lines in Q. 5, Fig. 1. A second subscriber may be added as indicated by the dotted lines.

(b) For teletype working at "B" from teleprinters at "A" a long distance teletype relay set with connections as indicated in Q. 5, Fig. 2, would be satisfactory at "B" in lieu of the long distance teleprinter panel. Since teletype machines in Australia have been converted to 404 operations per minute (50 baud), teleprinter and teletype machines may work satisfactorily in conjunction.



Q. 5, Fig. 2.

ERRATA

"Examination 2817—Engineer Transmission, Section 1—Long Line Equipment," Vol. 7, No. 4, June, 1949, page 255.

In column 2 expressions for β and α delete the square root sign over $(GR - \omega^2 LC)$. Also in the expression for α amend β^2 to R^2.

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