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AN AUTOMATIC TRAIN DESCRIBER SYSTEM

J. R. H. Stevens—Special Project Development Department

A brief survey is made of the development of railway power signalling systems leading to fewer signal-boxes, larger control areas and increased traffic. A basic train describer unit developed to meet the traffic and operational requirements of modern main line schemes is described functionally. The miniaturization of mimic diagrams by the use of indicators employing small cathode-ray tubes is outlined.

MODERN railway signalling practice does more than provide the essential traffic safeguards and controls. It is equally concerned with improving the speed and density of the traffic.

A means of identifying each train in the increasing traffic flow must be available to the signalman so that traffic and schedule remain co-ordinated. Train describing systems were developed to link, on the signal-box illuminated track diagrams, each train and its description. A basic Train Describer unit employing the electro-magnetic and electronic techniques of the telephone industry has been developed by the Company for the British Railways. The unit can be modified and elaborated to meet the operational and traffic requirements of any railway modernization project.

Even in basic form a train describer is a somewhat complex equipment and its purpose and functions may not be easily understood unless an elementary knowledge of modern railway signalling practice is available. To provide this, a greatly condensed and simplified description of the development of railway signalling techniques follows.

Block Signalling

In its most fundamental form, the traditional signalling practice secures safe control of the traffic by dividing the line into sections and placing a signal-box and two signals within each section. The signals are placed near the boundaries of the section, one—the distant signal—at the point where the train enters the section and the other—the home signal—at the point where the train leaves the section. The signals are used under ' Block Regulations ' which ensure that normally only one train is in a section at any time and that the train cannot leave the section unless permission has been given by the signalman in the next section. A safe distance between following trains is thereby maintained.

Communication between signalmen is provided by a block telegraph system which links adjacent signal-boxes. The telegraph instruments indicate in both signal-boxes whether the signalman in the signal-box ahead is prepared or not to accept the train into his section. Both signalmen operate their signals in accordance with the instrument indication.

Block Describing

The order of traffic flow is mainly predetermined and is shown in the traffic time-tables, but day-to-day adjustments are necessary. This makes it essential to ' describe ' a train as it is passed forward so that the next signal-box is aware of its identity. To permit this, the adjacent signal-boxes are linked by a block bell system. This enables the two signalmen to exchange standardized descriptions by bell code. A train is ' offered ' to and ' accepted ' by the forward signal-box by the sending and repeating back of the description on the block bell.

The description and times of all trains passing through the section are recorded in the signal-box log book.

With certain elaborations, these simple methods are used on many miles of line, but the traffic handling capacity of the line is limited. The length of a section is restricted by the need of the signalman to see when a train passes his signals, and by the physical strain of operating the mechanical signals and points over long distances.

Adjacent signal-boxes must be closely spaced and the offer and acceptance procedure is time consuming and a check on traffic flow.

Track Circuits

A great improvement in signalling technique was brought about by the development of the track circuit. Basically, this consists of a length of the track with the two rails electrically insulated at both ends. A battery is connected across the rails at one end and a relay across the other end and the current from the battery is adjusted so that the relay operates. When a train passes over the insulated rails, the wheel axles shunt the relay and it releases.

points, removed the limitation on section length imposed by the mechanically operated equipment. The large operating levers were no longer necessary and were replaced by miniature levers which operate relays whose contacts actuate the power devices.

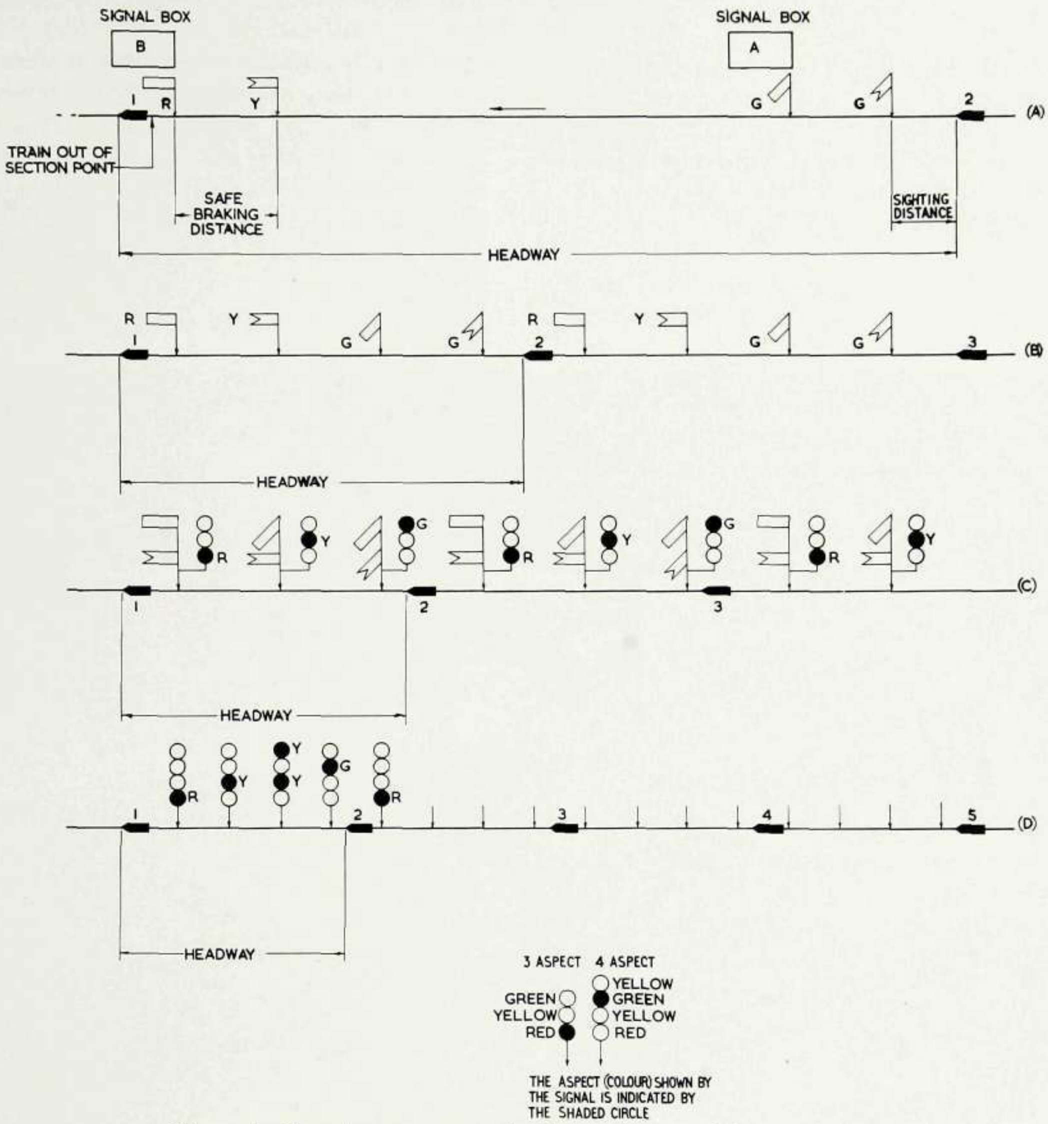

Figure 1—Signal arrangement leading to increased line capacity

Track circuits can be arranged before and after each signal, and from contacts of the track relays a visual indication can be given in the signal-box of the passing of the train. The length of the section need not therefore be restricted to that which can be seen from the signal-box.

Power Signalling

The development of trackside power devices—electrical and pneumatic—to operate the signals and

Contacts on the signal and point mechanisms operate remote indicating relays to give a check-back indication in the signal-box. The contacts of the operating and indicating relays are interlocked to give the equivalent of the mechanical interlocking of the large levers.

Line Capacity

The increase in section length now obtainable made it possible to work a line with fewer signal-boxes.

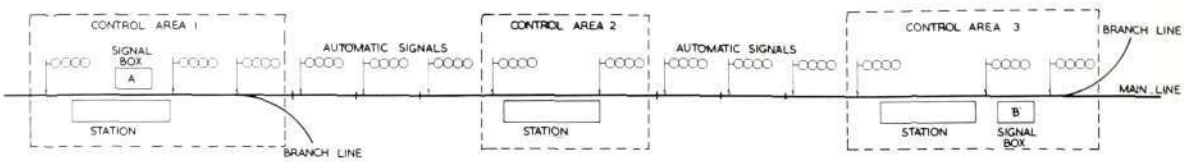

Figure 2—Siting of power-signal boxes

This offered potential operating economies but had the effect of reducing revenue by decreasing the traffic density. This can be seen if the working of adjacent signal-boxes is examined under conditions of unrestricted running, that is, worked so that no check to the traffic flow occurs.

Under 'Block Regulations' signal-box B (see Figure 1(A)), cannot accept a further train from signal-box A until the train already in section B has passed the 'train out of section' point beyond the B home signal. For unrestricted running, B must accept the next train and A must clear his distant signal before the train arrives within sighting distance of the signal, otherwise the driver will check speed. Thus the minimum 'headway' distance between following trains cannot be less than that between the sighting point in section A and the out-of-section

Figure 3—Power signalling control console

point in section B, that is, almost two section lengths. Hence, as the section length increased, so the line capacity decreased. To overcome this, a more elaborate provision of signals is necessary and so the long section is divided into subsections each with its distant and home signals, as in Figure 1(B). Each subsection is operated in the same way as a full section, and the minimum headway is reduced to the length of two subsections.

The limit to subdivision is governed by the purpose of the two signals. The distant signal gives a warning (yellow) if the home signal is at red, and full braking distance for the highest speed attainable at the distant signal must exist between the two signals, this distance being the minimum length of a subsection. However, by placing on each signal post the home signal of one subsection and the distant signal of the next subsection, as in Figure 1(C), the superfluous distance between these signals is eliminated and the headway can be reduced still further.

Colour Light Multi-Aspect Signals

The semaphore arms of the two signals sharing the same post can display one of three conditions, i.e. home off and distant on, both off, or both on, and this is known as three aspect signalling. The three aspects can be given more conveniently by colour lights—yellow, green and red respectively—as shown in Figure 1(C), and these are normally used instead of semaphore arms.

If a fourth aspect (yellow-yellow) is introduced, a driver can be given an advance warning of the state of the next signal should it be at yellow, and thus receives two successive warnings of his approach to a signal at red; yellow-yellow followed by yellow. The safe braking distance can now cover the distance between three signals, that is, from the speed check at a double yellow, through yellow to the stop at red. This, as shown in Figure 1(D), results in a further reduction of the headway and a higher permissible density of traffic.

Automatic Power Signalling

The combination of track circuitry, power signalling and multi-aspect signals has made it possible to control the traffic on a busy line by a track layout as shown in Figure 2. The signal-boxes can be many miles apart and need be situated only where track complexities, such as large stations and junctions, make local control essential.

Between these controlled areas, the trains run through automatic multi-aspect signals which are operated by the trains through the track circuitry. These signals automatically change to red when passed by a train and subsequently switch sequentially to yellow, yellow-yellow, and green as the train passes the 1st, 2nd and 3rd signals ahead.

A signal-box may control one or more remote areas as well as its local area, if the track and traffic conditions in the remote areas are not intricate. Area No. 2 could be controlled from signal-box A.

To obtain maximum occupancy of the high-capacity lines, the signal-boxes are, in general, equipped with an automatic power signalling system operated from a console similar to that shown in Figure 3. On the horizontal face of the console is a mimic diagram of the track layout, incorporating miniature control switches and illuminated point, signal and track circuit indications. The control switches and the illuminated symbols are fitted in the diagram in positions corresponding to the site situation of the associated point, signal or track circuit.

To pass a train through the control area, the signalman selects by the control switches the entrance and exit points of the required route. If the route is available, all further operations are performed automatically and the passage of the train can be observed from the ripple it creates along the indication lamps of the track circuits.

Basic Describer Unit

Modern train describing systems evolved from the block bell system concurrently with the evolution of modern power signalling systems from the block telegraph system. The train describer was developed to lessen the time and mental stress involved in the use of the block bell system and then, as the traffic density increased further, to remove the human element altogether, except in an emergency, from the data side of traffic handling.

In the basic describer unit a transmitter and a receiver now replace the bell link between signal-boxes; a storage equipment takes the place of the signalman's memory and an illuminated diagram serves, to some extent, the purpose of the log book.

The receiver accepts from the rear signal-box the descriptive code of a train approaching the section and places it into a store which represents a signal location. The code is read-off from the store and displayed as a description on a mimic track diagram at the point which indicates the position of the signal. The code is transferred from store to store by the passage of the train through the section and the description is moved along the mimic track diagram from signal to signal to keep in step with the movement of the train. Finally, as the train is about to leave the section, the code is offered by the transmitter to the forward signal-box.

The position of the train is ascertained from the contacts of the track relays used by the signalling system. The mimic diagram is associated with the control console where a power signalling system is used and the train descriptions are displayed on the vertical face of the console seen in Figure 3. Where a manually operated signalling system is retained, the mimic diagram is mounted on the block shelf in place of the instruments as in Figure 4.

A signal-box is passed by trains on the UP and the DOWN lines, i.e. in both directions. This means that in one direction it is the forward signal-box and in the other the rear signal-box, so it must transmit in and receive from both directions. This is met by using two basic describer units functioning in opposite directions. There may be two running lines—Fast and Slow—in each direction and, in this case, four basic units are used.

A train may cross from one line to another so it must be possible to transfer a code from the stores of one unit to those of another unit. The basic units are therefore interconnected and integrated into a Train Describing System with a mimic diagram common to all units.

The equipment is housed in cabinets on a unit basis, as in Figure 5, which shows an installation for UP and DOWN lines.

Train Codes

The British Railways standard identification code consists of four characters, of which the second is a letter, the others are digits. The first digit indicates the type of train (express, slow, etc.), the letter signifies the destination area and the other two digits show the route number. This code is carried on the front of trains for general identification, and is used by the train describing system in its displays.

Code Transmission

The four-character code is transmitted between signal-boxes in binary form. A binary code of four words is used of four, five, four and four bits respectively. Four word messages are also used to transmit information concerning co-operative action between describers and signalmen. The two states of the binary bit require two characteristic signals which may be a.c. or d.c. derived, depending upon the type of telecommunication channel used to link the signal-boxes. One channel is required for each describer unit used, that is, one channel for each transmitter-to-receiver link.

Transmission Accuracy

Errors in transmission are detected by repeating back the received binary code to the transmitter for comparison with the originating information.

The information to be transmitted is placed in decimal form upon uniselector arcs in an encoder and coded into binary form. The binary code is sent in series transmission by the transmitter and each bit is acknowledged by the receiver. The code is translated into decimal form by a decoder and is used to position uniselector switches. When the last word is received, the whole information is read-off the uniselector arcs by the decoder and transmitted back by the receiver. The transmitter converts the check-back information into decimal form and compares it with the original information stored on the arcs of the encoder uniselectors. If the two are identical, the uniselectors of encoder and decoder must be standing on equivalent contacts and there has been no transmission error. The transmitter notifies the receiver by an O.K. signal and the receiver releases into the describer unit the information recorded on the decoder arcs.

CIRCUIT ELEMENTS

A block schematic of a describer unit is shown in Figure 6. The inter-connections with the other units are shown from the transfer circuit. Only certain berth stores and track auxiliaries of the other units are involved in the interconnections, i.e. those concerned with cross-over tracks to the line associated with this unit.

Receiver and Decoder

The code of an approaching train is accepted by the receiver and placed in decimal form into the decoder. The train may be approaching through automatic signals and, normally, the signalman will have no control over it until it reaches the outer signal of his control area. It is desirable, however, that he has advance knowledge of the traffic he will handle a little later and so the descriptions of approaching trains are

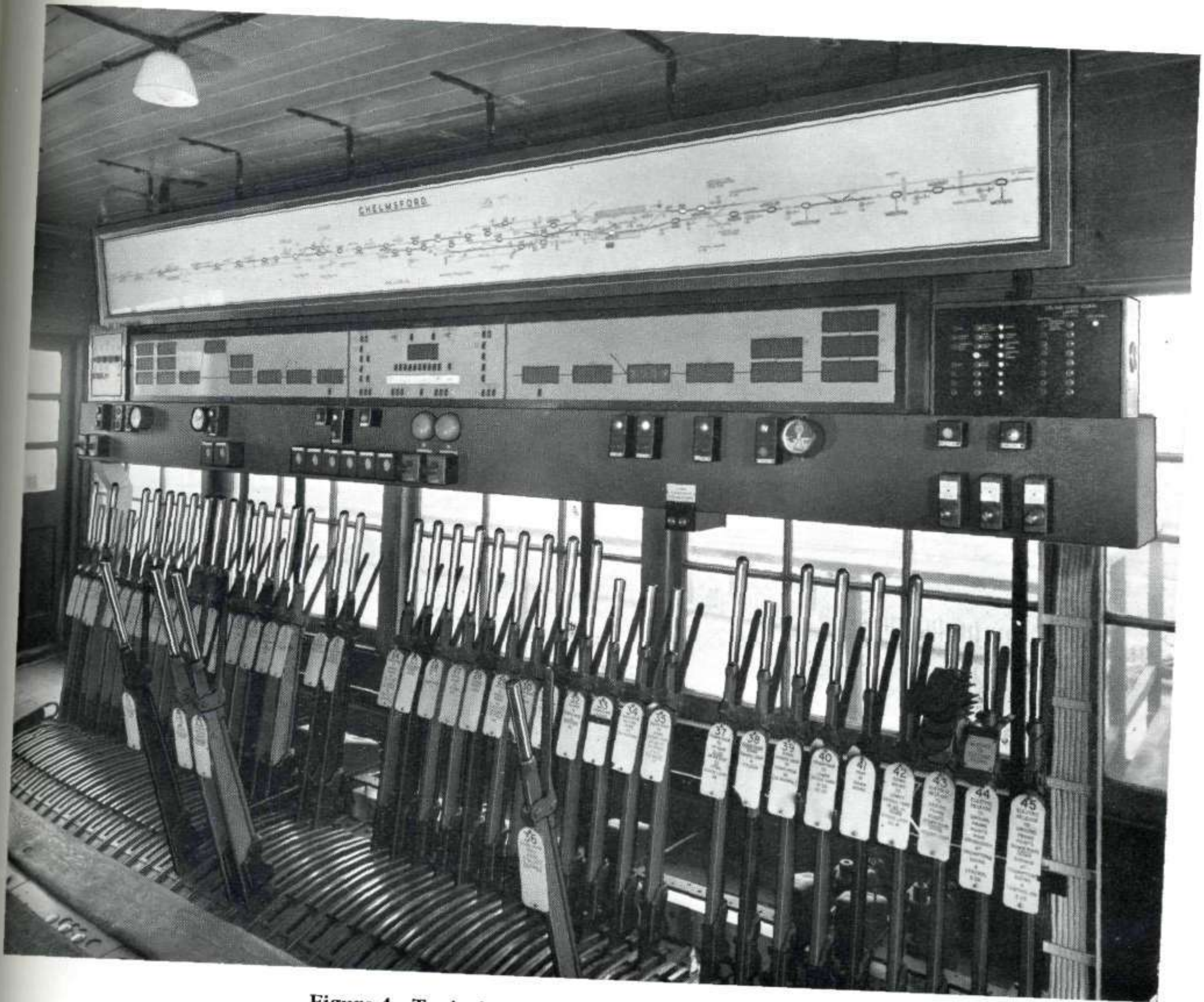

Figure 4—Typical mimic diagram in mechanical signal box

Figure 5—Switching apparatus for Describer Units used at installations for Up and Down lines

displayed. This is the function of the group store and, as soon as the accuracy of transmission is verified, the recorded information in the decoder is made available to the group store.

Group Store

This consists of a group of stores controlled by a common switching circuit. The stores are presented to the decoder for filling in a manner that ensures they share the work-load equally. When filled, the stores form a queue in the order in which they were filled. The presentation, filling and queueing is controlled by the switching circuit.

When the code of an approaching train is available in the decoder, it is transferred in decimal form to the store waiting to be filled. The decoder is thereby freed and the receiver can accept the code of the following train. The filled store takes its place in the queue and the next empty store is presented to the decoder. The codes are thus stored in the order they were received and are read-off and displayed as four character descriptions in the ' approaching ' display panels of the mimic diagram as 1st, 2nd, 3rd and so on approaching trains.

When the first train reaches the outer signal of the control area, its code is transferred, from the store displaying in the ' 1st approaching ' panel, to a ' berth ' store associated with that signal. The now empty group store leaves the head of the queue and moves to the position of last in the queue. The other stores move one position towards the head, and the store which was displaying in the ' 2nd approaching ' panel now shows its stored description in the ' 1st approaching ' panel, and so on.

Berth Store

A berth store is associated with each signal position on the mimic diagram where a description has to be shown. It receives the train code in decimal form and displays it as a four character description.

When the train whose description is displayed in the 1st approaching indicator enters the control area, the ' track auxiliaries ' of the outer signal are disturbed and this disturbance brings the transfer circuit into action to transfer the code from the 1st approaching store into the berth store of the signal. The description will now follow the train through the network of the mimic diagram, being transferred from signal position to signal position by the action of the auxiliaries and the transfer circuit.

Track Auxiliaries

The track approaching and the track beyond a signal are separately track circuited. The former is known as the berth and is the length occupied by a train when halted at the signal. The latter is the overlap and provides space in which a train may be brought safely to rest if the signal was at red when passed.

A description is conveyed through the mimic diagram to coincide with the position of the next signal to be passed by the train. This is logical because it is at the signal that the train is approaching that control over its movement is obtained. The track and indication relays which serve the signalling system also serve the describing system, hence train and description are kept in step. For this purpose the track relays of the berth and overlap sections and, where necessary, of ordinary track sections together with point indication relays are fitted with an extra contact. These contacts disturb the track auxiliaries consisting of groups of relays which trigger off and marshall the transfer of the codes from berth store to berth store. Each auxiliary is designed in accordance with the traffic movements that are possible at the site it represents on the actual track layout.

The ripple of track auxiliary disturbances from the passage of one train cannot be confused with the ripple caused by another train. The signalling system takes care that the two ripples do not meet, and should one pass the other it will occur while the trains are on different tracks. Each train remains clearly defined and its identity preserved.

Transfer Circuit

Each describer unit has a transfer circuit which is furnished with information concerning every transfer from berth store to berth store that can take place, that is, every movement from signal to signal that the track layout of the associated line permits.

If the number of transfers exceeds the capacity of one transfer circuit, the line network is divided and each part given its own transfer circuit. The information covers main-line through traffic; branch-line traffic to and from main line; main line to main line switching; traffic into and from sidings, and station shunting movements.

The transfer circuit is brought into action by a disturbance of the auxiliaries and searches for an active auxiliary amongst the dormant ones. When found, the transfer circuit is able, from the information with which it is furnished, to identify the signal which

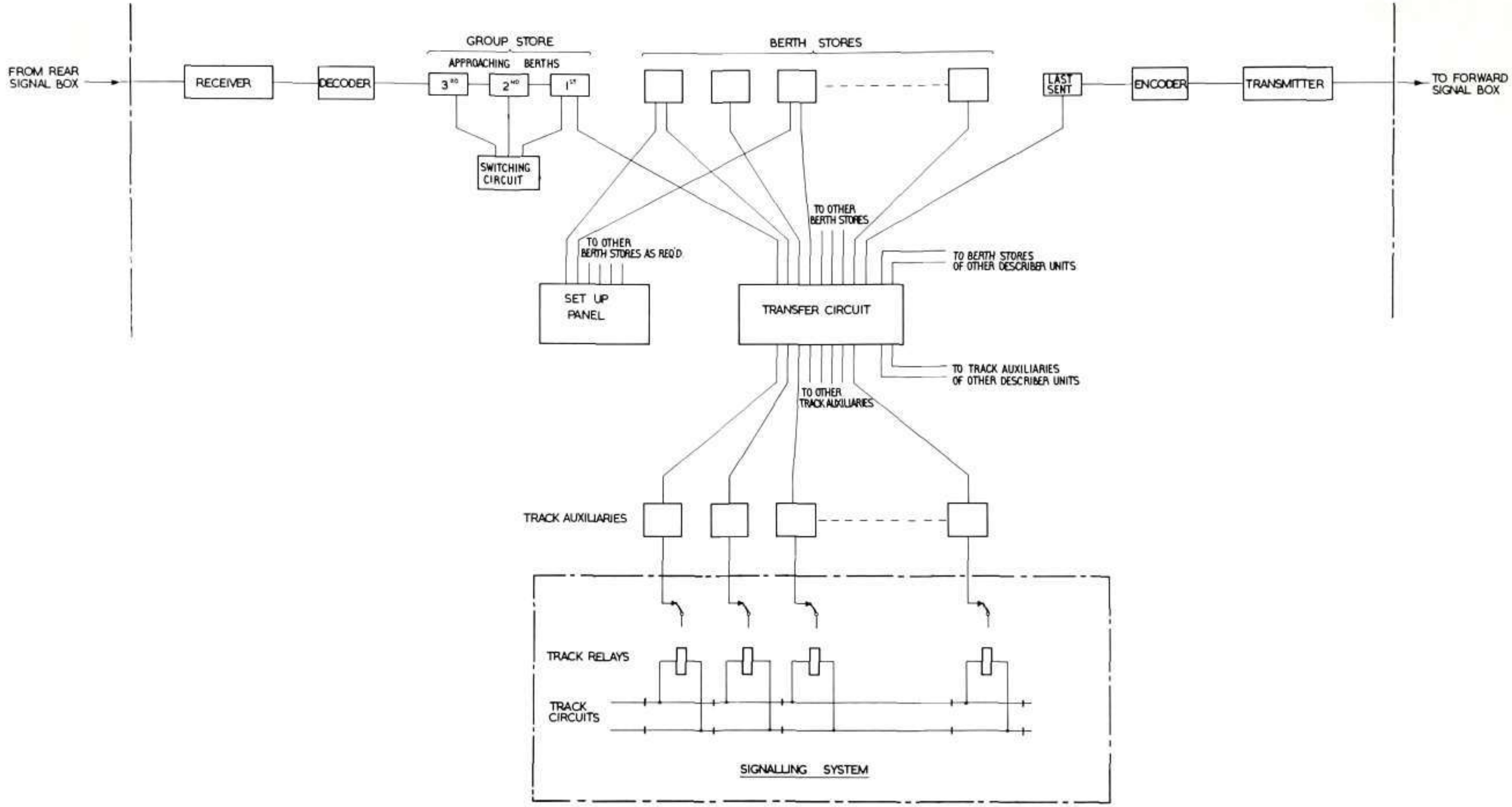

Figure 6—Schematic of basic Describer Unit

the auxiliary represents and, from the pattern of energization within the relays of the auxiliary, to determine the route the train is taking and hence the next signal it will pass. The transfer circuit selects the two berth stores concerned and transfers the train code, from the berth store associated with the signal which the train has just passed, to the berth store of the signal that the train is approaching.

It may help if the interworking of auxiliaries and transfer circuit is shown in a practical way. Figure 7 shows a simple track layout upon which equally simple traffic movements can be traced.

Assume a train is approaching signal 11 on the DOWN fast line. Its description will be already showing on the mimic diagram alongside the symbol for signal 11. When the train reaches the berth of signal 11, the disturbance of the auxiliary calls in the transfer circuit to identify the auxiliary as that of signal 11 and to ascertain from the auxiliary if points 101 are normal or reversed. If normal, the train must continue along the DOWN fast and, when it reaches the overlap of signal 11, the transfer circuit moves the code from berth store 11 into berth store 12 and simultaneously the train's description on the mimic diagram is moved from signal 11 to signal 12.

If the points are reversed, the train is being switched to the DOWN slow for a station stop, in which case, the transfer circuit moves its description to signal 21. When the train leaves after the station stop, the auxiliary associated with signal 21 indicates to the transfer circuit the position of points 201, and the description is moved accordingly to signal 13 on the DOWN fast or signal 22 on the DOWN slow.

Last Sent Store

The train having passed through the control area, taking its code from berth store to berth store and its description on the mimic diagram from signal to signal, will finally pass the last signal within the control area. The auxiliary associated with this signal transfers the code into the 'last sent' store to be read-off and the description displayed on the mimic diagram in the 'last sent' panel. The code is subsequently converted to binary form by the encoder and transmitted to the forward signal-box.

The description of the train normally remains in the last sent panel as a reminder until the train reaches the outer signal of the control area of the next signal-box ahead, that is, until its description has passed through the 'approaching' panels and entered the first signal panel on the mimic diagram of the forward signal-box. If another train leaves the control area before the description of the first train is removed, the description of the second train replaces that of the first.

Receiver Full

The number of 'approaching' stores provided within the group store is based upon considerations arising from the problem of average and peak traffic. If, for some reason, all approaching stores are filled, the receiver sends back to the transmitter a signal which inhibits further transmissions and a 'receiver full' alarm is given.

FRINGE SIGNAL-BOXES

These are the signal-boxes beyond which the train describer system does not extend. At fringe boxes,

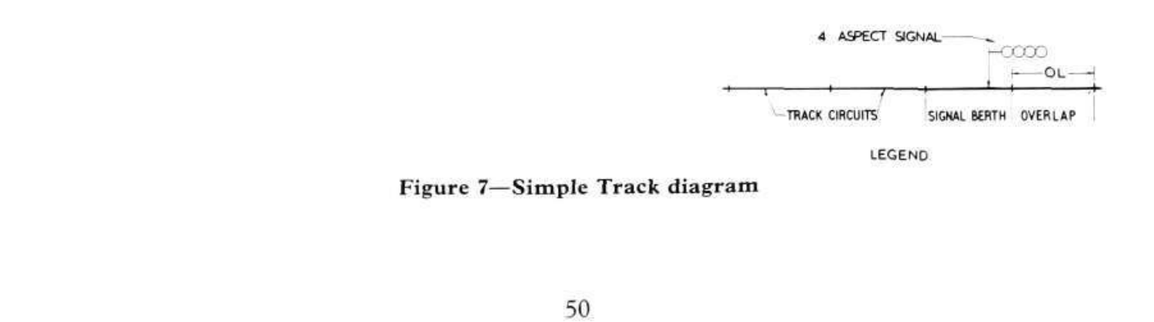

Figure 7—Simple Track diagram

Figure 8—Fringe signal-box set-up panel equipped with a key for each character appearing in train description

trains approaching the area covered by the system must have their descriptions placed into the system and those leaving the area must have their descriptions removed.

Traditionally, the UP line leads towards the Capital (London), so a signalman in a signal-box on the fringe of the system at or nearest to this terminus injects a description into the DOWN line and removes it from the UP line. A signal-box on the fringe remote from the Capital does the reverse action.

Set-Up

To permit a description to be placed into the system, each fringe signal-box has a set-up panel, similar to that shown in Figure 8, equipped with a key for each character that appears in the descriptions. The characters are picked out by pressing the appropriate keys, and the description, as it is built up, appears in a display panel above the key. If incorrectly set-up, the display can be cancelled and another attempt made. The decimal code of the displayed description can be injected into a selected berth store. If the signal-box is at the terminus station, this berth store could be that of the starting signal of the platform at which the train is standing. If the signal-box is not at a terminus, it would be the berth store of the outer signal on the approaching track.

As the train leaves the platform or passes the outer signal it will carry its description forward with it until leaving the system at another fringe signal-box or over a branch line at an intermediate signal-box. The description will be automatically removed as the train passes the last signal included in the system. The description must be manually removed should the journey end at a station platform.

Interpose

A set-up panel is provided at all intermediate signal-boxes to allow a code to be injected into some or all of the berth stores. This permits a code being placed into the berth store of the outer signal on a branch line to await the arrival of the train about to enter the main line traffic.

'Not Described' Code

If a berth store contains no code following a disturbance of its track auxiliary and a transfer is attempted, a 'not described' (ND) code is automatically injected by the transfer circuit into the berth to which transfer should have occurred. The

ND code consists of special characters such as asterisks and is displayed at the signal position associated with the second berth store.

If a signalman omits to allocate a code to a train as it enters the system, the train is automatically displayed as ND and this code is carried forward on the mimic diagram. This condition can be rectified by injecting from the set-up panel the intended code into the first berth store, with the interpose facility, ahead of the train. When this signal is reached, the ND code will be replaced by the injected code and the train goes forward correctly described.

Shunting Movements

Should a train making shunting movements enter the main lines, the ND display appears on the mimic diagram at the nearest signal, in the direction of travel, to the point of entry. The ND display proceeds to follow the movements of the train along the main-line and cross-over tracks until the train re-enters the siding. At this stage the display disappears.

Track Failure

If the relay of a track circuit releases for any reason other than the passage of a train, there is no code to be transferred and the ND display will appear. The faulty section or sections are thus indicated.

When a track circuit of only one signal is involved, the passage of descriptions through the mimic diagram is unaffected. When a train arrives at the faulty track section, the auxiliaries of the rear and forward signals 'lift' the train description across the dead section. However, if two or more consecutive track circuits fail, the train description is not lifted and will disappear, the train leaving the dead sections with a ND display.

Early Transmission

At certain signal-boxes, an earlier warning than normal of approaching trains is necessary if a check to their speed is to be avoided. The time-consuming control of a level-crossing over a busy road may be the reason. At the rear box, it is arranged that the transmission forward of the description takes place as the train passes signals prior to reaching the outer signal. An early transmission is necessary only if the route and track ahead is set up and clear, permitting a run through at scheduled speed to the forward signal-box. Under these circumstances, as the train passes each signal arranged for early transmission, a check is made to ascertain whether a clear road exists. If it does, a transmission takes place; if it does not, the check is made again at the next signal. Should an early transmission not be possible before the outer signal is reached, normal transmission occurs at this point.

Mimic Diagram

The indicators used in the mimic diagrams of Figures 3 and 4 are of a projection type. Each display consists of four indicators and each indicator can show a number of predetermined characters. Within each indicator, a lamp, a double convex lens and a photographic film bearing the character are provided for each character required. The lenses are angled so that the different projection paths meet centrally on a ground-glass screen at the front of the indicator and all characters are seen with equal clarity. Indicators showing characters as small as 5/8″ have been used. The indicators shown in Figures 3 and 4 do not employ the British Railways standard identification code.

The future trend in display panels for both signalling and describing systems is somewhat unpredictable. The amount of track layout information which must appear on the mimic diagram tends to increase as the number of signal-boxes becomes fewer and the control areas larger. The use of larger panels is limited by operational and space considerations and there is a tendency towards miniaturization, but this introduces difficulties when the signal-box has traffic controllers, seated at a distance from console and panels, who must observe train movements on the panels.

A common mimic diagram for both signalling and describing systems is possible, leaving the control switches on a console of convenient size.

A system being manufactured by the Company for the signal-box at Watford on the Euston terminus line employs a common diagram about 25 feet long. This diagram shows the track layout for 8 miles in the UP direction and 18 miles in the DOWN direction, and requires train descriptions to be shown at 130 signal locations.

The adjacent signal-boxes will ultimately be situated at 12 miles and 30 miles from Watford. The line is reputed to be the busiest main line in the world and carries over 400 trains a day.

Display indicator miniaturization is achieved by using small cathode-ray tubes one inch in diameter. Two tubes, mounted side by side, form a display with two characters appearing on each tube. A total of 260 tubes is required for the diagram.

The characters are 5/8″ high and each character is produced from a rectangular matrix of 13 x 9 possible spot positions. The matrix is normally suppressed and the required character is produced by brightening the necessary spots.

Character generation is from circuitry using solid state devices and starts with a multivibrator having a frequency of about 13 kc/s which is high enough, after the necessary sub-divisions of the frequency, to avoid optical flicker of the characters. The pulses from the multivibrator are fed to bistable chains to be distributed to 13 vertical and 9 horizontal pulse leads. The pulses on these leads trigger a matrix of AND gates to produce 117 spot pulses. These spot pulses are fed to the character gating circuits. A gating circuit is provided for each character and it permits only those spot pulses required to form the character to pass. On the output side of the character gates there is therefore an individual spot lead for each required character.

Controlled from the bistable outputs, X and Y sweep-generators supply the 'staircase' voltages to the plates of the cathode-ray tubes to deflect the beams to the spot positions.

The individual spot leads are connected to all stores and within a store the leads of the four characters to be displayed are selected. The pulses from the four selected leads are applied to the grids of the two cathode-ray tubes of the associated display unit to brighten the tubes and produce the spots required to form the four characters.

For future application, circuitry has been developed to produce the four characters on one tube.

ACKNOWLEDGMENT

The author wishes to acknowledge the use of Figure 1 which is based upon a diagram in a publication of the Institution of Railway Signal Engineers.

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CONTEMPORARY FLAMEPROOF TELEPHONES

P. F. Burton—Apparatus Engineering Department

A new range of flameproof wall mounting telephones for the chemical and oil industries is described. The telephones utilize the intrinsically safe handset and amplifier previously adapted to a desk instrument, the first of its kind to receive overall flameproof certification for hazardous atmospheres in the industries. Simplification of castings has made possible the development of further ranges of ironclad telephones without additional tooling.

ALTHOUGH flameproof telephones have been manufactured by the Company for more than forty years their construction, irrespective of usage, has been closely related to that of mining equipment for the greater part of this time. The construction of the mining telephone, dictated by the rugged conditions of its use, is necessarily robust and formed a ready and convenient basis of design for flameproof constructions also. The tooling and production costs involved in developing a separate range of equipment less massive in proportion and more suitable in appearance to typical surface applications, needed a sizeable demand to justify the expense.

The widespread growth of oil and chemical undertakings in recent times, and the expanding need for telephone equipment safe in the hazardous gas and vapour bearing atmospheres commonly found in these industries, provided such a demand and the opportunity was taken to design equipment more in keeping with the control room, the laboratory, and the chemical production line. Considerable development work was carried out by the Company in conjunction with the Oil Companies Materials Committee, BPO engineers and the Ministry of Power, which is responsible for the certification of equipment.

Such certification, for the purposes of use in the oil and chemical industries, specifies the gases in which equipment shall be flameproof (i.e. so constructed as to contain any internally generated explosion in these gases) as being of Groups 2 and 3 in BS.229, 1957. (For a definition of these groups, and a fuller account of the flameproof method of construction see Bulletin 36, January, 1958.)

The first outcome of the development was a desk telephone, introduced in 1956 and fully described in Bulletin 36. This instrument appeared in auto and c.b. forms, and to it have now been added a range of wall mounting telephones for operation on auto, c.b. and magneto systems, the first two with or without operator recall facilities. The desk telephone, though remaining identical in mechanical details to the 1956 instrument, has been fitted with a new type of handset and associated amplifier and re-certified for Groups 2 and 3a of BS.229, 1957. This handset has not been previously publicized and, with the amplifier, it has been adapted to, and forms an essential feature of, the whole range of flameproof instruments.

Handset Design

The handset fitted to the earlier desk telephone was one made ' safe by construction ', that is, having an armoured cord and inserts in the body to exclude pockets of gas. In order to provide an even higher degree of safety, attention was subsequently directed to making the handset intrinsically safe, i.e. arranging for such limitation of electrical energy within it as to make impossible the spark-initiation of a flame in the prescribed gases. This principle, entirely new in flameproof telephone design and fully acceptable to the Ministry of Power permitted full flameproof certification to be secured for the entire telephone, the first of its kind to have been so approved.

The new handset employs two identical rocking armature receiver insets of conventional type. One is used as a high performance receiver, but the other is employed as a sound power transmitter in conjunction with the amplifier, mounted in the flameproof body of the telephone. Advantage has been taken of the intrinsically safe design to improve the appearance and handling qualities by making the handset body of the latest high-impact lightweight plastic material and using an extensible p.v.c. cord.

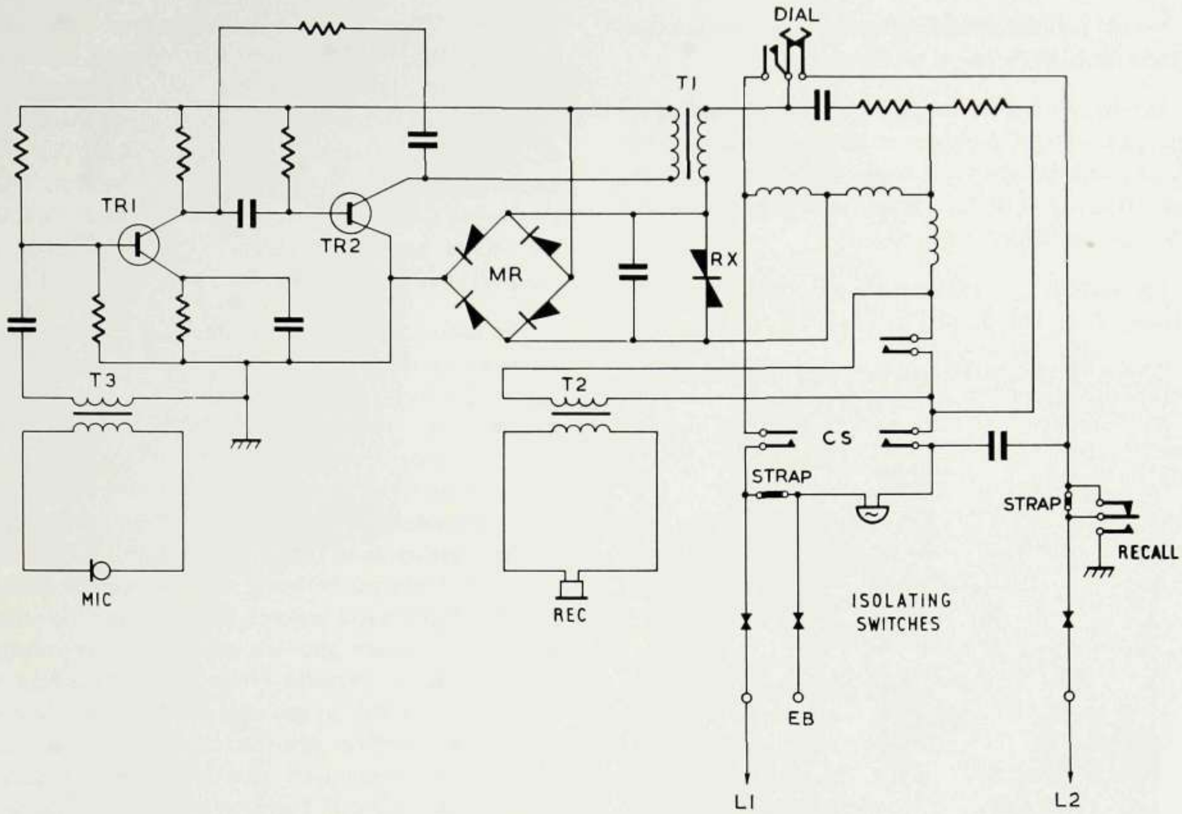


Figure 1—Simplified diagram of Telephone circuit

THE AMPLIFIER

The amplifier employs transistors and its operation may be followed by reference to Figure 1, a simplified circuit of the telephone. The input transformer T3 serves to match the impedance of the microphone to the base circuit of transistor TR1. Negative feedback is applied between the collectors of TR1 and the second stage TR2. Amplified speech signals are fed by transformer T1 to a point in the telephone circuit where the transmitter would normally be connected. The telephone circuit itself is of conventional design. The microphone-amplifier combination provides an output to line approximately equal to that of a transmitter P.O. No. 13 in the same circuit. The instrument line current passing through the non-linear resistor RX provides the operating potential for the amplifier to which it is applied through a rectifier bridge, thereby ensuring correct polarity with either direction of line current. The use of a non-linear resistor reduces the range of voltage applied to the amplifier under varying line conditions, thus stabilizing the gain. The transmission loss due to this resistance is minimized by a 20 μF tantalum-capacitor shunt. The isolation of the microphone from the telephone circuit provided by the input transformer T3, and similar isolation of the receiver by the 1: 1 transformer T2, ensure full safety in the operation of the handset.

The amplifier unit is mounted on an easily removable chassis and consists of a double-sided printed circuit panel, having the three transformers of miniature design on one side and the two transistors and associated components on the other. All the components are fully tropicalized and the complete unit is connected to the telephone circuit via solder tags.

THE WALL MOUNTED TELEPHONES

Design considerations

While the new telephones were intended to be lighter in weight and of cleaner, more modern appearance than previous flameproof equipment, it was necessary for the casework and components to be equally robust and reliable. Optional weather-proofing, giving a high degree of protection for all the external components on the front face of the instrument had to be provided, since possible situations of use could include airfield refuelling points and tanker jetties likely to be swept by heavy seas.

Maintenance of the telephone should be possible on site and for this purpose an isolating switch, automatic in operation on removing the instrument cover, was required both for safety reasons and to avoid affecting associated equipment.

Flameproof certification should cover gases in Groups 2, 3a and 3b of BS.229, 1957.

The telephones as designed fulfil all the above requirements.

Figure 2—External view of Automatic Flameproof Wall Telephone

GENERAL CONSTRUCTIONAL FEATURES

The overall mechanical construction is uniform throughout the range and its external features can be seen from Figure 2 showing the auto instrument. The overall dimensions are 11¼″ high x 13″ wide x 6¾″ deep (approx. 29 cm. x 33 cm. x 17 cm.).

Figure 3 shows two views of the same instrument fitted with a weatherproof cover. This cover, made of a silicon aluminium alloy chosen for its high resistance to corrosion and freedom from frictional sparking, is capable of being stayed in the horizontal position to afford some protection from rain when the telephone is in use. A neoprene gasket fits in a groove round the lip of the cover. The cover is opened by a straight pull on a stainless steel slam catch, and is then raised to the horizontal when a stainless steel latch automatically locks the cover in position. When the telephone has been used, the latch is released and the cover dropped shut, the slam catch securing the door automatically and effecting a compression of the neoprene tube on the machined face of the main body. This makes an effective seal enclosing the entire front face of the instrument. All metalwork not protected by the outer cover, such as the latches, hinges and screws are either of brass or stainless steel to avoid corrosion.

The main body of the telephone is of cast iron and is internally divided into three separate chambers; main apparatus, incoming line, and isolation switch, in accordance with the provisions of BS.229. The upper or apparatus chamber cover is of cast iron and the two lower covers, protecting the line and isolation switch chambers respectively, are of the same alloy as the weatherproof cover. Interchamber connections are provided between the line and isolating switch chambers and between the latter and the main apparatus chamber and are achieved by terminals moulded into a common block closely fitting in a carefully bored hole to maintain the necessary flameproof joint between adjacent compartments. The line chamber contains a moulded plate mounting three robust terminal posts of conventional design to which the incoming line is connected. The isolating switch chamber encloses a three-pole microswitch assembly fitted to the rear face of the cover of this chamber. The main component-bearing chassis of the telephone, together with the dial and ringer movement, is contained in the main chamber to which access is obtained by releasing the captive triangular-headed screws fixing the main cover. The replacement of the main cover is assisted by the provision of a locating dowel which accurately positions the cover, taking the weight prior to the refixing of the cover screws.

The cast bronze certification label is secured to the main cover by secret screws and forms a rigid plate extending over the cover of the isolating switch chamber. Into this chamber, and through the plate, passes a captive tamperproof screw which when tightened against an internal spring causes the three-pole isolating microswitch to 'make', thus connecting the instrument to the line; this is the normal working condition. The arrangement is such that before opening the main cover for maintenance, the isolating switch operating screw must be retracted, thus rendering the main apparatus 'dead' and allowing maintenance to be carried out in complete safety. This interlock between the main apparatus

Figure 3(a)

Figure 3(b)

Figures 3(a) and 3(b)—General views of Flameproof Wall Telephone fitted with flameproof cover

cover and the isolating switch is as demanded by the regulations of BS.229.

Two four inch diameter stainless steel bell domes are located in a recess at the rear of the telephone and are actuated by a striker which passes through a flameproof bearing to the interior of the main compartment. The design of the ringer is based on the standard post office 59A 1000 Ω type incorporating a ceramic permanent magnet. This provides a vigorous movement of the striker resulting in a calling signal of considerable penetration.

The chassis, bearing the induction coil, capacitors and transistor amplifier is identical to, and interchangeable with, the chassis used in the companion flameproof desk telephone. The instrument becomes operational on removal of the handset by means of a simple internal lever action and switch arrangement.

The dial movement is a modification of the P.O. No. 21 type and is operated by an improved version of the ‘ flyback ’ fingerplate system, incorporating the obligatory flameproof bearing to maintain the safety of the instrument.

The recall facility where provided is achieved by a pushbutton operating through a close fitting bush to operate a microswitch located inside the main compartment. The pushbutton is replaced by a blanking plug in the normal version of the telephone.

Mounting of the complete telephone is based on a stable three-point contact with the wall, maintaining adequate clearance between the wall and the rear of the instrument. The mounting holes provide clearance for $\frac{3}{8}''$ bolts which pass through three lugs cast integral with the main body, the lower two of which are open. Therefore only the top fixing bolt need be removed if the instrument is to be replaced for maintenance purposes, the lower two being merely slackened.

The termination of the handset cord to the main apparatus is such that the handset unit can easily be removed for maintenance without disturbing the main apparatus cover.

Magneto and CB Versions

The magneto version utilizes a rotating magnet generator in place of the dial movement. The generator is operated via a heavy flameproof bearing, by a handle on the front face of the instrument, thus being fully protected when the outer cover is closed. A feature of the design is that the generator, of standard form, is coupled to the handle assembly in such a way that the latter remains undisturbed if the generator has to be removed for maintenance at any time. This arrangement also ensures that the thrust of any violent handle rotation is taken by the heavy bearing, thus prolonging the life of the spindle bearings incorporated in the generator.

The local 3-volt dry or inert battery required for speech purposes is a single unit housed in the main compartment. Owing to the light drain current, it has a long working life and its replacement is simplified by the use of a non-reversible ' plug-in ' connector, obviating the need for screw type terminals.

The c.b. instrument is fitted with an operator recall button located centrally. The button, operating through a flameproof bush, actuates a microswitch in the main compartment. An alternative version without the recall facility is available, being fitted with a blanking plug in lieu of the recall button assembly.

On all types of wall telephone, the line connections are effected via sealing glands situated on the lower face of the instrument. These glands are of the modern running-coupler type incorporating a compressible sealing sleeve to provide an adequate flameproof seal over the cable without the use of sealing compound. They are common to both wall and table flameproof telephones thus simplifying the provision of spares.

Special attention has been given to the protective finish of the casework to combat oxidization under all circumstances. After an epoxy resin dip the final coating is of silver grey hammer finish stove enamel to minimize the internal temperature rise when used in strong sunlight. This is superior in appearance and quality to any previously offered on iron cased telephones.

Future Developments

The design of these telephones was not undertaken as an isolated development but was part of a programme aimed at simplifying the production of iron-clad telephones generally. The whole range of such telephones for both flameproof (oil and chemical industries) and intrinsically safe (mining) usage has in the past involved a total of over 30 different castings, each one associated with its own pattern equipment, manufacturing tools and production problems. It was appreciated that although the reasons for robustly constructed instruments differed between the flameproof and intrinsically safe telephones, i.e. the containing of internal explosion, and meeting the rugged conditions of underground mining respectively, the same broad principles of construction had always proved satisfactory for both, and it should be possible to design a relatively small number of castings that when assembled would fulfil the requirements of both spheres of usage. More than this, a further permutation of the same few castings would enable yet a third range of ' Weatherproof Industrial Telephones ' to be manufactured if desired.

This rationalisation of castings means that the evolution of the proposed new ranges can proceed with relatively little further tooling or development effort, since the major part of this has already been covered in the present range of flameproof telephones.

Conclusion

The new range of telephones, incorporating the intrinsically safe handset circuit and transistor amplifier, gives an exceptional degree of efficiency coupled with an order of safety that is the highest yet certified by the Ministry of Power for telephones to be used in the gaseous atmospheres of the oil and chemical industries.

Acknowledgment

The author wishes to record his appreciation of the assistance received from the Chief Testing Officer of the Ministry of Power Research Establishment, Buxton, the Engineers of the Post Office, and the Oil Companies Materials Committee.

U.D.C.621.318.5.

THE TYPE 12 RELAY

J. Searle—Apparatus Engineering Department

This new relay has been adopted by the B.P.O. to replace the 600 type in uniselector line-finder equipment. Springset adjustment is avoided in production and subsequent use, and a simple method of locating the components in accurate relative position, together with a substantial reduction in piece-parts compared with the 600 type, results in a device highly uniform in rapid production, and of low cost.

As the second most widely used relay in B.P.O. switching equipment, the 600 type has remained basically unchanged in its essentials over more than two decades. This points less to a conservatism in design than to the task facing the innovator, for the essentials of the relay are also those of the parent 3000 type, and it is not easy to make fundamental changes in a design whose initial conception both foresaw and provided for a large number of differing applications.

It is often possible however to re-design such a relay for a specific application, and this with advantage, for the design can be rationalized to the one purpose and may offer both an improved performance and a lower production cost.

Such an opportunity presented itself when the B.P.O., having decided upon eventual replacement of the 600-type relay in subscribers uniselector line-finder equipment, invited the development of a more economic alternative and issued design criteria. These included limitations of space as well as cost and imposed a requirement that springsets should be capable of replacement without adjustment. This in practice implies a similar freedom from adjustment of the completed relay in production. It is, in fact, a cardinal requirement since any relay fulfilling it would, with suitable contributory design, attain the virtue of low cost almost automatically. With the 600-type, about half the assembly time is occupied in hand adjustment of the springsets.

The Type 12 relay, perfected by the Company after intensive development work and accepted by the B.P.O., is now in full production. It fulfils all the requirements in a homogeneous design having many original aspects.

The Yoke and Magnetic Circuit

In subscribers uniselector linefinder equipment, relatively large numbers of relay units are usually grouped together. A first step in securing economy both of material and mounting space was therefore to produce the relay in strips of units with a common yoke, the most convenient number of units being five. The yoke also carries the core-irons of the individual relays and has mounting lugs at its ends. This one-piece construction may be compared with the forty separate piece-parts and mounting plate necessary to the corresponding functions in a strip of five 600-type relays.

The U-shaped armature is positioned centrally under each core-iron and completes the magnetic circuit with its bridge-piece square across the core-iron end. The two lugs at the tips of the U are swaged on their upper faces to give an accurate hinge action upon the yoke. In the completed assembly they are retained by hinge recesses in the coil former. Both yoke and armature are given a finish of dull chrome on nickel.

The short two-path magnetic circuit, together with careful annealing of the electrical-quality mild steel used, ensure that the maximum useful magnetic energy is extracted per ampere turn of coil.

General Assembly

The yoke serves as the primary anchorage for all the component parts of the relay, and its lower face, planished at each relay-station, forms a datum for an assembly accurately reproducible as regards the relative positions of its parts.

The order of assembly may be followed by reference to the exploded view, Figure 1. The first stage is the fitting of coil and armature to the yoke. The armature A is placed with its lugs in the recesses B at the heel end of the coil former and with its bridge-piece resting upon a back-stop formed by a projection C on the front of the coil former, the swaged faces of the armature lugs being uppermost. This sub-assembly is advanced on to the core-iron of the yoke Y until the rectangular cut-out D at the heel end of the coil former engages fully with the cross member of the yoke. The armature is now captive and hinging upon the cross member. Following this operation the

T-shaped spring clip E is inserted into the upper gap between coil aperture and core-iron as far as the step in the rounded tongue. During the insertion the cross-piece of the clip is pressed downwards to enable the large central slot to engage the end of the core-iron, thus holding the bottom edge of the slot to the datum plane and fixing the position of the cross-piece. The leverage of the clip upon the step of its tongue forces the coil upwards so that the lower face of the coil aperture is also held in contact with the datum plane. Since the armature travels between the back-stop on the coil former and the datum face, its limits of travel are thus accurately fixed.

The second and final stage of assembly is the addition of the springset assembly F comprising a U-shaped bracket carrying the springsets with buffers and operating combs. The tips of the U are pushed into and retained by the small rectangular slots at the ends of the cross-piece of the spring clip, and the rear end of the U is depressed so that the rectangular cut-outs G on either side of the bracket nestle down flush with the yoke. The ends of the operating combs are now correctly located with respect to the armature but separated from it by a small gap. This gap permits a small amount of free movement in the armature and ensures that the moving springs restore fully when the relay is de-energized. The vertical flat at the rear end of the U has an open locating slot H. This mates with a similarly shaped moulding on the projection at the heel end of the coil former. Above this slot is a hole, and there is a corresponding hole in the coil former projection. The bracket is secured by a hardened-steel fast-thread screw J inserted through the holes and engaging with a spring-steel nut K held captive by grooves in the projection L.

Since the tips of the bracket are accurately held relative to the datum and hence with respect to the armature, the active ends of the springsets are similarly fixed. The absolute position of the rear ends of the springsets, determined by the seating of the bracket on the non-datum face of the yoke cross-member, is also fixed within the tolerance variations of the yoke material, and these variations are small enough to be of no consequence. The freedom from adjustment of the relay as a whole thus depends on springset design alone.

Detail Assembly

The Springsets

It was regarded as essential that springset adjustment should not only be avoided in production but eliminated in subsequent use, and the design fulfils this latter requirement.

Higher than normal contact pressures are utilized and these derive purely from pretensioning of the springs. Their attainment in use is independent of contact wear or armature effort and requires only that the armature travel remains constant.

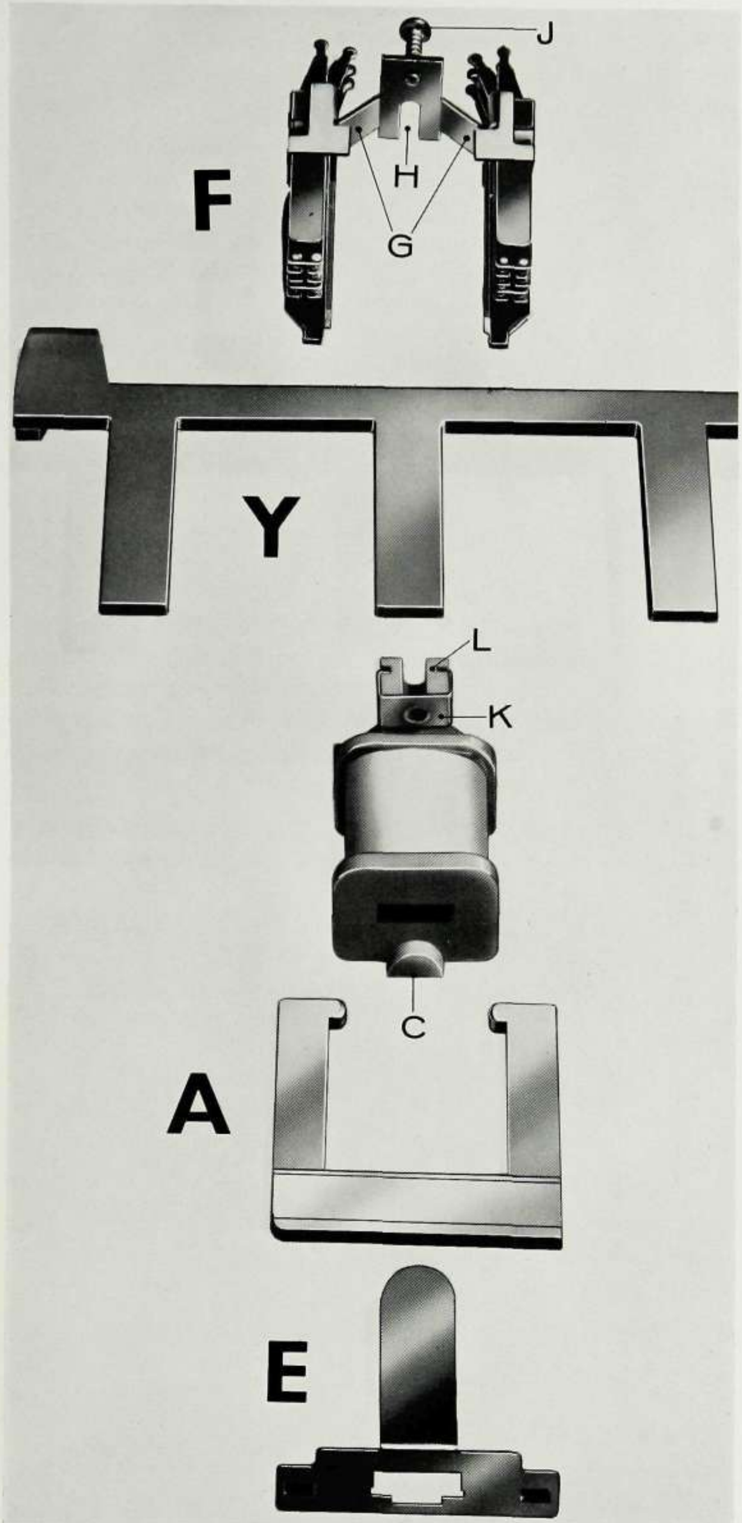
To achieve this, moving springs are made reverse-acting, that is, both make-and-break action springs are so pretensioned that they would bear on the fixed springs if they were in the free state. The moving comb of the assembly, upon the relay being energized, allows the make springs to move into contact with the fixed springs and forces the break springs away from the fixed springs. The comb is given excess travel by the armature, so that its ' make ' controlling faces separate from the make springs after the contacts have closed, thus leaving the springs free to exert their full preset contact pressure. In a similar way the ' break ' controlling faces of the comb separate from the break springs when the relay is de-energized. Figure 2 shows a change-over action in detail.

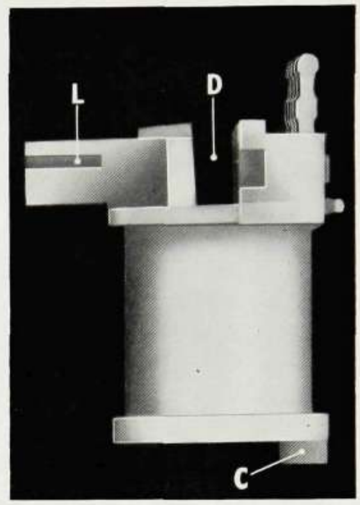
The fixed springs are pretensioned towards the armature and held by steps in the springset buffer, in accurately fixed relationship to the whole assembly.

A relatively large design-minimum for the contact gap of ·008″ and allowable spring tension limits of 20-40 grammes permits the realization in rapid production of an assembly requiring virtually no individual inspection. The only adjustment actually needed is that of the armature return spring, and is of a minor nature.

The springs are of hard phosphor-bronze with twin silver contacts, the fixed and moving springs being respectively ·016″ and ·010″ (0·4 and 0·25 mm. approximately) in thickness. Blanks ·006″ (0·15 mm.) in thickness are added to rear ends of the moving springs to increase their thickness within the mounting block and provide a stiffer tag anchorage for external connections, and these springs have bifurcated front ends to allow independent action of the twin contacts. Longitudinal ribs are stamped into the springs to minimize bowing and thus prevent excessive contact separation. Pretensioning is obtained by imparting a ' set ' in the short distance between the end of the rib and the point where the spring enters the mounting block.

The method of assembling the springset can be seen from the expanded view of the springset assembly (Figure 3). The mounting block consists of two separators, M. These are of plastic copolymer and mesh together with the springs clamped between them, the cut-out near the tag-end of the springs biting into ribs in the separator moulding. The end





A Armature
B Hinge recesses in coil former
C Armature back-stop
D Cut-out in coil former
E Spring clip
F Complete springset assembly
G Rectangular cut-outs in bracket
H Bracket locating slot
J Screw
K Nut
L Coil former projection

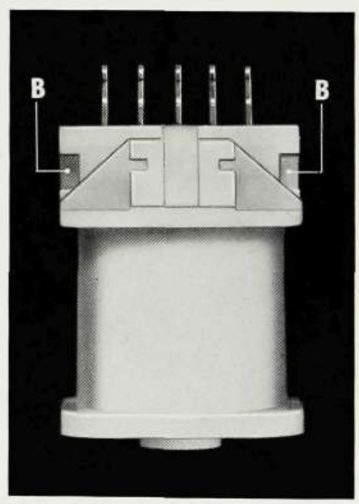


Figure 1—Exploded view of relay and two views of coil former

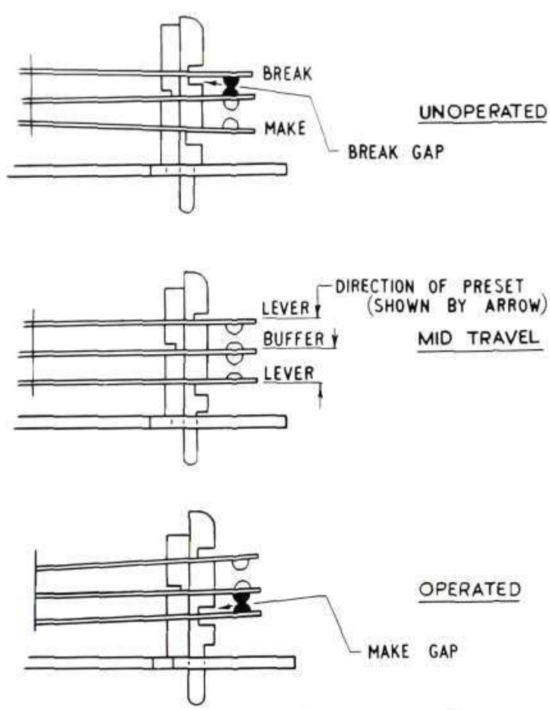
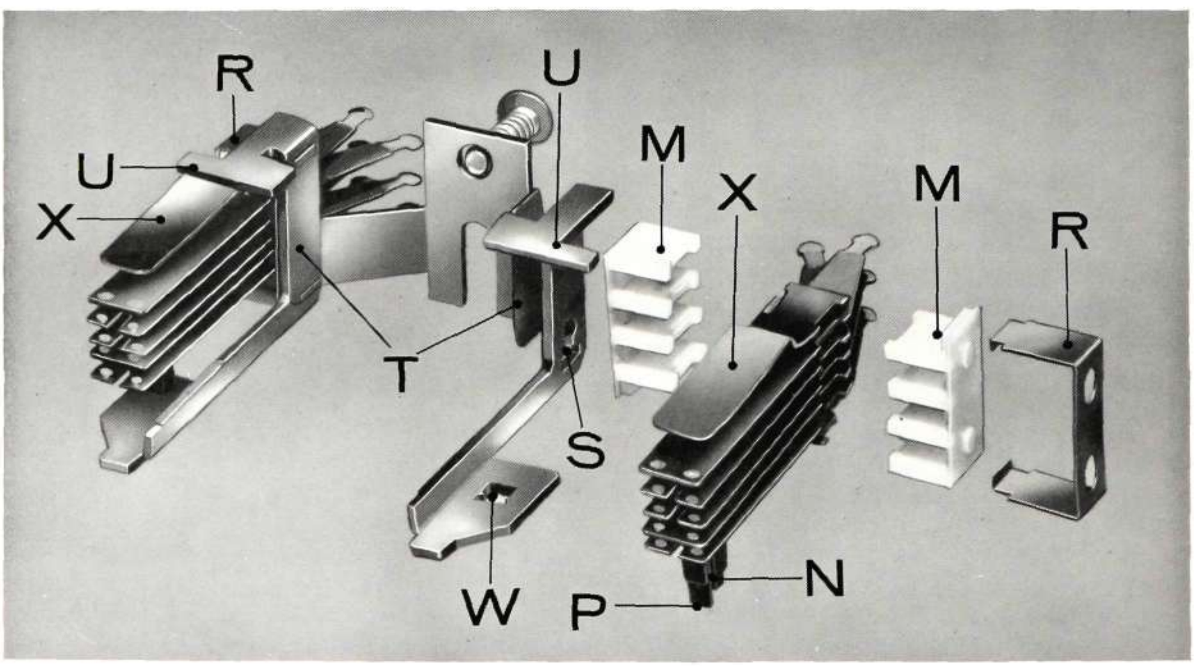


Figure 2—Springset changeover action

(upper) spring of the assembly is the armature return spring X and is of phosphor-bronze, nickel-silver plated. The two-piece design of the mounting block avoids the tolerance build-up usual with a stack of separate insulators, and the absence of metal inserts reduces the risk of electrical breakdown between the springs.

The springset buffer N and comb P are of different types of plastic to reduce friction in the sliding action required between them. The buffer faces to the rear and has a V-shaped groove down its front vertical face, accommodating a male V profile on the back of the comb. These mouldings are fed into the springsets and meshed up with the appropriate springs. The complete springset is fastened to the mounting bracket by a spring securing clip, or strap R. The claw-ends of the strap pass through slots S in the side of the mounting bracket. Two pegs on the bracket-side of the springset separator block engage in holes running into these slots, and two corresponding pegs on the other side of the separator block engage with similar holes in the strap. Thus the springset is accurately located with respect to the bracket. The strap is secured by a spring-plate T inserted between the claw-ends of the strap on the inner face of the bracket. A square cut-out, W, in the springset bracket serves to anchor the springset buffer by engaging this with its rear edge. The comb passes freely through the forward part of the cut-out.

The horizontal tabs U over the springset mounting faces of the bracket bear on the armature return



M	**Springset separators**	**R**	**Springset clips**	**U**	**Return spring adjusting tabs**
N	**Springset buffer**	**S**	**Slots in mounting bracket**	**W**	**Square cut-out**
P	**Springset comb**	**T**	**Securing plates**	**X**	**Armature return springs**

Figure 3—Expanded view of springset assembly

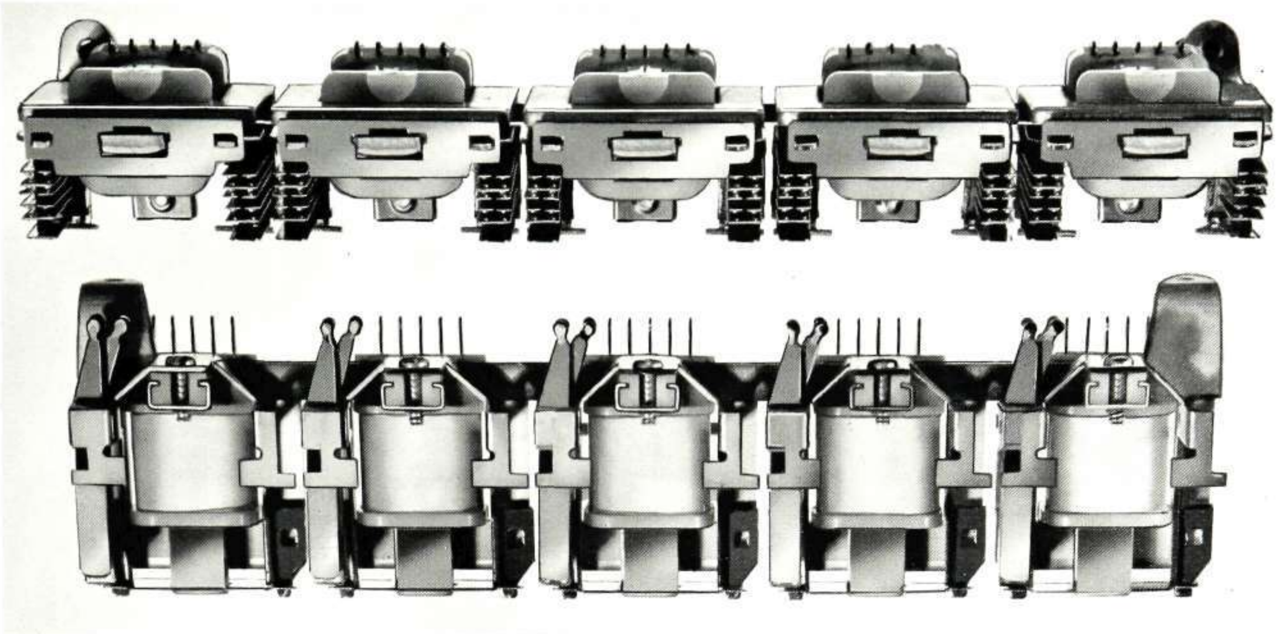


Figure 4—Two views of a complete strip of relays

springs and are bent, after the relay has been assembled, to give the required tension.

The Coil

Modern fast automatic moulding processes using thermo-plastics to produce a two-part coil former show considerable saving in cost over earlier processes using thermo-setting phenolics, and have been adopted in preparation of the coil former. Self-anchoring tags are introduced by impact, five being inserted at one pass of the machine.

The disadvantage with most thermo-plastics, of local softening during soldering operations when tags are inserted into the material, has been avoided by using a glass-filled nylon for the lower half of the former, carrying the tags. A normal copolymer is used for the upper half. The double-ended tags used are isthmused to reduce heat transfer during soldering.

Direct coil termination in conjunction with fast winding techniques reduces assembly time, and a variety of single and non-inductive windings can be accommodated. The winding and the coil designation label are covered by thermo-plastic tape.

Control of Armature residual

A three stage residual is obtained by the use of a pressure sensitive adhesive tape cured by a heat process. Layers of this tape, ·0025″ in thickness, are applied to the datum and back-stop faces of the armature bridge-piece to a constant total of three, thus giving a variable residual but a constant armature travel. The datum face is radiused on the right-hand side to identify the layers that fix the residual. Their number can be assessed visually or by touch.

General

The assembly of five relays weighs approximately 14 oz. (395 grm.) and has overall dimensions of approximately $7\frac{3}{4}''$ x $2\frac{1}{8}''$ x $1\frac{1}{8}''$ (20 cm. x 5·4 cm. x 2·9 cm.). Two views of the assembly are given in Figure 4. Spring-banks are available with any combination of make, break or changeover actions within a maximum of 6 springs in either bank. A range of coil resistances may be obtained to cater for different springset loads, and standard safety factors apply to the operate current figures in all cases. The permissible dissipation of the coil is 4 watts maximum, and the contacts are rated at 250V a.c. 300 mA or 250V d.c. 100 mA. Life tests have shown that the design objective of 100,000 operations is reached without effort.

Conclusion

The design of the relay represents a technical advance on the 600 type within the intended application, the more noteworthy by reason of the stringent limitations of cost imposed in its original specification and realized in production. It is expected that other applications will suggest themselves and follow in due course.

U.K. Patents 923,804. 923,805.
Aust. Approval 12174/61. 12175/61.

New Zealand Approval 130891/61. 130892/61.
Sth. Africa Approval 2701/61. 2702/61.

U.D.C.621.383:628.971

THE SOLAR SWITCH

E. W. SUMMERS, Grad.I.E.E.—Relay Development Section, Engineering Department

The article describes a low-cost photoelectric device suitable for lamp switching on roads where all-night illumination is employed. Use of the recently developed calcium sulphide photocell results in a rugged and simple device, and extensive field tests on an important section of carriageway point to its eminent suitability for general use.

THE most widely used device to control street lighting is the time switch; an electrically driven clock mechanism which is installed at each lighting standard and arranged to switch on or off at predetermined times, automatic correction being made for the daily variation in the time of sunrise and sunset. This means of control is not without disadvantages. In certain weather conditions, particularly in winter in this country, the natural illumination before recognized lighting-up time, often falls far enough below a safe level to warrant emergency lighting but this cannot be provided. Further, any power failure other than of brief duration means that the clocks must be reset manually and, if a wide area is involved, this can be a protracted and possibly expensive process.

One way of overcoming these difficulties is by the use of 'ripple control' systems, employing audio frequencies superimposed on the power supply to operate tuned relays to control the lights. Such systems, though reliable in operation, are initially expensive.

Photoelectric controllers[1&2] have received some attention in recent years, for they form a convenient means of relating switch-on and switch-off to the prevailing natural illumination rather than a predetermined time. Their use has been limited, however, since the relative insensitivity of the photoemissive or photovoltaic light-sensitive cells so far available makes amplification necessary in order to work a switching relay, and the equipment has thus been both complex and costly.

The mileage of roads needing all-night illumination and hence suitable for this form of lighting control is continually increasing as urbanization spreads and traffic becomes heavier, and there is thus a genuine need for a photoelectric controller, simpler in design and of reasonable cost.

THE SOLAR SWITCH

The Company's Solar Switch is intended to fulfil these requirements. It utilizes the recently developed cadmium sulphide cell, a robust device whose sensitivity and relatively high power dissipation makes possible the direct operation of a relay without amplification. The electrical resistance of the cell is dependent on incident illumination and, by suitable design, the relay is made to operate and release at natural illumination levels convenient for the control of road lighting.

The Solar Switch illustrated in Figure 1 consists of two separate items: a cadmium sulphide photocell and a special heavy-duty relay. The photocell is enclosed in a weatherproof housing and mounted at the top of the street lighting column, usually on top of the lantern to avoid interaction between the lamp and photocell. The relay unit, shown with the cover removed in Figure 2, contains the relay and a small bridge rectifier which provides a low current 220-volt d.c. supply for the relay and photocell. This unit is installed in the gear compartment at the base of the column, connection to the photocell, lamp and mains supply being made via the 6-way terminal strip forming an integral part of the moulded relay-housing.

The resistance of the cadmium sulphide photocell decreases as the incident illumination increases. In strong daylight the cell resistance is only a few hundred ohms whilst in darkness its resistance is of the order of 1 megohm. When the cell is connected in series with a relay and the combination fed from a d.c. supply as shown in the circuit diagram (Figure 3), the current flowing through the relay coil is dependent upon the illumination of the photocell.

During the hours of darkness the relay is not operated and the mains supply is connected to the lamp via the normally closed relay contact. At dawn,

[1]Photoelectric Street-lighting Control, C. E. Marshall, *Electronics*, September, 1946

[2]Photoelectric Controls for street lights, E. K. Howell, *Electronic Engineering*, October, 1961

Figure 1—The relay and photocell units which together form the Solar Switch

the photocell resistance decreases slowly, causing the relay to begin to operate. If an ordinary relay were used, the contact pressure would decrease gradually and chatter would occur to cause not only faulty operation of the lamp but the burning of the contacts, thus seriously curtailing the life of the relay. The relay used, however, has a special toggle action so that, during the gradual operation of the relay, contact pressure is maintained until the toggle action takes over to make the contacts fly apart and switch off the lamp. During daylight the relay remains operated, and at dusk the photocell resistance increases and the process which occurred at dawn is reversed, the toggle action again ensuring that the contacts close firmly to switch on the street lamp.

The Solar Switch has been designed to switch-on at an illumination between 1·5 foot-candles and 0·5 foot-candles and to switch off at an illumination not greater than 4 foot-candles. These illumination levels are fixed in production, and the design permits any photocell to work with any relay without attention to tolerance departures.

The Relay

The relay was designed to satisfy the following main requirements.

(*a*) To be suitable for use in the marginal conditions previously described.

(*b*) To switch load currents up to about 10A at 250V a.c.

(*c*) To have a closer operate/release differential than the normal relay.

(*d*) Cost to be kept to a minimum.

The construction of the relay is shown in Figure 4. The toggle arm T, which carries a large-diameter domed contact is pivoted at the points P on the fixed bracket by two stainless steel pins and its movement

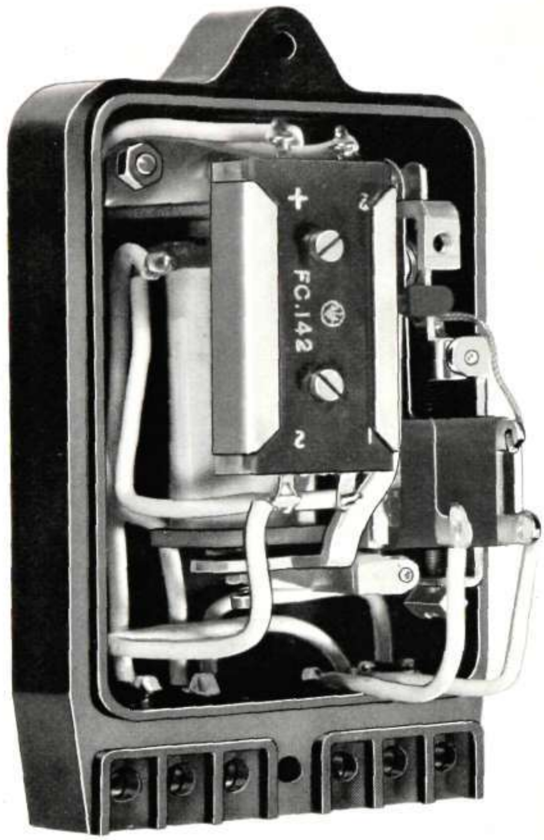


Figure 2—A view of the relay unit with the cover removed

is controlled by the helical spring S. When the relay is not energized the contact spring C carrying the flat contact is tensioned against the lifting bar B, and the two contacts are held together under pressure by the action of the helical spring. If the relay is operated slowly, the armature movement is transmitted via the contact spring and the closed contacts to the toggle arm which is moved in an arc about the pivot point. When the plane of the toggle arm is parallel to the axis of the helical spring, the direction of the force on the toggle arm is reversed and a further small movement of the armature causes the contacts to break abruptly, the motion of the toggle arm being limited by a stop L forming part of the fixed pivot bracket.

As the relay releases, the contact spring C is lowered by the armature and this motion is transmitted to the toggle arm by the shoulder of the 'tufnol' retracting stud R attached to the tip of the contact spring and passing through the forked end of the toggle arm. This results in the toggle arm being pulled down towards the contact spring and, after the dead centre position is passed, the toggle action occurs, closing the two contacts.

This relay has completed over 18,000 operations without failure in life tests, switching a current of 7·5 amps at 250 volts, equivalent to about 50 years use in its street lighting application. The relay is adjusted to operate between 5 and 6 mA and to release between 3 and 4 mA.

The Photocell Unit

The cadmium sulphide photocell is manufactured in the Physics Division of the Company to a production tolerance which permits variations in photocell current from 2 mA to 8 mA when measured with a polarising voltage of 50 volts d.c. and an illumination of 1 foot-candle. To obtain the illumination switching limits required when the cell is used in conjunction with the relay in the circuit arrangement of Figure 3, the maximum acceptable variation of cell current is from 1 mA to 2 mA when measured under the conditions stated above. It is not an economic proposition to manufacture the photocell to such a close tolerance and so a method of adjustment has been devised which entails regulating the amount of light falling on the photocell by use of a limiting screen.

The limiting screen consists of a translucent disc, silk screened on one side with an opaque ink to blank off a portion of the surface area, leaving a pattern of clear circular patches. A range of six different screens is required to obtain the necessary compression

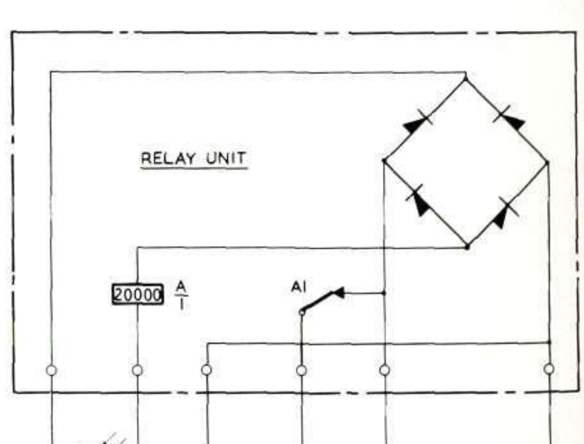


Figure 3—Circuit arrangement of the Solar Switch

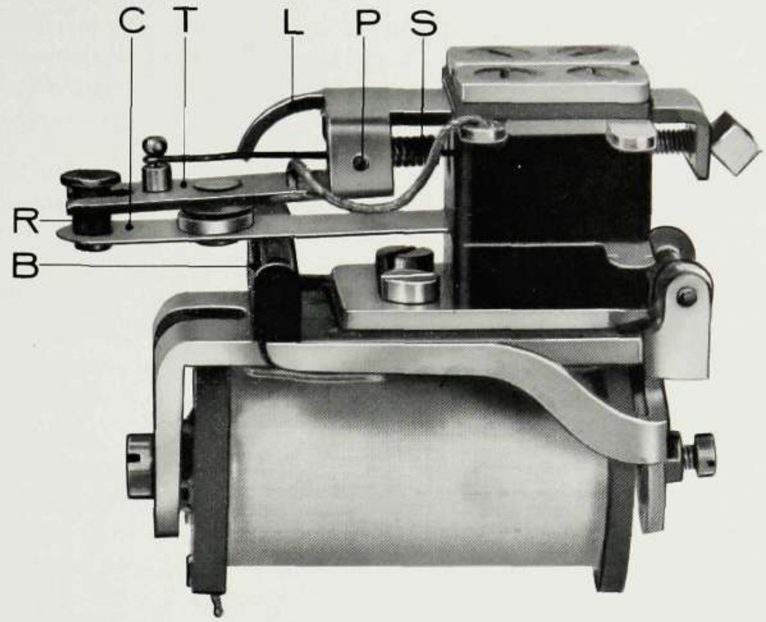


Figure 4—The 'snap-action' relay

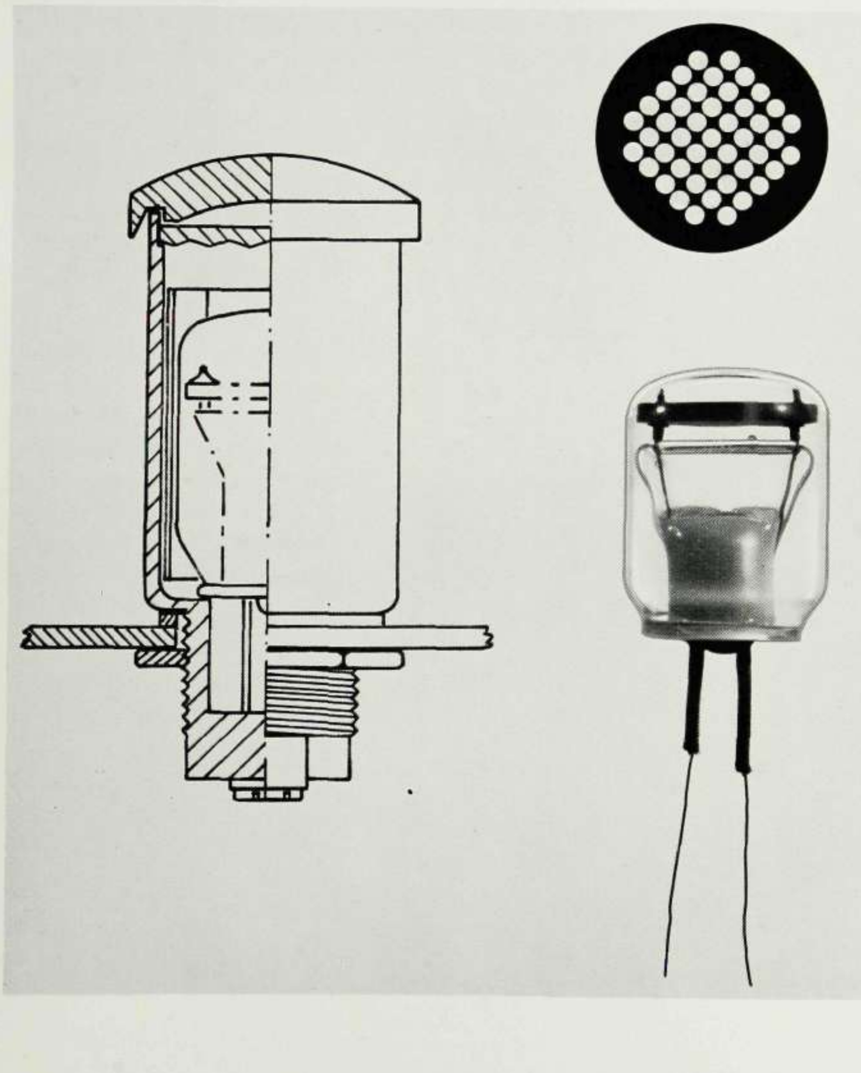


Figure 5—A half-section of the photocell unit showing the method of mounting on the lantern. The unit is seated on a neoprene washer to prevent entry of water into the lantern. Also shown are the photocell and a typical limiting screen

of the cell characteristics, each grade of screen in the range having the same number of clear patches but of different diameters. The non-printed side of the disc is dimpled to diffuse the light after passing through the limiting screen to ensure uniform illumination of the photocell.

The photocell and its associated screen are contained in a tubular plastic housing, threaded at the terminal end to facilitate fixing to the lantern, and the assembly is sealed by cementing a transparent domed cap over the open end. The photocell and a typical limiting screen are shown in Figure 5 with a cross-section of the photocell unit.

Field Trials

During the past 18 months, an extensive field trial has been in progress involving some 90 units on a $1\frac{1}{2}$ mile dual carriageway section of the A52 Nottingham to Derby trunk road and has been under observation by the Divisional Road Engineer of the Ministry of Transport. This trial has been an unqualified success and has proved the reliability of the device under a wide range of weather conditions.

A definite point emerging from the trials has been that, due to the domed shape of the photocell cover and the washing action of the rain, dirt and other deposits do not accumulate sufficiently to interfere with correct operation, and no cleaning is required other than as part of the periodic routine maintenance.

Conclusion

Although the Solar Switch is of quite recent development, considerable interest has already been shown by local authorities and by other bodies connected with various aspects of road illumination. Its simplicity, low cost and outstanding advantages in the control of all-night lighting recommend it for adoption on a wide scale.

U.K. Patents 903,918. 924,492.

U.D.C.621.395.23

NEW 3 + 12 AND 4 + 18 LAMP SIGNALLING CORDLESS PMBX SWITCHBOARDS

I. R. Gale and G. R. Gunson—Circuit Development Engineering Department

The two cordless desk-top switchboards described complete a new range of cordless, B.P.O.-approved private manual branch exchange switchboards developed by the Company for use in subscribers' premises. Attractive appearance, compact size and improved facilities including lamp signalling and power unit operation are some of the features of the new switchboards which have capacities for three exchange lines and twelve extensions (3 + 12) and four exchange lines and eighteen extensions (4 + 18).

In an earlier article[1] a new type of BPO-approved cordless private manual branch exchange was described. This PMBX, equipped for a maximum of two exchange lines and six extensions (2 + 6) was the first of a new range designed to meet the various capacity and service requirements of small and medium sized business organizations. To complete the range, two further cordless PMBX's of 3 + 12 and 4 + 18 capacities have been developed in conjunction with the BPO. Their design has been based on similar objectives as determined for the 2 + 6 in order to reproduce the desirable features of convenient size, attractive appearance, better service for extension users and easier operation for the switchboard attendant.

Increased facilities are offered by the larger switchboards but, despite this, economy of equipment has been maintained through the continued use of the 4-wire principle in the circuit arrangements. This principle[2] requires one wire and an earth at each extension telephone in addition to the two wires provided for speech.

Although the switchboards are essentially for use with 4-wire extensions, provision is made for the inclusion of a limited number of 2-wire extensions, inter-switchboard extensions or private circuits.

Facilities

The main features of the two larger switchboards are as follows:—

(*a*) Lamp signalling for exchange and extension calls.

(*b*) Automatic ' hold ' of exchange calls.

(*c*) Follow-on-exchange call trap.

(*d*) Separate supervisory signals on extension-to-extension calls.

(*e*) ' Operator recall ' on extension and exchange calls.

(*f*) Operator's headset in addition to operator's telephone, when required.

(*g*) Night Service.

(*h*) Mains-failure safeguards.

(*i*) 5 connecting links on the 3 + 12 switchboard and 7 on the 4 + 18.

Figure 1—The 3 + 12 Line Switchboard

[1] & [2] *Bulletin* No. 43, pp. 57-62

(*j*) Connection of 2-wire circuits by simple rearrangement of cords and straps in the switchboard.

(*k*) A maximum line resistance of 500 ohms for extension circuits and 935 ohms for extension-to-exchange connections.

(*l*) Subscriber Trunk Dialling trip meters when required.

(*m*) Free connecting link lamp signals. (4 + 18 switchboard only.)

(*n*) ' Overcall ' circuit to allow the operator to answer exchange and extension calls when all connecting links are engaged. (4 + 18 switchboard only.)

EQUIPMENT

By use of similar constructional elements a standard shape has been made possible for all the PMBX's in the range, and dimensional and weight characteristics have been contained within suitable limits. The 3 + 12 PMBX illustrated in Figure 1 has overall dimensions 17" wide, 8" high and 13" deep (43 x 20 x 33 cm) and weighs 33 lb. (15 kg), while the larger 4 + 18 switchboard shown in Figure 2 is 22" x 9" x 15" (60 x 23 x 38 cm) and weighs 56 lb. (26 kg). Both switchboards are normally provided in two-tone grey with matching operator's telephone.

The light french-grey covers of each switchboard are fabricated in one piece by injection moulding and composed of a durable co-polymer plastic. Each cover drops easily into position and is firmly retained by its leading edge beneath the front of the face panel and by two screws at the rear of the baseplate.

The face-panel, mounting the keys, lamp jacks and designation labels, is finished in hard wearing elephant-grey plastic with an attractive leather grain pattern overall. Legends are in white and clearly impressed upon the plastic by a hot-stamping process.

The keys are of the now well-established miniature type,[3] and the colours of the wedge-shaped handles have been chosen to permit ready identification of the keys associated with a particular circuit. They are light ivory for the exchange-line and operator's keys, and alternately light ivory with black inserts and french grey with black inserts on the extension positions. Above these the extension and exchange line lamps are mounted behind a diakon lens strip, the arrangement being such as to permit quick lamp replacement, no lamp extractor or removal of the switchboard cover being necessary. The lamp-cover strip is simply withdrawn to reveal the lamp-jack screws which on release allow the lamp jack to be moved forward and the lamps withdrawn by hand.

When the cover of the switchboard is removed, a 3-section metal chassis is exposed. The face-panel and the relay plate which are respectively hinged to the front and rear of the baseplate can be opened in book fashion to afford a high degree of accessibility as shown in Figure 3. The relays, consisting of 3000 and 600 types are mounted on the rear plate under a clear plastic dust cover. Transmission relays are provided with non-removable relay shields to minimize crosstalk between circuits.

Some static components are mounted on the base together with the connection blocks. One type of connection block has soldered connections, while the other type is equipped with screw terminals and is used for the connection of the operator's telephone and line circuits. Screw terminals are also provided to permit re-arrangement of the straps and cords when 2-wire extensions, private circuits or inter-switchboard extensions are required. Extension circuits 7 to 12 on the 3 + 12 PMBX, and 10 to 18 on the 4 + 18 PMBX can be used for 2-wire circuits.

The switchboards are provided with multi-way cords, the free end being terminated on small connectors that plug into wall-mounted jack assemblies. The 3 + 12 is equipped with a 68-way cord and the 4 + 18 with a 100-way cord.

On the 4 + 18 switchboard there are 88 keys to scan before selecting a free connecting link. For this reason this switchboard accommodates a free-link signalling system which permits easy selection of a free connecting link and therefore increases speed of answering calls. The free-link signals are given by amber-coloured lamps arranged vertically on the left-hand side of the face panel. Two lamps are provided for each row of keys, one for the upward movement and one for the downward movement.

For installations where Subscriber Trunk Dialling (S.T.D.) is operative, space is provided on the face-panel for private trip meters, when required. These are used on S.T.D. calls and located in line with the appropriate exchange-line keys. Meters can be provided individually for each exchange line or one common meter can be employed to serve all exchange lines.

A further optional extra is the operator's headset. When this is required the standard Etelphone used for the operator's telephone is replaced by a Plan-Etelphone, and a headset jack is provided below the

[3]See *Bulletin* No. 35, p. 38

Figure 2—The 4 + 18 Line Switchboard

face-panel in the lower left-hand corner of the baseplate. Changeover from the handset is arranged by auxiliary cradle springsets in the Plan-Etelphone so that when the handset is on its rest the headset is operative. Conversely, when the handset is lifted, the transmission path is automatically transferred to the handset.

OPERATIONAL FEATURES

Automatic Holding of Exchange Calls

When an exchange call is answered, an exchange holding loop is prepared, to be made effective when the attendant restores the 'Operator Speak' key. When this occurs a 'Call Held' lamp, common to all connecting circuits, glows as a visual reminder to the operator that supervision of the switchboard is still required. If the line is subsequently switched to an extension, the holding circuit is released and the 'Call Held' lamp extinguished when the extension answers the call.

If the operator wishes to release an exchange call without connecting it to an extension, the holding circuit is released when the exchange key is restored.

Exchange Call Trap

At the conclusion of an exchange—extension call, the clearing signal is given by the extension calling lamp as the extension telephone handset is replaced. This action operates a call trap relay to reconnect the exchange-line signalling relay across the exchange line and disconnect the exchange line from the connecting circuit. Thus a follow-on incoming call is trapped on the signalling relay and operation of the extension telephone bell prevented should the call not be immediately cleared down at the switchboard.

Free-link signalling

All lamps are extinguished in the idle condition. When an incoming call arrives, the first lamp glows and the operator answers the call using the associated connecting link. The free-link signal now steps to the second lamp to indicate that connecting link 2 should be used for the next call.

The sequence is always the same, but if any link should be taken out of turn the remaining lamps still glow in the same order, excluding the circuit taken out of sequence if it is still in use. When a circuit becomes disengaged, the free-link lamp glows again if it is the first free link in the sequence. When all seven connecting links are engaged the eighth lamp (the 'overcall' lamp) glows to indicate that all connecting circuits are engaged and any following call must be answered by means of the overcall facility.

Overcall

Overcall enables the operator to answer a call when all 7 connecting circuits are engaged.

To answer an extension call under these conditions, the ' Speak On Overcall ' key is operated to disconnect the ringing supply and extend the operator's telephone to the extension ' Ring ' key. The operator can now speak to the calling extension by holding operated the appropriate ' Ring ' key. The ' Speak On Overcall ' key must be restored before a normal call is answered.

An exchange call is answered by operating the ' Speak On Overcall ' key and the appropriate ' Exchange Overcall ' key. The operation of these keys extends the exchange line to the operator's telephone and also applies an exchange holding loop to permit the operator to leave the circuit if necessary. The operator may wish to leave the connection to offer the call to an engaged extension and then, if required, break down the connection and extend the exchange call to the extension. When the call has been dealt with, the ' Exchange Overcall ' key and the ' Speak On Overcall ' key are restored.

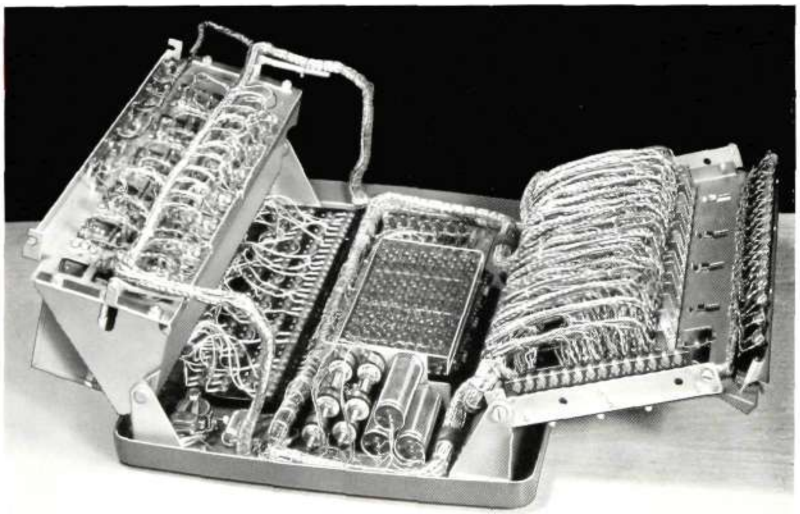


Figure 3—Switchboard with hinged mountings lowered

Press Button Recall

Each extension telephone is provided with a press button key for recall purposes. Recall is available on all extension and exchange calls.

Night Service

Night service arrangements are provided by the Night Service key. The key disconnects the extension calling lamps and renders the exchange line call-trap circuits ineffective. Selected extensions can then be connected to the exchange lines by operating the appropriate ' Exchange ' and ' Extension ' keys.

Mains Failure

As the switchboards have been designed to operate from a mains operated power unit the circuits have been arranged so that exchange line service is maintained under mains failure conditions. The operator can answer or originate a call under mains failure conditions in the normal manner.

The exchange lines can be connected to selected extensions if mains failure should occur and the selected extensions will then have direct exchange line access.

Electrical Design Characteristics

For simplicity of design a parallel-feed transmission bridge is employed for extension-to-extension traffic. The output of the bridge is capacitance coupled to line to give satisfactory side-tone balance, and crosstalk attenuation between circuits is increased to at least 75 db by screening shields on all transmission-bridge relays.

Improved lamp signalling and elimination of line signalling relays have been obtained by use of a newly developed switchboard lamp. This maintains a reasonably uniform level of illumination throughout the prescribed loop resistance for extension lines (see Line Limits).

No hand generator is fitted in the new switchboards. Ringing can be provided by a 25-cycle transistor generator unit which may be included in the switchboard itself or be suitably arranged for wall mounting according to requirements. Alternatively, use can be made of a suitable ringing source if this exists on site.

The circuits of both switchboards are designed to operate from a nominal 50V d.c. supply and within the wide voltage range of 45 to 55 volts. Power is normally derived from a mains-operated power unit the size of which depends on the type of switchboard and the amount of auxiliary apparatus used. To meet all requirements, power units having outputs of 1, 2 and 4A are available.

Line Limits

Satisfactory operation is ensured on extension lines having a maximum loop resistance of 500 ohms. The exchange-to-extension transmission and signalling limit is 935 ohms but where 2-wire conversion units are required this limit is reduced to 850 ohms.

U.D.C.621.394.34

A NEW ELECTRONIC SIGNAL GENERATOR FOR TELEX EXCHANGES

D. BARNETT, A.M.Inst.E. and G. H. BIRD, Grad.I.E.E., Grad.Brit.I.R.E.—
Circuit Laboratory Engineering Department

This article describes a transistor signal generator designed to provide service signals, with associated phasing and miscellaneous timing pulses, for use in the automatic Telex service.

IN the automatic Telex service a series of service signals, analagous to the various tones in an automatic telephone system, is needed to inform the teleprinter subscriber of progress in setting up a connection. These signals are generated by central equipment in the Telex exchange and distributed as necessary to subscribers, who receive them as printed characters on their machines. The following service signals are commonly used:—

Signal	*Significance*
WRU	Who are you?
NC	Route engaged
NP	Route not available
ABS	Called station closed
OCC	Line engaged
DER	Line out of service (plugged up)
MOM	Wait (from manual positions)

THE TELEGRAPH CODE

In the Telex system each printed character, together with the various auxiliaries necessary to produce such functions as ' carriage return ', ' line feed ' and ' letter shift ', is associated with a coded signal consisting of a unique assembly of five signal elements of equal duration. These signal elements may individually be either ' mark ' or ' space ' and the two conditions are defined in the system by voltages of opposing sign, or by the presence or absence of a signalling parameter. The system is standardized on a transmission speed of 50 signal elements per second, or 50 bauds. With every group of five elements there is associated an initial ' start ' element and a final ' stop ' element. These are invariably space and mark respectively. The start element has a duration equal to one signal element, i.e. 20 ms, but the stop element, to allow for differences of machine speed, is prolonged to 30 ms. The complete train of elements thus consists of $7\frac{1}{2}$ signal elements with a duration of 150 ms. For convenience it is referred to as the $7\frac{1}{2}$-unit code but it should be borne in mind that the actual intelligence is conveyed by the 5-unit code within it. The structure and timing of the code is shown in Figure 1.

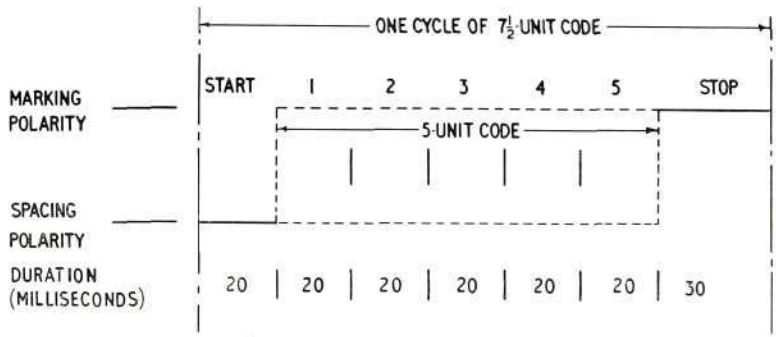


Figure 1—Structure and timing of $7\frac{1}{2}$-unit code

ELECTROMECHANICAL GENERATORS

A motor-driven machine employing cam-operated springsets and commutator switching is commonly used for generating service signals. In addition to these, it provides a number of miscellaneous pulses for use within the exchange for test and signal selection purposes, and for setting up delay periods. Further special signals can be provided for where these are needed in a specific exchange.

THE ELECTRONIC GENERATOR

The aim in developing the electronic generator was to provide all the facilities of the electromechanical apparatus at comparable cost, to achieve a standard of signal accuracy at all times equal to any foreseeable demand on it, and to reduce maintenance to the minimum.

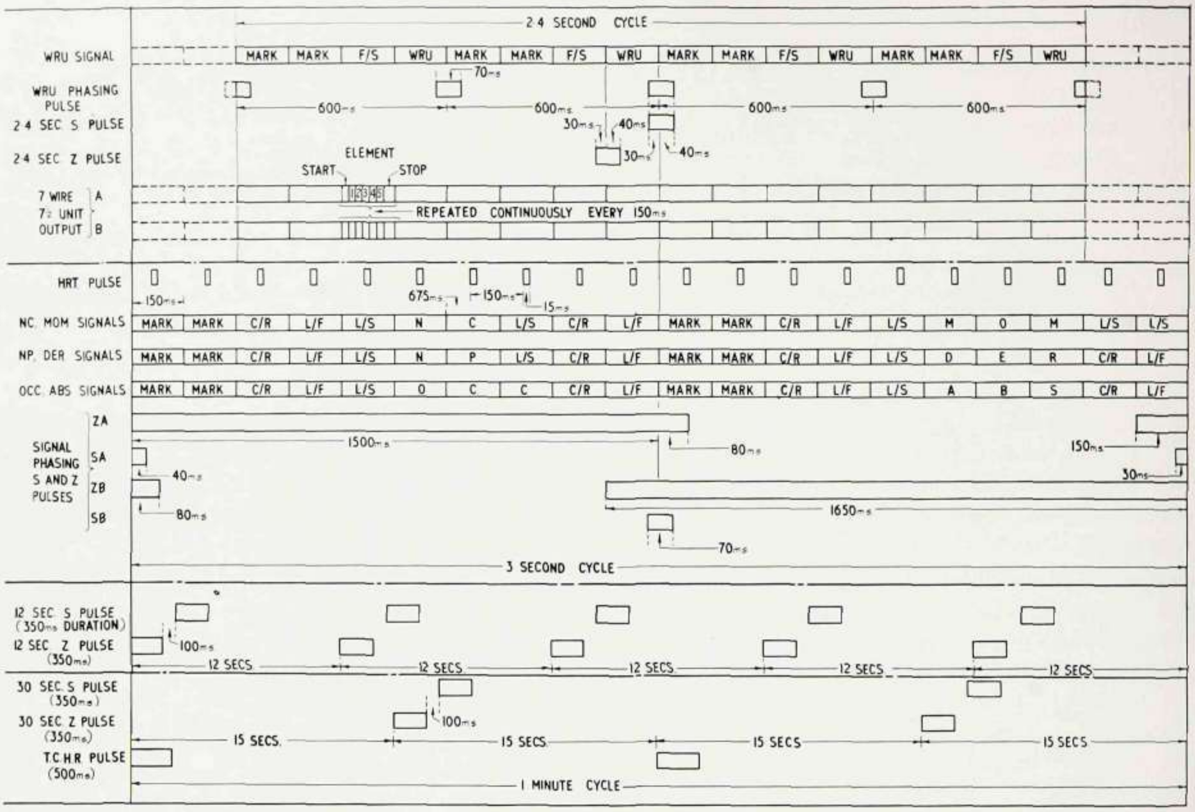


Figure 2—Timing chart showing complete range of signals and pulses generated by electronic generator

Unvarying accuracy is more readily attained if the time constants of operation of switching elements are small compared with the shortest time interval requiring to be signalled. This condition is ideally fulfilled by electronic switching elements and these have been employed for all the critical functions of the equipment. Semiconductors were chosen because of their small size, power economy and reliability, and for their excellent switching performance with relatively uncomplicated circuitry. The relatively infinitesimal time constants of circuit elements ensure that no measurable variation in the signal intervals due to change of component characteristics, other than outright failure, will occur during the life of the equipment.

Range of Signals and Pulses

The complete range of signals and pulses produced by the electronic generator is shown in the Timing Chart (Figure 2). There are four separate cycles, and two of these, the 2·4 and 3-second cycles, contain signal text. It will be seen that the trains include auxiliary characters such as C/R L/F and L/S, to position the teleprinter carriage correctly in order to receive the text.

In the 3-second cycle the signals are formed in pairs in a 20-character sequence. Each of the three pairs is taken from the generator and distributed round the exchange on a single lead, associated S and Z pulses enabling the required signal to be extracted by the exchange equipment.

Method of Signal Production

The production of the three character sequences in the 3-second cycle only is discussed; the other signals are formed by similar logic, or by extension of it.

The basic switching device is a 3-stage binary counter cycling every 150 ms, the time occupied by one telegraph character. The device has seven states and is driven from one to the next by 20 ms pulses derived from the exchange 50 c/s stabilized tuning-fork supply. There are two trains of pulses phased 10 ms (180°) apart and the seventh state is prolonged to 30 ms by suitably switching the incoming pulses. Thus the basic intervals of the $7\frac{1}{2}$-unit code are produced.

Seven outputs are derived from the counter. Each is associated with a separate element in the $7\frac{1}{2}$-unit code and for the duration of this element it

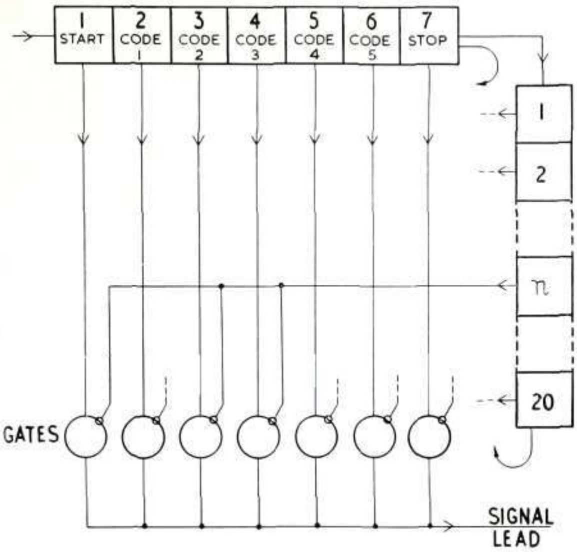


Figure 3—Simplified schematic showing logic used in formation of signals

can cause a mark condition to be delivered to the final output of the generator. At all other times it is ineffective. These conditions are produced by connecting each output lead via a group of diodes to suitable parts of the counter circuit. At any given state of the counter, only one group of diodes is biased in such a way as to permit the associated lead to be electrically active.

Whether an output does cause a mark to be delivered or not is determined by gating it under control of a 5-stage binary counter. This has twenty states, triggered in turn by pulses from the 3-stage counter and has a cycle period of 3 seconds, corresponding to 20 telegraph characters. Twenty outputs, each again effective only during the particular character interval associated with it, are derived from the counter. If during such a character interval a given output of the 3-stage counter is required to deliver a mark condition to the final output, connection between its gate and the appropriate 5-stage counter output is omitted; if on the other hand a spacing condition is required, connection is made. The reverse sense of this gating control, in that active connection to the 5-stage binary closes the gate, is chosen for convenience of design. By suitable choice of cross-connections a unique combination of marks and spaces in every interval of the 20-character sequence can be built up to form any desired sequence of characters.

The logic employed in signal formation is shown diagrammatically in Figure 3.

Since three different final outputs are required, each 3-stage counter output is commoned to three gates, separately routined by the 5-stage counter. Three groups of gates are thus formed. The combined outputs of each group are passed to three transistor final output stages.

Output stages are necessary with the equipment to provide the correct output polarity and voltage excursion. The exchange distributing equipment will, however, contain repeaters and there will be little current demand, hence low power transistors are used.

Equipment Features

A view of the generator is shown in Figure 4. The cabinet occupies small space, having overall

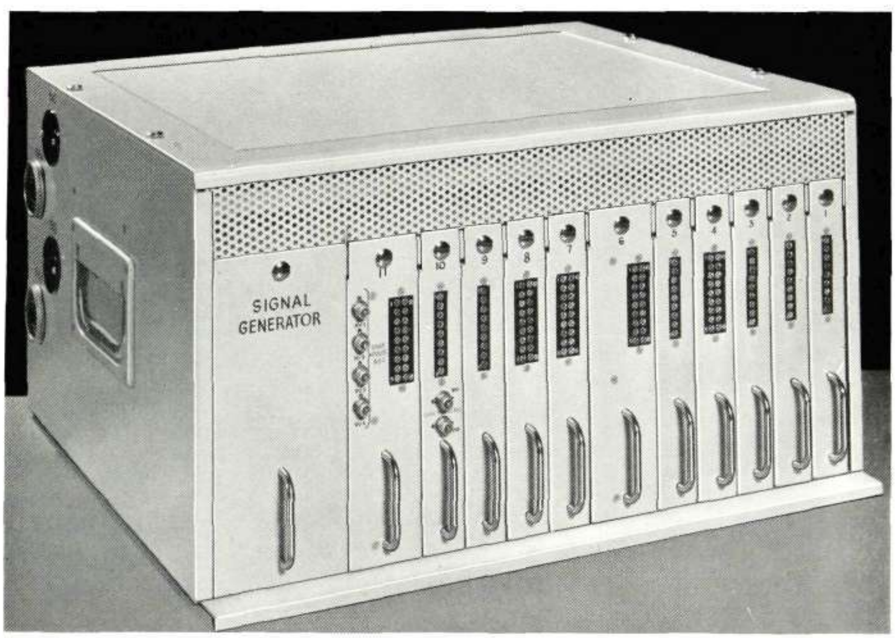


Figure 4—General view of electronic generator

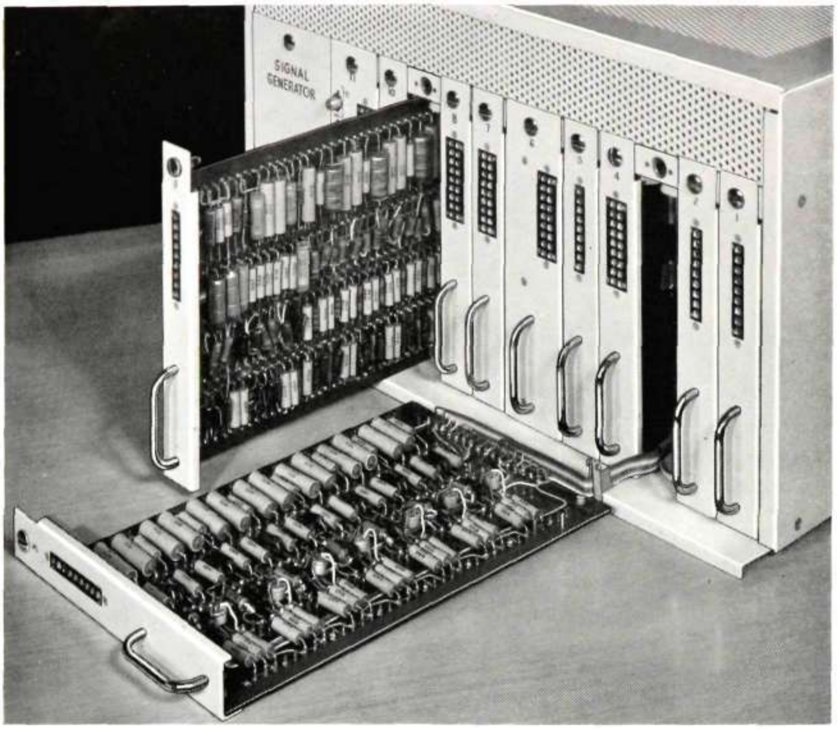


Figure 5—Easy withdrawal of units for servicing

dimensions 18½″ wide, 10″ high and 17″ deep (47 cm. x 25·5 cm. x 43 cm.).

A unit construction is employed, each unit having a front panel forming part of the face of the equipment. The units are permanently wired to a main tag panel by individual swan-neck ribbon cables. These normally stow at the rear of the cabinet but have sufficient length to permit units to be withdrawn separately for servicing, as shown in Figure 5. Plug-and-socket connections have been avoided throughout the equipment, except for the external outlets and supplies. Test points are located on the front panels of the units for waveform checking purposes. All resistors dissipating appreciable power are located on a horizontal plate above the units and immediately under the ventilated top cover of the cabinet.

The generator incorporates an alarm circuit; this closes upon failure of any of the d.c. supplies, the 50-cycle stabilized supply, or any part of the principal counter circuits.

POWER SUPPLIES

Supplies of —50 and +80 volts are required. These, together with a stabilized 50 c/s tuning-fork supply are normally available in a Telex exchange.

FIELD TRIAL

The generator prototype has been in almost continuous operation at the Fleet Telex exchange of the BPO since June, 1962. The only significant maintenance was occasioned by one faulty transistor, and this was quickly located and replaced. The trial has indicated that owing to the precision of the signals given by the generator, allowable tolerances on distortion by the exchange distribution equipment can be made less stringent. Thus a two-fold saving in maintenance staff occupation can reasonably be expected in exchanges where the generator replaces electromechanical apparatus.

U.K. Patent 933,992.
West Germany Approval E22,754
Sweden Approval 7102/62.