

# The Ericsson Bulletin

No. 15

JULY, 1939

## Contents

Ladbroke Telephone Exchange .. ..	Page 3
Packing for Export .. ..	Page 8
The Code Ringing Delay Unit .. ..	Page 12
Battery Mining Bell with Lamp Signal ..	Page 16
P.A.B.X. Equipment, Waverley Station, Edinburgh .. ..	Page 17
The Design of Pawl-and-Ratchet Selector Drives	Page 20

Published by



TELEPHONE WORKS,  
BEESTON, NOTTINGHAM

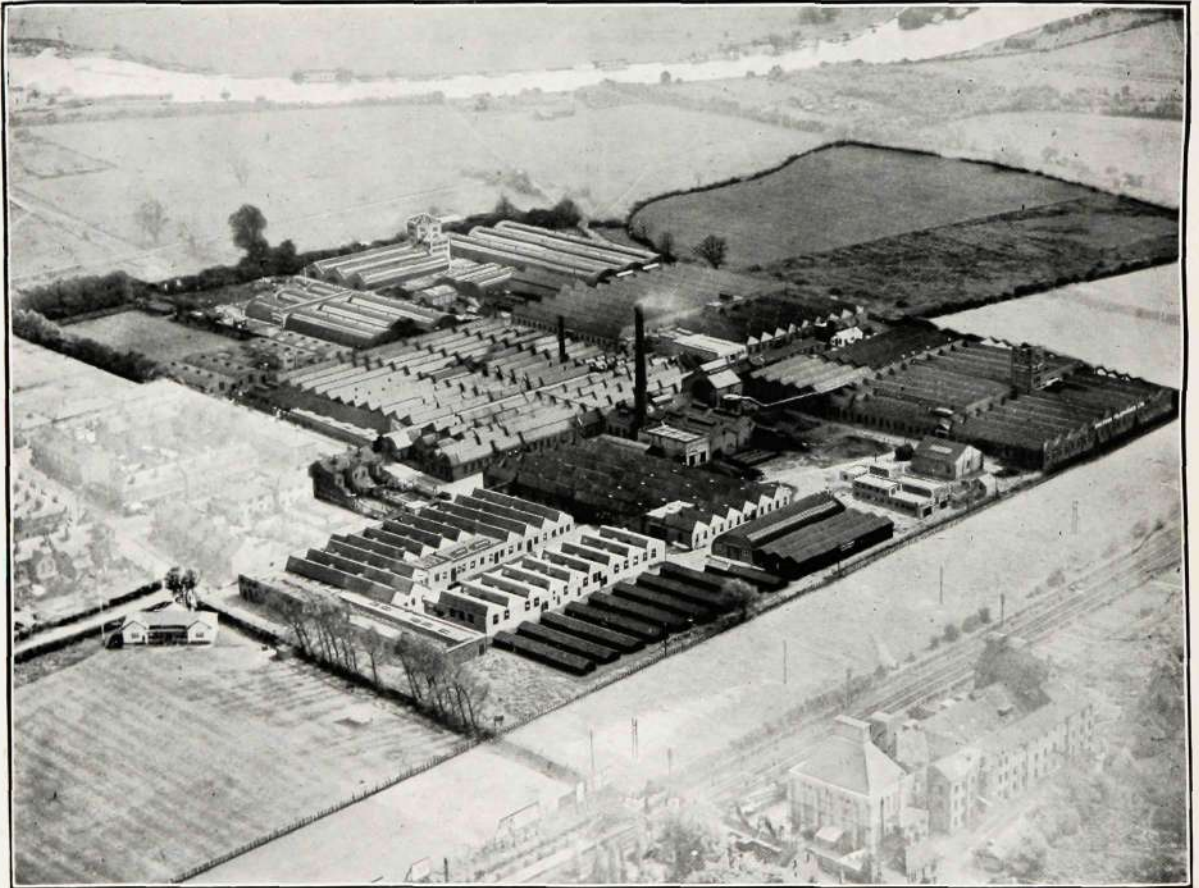
*Telephones : Beeston 54225 (3 Lines)*

Head Office :

22, LINCOLN'S INN FIELDS, LONDON, W.C. 2


*Telephones : Holborn 6936 (5 Lines)*

*Telegrams : Ericsson, Holb., London*



**Aerial View of The Ericsson Works, Beeston, Nottingham**

## Ladbroke Telephone Exchange


**ADBROKE** Telephone Exchange is the first exchange using Post Office "2000" type equipment to be installed by Ericsson Telephones Ltd., in the London Director Area. It is situated in Harrow Road, Kensal Green, and serves a mainly residential district.

Equipment for 3,300 lines and 15 auto-manual switchboard positions was supplied for the opening date, and a further 1,000 lines are to be added in the near future; the ultimate capacity of the exchange being 5,000 lines.

The most outstanding features incorporated in this work constitute the introduction of the "2000" type switch mechanism, the new channel shelf and the power distribution scheme. The British Post Office have taken advantage of the change-over from the original Strowger to the "2000" type switch to ensure that all equipment will, for the future, be inter-changeable, and the Post Office engineers have issued standard specifications and drawings for this purpose.

The "2000" type mechanism has mainly the advantages of reduced overall dimensions and weight, the selector frame being die cast of 90% aluminium. Another important point is the abolition of a separate release magnet, the release of the switch being accomplished by rotating the wipers to the 12th step. The wiper shaft then restores vertically and rotates in a reverse direction under the tension of a spiral spring. The new design also allows greater ease of adjustments, as these can be made without removing the selector from the shelf. Some idea of the relative sizes of the switches can

be obtained from Fig. 1, and the following table gives the various rack capacities for the two types of equipment.

TYPE OF RACK.	"2000" Type.	"Pre-2000" Type.
PRIMARY FINDERS .. .. .	60	50
1ST CODE SELECTORS .. .. .	40	30
2ND CODE AND NUMERICAL SELECTORS (200 OUTLET) .. .. .	80	60
"A" DIGIT SELECTORS .. .. .	80	60
DIRECTORS .. .. .	20	10
FINAL SELECTORS, ORD. AND 2/10 P.B.X. .. .. .	60	50
FINAL SELECTORS, 11/20 AND OVER 20 P.B.X. .. .. .	50	50

The concentration of the equipment involved new cabling and wiring problems, and how successfully they were overcome may be seen from Fig. 2 which shows a

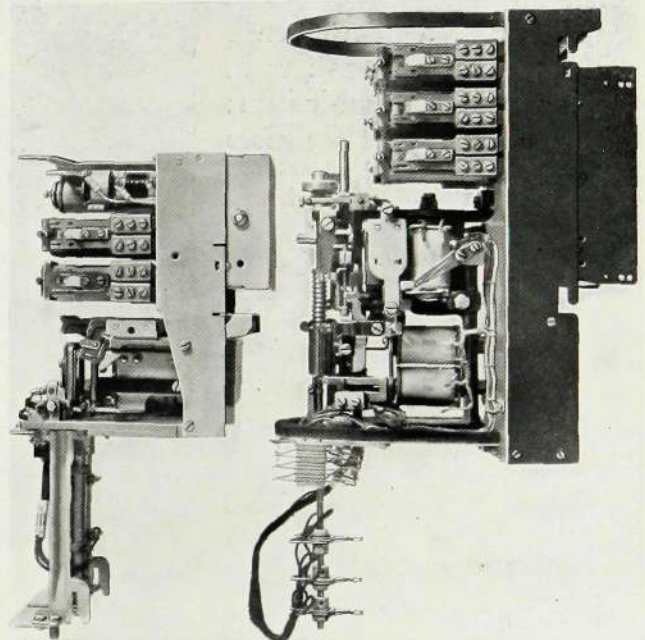
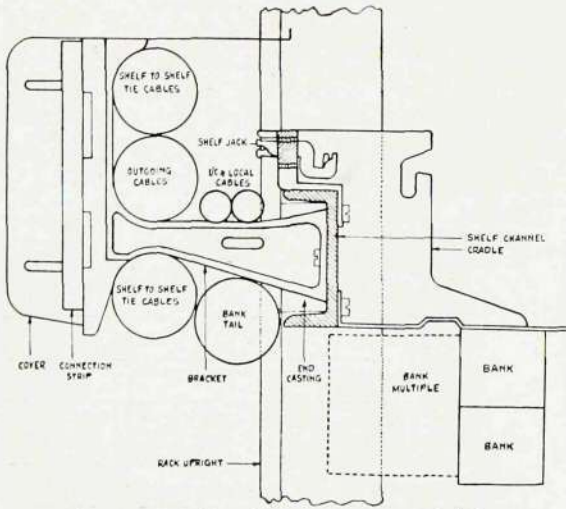


Fig. 1—Comparison in size of New and Old Switches



**Fig. 2—Details of Mounting and Cabling**

typical view of the mounting and cabling arrangements.

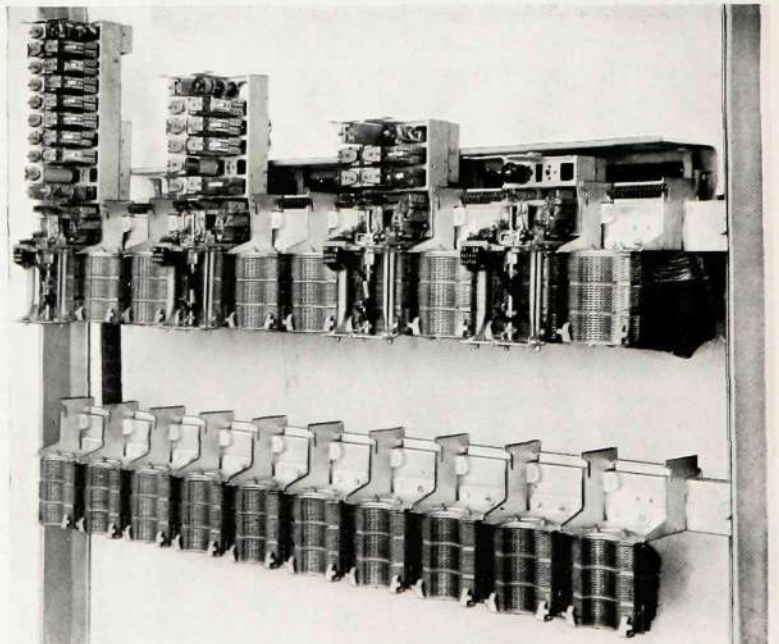
The new shelf is constructed of  $2\frac{1}{2}$ " x 1" rolled steel channel, and is fixed to the rack with the flanges pointing towards the rack uprights—the reverse direction to "pre-2000" type practice. Each shelf is fitted with a series of cradles to which the selector banks are fixed. An advantage of this arrangement is that a switch may be removed from its shelf without loosening bank rods, making it a truly jacked-in item; Fig. 3 shows a view of shelves illustrating these points.

Probably the greatest departure from the "pre-2000" type equipment as regards rack layout has been in connection with the directors. The new rack provides accommodation for 20 directors against 10 under the old design. The actual layout of the directors themselves has been entirely revised, the translation field being mounted at the rear of the "BC" switch, thus allowing the width of the mounting plate to be

considerably reduced. The relays and uni-selectors are also fitted on a narrower plate.

The power feed cables on the racks have been replaced by bus bars of  $\frac{1}{2}$ " x  $\frac{1}{4}$ " copper. The fuse panels are fitted to the -ve and +ve bars by means of the fuse post screws, which pass through the panel into the bus bars, these being drilled and tapped on  $\frac{1}{2}$ " centres. This method permits the fuse panels to be fixed in any convenient position on the rack. The battery bar is insulated by means of blue paper sleeving, which is stripped from the face of the bar where the fuse panels are fitted.

Fig. 4 shows the A.E.R. and combined coder and C.C.I. relay set racks which illustrate clearly the power distribution scheme. It may also be noticed that the coder and C.C.I. rack is of "pre-2000" type construction, as the Post Office did not deem it economical to redesign this rack in view of the fact that coders and C.C.I. relay sets will eventually be dispensed with, due to the conversion to automatic working.



**Fig. 3—2000 Type Shelves and Selectors**

The latest type of fuse panel rack may be seen in Fig. 5. This consists of a series of small "Sindanyo" panels, each accommodating either 40 or 80 fuses. The

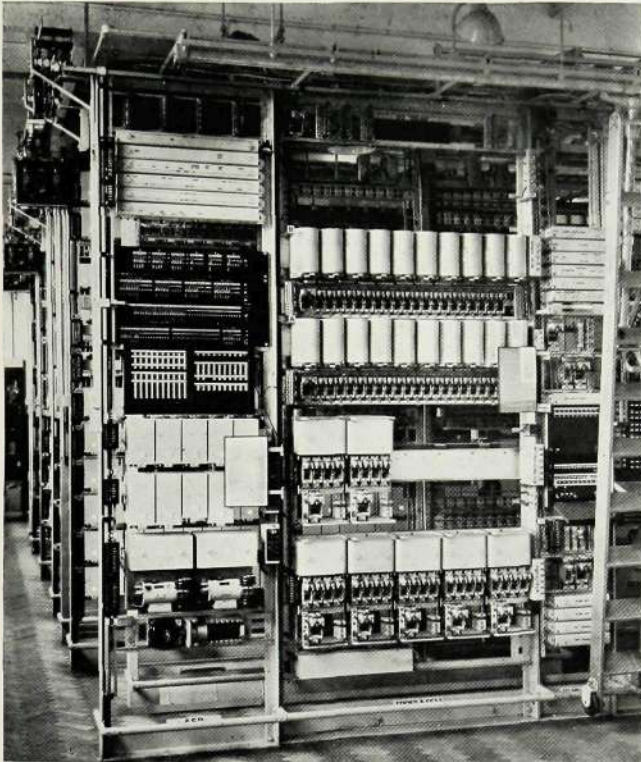


Fig. 4—A.E.R. and Combined Coder and C.C.I. Racks

ringing resistor bulbs for the P.B.X. lines are fitted on the upper portion of the rack. The lower panels accommodate the 30 volt P.B.X. power fuses, connection being made to the C.E.M.F. battery lead by means of a link passing through to the rear of the panel. The same method is employed for the positive battery fuses, while it will be seen that the 50 volt fuses have a direct connection to the main bus bar through the medium of clamps. These fuses serve the manual switchboard, supervisors desk, test desk and battery jacks which are not fused locally.

The compactness of the selector racks is

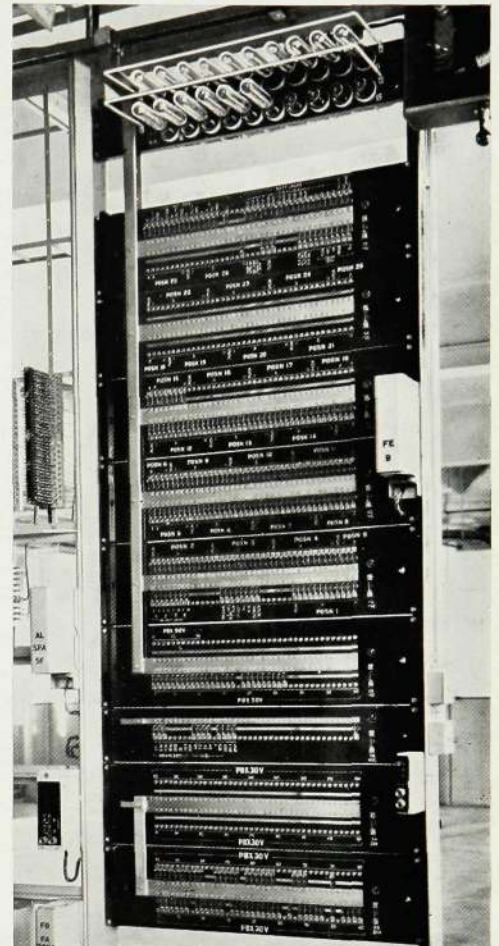


Fig. 5—The Fuse Panel Rack

emphasized in Fig. 6, which also illustrates the new selector cover and label holder. To avoid covers being mounted in incorrect positions after they have been removed by maintenance officers, a duplicate label showing the position of the switch on the shelf is provided on the selector test jack in addition to the one on the cover.

The line relay, primary finder and 1st code selector racks are installed on the second floor, a view of which is shown in Fig. 7. This figure also illustrates at the top of the picture the method of mounting the fuse alarm, release and supervisory lamps external to the rack on the overhead ironwork.



Fig. 6—Final Selector Racks

The manual switchboard together with the supervisors desk, Fig. 8, occupies the third floor. The switchboard consists initially of 15 positions. The first 5 of these are allocated for toll working, 6 is a trunk offering position, 7 a P.B.X. and 8 to 15 are "A" positions. Time check circuits are equipped, using P.O. clocks No. 44. The clocks are fitted on the keyshelves and display the duration of trunk and junction calls in minutes and tenths of a minute up to a maximum of 9.9 minutes. After 2.8 minutes have elapsed from the commencement of a call "pip-pip" tone is applied to the line to

inform the subscriber that the fee period has almost expired. The time check lamp also glows on the switchboard for 12 seconds. The same operations occur at 5.8 and 8.8 minutes. At the ninth minute the clock stops and the check lamp is caused to flicker to notify the operator that a nine minute period has elapsed, and the clock requires resetting for a further timing cycle. The timing automatically ceases when the calling subscriber replaces his receiver. This method of timing calls occupies less space than the "chargeable time indicator" system, as the need for automatic racks is dispensed with, the clocks No. 44 being operated directly by means of pulses from a master clock.

The supervisors desk accommodates the usual B/W, listening-in and fire alarm circuits, and is situated in the centre of the manual room floor.

The power board, generators and batteries occupy the ground floor and a general view is given in Fig. 9. The power board consists of 5 sections, 1 for the ringing machines,

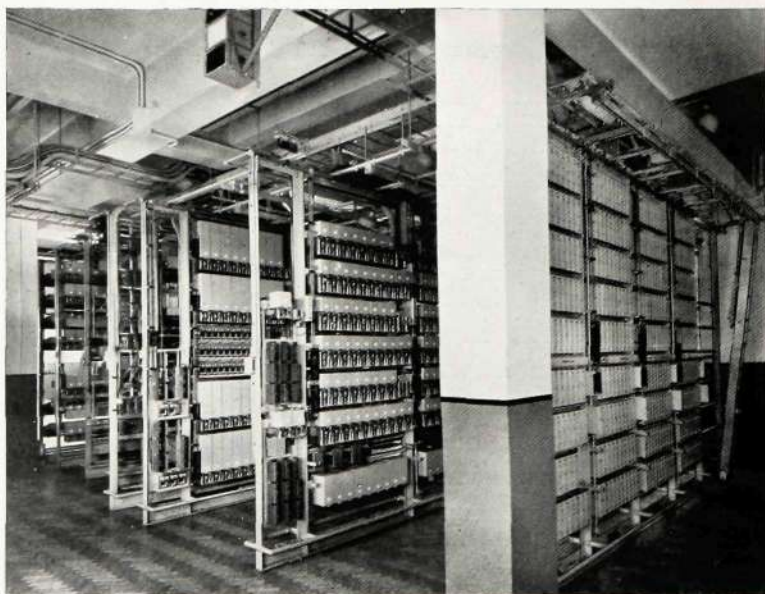


Fig. 7—Line Relay, Finder and 1st Code Selector Racks



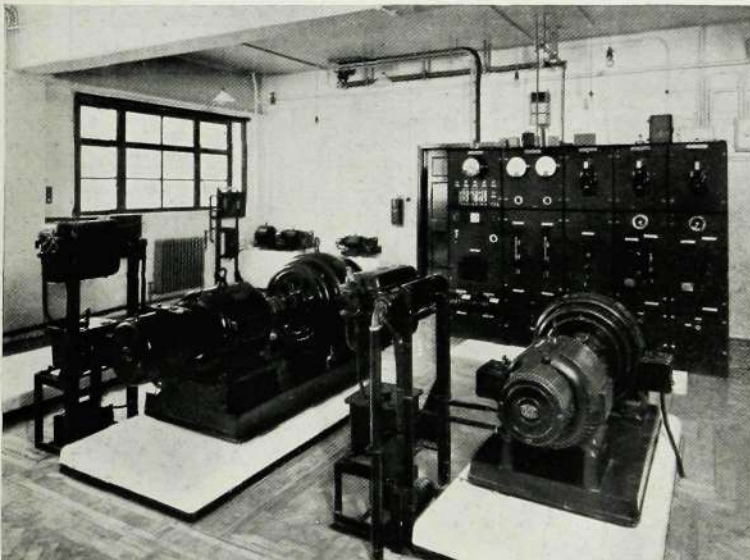
**Fig. 8—The Manual Switchboard and Supervisor's Desk**

1 for the batteries and 3 for the motor-generator sets.

Two generator sets are provided initially, one having an output of 100 amps and the other 200 amps at 51 volts. Two exchange batteries are provided, each with plates for 800 ampere hours and capacity for 1200 ampere hours. The "divided battery float" system is employed at this exchange, the generator being connected through

smoothing chokes to the exchange equipment in parallel with the battery on discharge. The two ringing machines can be seen at the left of the power board. The mains driven ringer is normally used, but in the event of the mains failing the battery driven machine is automatically brought into service.

In conclusion it may be added that Ladbroke Telephone Exchange was successfully cut into service on Thursday, 6th April, 1939, and signifies yet another step forward in the development of automatic telephony.



**Fig. 9—Charging and Ringing Machines and Control Board**

NOTE.—For detailed information regarding the mechanical details of the "2000" type switch and associated equipment racks, the reader is referred to two articles by Messrs. J. S. Young, A.M.I.E.E. and W. H. Diack of the British Post Office in the January 1936 issue of the P.O.E.E. Journal.

Circuit descriptions of the switch are also available in the July 1936 issue of the same journal under the heading "The development of "2000" type selector circuits," by Messrs. R. H. Chapman, B.Sc. and J. S. Groome.

## Packing for Export

**P**ACKING for delivery in the home market is very little more than a matter of paper and string owing to the excellent modern transport and handling facilities.

Export packing on the other hand is intricate and exacting and a very costly item for firms manufacturing delicate goods such as telephones and exchange equipments.

A modern automatic exchange, for instance, comprises a large amount of very delicate and precision adjusted apparatuses which require very careful and even scientific packing in order that they may reach a foreign destination without suffering any serious damage during transit and unskilled handling.

In the Ericsson shipping department

elaborate precautions are taken in packing goods for customers abroad, especially when destined for a tropical climate. Certain of these precautions are taken even if the boat conveying the goods is only passing through the tropics.

Many and varied are the materials used for packing purposes. Wood is mostly used for the packing cases; fine quality paper free from injurious acids, cotton wool, thick felt, corrugated strawboard, wood-wool, used motor tyres and balsa wood, are a few of the principal contingents employed for interior packing. These are mostly used to absorb concussion due to rough handling when loading and unloading, etc.

The wood, for the construction of packing cases and battens for securing the apparatus, is given careful attention regarding moisture



Fig. 1—Section of the Packing-for-Export Department

content. The cases may be lined with bitumastic felt or in some instances a hermetically sealed zinc lining is specified, depending upon the nature of the goods, the route during transit and the destination.

The linings are to prevent the ingress of moisture from the ambient air, but a more vital factor to be reckoned with is internal moisture forming on the delicate mechanisms, usually due to condensation resulting from rapid variations in temperature which takes place in the tropics. This contingency is met to a certain extent by placing a quantity of silica-gel air drier in a convenient position inside the packing case.

A section of the Ericsson packing-for-export department is illustrated in Fig. 1 where all cases to be seen are either packed or are being packed for shipment abroad, with the exception of the one in the foreground which is for a near port. In the left-hand middle a case may be seen being lowered into another one. This case contains a selector rack for an automatic exchange and is destined for Australia.

A description of the packing of the selector rack will provide an insight of the great amount of labour, material and expense involved in preparing a complete automatic exchange equipment for shipment overseas, especially when it is realised that upwards of 325 packages of a similar character are required for an equipment covering 4,000 lines.

The selector rack is first prepared by protecting the banks with strips of plywood which are stencilled with a caution notice for unpacking purposes. This is followed by a wrapping of corrugated strawboard as in Fig. 2 where some of the wrappings have been removed, so that the description may be more readily followed.

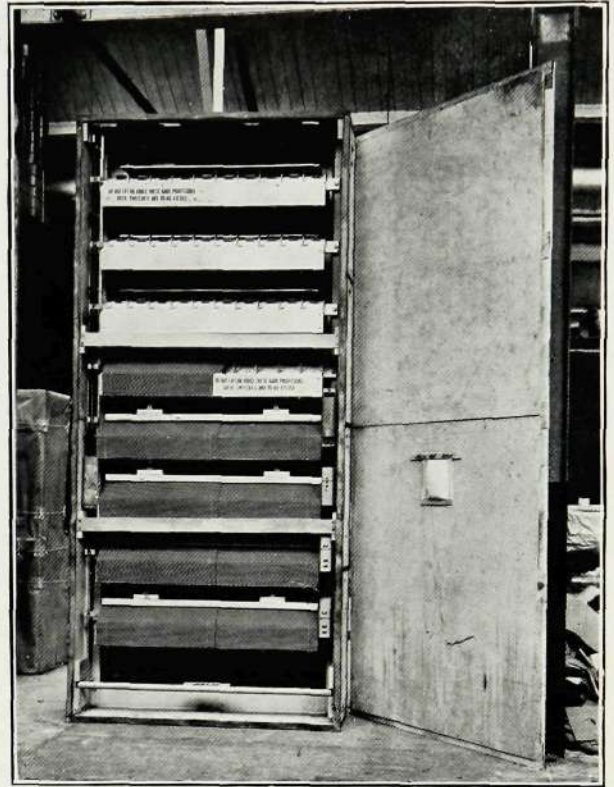


Fig. 2—Preparation and Packing of a Selector Rack in Inner Case

The case, which is made of 5-ply wood glued and close nailed to an outer framework of 4" x 1" seasoned deal, is prepared inside by means of wood blocks and 'cradles' to support the main members of the rack, and, as may readily be seen from the illustration, is made-to-measure. Further wood blocks and cradles are fitted on the upper side or front of the framework, after the rack is inserted in the case, to prevent movement, and strips and wedges of balsa wood are forced between the one side and top end of the case and the frame, also to prevent movement and absorb shocks.

A clamp is then placed over the sides of the case and tightened up to maintain an even width while two battens are secured to blocks fixed to the opposite sides. Around the edge a double piping of bitumastic felt



The completed case is illustrated in Fig. 4 where it is actually seen on the weighing platform in order to obtain the gross weight.

It will now be appreciated that the method of packing, by floating one case inside another as briefly described, provides a maximum of protection to delicate goods and that nothing is spared to achieve this end. The outer case may be roughly handled and to a certain extent distorted without serious damage to the contents.

It will of course be understood that not all racks or pieces of apparatus require so complete inner protection as that indicated above. In some instances an open frame or crate answers the purpose, the main members of the rack or ironwork being bolted to the crate and then floated as before.

Telephone instruments and small switchboards are packed in varying quantities per case according to their size. They are first completely wrapped in strong paper, the micro-telephone being housed in a special cardboard box. Each item is then floated, i.e. separated from one another and from the case by wood-wool, and strapped tightly down by means of wood battens covered on the underside with thick hair felt. Fig. 5 illustrates this method of packing a small switchboard such as that seen external to the packing case which in this instance contains 6 switchboards packed on their sides.

Instruments with bakelite and other moulded cases are provided with strong cardboard boxes specially designed with compartments, bridge pieces, spacers and

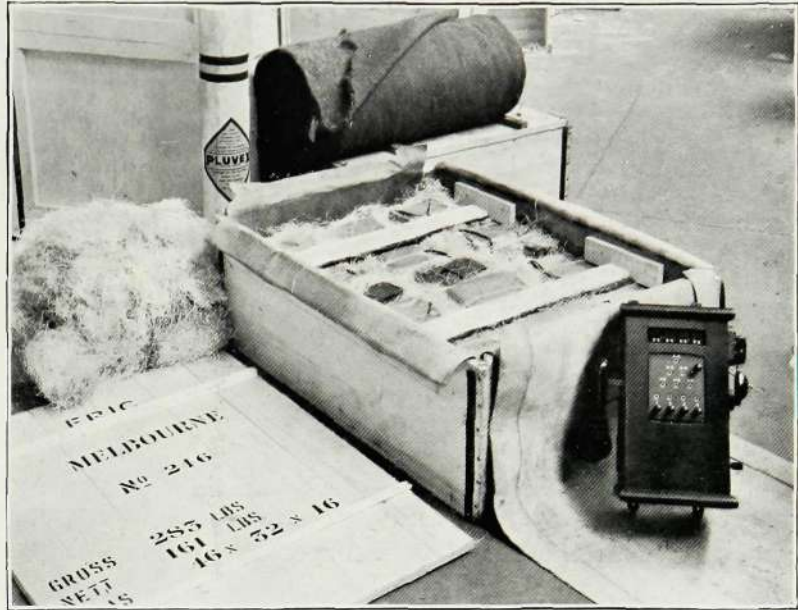


Fig. 5—Method of Packing Small Switchboards

packings and are truly made-to-measure to prevent any movement taking place during transit, and also serve as a useful means for stocking. They are then packed in a substantial wood packing case on the lines of that in Fig. 5.

In addition to the foregoing elaborate packing precautions, the Company is continually making costly experiments in connection with goods for overseas, especially when they are for use in a tropical climate. All packing materials are scientifically tested to ensure that they do not affect the finishes of the articles due to injurious acids, etc., and prolonged contact during transit. Ceaseless research is carried on to secure the most durable finishes for metal parts, and in this connection, a specially constructed humidity compartment capable of reproducing tropical conditions is one of the many means employed.

It will thus be manifest that the Ericsson Company uses every endeavour to provide the best, packed in the best manner for export to overseas customers.

## The Code Ringing Delay Unit



THIS equipment was developed to meet the need for an apparatus which would permit inter-party code calling on a party line but without calling the exchange except when required. The general appearance is shown in Fig. 1.

When development commenced the actual requirements were of a particularly indefinite nature and a certain amount of field work was necessary. The conditions associated with the most promising commercial outlet were therefore examined.

- (c) The duration of a short ring varies from 200 to 750 milliseconds.
- (d) The interval between rings varies from 200 to 500 milliseconds.
- (e) A minimum waiting period of ten seconds occurs between repeat rings.

It will be appreciated that the human element is a controlling factor in the majority of the points enumerated and therefore a mere machine could not be economically produced which would em-

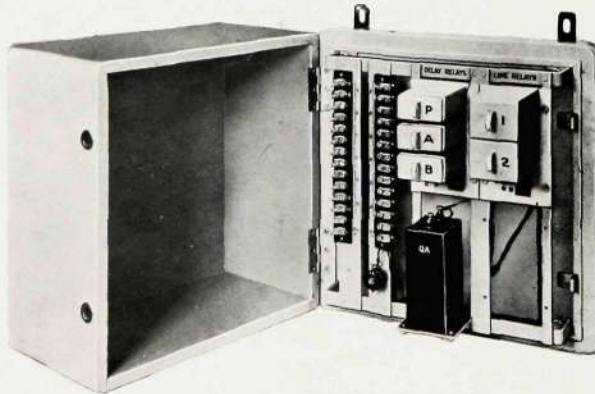


Fig. 1—Code Ringing Delay Unit

The facility afforded an exceedingly useful application to the multi-party lines used on haulage roads in coal mines and, from the review of conditions encountered in this field, the following more precise information was obtained :—

- (a) Code calls are usually a series of short rings numbered according to the position on the line of the called party.
- (b) Five instruments per line forms an efficient maximum.

brace the complete human divergence in these matters. Attention was therefore confined to the more reasonable limits outlined above.

Next came the problem of how it was to be done. Was the final form to be a completely new system, or should it be a unit which could be added to an existing system? From a circuit point of view a new system is usually preferable, but in this case the circuit elements could take either form. The provision of a unit that

could be added to existing approved systems was therefore chosen. This decision narrowed the development to an equipment which could be interposed between the line and the exchange calling signal and which would absorb all short rings but enable a prolonged ring to actuate the exchange calling signal.

The next requirement was to decide the minimum length of time that a normal person could be expected to ring continuously when calling the exchange. Six seconds was considered satisfactory. The unit was therefore designed to absorb all calling signals of less than five seconds. It will now be obvious that whether the operator is called or not will depend on the length of time a calling signal persists. A method of measuring this time was therefore necessary. This measurement may be made by mechanical or electrical means. Although mechanical methods are generally more accurate than the usual electrical ones, this is only the case if adequate maintenance and lubrication are given. Moreover, if a mechanism fails the chances are that the operator would never be called, because the delay limit would not be reached. This would be serious if the call was made in an emergency. Battery operated electrical methods on the other hand, are usually subject to wide timing ranges due to normal battery voltage variations. The system under consideration was designed to overcome these shortcomings. There is no intricate mechanism, the only moving parts being ordinary relays. Also, if the delay source fails, the delay period is automatically decreased.

The actual delay period is dependent on the time taken for the gradual release of energy stored by an electrolytic condenser. This energy maintains a relay operated until

the discharge current from the condenser through the relay reaches the release current value of the relay. The release of this relay marks the limit of the delay period. The effect of battery voltage variation is minimized by controlling the charge time of the condenser according to the battery voltage. The condenser is charged for the operating time of a relay. Consequently if the volts are high this period is shorter than if the volts are low and the energy stored by the condenser is thus controlled. On the release of the delay equipment any residual charge is dissipated practically instantaneously. The delay period, therefore, is not extended or shortened by successive calls.

Consideration of call traffic has led to the provision of an equipment which may be common to more than one line. In practice the delay unit will function satisfactorily unless all the following adverse conditions occur at the same time :—

- (a) Two or more calls are made simultaneously.
- (b) Two or more codes are being rung simultaneously.
- (c) The ringing periods are so disposed that the silent periods of each code are completely masked so that there is no silent period during the whole time for which the delay unit is set.

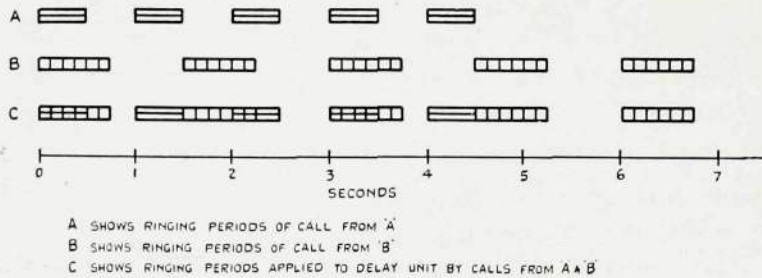
Now examine an actual case of simultaneous calls—one from A on line 1, and one from B on line 2. They both want to ring the party on their respective lines whose code call is five short rings. A “short ring” may be half a second to A with a half second interval, and to B it may be three quarters of a second with three quarters of a second interval. Let

them start ringing together. The relationship of their ring periods is shown in Fig. 2.

It will be seen that the longest ring period without a silent period on the common delay equipment is one and half seconds.

Examination of various similar diagrams with slight differences in the code ring periods will soon show that the possibility of even three simultaneous calls giving a

Delay Units certified safe for Mines (Certificate T/Tel. 48), are usually kept in stock for use with two, four, or six lines. A 2-line unit is illustrated in Figure 1. They are available for use with either magneto or battery call systems. On the latest Ericsson mining switchboards of the N.550 and N.530 types wiring and terminals already exist for the addition of the delayed exchange call facility on certain lines. The provision of these lines is shown below :—



**Fig. 2—Relationship of Simultaneous Calls**

continuous ring period of five seconds to the delay equipment is exceedingly remote.

A diversity factor of 4 is, therefore, suggested when a delay period of five seconds is used. This means that four lines are recommended as a maximum to be connected to one delay unit if code signalling is in general use on each line.

Practice may prove that another diversity factor may be used under different local conditions, such as, the varying interval between calls on the same line, the probability of simultaneous calls from different lines at the same time, the maximum length of the code call, the maximum number of false exchange calls tolerated without complaint, and similar considerations.

The circuits are shown in Figure 3.

No. of lines on Switchboard.	Lines wired for delayed call facility.
10	2
15	4
20	4
25	6
30	6

#### INSTALLATION.

The method of connecting for new equipment will be obvious from the circuits. The lines wired for delay unit facilities merely require connecting to the equivalent terminals of the delay call unit.

At the switchboard the following straps should be removed, JA—SA and JB—SB. Connections should then be made between these terminals and the corresponding

terminals on the delay unit, i.e., JA on the switchboard to JA on the delay unit, JB to JB, SA to SA and SB to SB.

Similar connections must be made for each line associated with the delay unit.

When the delay unit is added to an existing system it will be necessary to disconnect the wiring between the inner springs of the answering jack and the indicator. The wiring from the delay unit terminals SA, SB, JA and JB must then be connected to these points in the manner indicated on the line circuits shown in Figure 3.

The battery supply may be taken from any suitable source within the voltage range of 12 to 20 volts. Care must be taken that the supply is correctly connected in accordance with the polarity marked on the delay unit.

Another use for the delay unit is the prevention of code ringing from affecting a particular party on a party line. For instance, where a telephone in a private house is connected to a party line used for code ringing the addition of a delay unit at the house would suppress the code ringing and still enable a call to be made to the telephone by a prolonged ring.

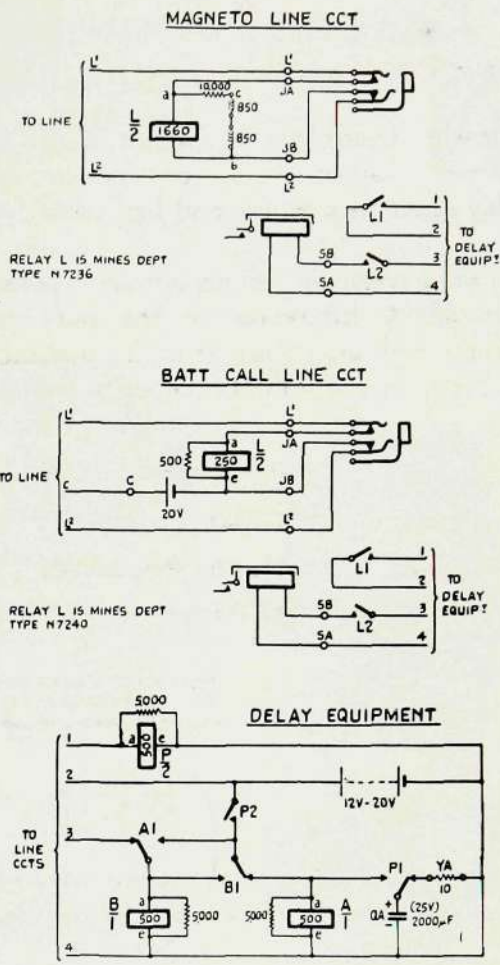


Fig. 3—Line and Delay Unit Circuits

The advantages are particularly obvious where code ringing is used during the night.

(The Ericsson Code Ringing Delay Unit is protected by Letters Patent No. 495,253).

## Battery Mining Bell with Lamp Signal



A new feature has been introduced to increase the usefulness of the Ericsson range of battery mining bells.

In engine rooms, power houses and other noisy situations served by two, three or more bell circuits, difficulty is sometimes experienced in the rapid identification of

The device must of course meet the requirements of the Mines Department as regards safe signalling and the regulations governing lamps. It was decided, therefore, to place the lamp signal on the terminal-chamber cover so as to form a unit which in the case of an existing bell could replace the original cover. The illustrations show a certified bell fitted with visual lamp signal, the method of making connection with the terminals, and the terminal cover with lamp cover removed.

The lamp chamber is placed centrally upon the terminal chamber cover and is a strong casting with a robust grille guard protecting the powerful lens. Rubber packing is used to render the lens mount waterproof. The screws fixing the lamp chamber are captive, as are those of the terminal chamber cover, also the latter must be removed from the bell before the lamp chamber can be opened and the lamp exposed.

The lamp chamber is extremely small and closely encloses the festoon lamp, and the bakelite block limits movement during screwing up, so that the lamp is free from risk of damage either during assembly or in service.

Of the two springs which make contact with the terminals of the bell (right-hand top of illustration) one can be placed in either of two positions so that single stroke or trembler working is provided.

The lamp signal is most effective in operation, the bright green light from the lens immediately arresting the attention.

The Mines Department have given supplementary certification for the device as an approved addition under certificate T'BR 63, and a certificate "Lights Approval No.13'10" has been issued also to cover its use under regulation No. 13.

Another modification which has been approved by the Mines Department is to place the certification information on the bell cover itself, by casting the lettering on the face.



**Mining Bell with Lamp Indicator**

the particular bell which has been rung, even though dissimilar gongs are fitted. Various expedients have been used to overcome this difficulty, of which a light signal associated with the bell is by general consensus of opinion the most satisfactory. Means were therefore sought to incorporate a visual indication of this type with the certified mining bell so that it could also be added at will to existing bells without the necessity of replacing the bell or removing it for conversion.

## P.A.B.X. Equipment Waverley Station, Edinburgh



EARLY in the year 1938 the London and North Eastern Railway Company decided to replace the existing manual telephone system at the important Waverley Station, Edinburgh, by a modern automatic installation with full facilities for direct access to the public exchange. After a careful study of the particular requirements, Ericsson Telephones Ltd. were successful in securing this valued contract. The work was quickly put in hand with the result that the new exchange was successfully cut into service early in November 1938.

The station itself is disposed around a block of central office buildings, and it is in these buildings that the exchange equipment is located.

Two hundred subscribers were catered for initially, but it is anticipated that the service will be extended to 300 lines.

A three-digit numbering scheme is employed. The apparatus used is of British Post Office standard type, consisting of fifty-point rotary line switches as line finders, and two-motion switches of the 100-outlet, 2000-type, as group and final selectors.

The switching equipment is mounted on three types of single-sided open racks, viz.:—line relay and finder rack, group selector rack and final selector rack.

Two line relay and finder racks are provided, each with capacity for 150 line circuits and 27 line finders, these being arranged in three groups of 50 lines, with 9 line finders per group. Traffic figures, however, make only 8 line finders per 50 line group necessary at the outset, the ninth position being for ultimate extension. The first rack is fitted with its full complement of three groups, the second has wiring for two groups and equipment for one.



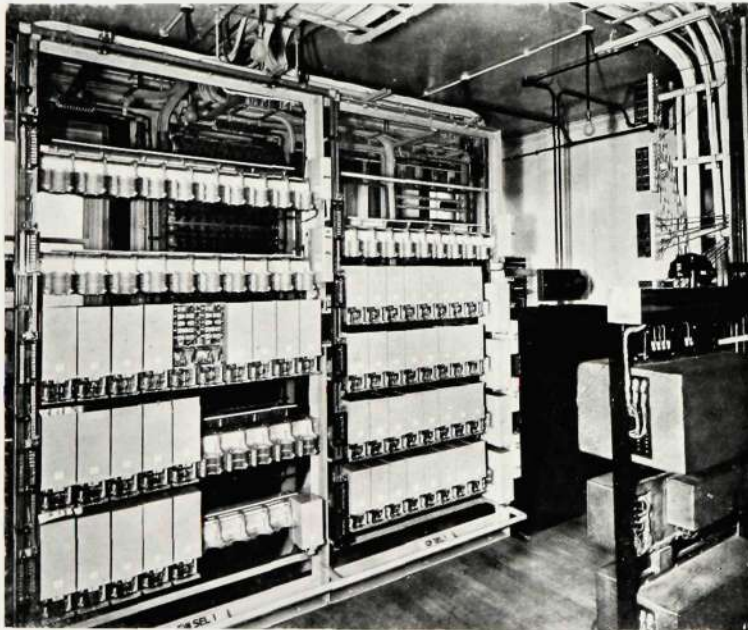
*Photo by Valentine, Dundee*

**View of Waverley Station and Hotel, Edinburgh, from the Castle**

Waverley Station has an ideal situation in the centre of Edinburgh, as is clearly seen from the view included with this article. It lies in the hollow formed by the draining of the Nor' Loch, and the historic Edinburgh Castle towers on the hill above.

figures, however, make only 8 line finders per 50 line group necessary at the outset, the ninth position being for ultimate extension. The first rack is fitted with its full complement of three groups, the second has wiring for two groups and equipment for one.

The group selector rack has capacity for 6 groups of switches, each group consisting of nine group selectors and one assigner. As in the case of line finders, only 8 group selectors per group are fitted, the ninth position being for ultimate extension. Wiring for five groups is provided initially, with equipment for four groups. Each group occupies one shelf on the rack. The general arrangement of the group selector rack, and also of the final selector rack, is shown in the illustration of the equipment.



Automatic Exchange Equipment, Waverley Station, Edinburgh

The final selectors are also arranged in groups, each catering for 100 subscribers lines. A full group would consist of 15 switches, but only 10 switches per group are required to cover present traffic figures. The final selector rack is wired for the full capacity of three such groups, but only two are equipped. The height of this rack, as of all the auto racks, is 8'-6½". Suitable alarm arrangements are provided throughout, and are extended to the manual board.

This is of the floor pattern type, with two operators' positions, the woodwork being teak. The subscribers lines are terminated in jacks and lamps on the jack field; here also are the jacks, lamps and keys for the special trunks. These trunks form permanent connections from Waverley Station to such towns as Glasgow, Aberdeen, Newcastle, York, Burntisland and Coatbridge. Although the relays for cord circuits, pilots and operators' telephone circuits are fitted inside the rear door of the switchboard sections, a miscellaneous apparatus rack is provided for the relays for the trunk circuits.

The system operates from a 23 cell battery, having a capacity of 150 ampere hours at the 10 hour rate of discharge. The battery is accommodated in a room adjoining the apparatus room, and is kept in a fully charged condition by means of an automatic battery charger, operating on a 230 volts, single phase, 50 cycles A.C. supply, and having a maximum output of 14 amperes at about 50 volts. If the exchange load exceeds the output of the charging unit, the whole of the latter is

absorbed by the load, the deficit being obtained from the battery.

If the exchange load is less than the output of the charging unit, the surplus serves to charge the battery until it is fully charged. The charging unit then automatically changes to a trickle-charging rate until the battery falls below the prescribed limit, at which stage charging re-commences and the cycle of operations is repeated.

Ringings and tones are generated by a dynamotor, operating from the exchange battery. Duplicate ringing machines are fitted, and arranged so that in the event of No. 1 machine failing, machine No. 2 is automatically brought into service. The dynamotor only runs whilst a call is in progress, a switch being provided for continuous running if necessary.

The exchange operates on standard P.A.B.X. principles and provides the following facilities.

- (1) Full automatic intercommunication between all auto extensions.
- (2) Dialling '0' enables an auto extension to call the local telephonist who can then make any connection.
- (3) Dialling '9' enables certain of the auto extensions to gain direct access to the Edinburgh public system.
- (4) Dialling '9' from an auto extension not provided with facility (3) causes the local operator to be signalled. The caps on the lamps of these lines are a different colour to those on the lines with direct access facilities and consequently the operator gets an indication that the call must not be routed through to the public exchange.
- (5) Through clearing between extensions and the public exchange.
- (6) All lines terminate on lamps and jacks on the manual board, so that the operator can gain direct access to any line.
- (7) The operator can offer a trunk or exchange call to extensions engaged on the auto equipment, without breaking down the existing connection.
- (8) Priority facilities are provided on certain specified extension lines. Access to engaged lines is made by depressing the priority button on the extension instrument.
- (9) Two extension lines can be connected to the same pair of wires and operated on a party line basis. Each party is allocated a different directory number.
- (10) Provision is also made to enable three extensions to be connected to the same pair of wires; code ringing being employed to call the required party.
- (11) Line No. 270 provides communication between auto extensions and 8 manual extensions on a P.B.X. in the station hotel. The 8 lines are connected in parallel with line 270 which terminates on a standard instrument at the hotel switchboard. These lines are provided with instruments minus bells in addition to the instruments connected to the P.B.X. system. Should one of the auto extensions wish to speak with an extension on the P.B.X. system, he dials 270 and is answered by the hotel operator who takes the demand and rings the required extension over the P.B.X. system. The called extension answers on the instrument connected to the P.B.X. and is requested to clear and take the call on the other instrument. He is then connected to line 270 and can converse with the calling auto extension. Calls can of course be routed in the opposite direction.

The exchange room was originally occupied by the local manual board and a Post Office P.B.X. It is interesting to note that these equipments were removed and the new one installed without any break in the service.

## The Design of Pawl-and-Ratchet Selector Drives



STEP-BY-STEP selectors driven by pawl-and-ratchet mechanism form an important part of most automatic telephone systems, and excellent descriptions of individual types are readily accessible. Little appears to have been published, however, regarding fundamental problems of their design, and the following description of an attack upon the subject from first principles may be of interest.

### POSSIBLE TYPES OF MECHANISM.

Electromagnetic pawl-and-ratchet mechanisms may be divided into the eight elementary types shown diagrammatically in Figure 1. In that marked A, the armature bearing *ab* lies between the magnet *m* and the pawl bearing *pb*. The pawl *p* drives the ratchet wheel *w* by a pulling action during the return stroke of the armature. In operation, the pawl is subject to tensile and bending loads, both being intermittent.

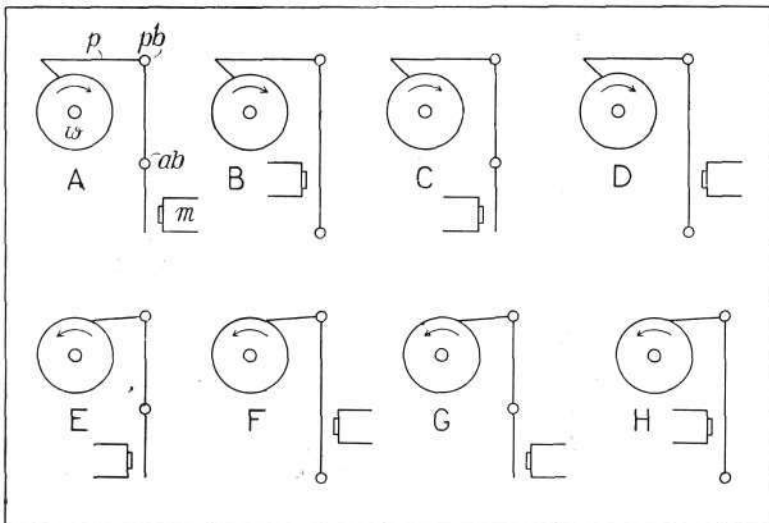
The mechanism shown at B is similar, save that the pawl bearing and magnet are situated on the same side of the armature bearing.

Types C and D are similar to A and B respectively, but the ratchet wheel is driven on the forward stroke of the armature instead of on the return stroke.

Types E, F, G and H are equivalent to A, B, C and D respectively, but in each case the pawl drives the ratchet wheel by a pushing action. The pawl is in compression during the working stroke, and by suitable design appreciable bending loads can be eliminated. In order to distinguish the two types of drive, they will be referred to as pull-drive and push-drive.

It is interesting to examine the various selector mechanisms with which one is familiar in order to find out to which of the eight elementary types each one belongs. There are, of course, many more or less superficial differences in the shape of the armature and the position of the return spring, but little difficulty should be experienced in assigning any given design to its proper class.

The choice between a selector operating on the forward stroke of the armature and one operating on the backward stroke is commonly dictated by circuit requirements, but the choice between pull and push drive and of the relative positions of the armature bearing and magnet are questions within the province of the selector designer.

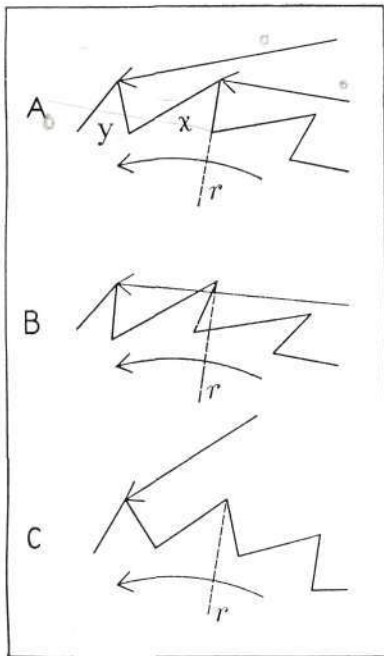


**Fig. 1—Possible types of electromagnetic pawl-and-ratchet mechanism**

It is obvious from Figure 1 that push-drive mechanisms tend to have shorter, lighter and simpler pawls than those of the pull-drive type. This is a very real advantage in the design of a reliable and sweet-running mechanism.

#### SHAPE OF RATCHET TEETH.

Figure 2 shows three possible forms of ratchet-wheel tooth. For the sake of simplicity, the teeth are shown without "land" at the tip or radius at the root.



**Fig. 2—Shape of ratchet-wheel teeth**

A tendency for the pawl to slip out of engagement with the ratchet if at any time during the stroke the pawl pivot lies further from the centre of the wheel than a line normal to the working face of the engaged tooth. There is a similar tendency in a push-drive selector if at any time the pawl pivot lies nearer to the centre of the wheel than such a line. If a line at right angles to the tooth face is drawn from the tip of the tooth (as indicated by the arrows in the drawing), then for a push-drive selector the pawl

The driving side of each of the teeth shown at A coincides with a radius (such as  $r$ ) of the wheel. Suppose that in one working stroke the tooth in contact with the pawl moves from position  $x$  to position  $y$ . In a pull-drive selector there is a

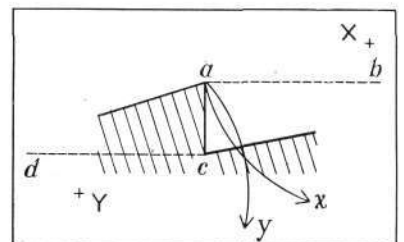
pawl should remain above this line. For a pull-drive selector the line must be drawn from the root of the tooth and on the other side of the tooth face, and the pawl pivot should remain below it. In either case the most exacting condition clearly occurs at the end of the stroke, and this is usually the only one that need be considered.

Ratchet-wheel teeth have sometimes been undercut as shown at B. This does not necessarily improve the grip of the pawl on the ratchet; what it does is to rotate the line above or below which the pawl pivot must not pass. In the first case this line was tangential to the wheel, but it now cuts it on the right of the working tooth. Undercut teeth are naturally weak, and prone to wear at the tip.

On the other hand, the working faces of the teeth may be inclined in the opposite direction as indicated at C. Provided that the pawl pivot still operates on the proper side of the line normal to the tooth face, the pawl will still grip the wheel satisfactorily. This line now cuts the wheel to the left of the working tooth. The comparatively blunt form of the teeth results in a robust and long-wearing wheel.

#### LOST MOTION.

In Figure 3, which represents a single radial tooth,  $a b$  is the critical line for a push-drive selector and  $c d$  that for a pull-drive selector. Let the position of the pawl bearing, at the moment at which the pawl drops over a tooth in preparation for a working stroke, be at X for push-drive and at Y for pull-drive. (The distance of these points from the



**Fig. 3—Origin of lost motion**

working tooth is reduced in the drawing in order to exaggerate the effect.) The path of the pawl tip is indicated by the arrows *x* and *y* respectively. In neither case can the pawl tip reach the ratchet exactly at the foot of the working face. If, therefore, the pawl drives only at its tip, a certain amount of lost motion at the beginning of the working stroke must be tolerated. This will be referred to again later.

#### SHAPE OF PAWL.

In some mechanisms, the angle of the pawl tip has been made equal to the angle of the teeth, as indicated at A in Figure 4. Unless such a pawl is attached to an armature pivoted on the same centre as the ratchet wheel, it cannot seat properly

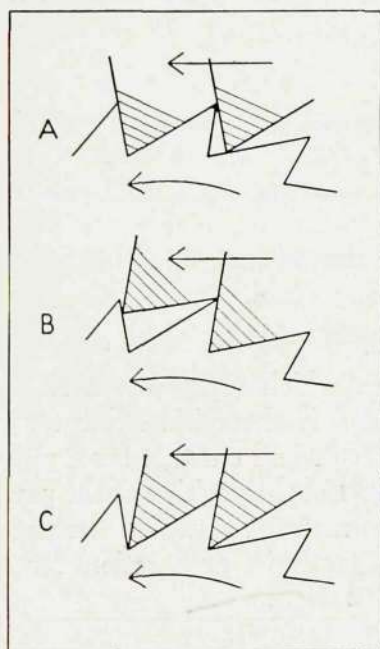


Fig. 4—Shape of pawl tip

during the whole of its stroke, and in practice it lies awkwardly either at the beginning of the stroke (Figure 4, A) or at the end (Figure 4, B). The effect of A is an undesirable hammering action on the tip of the tooth, while that of B is an equally undesirable scraping action on the working face as the stroke proceeds. It follows, therefore, that the proper angle of the pawl tip is less than the re-entrant angle of the ratchet teeth by at least the

angle moved by the wheel during one operation, or by  $7 \cdot 2^\circ$  in the case of a 50-tooth wheel. This condition is shown at C, and it will be observed that it allows the faces of the pawl and the tooth to meet squarely at the beginning of the stroke and to move without interference until the end.

It may be argued in support of A that the amount of the lost motion already referred to is reduced. Perhaps it is more correct to say that it is masked. In any case, with proper design this lost motion does not exceed a few thousandths of an inch, and is small compared with the excess pawl stroke normally allowed.

Another possible objection to C is the reduction in the angle at the tip of the pawl. This angle, however, is a function of the tooth angle, and by the use of teeth of the form shown in Figure 2 (C) it can be considerably increased. The result is a very satisfactory shape for both pawl and tooth.

#### RELATION OF PAWL AND RATCHET.

The maximum driving force is obtained if the pawl operates tangentially on the ratchet wheel, as indicated at *a* in Figure 5. It must be remembered, however, that the pawl, in conjunction with the pawl stop, has a second function to perform, that of preventing further rotation of the wheel when the stroke is completed.

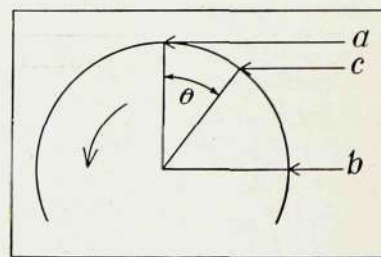
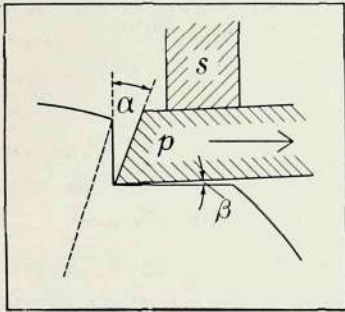


Fig. 5—Relation of pawl and ratchet

The tangential position is the least favourable for this purpose, the best stopping action being obtainable by acting radially, as indicated at *b*. In this position, of course, the pawl could not drive the wheel.

A compromise can be achieved by operating at some angle  $\theta$  from the tangential position at which a satisfactory stopping action is obtained without unduly reducing the useful driving force. An angle of  $20^\circ$ , for example, is sufficient to give a very effective lock, while the driving force is reduced by little more than six per cent.



**Fig. 6—Conditions at end of stroke**

Such a position, moreover, lends itself to the use of the blunt teeth already referred to in connection with Figure 2 (C). Figure 6 illustrates a typical arrangement.

The pawl  $p$  is shown at the end of its working stroke, the angle  $\alpha$  being equal to the angular spacing of the teeth on the wheel. A small clearance angle  $\beta$  is provided to ensure that the lower face of the pawl is always clear of the tooth.

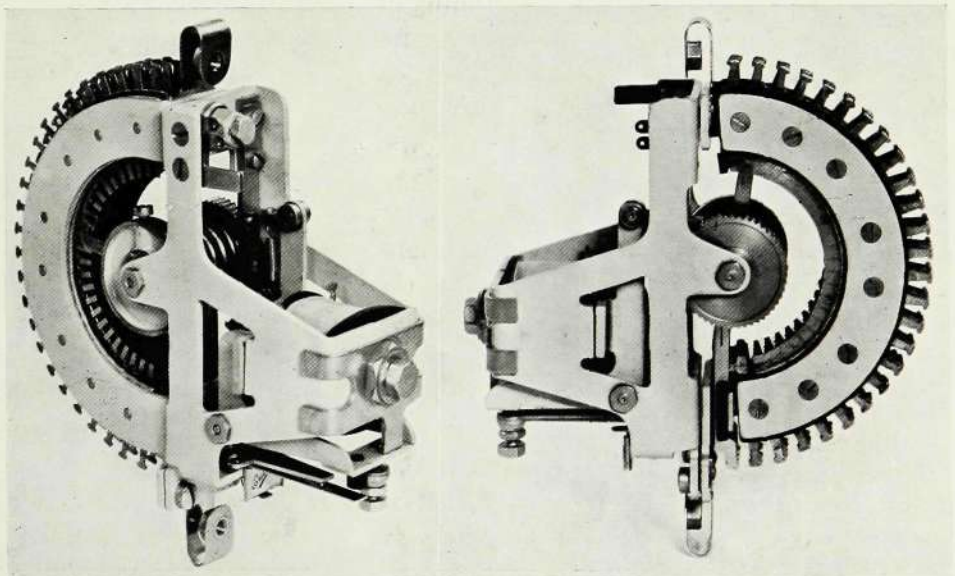
In practice, of course, the pawl bearing does not reciprocate in a straight line, and in fixing the values of the angles  $\alpha$  and  $\beta$  regard must be had to the movements of both the armature and pawl about their respective bearings. The movement of the pawl

in withdrawing from the tooth is now substantially in line with the longer face of the tooth. There is therefore no tendency for the pawl to fly away from the wheel at the end of the stroke and to return forcibly to the wheel when its inertia has been overcome by the pawl spring.

Teeth of a similar form have long been appreciated as desirable by the makers of electric secondary clocks.

A further advantage resides in the fact that the pawl stop  $s$  can be brought close to the tip of the pawl, where it is able to exert its full effect without strain. In the selector mentioned below, in which advantage is taken of this fact, there is no substantial difference in the running if, after adjustment, the normal armature back stop is completely removed, the pawl stop then forming the only limit to the retraction of the armature.

If, as is convenient in practice, the upper and lower sides of the pawl are parallel, the angle  $\beta$  is repeated on the upper side of

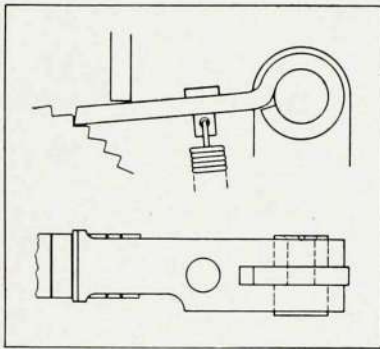


**Fig. 7—Push-drive uniselector**

the pawl, and if the pawl moves substantially horizontally to the right, a clean withdrawal is assured. Too great an angle renders the stopping action less effective.

**DETENT.**

The relation of the detent or retaining pawl to the ratchet wheel should be such as to reduce backlash to a minimum. A straight detent is naturally preferable to the hooked equivalent of a pull-drive pawl, and it should lie near the line normal to the face of the tooth over which it drops at the end of a step.



**Fig. 8—Pawl, pawl-stop, and ratchet**

**PRACTICAL RESULTS.**

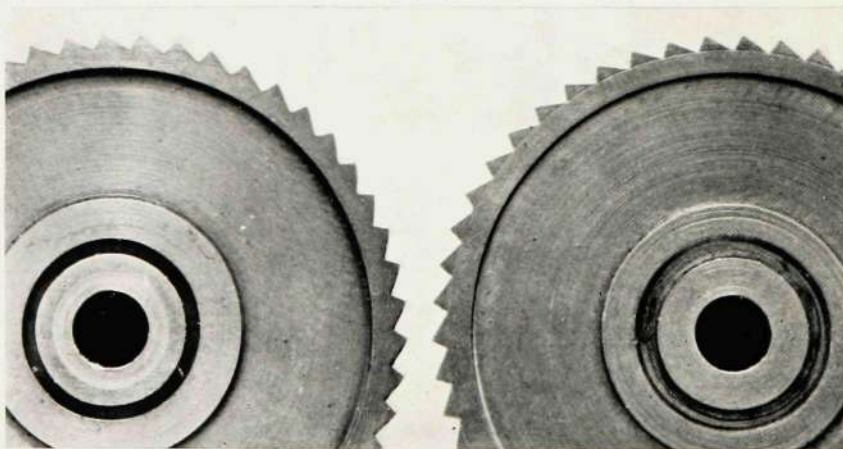
Figure 7 shows a subscriber's 25-point uniselector (*Brit. Pat. App. No. 21376/38*)

using a push-drive mechanism designed in accordance with the above principles. Figure 8 shows the relative positions of the pawl, pawl stop and ratchet at the end of the working stroke. Throughout the stroke, the line of thrust lies wholly within the pawl.

An experimental selector of this type was still running efficiently at its normal speed after ten million half-revolutions (250,000,000 steps), no parts having been replaced. It would take a subscriber's lineswitch, making twelve calls per day and returning to normal after each call, over 2,000 years to complete the same number of steps.

The wear on the ratchet-wheel teeth at the end of the run is shown on the left of Figure 9, which is reproduced from an untouched photograph. Part of an unused ratchet wheel is included on the right for purposes of comparison. The wear on the pawl bearing was very slight, and that on the armature bearing barely perceptible.

During the test the selector was adjusted only seven times, and the temperature rise after several hours of continuous running was less than 32°C.



**Fig. 9—Untouched enlargement of used and unused ratchet wheels**