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Editorial

When we contemplate the heights in the realm of science to which the inventive genius of man has brought us in the last hundred years, we cannot help but wonder, with H. G. Wells, what will be "the shape of things to come." Considering the progress made to date in only one branch of science—telecommunication—we see how one development has led to another, and it is reasonably safe to assume that the momentum will increase in the future.

Looking back over the history of communication we see the gradual development of electrical methods using wired circuits ; the early days of simple telegraphy, then speech transmission and the accompanying demand for telephone service, a demand which increased rapidly as the value of the telephone was more widely appreciated. Carrier telephony was then introduced to cope with the ever increasing need for service at economical cost. Along with the development of transmission equipment came higher quality circuits capable of careful and precise control and leading to the present coaxial cable systems in which large numbers of circuits are superposed on two cables, one for each direction. Such systems now form the basic circuits for trunk routes in highly developed territories.

Considerable progress has likewise been made in the field of radio communication and a high standard of service is now possible. Installation of radio equipment is a simpler proposition than the laying of costly cable and the demand for radio systems is apparent in areas where communication is rapidly expanding and where cable laying is often impracticable.

The idea of applying multi-channel telephony to radio circuits follows quite naturally and although the present coaxial cable systems set a very high standard of performance, radio is rapidly approaching similar standards and now holds an assured position as a reliable method of communication.

An article in this Bulletin describes a radio telephone system with up to six channels and which has been designed to provide good quality commercial circuits, with particular emphasis on testing facilities to enable it to be maintained satisfactorily in locations where skilled maintenance staff is not readily available.

Flin Flon, Canada
Automatic Telephone Exchange

BEYOND the fifty-third parallel, in Manitoba, lies hidden the unusual town of Flin Flon; hidden because it is set deep in the rocks of the remote northland, and unusual because, although it holds almost 10,000 people, access was only by air, single-track railway, or canoe, until the recent completion of a roadway. The rapidity of the town's growth has been almost as romantic as the following legend from which its name is supposed to have originated.

It is said that a group of miners, prospecting in the vicinity, found a tattered copy of an English novel, "The Sunless City," the hero of which was a character named Joseph Flintabbaty Flonatin. This man, according to the tale, descended through a bottomless lake, by means of a home-made submarine, and found deep in

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The Source of Flin Flon's Wealth

This man-made chasm in the solid rock originated from the 10 feet diameter hole which was reputed to be "Old Flin Flon's Mine" the earth a city paved with gold. The prospectors joked about the story until, one day, one of them found a conical hole some ten feet in diameter, and is reputed to have called out to his companions, "Boys, I guess we've found old Flin Flon's mine!" Today, the town of that name, carved in the bare rocks nearby, and one of the most thriving industrial centres in Canada, owes its existence to the gold, silver, copper and other metals which are being mined there.

The rapid growth of Flin Flon has naturally created an urgent demand for increased telephone service and as a result the Company was privileged to receive a contract from the Manitoba Telephone System (M.T.S.) for the supply and installation of the Dial Central Office equipped for 3,000 multiple numbers and catering ultimately for approximately 8,000 lines.

The provision of such a large number of lines for a town of some 10,000 inhabitants gives an indication of the enterprise of these people of the North, while the capacity allowed for implies that the area is expected to develop considerably in future years.

The automatic equipment generally conforms with that used in British Post Office (B.P.O.) public exchanges and is of the Strowger step-by-step type, the trunking arrangements being as shown in Fig. 1.

The switching system comprises subscribers' uniselectors, first and second selectors and connectors, giving a 4-digit numbering scheme, the selectors being 100-outlet, B.P.O. "pre-2000" type, while the uniselectors are the new standard type accommodated 300 per rack.

From Fig. 1, it will be seen that the external lines terminate on the vertical side of the C.D.F. (Combined distribution frame). The frame is arranged for growth at either end and has protectors on the external (line) side for 304 pairs per vertical. Fuse mountings are not provided and the lines are cross-connected to terminal strips on the horizontal side of the frame.

Provision is made for four classes of subscribers—(a) ordinary or party line, (b) coin box, (c) P.A.X. unrestricted, and (d) P.A.X. restricted.

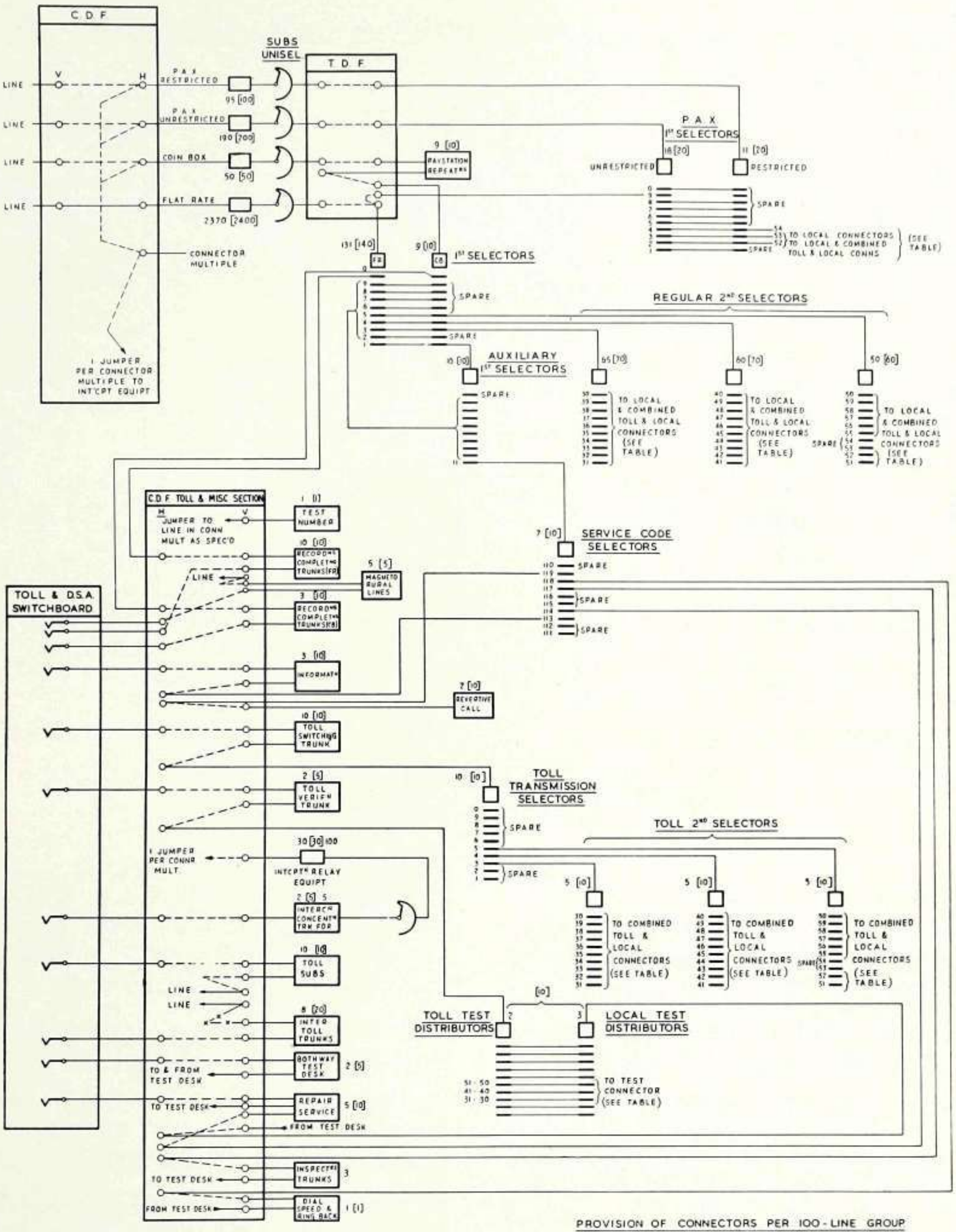
Subscribers, excepting group (b) are on a flat rate, therefore registers are unnecessary.

The line circuit terminals on the horizontal side of the C.D.F. are jumpered to the connector multiple terminations on the same side of the frame, while grading between the switching stages is done on two separate trunk distribution frames by means of bare wire strappings and jumpers.

The automatic equipment racks are 10'-6" high and are held rigid by interconnecting overhead ironwork which supports the inter-rack cables, lighting units, travelling ladders, and the copper power distribution bars. The standard B.P.O. arrangement of group fusing is followed, i.e. suites of racks are grouped together for purposes of power distribution, fuses being inserted between the main bus bar and the subsidiary bars for each group. Where necessary, vertical copper bars carrying small fuse panels are fitted to rack uprights and are clamped to the subsidiary overhead bars.

Lamps of different colours are switched into circuit, in conjunction with audible signals, to facilitate the speedy locating of faults, provision being made for alarms to indicate the failure of supply mains, ringing, tone, and pulse supplies, undue delay in the release of switching equipment after use, also other types of faults, in accordance with standard practice.

The principles of Strowger switching and of normal B.P.O. type exchange practice, which apply also to the Flin Flon equipment, are sufficiently familiar, therefore reference will now be made to items of more particular interest.



PROVISION OF CONNECTORS PER 100-LINE GROUP

TYPE OF CONNECTORS	GROUP Nos 30	31–33	34	35–51	52	53	54	55–59
REG OR CB (LOCAL)		6		6		6	9	6
REG OR CB (COMBINED TOLL & LOCAL)		2		2		3		2
ROTARY (LOCAL)			8		8			
ROTARY (COMBINED TOLL & LOCAL)			5		5			
10-PARTY LINE (LOCAL)	7							
10-PARTY LINE (COMBINED TOLL & LOCAL)	2							
TEST	1	1	1	1	1	1	1	1
BANKS	10	10	20	10	20	10	10	10

CONVENTIONS

FIGURES SHOWN THUS 5 DENOTE INITIAL EQUIPMENT
" " " [10] " BANKS OR WIRING
" " " (100) " ULTIMATE CAPACITY

Fig. 1—Trunking Diagram

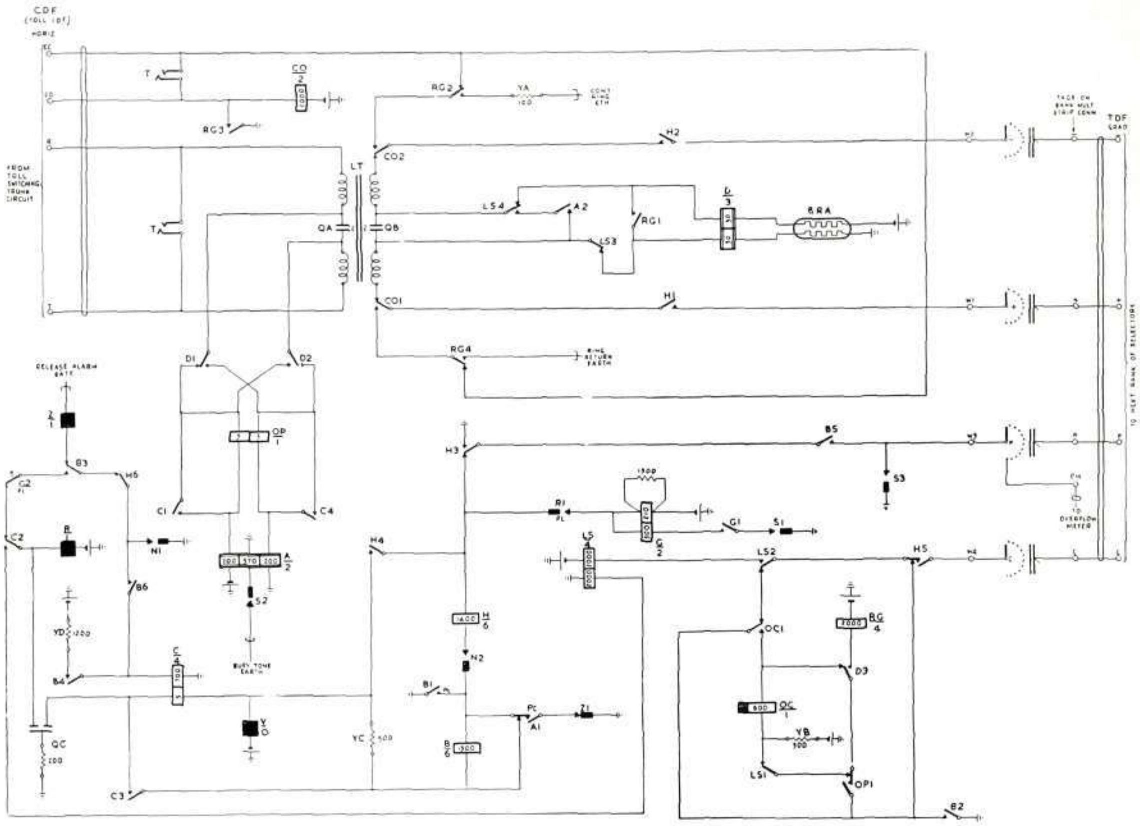


Fig. 2—Toll Transmission Selector Circuit

Coin Control.

Buttonless type prepayment coin boxes are employed at paystations, the control of coins being effected automatically by the exchange equipment. This is done by the use of a 3-position polarized relay in the coin box, the operation of the relay being controlled by a discriminating signal passed back by the automatic equipment according to whether or not the call matures.

The procedure is as follows :—A coin is inserted in the coin box and the caller is connected to a first selector via a paystation repeater relay set. In the case of calls to local subscribers, a battery reversal from the final selector when the subscriber answers, operates a relay in the paystation repeater which causes a pulse of 110v positive battery to be applied to line when the calling subscriber clears. This operates the coin box polarized relay in the " collect " direction and ensures collection of the coins deposited. The absence of a battery reversal, in the case of calls to local subscribers which do not mature and also certain special calls for which a fee is not required, results in the paystation repeater relay set applying 110v negative battery to line when the calling subscriber replaces the receiver. This actuates the coin box polarized relay in the opposite direction and a refund of the coins is effected.

Manual Board.

In order to conform with M.T.S.

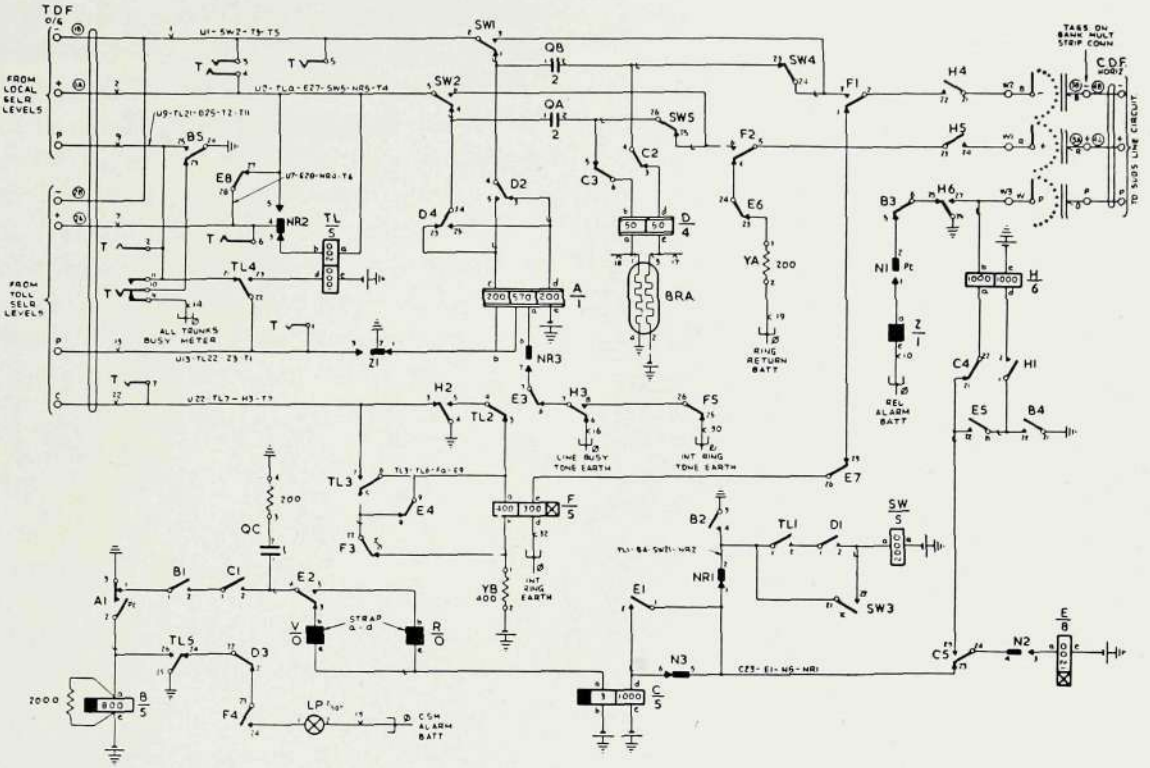


Fig. 3—Combined Toll and Local Connector Circuit

standards, the toll board and associated relay equipment have been supplied on our behalf by the Northern Electric Co. of Canada, and provide facilities similar to those on a standard B.P.O. sleeve control switchboard, with the addition of coin control.

The equipment is so arranged that when a paystation subscriber calls the toll board, the initial coin deposited is automatically returned when the operator answers. The control of subsequent coins is in the hands of the toll operator, who may use either a " coin collect " or " coin return " key in the position circuit to apply a positive or negative battery to the line, as previously stated.

Toll Train.

Operator access to a particular subscriber is gained via a toll switching trunk circuit associated with the toll board, a toll transmission selector, toll second selector, and a combined toll and local connector.

The toll transmission selector circuit and a typical combined access connector circuit are shown in Figs. 2 and 3.

Relays A, B, C and LS (Fig. 2) are operated when a loop is applied to the T & R leads in the toll switching trunk circuit. The first impulse train is directed to the vertical magnet. At the end of the impulse train, relay C releases and energizes the rotary magnet circuit, the wipers being stepped to the first contact of the level dialled and searching over the level in the normal manner until a free toll second selector is found. Relay H now operates, connects an earth to the private to guard the P wire and switches the negative and positive leads through to the subsequent selector. Further impulse trains actuate subsequent switches, and finally the connector, to reach the called line. If the called line is busy, " line busy tone " is returned to the operator. If the called line is free, relay H in the connector is energized, operating relay ' F ' and disconnecting earth from the C lead, thereby releasing relay LS in the toll transmission selector and so causing earth to be extended over the C lead to hold the F relay in the connector, in order to control the application of ringing to the called line. The position circuit on the toll board is arranged so that the ringing condition, passed forward to the toll switching trunk and thence to the connector, may be applied automatically by release of the position dial key when the required line is found, or may be delayed until the cord circuit ringing key is actuated by the operator.

When the ringing condition is applied to the line, battery is sent from the toll switching trunk over the negative and positive legs, thus operating relay OP in the toll transmission selector, due to the unbalance of current in its windings. Contacts of relay OP operate relay OC, thus disconnecting earth from the C lead and releasing the F relay in the connector. Ringing is then applied to the called party's line by the connector. When the operator restores the cord circuit ringing key, or in the case of the automatic application of ringing, after a suitable time interval, relay OP releases, short circuiting relay OC via contacts of LS and D. Relay OC releases slowly and ensures sufficient time for the release of relay F in the connector. If the called party answers and then restores, the toll operator can re-call by again initiating the circuit functioning described above, thus releasing relay F in the connector by disconnecting earth from the C lead. The release of relay F re-connects ringing to the called party. When the through connection is established, relay D operates and reverses the lines back to the toll switching trunk circuit for supervisory purposes.

The facility of ringing the called subscriber while the handset is off its rest, is provided for. In this case the operation of the cord circuit ringing key energizes relay OP which, with relay D operated, causes relay RG to function. Relay RG holds D and operates relay CO, relays CO and RG then connect continuous ringing to the line.

As already stated, the toll operator can control the collection or refunding of coins at a paystation by means of the appropriate keys. Their operation energizes relay CO via the CO lead from the toll switching trunk circuit. Relay CO operated with relay RG normal, connects both the negative and positive lines in parallel to the collect and refund lead CC.

Test Desk.

The test desk is somewhat different from the standard B.P.O. type but incorporates all the usual testing facilities, with some additional ones to cover the particular requirements of the main equipment. The desk comprises a single position, with provision for extension to two positions ultimately. The measuring instrument is a volt-milliammeter having four scales, 0–120 volts, 0–24 volts (1.2 m.a.) 0–24 volts (24 m.a.) and 0–480m.a. while the two testing batteries used are of 20 and 100 volts. Line resistance tests can be made by the use of the milliammeter winding, in addition to the normal method using the voltmeter windings. In this case, battery in series with the milliammeter is applied to line and the deflection in milliamps caused by an earth or a loop fault is noted. The test plug is then withdrawn from the jack associated with the line under test and is inserted into a short-circuit jack, after which a rheostat is brought into circuit in series with the milliammeter to adjust the current until the same deflection is obtained. The fault resistance is then read directly from the rheostat setting.

A Wheatstone bridge which is accommodated in a drawer in the front of the desk can also be used for line resistance tests, being brought into use by the operation of the appropriate key on the front equipment.

Coin control tests for the correct operation of the polarized relay in a coin box are made with the co-operation of a faultsman at the paystation. Operation of the collect or refund key with the rheostat key, connects 110v positive or negative battery to line in series with the milliammeter and a rheostat. The current is then adjusted by variation of the rheostat to give operate and non-operate tests on the polarized relay, in either the collect or refund direction, the current being read directly on the meter.

A high-voltage insulation breakdown test is used to check the insulation resistance between one leg of the line and earth, or the pair to earth. By means of a stepping uniselector, a 200v battery through a gradually decreasing resistance is applied to the line, the maximum voltage being applied for a period of 3 seconds during which time the test clerk may read the meter. Normal insulation tests should be made before and after the application of the high-voltage breakdown test. A full breakdown to earth is indicated by the glowing of a lamp.

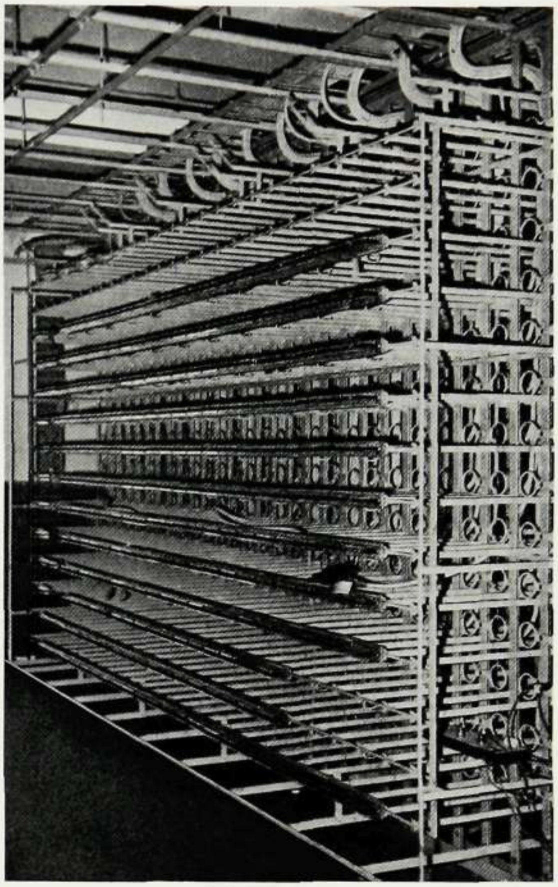


Fig. 4—Horizontal Side of the C.D.F. with Cabling Partially Completed

Access to the dial speed test equipment may be obtained from the test desk, as described later.

The rheostat previously referred to may be used to cut down the current through the subscriber's instrument, if required during transmission efficiency tests. The dial of the rheostat indicates the magnitude of the resistance inserted into each side of the line, and by operation of the milliammeter key the meter may be connected in circuit so that the current through the subscriber's set can be measured.

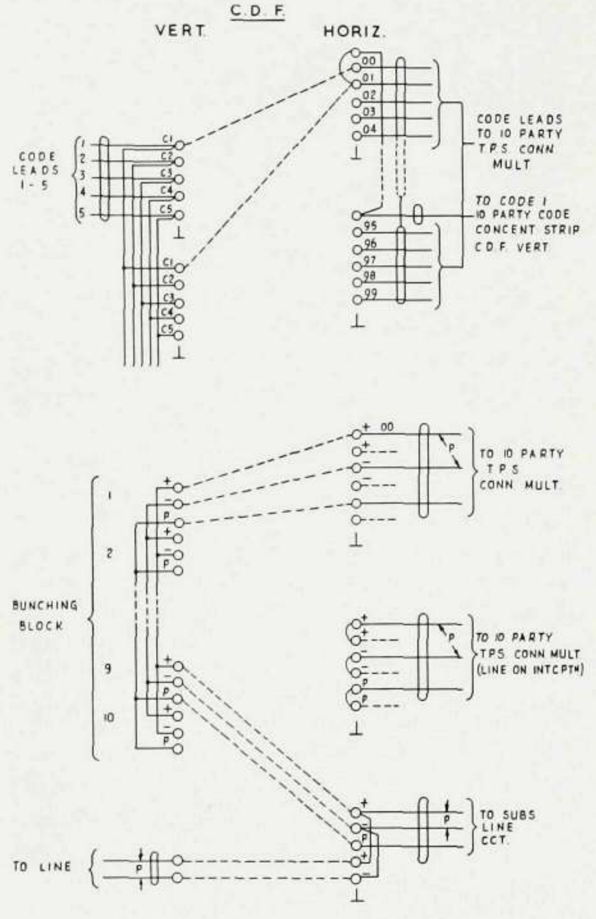


Fig. 5—Party Line Cross-Connections

PARTY LINES.

One hundred numbers are allocated to rural party lines. Each party line can accommodate a maximum of ten subscribers—five connected on each leg—and code ringing is used for signalling, the ringers at the subscribers' premises being connected from one side of the line to earth. The transmission of any one of five different codes thus results in the five subscribers on one side of the line being rung simultaneously, it being left to the required party to recognize and answer the call.

The only items of switching equipment which differ from those required for the ordinary lines, are the connectors and the additional code ringing cams on the ringing machine.

Cross connecting arrangements at the C.D.F. are shown in Fig. 5. Bunching blocks for cross connecting the —, + and P wires of connector multiple numbers to line, are provided on the vertical side of the frame and it will be seen that the — and + conductors of the circuits are reversed between each appearance. These reversals, which are permanently wired, avoid the necessity for reversals in the C.D.F. jumpers of the even-numbered stations and which would otherwise be necessary in order to send out the ringing on the proper side of the line. The fourth wire associated with the connector multiple is terminated on the horizontal side of the C.D.F. and jumpered to a code concentration block to determine the code allotted to the particular multiple number.

It will be seen from the above that each subscriber on a party line has a number in the connector multiple, and that subscribers may be added to a line by running a 3-way jumper to associate the connector multiple number with the required bunching block terminals and a single-way jumper for the code ringing connection.

The party line connector functions as an ordinary final selector up to the point where the H relay tests in on the P wire. If the called line is free, relay H operates to the battery on the P wire, and locks. Relay H, operating, prepares the circuit for another relay which is connected over a fourth wire to the ringing machine, and responds to earth pulses, corresponding to the ringing code associated with the called line, as they are transmitted from the ringing and tones circuit via the code concentration block on the C.D.F. Ringing conditions are thus connected and disconnected from the called

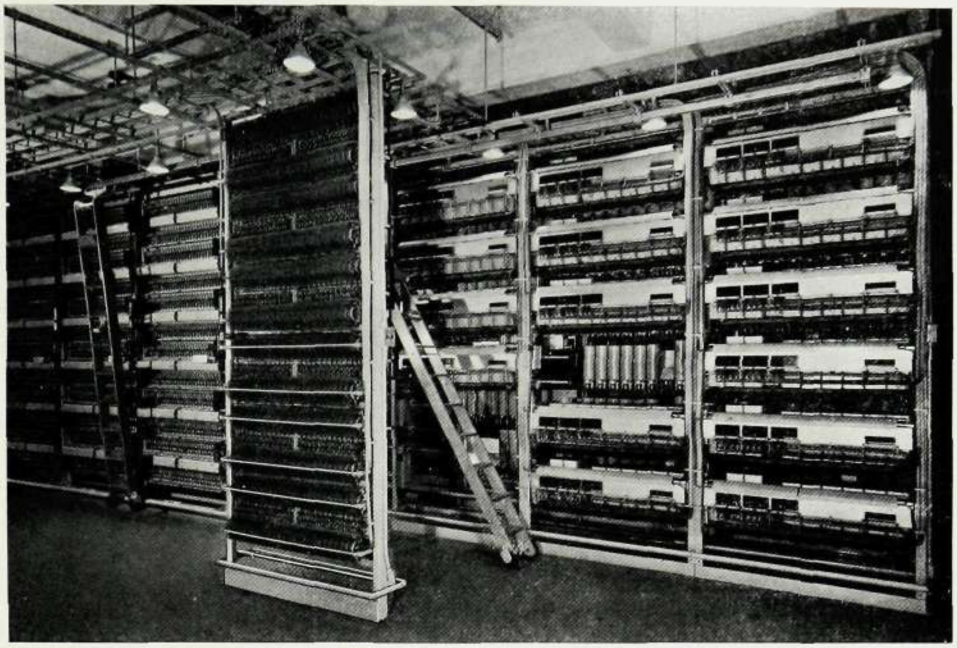


Fig. 6—Uniselector Racks (left and foreground) and wiring side of Connector Racks (right)

line, and ring tone to the caller. When the called party answers, the ringing is tripped, ringing conditions and ring tone are disconnected and speaking conditions are established. The potential on the incoming lines is reversed for supervisory purposes.

For revertive calls, i.e. when one party line subscriber calls another on the same line, the caller removes his handset but restores it after dialling the required number. The bells of both subscribers will ring until the called party answers. The cessation of ringing is a signal to the caller to again lift the handset and thus complete the connection. The circuit operation is as follows :—

As the calling subscriber is on the same line as the called subscriber the line will test busy, relay H will not operate and busy tone will be connected to the caller. When the calling party replaces the handset, earth is momentarily disconnected from the incoming P wire to release preceding equipment, thus the calling line circuit uniselector homes, and the guarding earth is reconnected to the P wire. With the uniselector normal, the H relay re-operates to the K relay in the line circuit. Subsequent operations are as previously described, except that during the release period of the code ringing relay a special ringing signal is connected to the positive wiper, and if the subscribers' bells are on different legs of the line, the caller receives this special signal, but if both bells are on the same leg, the caller will be rung with the same code as the called party. When the latter answers, ringing is tripped and the potential on the incoming line is reversed as before. Speaking conditions are established, or, in the case of an unanswered call, ringing is cut off, when the calling party's handset is removed. Release from a revertive call is obtained when both parties have cleared.

Dial Speed and Ringer Tests.

Apparatus is provided to enable automatic tests to be made on subscribers' and test dials and subscribers' instrument ringers. As will be seen from the trunking diagram, access to the equipment is obtained from level 8 of the special service selectors. The ringer test equipment thus seized, returns an earth over the P wire to hold the special service selector, and returns dial tone to line. The circuit now responds to digits 1 to 0 as follows :—

Digit

1 Absorbed. This ensures correct functioning of the circuit in the event of a false impulse being generated through accidental flicking of the switchhook or a similar misoperation.

2 Connects the dial test circuit—range 8–11 i.p.s. (Subscriber's dial test limits).

3 Connects the dial test circuit—range $9\frac{1}{2}$–$10\frac{1}{2}$ i.p.s. (Subscriber's dial readjust limits).

4 Connects the dial test circuit—range 11–13 i.p.s. (Test dial test limits).

5 N.U. tone returned.

6 N.U. tone returned.

7 Ringer test—(Ring party). For tests on ordinary subscriber's ringer, or on party line subscriber's ringer connected to the "ring" side of the line.

8 Ringer test (Tip party). As above, but party line subscriber's ringer connected to the "tip" side of the line.

9 N.U. tone returned.

0 N.U. tone returned unless the previous digit was 2, 3 or 4.

The first impulse of each impulse train is absorbed while the remainder control the stepping of a uniselector which self-drives to the home position after the completion of each train. If digits 2, 3 or 4 are dialled, the position of the uniselector wipers causes earth to be applied to the start lead of an allotter which will normally be standing on a free dial test circuit containing a finder switch that searches for the ringer test circuit concerned. When connection is established, dial tone is returned to line via the ringer test circuit. The test digit 0 is then dialled to ascertain the speed of the dial, and tones are returned to indicate whether it is below, within, or above the selected range, as follows :—

Slow —"Line busy" tone (133 c.p.s. interrupted 60 per min.).

Correct—"Interrupted ring" tone (20c.p.s. with 400c.p.s. super-imposed, 2 secs. on, 4 secs. off).

Fast —"All trunks busy" tone (133 c.p.s. interrupted 120 per min.).

The dial speed test may be repeated as often as desired, the circuit comparing the speed with the selected range each time digit 0 is dialled, or the range may be changed by dialling the appropriate digit 2, 3 or 4, waiting for dial tone and then again dialling 0.

When it is required to make a ringer test, digit 7 or 8 is dialled and the uniselector steps accordingly to operate a relay which causes line busy tone to be returned to line. The circuit arrangement is such that if any further digits are dialled, the impulsing relay responds without effect, so that tests for bell tinkling may be made as desired.

If the handset of the subscriber's instrument is now replaced, the loop across the line is broken but the holding earth is maintained on the private, and ringing current is applied to line —to the negative leg if digit 7 has been dialled, to the positive leg if digit 8 has been dialled—and the subscriber's ringer is operated. When tests are completed, the handset is lifted, and the ringing is tripped, the circuit being left in a condition to receive impulses for a repeat ringer or dial test.

Fig. 7—The Test Desk

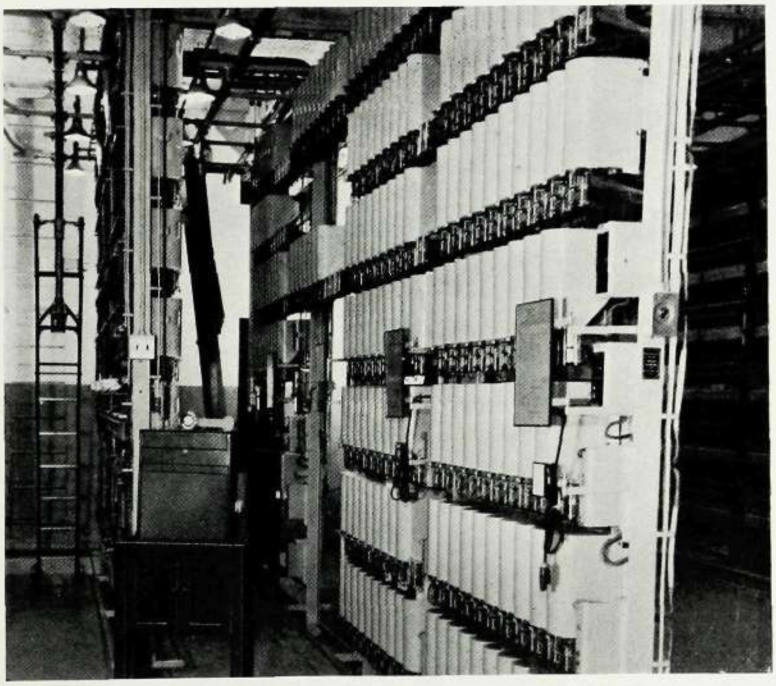
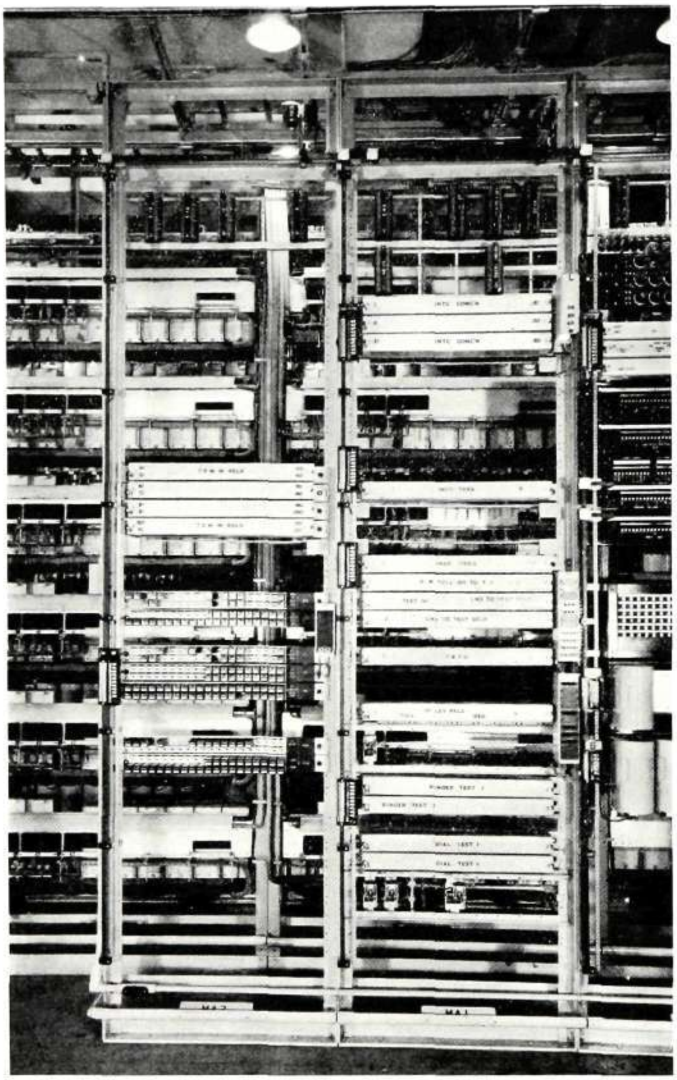


Fig. 8—Some of the Group Selector Racks Portable Tester on left

Access to the dial tester equipment may be obtained from the test desk by the operation of a key which causes the finder switch of the dial test circuit to search for the test cord circuit. A special lamp on the desk flashes when switching occurs and continues to flash as long as the two circuits are associated. The dial tone which is then returned, and all subsequent tones, can be heard by the test clerk, who selects the range to be tested by operating the appropriate key. The circuit can be restored to normal at any time by the restoration of the dial test key.



Miscellaneous Apparatus Racks

The progressive development of the town of Flin Flon, that isolated hive of industry in Northern Manitoba, was materially assisted when the new "Dial Central Office" was brought into service in March 1952.

The story of Flin Flon's origin and growth is one which appeals to the imagination. It reminds us of the romantic days of "98," except that this town is no ramshackle collection of hutments but a thriving industrial centre in which the resources of modern science are fully used to win the precious metals from Mother Earth.

The new telephone equipment is of the finest modern type and will undoubtedly play a considerable part in expediting production. We would like to think that the silver, copper, cadmium and zinc used extensively in the manufacture of this equipment designed to assist the people of Flin Flon, originated from the mines in which they labour so industriously.

Multi-Channel V.H.F. Radio Telephone Systems

THE multi-channel v.h.f. radio-telephone systems to be described have been developed jointly by the Company and the Telecommunications Division of Pye Ltd., Cambridge, who have designed the radio apparatus and have provided material for the information on the radio aspects of the problems discussed.

As the equipment consists essentially of a radio system combined with carrier telephone equipment of normal design the bulk of the development has been on the radio side with its attendant problems of propagation, aerials, repeater stations etc.

The results obtained have proved that a very satisfactory system can be installed and maintained, and while the developments described here cover three-channel and six-channel equipments only, further development is being carried out to cover twelve, and groups of twelve channels.

Considerable attention has already been given to the problems associated with wired circuits, with the result that multi-channel systems which make use of underground cables or open wire overhead routes are now well established. Radio links, however, are being used to meet the ever increasing demand for telephone trunk service and, at the same time, to eliminate the cost of the extra cables or open wire lines which would otherwise be necessary.

The advantages of being able to provide a number of channels by the use of a radio link, and so completely eliminate the physical circuit, become very obvious, especially when the difficulties experienced in crossing stretches of water or undeveloped and inaccessible terrain are considered. Not only is the initial cost of installing physical routes under such conditions very high but also the recurrent costs of maintenance, while the loss of revenue during a breakdown, which might last for some days, would be appreciable.

Submarine cables between islands and the mainland, or across river estuaries are always liable to damage by shipping, and the problems and costs of lifting and repairing them are well known.

Open wire routes, particularly in tropical areas, are subject to damage by storms and animals, or through theft of the copper wire by the natives; also, where the wires are relatively low as on a normal pole route, the rapid growth of vegetation in wet seasons can be a serious problem for the maintenance staff, whereas the comparatively high towers used for the aerials of the radio system are not affected by these conditions.

Application.

The radio link provides a four-wire circuit between terminal stations, and is capable of extension in length by the introduction of intermediate repeaters. The radio circuit differs from the usual four-wire physical circuit in so far as, in the case of a line circuit, the length of the repeater section and the gain of the repeaters can be arranged to be of fixed values suitable to achieve a required signal/noise ratio for

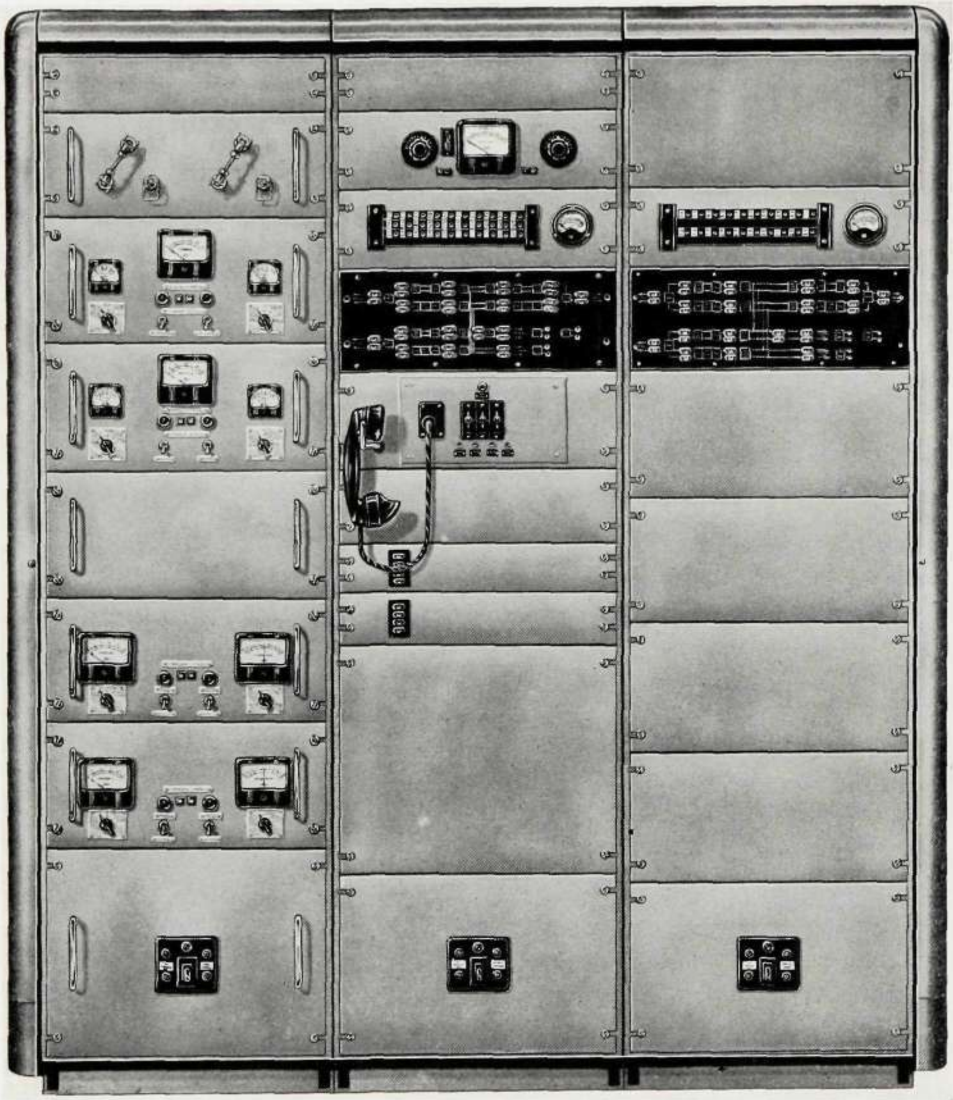


Fig. 1—The V.H.F. Radio Link Equipment, Six Channel System

the circuit. The positioning of the repeaters of a radio link, however, will be controlled by geographical rather than performance factors and therefore the same control over the signal/noise ratio may not be obtainable at an economical cost, thus the number of repeaters and the length of the circuit will be controlled by the signal/noise ratio which can be tolerated in relation to the permissible cost.

The terminal equipment falls naturally into two parts, the radio, comprising the transmitters, receivers and auxiliaries, and the channelling, which arranges the various telephone channels into groups and frequency bands suitable for transmission.

There are various types of circuits to which a radio link might be applied, from simple point to point working up to long sections of a large trunk route with many channels. In general, however, these circuits will fall into one of two categories according to the performance required, and so two types of equipment are available. The first of these—described in this article and illustrated in Fig. 1—provides up to 6 channels in a frequency band between 6 and 30 Kc/s, each channel having a speech band up to 2700 c/s. It is based on the use of three-channel carrier equipment as used for open wire circuits and is applicable in similar conditions. A radio link of this type would cover the requirements of point to point working or spur routes where good commercial speech is the first requirement. The second type utilizes transmitters and receivers of wider band widths, together with channelling equipment which provides a service based on the 12 channel group, with a 4 Kc/s spacing. The groups are placed in a frequency band of from 12 to 108 Kc/s and this link is suitable for inclusion in a high quality main trunk route.

There may be times when, due to the growth in traffic, it will be necessary to provide more channels than the radio equipment has been designed to handle initially. When this occurs, a second link may be set up in parallel with the first by utilizing on new frequencies the transmitters and receivers which are normally supplied as spares for the working system. This is a very economical arrangement and, in the event of a fault occurring, ensures that there will not be a loss of all circuits simultaneously. This eases the problem of maintenance and eliminates the need for elaborate alarm circuits, while the use of radio equipment with restricted band widths will give a better overall circuit than where very wide band local receivers are in use. By this means also it is possible at the initial installation to provide a larger number of channels.

Installation.

There are occasions when it is desirable to install the radio equipment at some distance from the exchange in order to take advantage of high ground as a suitable aerial site. This leads to alternative arrangements for the positioning of the channelling equipment ; in the first case it may be associated with the radio equipment, the audio circuits being extended to the exchange by cable or open wires ; alternatively it may be located in the exchange and the two equipments linked by two pairs, one "go" and one "return". The output and input levels of the channelling and radio equipment at the carrier frequencies, are suitable to allow for the use of several miles of cable or open wire.

The output level and impedance of each telephone channel at audio frequency is such that the channel may be extended to a four-wire circuit or terminated on the local switchboard through a suitable hybrid transformer.

Radio Equipment.

Choice of Frequency Band.

For multi-channel radiotelephone links the v.h.f. band (nominally 30–300 Mc/s) has many advantages over both medium (m.f.) and high (h.f.) frequency bands. In the first place, the m.f. and h.f. bands (nominally 300 Kc/s to 3 Mc/s and 3 Mc/s to 30 Mc/s) are already overcrowded by existing services, and suffer severely from noise caused by electrical machinery and atmospherics. Secondly, rapid fading, daily and seasonal variations in propagation, and occasional complete fade-outs, all make the maintenance of circuits most difficult. Whilst very long ranges are obtainable at these frequencies, interfering signals also travel great distances.

Above 60 Mc/s, on the other hand, the attenuation of signals increases rapidly beyond the optical range of the transmitting aerial, so that long distance interference is not experienced except under freak conditions. Atmospheric and other noise is much diminished and continues to decrease as the frequency increases. Whilst signals of reasonable strength are commonly received well beyond optical range — especially in the lower part of the v.h.f. band—their use is limited by the extent to which fading can be tolerated. Within optical range, paths are substantially free from fading and for multi-channel services it is advisable, as far as possible, to operate links within this range. Because this is not always essential, however, v.h.f. systems allow more freedom in station siting than micro - wave systems, which demand absolutely optical paths.

A further advantage of v.h.f. over lower frequencies is that it is practicable to construct aerial arrays of high gain and directivity without their becoming unwieldy. This advantage applies more especially to the upper part of the v.h.f. band. The extra gain permits lower transmitter power to be used, and this in turn tends to increase the reliability of the system. The directivity of the aerials greatly reduces the risk of interference from other v.h.f. services.

The bandwidth occupied by the significant sidebands of the frequency modulated (f.m.) six-channel system described, is about 240 Kc/s (it is important to note that much of the advantage of f.m. derives from the use of a high deviation ratio). In the m.f. and h.f. bands, adjacent single speech channels are normally separated by little more than the bandwidth required for the carrier and sidebands, so that a six-channel system would displace many more than six individual single channel services at these frequencies. In the v.h.f. band, on the other hand, adjacent single channel services are normally separated by 50 Kc/s at 80 Mc/s or 100 Kc/s at 160 Mc/s, due to frequency stability difficulties. A six-channel system will therefore displace fewer than six single channel services in the v.h.f. band.

Choice of Modulation System.

The preceding paragraph indicates that f.m. is suitable, from a band width point of view, in the v.h.f. band. The C.C.I.F. recommendations for noise and crosstalk on the telephone channels are also most satisfactorily met by the use of frequency modulation. Amplitude modulation, while still the best system for many types of communication, is inferior to frequency modulation using wide frequency deviation, where a very high signal/noise ratio is required. Since distortion of the carrier frequency signals results in crosstalk between the speech channels, the linearity of the modulation characteristic is of prime importance, and this is more easily obtained by frequency modulation. The carrier frequency is modulated at a low frequency in the early stages of the transmitter, while subsequent stages merely multiply the frequency and amplify the signals. The great advantage of this is that a high power amplifier can, when required, be interposed between the aerial and the standard transmitter without modification of the latter.

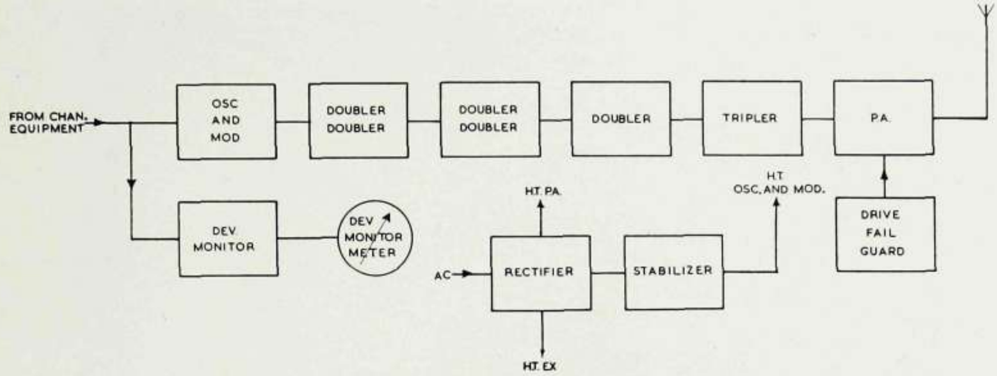


Fig. 2—Block Diagram of the Transmitter

The various types of pulse modulation are theoretically attractive, but the complexity and unfamiliarity of the techniques involved would make maintenance difficult, without intensive training of staff. The bandwidth requirements of pulse systems force them into the microwave region.

Transmitter and Receiver.

Block schematic diagrams of the transmitter and receiver are shown in Figs. 2 and 3 respectively. The equipment is designed for operation on frequencies between 60 and 216 Mc/s. The higher and lower parts of this band each have their own advantages which must in each case be considered in relation to the characteristics of required links.

Switched meters are fitted on the transmitter and receiver front panels to facilitate routine checks and adjustments, while the frequency deviation of the transmitter is continuously monitored on a separate meter on the panel.

In the transmitter, the initial drive is derived at a comparatively low frequency from a special Pye temperature-controlled crystal contained in an evacuated B7G glass envelope. A series of frequency multiplier

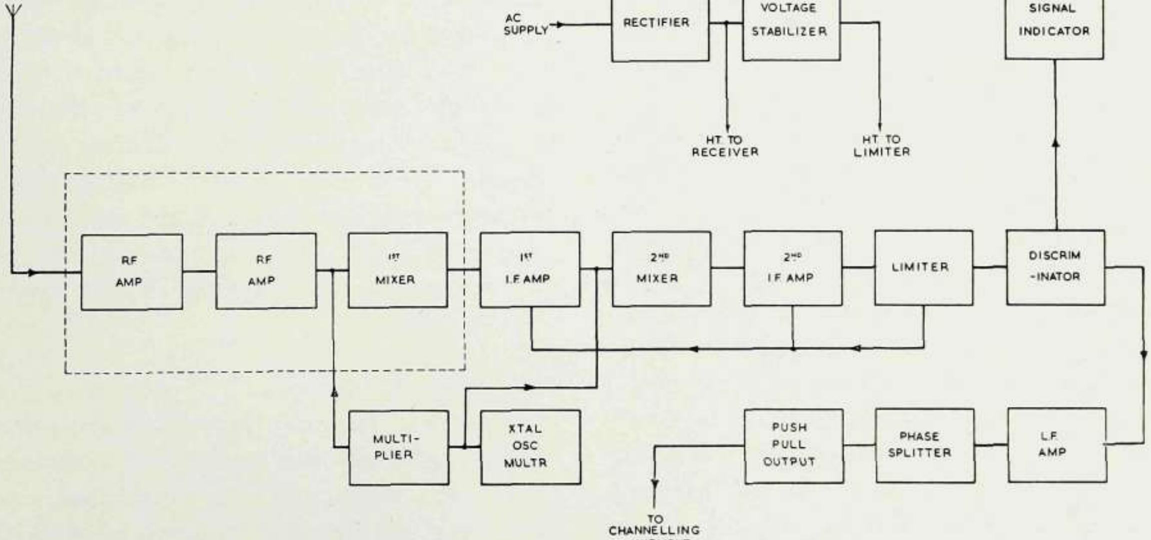


Fig. 3—Block Diagram of the Receiver

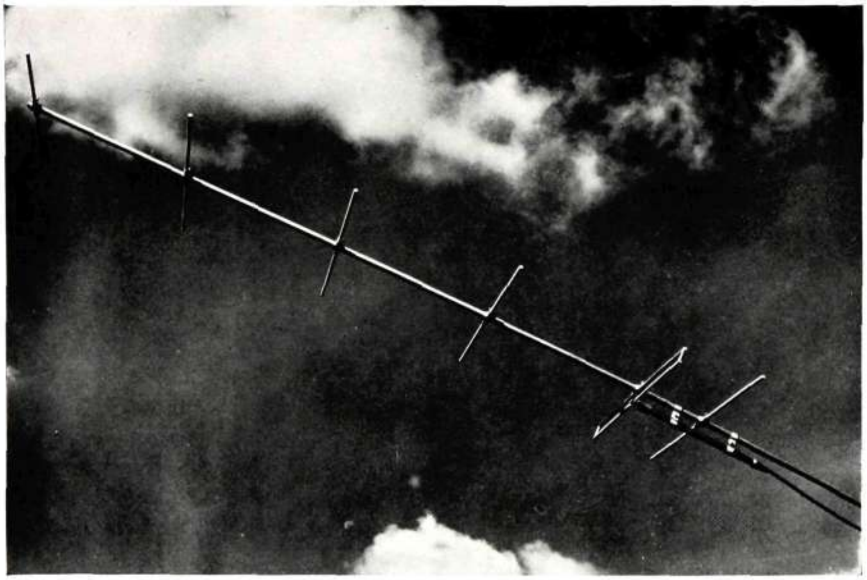


Fig. 4—The "Yagi" Aerial Array

stages leads up to the final amplifier stage, which has a power output of 10 watts. In the event of failure of the drive from the earlier stages, the power amplifier valve is protected from damage by a circuit which automatically limits the current drawn by the valve. Where additional power is required on long links, to obtain a sufficient signal at the receiver, a 50-watt r.f. amplifier mounted with its own power supplies on a separate chassis can be connected to the standard transmitter.

The receiver is a double superheterodyne, the first mixer being preceded by two stages of r.f. amplification. The local oscillator injection for both mixers is derived by multiplication from a single crystal similar to that used in the transmitter, and the output circuit is designed for direct connection to the channelling equipment. In the design of the first stage of the receiver, special attention has been given to keeping the noise level low, and the performance is such that a signal/noise ratio of 55 db on an average speech channel is obtained when the r.f. input to the receiver is 100 microvolts. Where a signal/noise ratio of 40 db is adequate, an input as low as 20 microvolts can be used, subject to freedom from interference from electrical machinery.

Of the various types of directional aerial array available, the "Yagi" (Fig. 4) was chosen on account of its relative simplicity. There is only one driven element in this array, the directional properties being achieved by means of parasitic elements. For the lower part of the frequency range, a "Yagi" with a reflector and two directors is used, giving a gain of 6 db over a plain dipole. For the higher frequencies a reflector and four directors are used, giving a gain of 10 db. These aerials are designed for connection to a standard 75-ohm coaxial feeder cable.

Repeater Stations.

Repeater stations, where required, consist of two radio terminal equipments connected back to back. The transmitters and receivers are identical to those used at the terminals, so that maintenance arrangements are simplified, and as territories are developed, telephone channelling equipment may be fitted at repeater stations.

Telephone Channelling Equipment.

For satisfactory two-way radio transmission, the two transmitters have to work on different frequencies. This is equivalent to four-wire working in cable systems and therefore the frequency allocations for the channelling equipment are the same for both terminals.

The various bands have been arranged as follows :—

Channel	*Transmission Band Kc/s.*	*Carrier Frequency Kc/s.*
Engineering ..	0.3 – 2.7	—
Alarm and special signalling ..	3.0 – 6.0	—
Telephone Channel 1..	6.6 – 9.0	9.3
,, 2..	9.7 – 12.1	12.4
,, 3..	13.2 – 15.6	15.9
,, 4..	18.0 – 20.4	20.7
,, 5..	21.7 – 24.1	24.4
,, 6..	25.8 – 28.2	28.5

From the block schematic of the channelling equipment shown in Fig. 5 it will be seen that the derivation of the various channels follows standard carrier practice. Each speech channel modulates the particular carrier oscillator, and the carrier and upper sideband are suppressed by the balanced modulator and band pass filter. The outputs of the several channels are now passed together into the group amplifier for feeding to the transmitter at the correct level. Similarly, on the receive side, the radio receiver output is ample for demodulation without further amplification. After demodulation, audio amplification and equalization provide a good quality output of the correct level for normal switchboard working.

Oscillators.

As the same frequencies are used for the send and receive paths, only one oscillator per channel is necessary at each terminal, for both modulation and demodulation.

To avoid the problems of synchronization of the carrier oscillators, quartz crystals with the low frequency flexure mode of vibration are used. These can be set accurately and remain stable over a wide range of temperature. Frequency differences between the two ends of any one

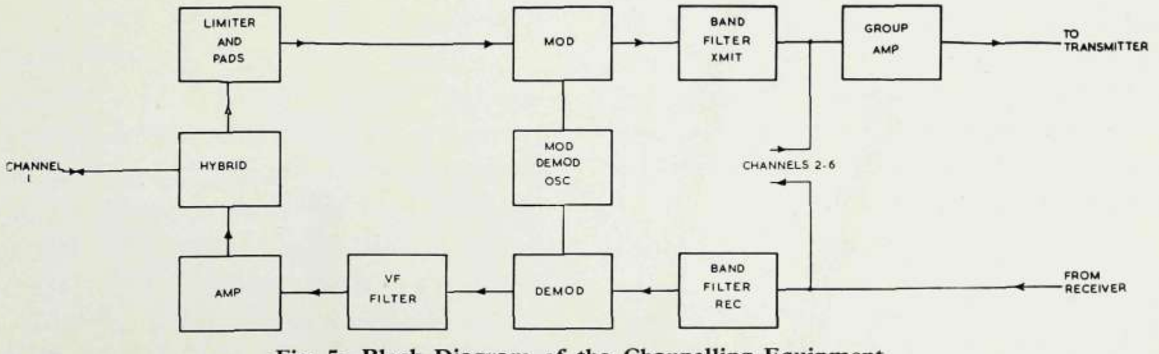


Fig. 5—Block Diagram of the Channelling Equipment

channel will therefore never exceed the close limits demanded of non-synchronized circuits.

Modulators.

The modulators and demodulators are of the conventional ring type, using sets of aged and matched copper oxide rectifiers which have the advantage of remaining sufficiently stable and balanced to maintain the carrier leak within allowable limits. A balancing resistance potentiometer is included to enable an optimum balance to be initially obtained.

Voltage Limiters.

Voltage limiters incorporating metal rectifiers are used in the transmit circuits before modulation, to prevent the overloading of the modulator and following circuits. Overloading in common circuits, e.g. group amplifier or radio, would cause inter-modulation and give rise to excessive noise in other channels. Should any particular channel be required for telegraph working, the voltage limiters are readily disconnected. This is necessary to prevent distortion of the telegraph signals, but as the signals are of controlled amplitude, no inter-modulation due to the omission of the limiter will arise in common circuits.

Filters.

The band pass and voice frequency filters used are of conventional design and have sufficient attenuation outside their pass bands to reduce sideband interference to acceptable levels, and to ensure that only the audio band of the telephone channel is transmitted to the switchboard.

Amplifiers.

The group amplifier, provided to raise the level of the sidebands to zero for feeding into the transmitter, has ample power output, and, at a level of +17dbm per channel for three-channel working, or +11dbm per channel for six-channel working, the distortion produced is less than 0·1%. As the normal output is zero dbm per channel, the distortion and inter-modulation products are obviously of a very low level.

The amplifier in the receive path raises the level of the demodulated signal to normal switchboard level and a zero equivalent is attainable for any channel. This amplifier also has adjustable feed-back paths to set any channel response within accepted limits.

Levels.

The minimum input to the band pass filter on the receive side is −11dbm and the output from the radio receiver is arranged to be at zero level. The group amplifier output to the transmitter can be up to +11dbm per channel if required, although the transmitter requires only zero level input per channel. This extra power is available for use when the radio part of the equipment has to be separated from the channelling equipment. Lines carrying the various channel frequencies can therefore have a loss of up to 11db at the highest frequency used.

Signalling.

Signalling over the channels follows standard carrier practice. 17 c/s ringing current is accepted from the switchboard and converted to 500/20 c/s for transmission through the channelling equipment. The receipt of this signal at the distant terminal operates a ringing receiver which transmits a 17 c/s signal to the exchange. Alternative arrangements are available to suit various types of exchanges which may be in use, and auxiliary equipment can be provided to give dialling facilities in the case of automatic systems.

Testing and Maintenance.

In view of the difficulty of providing adequate testing facilities and trained staff in many territories, every effort has been made to reduce routine adjustments to a minimum and to make routine tests or checks as simple as possible and capable of being carried out by unskilled labour. To this end, as already mentioned, all channel oscillators are crystal controlled, and synchronization is not necessary between the terminals. The anode current of each valve, and the various supply voltages, can be measured by the insertion of a plug in a central jack field.

An oscillator giving a zero output of 800 c/s, together with a level measuring set, provide facilities for testing or lining up each channel to its correct level. This test is considerably simplified by the use of panels in which the more important points of the circuit are brought out to 'U' link connections so that level tests may be made, or the circuit disconnected, to enable faults to be readily located. The panels may be seen in Fig. 1 and are suitably engraved with a block schematic so that the engineer knows exactly at which point in a channel he is testing.

Repeater Station Alarms.

It is to be expected that under certain conditions a long route may be provided with one or more repeater stations which may be completely unattended or have only caretaker supervision. In the event of an apparatus or power failure at such a station, it will be necessary to convey suitable information to a terminal, so that appropriate action may be taken. To what degree the information conveyed should identify the cause of the breakdown, is best determined by the user of the system taking into consideration the cost and the methods of maintenance.

If, on receipt of a fault signal, a visit to the repeater station can always be made within a reasonable time, it may not be necessary to provide for discrimination over the link ; therefore it will be sufficient to give a general alarm, but it would appear desirable to differentiate between an apparatus fault which causes a break in the service and requires immediate attention, and, say, a power failure which puts stand-by plant into operation. The complexity and arrangement of the alarm scheme will be governed by the conditions under which the radio link is operated. It has already been stressed that a system using two parallel paths with half the circuits on each path has many advantages to offer, and if this system be used, it demands a much less complicated alarm scheme, as the whole of the channels are not lost in the event of a minor fault. If, on the other hand, all the circuits are transmitted over one link, more detailed fault indication is needed and possibly the provision of facilities for putting into circuit the stand-by radio equipment. It is not, therefore, proposed to describe in detail any particular alarm scheme but to indicate the types of alarms for which provision might be made.

An alarm could be given from the repeater station, in the form of a suitable signal controlled by the action of a relay, to indicate :—

(1) A receiver failure
(2) A transmitter failure
(3) A working power supply failure
(4) Low fuel supply

In the case of the power failure, further signals could indicate the reason for a changeover to stand-by, e.g. low oil pressure or overheating ; conditions which might not be obvious by the time the maintenance engineer arrived. Each repeater station could be equipped with one or more fixed frequency oscillators so that in the case of a failure a frequency would be fed to the working path and received at the terminal by a selective receiver equipment, the operation of this receiver causing a relay to operate and give both local and extension alarms. The number of oscillators and, therefore, of the signal receivers necessary, would be governed by the complexity of the information to be transmitted.

POWER SUPPLIES.

The equipment operates from a 110/250 volts, 50 cycles supply which may be obtainable from the local power mains. If, however, these are unsuitable, or connection cannot readily be made, an alternative source of power must be provided. A typical installation could comprise two diesel alternators, one working and one standby, with automatic changeover facilities. The small diesel engine has been found most suitable for this class of work, as it is capable of running for considerable periods without attention—a very desirable characteristic when engines are used at repeater stations which may be unattended for days, or even weeks.

There are, of course alternative schemes and the choice would be dependent upon the existing local conditions.

The Dekatron

The domestic story of the Company's cold cathode valve

AS part of our investigation on electronic switching we are carrying out an extensive enquiry into cold cathode valves. They are now of considerable interest because recent developments have shown the way to control the discharge action in a more reliable manner.

Man's early reverence for a discharge phenomenon in the form of lightning was turned, with the invention of the vacuum pump and the discovery of the fundamental electric particles, into an intense scientific study which has continued for the past sixty or more years. This study, which has formed the basis of design work on all electronic devices such as valves and cathode ray tubes, is still incomplete. Such phenomena as the effect of impurities in a material on its work function, or the effects of adsorbed surface layers of gas are now more clearly understood ; as higher vacuum, purer gases and new materials become available it is possible to control the discharge within finer limits and to determine more precisely the nature of its physical mechanism.

Rather more than four years ago, when we began to give really serious thought to an electronic telephone exchange, one of the major problems appeared to be the power consumption needed to heat the filaments of ordinary types of valves and the possible limitation of their life. Any component of an electronic exchange must have a life equal to, or better than, the electromagnetic-mechanical components. It was considered that this condition might well be met by cold cathode valves, and we immediately set about building up a fairly extensive research laboratory to investigate the possibility. We were fortunate in recruiting several specialists whose keenness for this class of work matched our own and we have gone ahead from a flying start.

The first valve developed is a scale-of-ten counter or selector. It consists of an anode plate or disc, surrounded by a number of guide wires and cathodes. Fig. 1 is a plan view showing the arrangement of the wires, while the construction is to be seen in Fig. 2. All the G_1 electrodes are connected together and all the G_2 are connected together. If now a discharge is struck from the anode to cathode K_1 and a pulse is placed on guide wires G_1, the

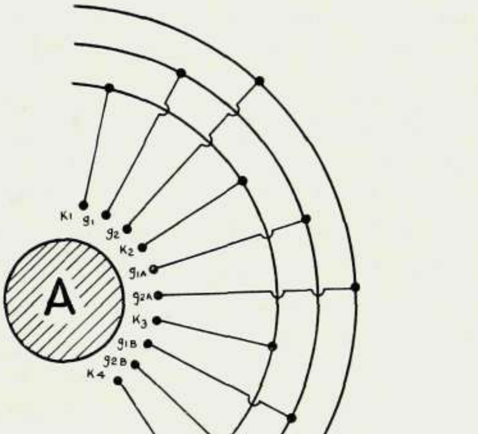


Fig. 1—Diagrammatic Plan of the Wires in the Dekatron

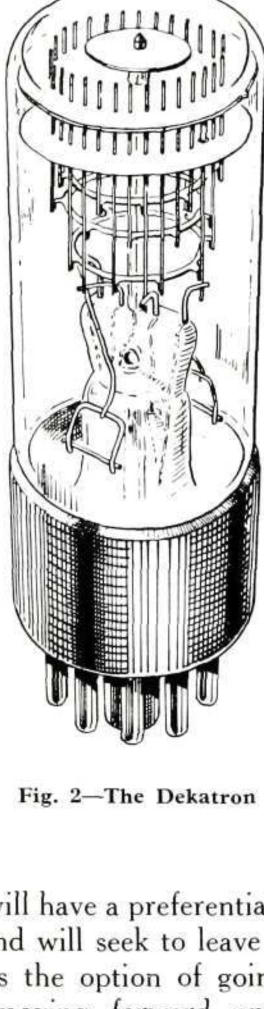


Fig. 2—The Dekatron

discharge will have a preferential path to the G_1 wires and will seek to leave the cathode K_1. It has the option of going back two wires or moving forward one ; due to diffusion of effective ionization, it moves forward to the nearest G_1 wire. The impulse then appears on the G_2 wires and again the discharge passes forward. As the impulse decays the forward movement is repeated and the discharge settles on cathode K_2. In actual practice the movement of the discharge is not quite as clear cut as outlined here. With the pulse on G_1, the discharge sits on both the cathode and guide wire, then as the pulse reaches G_2 it sits on G_2 and G_1 wires, and as the pulse goes entirely from G_1 the discharge starts moving partly on to the next cathode. The details of this tube have appeared in *Electronic Engineering.** Reprints of these papers are available on application.

The valve has a most important advantage in that the glow is very clearly visible through the end of the glass envelope. If a numbered escutcheon is placed round the tube, the valve can be made to act both as an electrical counting circuit and its own visible indicator.

Our early work with this type of valve gave some extremely high speeds of operation—counting speeds of 30,000 to 40,000 impulses a second—but it was not possible to obtain both extremely long life and a high counting speed. Accordingly, work was concentrated on similar valves using a gas mixture which, although giving a slower counting speed, 600 per second, appeared more promising from the life aspect, and valves of this nature which have been under life test continuously for some 18,000 hours are still operating satisfactorily. With further research, however, a new mechanism has been developed which overcomes the high speed difficulty and at the same time gives rise to simpler external circuits. This new valve is still in the research stage and samples are not expected to be available before the middle of 1952.

We were at some difficulty in naming this new series of valves. In all counting and computing work the systems normally fall into two classes, binary and decade. Most valve and relay counters, because of their ' stop-go ' nature, have tended to work on a binary system. This new valve could clearly be made to operate with any convenient base, but because it could open up

* A new cold cathode counting tube. Bacon, R. C. and Pollard, J. R. *Electronic Engineering*, May 1950.

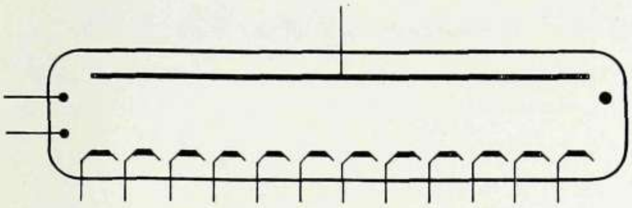


Fig. 3—Circuit Symbol for Valve Type GS. 12A

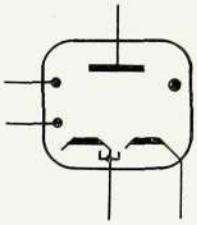


Fig. 4—Circuit Symbol for Valve Type GS. 10A

the decade field so advantageously, we have called it the Dekatron. It is, perhaps, the fortune of all who name a new device to see the device modified for special applications. In our early work on electronic switching, in which we proposed to use the valve as a selector and for digit storing, ten outlets were needed for the numbers 0 to 9 and then two more outlets for rest and marking. This valve has been given the type number GS12A and the circuit symbol is shown in Fig. 3. However, the first major customer for this valve wished to use it as a number indicator, and for this purpose only one cathode need be brought out separately, the other nine being connected together internally to a common external lead. This tube is called the GC10A and is shown in circuits as Fig. 4. We consider it desirable to use the term Dekatron to cover all this family of valves which depend on the movement of a discharge to provide their counting, marking or selecting mechanism. The code numbering of the valve then becomes simple : G indicates gas-filled, C a counter, where the cathodes are not all brought out separately, and S a selector. Thus GC10 would be a gas counter, ten-way.

The Dekatron has the particular advantage that if the connections to guide 1 and guide 2 are reversed, the operation of the counter is reversed, i.e. it can be made to count either forward or backward. It is now fast finding extensive scientific, commercial and industrial uses. The valve has been employed in such instruments as a crystal reference low-range frequency meter where, at say 100 cycles, it is possible to obtain four figure accuracy in a measuring time of ten seconds. It has also been used for an interval timer with an accuracy of 0.001 second. A much more ambitious application is illustrated in recent issues of *Electronic Engineering.**

We feel very confident of the future of the Dekatron with its novel features, long life and reliability.

* An electronic digital computor. Barns, R. C. M., Cooke-Yarborough, E. H. and Thomas, D. G. A. *Electronic Engineering*, August and September, 1951.

Recent Scientific Publications by Members of the Research Laboratories

THE DEKATRON: A NEW COLD-CATHODE COUNTING VALVE

by R. C. Bacon, B.Sc., A.Inst.P. *and* J. R. Pollard, M.A., M.I.R.E.

Electronic Engineering, Vol. 22, *No.* 267, *May* 1950, *pp.* 173-177.

A general study of the work already carried out in the field of electronic counting and computing, leads inevitably to the impression that, despite considerable ingenuity on the part of circuit engineers, there remains a fundamental need for specialized valves designed to meet new problems. In this approach to circuit simplification, it is logical to attack the problem by dealing in the first place with speeds that are in the immediate range above that at which mechanical devices can be safely and reliably operated. To fulfil this need a range of 'Dekatrons' has been designed which comprises, at present, three types of multi-electrode cold-cathode valves.

SAFE COMMUNICATION IN INFLAMMABLE GAS OR VAPOUR HAZARDS

by R. C. Woods, M.I.E.E.

Proceedings of the Institution of Electrical Engineers, Vol. 98, *Part I, No.* 109, *January* 1951, *pp.* 12-13. *Abstract of Chairman's Address to the East Midlands Centre.*

Deals with the provision of signal and telephone equipment which is safe in coal-mine and other industrial hazards and outlines development since the earliest research work, in the two separate categories 'intrinsic safety' and 'flameproofness'. Concludes with a forecast of future trends.

METHODS OF INCREASING THE POWER RATING OF VIBRATORY CONVERTERS

by K. H. Dixey, B.Sc., Grad.I.E.E. and C. V. Wilman, Grad.I.E.E.

Proceedings of the Institution of Electrical Engineers, Vol. 98, *Part III, No.* 52, *March* 1951, *pp.* 105-111. *Paper No.* 1047.

Discusses some of the difficulties encountered when extending the load capacity of vibratory converters, and, in particular, those which are imposed by contact deterioration due to arcing. Two methods are described by which these difficulties can be overcome, both making use of special circuits designed to reduce the current carried by the contacts at the moment that they break the circuit. Reference is also made to methods of dealing with certain vibrator defects, and with transformer surges. Finally, examples are given of practical applications of the circuits described.

THE TESTING OF FINE WIRES FOR TELECOMMUNICATION APPARATUS

by R. C. Woods, M.I.E.E. *and* J. K. Martin.

Proceedings of the Institution of Electrical Engineers, Vol. 98, *Part II, No.* 64, *August* 1951, *pp.* 529-538. *Paper No.* 1064.

Existing acceptance and quality tests are discussed. War conditions brought increased inspection and an urgent need to classify quality. Most tests were found to be limited in application, or of doubtful value, owing to the wide scatter of results. Abrasion and electrical breakdown are considered in greater detail and a limited enquiry into the pinhole test for enamelled wire is described. The difficulties of chemical tests by the purchaser on textile coverings make such tests impracticable as a control. There is need for some new, improved tests and for appreciation of the limitations of the existing ones.

While stocks last, reprints of the above publications are available on application to the Research Department at Beeston.