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A FREQUENCY-GENERATING EQUIPMENT FOR MULTIPLEX COMMUNICATION SYSTEMS

(TYPE ETFG.601)

A. J. McMillan, Grad.Brit.I.R.E.—Carrier and H.F. Development Department

The article describes a new transistor frequency-generating equipment, of high stability and accuracy, designed to supply the carrier and signalling frequencies required by multiplex systems based on the ETG 121-type channel-translating equipment. The design allows ready expansion of power requirements to cater for large station installations.

THE ETFG.601 frequency-generating equipment complements the channel-translating equipment described in a preceding article.[1] Basically, it is an equipment designed to provide the necessary carrier supplies for deriving the CCITT basic group B (60–108 kc/s) and supergroups in the bands 12–252, 60–300 and 312–552 kc/s. In addition, it provides the out-of-band signalling supplies required by the basic group.

An essential design aim for the equipment was carrier stability. In the CCITT recommendations for an international circuit comprising three carrier circuits in cascade, the overall permissible frequency-error is 2 c/s, a limit suitable from considerations of speech and v.f. telegraphy. This small degree of asynchronism demands a very high standard of frequency stability. For this reason, particular attention has been paid to the achievement of a frequency long-term stability of a few parts in 10^7 for the master oscillator from which all carrier supplies are derived.

Reliability was a further major objective for the generating equipment, since failure of a carrier on a multi-channel link could result in a complete breakdown of communication. Thus, for dependability, components of proved reliability are used throughout, and all frequency-generating equipment is duplicated and arranged for automatic changeover from ' main ' to ' standby ' on failure of any carrier or signalling frequency supply.

An important feature of this complete changeover system is that changeover is almost instantaneous to ensure continuity of service. Moreover, on failure of a carrier or signalling frequency supply, it allows the faulty equipment to be removed for repair without interrupting the service given by the associated carrier system.

For flexibility of use, the equipment is physically divided into three parts, comprising a basic frequency-generator panel, a group-translation frequency-generator panel and a panel for the supply of signalling frequencies.

The Basic Frequency-Generator Panel

This panel, illustrated schematically in Figure 1, provides the channel and sub-group carrier frequencies for the translation of 12 audio circuits into the basic 60-108 kc/s, 12-channel group. In addition, it supplies frequencies for group and supergroup generation and a 60 kc/s line pilot.

The frequencies are generated from a single crystal-controlled master oscillator contained in a temperature-controlled oven (see Figure 2) mounted on the basic panel. The oscillator is a negative-impedance type employing a 128 kc/s 5° x-cut crystal which has a parabolic temperature coefficient with its point of inversion at 52°C.

Control of the oven temperature is effected by a slave relay controlled by a mercury capillary contact thermometer. By this means the temperature in the oven is held to within ± 0·3° of 52°C and thus the crystal is maintained at its most stable operating point. As a safeguard, two alarm contact thermometers are included in the oscillator-card assembly to cause audible and visual alarms to be given should the working temperature of the oven vary by ± 2°C of the nominal. The master oscillator is also protected against supply-voltage variations by a zener diode

[1]Bulletin No. 45, pp. 66-72

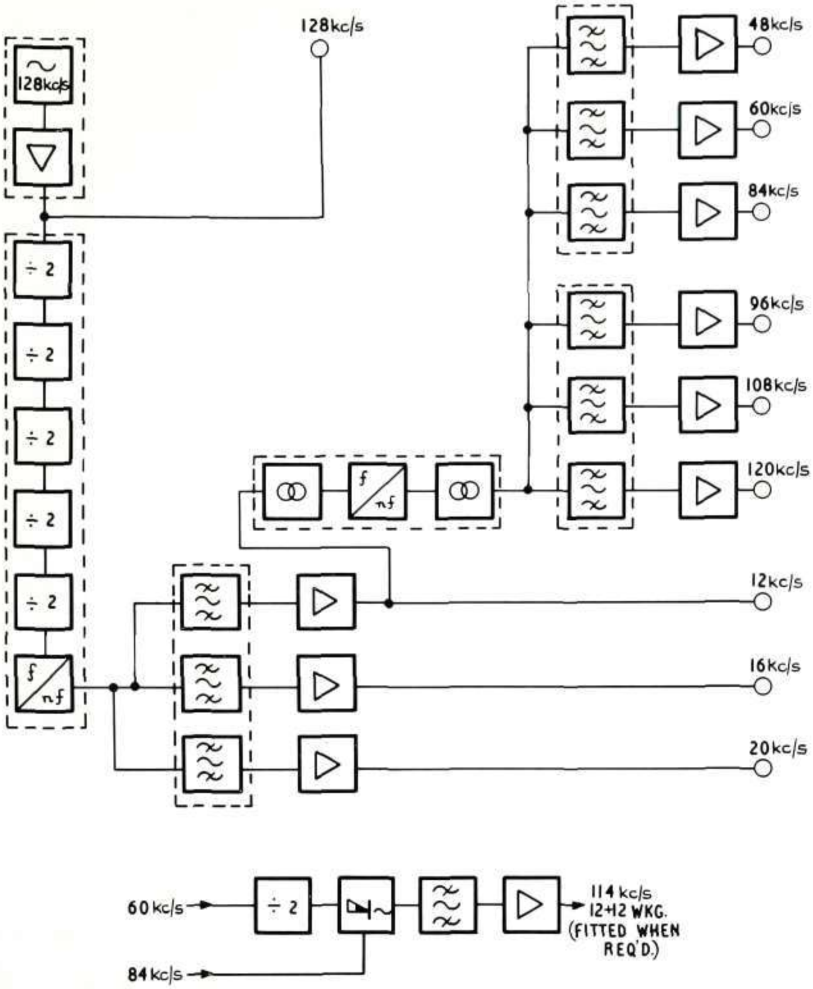


Figure 1—General arrangement of the basic frequency-generator panel

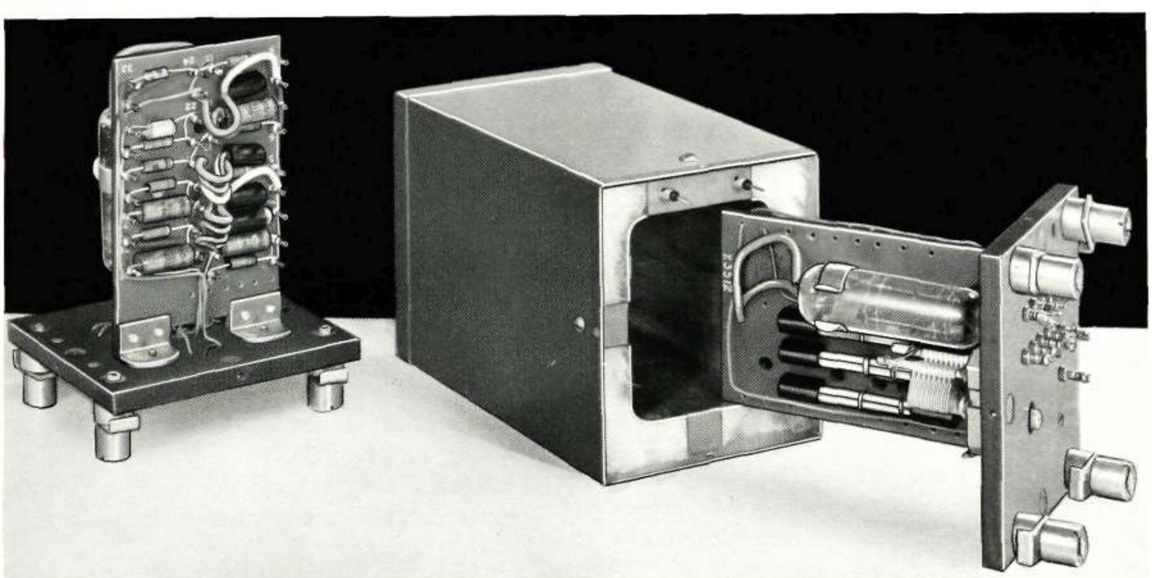


Figure 2—Master-oscillator card assembly and temperature-controlled oven

which keeps the oscillator voltage sensibly constant over a supply variation of ± 10%. With this method of control, a short-term stability better than two parts in 10^7 is achieved for the oscillator. It is of interest to note here that the long-term stability is two parts in 10^7 per month after three months of running.

The 128 kc/s square-wave output of the oscillator unit is applied to a chain of five Eccles-Jordan binary dividers to produce a 4 kc/s square wave which is subsequently fed into a harmonic generator. From the square wave, this generator produces a series of positive 'spikes' rich in both odd and even harmonics of 4 kc/s. The 3rd, 4th and 5th harmonics (12, 16 and 20 kc/s) are 'picked off' by coil and capacitor filters having typical response curves as shown in Figure 3, and the filter outputs are then individually amplified by variable-gain power amplifiers.

The output of the 12 kc/s amplifier is fed into another similar harmonic generator to provide an output rich in harmonics of 12 kc/s. From this output, the 4th, 5th, 7th, 8th, 9th and 10th harmonics are separated by means of filters, similar to those already mentioned, and amplified by identical amplifiers to give the sub-group carrier feeds, the 48 and 60 kc/s for group and supergroup translation carrier-frequency generation and the line pilot.

The generator is capable of providing a 114 kc/s group-translation carrier when required for use with 12 + 12 channel systems. This is accomplished by feeding the 60 kc/s pilot into a binary divider and applying the 30 kc/s output of the divider, together with the 84 kc/s carrier frequency, into a ring modulator. The upper sideband output of the modulator is filtered and amplified as before to provide the required 114 kc/s carrier supply.

For stations equipped with more than five groups, the output of any carrier frequency may be increased by the addition of auxiliary amplifiers.

Group-Translation Frequency-Generator Panel

This panel provides carrier supplies for the translation of five basic 60–108 kc/s groups into the basic supergroup of 312–552 kc/s. The frequencies supplied may also be used to translate the basic supergroup into the lower supergroup frequency range 60–300 kc/s or into the 12–252 kc/s range for a CCITT Scheme 2 balanced cable system.

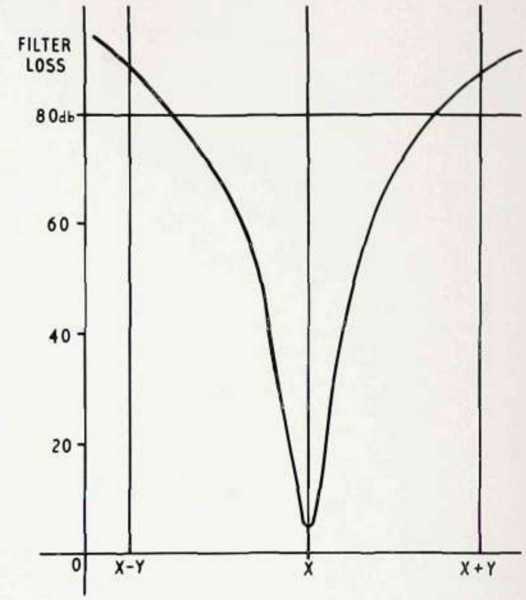


Figure 3—Response curve of a typical carrier filter

From Figure 4 it will be seen that the 60 kc/s supply from the basic generating panel is fed into a harmonic generator of similar type to those described in the previous section. In this instance, the 7th harmonic contained in the output is filtered and amplified by a variable-gain, low-output impedance amplifier to give 420 kc/s, which is the 1st group-translation carrier feed.

The 48 kc/s output from the basic generator is similarly connected to a harmonic generator. Here the output is applied, together with the 420 kc/s carrier feed, into a ring modulator. The upper sideband output of this modulator contains the remaining four group-translation frequencies (468, 516, 564 and 612 kc/s), which are subsequently filtered and amplified.

A 308 kc/s pilot can be derived by feeding both the 60 kc/s and the 128 kc/s basic-generator outputs into a ring modulator. The 60 kc/s is fed via a high resistance to the carrier input of the modulator thus producing in the modulator a 60 kc/s square wave. The 308 kc/s component in the modulator output is filtered and amplified to give the required pilot supply.

For 60-circuit balanced-cable systems, the 308 kc/s pilot is not required and its generating equipment is

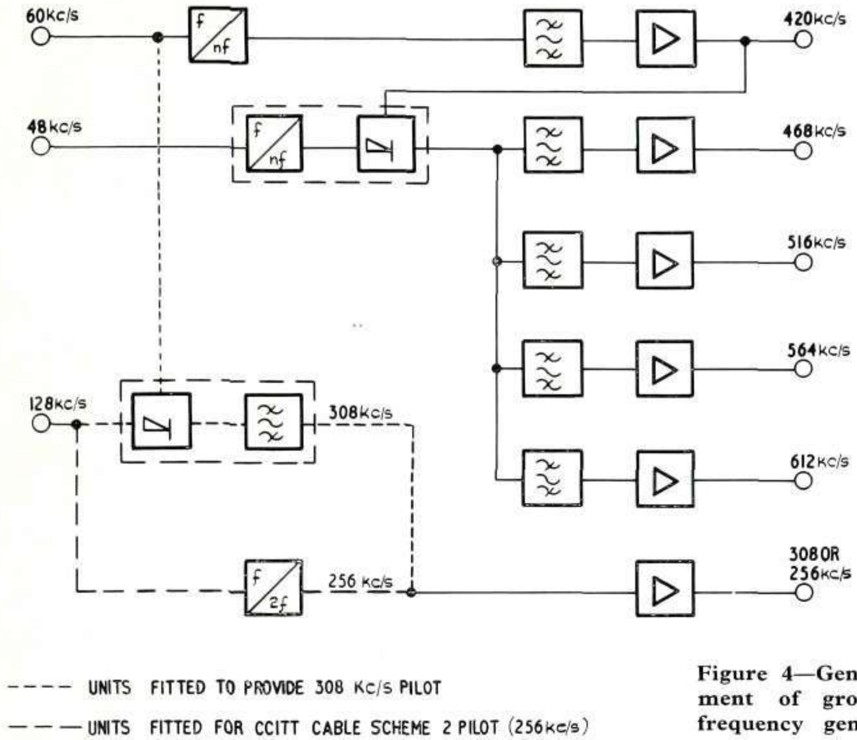


Figure 4—General arrangement of group-translating frequency generating panel

Alarm and Standby Facilities

Each carrier amplifier has an auxiliary winding on its output transformer, and this winding is connected to a rectifier circuit to produce a d.c. output. This output is continuously monitored by the alarm-and-changeover circuit as shown in Figure 5.

All generating equipment is duplicated by standby equipment which is kept in constant readiness but with its master oscillator suppressed by the alarm-circuit relay to prevent carrier

replaced by a frequency doubler into which is connected the 128 kc/s supply. The 256 kc/s output is then filtered and amplified as before to give a 256 kc/s high-frequency line pilot.

Signalling-Frequency Panel

Three signalling-frequency supplies, 15·825 kc/s, 19·825 kc/s, and 23·825 kc/s are required for the ETG. 121 channel-translating equipment and these are provided on the panel by means of three identical coil and capacitor oscillators. These are of low-output impedance and have a frequency stability of ± 5 c/s when operated over a temperature range of −10°C to + 50°C and a supply voltage variation of ± 10%. Each oscillator is capable of supplying up to twenty ETG. 121 equipments (i.e. 240 circuits).

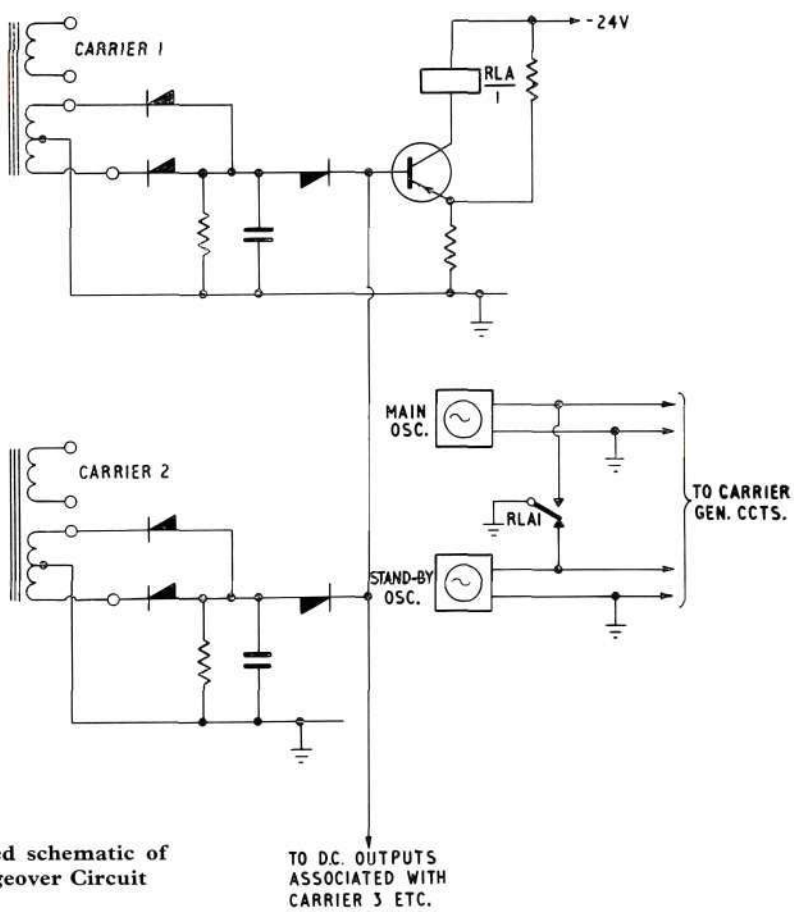


Figure 5—Simplified schematic of Alarm and Changeover Circuit

generation. Immediately any carrier supply fails, the absence of the d.c. supply causes the alarm relay to release. This action removes the suppression from the standby master oscillator and, at the same time, suppresses the main oscillator so that complete changeover of the generating equipment takes place. This changeover occurs without interrupting the service given by the associated channelling equipment, since the changeover time is less than 5 milliseconds for the failed carrier and almost instantaneous for the others.

The signalling oscillators are duplicated by standby equipment and monitored by a similar alarm-and-changeover circuit. When changeover occurs in this instance, however, the three outputs are switched by relay contacts from one set of oscillators to the other and all six oscillators are continuously operating.

Both main and standby generators are fed from separate power supplies. The requirements of the alarm circuits are divided between these two power supplies in such a manner that if one supply fails, appropriate alarms will be given.

Carrier-Feed Arrangements

The channelling equipment receives its carrier supplies via the carrier hybrid transformers. The main and standby carrier supplies are connected to the two inputs of the hybrid transformer and the load is divided evenly between the two outputs.

For the signalling frequencies, no hybrids are necessary, as the output switching is done by relay contacts.

Carrier Synchronization

With large multiplex carrier systems it is always necessary to provide some means of measuring the frequency difference between the master oscillators at the two terminals of the system. In the ETFG. 601, relative changes in frequency can be detected by comparing the 60 kc/s pilot frequencies of the two terminals or by comparison between the local 60 kc/s pilot and a 60 kc/s standard of frequency, if the latter is available.

Either method entails the feeding of the two 60 kc/s supplies into two limiting amplifiers, each giving a square-wave output. From each of the outputs the 17th harmonic is selected and amplified by a 1·02 Mc/s tuned amplifier. In the following stage, the outputs of these two amplifiers are heterodyned together, the difference between them being displayed on a meter as a beat. A ‘ sense ’ arrangement in the equipment enables the higher frequency to be determined for adjustment purposes.

The frequency of each oscillator is adjustable by a variable air-spaced trimming capacitor. The normal procedure is for the main-station oscillator to be synchronized to a frequency standard, after which all satellite stations are synchronized to the main station,

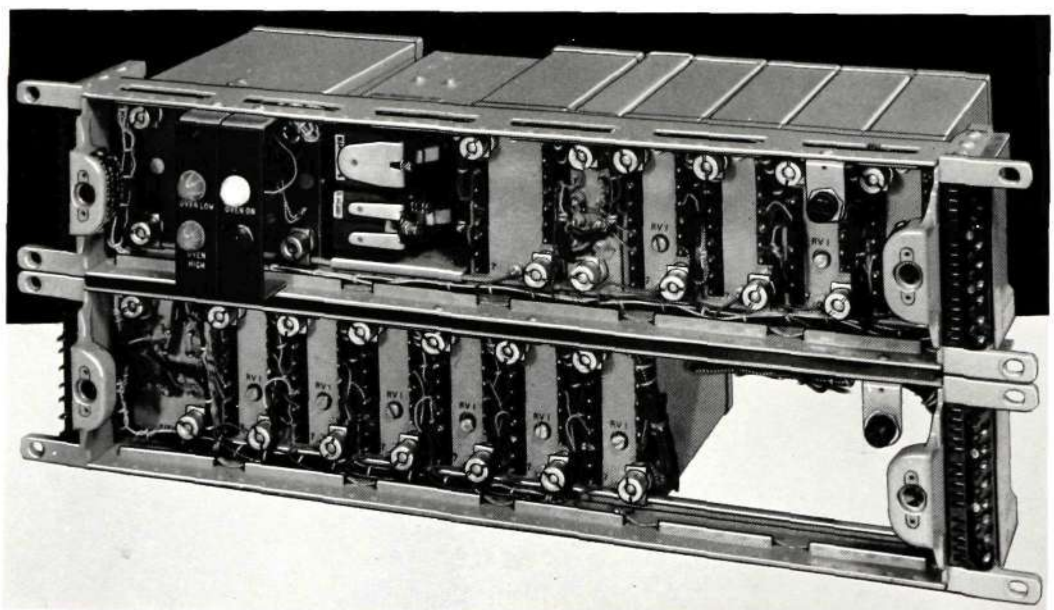


Figure 6—General view of basic-frequency generating panel with front cover removed

frequency comparator equipment being available at all terminal stations.

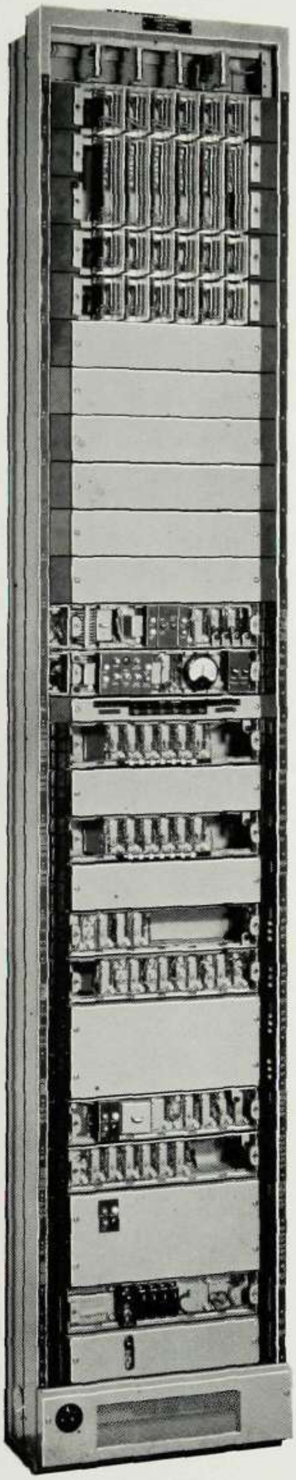


Figure 7—A frequency-generating bay for 60-circuit cable systems

MECHANICAL CONSTRUCTION

All equipment, including standby apparatus, is arranged on panel units of B.P.O. 51-type construction. The carrier-frequency generator and translating units are accommodated on 7″ panels of the jack-in type illustrated in Figure 6. Auxiliary amplifiers are mounted on jack-in panels of 3½″ depth.

The alarm, changeover and frequency comparator equipment is arranged on a 3½″ hinged panel, as are the six signalling oscillators together with their associated alarm and changeover equipment.

Although the panels are of standard form, their rack layout varies according to the type of carrier system with which the generating equipment is associated. Figure 7 shows a frequency-generator bay capable of feeding four 60-circuit cable systems operating in the CCITT Cable Scheme 2 frequency band of 12–252 kc/s. Alternate panel covers are removed for illustration purposes.

Mounted at the bottom of the rack are the two main and standby power-supply panels. Above these are consecutively mounted two basic-frequency panels, two group-translation frequency-generator panels, and four 3½″ auxiliary-amplifier panels.

Approximately in the centre of the rack, at eye level, are the two hinged panels incorporating the signalling oscillators, both sets of alarm and changeover units and the frequency comparator. The meter of the frequency comparator is clearly visible on the lower of the two panels.

The hybrid transformers are accommodated in the upper half of the rack and at the rear of the terminal strip field, where all carrier feeds terminate. Signalling feeds and miscellaneous services terminate in the connection block area at the top of the rack.

POWER SUPPLY AND CONSUMPTION

The equipment operates from the same supply as provided for the associated ETG. 121 channelling equipment, i.e., a.c. mains or normal exchange batteries (24 or 50 volts).

Power consumption of a frequency-generating rackside varies considerably, depending upon the type and number of terminal equipments supplied. The rackside illustrated consumes approximately 72 watts plus a further intermittent 14 watts for each oven heater.

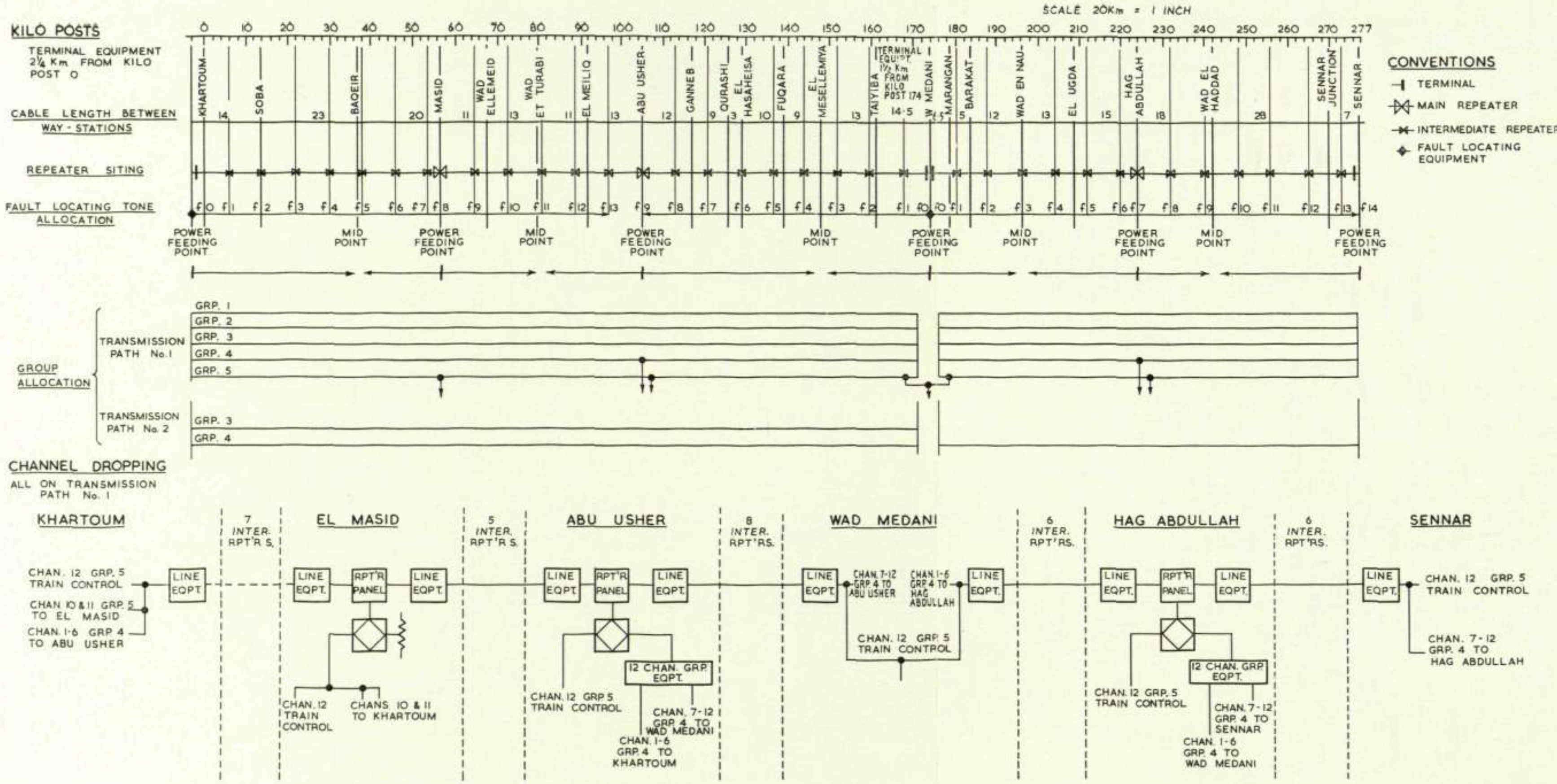
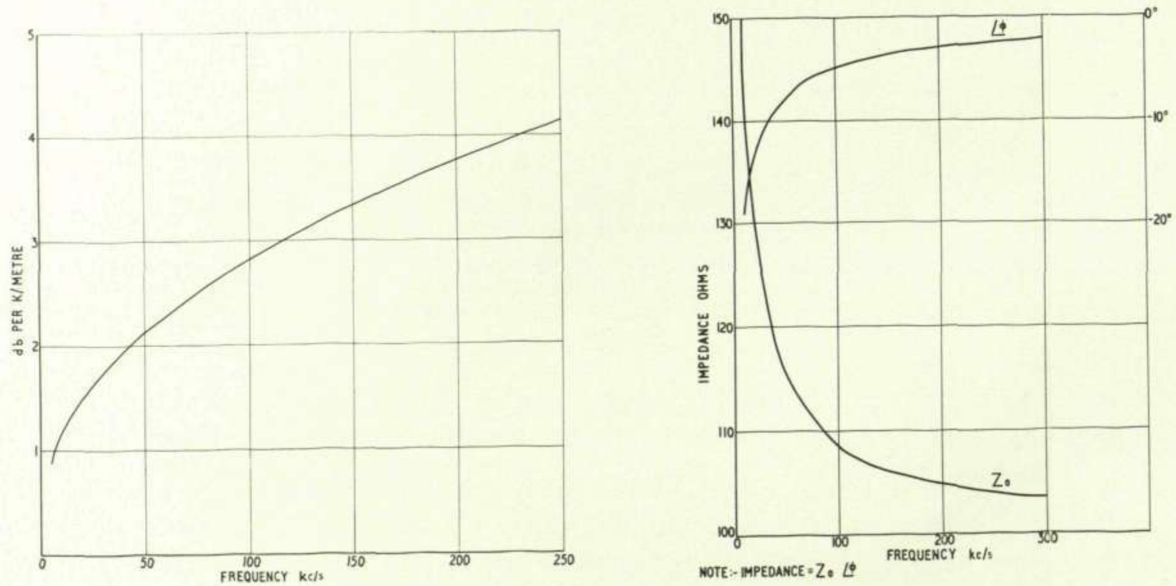


Figure 1—Route details of Khartoum-Sennar Cable Scheme



(*a*) **Insertion loss**

(*b*) **Impedance**

Figure 2—Approximate transmission characteristics of cable used on Khartoum-Sennar route

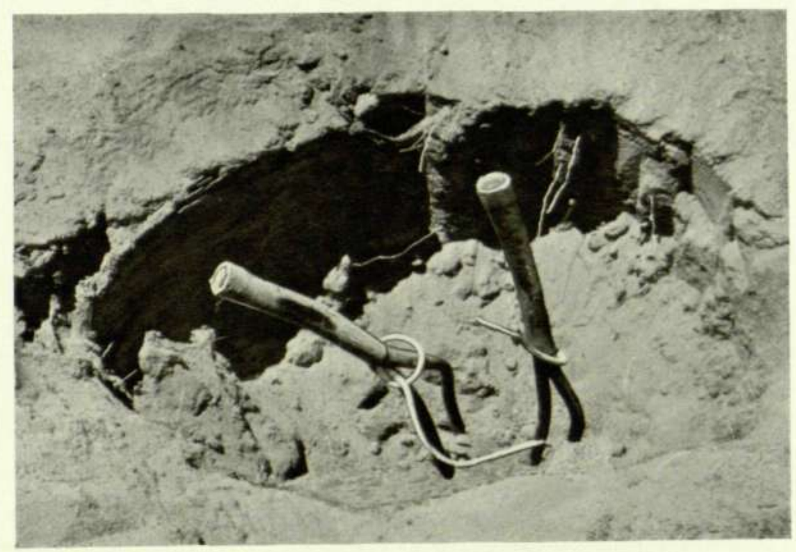


Figure 3—Typical cable joints with screen connections readily accessible for maintenance purposes

THE KHARTOUM — SENNAR CABLE SCHEME

J. ATTEWELL, A.M.I.E.E.—Carrier and H.F. Development Department

This is the final of a series of three articles[1] concerning the latest carrier equipment developed for use in multi-channel transmission systems. The article describes a typical application of the ETC 601 equipment in the Sudan. The equipment, operating over two polythene single-quad cables laid by a tractor-drawn plough, affords an economical solution to the problem of providing trunk circuits in sparsely populated country.

THE provision of long distance communication in the Republic of the Sudan, as in all large and relatively undeveloped countries, is a difficult problem. Compared with the U.K., centres of population are smaller and very much further apart; consequently, that proportion of the capital cost of providing trunk circuits which is expended on line as distinct from terminal equipment is very high and, if an attempt is to be made to reduce the high cost per circuit, it is in the line equipment that economies will be most effective.

At present, the country has a network of open-wire lines on poles but, with the recent rapid development of the country, these have become inadequate. The cost of transposition in order to increase the number of open-wire carrier circuits is high and, in any case, new areas where no pole-routes exist are now being developed. In consequence, the Department of Posts & Telegraphs has devised a scheme whereby very considerable savings in cost may be made by a departure from the traditional open-wire lines to a comparatively cheap balanced cable which may be buried in the ground quickly and cheaply.

The first of the cable routes to come into service is for the Khartoum-Sennar scheme. Originally, a 280 km open-wire pole route ran alongside the railway between the two towns, but in November 1962 the 110 kV power line, built parallel to the railway at a distance of 200 metres, was due to be brought into operation when it was expected that the open-wire route would become unserviceable. It was therefore necessary to replace the open-wire by a cable system which would provide every facility hitherto given by the original open-wire system, i.e. through-carrier circuits; carrier circuits dropped at intermediate points; audio and d.c. circuits for communication between way-stations; and a railway signalling circuit working on a party-line basis between Khartoum and all the way-stations.

The Company's engineers, in consultation with the engineers of the P & T Department, have designed a system to operate over the cables, one which is comparatively cheap and yet sufficiently versatile to give all these facilities. The carrier equipment, using transistors throughout, is designated ETC. 601.

The route is illustrated in Figure 1. The scheme comprises two separate transmission links, Khartoum-Wad Medani and Wad Medani-Sennar, each link having an ultimate capacity for 120 circuits. Two cables are used in a four-wire arrangement; 60 channels in the CCITT Scheme 2 frequency spectrum (12-252 kc/s) being transmitted from Khartoum on each of the two pairs of one cable which is designated the 'Go' cable. The other cable, bearing the return channels into Khartoum, is designated the 'Return' cable.

THE CABLE

The cable used on the Khartoum-Sennar route is a single star-quad of 40 lb.-per-mile conductors, polythene insulated with a double polythene sheath, the two sheaths being separated by a copper tape screen. The transmission characteristics are approximately as shown in Figures 2a and 2b.

The cable is purchased in 1 km lengths. The P & T Department have developed a quick and easy method of jointing lengths using epoxy resin encapsulation. With this method the conductors are soldered and insulated with plastic tape and inserted into a plastic tube which is sealed at one end and filled with epoxy resin to form a watertight joint.

Typical joints are shown in Figure 3; the screen connections can be seen to be readily accessible for maintenance purposes.

[1]See Bulletin No. 45, July 1962, pp. 66-71 and this issue, pp. 2-7.

Figure 4—Cable-laying operations with tractor and plough

CABLE LAYING

The P & T Department, after experimenting with various cable-laying devices, found that the combination of a cable plough and a tractor was very successful. In the hard clay of the Sudan clay plain, with the ground free from major obstructions, cable could be laid at a depth of 80 cm at a rate of 3 km per hour. The whole of the Khartoum-Sennar two-cable route was laid in 23 working days.

Figure 4 shows cable-laying in progress. The blade of the plough is fitted with a curved guide along the trailing edge down which the cable is drawn as the

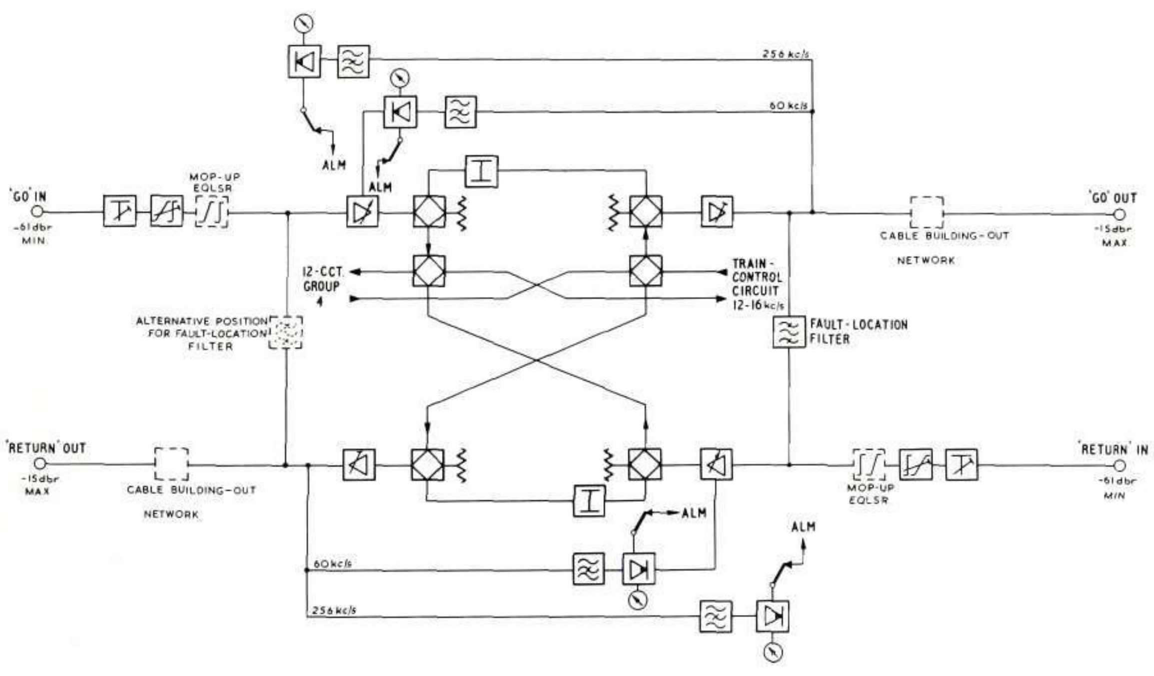


Figure 5—Simplified block schematic of Main Repeater Circuit

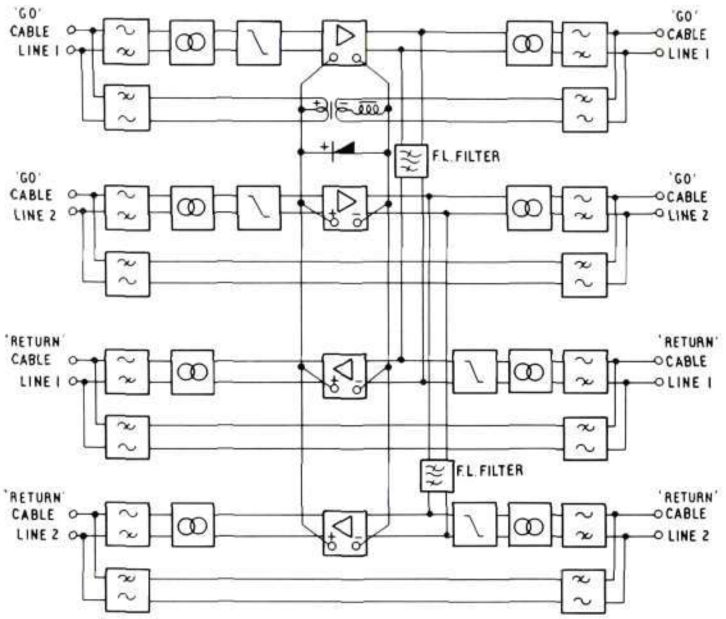


Figure 6—Block schematic of buried-repeater circuit

plough moves forward, and a heavy chain, dragged behind, serves as a useful earth-levelling device.

The plough is towed by a Caterpillar D9 tractor which may be equipped with a hydraulically-operated ripper tooth to break up the ground ahead of the plough if necessary.

Cable Balancing

The Khartoum-Sennar scheme has two 60-circuit systems in parallel and, since both pairs of each quad are used for traffic, far-end crosstalk between the pairs is important. The cable specification calls for a crosstalk attenuation of better than 74 db per kilometre length at 60 kc/s; at the highest frequency used (256 kc/s), the crosstalk is approximately 10 db worse than this.

With the route length being 280 km, this degree of attenuation was obviously inadequate and, although the balance of an average length was found to be about 6 db better than the specified figure, crosstalk balancing was found to be necessary.

It was decided that a convenient cable section for balancing was the length between intermediate repeaters. Far-end crosstalk was measured on each section, and it was found that by adding capacitance between a conductor of one pair and a conductor of the other pair at the far end, a crosstalk attenuation figure of 75 db at 250 kc/s per section was attained. The small, fixed polystyrene capacitor was fitted permanently into the cable in the epoxy-resin cable joint.

Line Equipment

As indicated by the curve shown in Figure 2a, the transmission loss of the cable is comparatively high, consequently it is necessary to install repeaters at frequent intervals along the route.

There are two types of repeater, main and intermediate. Main repeaters are rack mounted and installed in buildings where power supplies are available. They serve the triple functions of:—

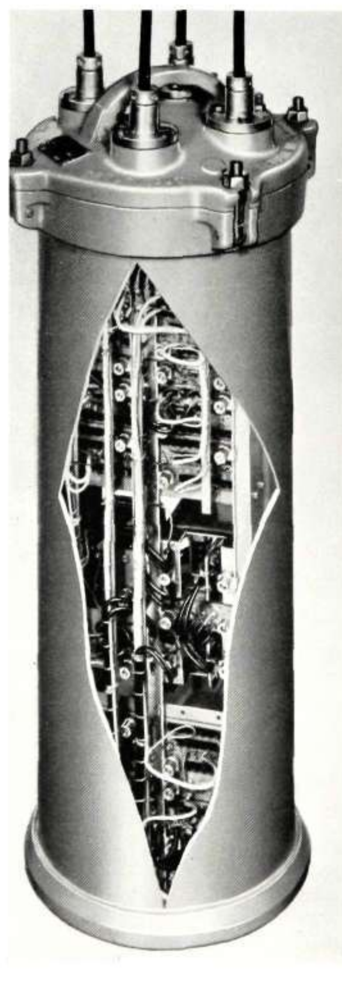


Figure 7—Cut-away photograph showing internal apparatus of intermediate repeater mounted in air-tight container for accommodation in concrete manhole

Figure 8—Engineers installing intermediate repeater (author 2nd from right)

(*a*) feeding power to the intermediate repeaters, (*b*) providing automatic-gain regulation to compensate for changes in cable attenuation due to climatic conditions and (*c*) providing facilities for dropping circuits. On this scheme, the main repeaters are at El Masid, Abu Usher and Hag Abdullah; a circuit schematic is shown in Figure 5.

The intermediate repeater, the circuit of which is shown schematically in Figure 6, is actually a pair of 4-wire repeaters providing amplification and equalization for the two parallel 60-circuit systems. The equipment is mounted in a cylindrical air-tight container, which is housed in a concrete manhole. A cut-away illustration of the container is shown in Figure 7.

The manhole consists of an open-ended pipe through the bottom of which the cables are fed. The pipe is buried upright in the ground and the bottom is sealed by pouring in concrete. The lip of the manhole protrudes approximately six inches above ground level to prevent surface water running inside, and a concrete lid is affixed by nuts and bolts, a neoprene gasket helping to prevent the ingress of moisture. Finally, the lid is covered with earth to insulate the manhole and its contents from the direct rays of the sun. Figure 8 shows a repeater being installed.

Repeater Spacing and the Principles of Equalization

Fundamentally, the length of cable between two repeaters is limited by the power-handling capability of the repeater amplifier which in turn is restricted by the necessity to limit the power fed along the cable; the power supply to each amplifier is approximately 16 mA at 11 V and this restricts the overload point to + 10 dbm.

To reduce the possibility of intermodulation noise, the nominal transmitting level should be as far as possible below the overload point but, if the level is reduced too far, the input level to the amplifier approaches the inherent noise level, and the amplifier gain must be reduced. A compromise must therefore be effected between inherent noise, intermodulation noise and amplifier gain, and it was found that the optimum condition was a 43 db-gain amplifier with a nominal transmitting level of − 15 dbr.

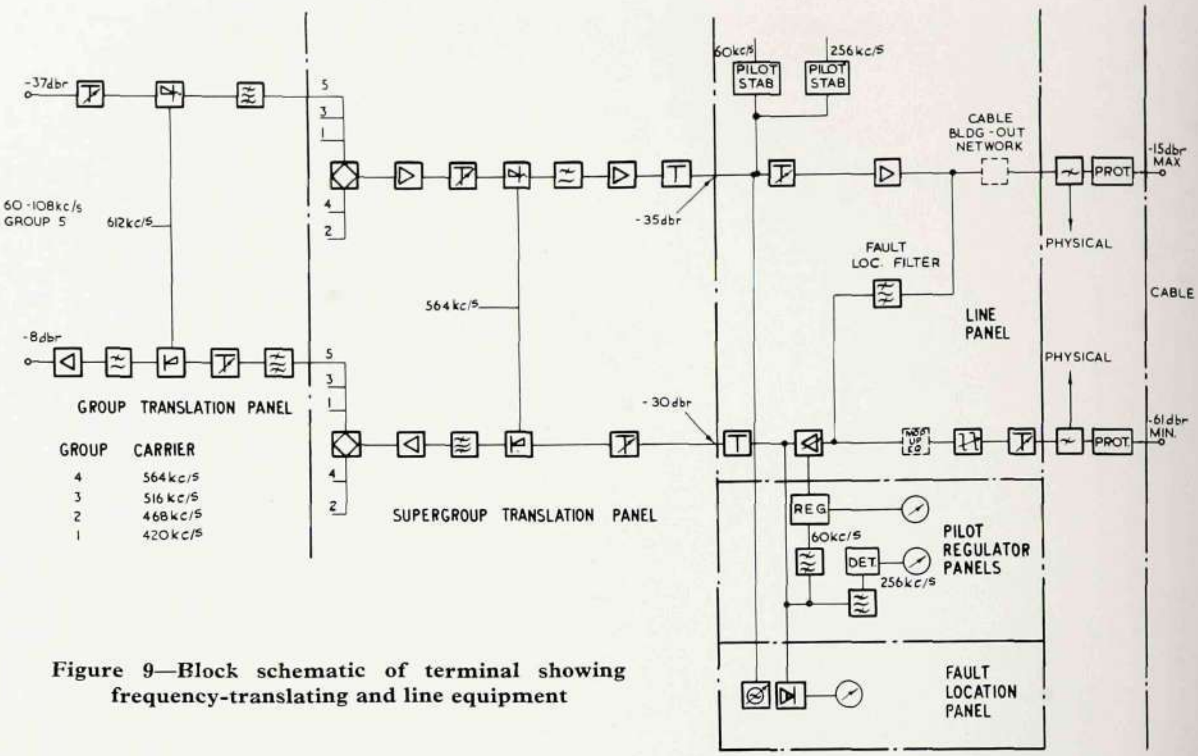


Figure 9—Block schematic of terminal showing frequency-translating and line equipment

Equalization for the attenuation/frequency characteristic of the cable is, in the main, carried out by a cable equalizer, fitted in the intermediate repeater circuit. which equalizes the slope of approximately 9 km of cable. The equalizer is fixed but can be made to compensate almost exactly for the cable by judicious adjustment of two variables, i.e., the length of cable between repeaters, and the

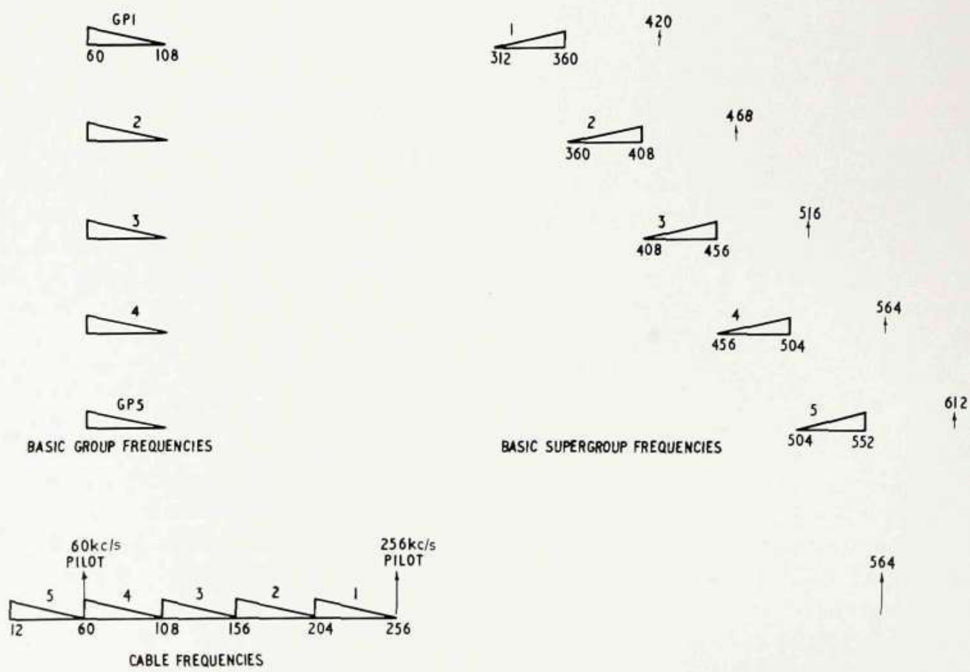


Figure 10—Frequency spectrum diagram showing derivation of base-band frequencies

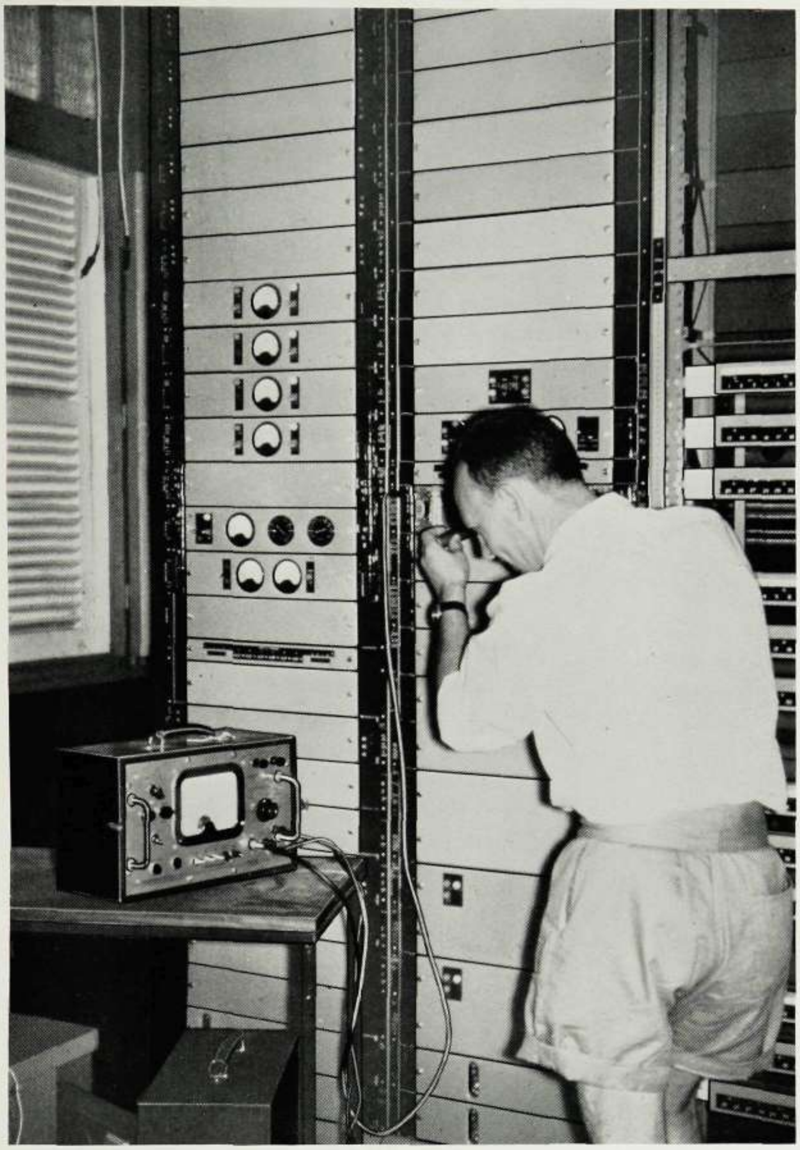


Figure 11—Some of the equipment at the Khartoum terminal: translating and line equipment rackside on left

amplifier gain which is adjustable in 1 db steps from 40 to 47 db.

The residual slope is corrected by variable cable equalizer units, which are fitted in the receive input circuits of the main repeaters and terminals and also serve to compensate for lengths of cable less than the nominal repeater spacing. In series with the variable cable equalizer is a 'mop-up' equalizer which compensates for the cumulative error in the equalization.

Terminal Equipment

The bulk of the equipment at a terminal consists of ETG. 121[1] type channel-translating racksides and an ETFG. 601 frequency generator rackside (described elsewhere in this issue), but there is also an ETC. 601 type terminal rackside which mounts all the translation and line equipment shown schematically in Figure 9.

In the transmit direction, five 60–108 kc/s groups are translated by carriers of 612, 564, 516, 468 and 420 kc/s to produce a basic 60-channel supergroup in the frequency range 312–552 kc/s. This supergroup is further translated by a carrier of 564 kc/s to produce the line frequency spectrum 12–252 kc/s. A frequency spectrum, showing the derivation of this group, is shown in Figure 10.

The output to line is –15 dbr, and pilot frequencies of 60 and 256 kc/s are transmitted to line at –27 dbm, i.e. 12 db below nominal sideband level.

In the receive direction, the incoming 12–252 kc/s band is translated back to the basic 60–108 kc/s, using the same carrier frequencies as in the transmit direction. The minimum input level to the equipment is –61 dbr.

Some of the equipment at the Khartoum terminal is shown in Figure 11, the translation and line equipment rackside being on the left.

Power Supplies

All the rack-mounted equipment is designed to operate from a 24-volt positive-earthed d.c. supply which may be derived from a.c. mains by a power panel mounted on the racks.

The availability of mains power supplies is limited in the Sudan and, when the scheme was installed, the terminal stations only (Khartoum, Wad Medani and

[1]Bulletin No. 45, pp. 66-71

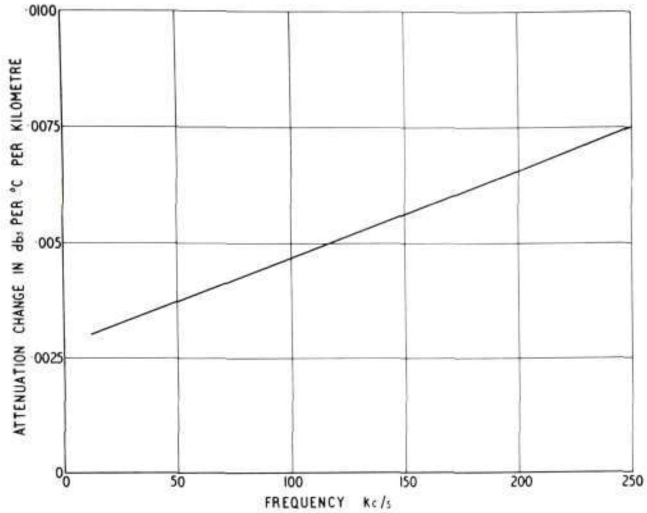


Figure 12—Typical temperature attenuation frequency characteristics of Khartoum-Sennar cable

Sennar) had mains power. At the main repeater stations (El Masid, Abu Usher and Hag Abdullah) power is obtained from batteries which are periodically charged by diesel generators.

The intermediate repeaters are power-fed from the nearest terminal or main repeater over the phantom of the ' Go ' cable pairs, an 80 + 80 volts d.c. power panel or an 80 + 80 volt telegraph type battery being used.

The current is stabilized at 65 mA by a barretter, a variable series resistor also being fitted so that the voltage across the barretter may be adjusted to its optimum operating range. Under these conditions the current will not change by more than 5% from nominal if the cable resistance and the power feed voltage vary by up to 10% simultaneously.

AUTOMATIC LEVEL REGULATION

The cable was laid approximately 80 cm below the surface and at this depth the temperature change of the cable, summer to winter, is about 8°C. The change in cable attenuation, shown approximately in Figure 12, is such that over the whole 280 km route the attenuation at 60 and 250 kc/s reduces by 10 and 16 db respectively from summer to winter.

To cater for this level change, a 60 kc/s pilot at a level of -27 dbm (-12 dbmO) is fed into the cable at each terminal and automatic regulation equipment, under control of this 60 kc/s pilot, is fitted at each terminal and main repeater.

The circuit of the equipment is shown schematically in Figures 5 and 9. The pilot is picked off at the output of each receive amplifier by a narrow-band crystal filter and is then amplified and detected. The d.c. produced is applied to the heater of a thermistor, which is wired in the feedback path of the receive amplifier in such a manner that if the pilot level rises due to a reduction in cable temperature, the amplifier gain is reduced to bring the level back to normal. Series and parallel resistors are included in the feedback circuit so that the gain variation is limited to ±6 db of the nominal gain of the amplifier.

The pilot level is constantly monitored by a meter, calibrated in db relative to nominal level, and audible and visual alarms are given in the event of the regulated level moving by more than 2 db from nominal.

The regulation is flat, i.e. to compensate for the 10 db change in cable attenuation at 60 kc/s the amplifier gains are changed by 10 db over the whole frequency range. The extra 6 db change at 250 kc/s is not compensated but an extra pilot at 256 kc/s is injected and monitored in a similar manner to the 60 kc/s pilot, and alarms are similarly given when the level, after regulation, moves more than 2 db from nominal so that a manual adjustment of the variable cable slope equalizer may be made.

CHANNEL DROPPING AT MAIN REPEATERS

A feature of the system is that limited dropping facilities are provided simply and cheaply. Group 4 occupies the same frequency band in the 12–252 kc/s line frequency spectrum as the basic 12-channel group, 60–108 kc/s (see Figure 10) and may be extracted at main repeaters from the through-transmission path by means of hybrids as shown in Figure 5, and taken straight to standard ETG. 121-type channelling equipment without using group translation equipment. Similarly, channels 10, 11 and 12 of group 5 may be picked off, using special channel panels.

The initial channel dropping facilities are shown in Figure 1. Since only a limited number of dropped circuits was required, it was possible, in the interests of economy, to waste some of the frequency spectrum but, if it had been necessary, the facilities could have been extended by fitting band-stop filters so that the same frequency spectrum could have been used on both sides of each main repeater, thus doubling the number of circuits available.

Cable Physical Circuits

Another requirement of the scheme was that local circuits should be made available so that each railway way-station would be able to communicate with its immediate neighbours both by magneto telephone and by d.c. signalling devices. To this end, the four cable physicals were used, by-pass filter equipment being provided at all way-stations and line filters being fitted in all repeaters and terminals. A picture of the wall-mounted by-pass equipment in Soba way-station is shown in Figure 13.

Since the cable pairs are unloaded, the physical circuits are of low quality. For instance, the attenuation of 20 km of cable varies from approximately 6 db at 300 c/s to 20 db at 3 kc/s and the mismatch of the line filters to the cable impedance considerably increases this loss. However, a workable circuit is obtained in the worst case: the 28 km length between Wad el Haddad and Sennar Junction.

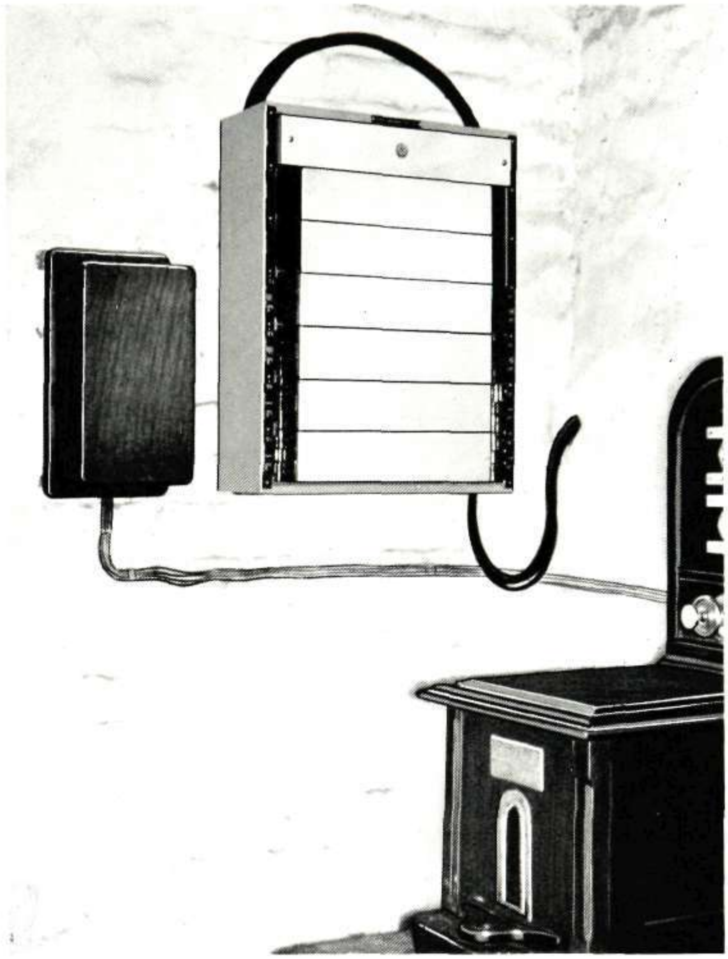


Figure 13—By-pass equipment at Soba way-station

Train Control System

Over the original open-wire route, a railway signalling-control system operated, each way-station telephone being connected on a party-line basis with a Controller in Khartoum. A selective calling system operated by the Controller enabled him to call any way-station by high voltage $3\frac{1}{2}$ c/s a.c. pulses. The system was unworkable over the cable due to the greatly increased losses at both speech and signalling frequencies.

It was desirable that the railway signalling apparatus should be disturbed as little as possible and, in order that this equipment could remain as it was, a scheme was devised using a carrier circuit (Channel 12, group 5) to the nearest main repeater or terminal, reducing the distance over which the cable physical is used to a maximum of 30 km.

The dropping-off of this circuit is illustrated in Figure 1. The carrier channel is carried through from Khartoum to Sennar on a party-line basis, being dropped off at El Masid, Abu Usher, Wad Medani and Hag Abdullah, and fed into the physical of line 2 of the 'Return' cable in both directions at these points. This necessitates matching units and the modification of the carrier levels to cater for the higher power requirements.

A block schematic of part of the new signalling system is shown in Figure 14. The sending apparatus at Khartoum is as it was with the original open-wire system but a relay-set is used to convert the $3\frac{1}{2}$ c/s high voltage signalling (which is still used to feed into the cable physical) into E & M, for signalling over the carrier system, and a hybrid feeds the speech from the telephone into the carrier system and the cable physical simultaneously. At the main repeater, a further relay-set is used to convert the E & M into the original $3\frac{1}{2}$ c/s, and a hybrid feeds both speech

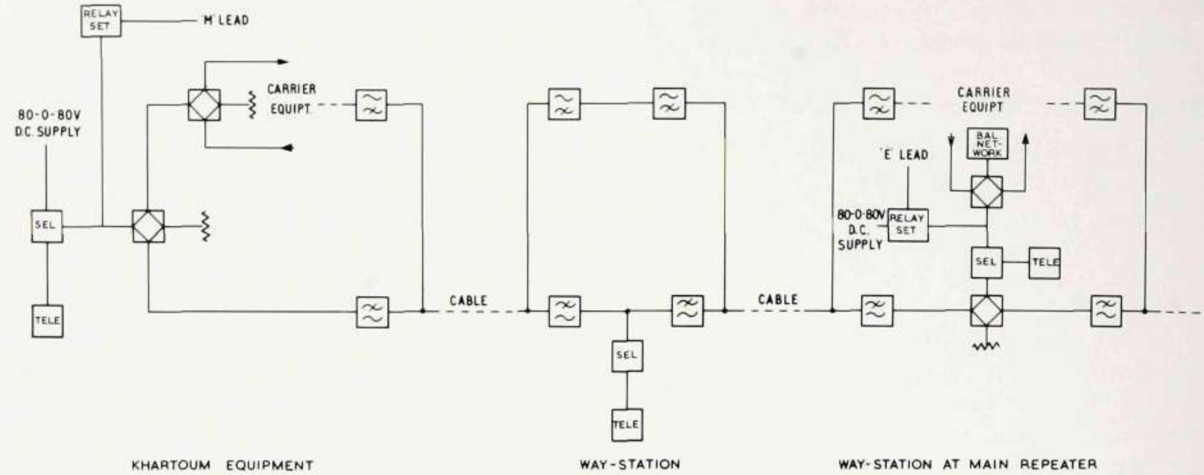


Figure 14—Block schematic of typical train-control circuit

and signalling frequencies into the cable physical circuit in both directions. At the way-stations the original equipment is unchanged, speech and signalling frequencies being picked off from the cable in exactly the same manner as with the open-wire line.

BASE-BAND SWITCHING

Provision is made for the link to be modified from two separate traffic-carrying 60 circuit systems to one system, operating over either of the two transmission paths on a ' Main and Standby ' basis with automatic changeover. The terminal and repeater racksides are wired for baseband switching panels but will not be equipped until it is decided, at a later date, to put the changeover system into operation.

With a system using ' Main ' and ' Standby ' paths, changeover is effected on failure of the 60 kc/s pilot on the ' Main '. The standby path, although not normally carrying traffic, is kept in an immediately usable state by the fact that it is always under the control of its own 60 kc/s pilot.

If the main path fails, alarms are given and the base-band is switched on to the standby path by static relays. The base-band may be held on the standby path while the pilot is re-injected manually into the main path in order to determine the faulty section of the link. After the fault has been repaired, switching back to ' Main ' is effected by re-injection of the pilot.

Alarms are also given on failure of the standby path, and switching of the base-band on to the faulty path is prevented.

This sytem has the obvious disadvantage that only half of the total capacity of the link may be used. To remedy this, provision has been made to use the standby path to carry non-priority traffic so that, on failure of the ' Main ', the priority circuits are switched to ' Standby ' and the non-priority circuits are switched to the faulty main path.

FAULT LOCATION

In the event of a transmission failure, it is essential that it should be possible to locate the fault quickly and to this end a fault location system is incorporated in the scheme.

At each fault locating station a panel is provided containing a switched variable oscillator and a level-measuring set. Tones are fed along the cable from a fault locating station; each terminal and repeater includes a narrow-band filter which allows one particular tone to leak across to the return path and thus the tone is transmitted back to the originating station where it is monitored and its level noted. Any particular tone which is not returned to the originating station is indicative of failure in the equipment appropriate to that tone.

The intermediate repeater fault locating filters are plug-in units, and a stock of the complete range is held in Khartoum together with two spare repeaters. If a working repeater fails, one of the spares will be fitted with the appropriate filter from the stock to make it identical with the faulty repeater so that a complete repeater replacement may be carried out quickly by cutting and rejointing the cable tails without unsealing the repeater canister in the field.

A total of sixteen tones is available, the frequencies being spaced at 300 c/s intervals from 6 to 10·5 kc/s. As may be seen from Figure 1, the fault-locating stations are at Khartoum and Wad Medani; from Khartoum the link is tested as far as the last intermediate repeater before Abu Usher; from Wad Medani the link is tested, in one direction, as far as, and including, the main repeater at Abu Usher, and in the other, the whole Wad Medani-Sennar link.

Protection

The southern section of the route is exposed to a considerable amount of lightning in summer and the proximity of the whole of the route to the adjacent 110 kV power line gives rise to the possibility of high induced voltages in the cable due to power-line fault conditions. The main protection is by gas discharge tubes, which strike at 150-200 volts and are fitted between each conductor and earth wherever the cable comes above ground.

Although this arrangement ensures safety to personnel by limiting the voltage, heavy currents in the conductors may result, necessitating extra protection for the repeater amplifiers which are fed along the cable. Zener diodes are therefore fitted across the supply terminals of the amplifiers to ensure that the voltage across these terminals is not excessive, and series chokes are included in order to prevent heavy currents damaging the diodes.

In principle, all the equipment and the cables are earthed at the terminals and main repeaters only. The continuous metallic circuits are kept as short as possible but, due to the fact that the power for the intermediate repeaters must be fed along the cable, the breaking up of the link into segments as short as possible to limit the build-up of induced voltages is limited. The best that could be done in this respect was to break the power feeding circuits at the mid-points between main repeaters and feed the power from both ends, thus limiting the continuous metallic path to half the distance between main repeaters.

In general induced voltages are longitudinal but any unbalance will cause transverse voltages to appear between the conductors of the cable. The transistor line amplifiers are vulnerable to these transverse voltages and protection is provided by fitting germanium diodes between the transistor base and emitter.

Conclusion

The scheme has proved that, in open and sparsely populated country, ploughed-in cable together with power-fed repeaters designed to suit the particular cable, is a financially attractive proposition. It would appear that on the basis of the figures quoted in Mr. Burton's article (see 'Acknowledgments') together with present day costs of cable and equipment, it could be expected to obtain CCITT-quality circuits for less than £6 per kilometer-circuit even for a system not fully equipped for 120 channels.

Acknowledgments

The author is indebted to R. N. Burton, M.I.E.E., until recently Chief Engineer of the P & T Department of the Republic of Sudan, who planned the scheme and gave much useful advice on the design of the equipment. The facts and figures on cable laying and the photograph of Figure 4 have been taken from Mr. Burton's article 'A low-cost trunk cable system' which appeared in the March 1961 issue of 'British Communications and Electronics'.

The author also gratefully acknowledges the assistance given by the engineers of the Sudan P & T Department, in particular by Mustafa Awad Allam who was the executive engineer in charge of the installation of the scheme.

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SLIDING CONTACTS IN AUTOMATIC TELEPHONE APPARATUS, TWO-MOTION SWITCHES

The improvement of bank and wiper performance in two-motion switches has for some time been the objective of applied research in the Company's Laboratories. This article describes some of the investigations and sliding contact wear phenomena which have led to the production of a flush-type, nylon-insulated bank of outstanding mechanical performance.

The work is based mainly on further exploration of the dry-transfer lubrication technique devised originally by the B.P.O. Research Department, Dollis Hill.

THE progressive improvement of long-term electrical efficiency and durability of bank and wiper contacting members in two-motion automatic selector apparatus is an important aspect in the technical development of the step-by-step switching system. In this system, economics and accepted practice require the use of base metals (e.g. nickel-silver alloys or brass) for banks and wipers, in contrast to the general application of noble metals for relays and other similar devices. Moreover, unless equipment racks are dustproofed,[1] the bank contacts of 2-motion switches are open to the atmosphere within the telephone exchange building, whereas relay and other contacts are protected by well-constructed covers.

Nevertheless, the technical and service requirements for the two-motion selector are exacting. For example, with an 'A' digit selector, over 7,000,000 operations may be involved during an exchange life of up to 35 years, so that a target performance, for a switch to function efficiently for 6,000,000 calls (600,000 per bank level) is realistic. Fundamentally, a satisfactory operational life depends on minimum inter-metallic wear between wiper and bank contacts, combined with the maintenance of 'low' electrical resistance.

A recent paper[2] presented to the Institution of Electrical Engineers, 'Long-Life Low-Voltage Contacts', provides an important survey of many aspects of existing knowledge in this field and, in particular, deals with performance standards, testing principles and methods of construction. The paper recognizes that the behaviour of sliding metal contacts is largely determined by the properties of any surface films which may be applied or result from the environment. Also, the development of improved performance and durability involves the provision or control of these films. For example, it is established that very thin films of lubricant are most effective in minimizing metallic wear, but are nevertheless penetrable in the electrical sense. However, the advantages offered by oil-trace lubrication are soon negated and the technique rendered ineffective if the surfaces are subjected to the deposition of dust films; gritty particles accumulate and inter-metallic wear is progressively increased. Thus, it is stated that 'test procedures which purport to be realistic must take account of all the effects of environment. This is not a simple requirement since it involves answering a question which may have no single simple answer'.

The paper discusses means of reducing inter-metallic wear by a technique described as 'dry-transfer lubrication'. This was devised by the B.P.O. in 1951 for application to sliding contacts as used in the Strowger system of automatic telephony. The wiping contacts slide over an area of plastic material at least once during each switching cycle. Initial experiments were carried out with polytetrafluorethylene (p.t.f.e.) and marked reductions in inter-metallic wear were observed. This was apparently due to the transfer of minute traces of the plastic to the wiping contacts, resulting in a system of lubrication, and it was suggested that similar results could be obtained with other metal-to-plastic combinations. Thus, a new field of investigation was proposed for improving the contacting efficiency of two-motion selectors.

Electrical contacting devices are of such fundamental importance to the Telecommunications Industry that considerable research and development effort in this field is maintained. The Company's contribution is provided by the metallurgical and plastics laboratories, where special techniques have been developed for study and evaluation of materials used in the construction of banks and wipers.

[1]See 'Protection and Dust-proofing of Electrical Equipment', Bulletin No. 44, pp. 16-23

[2]A. Fairweather, F. Lazenby and A. E. Parker, I.E.E. Paper No. 3789E, February 1962

Figure 1—General view of disc and wiper test

FACTORS WHICH INFLUENCE TEST PROCEDURES

In formulating laboratory tests, it should be realized that the rate and nature of metallic wear between all forms of ' rubbing ' contact surfaces depend on a number of factors:

(*a*) The metallurgical properties and characteristics of the different metals which are in rubbing contact.

(*b*) Surface lubrication. This is a matter of the greatest importance, since the maximum rate of metallic wear occurs when surfaces are ' chemically clean ', solvents having removed all traces of lubricating film including that which results naturally from manufacturing processes.

(*c*) The nature of the insulating material over which the moving members must pass during transit from one contact to another.

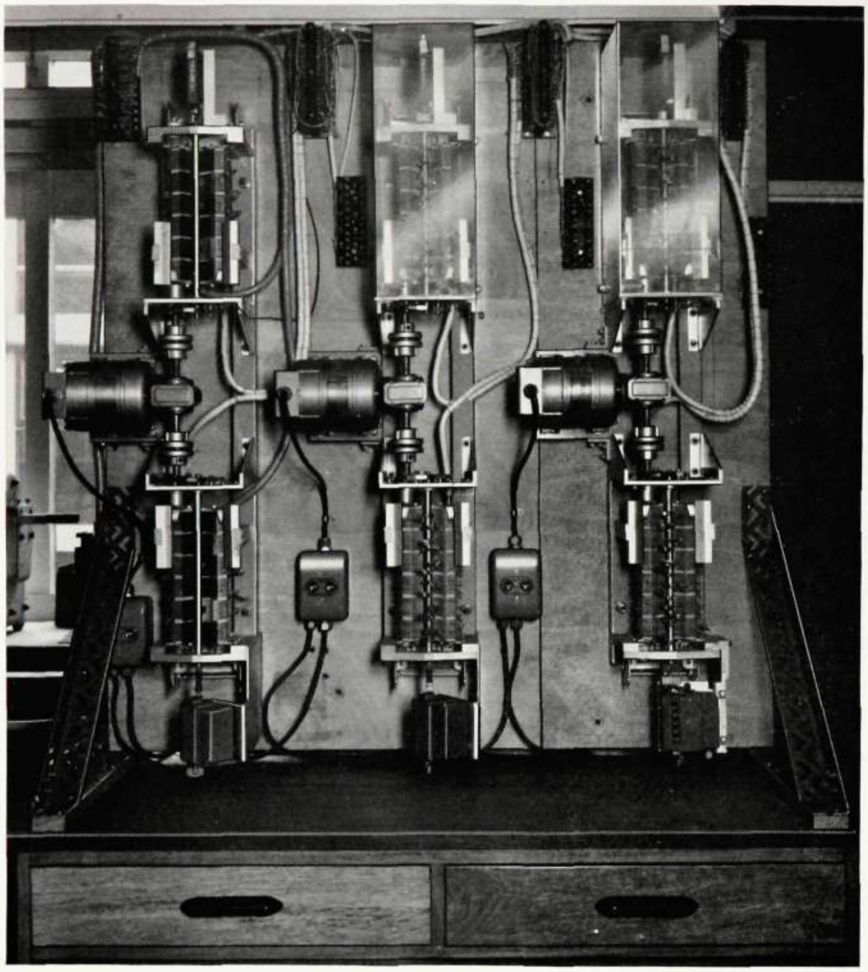
(*d*) Some forms of dust or dirt which can violently accelerate contact wear. In the Middle East, for example, the presence in telephone exchanges of airborne fine silica sands has resulted in severe abrasive conditions.

(*e*) Spark erosion of electrically-loaded contacts, especially in highly inductive circuits, where high-voltage transients may rapidly accelerate metallic wear.

(*f*) Chemically-active constituents of the atmosphere; these may produce conditions of a corrosive nature.

The testing procedures used by the Company's laboratories to study sliding contact phenomena are designed to assess the influence of each factor and are largely based on the following:—

(*a*) The rotating disc-and-wiper method (Figure 1) which is used for the comparison and evaluation of basic or elementary frictional and wearing properties of different materials at normal wiper speeds and pressures.



rigid back-plate as in Figure 3 with a rotating wiper in contact with their surfaces. The wiper tip describes a circular path equal in diameter to that of a similar wiper operating on a two-motion switch and the speed of rotation and wiper tension are adjusted to those of a normal switch. The wiper travels a distance equivalent to 500,000 wipes on a single two-motion switch level and the test conditions therefore bear a definite relationship to practice.

The wear characteristics of metals and plastics are determined with materials which are thoroughly cleaned and free from traces of grease and other contaminants by solvent washing.

Control data are established for contacts and wipers of brass and nickel silver and separators fabricated in p.v.c. and s.r.b.p., these being the

Figure 2—Motor-driven bank testing machine

(*b*) The use of a motor driven unit (Figure 2) which incorporates normal banks and wipers and reproduces horizontal stepping speeds and conditions via ratchet and pawl.

Since it is almost impossible to develop accelerated bank and wiper tests which simultaneously take into account all the above factors, it is important that any laboratory tests are supplemented by trials in a telephone exchange, where relevant conditions are known and recorded.

Disc and Wiper Measurements

As new materials become available for manufacture of bank and wiper components, a standard testing procedure is used to provide a precise quantitative evaluation of their characteristic wearing properties. Metal or plastic discs are secured horizontally to a

Figure 3—Disc and wiper

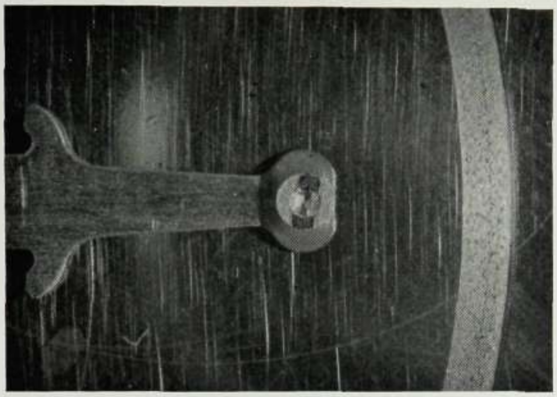


Figure 4—Nickel-silver wiper and disc
Without lubrication
Wiper loss : 2,300 μ gms

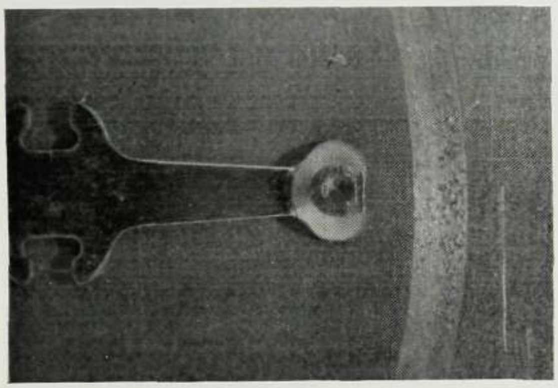


Figure 5—Nickel-silver wiper, brass disc
Without lubrication
Wiper loss : 3500 μ gms

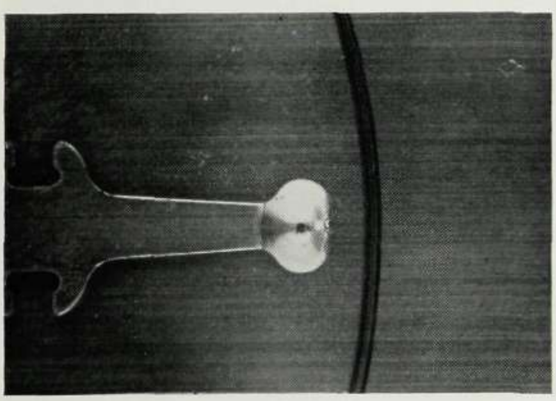


Figure 6—Nickel-silver wiper and disc
Film lubricated
Wiper loss : less than 10 μ gms

materials in current use. For example, Figure 4 shows the wiper and track when a nickel-silver wiper is run in conjunction with a nickel-silver disc in dust-free air and without lubrication. The wiper (shown here reversed for illustration purposes, as are all other wipers in succeeding photographs) is severely worn, but a satisfactory assessment and record can be made only if the wear is expressed quantitatively. The weight of metal removed from the wiper tip is the most convenient measure of wear, and this can be estimated with reasonable accuracy.

One of the techniques of metal-loss measurement developed by the laboratories is based on the regular geometrical shape of the Type 22 wiper. When wear at the tip is not excessive, the metal removed is represented by a missing spherical cap since, to a first order approximation, the wiper tip is part of a sphere. It is therefore possible to calculate the weight of eroded metal by microscopic measurement and to express the wear in terms of this weight.

If wear is severe, as with the dry nickel-silver disc and wiper, a hole is formed in the wiper and the metal loss is no longer simply related to the projected diameter at the tip. At this stage, therefore, the relationship is determined by accurate weighing.

Other methods of wear assessment include micro measurement of wiper track and the construction of solid plastic replicas for estimating metal loss on individual contacts, but these are not discussed in this article.

When measured by the wiper-loss technique, the wear shown in Figure 4 is equivalent to 2300 μ gms (micrograms) of metal loss. A nickel-silver wiper in conjunction with a brass disc is shown in Figure 5. As before, the test was carried out in dust-free air and without lubrication, the metal loss under these conditions being 3500 μ gms.

Application of lubricants, even in minute quantities, causes a most marked reduction in inter-metallic wear. Figure 6 shows the effect of a thin film of light lubricating oil (P.O.16) applied with an impregnated pad to a nickel-silver disc and wiper. The metallic wear is reduced from 2300 μ gms to less than 10 μ gms, confirming the need, widely established in practice, for a system of film lubrication on base metal contacts. Similar results are obtained with brass discs.

Nickel-silver wipers are also tested in conjunction with plastic discs to establish the extent of plastic-to-metal abrasion. In all cases, the wiper wear is much

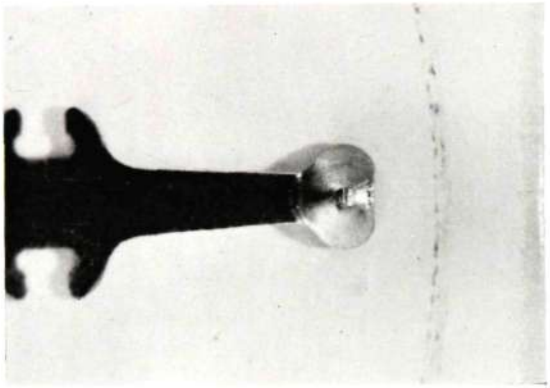


Figure 7—Nickel-silver wiper, p.v.c. disc
Without lubrication
Wiper loss : 40 μ gms

Figure 8—Nickel-silver wiper, s.r.b.p. disc
Without lubrication
Wiper loss : 40 μ gms

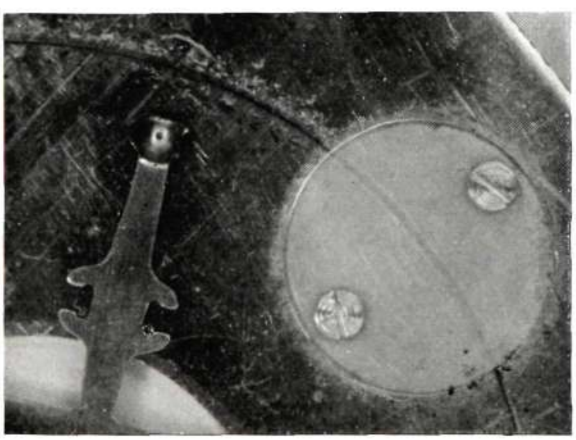


Figure 9—Nickel-silver wiper and disc
One p.t.f.e. insert
Wiper loss : less than 10 μ gms

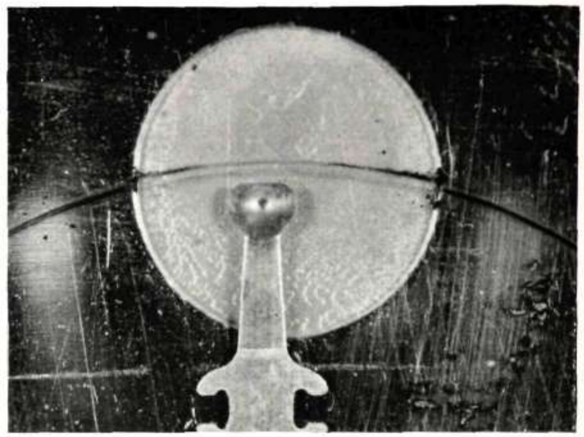


Figure 10—Nickel-silver wiper and disc
One nylon insert
Wiper loss : 14 μ gms

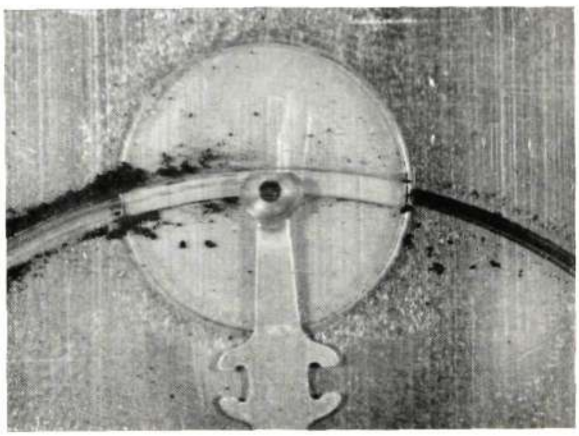


Figure 11—Nickel-silver wiper, brass disc
One nylon insert
Wiper loss : 500 μ gms

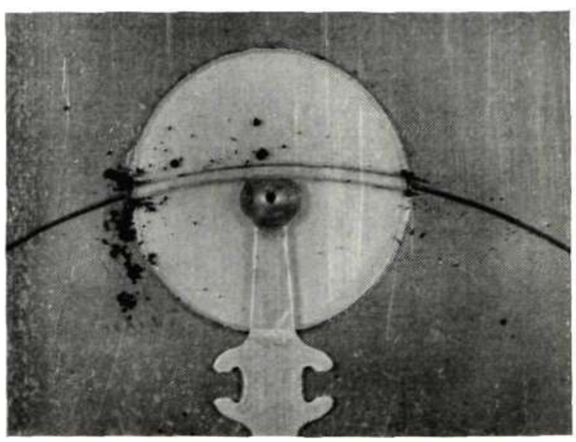


Figure 12—Nickel-silver wiper, brass disc
Four nylon inserts
Wiper loss : 22 μ gms

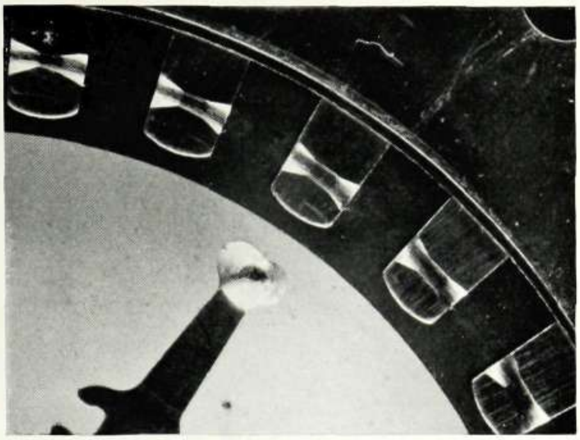


Figure 13—S.R.B.P. Separator (250,000 wipes)

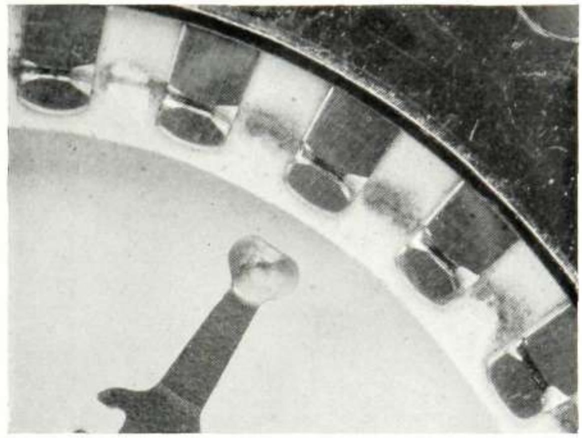


Figure 14—P.V.C. Separator (250,000 wipes)

Typical levels showing wear which occurs without lubrication
(All traces of lubrication chemically removed before testing)

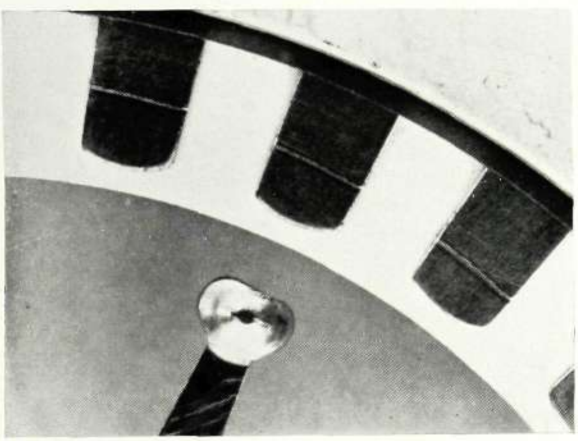


Figure 15—P.V.C. Separator (280,000 wipes)

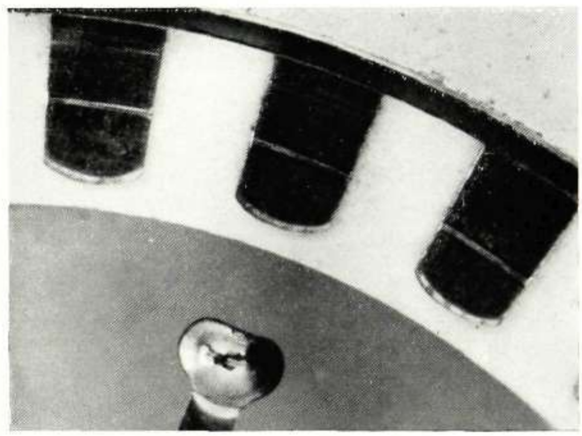


Figure 16—P.V.C. Separator (800,000 wipes)

Reduction in Metallic Wear when levels are cleaned and lubricated after each 40,000 wipes

Figures 13 to 16

INFLUENCE OF FILM LUBRICATION ON BANK CONTACTS WITHOUT ELECTRICAL LOADING

less pronounced than with metal discs (Table 1). Typical examples are p.v.c. (40 μ gms) and s.r.b.p. (53 μ gms) shown in Figures 7 and 8. A great variety of plastic materials were tested in conjunction with nickel-silver wipers including nylon, polyacetal, polyester and p.t.f.e.

Experiments with Plastic Inserts

Having established the basic wear properties of dry and lubricated surfaces, the phenomenon of ' dry plastic lubrication ' was studied by a system of flush inserts pressed into the metal discs. These inserts are positioned so that the wiper tip passes over them during each revolution, without any change in level.

The first tests were carried out with p.t.f.e. inserts and nickel-silver discs. A typical example is shown in Figure 9, where the wiper loss is negligible, being less than 10 μ gms. This confirms the important original work carried out by the B.P.O. on dry-transfer lubrication with p.t.f.e. on two-motion switches. However, further trials with pressed inserts demonstrated that a variety of other plastic materials produce a considerable reduction in wiper wear. For example, the introduction of one nylon insert in

Materials		*Wiper Loss* (μ *gms.*)	
Wiper	*Disc*	*No Lubrication*	*Lubricated with P.O. No. 16 Oil*
Brass	Brass	7,500	4,500
Phosphor Bronze	Brass	1,800	18
Phosphor Bronze	Nickel Silver	18	12
Phosphor Bronze	Phosphor Bronze	63	48
Nickel Silver	Brass	3,500	183
Nickel Silver	Nickel Silver	2,300	10
Nickel Silver	P.V.C.	40	11
Nickel Silver	S.R.B.P.	53	12
Nickel Silver	Polythene	5	No tests with Lubrication
Nickel Silver	Polyester Film	2	
Nickel Silver	Nylon	10	
Nickel Silver	P.T.F.E. coated P.V.C.	3	
Nickel Silver	P.T.F.E. coated S.R.B.P.	10	
Nickel Silver	Nylon (loaded with Molybdenum Disulphide)	14	

Table 1—Basic wear characteristics of various wiper and disc materials with and without lubrication

Wiper Material	*Disc Material*	*Number of Inserts*	*Wiper Loss* (μ *gms.*)
Nickel Silver	Nickel Silver	Nil	2,300
Nickel Silver	Nickel Silver	P.T.F.E. (1)	Immeasurable
Nickel Silver	Nickel Silver	P.V.C. (1)	13
Nickel Silver	Nickel Silver	S.R.B.P. (1)	8
Nickel Silver	Nickel Silver	Nylon (1)	14
Nickel Silver	Nickel Silver	Polyester Film (1)	11
Nickel Silver	Nickel Silver	Polyacetal Film (1)	9
Nickel Silver	Brass	Nil	3,500
Nickel Silver	Brass	P.V.C. (1)	16
Nickel Silver	Brass	S.R.B.P. (1)	155
Nickel Silver	Brass	Nylon (1)	500

Table 2—Influence of plastic-insert materials on basic wear characteristics

Wiper Material	*Disc Material*	*Number of Inserts*	*Wiper Loss* (μ *gms.*)
Nickel Silver	Nickel Silver	Nil	2,300
Nickel Silver	Nickel Silver	Nylon (1)	14
Nickel Silver	Nickel Silver	Nylon (2)	25
Nickel Silver	Nickel Silver	Nylon (4)	33
Nickel Silver	Brass	Nil	3,500
Nickel Silver	Brass	Nylon (1)	500
Nickel Silver	Brass	Nylon (2)	56
Nickel Silver	Brass	Nylon (4)	22
Nickel Silver	Brass	Nylon (6)	23
Nickel Silver	Brass	Nylon (7)	40

Table 3—Effect on wiper wear of increased plastic-to-metal ratio

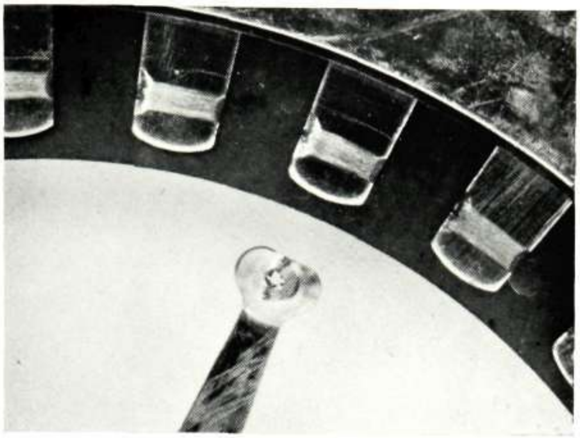
the track of a nickel-silver disc dramatically reduces the wiper wear from the original figure of 2300 μ gms to a loss of 14 μ gms (See Figure 10). Similar results are obtained for other plastic inserts in conjunction with nickel silver and these are detailed in Table 2.

With brass discs, a single nylon insert produces a substantial reduction in wear, but the effect is not as pronounced as with nickel silver. After the standard test, the wiper shown in Figure 11 has lost 500 μ gms of metal. Each insert occupies approximately 8% of the circular wiper track and, to study the effect of an increased plastic-to-metal ratio, additional inserts were spaced at regular intervals along the wiper track. The standard inter-metallic wiping distance was maintained by an appropriate increase in the number of revolutions.

Brass discs show a progressive reduction in wiper wear when the inserts are increased in number, and Figure 12 shows a typical wiper, with 22 μ gms of metal loss, after tracking the standard distance over four nylon inserts. On the other hand, the superlative results obtained with a nickel-silver disc and one nylon insert are virtually unchanged by the addition of further inserts as will be seen in Table 3.

Second Stage Testing Technique

Although disc and wiper tests provide a useful means of assessing basic wear characteristics, there are other factors which must be taken into account if selected materials are to be successfully employed as contacts and wipers in actual selectors. For example, the wiper track is often uneven, with the contacts situated at a different level from the areas of insulating material between them. Frequently, wipers must withstand considerable impact as they meet each contact and further impacts as they pass over the insulating material when leaving the contact. Furthermore, the applied circuitry frequently contributes to erosion at the contact faces. Subsequent trials are therefore carried out with normal banks and wipers fitted to a motor-driven machine which reproduces the horizontal stepping of a two-motion selector. The unit, shown in Figure 2, has facilities for dustproofing and for electrical connections to



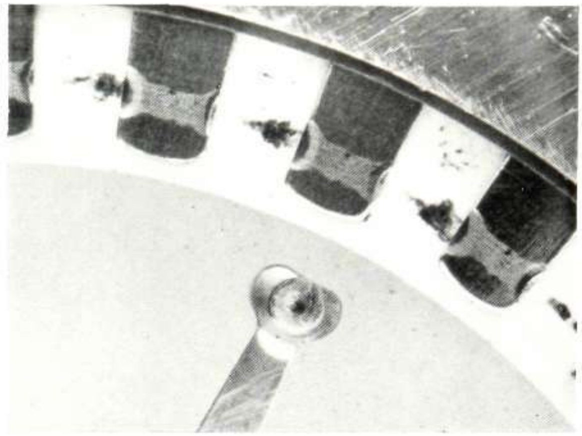
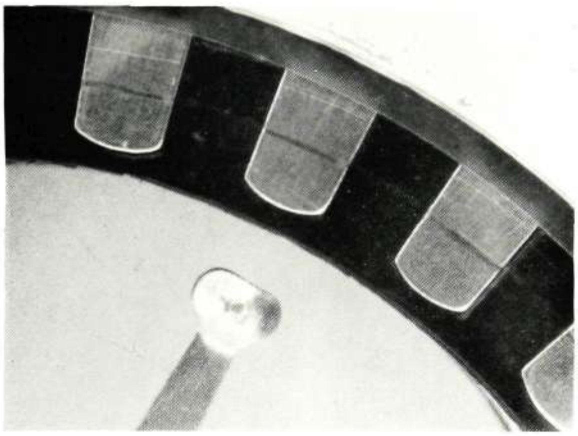


Figure 17—S.R.B.P. Separator (200,000 wipes) **Figure 18—P.V.C. Separator (200,000 wipes)**

Effect of severe electrical test conditions on levels without lubrication



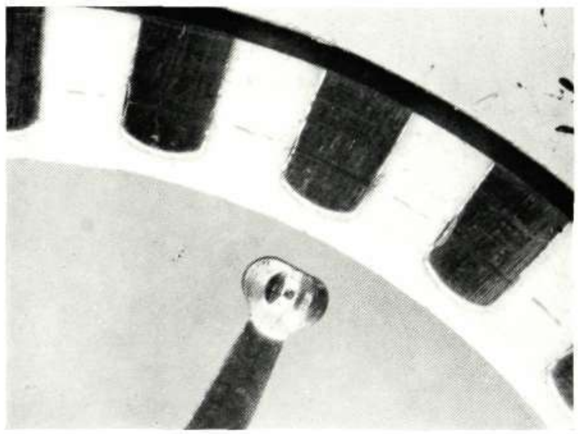


Figure 19—S.R.B.P. Separator (250,000 wipes) **Figure 20—P.V.C. Separator (250,000 wipes)**

Reduction in Metallic Wear when levels are cleaned after each 40,000 wipes

Figures 17 to 20

INFLUENCE OF FILM LUBRICATION ON CONTACTS WITH SEVERE ELECTRICAL LOADING

contacts and wipers. Wiper wear is calculated as before from microscopic measurement at the tip. In order to assess the effect of electrical erosion, provision is made for each pair of contacts to be connected in a simple external circuit consisting of a 200-ohm relay in series with a 50-volt battery; the wipers completing the circuit at each step. At regular intervals during each life test, the resistance between contact and wiper was measured at 1000 c/s with a maximum voltage of 40 mV. or current of 40 mA.

The testing procedure gives remarkably uniform and reproducible results while providing a means of carrying out a large number of tests on each individual theme or experiment. Figure 13 shows the basic wear which takes place between nickel-silver wipers and contacts with s.r.b.p. separators when no lubricating film or electrical loading is applied.

Total metal abrasion under these conditions is approximately 0·035 gms. A similar effect is obtained with a p.v.c. separator as shown in Figure 14, and numerous experiments have proved that, with this form of bank construction, different insulating materials have negligible effect on rate of inter-metallic wear.

The apparatus also demonstrates that controlled film lubrication virtually eliminates metallic wear. Figure 15 shows that negligible wear has taken place after 280,000 wipes on a level which has been cleaned and re-lubricated at intervals of 40,000 wipes. It is important to note that film lubrication involves the application of an imperceptibly thin layer of lubricant. The technique is effective over extended test sequences, and Figure 16 shows that there is little or no increase in wear after 800,000 wipes have been completed.

Tests on Selector Levels under Adverse Electrical Conditions

An important requirement in a sliding contact system is the 'tracking' resistance of the insulating material. This must be adequate to withstand the thermal effects imposed by the most severe electrical circuit conditions. Appropriate circuits have therefore been devised to simulate these conditions in conjunction with the life testing equipment. For example, in addition to operating a highly inductive circuit at each step, adjacent contacts are arranged to carry opposite potentials of 50V d.c. If metal dust is permitted to accumulate between the contacts, a conducting path is set up on the surface of the insulator and, in some cases, sufficient heat may be generated to burn the separator.

Figures 17 and 18 show the increased deterioration caused by this 'arcing' circuit when testing in conjunction with nickel-silver contacts and wipers free from lubrication. Clearly, there is a notable increase in wiper wear, while incipient burning can be observed on the insulating materials. (In these photographs the products of abrasion have been removed to facilitate observation.)

As with previous experiments, regular cleaning and film lubrication provides a most effective means of improving performance, and the results shown in Figures 19 and 20 contrast most favourably with those obtained with levels having no lubrication (Figures 17 and 18).

Wiper and separator faults are caused primarily by excessive wear and formation of metal dust between contacts. The most effective solution, therefore, is one which minimizes the degree of metal abrasion without loss of contact efficiency.

THE NYLON FLUSH SEPARATOR

The disc and wiper experiments have demonstrated that an insert of plastic material, fitted flush with the wiper track, produces a major reduction in wear. A similar reduction could therefore be expected in bank and wiper wear if the inter-contact areas were raised to the level of the contacts. Although a number of plastic materials give marked improvement as disc inserts, the choice of material for a flush-bank separator is limited to those which can readily be formed or moulded to the desired shape. In addition, it must be possible to manufacture to exacting tolerances with the maintenance of dimensional stability.

Stepped separators were produced in nylon with an experimental tool, and Figures 21 and 22 show the moulding and an exploded view of assembly. The dimensions and shape of the moulding are identical with the existing p.v.c. or s.r.b.p. separators, except for the increased thickness in front of and between the bank contacts. To avoid the possibility of any contact being recessed, the inter-contact areas are 0·003 inches below contact level.

Life tests on these flush-nylon levels were carried out first without lubrication or applied circuitry in dust-proof enclosures. With subsequent tests, the severe electrical circuits already described were applied.

Contact resistance measurements were made after each 25,000 wipes per level until either failure occurred or the life-test was discontinued.

Outstanding Performance of Flush Nylon Bank Construction

Figures 23 and 24 show typical flush-nylon levels after completing 750,000 wipes, with and without electrical applied circuitry.

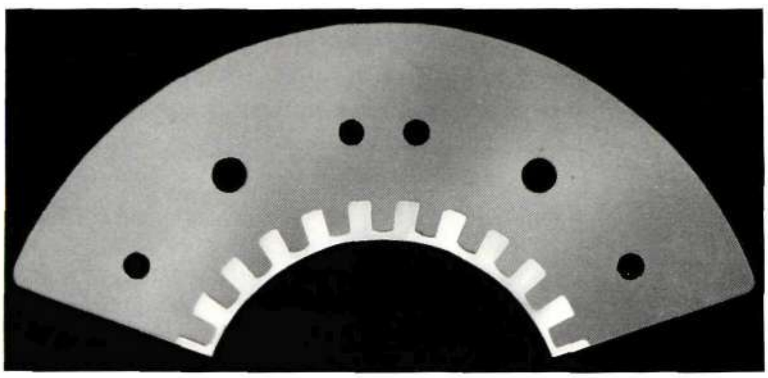


Figure 21—Stepped nylon separator

Figure 22—Bank Assembly with flush nylon levels

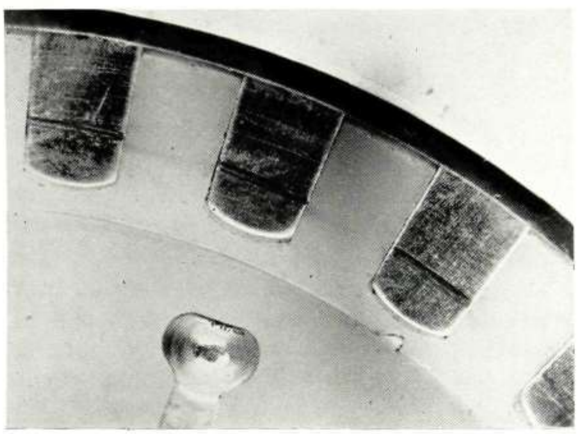


Figure 23—No electrical loading (750,000 wipes)

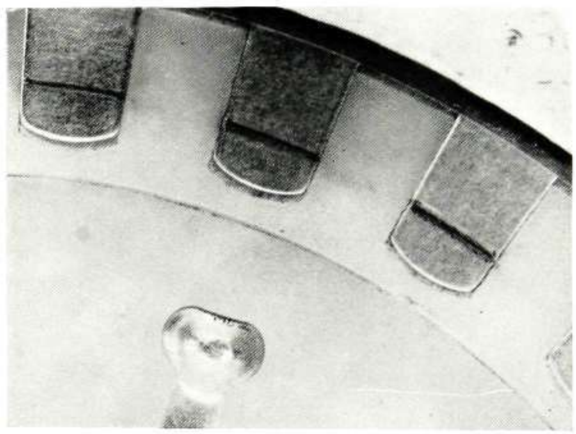


Figure 24—Severe electrical loading (750,000 wipes)

Flush nylon levels after completing 750,000 wipes without oil film lubrication or intermittent cleaning

As in the disc and wiper tests, the introduction of flush areas of nylon between contacts causes a remarkable reduction in wear. It has been suggested that this reduction is due to the transfer of minute quantities of plastic material to the wiper, thus providing a fine lubricating film between wiper and contact.[1]

Disc and wiper tests show that flush construction is an important design feature since inserts of many materials, including p.v.c. and s.r.b.p. , are also effective in reducing wiper wear.

A large number of contact measurements were taken during the life tests to prove that the contact efficiency is not materially affected by the flush insulation. From these measurements it was concluded that there is no significant difference in the electrical performance of nickel-silver wipers and contacts whether used in conjunction with flush-nylon levels or levels employing separators of standard materials (p.v.c. or s.r.b.p.).

The final assessment of any improvement to the Strowger switching system must be carried out under conditions of actual service in telephone exchanges. Field trials with flush-nylon banks are already in progress at several telephone exchanges and a number of these banks has been included in a research programme initiated by the B.P.O. Contact Research Department, Dollis Hill.

[1]The considerations involved are discussed in the paper by A. Fairweather, p. 570

TELEPHONE DICTATION

E. C. Dyson and N. S. Bonser—Circuit Development Engineering Department

Access to centralized dictating machines over a PAX or PABX network offers benefits to both business executive and typing staff. The article briefly reviews various applications of dictation machines, the facilities offered and some of the technical features involved.

THE machines provided by Companies specializing in dictation recording-machine manufacture are usually designed for individual use and intended to occupy a position on office desks. The user is able to record messages or letters independent of the stenographer and can incorporate any special instructions on index slips which are attached to recordings when forwarded to a typist for transcription. Recordings of good quality can be obtained if a correctly matched crystal or moving coil microphone is used, and such individual machines form the basis of many satisfactory correspondence systems.

Recording machines for individual use, however, occupy valuable desk space and, in general, are not economically employed, since few are subjected to continuous dictation and many are in operation for only a small fraction of the day. Moreover, some users find the tending of machines an irksome task and, from the standpoint of the messenger service, additional work is imposed by the need for conveyance of recording media to the particular location of each machine and the subsequent despatch of completed recordings to the typing pool for transcription.

For these reasons, many organizations prefer to centralize the recording machines, leaving the dictator with simply a telephone having a suitable number of control buttons. Access to a disengaged machine is given when the handset is lifted.

With this remote control arrangement, machines are used more efficiently; the number of machines can be considerably reduced, and the typing pool receives a more even flow of work, since there is no longer dependence on bulk delivery by the messenger service. The disadvantages, on the other hand, are the high cost of separate telephones and associated cables which, for more distant locations, can amount to as much as a separate machine. Furthermore, correction and end-of-letter index markings necessitate solenoid-operated punches which are somewhat more complex than the simple mechanical devices provided for similar purposes on individual machines. Moreover, any special instructions outside the scope of the index marking system must be either recorded or verbally conveyed by speech link to the transcribing typist or monitor tending the pool machines.

To avoid the cost of providing separate telephones, it is a logical step to make use of an existing private automatic telephone installation. Access to the recording machines is then given from a selector level and the selected machine may be controlled from the telephone dial or by means of a push-button unit connected to the telephone line. A push-button unit, although more costly, has the advantages of simpler operation and more precise control.

Certain limitations arise, however, when dictation schemes are integrated with existing telephone installations. Firstly, there is the possible excessive increase in traffic that can occur due to long recorder connections. As a result, the number of connecting links available for normal telephone traffic may be reduced for long periods below acceptable standards. Whilst the extra traffic can be accommodated in large-capacity exchanges or where prevailing traffic conditions are light, it could result in congestion in exchanges served by a strictly limited number of links. This problem, should it arise, may be resolved in several ways. The simplest solution would be for arrangements to be made within an organization to confine dictation to periods of reasonable duration outside the hours of peak telephone traffic. Failing this, more switches could be provided or access to a recorder given direct from the individual line circuits of extensions most frequently engaged in lengthy dictation.

A further limitation in the use of telephone equipment is the carbon telephone-transmitter inset. This introduces some distortion and background noise. Speech intelligibility is therefore slightly degraded compared with that of a good crystal or moving-coil microphone.

Nevertheless, despite these minor drawbacks, it has been proved with the many different types of

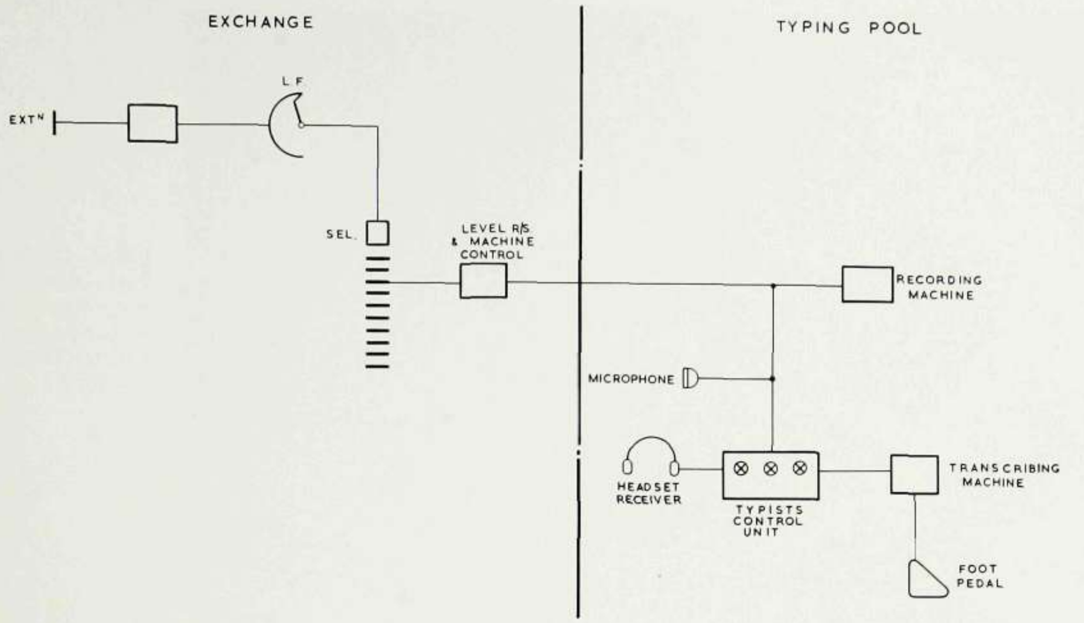


Figure 1—Paired-machine arrangement with control relay-sets mounted in exchange

dictation recording equipment connected to PAX's of the Company's manufacture, that the use of a good-quality machine ensures acceptable speech reproduction and makes possible the provision of an economic dictation system adequate to meet all normal dictation requirements.

The need for dictation facilities on PABX's has recently been recognized by the British Post Office, and permission may be obtained from this authority for the connection of approved machines to P.O.-maintained branch exchanges. The requirements are somewhat exacting and involve the insulation of the control circuits from mains voltages, the isolation of telephone lines from voice or high-frequency tones which the machine may generate, as well as stipulations concerning the recording and playback speech levels. Despite these stringent conditions, an

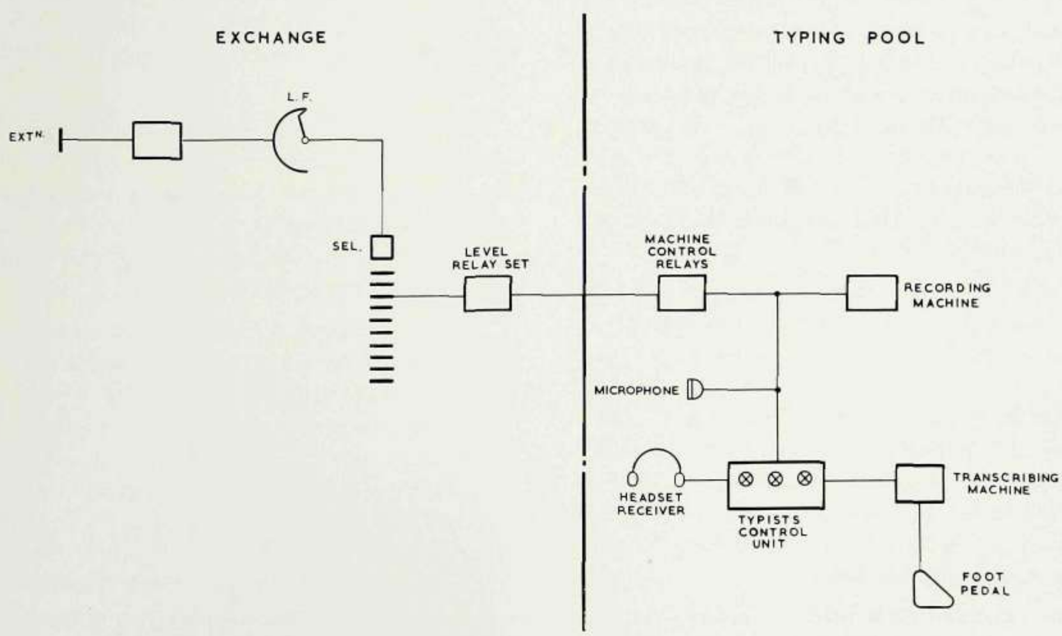


Figure 2—Paired-machine arrangement with control relay-sets in typing pool

Figure 3—Typical desk layout showing recording machine mounted above transcribing machine

increasing number of machine manufacturers are finding it possible to meet the requirements and, when the machine manufacturer cannot supply the remote control equipment, this can be provided by the PABX manufacturer.

The precise details of the equipment necessarily vary with the control requirements of different machines. Also, where the typing pool and exchange are not widely separated, it may be preferable to house the control relay-sets in the exchange and use multi-wire cables to the typing pool. This arrangement is shown in Figure 1. Conversely, the relay-sets may be located in the typing pool and a 2 or 3 wire circuit employed from each dictation machine as illustrated in Figure 2.

The method of operation of machines from the typing pool aspect falls into two broad categories. Either two machines may be provided on each typist's desk, one for recording and the other for transcription purposes, or a bank of recording machines may be used and the completed recordings transferred to standard transcribing positions. Illustrated in Figure 3 is a typical desk layout with the recording machine mounted above the transcribing machine to save space.

Where machines lack built-in facilities such as automatic warning when a dictator has almost exhausted the recording material, or if, for any other reason frequent attention is necessary, the paired or tandem machine arrangement is preferable. On certain tape machines, generally those of the non-cassette type, it is in fact the only possible method of working to avoid the tedious winding of tape. Furthermore, compared with the bank system, tandem working provides the dictator with a faster answering service when the typist or monitor is called.

On the other hand, the bank system illustrated schematically in Figure 4 allows a typist to concentrate exclusively on transcription, and attention to recording machines is reduced to the minimum, particularly on machines where the recording material does not require replacement after each call.

Trials on several designs of commercial machines have been conducted on the Company's PABX These include magnetic recorders which permit repeated playback and erasure for alteration of recordings, and non-erasable type machines using engraved recording medium. Machines of the latter type provide a permanent recording by stylus and, in general, give a recording of slightly better quality than magnetic recorders. Minor differences in operation occur in the various types of machines, but in general the procedure is as follows.

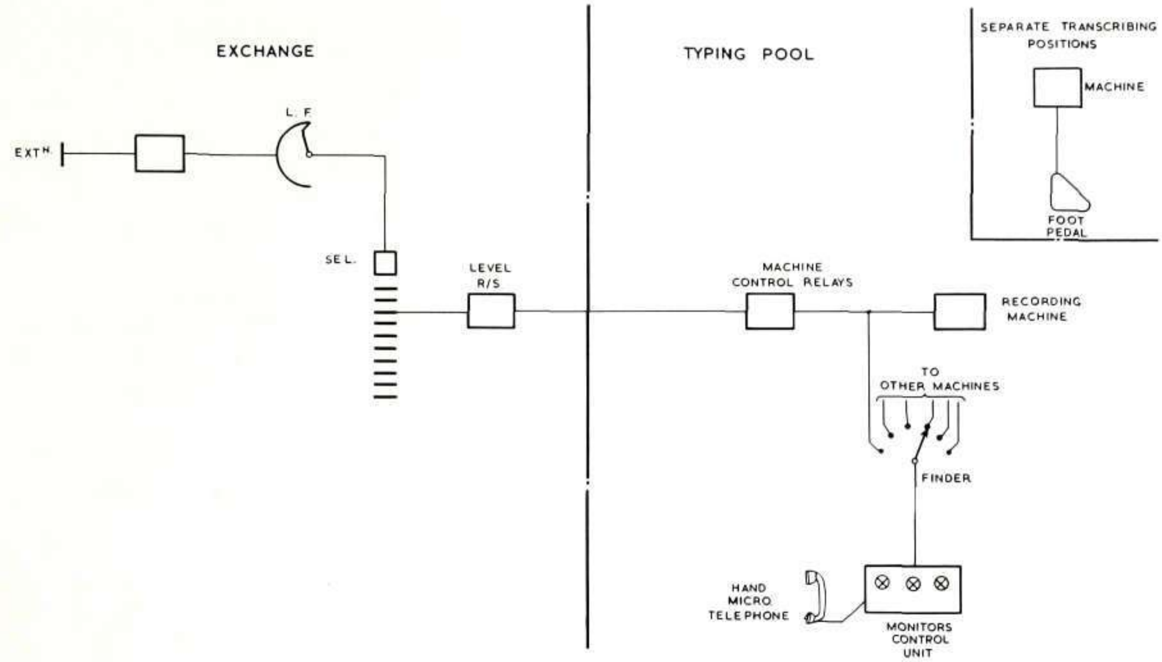


Figure 4—Bank system showing individual recording and transcribing positions

Access to an idle recording machine involves the dialling of the selector-level code assigned to the service. As soon as connection is established, a distinctive 'ready' tone is returned to the person wishing to dictate, who thereafter has exclusive use and control of the machine until replacement of the handset.

The various functions of the machine may be controlled entirely by dialling single-digit codes or, alternatively, where the PABX system employs modern telephones with an 'operator-recall' button, this button may be used to provide effective finger-tip control of the stop and start function.

To start dictating, a user may therefore dial digit '1' or press the telephone push-button momentarily, dependent upon the control method adopted. Either action sets the machine at 'record' and causes 'ready' tone to be removed from the connection, indicating that recording may proceed. Repetition of the same procedure stops the machine, which is reset to the ready condition.

If the recorder user wishes to dictate more than one message or letter and the machine is of the type arranged to indicate an end-of-letter index mark, digit '5' is dialled after completion of each letter dictated, except the last. In this instance, the required marking is automatic upon replacement of the handset.

To play back, the user dials digit '2' and the recording is heard together with a playback tone. This tone is necessary to warn the user not to dictate if the machine is playing back over unrecorded and therefore silent areas of recording material.

When it becomes necessary to replenish the machine with a new supply of recording material, an alarm sounds and the machine cannot be reseized until manually reset by the attendant.

The attendant may be called in at any time by dialling '3', although '0' could be used if preferred and other available digits can be employed for any other features which a machine may possess, such as 'correction index marking'.

Conclusion

This brief account indicates that whilst dictating machines from individual manufacturers differ in operation, an efficient and economic centralized dictating system, using machines in tandem or in banks, can be provided on PAX and PABX installations.

IMPROVED TELEPHONE SYSTEM AT DUFFRYN RHONDDA COLLIERY

PRIVATE AUTOMATIC BRANCH EXCHANGE AND MINES PARTY-LINE SYSTEM

J. P. Buck, A.M.I.Min.E.—Area Electrical Engineer, Maesteg Area, N.C.B. South-Western Division

and

E. Woodward—Circuit Development Engineering Department

This article is principally concerned with an operational description of an automatic telephone system for colliery work based on a modified form of private automatic branch exchange No. 3. The operational advantages and possibilities of the system are reviewed and compared with alternative systems of telephonic communication with particular reference to colliery requirements.

It is generally recognized that telephonic communication plays an important part in the operational control of any colliery, and is indeed a vital part of the colliery emergency organization. The value of such a system depends upon its efficiency and flexibility. These aspects will be considered later in the article.

The first system of the type under review was installed and commissioned at Duffryn Rhondda Colliery early in 1961. Duffryn Rhondda Colliery is situated in the Afan Valley, Glamorgan, and though it has been a working colliery since the early part of the century, it was one of the collieries selected by the National Coal Board for major reconstruction. The life of the colliery based on workable coal reserves is over 100 years and the Board has approved a total capital expenditure of some £3 million for the surface and underground development and modernization of the colliery.

In planning the reconstruction and in estimating for the approval of capital expenditure, adequate provision was made so that advantage could be taken of any developments in communications for mining application. An automatic installation of some kind was envisaged but at that time Post Office regulations precluded the possibility of an integrated system to serve both surface and underground and to handle external calls to and from the public system. Consequently, manufacturers were somewhat hesitant in devoting their attention to solving the problems associated with automatic working between the surface system which is non-intrinsically safe and an underground system which generally must be intrinsically safe and at the same time meet P.O. specifications for apparatus which could be coupled to the public system.

In 1960 when the demands on the existing system at Duffryn Rhondda and difficulties in maintenance had made it imperative to establish the new system, engineering work on the modified p.a.b.x. No. 3 was well advanced and N.C.B. engineers were already in negotiation with P.O. engineers in connection with the requirements of an integrated system. The long discussions which took place before approval was finally given also served to emphasize the shortcomings of the existing system.

The original telephone system at Duffryn Rhondda consisted of two private manual branch exchanges on the surface connected to the underground magneto board via six safe magneto coupling units. Although the Post Office incoming lines were terminated on one of the p.m.b.x.'s, this was most unsatisfactory since through calls from the underground to the public system were strictly restricted to those necessary under conditions of emergency.

It is apparent from the above that calls concerning the day-to-day running of the colliery could not be made from any underground extension, therefore the efficiency of the colliery must have been affected.

Other collieries have similar systems to the one replaced at Duffryn Rhondda, while at the larger collieries may also be found a private automatic exchange with safe coupling equipment to the mine magneto system. The personnel on these isolated systems have no access to the G.P.O. lines, unless they are provided with a second telephone connected to the Post Office p.m.b.x.

The private automatic branch exchange (p.a.b.x.) together with safe coupling equipment now installed at Duffryn Rhondda enables both surface and underground extensions to be connected to one system and also permits these extensions to have access to the public systems.

The running of a modern colliery that is equipped with all the latest aids in the getting of coal depends to a great extent on having an up-to-date telephone system which can handle expeditiously calls directly affecting the working of the mine.

Coalmining technique is based on gang working and the underground telephone system is thus mainly concerned with providing communication to groups of workmen whose telephonic interest rarely extends beyond their group. The community of interest within each group is best served by a party line common to all telephones of the group; this method of communication is still retained in the system under discussion and when used in conjunction with a p.a.b.x. system ensures economy of line plant and promotes greater efficiency. Up to four telephones can be connected to each party line.

The calls which in the authors' opinion will greatly benefit with p.a.b.x. working are:—

(1) Calls between Division or Area offices and the manager when he is on a tour of inspection.

(2) Calls between underground officials and the manager's home during back shifts.

(3) Calls between underground maintenance staff and Area workshops regarding spares.

(4) Calls from underground to a hospital or doctor seeking advice on rendering first aid to an injured workman.

P.A.B.X. Systems Available

The types of p.a.b.x. available to meet the requirements are known as types Nos. 2 and 3. As different procedures are involved in obtaining the equipment the following will be of interest.

P.A.B.X. No. 2 equipment is non-extensible, having a maximum capacity for 10 exchange lines and 49 extensions. A manual board is always provided for the control of exchange line calls and provision is made for 30 manual extensions when required. This type of p.a.b.x. is obtained from the Post Office, which supplies the complete exchange including surface telephones and line plant on rental. A connecting charge is made on the completion of the installation.

With p.a.b.x. No. 2, which should satisfy the requirements of the smaller collieries, the only equipment to be purchased by the colliery is the safe coupling equipment and the underground telephones.

The p.a.b.x. No. 3 equipment can be supplied for any number of extension lines and any number of exchange lines. This equipment is not available from the Post Office on rental but is purchased from the contractor together with the safe coupling equipment and the underground telephones. The contractor installs the exchange equipment but the Post Office supplies and installs the surface telephones, line plant, and also the 50-volt battery and charger on rental. As with the p.a.b.x. No. 2 a connecting charge is made.

The maintenance of these installations is carried out by the Post Office, and the charges for this service are included in the rental; this now includes the coupling equipment serving the underground lines. A fuse mounting is interposed between the shaft cable junction box and the main distribution frame, so that access can be gained by both colliery and Post Office personnel. This will enable both parties to test their respective equipment.

When a colliery has contracted to have a private automatic branch exchange type No. 3, the telephone manager's office covering the area is informed, since these installations are operated under his jurisdiction. A traffic survey is made to ensure that the switch quantities, exchange lines and private wires as offered by the contractor provide a grade of service acceptable to the Post Office. An assessment is also made of the expected growth of the installation in two, five and twenty years.

The grade of service given for extension-extension traffic is a lost call ratio of no higher than 1: 200 and extension-to-switchboard traffic of 1: 1000.

This traffic information is given to the contractor who may in the light of it have to revise his original offer. It is mentioned that in order to give a quotation in the first instance, the contractor bases his offer on what is known as 10 per cent trunking; briefly, for

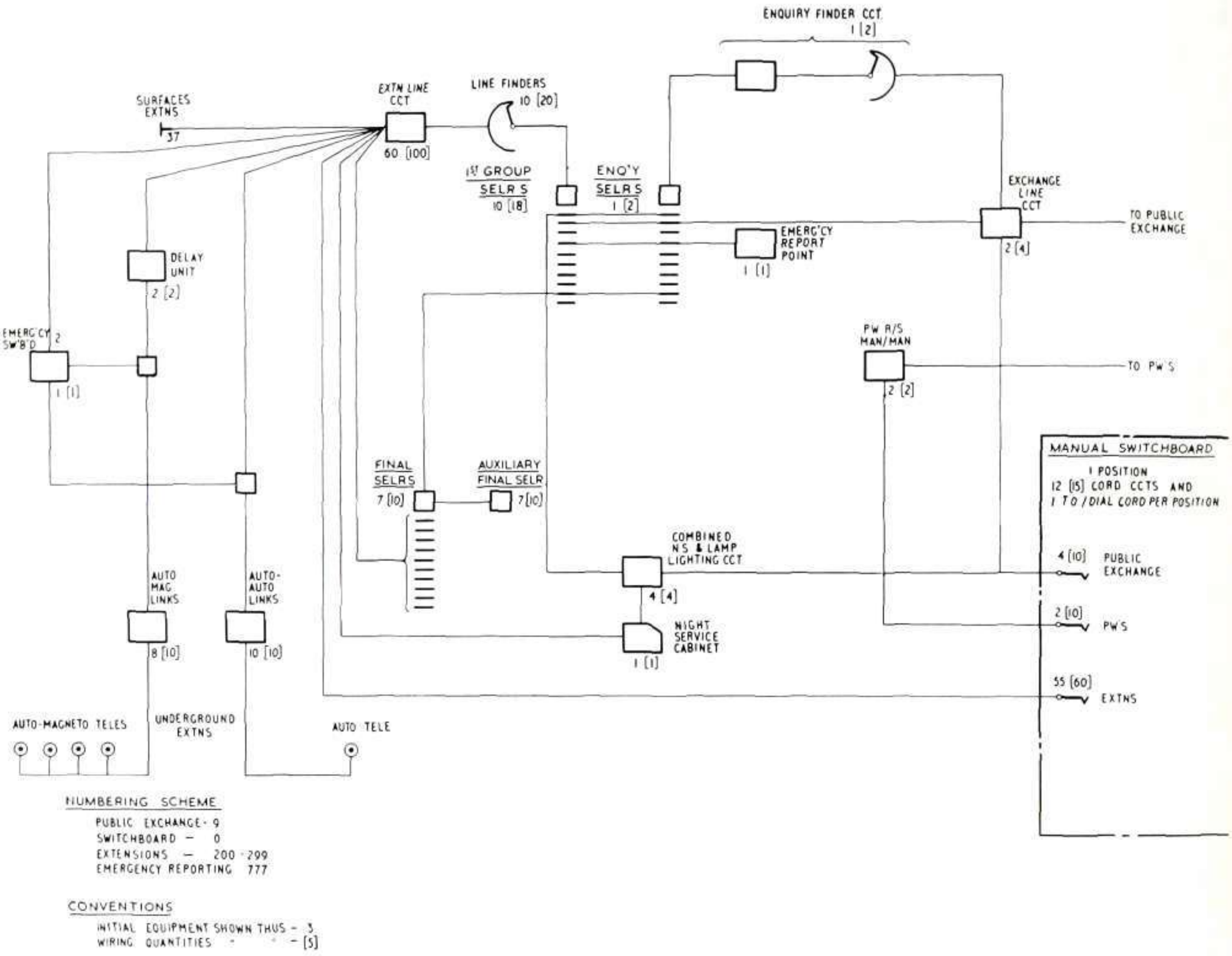


Figure 1—Trunking arrangements at Duffryn Rhondda

example, on a 100-line installation, sufficient group and final selectors are offered to enable ten simultaneous calls to be made.

During negotiations with the Post Office regarding the connection of mine telephone systems to its equipment, the P.O. was anxious that the safety of its plant was assured and that the barrier transformer used in the coupling equipment conformed to P.O. Specification D.1736, covering the connection to the G.P.O. system of apparatus which may be subject to parallelism with h.v. lines or even, on occasion, accidental contact with h.v. lines. Present-day underground cabling arrangements, however, reduce to a minimum the possibility of such conditions occurring.

It is well known in coalmining that when coupling a G.P.O. line or any other unsafe equipment to the mine magneto system, a safe coupling unit shall be used; this requirement is statutory. The isolating transformer and coupling unit are the two items of equipment on which agreement already exists between the National Coal Board and the Post Office for use in emergency.

Owing to the dangerous nature of coalmining, because of roof falls, transport hazards and the possibility of gas explosions, it is always considered essential to include in any mine telephone system some means of giving effective control of all underground lines. All alarm calls to the surface must be answered promptly and it must be possible to send a distinctive signal inbye to warn the underground personnel. The arrangements made to fulfil these requirements are met by providing an alarm reporting telephone (dial 777) in some location of the colliery such as the lamproom or power station, where there

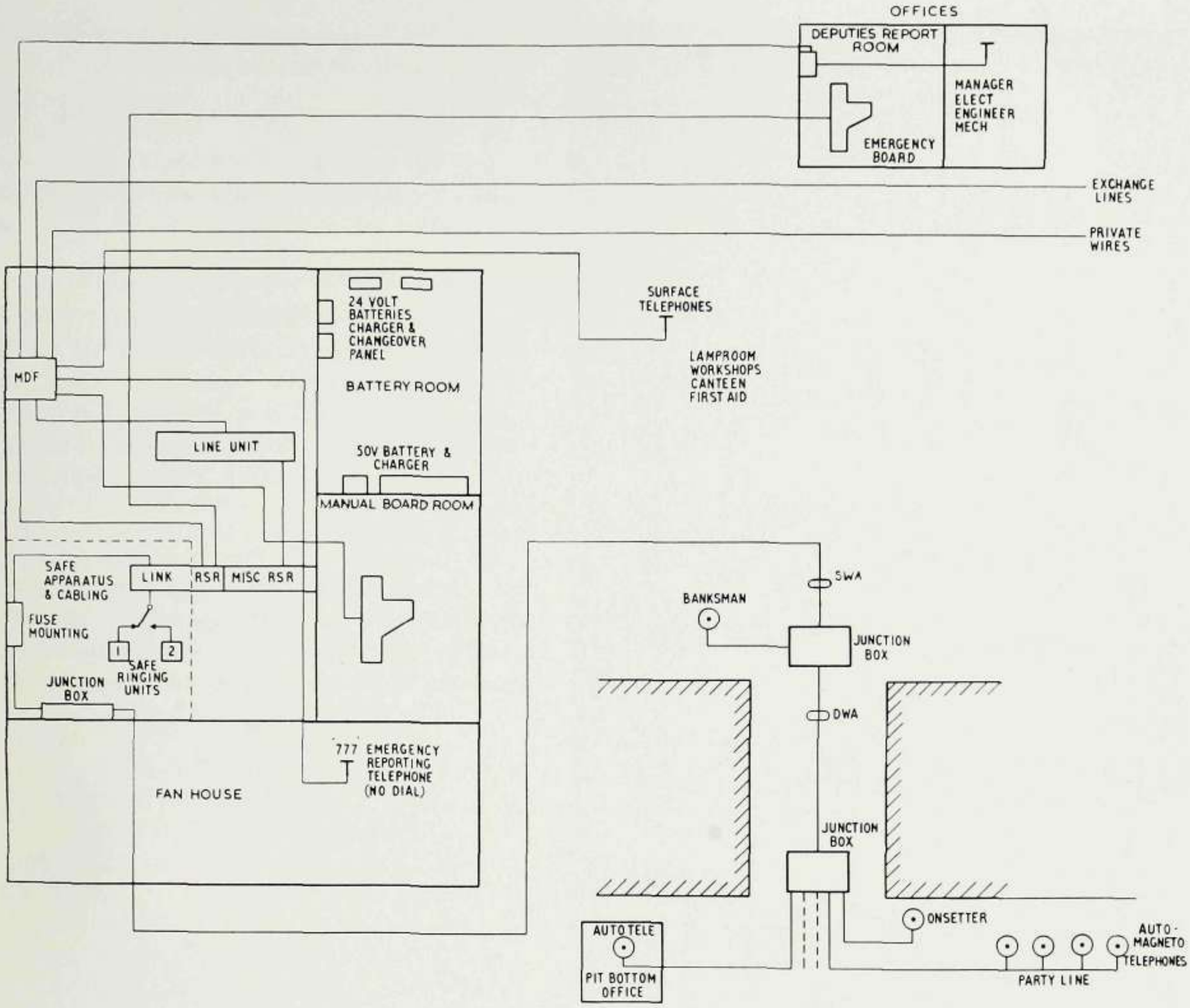


Figure 2—Disposition of equipment and cabling arrangements

is a 24-hour duty. This instrument, which must be free at all times for incoming calls, is not fitted with a dial. To give it special significance it is red in colour. An emergency control board is also provided and at Duffryn Rhondda this is situated in the deputies' report room. All underground lines can be switched to this board either singly or *en masse* to give manual control of all underground lines. It can also be used to maintain communications between surface and underground in the unlikely event of a failure of the automatic equipment.

Duffryn Rhondda Installation

The manner in which traffic is routed via the private automatic branch exchange at Duffryn Rhondda is shown in Figure 1, and the disposition of the equipment is indicated in Figure 2. Extension-to-extension traffic is switched via Strowger type group and final selectors by what is known as the step-by-step method. Exchange line calls, except outgoing direct access calls, are handled at the manual board and are extended by the operator to the local extensions by plugging into the line jack of the wanted extension.

The facilities provided by the combination of p.a.b.x. and the mine party-line system are as follows:—

(1) Extension-to-extension calls, both surface and underground, are connected automatically on dialling. Operator recall and enquiry facilities are given by using a pushbutton on the telephone (auto only).

(2) Party-line extensions use a hand generator to code ring a party on the same line.

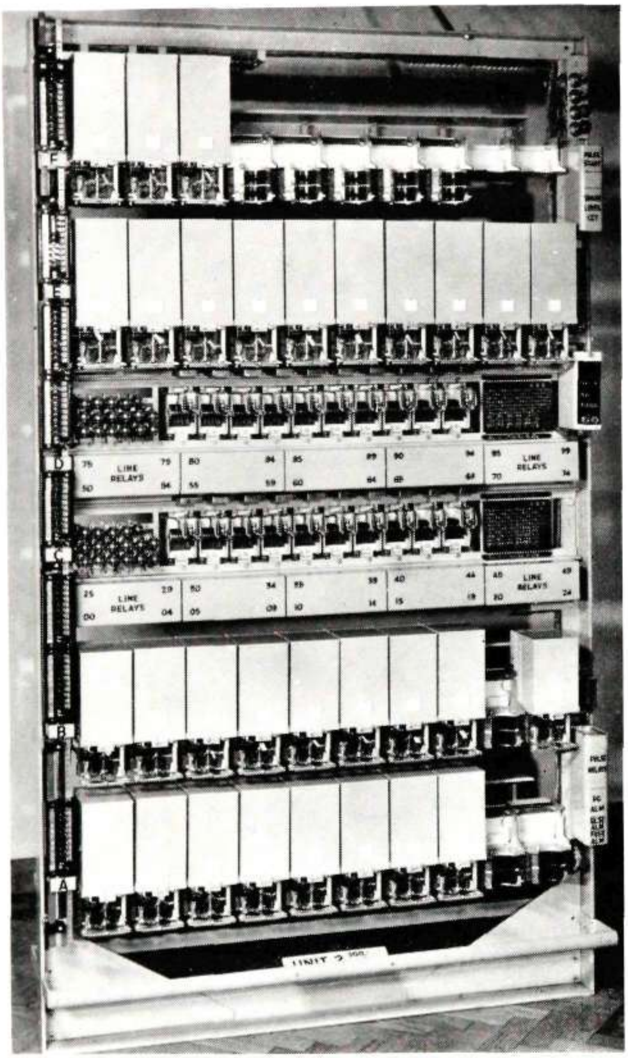


Figure 3—Typical 100-line auto unit, partially equipped

(3) Party-line extensions use hand generator to give a 4-sec ring to seize the automatic equipment before dialling to other lines.

(4) Code ringing to call party-line extensions, also coded tone signals to inform extensions in conversation on the party-line that the line is being called by another extension line. The codes used consist of 3, 4, 5 or 6 short rings.

(5) Dial 777 access from any extension to an emergency reporting telephone point.

(6) Manual control of all underground lines in the event of an emergency.

(7) Emergency control switchboard can be used as standby in the event of automatic equipment failure.

(8) Dial 9 access to the public exchange for selected surface extensions.

(9) Exchange calls handled by manual-board operator.

(10) Private-wire facilities to Area offices or other collieries as required.

Operating Procedure

(1) *Exclusive-to-Exclusive Line Call.* To make a call between exclusive-line extensions, surface or underground, the caller on lifting the handset receives dial tone and dials three digits to call the required extension; tones indicating the condition of the called line are returned to the caller.

(2) *Incoming Call to Party Line (line free).* In this instance the first three digits dialled select the wanted line and the fourth digit is routed to auxiliary equipment to set up the appropriate code ring of the wanted party-line extension.

(3) *Incoming Call to Party Line (line engaged on party call).* If an incoming call is received while a conversation between parties sharing the line is in progress, the line is not busied. The caller has access to the line and ring tone is returned to him, thus the caller is unaware that the line is engaged. The parties holding the conversation are warned of the incoming call by a coded tone identifying the party required. To answer the call it is necessary for both parties to replace their handsets, after which a coded ring is applied to the line to call the wanted extension. If the call is for one of the previously engaged parties it is not necessary to wait for ringing to be applied to line, the call can be answered by removal of the handset after the initial replacement.

(4) *Calls Between Parties Sharing a Line.* To call a party sharing the same line it is first necessary to lift the handset and listen to check that the line is free; if so, the hand generator is used to code ring the wanted party. To answer, the latter has only to lift off the handset to complete the connection. Such calls are local to the link circuit feeding the particular line and do not use any part of the automatic equipment, thus any number of these local calls can be in progress without degrading the service provided by the p.a.b.x. selector circuits.

(5) *Outgoing Call from Party Line.* To make a call outside the party line, the caller first listens to

make sure that the extension line is clear, then gives a long ring (of about 4 sec duration) after which he will hear dial tone and can dial the number of the required extension. If that extension is free, ring tone will be heard by the caller. If not free, busy tone will be received and another attempt can be made later.

(6) *Emergency Control.* Inbye personnel can initiate an alarm call by dialling 777. On the auto-magneto telephone (party line) it is first necessary to give a 4 sec ring before dialling. The alarm call is received at the alarm-reporting telephone where the attendant takes brief details of the call, obtains the number and location of the caller, and tells the caller to wait at the telephone. This information is passed to the manager or a responsible official for appropriate action.

The action taken depends on the nature of the call; if this is not serious the manager may decide to call the line direct by dialling, or, in the event of an incident affecting a whole district, he will appoint an official to man the emergency board who will put all the lines in that particular district under his control. This is done by operating the line ' ON ' emergency key and a red lamp is lit to record this action. To call any line, the associated ring key is held operated for approximately 10 sec. Ringing of this duration cannot be confused with normal ringing applied to the line and anyone hearing it is expected to answer the call. On removal of the handset a call lamp is lit and by operating the associated connect key the speaking path is established.

When under emergency control, calls from underground can be extended via two lines to the p.a.b.x. system and also via the manual board to the public network; it is possible to give direct access (dial 9) from these two lines if found desirable. Two connecting circuits plus a speak-on-ring arrangement are provided on the emergency board to give through connection.

EQUIPMENT

The equipment is accommodated on open-type racks 7 ft 9 inches high and either 4 ft 6 inches or 2 ft 9 inches wide depending on the purpose of the rack (see Figure 3). The line unit is designed to mount all the switching equipment normally needed for a group of 100 extensions, together with the extension calling circuits. Therefore a very flexible arrangement is made possible which ensures that as the number of lines increase the space for the additional equipment is readily available. The number of linefinders has been limited by the Post Office to 10 per 50-line group and this has led to the design of a unit with two independent groups of calling equipment each of 50 lines. The linefinder uniselectors, which require adjustment *in situ*, have been placed at a convenient height to facilitate maintenance. The bottom two shelves are occupied by jacked-in group selectors, each shelf accommodating ten selectors. The uppermost shelves are used for final selectors and enquiry selectors, etc., when required.

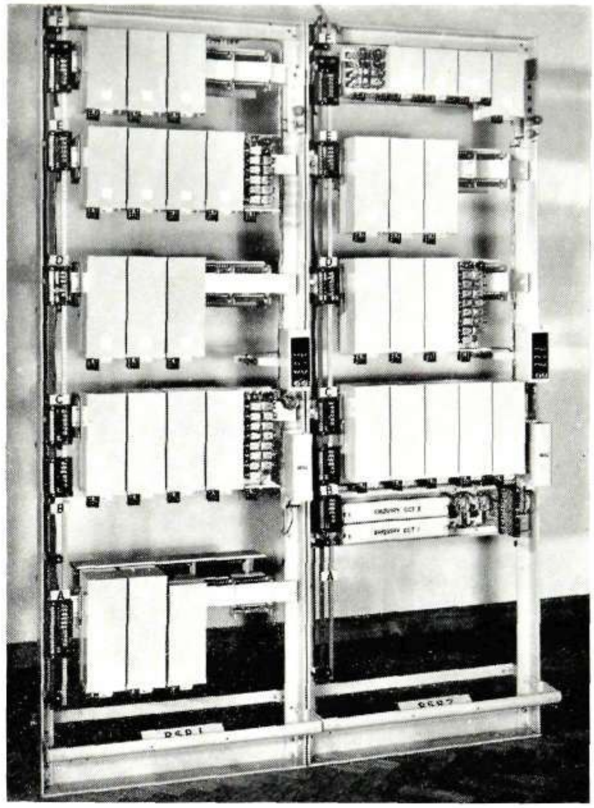


Figure 4—Typical relay set racks

A second associated rack (Figure 4) is provided for miscellaneous circuits and on which is mounted the ringing machine.

The safe link equipment is fitted to the rack shown in Figure 5; the top shelves are used for mounting the auxiliary final selectors and the remaining shelves are for the link relay sets; the total capacity is for twenty auto-auto or auto-magneto type links. Other pieces of equipment fitted to this rack are the delay

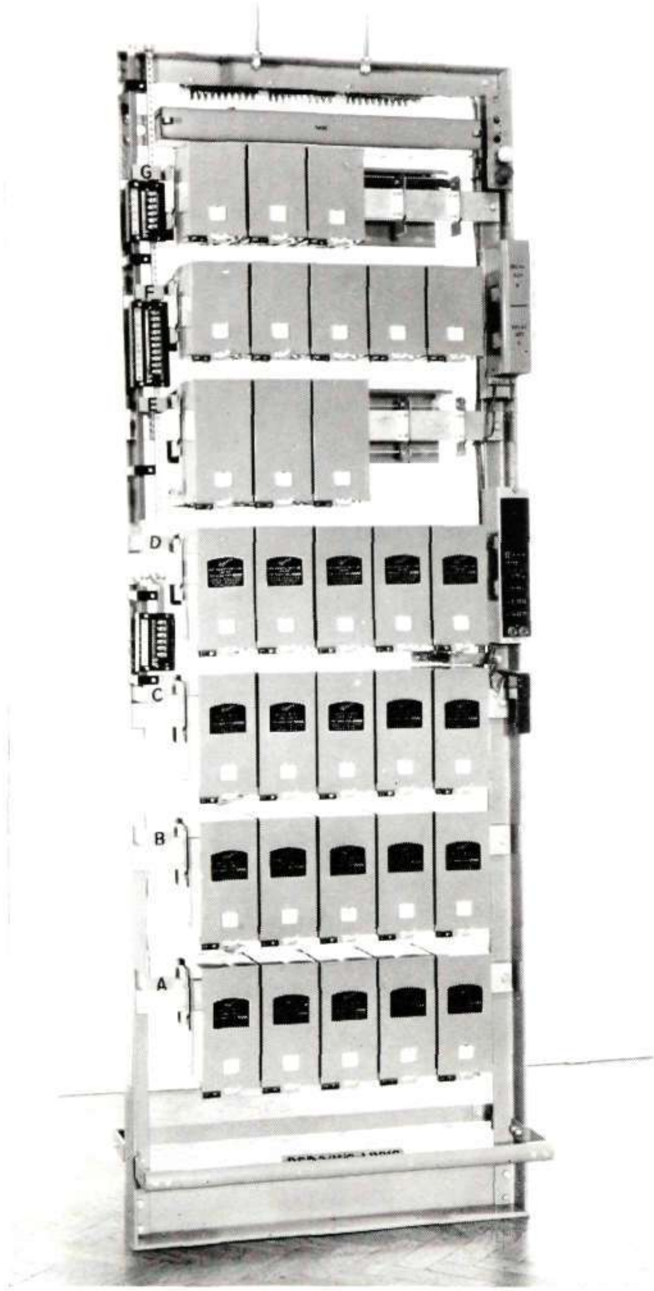


Figure 5—Safe link relay set rack

circuits, emergency relays and the code ring generator relay set.

In order to avoid contact between the 50-volt system and the underground line side of the links which are operated from a safe 24-volt supply, the wiring of both parts of the circuit, both rack and relay set, are in separate cable forms.

Figure 6 shows the manual board supplied with p.a.b.x. systems for the control of all incoming and also outgoing calls except for those made from extensions having direct access. All extensions have a combined call and answer jack, and lamp-per-line working is used. Provision is made for up to fifteen cord circuits; the relays for these are mounted on jacked-in relay sets in the rear of the switch section.

Night service arrangements can be satisfied by two methods. Additional jacks can be provided on the manual switchboard so that after normal working hours selected extensions may be left connected to exchange lines by means of cords. Alternatively, a night service cabinet can be used, installed in the lamp cabin or power station. This cabinet is a small cordless switchboard equipped with four connecting circuits. A key on the main switchboard diverts four exchange lines and four 'O' level circuits to the cabinet so that calls over these circuits can be connected by the night attendant.

The emergency switchboard as shown in Figure 7 has a normal capacity of forty underground lines and is equipped to satisfy the particular needs of a colliery; larger boards can be specially supplied to meet ultimate capacities in excess of forty lines. Each line is equipped with an emergency 'ON' key and lamp, a calling lamp and a double throw connect key and also a push key for ringing. Two line circuits are provided for connecting to the p.a.b.x. and a stand-by generator is included for use should the p.a.b.x. ringing supply fail.

The underground ironclad telephones (Figure 8) have a strong grey enamelled cast-iron case with a hinged inner door on which the internal components are mounted and which can easily be removed, complete with components for maintenance. Since power is obtained from the 24-volt central battery serving the link circuits, no cells are required in the telephones; thus maintenance work is reduced and ample safe power for signalling and transmission is always available. The directory card which is

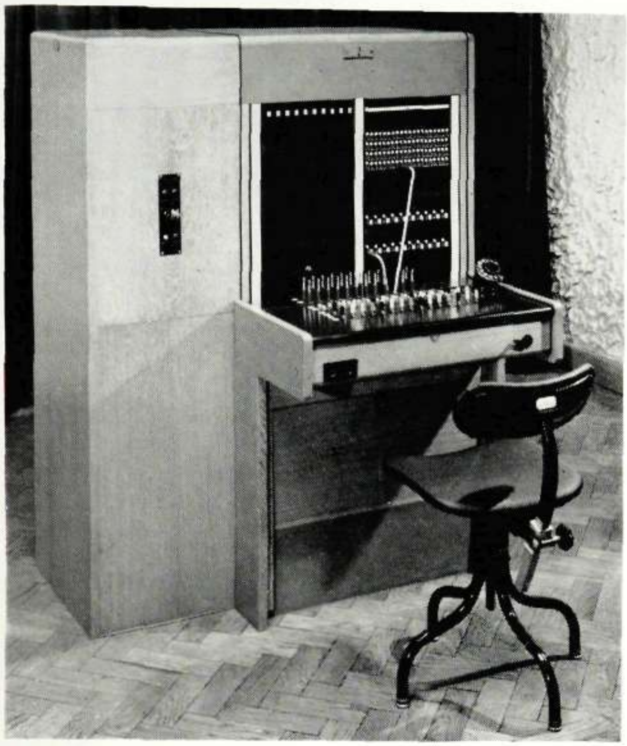


Figure 6—Typical one-position manual switchboard

Figure 7—Mine emergency switchboard

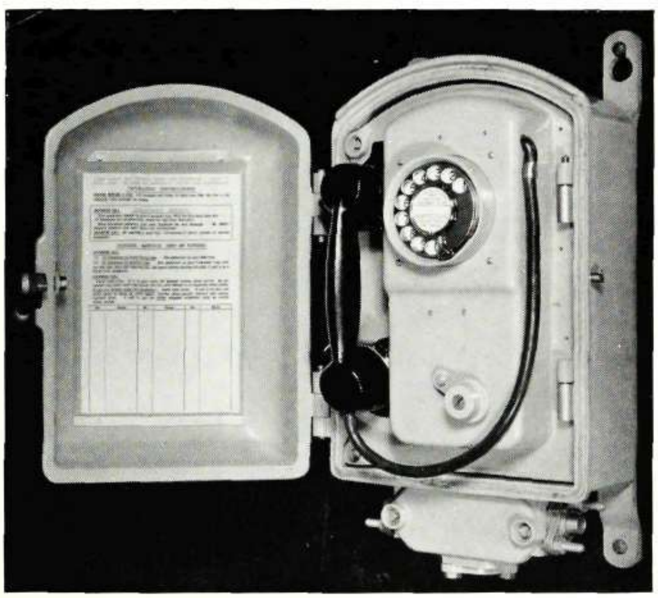


Figure 8—Auto-magneto party-line telephone

supplied as a standard part can be seen fitted to the inside of the outer door. This card is protected by a Perspex cover and contains operating instructions for both normal and emergency working; sufficient space is provided for directory numbers and location.

Conclusion

The advantages of the private automatic branch exchange at Duffryn Rhondda are becoming evident now that the system is coming more into use. As regards economy in operation, only one operator is required on the day shift—on the back shift the manual board is attended by the fan supervisor. It was originally intended to have a night service cabinet as shown in Figure 1, but owing to the final location of the manual board this was considered unnecessary.

There are no isolated groups now since all key personnel are connected to one exchange; the manager's home is an external extension on the colliery exchange.

One of the private-wire circuits provided is a direct line to the Port Talbot gasworks and enables the passing of calls regarding methane drainage to be made very quickly. Other private wires go to the Area headquarters at Tondu, the Group office at Cymmer, Glyncorrwg Colliery and Avon Colliery.

Similar installations to that at Duffryn Rhondda are being fitted at other collieries and another is already operating at Brynlliw Colliery in West Wales.

Now that the Post Office has accepted the coupling of mine telephone systems via p.a.b.x.'s to the main exchange network, collieries are able to enjoy facilities which have been available to other industrial organizations and business houses for a number of years.

Acknowledgments

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