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The Motor Uniselector and High-Speed Relay

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RECENT years have witnessed a marked change in the attitude of the public towards the telephone, chiefly in that it is used more freely and that the field of communication has been considerably enlarged. Amongst other things, this change of attitude has given rise to transmission problems of no mean order, and they in turn have resulted in administrations having to lay out a good deal of capital in plant external to exchanges. It is obvious, therefore, that if the development of a country's telephone network is to be encouraged by an efficient service at reasonable cost, not only should connecting mediums be reliable and durable but a high degree of communication efficiency should be attained, and plant, both inside and outside, should be worked to the limit of its revenue-earning capacity. These briefly are the main considerations that have led to the development of the motor uniselector and, as will be seen from later explanations, they account to a large extent for its unconventional design.

In common with other types of uniselectors, the motor switch exercises purely a searching function. When a free outlet has to be found within only a portion of its bank, dependent for instance, on a particular numeral having been dialled, it is brought about not by any form of local electro-mechanical selection but solely by electrical control from a remote point. This results in a very simple mechanism having a high degree of trunking flexibility. The most noteworthy feature of the switch is its high speed of search, one with double-ended wipers engaging bank contacts at the rate of over 3,000 per sec.

Description of Switch

As its name implies, the switch is driven by a self-contained electric motor. The armature rotates at a speed of over 3,000 r.p.m., causing the wipers to pass sets of bank contacts at the rate of about 220 per sec. Fig. 1 shows a left view of the switch and Fig. 2, a half-front view. The motor system is in the bottom right corner. Shrouding the horizontal magnet is an interrupter springset controlled by the motor, and this springset alternately closes each magnet circuit to produce armature rotation. The principle of operation is similar to that used in toy motors dating from many years back, that of attracting one armature pole until no further useful torque can be obtained, and then switching over to another magnet so relative to another pole that a good torque is restored. Practically all of these early motors, however, suffered from the disability of not being self-starting, and this has been one of the setbacks to their general commercial exploitation. In the motor uniselector the difficulty has been overcome and the motor is self-starting, in the right direction, from any angular position of the armature. The torque incidentally is not constant; it fluctuates to match the varying wiper load as represented by wipers sometimes being on contacts and sometimes being between them.

Attached to the wiper assembly is a 104-tooth gear wheel, and in Fig. 1 there can be seen a small idler gear coupling this wheel to the motor. The wipers are rotated in a clockwise direction. Selecting action is controlled by the latch magnet situated above the motor. An extension of the latch magnet armature carries a small three-toothed detail, and when the magnet is unoperated this is forced by spring action into the large gear wheel, thus holding the wipers firmly in their setting. When the magnet is operated, the detail is lifted clear of the wheel and at the same time, a contact completing the motor circuit is closed. At first sight, this latching device might seem a drastic way of stopping movement, particularly at the speed at which the wipers are passing bank positions, but as will be seen from later explanations, the principle is satisfactory and trouble-free. The only remaining component on the right side of Fig. 1 is the jack between the two motor magnets. This is a combined battery-cut-off, latch magnet calibrating and speed-checking jack.

The bank consists of 832 insulated contacts arranged in 16 arcs each of 52 segments. Arcs are traversed by permanently associated wipers, and these can be single-ended or doubled-ended or a mixture of both. With the wipers arranged as in Fig. 2, the switch consists virtually of two groups each of 104 outlets. Starting from the left end of the wiper assembly, No. 1 set is diametrically opposed to No. 2 set, so that if these two are commoned, they represent one set of wipers traversing 104 outlets.

The switch consists of two main parts, bank and mechanism. The latter is shown separate in Fig. 3, which gives a view of its right side. The cam and springset seen near the wiper wheel serve two purposes. The lower pair of springs is used for stopping drive to normal whilst the upper pair indicates to the controlling circuit when the switch has reached normal. This springset is of novel construction in that the contacts function precisely at the correct moment, independent of spring follow and contact wear. It operates on the "trigger release" principle. The lug on the right side of the mounting plate locks the mechanism securely into the bank after it has been swung into position. Incidentally, this plate, together with all other plates in the switch, consists of cold-rolled case-annealed steel; the switch has no castings.

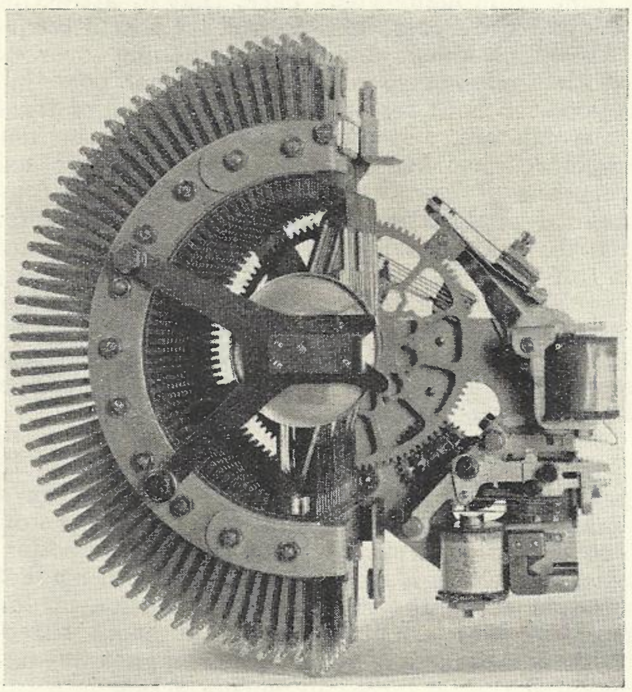

Fig. 1. Side View of Motor Uniselector.

Fig. 4 shows the mechanism partly dissembled, and the most interesting item at this stage is the rotor. It has no winding nor is any electrical connection made to it. The basic part is a steel tube with a pinion at one end. Forced on to the tube are two annealed soft iron details which form the actual armature. The remaining component is a fibre cam which actuates the springset shown on the right. One of the problems of a motor of this type and dimensions is lubrication. Oil must have free access to the bearing, but at the same time it must be kept free from dirt to stop sludging, and free from air to stop gumming. This problem has been solved by having a hollow rotor bearing spindle with transverse holes in the bearing surfaces to allow oil to get to the rotor. The spindle is fitted with a wick saturated in oil. When the rotor is slid into position, it completely envelops the bearing.

The armature comprises two main poles diametrically disposed and presenting circular faces, with two auxiliary poles of rectangular face also diametrically disposed but set between the main poles. The torque-producing action of the rotor will be seen from Fig. 5. In position **a**, the cam on the end of the rotor will be causing the energisation of magnet 1. In much the same way as an eyeball indicator movement, rotor pole 3 is attracted in a clockwise direction. When it takes the position in **b**, there will be practically no torque between 1 and 3, merely because the flux in the gap is being bent to an inappreciable extent. At this stage, however, the cam will have caused magnet 2 to be energised in place of magnet 1. Magnet 2 is now exerting a direct pull on the flat face of auxiliary pole 4, thereby maintaining the torque in a clockwise direction. In position **c**, the torque between 2 and 4 will

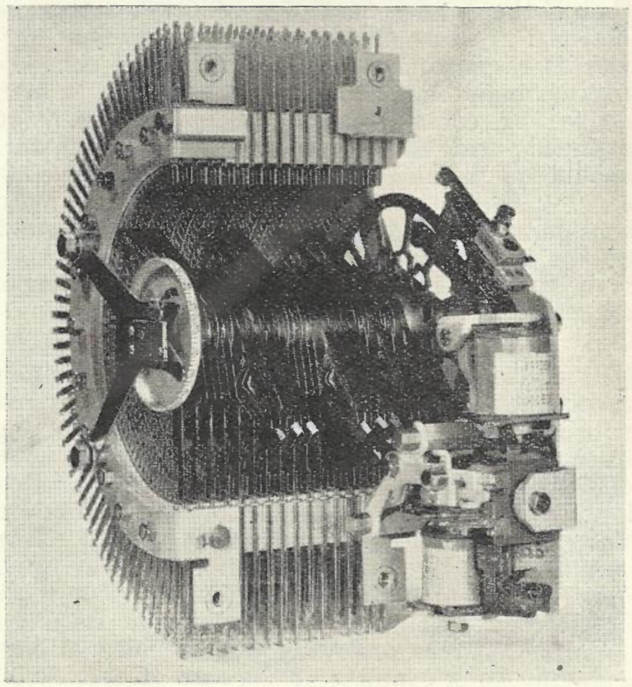

Fig. 2. Front View of Motor Uniselector.

have dropped to zero, but by this time main pole 3 is sufficiently close to magnet 2 to maintain the torque. It will be seen that pole 4 has placed its edge of restricted width against magnet poleface 2 so that it robs a minimum of flux from main pole 3. In position **d**, the interrupter has again functioned and magnet 1 is now pulling on auxiliary pole 6. The rotor does 90 deg. of movement for each step taken by the wipers.

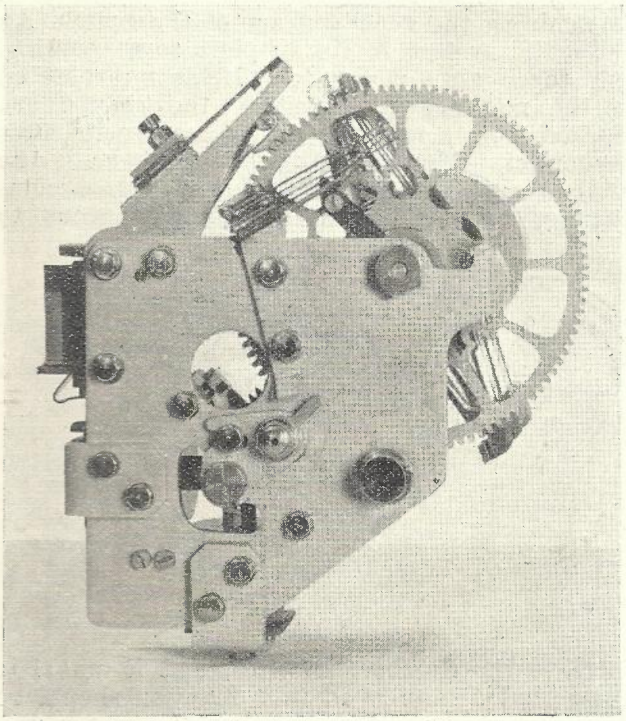

Fig. 3. Side View of Motor Uniselector Mechanism.

Electrical Connections

The complete action involved in the selection of a free outlet can be explained by reference to Fig. 6. The sequence is as follows:—

1. A start contact (somewhere in the controlling circuit) closes. The latch magnet operates, frees the wiper wheel, and at the end of its stroke closes the motor circuit.

2. Motor rotates wipers. The motor magnets are alternately energised by the action of the cam on the make-before-break interrupter springset.

3. When the wipers reach an outlet marked free by the presence of a battery potential, the test relay operates. This is a high-speed relay and is dealt with later.

4. The test relay contact disrupts the latch magnet circuit. The latch armature releases, first opening the motor circuit and then gripping the wiper wheel.

The switch is designed primarily to operate from a 50-volt d.c. supply. At this pressure the motor current is approximately 0.25 ampere and that taken by the latch magnet, 0.5 ampere. The test relay current is approximately 65 milliamperes.

Trunking Considerations

The motor switch is the outcome of a set of ideal general requirements laid down by the manufacturers as far back as 1922. The idea of a motor-driven selector, however, did not take root straight away but was preceded by a variety of designs which have never emerged from the factory. The first and foremost of these requirements was that the selector should comply with

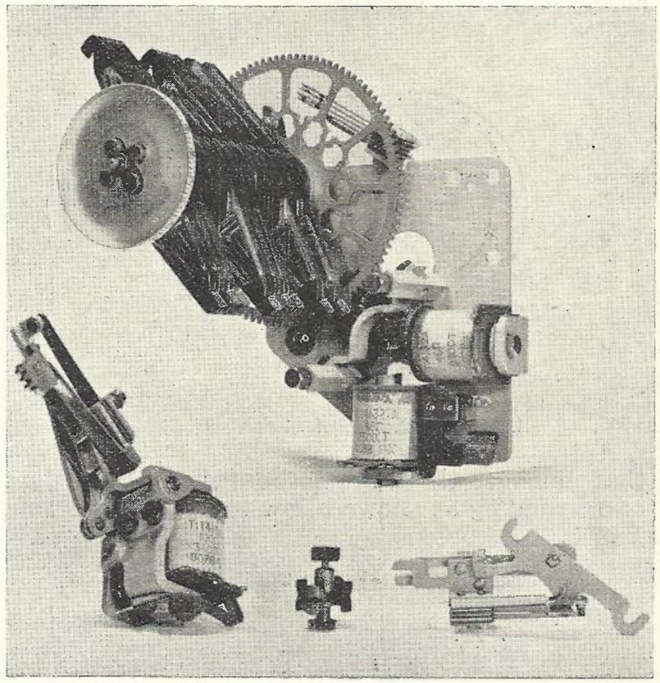

Fig. 4. Motor Uniselector Mechanism Partly Dissembled.

the principle of the "box fitting the contents." A selector is only a device for distributing parcels of telephone traffic, and the requirement means that the compartment of the switch individual to each parcel should be commensurate with the parcel size. Expressed in practical terms, outlet availability should be proportional to group size; this is only an adaptation of the manual board practice of allocating outgoing junction jacks in quantity proportional to the outgoing traffic.

A second requirement was that flexibility of outlet grouping should be attained by electrical means and not by variable mechanical subdivision. This was to keep the switch simple both in construction and action.

A third requirement was that outlet groups around the bank should not necessarily have to be arranged in numerical order. Nor for that matter should they be fixed as ten groups. If, for instance, the switch were used as a first selector, and only eight of the ten numerals of the first train were live ones, then the whole of the bank should be available for these eight groups. On the other hand, it should equally be possible for the bank to be divided into more than ten groups. It was foreseen that by completely divorcing the routing arrangements from the numbering scheme, appreciable economies could be made both in switching gear and outside line plant.

As an example of how the motor switch can meet the ideal of proportional availability, assume that a bank section of 50 outlets is available, and that amongst these are to be distributed outlets corresponding as shown below to dialled numerals 1 to 5.

1	None at all; group unallotted.
2	20
3	8
4	12
5	None at all; group unallotted.
Total :	40

Numerals 1 and 5 would have no appearance on the bank. The groups for the live numerals would be laid out head to tail until the first 40 contacts were taken up. The remaining 10 would serve as a common pool for extension of the live groups, or for outlets of numerals at present unallotted but subsequently used. From the last remark, it will be seen that, in addition to groups not having to be arranged in numerical order, the outlets of a particular group do not necessarily have to be together. This flexibility of allocation is one of the reasons why the switch has been made to search at the high rate of 220 steps per sec. The group to be tested cannot be determined, of course, until the impulse train has completely been received; the outlets might be anywhere in the bank. As the next train might commence after the lapse of only a quarter of a second, the switch must be able to complete its maximum permissible search within that time. This was arbitrarily fixed at 50 steps so that the minimum speed has to be 200 steps per sec. The extra 20 steps per sec. represent a factor of safety. For the case just quoted, only one "last contact" position would be required for the five numerals.

Certain other factors also were considered in determining the general shape of the switch. An automatic system in its simplest form requires only three wires per outlet. If, as incorporated in the motor switch system, the groups are marked from a remote point, these become four per outlet. Thus with an 800-point bank the total availability is 200. In special circumstances, however, it often is advantageous to increase the number of wires, and it was laid down that flexibility in this direction should be catered for. The result is that the motor uniselector can provide outlets having as many as 16 wires, the availability in which case is 50. On one particular installation 32-wire outlets were used, being met by working two switches in parallel.

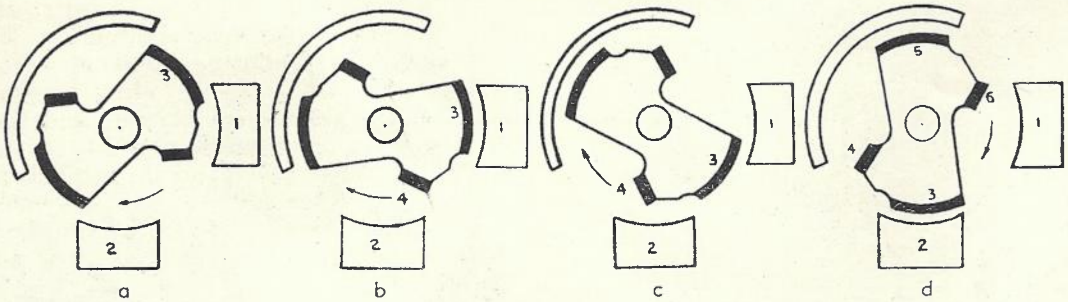

Fig. 5. Diagram Illustrating Action of Motor.

Connecting Path Characteristics

The mechanical design of a selector must be governed to some extent by the trunking arrangements and call-establishing procedure it has been decided to adopt. There is one function, however, that overrides these and all other considerations, viz., that of making a good electrical connection between a set of inlet wires and a selected set of outlet wires. It assumes primary importance merely because it is the function that gives rise to the existence of the switch. In most selectors, these connecting components usually appear simple and straighforward, but actually they represent one of the most difficult problems of modern switch development. The reason is that ideal conditions of electrical conductivity are extremely difficult to attain and maintain.

The problem can be stated simply. The resistance of speech paths should be as low as possible and should remain constant; at the same time, leakance should be negligible and paths should not be subject to inductive interference. It is the resistance question that is most difficult to solve. It arises in three main places: (1) The multiple; (2) the point of contact between wipers and banks; (3) in all apparatus external to the switches. This last item naturally covers a wide range of components and wiring, and though of importance, is not dealt with here as it is outside the scope of this article.

Amongst other things, resistance attenuates speech, and so far as multiple is concerned, it becomes of greatest significance when considering a connection involving outlets at the ends of gradings. Many up-to-date administrations

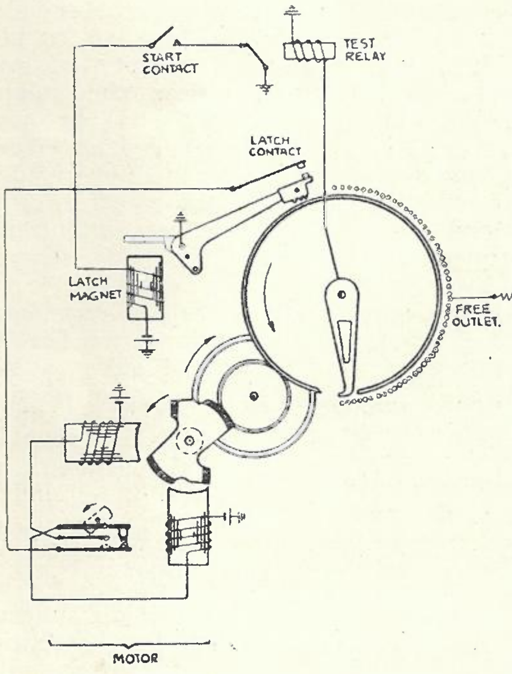

Fig. 6. Schematic Circuit of Switch.

spend thousands of pounds on outside plant in counteracting even only small amounts of attenuation, and this in itself is sufficient reason why energy losses in multiple should be kept down to a minimum. For given wire sizes, this can be done only by mounting switches closely together and running multiple wire from switch to switch in a straight line. As regards the resistance of the wiper/bank contracting point, the problem is not so much to get a joint of low resistance as to get one in which the resistance does not vary. The best and most reliable form of connection is a soldered joint, but this naturally cannot be considered a feasible method of joining a wiper to a bank. The next best is to simulate relay practice and to provide double contacting through precious metals, those whose oxides are highly conductive. Double contacting is not out of the question, but, on economic grounds, a switch having, for instance, silver wipers and banks, would not only be unduly expensive but wear would rapidly take place. The alternative therefore is to resort to cheap alloys such as brass or phosphor bronze, but these unfortunately produce oxides which are not highly conductive. Worse still, their electrical resistance is dependent on the mechanical conditions appertaining at the point of wiper and bank contact. This instability produces one of the worst bugbears of automatic switching, that of microphonic noise, and it is a trouble of no small order on systems carrying speech currents that subsequently are amplified. The trouble is caused by the wiper and bank forming a tiny microphone which in turn is activated by mechanical disturbances imparted from adjacent switches. There are three ways of combating it. One is to improve the point of contact itself, oiling the surfaces to minimise the formation of oxide and then applying heavy pressure via a plurality of contacting points, which, by being all in parallel, produce a joint of high conductance. This scheme goes a long way towards overcoming the trouble but unfortunately it is not in itself a sufficiently good remedy.

The second principle is to insulate mechanically one switch from another, such as by the suspension of mechanisms on felt pads attached to the common panel framework. It is practicable if certain bank sizes are not exceeded and if multiple skinners are kept fairly long. But if banks carry a very large number of wires, and short skinners are used, the mechanical bonding of the multiple nullifies to a great extent any insulation attempted by flexible suspension. This particularly is true if sections of a complete bank are packed closely together, thus entailing butts and skinners all being in close contact. If the ideal of a straight-wire type of multiple is aimed at, then the bonding effect becomes greater still.

The third principle, the most logical one, is to attack the trouble at its source, and allow no vibration at all. This ideal state of affairs is not altogether an impossibility, but the nearer one gets to its achievement, the greater become difficulties in other directions. Vibration can be reduced only by lowering the rate of change of velocity of moving parts, but to get it to a level so low that microphonic noise cannot be generated under any possible conditions of wiper contacting, the stopping and starting of switch movement has to be done very gradually—so gradually in fact that the establishment of connections must necessarily take place at a speed slower than that of impulse train transmission. This results in having to introduce registers, in turn giving rise to increased complication, expense and fault liability, and also putting no little time loading on every connection through an exchange. Moreover, if a system is of the type entailing call-establishment by exchange telephonists, slow switching action can greatly depreciate their call-handling capacity, and thus raise operating charges. The designer therefore has to arrive at a compromise, the most suitable for modern conditions being one which admits a degree of vibration commensurate with reasonable switch functioning speeds and exchange simplicity. He has at his disposal, however, two mechanical principles which simplify the problem, and which affect the quantity and quality, respectively, of impact shock. One is to adopt a drive in which the minimum possible number of impacts occur during search; as exemplified in the motor switch, the number actually is one, viz., the stopping impact when the required outlet is found. The other is to limit the pressure attained during impact, such as by introducing resiliency into the mechanical system.

It was these considerations that gave rise to the mechanism of the motor uniselector, and it is not a coincidence that the selfsame principles have resulted in the switch having rather remarkable durability characteristics. The reason is that the provisions made to combat the microphonic noise trouble in the ideal manner are to a large extent the same as those necessary for minimising friction and eliminating fractures due to fatigue effects.

An important feature of the switch is the manner in which it is mounted. Bank arcs are vertically disposed so that contacting faces do not present shelves for dust collection. This point was the guiding factor in determining which way the switch was to be mounted. Experience has shown that dust acts as an abrasive, and not only does it give rise to parasitic noises due to imperfect contacting, but it accelerates the formation of metallic particles which in turn rapidly bring on leakage troubles. Another point concerns the oiling of banks. If the contact faces are vertical, the formation of sludge, due to the continued mixing of oil and dust by wipers, takes place very slowly.

The bank contacting segments are brass, and they are flanked by bakelite sheets and aluminium separators. The whole assembly is rigidly held together under great pressure by high-tensile steel rods and nuts. The wipers consist of stout phosphor bronze leaves, stiffened where necessary by channelling, and likewise clamped together under heavy pressure. Wipers make contact on both sides of the segments, and not only does this provide a duplicate connecting path but it effectively overcomes one of the problems of commercial switch production. This is the cumulative effect of dimensional tolerances. Piece parts can be manufactured only within certain plus and minus limits of dimensions, and in no switch can it be guaranteed that a wiper always takes up its theoretically correct position in relation to every bank segment. Displacement is bound to arise somewhere in the bank, and it means a like displacement from theoretically correct tensioning. By making contact on both faces of segments, however, no ill effects accrue, as a loss of pressure on one wiper leaf results merely in an increase of pressure on the other.

Two types of wipers are used, those carrying speech having trailing tips, and those used for outlet testing having "bridging" tips. The bridging characteristic of the latter actually is of only secondary importance; the wipers really have "advanced" tips, the angle subtended by the back and front edges of the flat tip being determined by the angular velocity of wiper movement divided by the time the stopping devices take to function. The talking wipers have several interesting features of design. Firstly, tip wear cannot produce overbridging of adjacent outlets and thus cause clicks on live connections. Secondly, the wipers intentionally are arranged to bounce on the bank segments during drive. This considerably reduces wear as the time they are rubbing on the segments is lessened. Of greater importance is the fact that bank lubrication is scraped off at a much reduced rate. A third feature is that when the wipers are brought to rest on the selected outlet, a shock absorber in the latch magnet system allows the talking tips to move slightly forwards and backwards at a stage when tip bounce has ceased. In other words, the tips rub themselves into good contact on the selected outlet. The manufacturers claim that these devices for militating against wear give wipers an unusually long life. Under durability test conditions, assemblies have done as many as four million revolutions without need for replacement, and even if this figure is halved to represent actual conditions, it still represents a very long life. For instance, a line finder averages about 25,000 calls a year, which means that wiper replacements could be expected only after the lapse of about 80 years.

The switch has a "ribbon" multiple, not of the woven type as used in certain other systems, but consisting of the conventional type of multiple wire laid up between a folded adhesive tape. The wires thus have a double protection, each one individually having the usual double wrapping of insulating material, and the whole lot then being imprisoned in a moisture-resisting envelope. Bared loops project from the open edge of the tape at regular intervals, and these hook into slots at the soldering ends of the bank tags. The cables lie behind the loops so that every joint is open for inspection. Fig. 7 gives a view of some representative multiples. It will be seen that the outside cables feed directly on to the banks, a scheme which eliminates two soldered joints per wire (as represented by block termination), and which also appreciably reduces wiring resistance. The multiple wires themselves do not run in the ideal straight line, but the slight set necessary

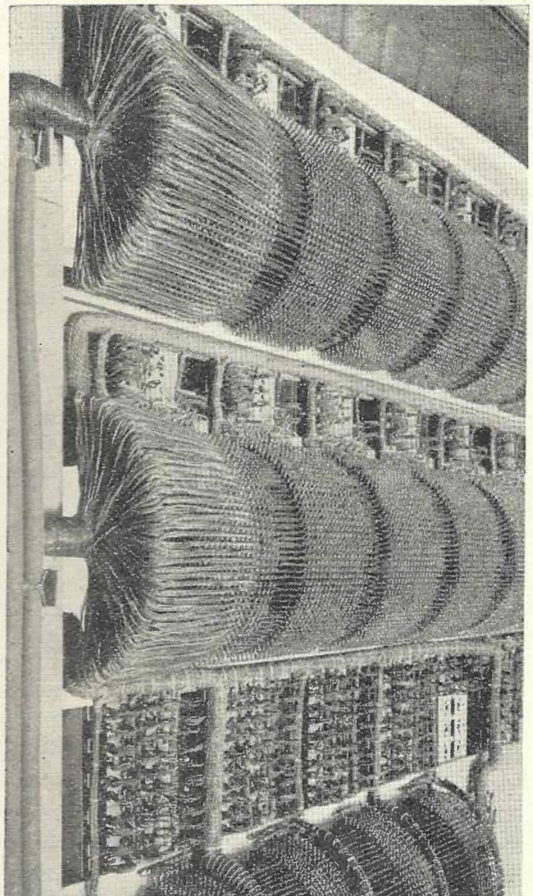

Fig. 7. Motor Uniselector Bank Multiple.

to get loops emerging in their correct positions increases the resistance above the absolute minimum by only a small amount. With this type of multiple, mass-soldering can be employed. Such a scheme results in each joint being soldered properly on both faces of the tags and, of more importance, every joint is soldered at the correct temperature.

Motor Features

Two points in the motor system are of particular interest, one being the method of speed adjustment, and the other the construction of the interrupter springset. The magnet winding characteristics hold the driving speed within certain limits and though not strictly necessary, means are provided for getting the speed within still closer limits. It is done by altering the phase relationship between the rotor cam and the springset. The latter can be swivelled over an angle of about 10 deg., and when "retarded" by swinging it in the same direction as rotor movement, the drive speed is reduced. Speed change is brought about by flux decay effects. If the interrupter is retarded, the main rotor pole will progress beyond the magnet-alignment position before the flux has fully collapsed, and a braking effect is produced. If the interrupter is "advanced," the braking effect is lessened because more time is allowed for flux to decay prior to the rotor aligning with the magnet.

It is obvious that if the motor must start from any position, the interrupter springset must be make-before-break in action. It means therefore that four times in each complete revolution of the rotor both magnets simultaneously are energised. It is a characteristic of this type of motor that up to a certain point of overlap, the simultaneous energisation of both magnets at the changeover stage adds appreciably to the torque; but beyond a certain amount, the torque drops. The interrupter has been designed to give the optimum amount. Referring to Fig. 6, the common contact is mounted on a rigid detail. The rotor cam engages the centre spring, and when this is pushed downwards, the contacting changes from top-to-bottom to centre-to-bottom. The overlap is obtained by the cam engaging the centre spring on one edge, thereby causing it to twist longitudinally when it touches the bottom spring. After a certain amount of torsion has taken place, the centre spring develops sufficient stiffness to move the bottom spring downwards. The converse of this action occurs when the cam disengages the interrupter. A novel point is the method provided for adjusting the whole springset assembly in relation to the cam. The springset has a "scissors" extension, and if a screwdriver blade is inserted into one or other of the slots thus formed, and twisted, the contact end of the springset is rocked up or down. The adjustment thus obtained is held by tightening the long-headed screw adjacent to the "scissors."

Latch System Features

Earlier reference was made to the shock absorber incorporated in the latching system. Its construction is best seen in Fig. 4. It consists of a pair of bowed stainless steel springs; when the latch detail is dropped into the rotating wheel, the springs splay slightly by the force longitudinally imparted to them. The splay is, of course, only momentary. This arrangement prevents the pressure between the flanks of the wiper wheel and latch detail teeth exceeding a certain amount, which amount is well below that required to produce shearing or even ultimate fracture arising from fatigue effects. The buffer action is so effective that even after many million stoppings of the wiper wheel in the same position, the teeth concerned on the wheel show little more than a polishing. Being of softer material, the latch detail wears at a greater rate, but durability tests have indicated that the average switch should go through its economic life with the original detail.

If a switch is passing outlets, say, at the rate of 220 per sec., the time between successive outlets is about 4.7 milliseconds. This is not, however, the total time within which stopping action can take place. Due to there being fairly large spacing between segments, the effective period is less, and is of the order of 2.5 milliseconds. Of this period, one-fifth is occupied by relay operation and four-fifths in latch armature release. At first sight, it might appear surprising that a fairly large magnet armature can be made to release in so short a time as two milliseconds. It occurs quite reliably, however, due to the use of two features. One is the small moment of inertia of the moving system coupled with the large amount of potential energy developed in the spring restore system. The other concerns the relationship between the magnetic pull and the restoring tension, also when the armature is operated. When the magnet circuit is broken, the flux will start decaying at once but it is not until it drops below a certain value that the armature can commence releasing. It follows, therefore, that the closer the relationship between the magnetic pull and restoring tension at the end of the operating stroke, the sooner will the armature start moving. If only a simple restore spring system be used, such close relationship cannot be attained; this is because the armature attractive force increases at a greater rate than the counter spring pressure. By the use of spring compounding, however, the counter pressure can be matched more closely to the magnetic pull at the end of the stroke, with the result that release can be started almost as soon as the flux commences to decay. The compounding is done by the contact spring which closes the motor circuit. It has a steeply-rising pressure characteristic and boosts the primary spring pressure just before the latch detail clears the wiper wheel.

Maintenance Consideration

The grade of service given by a selecting switch depends largely on the extent to which its components retain their original formation and adjustment; further, it depends on the ease with which maintenance staff can restore these characteristics, should they deviate beyond set limits. In both these respects, the manufacturers have set a standard not usual with larger types of switches. In the first place, it is reckoned that except for switches undergoing very heavy duty, a motor uniselector should never require part replacements within its economic life as the result of fair wear and tear. As regards maintenance facilities, adjustments are few and they are all simple and straighforward. Moreover, they can all be gauged, there being no cases where an adjustment depends on a maintenance man's personal conception of what it should be. The mechanism has only nine oiling points, and every one of these is accessible without having to remove the mechanism from the bank.

The wipers being the vital part of the switch, particular attention has been paid to facilitating their adjustments. Tension is imparted by a tool which straddles a wiper leaf at its base. The leaf is strained leftwards or rightwards, as required, until the correct tension between the tip and the bank segment is obtained. This can be measured directly by means of a tension gauge. The adjustments thus obtained are entirely independent of dimensional tolerances of banks and wiper assemblies. Screws are provided with stainless steel washers and in every case where the setting of a washer on the wrong side of a clamped detail would cause trouble, it is mechanically retained against the head of the screw.

An unusual feature of the switch is the absence of jacking contacts. Experience has shown that knife jacks with their single stationary springs of base metal and steep pressure gradient are potential sources of contacting trouble. The omission of these jacks is possible with the motor switch owing to its low fault liability and its capacity to retain set adjustments over very long periods. It does not mean, however, that wiring has to be unsoldered in the event of it being necessary to remove the mechanism from the bank for such purposes as cleaning. The wiring to the former (leading to a maximum of only eight soldering points) is in the form of a flexible tail, and sufficient length is available to allow the mechanism to be set into an outrigger which in turn is attachable to the bank. This device sets the mechanism forward clear of adjacent switches, and allows ample room for examination and adjustment of components.

The High-Speed Relay

The high-speed relay was developed conjointly with the motor uniselector. This was necessarily so because the switch depends mainly on the relay for its successful functioning. High speed types of relays actually were available at the time but, in addition to being unduly expensive, they all suffered from occasional "contact freezing." This arises from the "anvil" effect, in turn due to an armature of relatively high mass and stiffness being arrested at the end of its operating stroke by fixed and rigid contact members. Attempts were made to modify existing designs in order to overcome the trouble, but it was finally decided to embark on a new design altogether, incorporating precisely the type of mechanical action required.

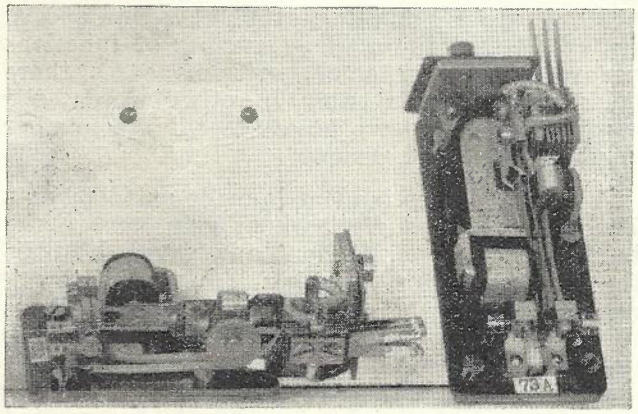

Fig. 8. High-speed Relay.

Fig. 8 shows two views of the relay, and its mechanics are illustrated in Fig. 9. Fixed block 1 carries phosphor bronze spring 2 which is stiffened by channelling at 3. It carries a double-sided platinum contact at 4. The iron armature 5 is attached to spring 2 by spot welding. Coil 7 is approximately the same size as a receiver bobbin and is carried by yoke 6. When buffer spring 8 is compressed by movement of the tensioning screw 9, it levers 4 and 11 into contact; at the same time, its free end keeps the armature and yoke in close contact at 5. When the relay is energised, contacts 4 and 12 close, and it is arranged by adjustment that a small armature/poleface gap still exists. This allows the restore pressure at 8 to be compounded by restore pressure developed in the channelled section, and it is this latter feature which gives the relay its remarkably fast release. On coil de-energisation, it parts from the make contact in less than 0.3 millisecond. The slight flexibility of the channelled section is also the solution to the "freezing" trouble mentioned earlier.

In addition to stopping switch drive, the high-speed relay has provided a solution to a problem of long-standing, viz., the elimination of double connections in automatic switching equipment. By "elimination," it is not meant that a critical period exists, which period is so short that the chances of striking it are exceedingly remote. It is meant in its literal sense. For instance, if two circuits are resting on an outlet waiting for it to go free, then when it does so, one and only one of the circuits will get it. Several factors help in bringing about this effect, but the chief one is the compounding action of the channelled spring referred to earlier. Despite the fast operating speeds attained, resort is not made to light contact pressures nor to heavy operating currents. The break contact pressure, for instance, is 17-20 grammes, which is comparable with that used on ordinary types of relays.

Although developed primarily for use with the motor uniselector, the relay has been applied in many other directions to solve difficulties of long standing. For instance, it hitherto has been no easy problem to stop a self-driving reverse-action ratchet switch with a relay testing for the presence of a battery potential. The mechanical principles involved result in a race between the relay and the switch armature. The high-speed relay does it so effectively that even if the wipers of the switch are set on a free outlet with the armature manually operated so that the pawl just does not drop over the next tooth, no kick can be felt on the switch armature if its magnet and test relay circuits are closed simultaneously.

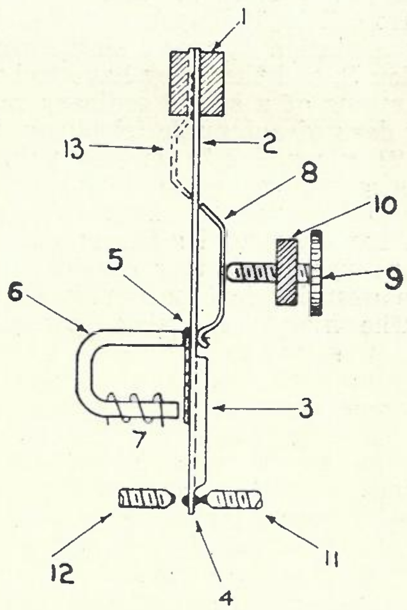

Fig. 9. Schematic Diagram of High-Speed Relay.

This is an extremely severe condition and one which no ordinary telephone relay will meet.

In some circumstances it is useful to know precisely when a selector in an automatic exchange switches the impulsing loop through to the next selector in the course of establishing a connection. In the past this has been a difficult thing to do, particularly if the next selector is in a different exchange and the only circuit over which a signal can be received is the junction loop. The high-speed relay provides a solution in the following manner:—If the relay winding is introduced into the loop immediately an impulse train is completed, it will operate via the distant selector's battery feed relay. When the selector switches through to the free outlet, the high-speed relay will respond to the momentary break in the line feed circuit. The recording of this momentary release is, of course, a matter for local circuit arrangements. More interesting still is the fact that even if the switching from one feed to the other is done by means of make-before-break contacts, no actual line discontinuity occurring, the relay still will momentarily release due to encountering an unfluxed feed circuit.

It has also had a marked effect on the design of counting relay circuits. Assume that trains varying from 1 to 10 impulses are to be transmitted from station A, over a single wire, to distant station B, and that they have to be counted at B by means of a set of ordinary relays. In the early days of automatic telephony, this used to entail 21 relays, one to terminate the line and ten pairs corresponding to the ten possible impulses to be counted. From time to time, designers have produced schemes requiring less relays, but the limit was considered reached when the quantity had been reduced to about seven. The high-speed relay now allows the absolute limit of four to be used. The solution lies in the fact that a high-speed relay at station A can detect contact changes occurring in distant station B.

Conclusion

It will be of interest to quote an application of the motor switch in which its features of both speed and flexibility are exemplified. The London Passenger Transport Board has its own telephone network, and this comprises a large number of small automatic exchanges situated about Greater London. To enable complete intercommunication without recourse to public exchange connections, the Board decided to introduce a motor uniselector type of tandem exchange. From this exchange bothway junctions radiate to all other exchanges, and as about 100 of these have to be catered for, it means that two digits have to be received at tandem in order to route a call to its terminating exchange. One special feature is that the average number of junctions per route is very small, in some cases there being only one or two. In other words, the tandem selectors have access to a large number of unusually small groups.

A call involving tandem is made as follows:—The caller dials a digit which gets him to the tandem exchange. Without any pause, he dials the two digits for directing him to the terminating exchange, immediately following these with the digits for the particular line in that exchange. The high speed of the tandem motor uniselector allows the pair of intermediate digits to be co-ordinated and a free line in the wanted group found before the succeeding impulse train commences. Moreover, the whole of the selection takes place on one rank of switches at tandem.