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AN EXTENSIBLE CORDLESS P.A.B.X.

E. C. Dyson Circuit Development Department

The present trend towards cordless switchboards for P.A.B.X. service is due largely to ever increasing operating costs, and in this P.A.B.X., all possible measures have been adopted to reduce the time and effort involved in manual switching. Calls once established need not be supervised or released by the operator, and incoming calls are distributed to switchboards in cyclic order.

Extensions may be equipped with intrusion facilities and allowed to transfer calls automatically. Moreover, under night service conditions, selected extensions may receive and transfer incoming traffic, the operation of the exchange being unaffected in all other respects.

THE objective of any branch exchange design is the production of equipment having both minimum operating and initial costs. Unfortunately these requirements conflict. A simple cord type P.B.X. clearly involves least initial outlay, but the more fully automatic an exchange can be made, the lower will be the operating charges.

P.A.B.X. systems provide the advantages of automatic service for house calls although an operator is still required to direct incoming traffic to the appropriate extensions. From the economic aspect it is desirable for the operator's time to be spent performing duties where the human element can be fully utilized, and to delegate mechanical or routine functions to automatic equipment. The provision of keysenders and keyless ringing on cord circuits produces some saving and probably represents the practical limit of development of the cord switchboard in this direction. But, by employing cordless principles, calls may be established without requiring any subsequent reviewing of supervisory signals or ultimate manual release. This important advance is due to the fact that cordless connecting circuits connect only the operator. They serve as control circuits enabling the actual connection between parties to be established in selectors. Nevertheless, the reduction in operating time is in itself hardly sufficient to justify a cordless system, since the greater initial cost of selectors designed to provide such facilities might more than offset the long term saving.

Other factors influence the choice. A higher degree of automatic service for extensions is being increasingly demanded to prevent time delays inherent in operator-assisted connections. Executives having urgent business often require to intrude immediately into engaged lines, whilst all users value the ability to contact other extensions during the progress of a public call. Furthermore, there is growing acknowledgment of the advantages obtained by automatically transferring exchange calls. Delays which may irritate a public exchange subscriber, and which on paid time calls cost money, are avoided. With automatic transfer there is no possibility of inadvertently flashing a main exchange operator, no time is lost in calling or giving instructions to the P.A.B.X. operator, and a transferring extension has the opportunity to make any essential remarks to a second extension in secrecy, before transfer is effected.

Since these facilities necessitate elaborate selector circuits, cordless systems fall logically into place. The switchboard connecting circuits can be arranged to utilize selectors in much the same manner as extensions, and an operator may then establish calls by transferring them from herself to the wanted party. Even so, two distinct arrangements for exchange lines are possible : each line can appear individually on the switchboard, or alternatively calls can be displayed when required on common connecting circuits under the control of automatic distribution equipment. In this P.A.B.X. the latter system has been adopted.

Automatic Equipment

As may be seen from the typical trunking diagram, Fig. 1, the exchange operates on Strowger step-by-step principles. The pre-selection stage utilizes heavy duty 50-outlet uniselectors as linefinders ; all uniselectors are in fact of heavy duty type. In

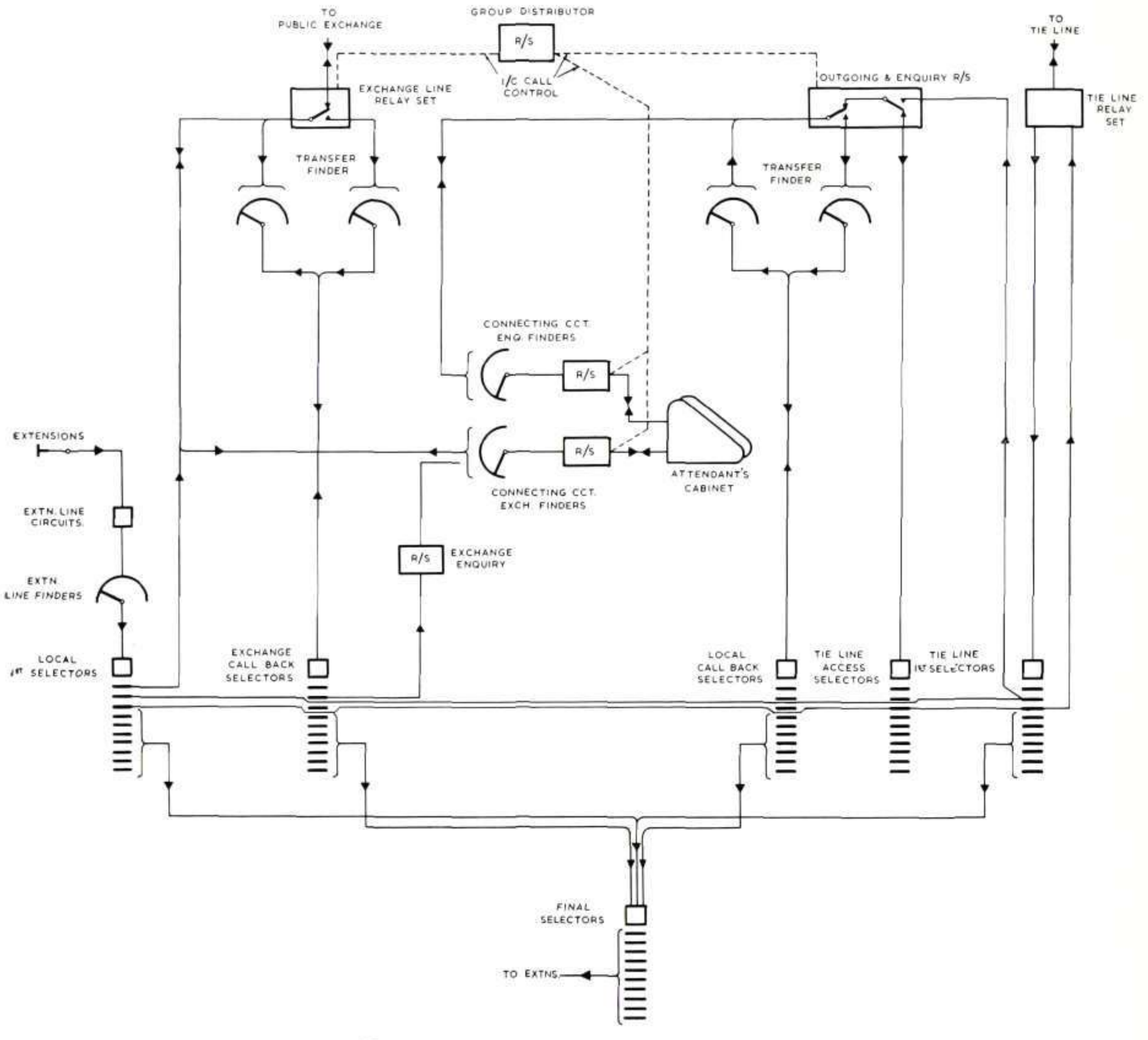

Fig. 1—Typical Trunking Arrangements

large exchanges the linefinders are sometimes associated with 25-point hunters to reduce the number of first selectors. The two-motion selectors, normally 100-outlet type, employ battery testing at all stages and have high safety factors to guard against testing into busy outlets and simultaneous testing into a free outlet. Transfer is accomplished in the transfer finder and call back selector stage. Because the transfer finder is a 25-outlet mechanism, a separate multiple is provided for each group of 25 exchange line, or similar, relay sets.

In Fig. 1, two almost identical call back gradings are shown. One serves exchange line traffic and the other is for local and tie line calls. The use of two separate gradings enables inter-communication between tie lines and the public exchange to be prevented, but the traffic facilities can easily be modified by suitable multiple tie cabling.

Standard open type racks 8 feet $6\frac{1}{2}$ inches high are used, the exchange line rack accommodating 20 relay sets together with associated transfer finders and call back selectors. The extension line rack has capacity for line relays, linefinders, group and final selectors for 100 lines, which is generally the minimum economic size for this type of P.A.B.X. As the P.A.B.X. expands, additional racks may be added, and second or even third selectors introduced if necessary, there being virtually no limit to capacity.

In the principal circuits nearly all relays are B.P.O. type 3000, whilst type 600 relays are used for extension lines. Certain functions such as digit storage in keysenders do not warrant a major relay, a miniature type being adequate, and in circuits where adjustment tolerances of 3000-type relays would be too critical, polarized or high speed relays are employed. As a result, battery voltage variations outside the nominal limits of 46-52 volts, although adversely affecting pulsing performance, will not cause chaotic failure until switch magnets cease to function.

Extensions

Each extension line circuit comprises two relays having P.G. lock-out facilities. Lock-out occurs after two minutes if an extension should fail to dial or if a faulty line causes seizure of a first selector ; in either case the circuit reverts to normal when the P.G. condition is removed. The switching train operates on calling party release principles, but if a caller does not replace his handset correctly the P.G. lock-out equipment is also brought into action to prevent a called line being permanently held.

To meet the requirements of different classes of users, provision has been made for any extension to be placed in one of the following categories :—

(*a*) Extensions with intrusion (preference) facilities and unrestricted access to the public network.

(*b*) Extensions without preference facilities but still having full main exchange service.

(*c*) Extensions barred direct access to the exchange but permitted incoming and transferred main exchange calls. Outgoing traffic is dependent on the sanction of the operator or a responsible extension.

(*d*) Extensions having no access to the public exchange.

Restricting equipment can be added to exchange line circuits to prevent all extensions or just the (*b*) and (*c*) groups from originating trunk calls ; N.U. tone is then returned if the public exchange trunk demand level is dialled.

Extension line jumpering facilities are provided on the final selector multiple connection strip, which includes additional tags for classification strapping.

Preference Facilities

The circuit arrangements for intrusion serve operators and preference extensions in the same manner and can be used for all calls to extensions, irrespective of the path of entry to the final selector.

Preference lines, and these alone, may intrude merely by dialling ' O ' in the face of busy tone. The final selector A relay responds and switching takes place when the pulse train terminates. Intrusion tone consisting of 4 pips of 400-cycle tone every three seconds then replaces busy tone, and contact between all three parties is established. A message may be passed without releasing the existing connection, but if exclusive use of the called line is necessary the intruder requests both parties to replace their handsets.

When the wanted line becomes free, ring tone is returned and ringing current is applied, the call subsequently proceeding normally.

Call Back and Transfer Facilities

Although extensions in most installations do not need to transfer or originate enquiry calls except when speaking to the public exchange, such facilities can be extended to cover other services. Operators, however, must be able to transfer over nearly all types of circuit, as it is their only means of effecting a connection between two parties, and the same principle applies in every case.

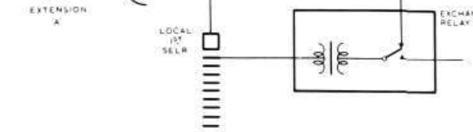

Fig. 2A—Direct Access. Extension ' A ' to Exchange

Figs. 2 A-D show the equipment involved at various stages in the setting up of enquiry and transferred exchange calls ; Fig 2A shows the trunking of a direct access call from extension ' A ' to the exchange.

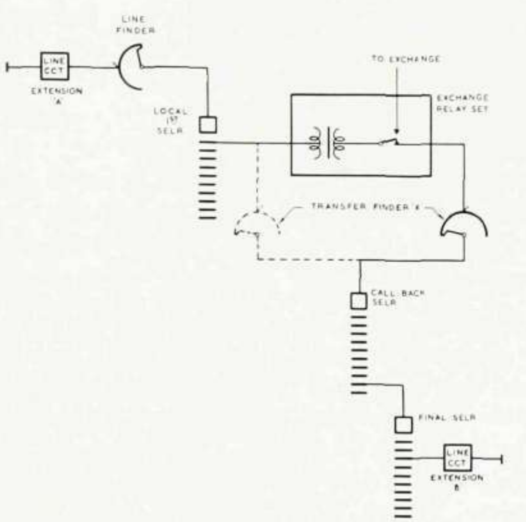

Fig. 2B—Extension ' A ' to Extension ' B ' Enquiry Call (Exchange Held)

Each telephone having enquiry and transfer facilities is equipped with a " transfer " button which, when pressed, earths the line. In the exchange line relay set a differential relay responds, and the contact shown in the block schematic diagrams can be regarded as operated and restored following alternate depressions of the transfer button.

Should extension ' A ' wish to originate an enquiry call, one depression will operate the contact and cause a transfer finder associated with a free call back selector to hunt for the exchange relay set. Extension ' A ' then hears dial tone from the call back selector and dials extension ' B ' over the route shown in Fig. 2B, the exchange line being held throughout. The path of entry to the final selector is not, however, the same as for ordinary extension-to-extension calls, and operation differs in three important respects.

Firstly, if the line tests busy, busy tone is returned while further tests are applied at three-second intervals ; this " camp on busy " facility avoids fruitless repeated dialling of engaged numbers and speeds the handling of exchange line traffic. The caller must use his discretion whether to wait, revert to the exchange line by pressing his button a second time, or intrude if his particular circuit is strapped for preference working.

Secondly, when the line is eventually rung, the ringing cycle is 0.75 seconds on—0.75 seconds off, repeated, instead of the usual cadence of 0.4 seconds on, 0.2 off, 0.4 on, and 2 seconds silence. A shorter cycle for exchange and exchange-call-back traffic gives prior warning of the class of call and also prevents a two-seconds delay if the caller has just missed the ringing period.

Thirdly, the final selector takes into account the traffic classification of the wanted line ; if it is barred exchange calls, a ticker signal at 0.75 second intervals is superimposed on the conversation. Enquiry calls are permissible and the signal advises the caller that transfer, even if it were attempted, is impossible.

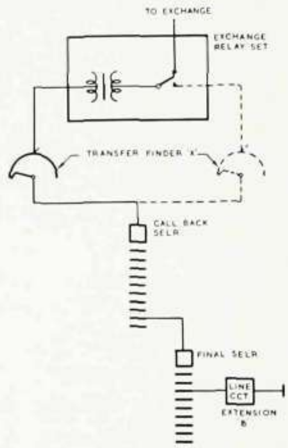

Fig. 2C—Extension ' B ' to Exchange. (Call Transferred)

If extension ' A ' wishes to revert to the exchange line, a further depression of the button not only releases the contact mentioned earlier, but also drops the call back selector train and leaves extension ' B ' locked out on his line circuit. Extension ' B ', of course, has only to press the cradle-switch for an instant if he should wish to originate a call, whilst the unnecessary seizure of first selectors normally associated with calling party release systems is avoided.

However, suppose that in this instance extension ' A ' wishes to transfer the exchange call to ' B '. All he does is notify ' B ' of his intention and replace the handset.

Now if ' B ' happened to be a barred extension, or if ' B ' also replaced his handset, extension ' A ' would not be released by the exchange relay set. Instead, extension ' A ' would be rung and on lifting the handset to answer, would be re-connected to the public exchange.

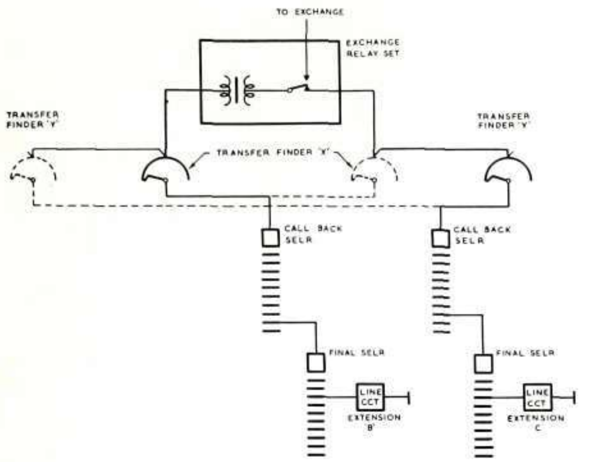

Fig. 2D—Extension 'B' to Extension 'C' Enquiry Call. (Exchange Held)

But, once all conditions are satisfied, extension 'A' and the local first selector train are allowed to release. The vacated in-going lines of the relay set are not liable to be seized from selectors, as the testing-in battery is disconnected. However, after about 100 milli-seconds they become re-occupied from the transfer finder, which transfers the speech path from the right-hand wiper group to the left-hand group. Two other operations take place in rapid succession ; the transmission bridge of the final selector is replaced by a metallic circuit, and the contacts restore automatically to connect extension 'B' to the exchange. This is the condition shown in Fig. 2C.

Extension 'B' is now in a position to control the relay set as 'A' controlled it earlier. Should 'B' press his button to originate an enquiry call, a second transfer finder, in Fig. 2D given the suffix 'Y', is driven to the same outlet. No mutual interference occurs, because different arcs of the X and Y finders serve the calling and called extensions respectively. Fig. 2D illustrates the routing on an enquiry call from 'B' to 'C', the two call back selectors being individual selectors in the same grading. Transfer of the exchange line to extension 'C' can take place as described previously, except that the 'X' transfer finder and 'B's selector train are released instead of 'A's local first selector.

Any number of successive transfers are therefore possible, and there is no inherent limit to the number of transferred calls which may exist simultaneously. It is simply a question of providing an adequate number of call back selectors.

Should it be necessary to obtain the operator or transfer the call to her, exactly the same procedure is employed except that the operator's code digit, shown as '9' in Fig. 1, is dialled.

The Attendant's Cabinet

Since all calls are routed via connecting circuits, every position in a multiple installation is alike. The absence of switchboard multiple cabling simplifies the addition of further positions, whilst the absence of cords reduces maintenance and avoids any distracting noise from falling plugs or swaying pulley weights.

The switchboards contain little more than lamps and keys, and are of such small dimensions that they may often be conveniently mounted on an office desk. In single-position installations the combination of small switchboards and operators able to devote considerable time to other duties, results in the term "attendant's cabinet" being generally applied to this form of construction.

The typical switchboard illustrated in Fig. 3 presents an attractive appearance, having a polished hardwood case with a green enamelled steel faceplate accommodating the keys, lamps and dial. Five connecting circuits, each comprising four lamps of different colour and a Speak key, are arranged in vertical columns on the left of the faceplate. Normally four of these circuits are associated with public exchange lines, leaving the one on the right for local and tie line traffic. Space is available for an ultimate sixth circuit, and since all are identical the ratio of exchange and tie line connecting circuits can readily be adjusted to meet varying conditions.

The push button keys on the right, comprising "release", "transfer", "refer back", "flash" and the digit keys, all of high-grade roller type, are common to the position, and function on a connecting circuit only when the particular speak key is operated. The layout bears some similarity to a typewriter keyboard, all controls being conveniently placed for the operator's fingertips, to promote maximum speed of operation with minimum fatigue.

Fig. 3—The Attendant's Cabinet

Call Distribution

Incoming calls on a conventional cord pattern P.A.B.X. switchboard are displayed over all positions as they arrive, and when a number of calls are received they are frequently answered at random.

Advantage has been taken of the connecting circuit system to incorporate automatic distribution. Sequential tests for calling conditions exclude the possibility of any one line being subjected to excessive delay, and calls are extended in turn to all staffed positions free to accept further traffic. Thus when the load is light, work is shared evenly, but during busy periods each operator can work at full capacity.

When any position is unattended, it is busied by the removal of the operator's telephone, and when all positions are vacated the exchange reverts to night service working. Each position is also equipped with a busying key for use when only outgoing traffic is being handled.

Connecting circuit finders are 50-outlet uniselectors, and lines must therefore be divided into traffic groups of 50 for incoming purposes.

When a number of calls from different traffic groups await attention, a " group distributor " is arranged to select, in turn, one call from each group for display, until all are answered. Thus, under control of the distributor, a calling line is hunted by the connecting circuit finder of a free connecting circuit on a free position. If one call on a particular position is already displayed, or if the operator has any speak key depressed, that position is busied to incoming calls.

As soon as the finder has been positioned, the ' answer ' lamp glows and the control circuits deal with any further waiting calls if free equipment exists, calls being stored if no connecting circuit is available. Meanwhile a " wating call " lamp glows on each position.

Exchange Line Traffic

To answer, the appropriate speak key is operated. The answer lamp is then extinguished and a ' busy ' lamp glows. After ascertaining the extension required, the operator depresses the position " transfer " key, which, as in the case of an extension, causes the seizure of a free call back selector. The operator always has the choice of dialling or keysending but would usually key the necessary digits.

The keysender generally has a capacity equal to the P.A.B.X. numbering scheme and as soon as the complete number is stored, a blue warning lamp lights and pulsing out commences.

At this stage the operator is free to attend to other calls, although she cannot use the keysender until the lamp has extinguished to denote that all pulse trains have been transmitted on the previous call. This is about three seconds, nearly always less time than is required to discover the next caller's requirements.

When the extension answers, he will normally be connected directly to the public exchange, and the busy lamp on the attendant's position will be extinguished as the connecting circuit automatically releases.

Should the operator wish to introduce the call, she leaves the connecting circuit speak key operated. Transfer and release of the connecting circuit then take place after introduction, when the key is restored. Each connecting circuit has a supervisory lamp which glows during the ringing out period and provides the busy flash indication if the called line is engaged, in which event the operator may leave the caller " camped on busy ", or decide to offer the call by dialling ' O ' to intrude. If she keys the ' O ' digit it is also necessary to depress momentarily the " send start " key, as the sender's storage capacity is not filled. After intrusion, through switching and transfer proceed as before, if the extension agrees to accept the offered call and clears his existing connection.

If, on the other hand, the operator wishes to dial another extension, this is accomplished following two successive operations of the transfer key. The first releases the local connection and reverts her telephone circuit to the exchange line, whilst the second seizes another call back selector. To prevent any possibility of confusion, the routing of a connecting circuit is indicated by a lamp, designated " internal ", which glows when the connecting circuit is extended to a call back selector.

Should the number called be restricted from exchange service the operator, like extensions, can speak but not transfer. In addition to the ticker signal, and to warn her when she is not listening on the circuit, the supervisory lamp flashes after the called party has answered. There is one further feature to aid the operator. Unlike extensions, she has a " refer back " key which enables her to revert to the exchange without releasing the local switches. She can therefore readily advise the caller regarding the progress of the connection. On all types of call it is fundamental that the operator speaks to one party or the other—never to both—unless her presence on the line is accompanied by intrusion tone. In this way secrecy requirements are fulfilled.

Outgoing Exchange Calls

The operator seizes a free exchange line simply by pressing the speak key of a free exchange connecting circuit. The required number may be obtained with the aid of the dial or keysender, and the call can subsequently be reverted to an extension, exactly as an incoming call would be. This is in fact the usual procedure for dealing with exchange calls for extensions barred direct access.

A lamp denoting all exchange lines busy is provided on each position to guard against useless attempts at seizure.

Whenever the operator wishes to release a connecting circuit without transferring to an extension, it is necessary to operate the speak key and the common " release " key simultaneously.

Exchange Enquiry Calls

This term has been applied to enquiry traffic to the operator from extensions engaged on exchange calls.

The operator is signalled over the normal exchange connecting circuits, but to provide discrimination the supervisory lamp flashes in addition to the steady glow of the answering lamp. When the call is answered, the lamps and controls function as for ordinary exchange calls, although the operator is initially in a similar position to an extension answering a consultation call. She may merely be required to give information, or the originating extension may replace the handset and so transfer the exchange line to her. In the latter event the operator subsequently transfers the call again or deals with the matter as best befits the situation.

Tie Line and Inter-switchboard Services

The combination of facilities required in specific installations is greatly variable. Tie lines may be

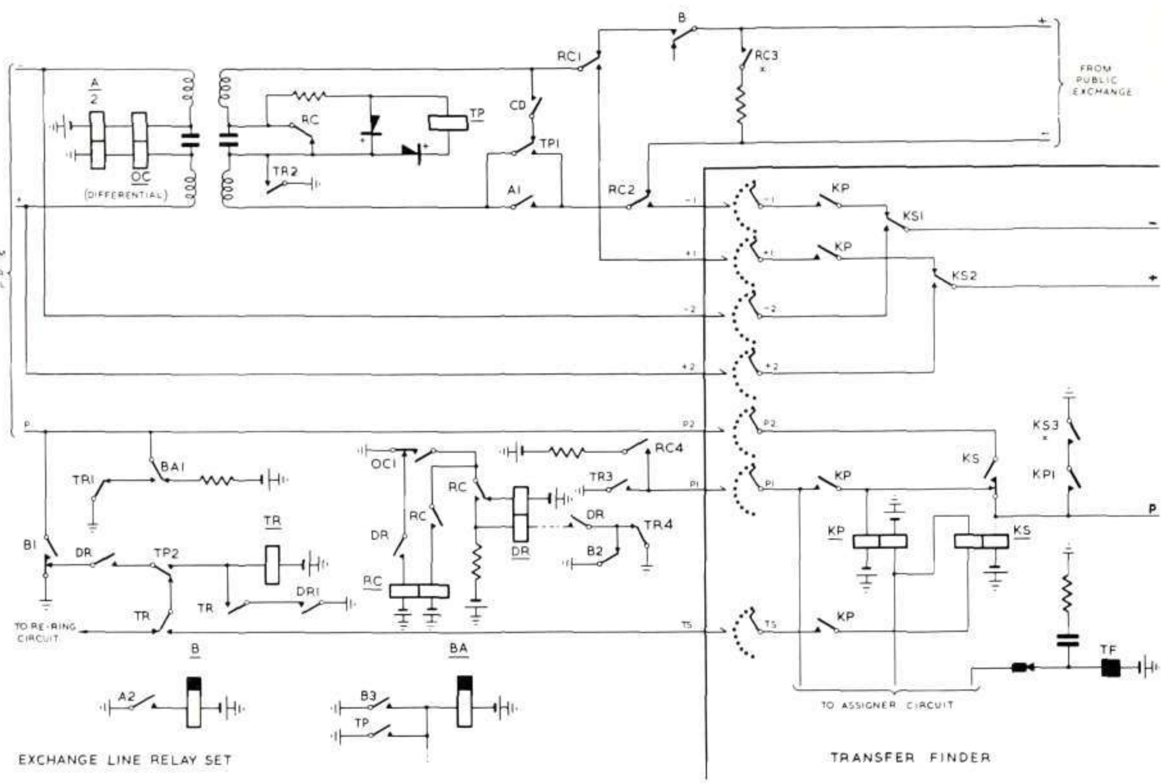

Fig. 4A—The System of Transfer (See also Fig. 4B)

purely manual ; dialling in one or both directions and bothway or unidirectional working may be required. Some lines may have access to the public network ; others may not.

The typical trunking arrangements in Fig. 1 show but a single group of auto tie lines, prohibited from the exchange but accessible from extensions via level ' 8 '. Incoming calls seize a directly connected selector having access to finals and to " outgoing and enquiry " relay sets trunked from level ' 9 '. Seizure of these relay sets results in an incoming call indication on the attendant's cabinet over a local connecting circuit. Such calls may be handled and transferred by the operator, like exchange traffic, but normally there are no restrictive conditions. Tie line service is usually available to all extensions.

Whatever the type of signalling, tie lines can never be given individual appearances on this type of switchboard, and to make an outgoing call the operator presses the speak key of a free local connecting circuit. This seizes a " tie line access " selector, and the appropriate digit is then dialled or keyed to gain the required route. As before, the call may be transferred to an extension, but extensions are not generally allowed to transfer the call a second time.

Incoming circuits working on a manual basis are equipped with a uniselector which, on seizure of the circuit, searches for a free outgoing and enquiry relay set.

Local Enquiries

Direct communication between extensions and the operator is conveniently arranged by grading the outgoing and enquiry relay sets also to level 9 of the local selectors. Local and incoming calls then share the same equipment. However, in many installations where provision for tie or similar lines is not required, economy can be effected by using separate incoming and outgoing circuits without transfer facilities. The incoming circuits are then comparatively simple assistance relay sets, and the outgoing

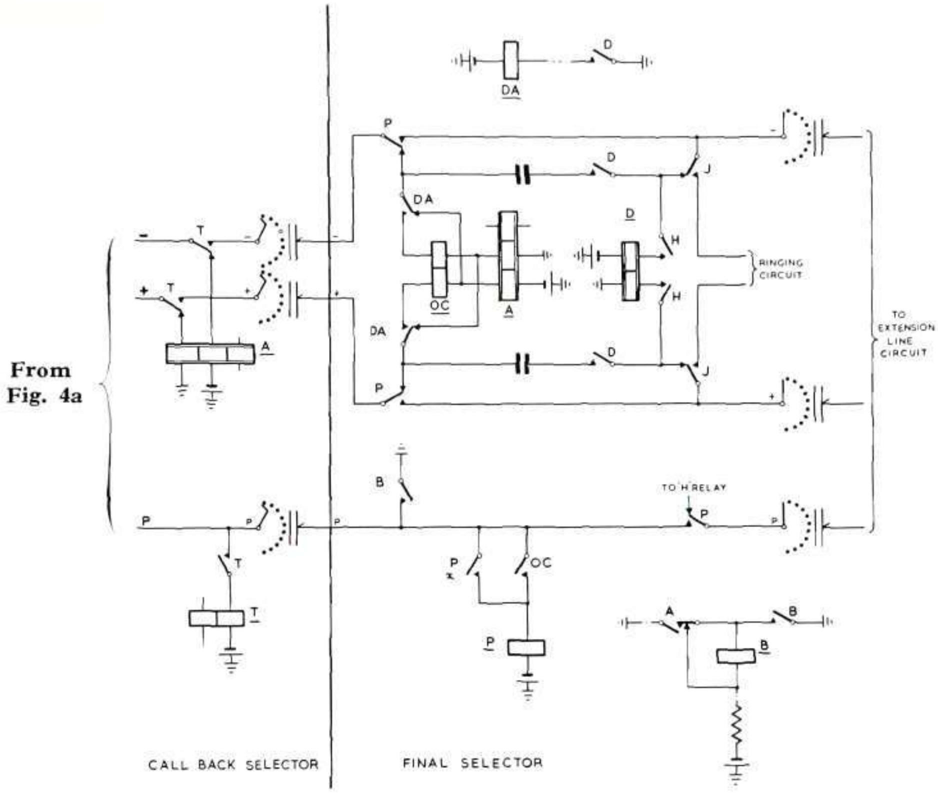

Fig. 4B—The System of Transfer (continued)

circuit merely converts the signalling conditions obtained from a special extension line to those required for supervision. From the switchboard, the operator thus has an individual circuit for ringing extensions.

Night Service

During night service periods all calls to the attendant's cabinet, including exchange, exchange enquiry, tie line and local enquiry calls, can be diverted to one extension. This extension, perhaps the night porter, can then perform the duties of an operator and transfer calls to the appropriate departments.

By means of jumpers any extension can be connected to receive all incoming calls, or the traffic may be divided between a number of telephones (even to the extent of having an individual instrument per incoming line), normal service being unaffected. Whereas in conventional cord switchboard practice the lines are permanently plugged through and one night service extension can only reach another via the public exchange, the cordless P.A.B.X. avoids incurring call fees on such occasions. Furthermore, night service extensions not given preference facilities during the day are allowed to intrude when extending night calls, in order to speed re-direction of traffic.

Other Facilities

In the space of this article it is not possible to describe in detail every facility which can be applied to the Extensible Cordless system. An attempt has been made to cover the more outstanding features and to give a clear picture of the basic method of operation and its merits. The usual services for watchman's patrol, round call, conference, etc., can all be incorporated without difficulty, whilst power plant, ringing and tone equipment and alarms all conform to conventional standards or can be arranged to suit individual requirements.

Appendix

How Transfer is Achieved

The elements involved in transfer are shown in Figs. 4A-B and include portions of an exchange line relay set, transfer finder, and call back and final selectors.

Relay A of the exchange line relay set is operated by the extension loop. A operates relay B to maintain a holding earth on the P wire and loop the exchange line ; BA relay is operated at B3 contact.

The transfer button when depressed applies a full earth to the extension line, and relay OC being differentially connected, responds. Alternate operations of relay OC operate and release the two relays DR and RC.

To originate an enquiry call the transfer button is momentarily depressed once. RC3 applies a holding loop to the public exchange, and RC4 a battery potential to mark the outlet of the exchange line relay set on the transfer finder multiple. An assigner start circuit, not shown in the diagram, causes a free transfer finder to hunt for the marked outlet. On seizure, relay KP is operated by the assigner. With relay RC in the exchange line relay set operated, the circuit to the call back group selector is completed and dial tone is returned.

The calling extension now dials the wanted number.

After the call is answered, the relays of the final selector shown in Fig. 4B which are operated are : A, B, D and DA. DA will not operate as a relief on D unless the called line is unrestricted. If DA operates it introduces differential relay OC and reverses the lines to operate relay TP in the exchange line relay set. Contact TPI short circuits contact A1 in the outgoing pulsing loop.

When the calling (first) extension replaces the handset, relays A and B release in turn. Since relay TP is operated, relay TR operates from B1 to start the transfer process. If TP had been normal, the B1 earth would have been extended to a re-ring circuit (not shown) and, on lifting the handset again, the extension would have been re-connected with the exchange line. However, TP being operated, relay TR operates, removing at TR1 the last earth from the incoming private. The first extension's switch train thus releases, but the circuit is still busied to other traffic as the testing-in battery is disconnected at BA1.

TR2 contact applies an earth to the −ve and +ve lines in such a sense that relay TP remains operated and relay OC in the final selector responds to the unbalance and operates relay P. P removes all bridging equipment and locks to the private. A, B, and a number of other relays in the final selector start to release, but the switch train holds, as the private is earthed at TR3 in the exchange line relay set. As a result of the operation of relay P, the circuit of relay TP is extended over the −1 and +1 lines to the extension loop, and releases.

TP2 contact completes a circuit from earth at B1 to the TS arc of the transfer finder, and operates relay KS in series with KP. KS1 and KS2 contacts enable relay A to re-operate over the −2 and +2 arcs of the transfer finder and the extension loop.

KP1 and KS3 contacts maintain a holding earth to the call back and final selectors during the period between the operation of relays KS and B. However, B operates within a few milliseconds, and then, since B2 and TR4 contacts are both operated, relays DR and RC release in turn. DR1 contact releases TR. TR3 releases KP, leaving the main B1 and TR1 earths to hold, respectively, relay KS in the finder, relay T in the call back selector, and relay P in the final selector circuit.

Transfer is now complete.

Should the second extension subsequently have cause to press his transfer button, a second transfer finder is driven to the same output, but the −2, +2 and P2 arcs will be released by the first finder before they are required by the second, in the event of the call being transferred again.

AUTO SUBSCRIBER SERVICE OVER SINGLE CHANNEL RADIO LINKS

K. Phillips   Carrier and H. F. Development Department

Cases frequently arise where automatic telephone service is required for subscribers but physical lines are too expensive to install or too difficult to maintain. This article describes how standard radio equipment can be utilized to give subscribers full automatic service without the necessity for physical lines.

SIMPLE and inexpensive radio equipment for use by subscribers can be of many different types and may employ amplitude or frequency modulation.

The equipment described has been designed for universal application and can form an addition to most duplex links originally installed for manual working.

At the " exchange " end an exchange line is terminated at the transmitter-receiver, which may be situated anywhere in the exchange service area. At the subscriber's terminal a similar transmitter-receiver can be connected over two wires to either a telephone instrument or a private manual or automatic branch exchange, and used in the same manner as a simple physical circuit.

Signalling over manually operated links is nearly always by carrier switching alone. When a transmitter is switched on, the resultant carrier causes the energization of the muting relay in the distant receiver, the muting relay contacts being arranged to provide the necessary calling signal. For automatic service a contact of this relay could, theoretically, be inserted in a subscriber's loop and be made responsive to dial pulses. However, the muting relay operating circuit is generally safeguarded to prevent energization by impulsive radio noise and therefore is not suitable for accurate response to short pulses. Thus, in order to retain full safeguards yet permit the transmission of dial pulses, voice frequency signalling is necessary. But as single channel radio links are generally capable of transmitting a wide v.f. band, the frequency chosen is 3.8 k.c/s, and a signalling channel of adequate bandwidth is separated from the speech path by means of filters.

Basic Signals

The basic signals which must be transmitted over exchange lines are only two in number, one in each direction.

Firstly, from exchange to subscriber, the application of a.c. ringing current at the exchange must ring the subscriber's bell, and secondly, from subscriber to exchange, the condition of the d.c. loop through the switch-hook and dial contacts of the telephone must be signalled to the exchange.

Principle of Operation

This is shown in the simplified diagram, Fig. 1, in which it will be seen that the system of signalling is inter-linked with the necessity for transmitter switching. Mains operated receivers are in a continuously receptive condition but in battery operated installations, where it is necessary to conserve power supplies, provision is sometimes made for automatically switching the receivers on at intervals.

When the carrier is received, the muting relay RL1 in the receiver operates. The transmitters, however, are normally quiescent and an earth must be applied to the lead SWT to connect h.t. and transmit carrier.

In the case of a call to the subscriber, ringing current is applied at the exchange and relay RG responds to this current. Contact RG1 causes the carrier to be transmitted during the ringing period and, at the subscriber's terminal, relays RL1 and J respond.

When relay J is operated, ringing current is extended to the telephone or switchboard. Relay A operates to the loop when a call is answered, and

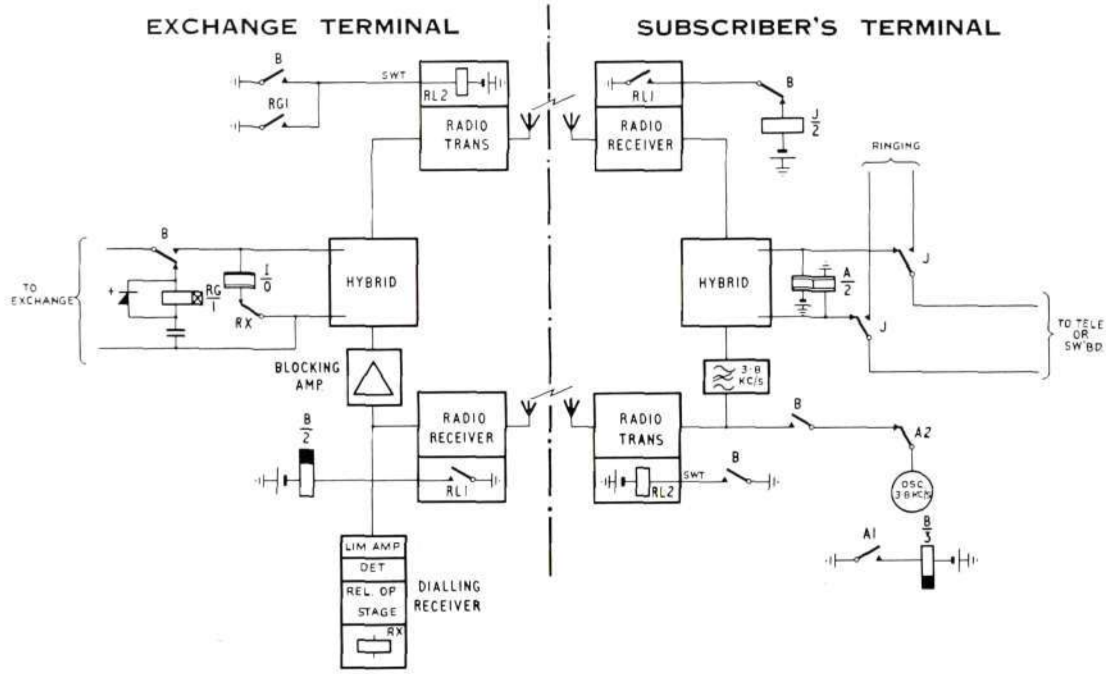

Fig. 1—Simplified Schematic of Signalling Equipment for Radio-Telephone Subscriber

contact A1 operates relay B. B switches on the subscriber's transmitter and, via RL1, energizes relay B at the exchange end, where the B contact completes a loop to trip ringing and to maintain the exchange end transmitter in the sending condition, since relay RG is disconnected.

Conversation may now take place.

In the case of a call originated by the subscriber, operation is similar, in that relay A is energized over the subscriber's loop to operate first the local, then the distant B relay, in order to switch both transmitters to the transmit condition and complete a loop on the exchange line to seize the exchange equipment. Dial tone is then extended to the subscriber.

When dial pulses release relay A, 3.8 kc/s tone pulses are transmitted to the distant terminal to operate relay RX in the receiver. Contact RX1 repeats the break pulses to the exchange equipment.

Although certain auxiliary features such as F and CD relays and static modulation have been omitted in Fig. 1, the essential simplicity of the arrangement will be recognized.

SIGNALLING EQUIPMENT

Since the radio path is the equivalent of a four-wire line, a hybrid is necessary at each terminal in order to provide a two-wire speech path. The hybrids are of standard type, comprising two transformers arranged to provide a low-loss path between " two-wire " and " four-wire ", and a high-loss path between " four-wire transmit " and " four-wire receive " pairs.

The a.c. signalling equipment comprises a 3.8 kc/s oscillator and band stop filter at the subscriber's terminal, and a dialling receiver and blocking amplifier at the exchange terminal. The oscillator is of the two-stage resistance-capacity type. Frequency and output levels are stabilized over a wide range of variations in supply voltages. The output is shunt fed into the " four-wire transmit " path via a static modulator under control of the A relay. Tone level is usually arranged to be of the same order as the nominal speech level.

The static modulator is unusual, in that it is of the self-biasing type requiring only one supply voltage, which may be as low as six volts. The principle of operation can be understood by reference to Fig. 2

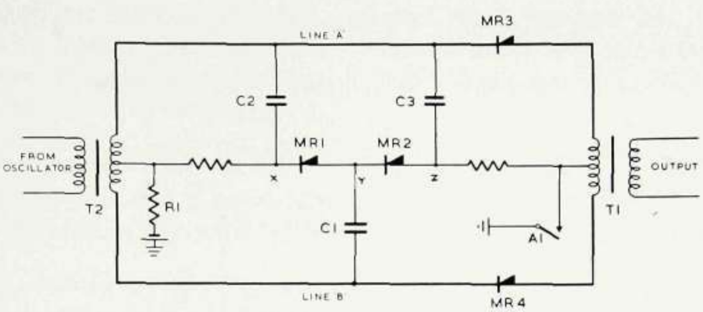

Fig. 2—Principle of Self-Biassing Static Modulator

in which it will be seen that the oscillator output is applied between line ' A ' and ' B '. Assume that the capacity of C1 is large, compared with C2 and C3. When line ' B ' is positive, current flows via C1 and MR1 to charge capacitor C2. Point (X) thus becomes positive with respect to point (Y). When line ' A ' is positive, capacitor C3 is charged via MR2, C1, and point (Y) becomes positive to (Z). This is of course a conventional voltage doubler circuit, and a d.c. voltage of nearly twice the oscillator peak voltage appears across (X) and (Z). It is fed via the centre-tapped transformers in such a manner that germanium rectifiers MR3 and MR4 are back biassed and provide at least 50 dB suppression up to a temperature of 60°C.

When A1 contact operates, the supply voltage between earth and battery at R1 is applied in opposition to the derived voltage. Since the latter is smaller, rectifiers MR3 and MR4 conduct, transmitting tone via transformer T1.

The band stop filter has a mid-band frequency of 3.8 kc/s and effectively suppresses the band of speech frequencies liable to cause false operation of the dialling receiver. It is thus impossible for subscribers to energize the receiver, even by a pure tone

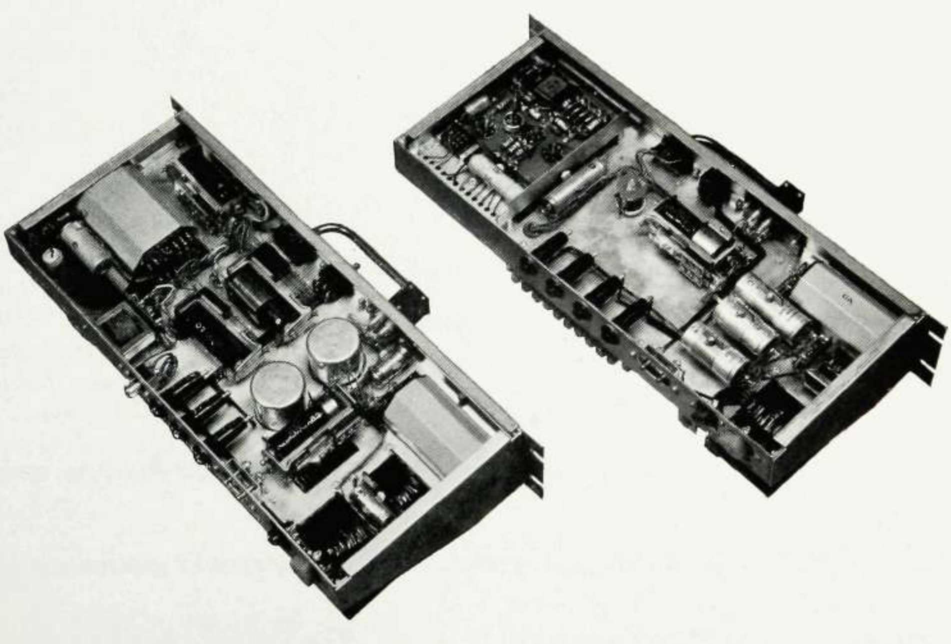

Fig. 3—Subscriber and Exchange Terminal Units

of signalling frequency. The response of the filter to the band 300 c/s to 3.4 kc/s is substantially flat and C.C.I.F. recommendations for audio bandwidth are therefore met.

At the exchange terminal the dialling receiver is connected across the radio receiver output. Signal tones pass through an amplifier stage tuned to the signal frequency, and are then rectified. The resultant d.c. pulses are applied to a relay operating stage and operate a sensitive polarized relay in the anode circuit. The receiver also incorporates a limiter such that variations over a range of some 20 dB in signal level can be accepted. Changes in h.t. supply voltage of $\pm$ 10% are also permissible.

The receiver will reproduce dialled pulses with not more than $\pm$ 3% distortion, within the foregoing conditions, and allows a considerable margin for any possible frequency drift.

Although voice immunity is achieved mainly by separation of the speech and signalling paths, the receiver incorporates a low co-efficiency guard circuit which prevents false operation of the receive relay by harmonics of speech frequencies which may be generated if the radio equipment is overloaded.

It is not desirable to rely solely on a guard circuit, since this would then necessitate a high guard coefficient and render the receiver liable to blocking during periods of severe radio noise.

The blocking amplifier prevents the performance of the receiver being affected by speech currents or switching surges in the two-wire line.

The terminal units, each comprising a.c. signalling apparatus, hybrid, relays and power supplies, are illustrated in Fig. 3.

Multi-Party Service

When a number of radio subscribers are required in an area, it is not always possible or economical for entirely separate links to be used for each one. Sometimes the telephones may be conveniently interconnected by physical lines and operated on a party-line basis.

In other cases a common exchange radio equipment may be required to operate in conjunction with a number of subscribers' equipments on a common radio frequency, and selective calling and selective metering can be provided.

A RECENT SCIENTIFIC PUBLICATION

BY A MEMBER OF THE RESEARCH LABORATORIES.

ELECTRONIC TELEPHONE EXCHANGES

J. R. Pollard, M.A., M.I.R.E., A.M.I.E.E.

British Communications & Electronics, May, 1956.

In recent years consideration of electronic automatic switching techniques has been made by many telephone companies. This article reviews some of the principles involved.

Reprints of the article are available on application to the Research Department at Beeston.

AIR SPEED-RECORD ELECTRONIC TIMING

N. B. ACRED AND G. BISHOP   Instrument Division

(Reprinted from " British Communications and Electronics " by kind permission of the publishers.)

On 10th March, Great Britain regained the world air speed-record when a Fairey Delta II achieved a speed of 1,132 m.p.h. Electronic timing equipment based on the well-known " Dekatron " provided the high standard of timing accuracy.

IN ascertaining the speed of a high-speed aircraft certain difficulties arise because the true speed cannot be measured directly but must be calculated from other measurable quantities. Probably the simplest way of determining the speed is by measuring the time taken by the aircraft in travelling over a known distance. From this information the speed can be calculated with an accuracy which is dependent on the accuracy of the time and distance measurements. This method was used in the recent attempt on the world air speed-record made under conditions laid down in the " Sporting Code " formulated by the Fédération Aéronautique Internationale*. The careful and strict control exercised by the F.A.I. makes the holding of a world record particularly valuable to all concerned in the attempt.

Although the main purpose of this article is to describe the electronic timing equipment used in the recent attempt, the regulations under which an attempt is made and some of the problems involved are briefly mentioned in order that the functions of the equipment can be more fully understood.

Until recently, the main conditions governing a world air speed-record attempt stated that the aircraft concerned should make four runs, two in each direction, in level flight over a course 3 kilometres (approximately 1$\frac{7}{8}$ miles) long at a height not greater than 100 metres (approximately 325 feet). The speed adopted was the average of the four runs, and this must exceed the existing record speed by at least 1%. The overall accuracy should be at least 1 part in 400 (0.25%).

The F.A.I. periodically review the regulations, and in recent years important changes have been made. The 3-kilometre course can still be used but an alternative course has been introduced, and this is now generally preferred. It can be of any length between 15 and 25 kilometres (approximately 9$\frac{3}{8}$ and 15$\frac{5}{8}$ miles) with no restrictions on height. There are, however, certain regulations appertaining to height which are designed to prevent the aircraft gaining unfair advantage by diving on to the course. Two runs, one in each direction, must be made and the speed adopted is the average of the two. This must also exceed the existing record by at least 1%, and the overall accuracy called for is again 1 part in 400. Various other conditions must also be met, and before an attempt is confirmed as a world record, comprehensive documentary evidence must be submitted to the F.A.I.

It can be seen that to conform with the regulations referring to overall accuracy, both time and distance must be measured with great accuracy. As a 3-kilometre course can be laid out and measured to better than 1 part in 100,000 and the longer course can be measured with comparable accuracy, the problem of obtaining good overall accuracy rests largely with the interpretation of the results obtained from the timing equipment.

Several methods have been suggested for determining the speed of an aircraft flying over a given straight course. Some of these propose the use of radio, radar or television systems, but the method adopted by the Royal Aircraft Establishment follows traditional lines, whilst making use of the most up-to-date techniques. Although the advocates of the alternative proposals suggest that higher accuracies might be obtained, the system described easily meets the requirements of the F.A.I. regulations. The primary considerations in choosing the method of measurement are :—

* The F.A.I. was formed in 1905 for the regulation of aeronautical sporting events and most National Aero Clubs are represented on its various Committees.

1. An order of accuracy much greater than the regulations demand.
2. A very high degree of reliability.
3. Equipment of convenient physical size which is simple to set up and operate, and which will work with consistent reliability under arduous climatic conditions.
4. Equipment that is not fundamentally affected by site error, (e.g. radio systems).

Whilst expense is not a primary consideration, cost does assume importance when the above requirements are met. The timing equipment commissioned by the Royal Aircraft Establishment makes use of a Dekatron type timer, since the Dekatron tube is well known for its reliability and long life. The cameras associated with this equipment are described elsewhere.*

Principles of Timing

The principle generally used in timing an aircraft is shown in Fig. 1.

As the aircraft approaches the course it is tracked by an observer using telescope 1. When the telescope is in line with the start of the course an electrical signal operates the camera and a similar signal from the camera shutter starts the timing equipment.

A similar sequence of events occurs at the end of the course (telescope 2 and camera 2), but in this case the camera shutter signal stops the timing equipment. In this way photographs are obtained showing the position of the aircraft in relation to datum lines marking the beginning and end of the surveyed course. In the case of the 3-kilometre course the datum was usually a vertical post. In more recent attempts, where the long course was used, a datum line was obtained on the photograph, either by marking the plate or by photographing horizontal wires erected over the camera.

* "Improved equipment for timing air speed-records at high altitudes"—R.A.E. Farnborough Report No. INSTN. 6. April 1956, by N.E.G. Hill, B.Sc., E.E., M.I.E.E., and W. Goldsmith, B.Sc., A.R.C.S., D.I.C., A.Inst.P.

Since the photographs rarely show the aircraft actually crossing the datum line, a course length correction has to be made by comparative measurements on the photographic plates. A time correction is also necessary to allow for the time delay between the exposure of the aircraft image on the plate and the starting or stopping of the timing equipment by the signal from the camera shutter.

Sources of Error

With the method used there are three main sources of error.

(*a*) Surveying and laying out of the course and positioning of the cameras. The resultant error in course length is generally not greater than 1 part in 10^5.

(*b*) Timing error inherent in the equipment. This is the resultant of two errors. One is due to the time base and is less than 2 parts in 10^5. The other depends on the smallest increment of time which can be recorded, expressed as a fraction of the transit time. In the recent attempt this error was less than 4 parts in 10^5.

(*c*) Interpretation of photographs. This is the source of the greatest error, since it depends largely on comparative measurements taken from the photographs. The corrections to the course length and the transit time can generally be computed with an error of less than 1 part in 10^3.

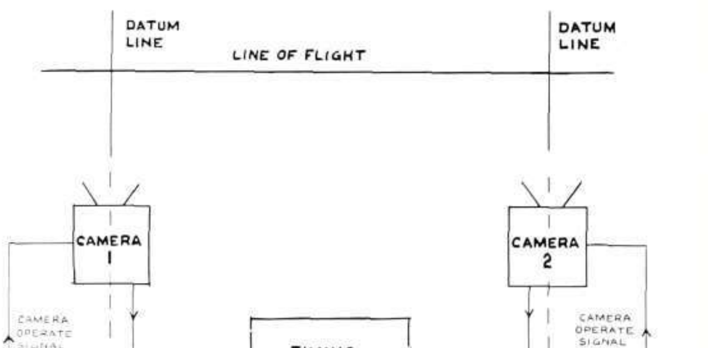

Fig. 1—Method Generally used in Timing a High-Speed Aircraft over a Measured Straight Course

TIMING EQUIPMENT USED IN THE RECENT ATTEMPT

In an endeavour to maintain the photographic error in the same order of magnitude as that specified in the previous paragraph, and also to reduce the errors from other sources, the equipment used in the recent attempt on the air speed-record not only measured and recorded the transit time but also provided time calibration marks at 10-millisecond intervals on the photographs. These marks are used to compute the correction to the measured transit time made necessary by the time interval between the exposure of the aircraft image on the photographic plate and the operation of the camera shutter contacts.

Two aircraft cameras, each fitted with two sets of shutter contacts, and two timing equipments are used. The block diagram, Fig. 3, shows the timing equipment installed at one end of the course with its connections to the local and distant cameras. The installation at the other end is similar, but the timing equipment is operated by the second set of camera shutter contacts.

The timing equipment consists of two units, the gate unit and the display unit, mounted in a rack cabinet ; the time-base is derived from a 20-kc/s crystal-controlled oscillator. It was expected that the equipment would be used under widely varying conditions, some of which might involve dust-laden atmosphere, and ambient temperatures up to 130°F. This necessitated special care in the design of both the circuit and the rack cabinet. The cabinet was sealed against the ingress of dust, and a very robust form of construction was adopted to ensure that the equipment would not be affected by the arduous conditions often met in field operations of this type. To ensure minimum temperature rise within the cabinet, and to obtain maximum reliability, the circuit design makes the fullest possible use of cold-cathode tubes in preference to thermionic types.

The 20-kc/s quartz crystal oscillator from which the time-base is derived has a short term frequency stability of 3 parts in 10^6 and a long-term stability of 20 parts in 10^6. This order of accuracy is obtained by enclosing the quartz crystal in a thermostatically controlled oven, and also by stabilizing the amplitude of the crystal drive voltage. The crystal oven is maintained at 167°F, since this value will not be exceeded by the internal temperature of the cabinet, even under extreme conditions.

The lines connecting the cameras to the timing equipment are normally charged to approximately 150 volts. Operation of a pair of camera contacts discharges the associated line and this provides the start or stop signal. An artificial line is included to equate the signal delay in the two lines.

Fig. 2—The Electronic Timing Equipment

As shown in Fig. 3, the local camera contacts initiate the timing period and the distant camera contacts terminate it. These functions can be reversed by operation of the direction switch. On receipt of the start signal the gate is actuated and the output from the 20-kc/s crystal oscillator is applied to the ÷ 10 circuit. A Dekatron is used as the divider, and the output pulses of 2 kp/s repetition rate are connected via a cable to the Eccles-Jordan ÷ 2 circuit in the display unit. The 1 kp/s output obtained from the ÷ 2 circuit is applied to the first of the display Dekatrons via a coupling circuit which utilizes cold-cathode trigger tubes. Subsequent display Dekatrons are coupled to the preceding Dekatron stage by cold-cathode tubes. The Dekatron display exhibits time interval increments of 1

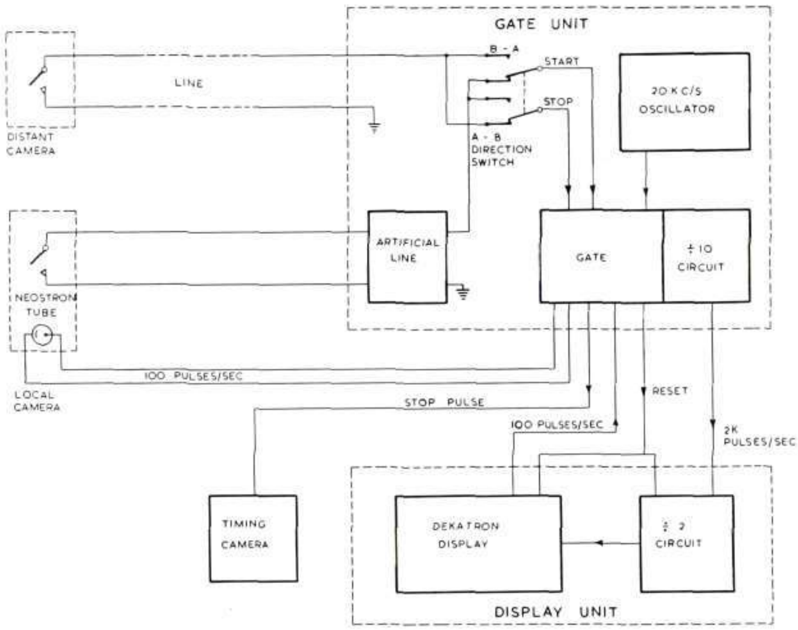

Fig. 3—Block Diagram of the Timing Equipment

millisecond to a maximum of 99.999 seconds. A neon lamp associated with the ÷ 2 circuit indicates time interval increments of 0.5 millisecond, which enables the displayed transit time to be rounded off to the nearest millisecond. The start signal also causes the Neostron tube, mounted in the local camera, to flash, and subsequently, pulses derived from the display unit cause the tube to flash every 10 milliseconds. These flashes are recorded on the photographic plate, and time pulse calibration of the local camera shutter is thus achieved.

On receipt of the stop signal, the gate is restored to its quiescent condition and this prevents the output from the 20-kc/s oscillator reaching the ÷ 10 circuit. Operation of the timing camera is initiated by the stop signal, and the resulting photograph records the displayed time interval together with other information required for identification and record purposes. If more than one photograph of a particular display is required, the timing camera can be operated via a switch on the gate unit.

A reset switch is provided to restore the Dekatron display to zero and prepare the equipment for the next time interval measurement.

The authors wish to thank the Ministry of Supply for permission to publish this article. They are also grateful to the director and staff of R.A.E., Farnborough—who designed and constructed the timing cameras and with whom the electronic timing equipment was developed—the Royal Aero Club, and the Fédération Aéronautique Internationale.

INSTALLATION OF THE KARACHI-SUI V.H.F. COMMUNICATION SYSTEM

F. H. Reynolds   Carrier & H. F. Development Department

An article in the January 1956 edition of the Bulletin described the communication equipment supplied for the Sui Gas Transmission Company's pipeline in West Pakistan. The following account of the installation of the equipment includes some interesting details of the locality and describes the testing of the pipeline prior to its being brought into service.

ENGINEERS working in under-developed territories must inevitably experience something of the spirit of pioneering. The effort expended in overcoming the difficulties and perhaps the hardships with which they have to contend is amply rewarded by their satisfaction in completing a task which makes a positive contribution to progress where it is most needed. The Sui Gas Project, a bold enterprise launched to harness vast underground natural resources for the benefit of the people of Pakistan, was such a task, and this account of the installation of communication equipment along the pipeline route would be incomplete without a brief description of the pipeline itself and conditions prevailing in the area. Installation of the communications system coincided with the culminating phase of the project and was characterized by the spirit of enthusiasm that had initiated and carried through this important enterprise.

The recent completion of the Sui-Karachi pipeline which makes available the extensive reservoir of rich natural gas discovered at Sui may well herald an industrial and economic revolution in Pakistan. Wide distribution of the hydrocarbon fuel will make possible rapid industrial expansion which in the past has been retarded by deficiencies in available power. Moreover, Pakistan is at present an importer of both coal and oil, and the exploitation of indigenous fuel will effect large savings in foreign exchange.

Laying of the 350 mile main pipeline from Sui to Karachi was completed in April 1955, and the early replacement of oil and coal by gas fuel in power stations and factories in the Karachi area thus became a practical possibility. Distribution pipes from the main line, which traverses Sind and Khairpur, will supply the gas also to industrial plants in these provinces. Many plants have already been converted for the new fuel and the gas is being supplied to industrial consumers on a constantly increasing scale.

The main pipeline to Karachi is designed to take a self propelled flow of 70 million cu. ft. a day at an initial pressure of 1070 pounds per sq. in. In due course, two compressor stations will increase the capacity to 110 million cu. ft., enabling domestic users in Karachi to be served, but at present industry has first priority.

Construction work is about to commence on a 210-mile extension North East from Sui, to carry gas to Multan where a large thermal power station and a steelworks will be built. It is anticipated that this new pipeline will be further extended to Lahore in the Punjab. This densely populated northern province is an important agricultural and industrial area which is particularly deficient in coal. It so happens that the gas field is very convenient to serve this area, being roughly midway between Karachi and Lahore, the chief town of the Punjab and also the capital of West Pakistan.

The source of the gas is a huge fold in a thick strata of porous limestone some 4,000 ft. below ground level. The gas lies trapped in this fold at a natural pressure high enough to propel it along the 350 mile transmission line to Karachi. Reserves of gas are now known to be much greater than was at first anticipated, and the field is estimated to be one of the largest in the world.

Sui Gas is rich in methane and so has a high calorific value. Impurities are low in content and can be readily removed. The gas is a suitable heating agent for a wide variety of industrial processes and for

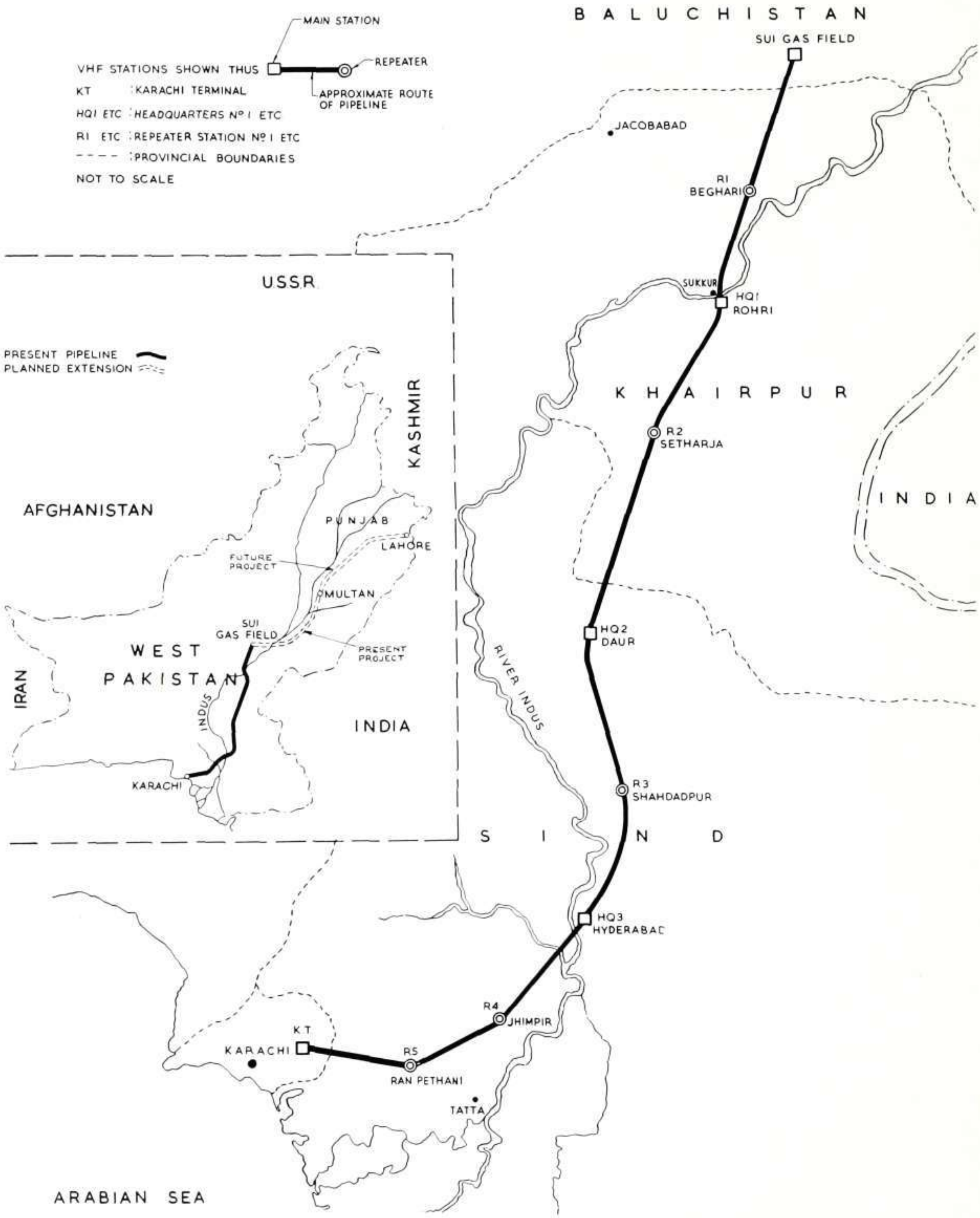

Fig. 1—The Pipeline Route, showing V.H.F. Stations and (inset) Planned Extension to the Punjab

domestic use ; it is also a valuable raw material for the chemical industry. However, its most important application is probably in the field of electricity generation, and this will no doubt be its primary use for some time. A basic advantage of this gaseous fuel is that the supply is not dependant on vehicular transport, a particularly important factor in a region where good road and rail communication is the exception rather than the rule.

The Sui Gas Transmission Company operates the main pipeline from the Sui gas field to a terminal some ten miles from Karachi. This terminal station is the operational headquarters of the company and is staffed by gas control, cathodic protection, communication and electrical engineers, and administrative officers. At the Sui terminal are staff responsible for operating the wells and the gas purification plant.

The pipeline is sectionalized under the control of Section Engineers with headquarters situated on the route. These headquarters stations consist of offices, workshops, power plant, and living accommodation for the operating and maintenance personnel.

The two terminals and three headquarters constitute the five main stations on the line. In addition there are five radio repeater sites manned only by engine operators who attend the gas-engines which generate power for the radio equipment. Valves for the control of gas pressure are built into the pipeline at each of the ten stations and at a number of intermediate points. The locations of the various sites are indicated in the diagram, Fig. 1; much of the pipeline route is over the Indus flood plain.

Communications always play a vital part in long distance gas transmission, but especially so in this instance since much of the pipeline passes through areas not served by public telephone and telegraph networks. Access to the route is generally difficult, as the terrain varies between the two extremes of swamp and rocky desert. A high degree of reliability is thus required of the communication system.

For normal gas transmission, pressure readings at significant points along the line must be reported regularly to the gas control engineers who in turn must be able to instruct valve operators at any time and so control the flow of gas. In the event of a leak or other emergency, immediate and continuous communication is required between Karachi or Sui and the section engineer concerned, whether he be in his office or quarters, or out on the line in his jeep. Finally, efficient day to day administration involves heavy telephone and teleprinter traffic between the Karachi terminal and all main stations.

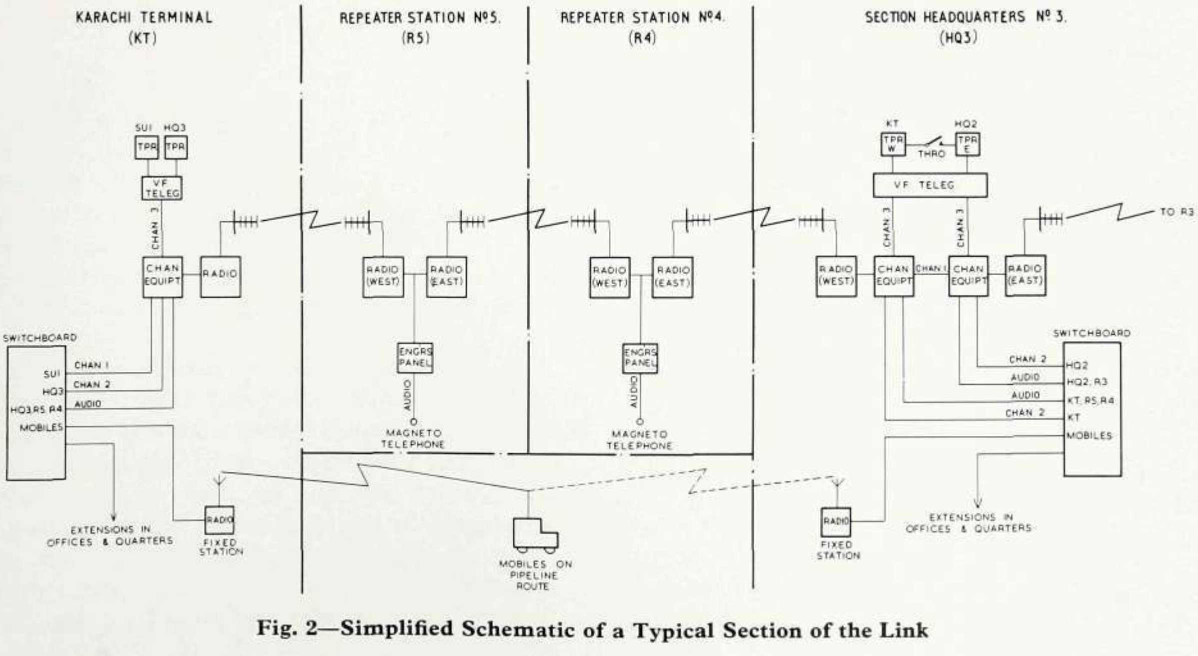

Fig. 2—Simplified Schematic of a Typical Section of the Link

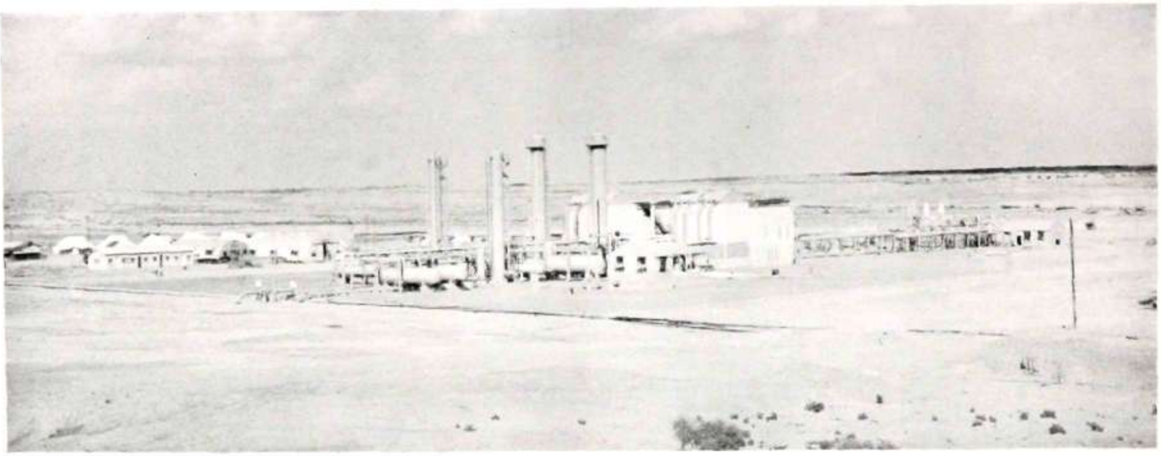

Fig. 3—Gas Purification Plant at Sui

These requirements are met by the multi-channel v.h.f. telephone and telegraph network, which allows full inter-communication between all stations on the line and with patrol vehicles. The network is safeguarded against a temporary failure of the radio path by a pilot alarm facility which warns the attendant at the Karachi Terminal. Here a remote change-over control panel enables the attendant to identify the faulty station and switch in standby radio equipment without delay.

Each main station is provided with a C.B. cordless switchboard at which the speech channels are terminated. The first section of the link, Karachi to Hyderabad, is illustrated in schematic form in Fig. 2, the arrangements shown being typical of a terminal and a headquarters station respectively. It will be seen that a terminal operator has direct access to the distant terminal on Channel 1, and to the adjacent headquarters station on Channel 2, whilst a headquarters operator has access to adjacent main stations in both directions, again on Channel 2. Calls can be extended over any number of sections of the link by coupling the two-wire ends of Channel 2 at intermediate station switchboards. The audio channel is also terminated at all switchboards and can be similarly extended. On this channel, switchboard operators can connect extension telephones to repeater stations, each of which has a magneto instrument working on a party line basis.

Switchboard lines to Pye v.h.f. 'fixed stations' enable operators to call vehicles equipped with mobile sets. The latter are of the two-frequency simplex type operated on a 'press to talk' basis, therefore du-simplex working between the mobile set and the switchboard or extension is adopted. All 'fixed stations' use common radio frequencies in order that patrolling engineers can call any main station within range.

Offices and quarters have standard C.B. telephone instruments wired as extensions to the station switchboards which, therefore, provide for communication between all officers of the company, whether at Sui, at the Karachi terminal, at any headquarters or repeater site or in a vehicle on the pipeline route.

Teleprinters situated at terminals and section headquarters' enable pressure readings and routine messages to be transmitted between any two main stations. Channel 3 is allocated for this purpose ; it accommodates two v.f. sub-channels providing, respectively, a direct terminal-to-terminal circuit and a circuit terminated at all main stations and extendable by d.c. switching on a link-by-link basis.

In January 1955 the first consignments of communication equipment were shipped from the United Kingdom, and the installation team assembled in Karachi towards the end of April. The team consisted of engineers from Pye Ltd, who were responsible for the radio section of the installation, and from our own company. Pakistan technicians were already being engaged for maintenance duties and were made available for installation work, under instruction, as this would constitute part of their training programme. Transport, provided by Pye Ltd, consisted of two Land Rovers, one jeep and two 1-ton trucks ; all vehicles had four-wheel drive, an essential requirement in view of the sandy and swampy terrain.

The first problem was to distribute rather more than 500 cases of equipment to the ten sites. For various reasons road haulage was the only practicable means, and to reach Sui, the most distant site, entailed a 500-mile journey including 70 miles of desert. Several other sites were separated from the nearest road by up to 20 miles of rocky or sandy track or by dust roads along the banks of irrigation canals. To ensure safe delivery the equipment was transported under the close supervision of members of the team, and distribution was completed without loss or damage.

First impressions of South East Baluchistan, in which the Sui gas field lies, were of a barren wasteland best described as a wilderness. The region is generally acknowledged to be one of the hottest in the Indian sub-continent, and the only inhabitants are nomadic Bugti tribesmen. However, a large, well-established camp maintained in the gas field includes air-conditioned huts in which the installation team enjoyed hospitality and welcome relief on a number or occasions. A point of interest is that the camp water supply is piped from the Indus across 32 miles of desert. Bungalows for permanent staff and their families were under construction, and in due course a small township will no doubt flourish in this remote area.

The initial priority was to provide some means of communication, however provisional, along the route in order that the Sui Gas Transmission Co. could prove the pipeline. With this end in view, basic equipment was installed and tested at each site in turn as rapidly as possible. This included channelling bays, switchboards and batteries at the five main stations, and audio-channel equipment at the repeaters. Pye engineers installed v.h.f. radio equipment at all stations, including ' fixed stations ' for the mobile network, the 150 ft. aerial towers erected at each site serving also as useful landmarks to those seeking the more remote stations.

Fig. 4—Karachi Terminal

Working conditions were arduous. The summer heat was intense and there were frequent dust storms ; the equipment rooms at the various sites were not air-conditioned at the time, so that plant, in addition to those installing it, was subjected to a severe test. However, both successfully withstood these stresses and in due course all main station equipment rooms were air-conditioned. By previous agreement no provision was made for air-conditioning the repeater equipment rooms ; as these were to be unattended, ventilation by fans was considered adequate.

Much time was spent in travelling between sites, and it was never possible to complete all work in one visit, but by mid-August all speech channels and the mobile network were in service although system tests and adjustments were incomplete. At this stage duplicate aerial feeders were not available and the remote changeover facility was therefore inoperative. Also there was no teleprinter service, but speech

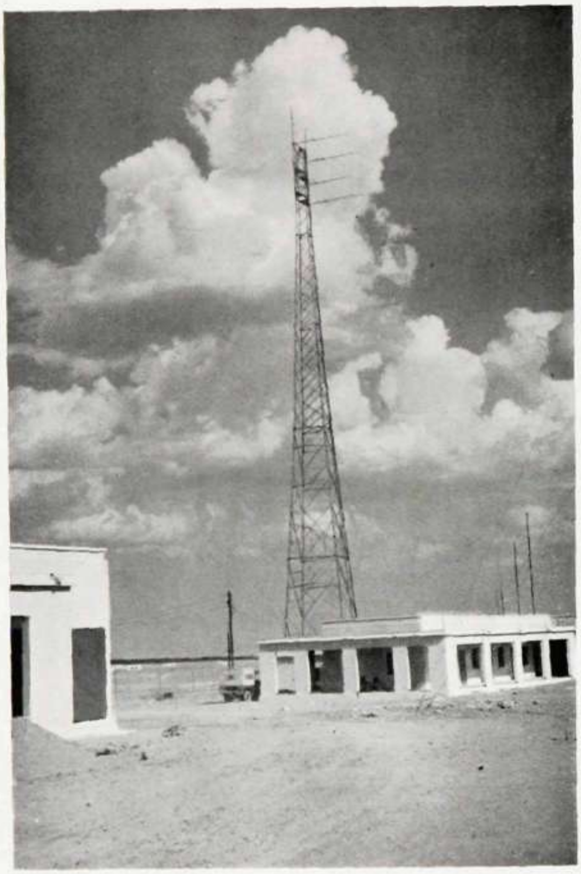

Fig. 5—Sui Terminal

traffic between switchboards was possible and trained operators were allocated to all main stations.

It was imperative that the pipeline be given a working test without delay in order that the gas transmission could begin. The line had already been hydraulically tested in sections to a maximum pressure of 1350 p.s.i., a process which took three months. Each section in turn had been cleared of water and silt by blowing through plugs (pigs) by means of compressed air. With this formidable task completed the line was ready for the purging of air, filling with gas and pressurising. This critical purging and gas filling operation requires continuous control and the hourly reporting of data from all main line valves, and is particularly dependent on good communications. The Sui Gas Transmission Company decided to rely on the v.h.f. system as it stood, and began the operation at the end of August. The initial task was to expel air from the pipeline prior to the introduction of gas. A mixture of gas and air in the pipe could not be allowed, as sparks caused by sharp stones carried along by the flow could easily cause ignition and an explosion which would burst the pipe, therefore the two elements were separated by a column of inert gas pumped into the pipeline at Sui before the release of natural gas. At Karachi a valve was opened to discharge air, followed by the inert gas and finally the natural gas. Expulsion of the first two elements was a lengthy process, and the arrival of the gas, awaited with keen expectation, was an event of great satisfaction to all concerned. The first hurdle having been cleared without mishap, the next step was to close the valve and gradually and progressively to increase the gas pressure to the maximum working level, after which full pressure was maintained for a period of 24 hours whilst the complete system was tested for leakages.

The final and most spectacular phase of the testing procedure was the discharge of gas at full pressure through an open stack at the Karachi terminal, in order to cleanse the pipeline of any liquid or solid matter. Lighting of the jet resulted in a flare 75 feet long which generated formidable heat and noise.

During the nine days testing period a change in the weather brought heavy rains which caused floods in many areas, thus hampering movement on the route. The situation rapidly deteriorated, and early in September several breaches appeared in the banks of the swollen Indus. The township of Tatta was completely submerged and the metalled road from Karachi to Hyderabad was impassable to all traffic until the end of the month. Indeed the flooded area was so extensive that Headquarters No. 3 could be reached only by a diversion of 100 miles across rough desert. The radio telephone network was therefore required to carry a large amount of administrative traffic, in addition to an increasing volume of regular operational traffic as distribution pipelines were installed and tested and gas was supplied to industrial consumers in Karachi, Sukkur and other towns near the route. It was thus essential to complete the installation of the communication system without interruption of this traffic, other than for short breaks. Work proceeded on this basis, and in due course standby radio equipment was commissioned at all stations, enabling the pilot alarm and remote changeover feature to be brought into service.

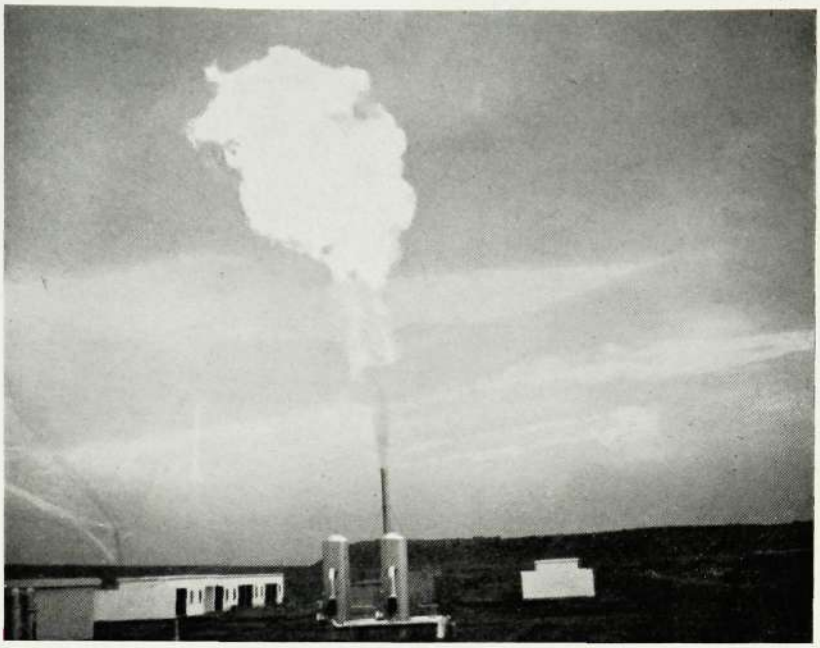

Fig. 6—Gas Flare at Karachi Terminal

At the main stations, teleprinters were installed and the associated v.f. telegraph circuits tested, while buildings were wired for switchboard extension telephones. Switchboard lines to 'fixed stations' were modified to allow 'talk through' operation from mobile to mobile, and this was found to be a valuable additional facility for patrol vehicles. Finally, overall tests and adjustments were carried out. Transmission level settings were such that Channel 1 provided an equivalent 3 dB circuit from terminal to terminal, whilst each section of Channel 2 was a 1 dB circuit in order to maintain a good overall level on extended calls. Long term level variations were insignificant, but on occasions exceptionally severe propagation conditions caused short term reductions in level of a few dB on Channel 1. Speech intelligibility was always very good.

Although intended primarily as an engineer's circuit and party line for repeater stations, the audio channel carried regular traffic between main stations. Operators frequently extended calls over two or three sections of this channel when Channel 2 was engaged. Indeed every combination of channel sections was connected for calls from switchboard extensions, from repeater stations or from mobile equipment ; in no case was loop instability evident, and the network was thus proved to be fully flexible.

Plans for the extension of the pipeline from Sui to the Punjab town of Multan, a distance of 210 miles, are proceeding and the equipment is now in course of manufacture, Pye Ltd. having already made a radio survey of the proposed route.

The article would not be complete without an expression of appreciation to the staff of the Sui Gas Transmission Company for the considerable assistance which our engineers received during the installation period

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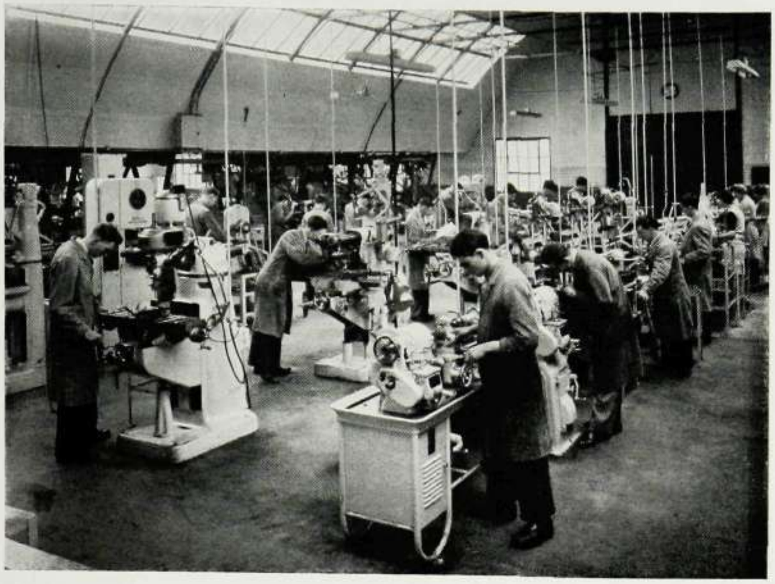
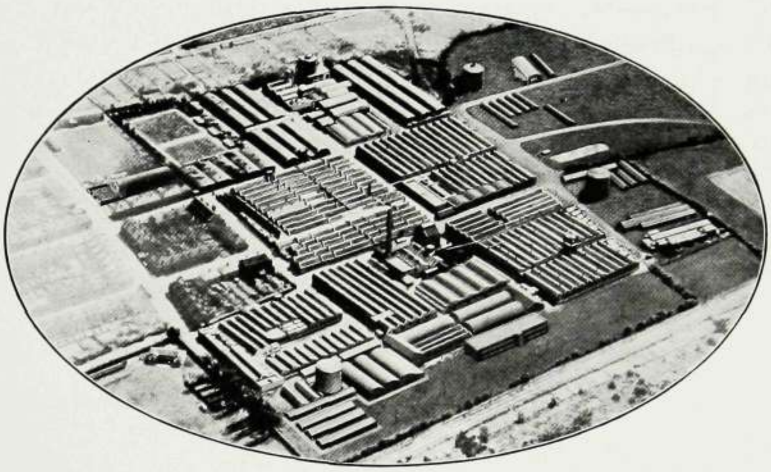
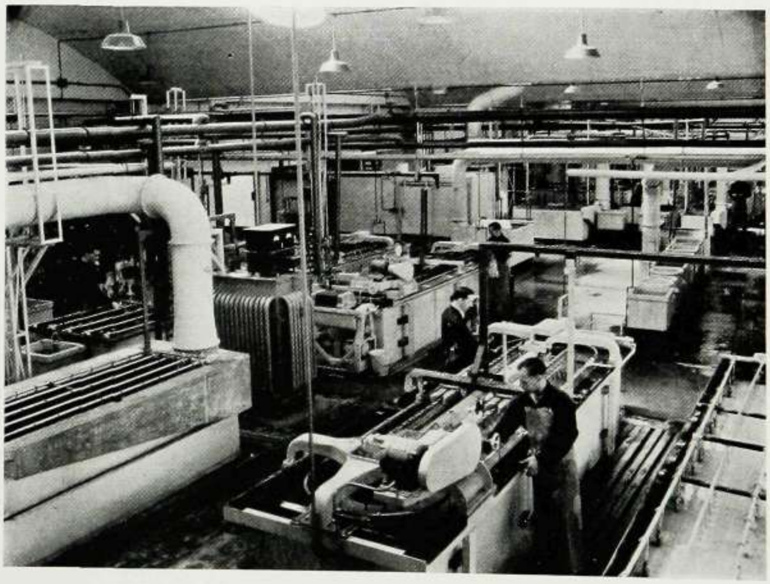


Part of the "Model Room" at the Beeston, Nottingham, Works



The Main Works at Beeston, Nottingham, England



Some of the Modern Plant Used in Metal Finishing Processes at Beeston