Production of the Automatic Dial

An outline of manufacturing and inspection processes with reference to features of the design of B.P.O Dial Auto No. 10

Fig. 1.—B.P.O. Dial Auto. No. 10.

AFTER installation, the apparatus in telephone exchanges receives at the hands of skilled workmen such routine attention as may be necessary and, being in buildings in which temperature, humidity and atmospheric conditions generally are more or less controlled, operates throughout its service life under the best protective conditions that can be afforded. Apparatus at subscribers' premises, however, is subject to treatment by users who may give no thought to the instrument placed at their service and is often installed where conditions are the opposite to those obtaining in exchanges. Long and trouble-free service life thus demands that subscribers' telephones, even more than exchange apparatus, be designed and manufactured with probable adverse service conditions always in mind.

When viewing an automatic telephone in regard to reliability, the dial at once presents itself as of major importance. It is operated for every call, sending from one to seven trains of impulses , it functions at a comparatively high speed which must be closely regulated , it must not tend to stick , the impulse and off-normal springs must retain correct adjustment , and, finally, the whole mechanism must withstand mechanical shocks which may be received at the hands of the user

The British Post Office standard dial (Fig. 1), as manufactured by The General Electric Company, has been designed in the light of its importance in an automatic telephone system and with an appreciation of the need for a trouble-free mechanism. It incorporates features which have been the outcome of research at the Company's Works, and over a period of years has gained a world-wide reputation for stability of adjustment and freedom from premature mechanical failure.

A survey of manufacturing and assembly processes, showing the care exercised in the production of this dial, can be made by all visitors to the Works, and whilst notes in these pages may not convey as much as a personal inspection, it is felt that they are presented here in a manner such as will suffice to give a good understanding of the constructional merits of the B.P.O. No. 10 dial.

Construction.

A nickel-plated brass case has a central bearing for the main spindle, which carries the finger plate at the front and, at the rear, a cup housing the main spring (Fig. 2) which is anchored to the case. To the spindle projecting beyond the spring cup is fitted the impulse wheel and slipping-cam assembly With rotation of the finger plate the slipping cam moves round with the impulse wheel until a stop prevents its further movement. The cam shields the teeth of the impulse wheel during this rotation and prevents the impulse springs being affected. From the point at which the cam is stopped the impulse wheel continues to rotate with the finger plate. When the finger plate is released, the main spring rotates the whole assembly in the reverse direction. The slipping cam moves with the impulse wheel and shields the teeth until again brought to a stop. The impulse wheel continues its rotation and, affecting the impulse springs, introduces the required breaks in the line loop, the action of the slipping cam having ensured that the necessary delay is introduced to permit the exchange apparatus to prepare for receipt of the impulses. It is important to note that this delay is introduced before impulsing commences, and then between digits, thus ensuring that the length of time allowed to selectors throughout the setting up of the connexion is never less than a predetermined minimum which is independent of the human element. The assistance this delay offers to switches was a vital factor responsible for the preference for this design shown by the many Administrations who have adopted it.

Fig. 2.

The speed of rotation on the return motion is controlled by the governor A gear wheel, fixed to the main spindle, is in mesh with a small pinion, on the spindle of which is the star wheel engaging with the worm of the centrifugal governor Coupling of the pinion and star wheel is not rigid but is made through a small spiral spring clutch which, on the return of the finger plate, locks the two members together and brings the governor into action. When the finger plate is rotated by hand to the finger stop, the clutch is inoperative and although there is sufficient coupling to cause the governor to rotate, pressure on it is relieved and wear consequently minimised. Furthermore, the greater the force with which the finger plate is rotated by hand the greater is the slip. The action of the clutch is explained more fully in a later reference to the parts themselves.

A further feature of the design, which has as its object the reduction of wear, is found in the slipping cam and impulse wheel assembly If, during the break period of impulsing, the moving member of the impulse springs were in contact with the rotating impulse wheel, a very definite source of wear would be introduced. The slipping cam is shaped, however, to present an edge on which the spring drops and, since this is stationary, wear at this point is minimised.

Fig. 3.—Successive stages in the production of the case.

Production.

The dial comprises a total of 102 parts, involving in their production some 300 operations in the Company's factory, exclusive of all inspection and assembly A wide variety of accurate tools is required and is provided by the tool design department, to which, in many respects, is due the credit for the excellence of the finished product.

Case.

Apart from the finishing processes of buffing and plating, the case requires sixteen operations, being blanked and drawn from brass sheet, crushed, pierced and bent in succession. The stage of production reached after each operation represents the furthest advance which the strength of the material and ability of the tool to give the required accuracy, render possible or practicable. The successive stages are illustrated in Fig. 3.

Main Spindle.

The main spindle is produced to fine limits by automatic machines, whilst the impulse wheel, slipping cam and star washer are made on light presses. A finishing operation to the slipping cam, termed profile burnishing, ensures correct register with the periphery of the impulse wheel teeth. Included in the assembly of slipping cam and impulse wheel is found a device introduced by the G.E.C.—steel washers made to fine limits—the incorporation of which maintains the precise degree of friction necessary between cam and wheel. These washers are pressings from steel of requisite hardness.

Gear Wheel.

Gear wheels are produced from brass discs by a hobbing process in which a hob—the cutting tool—rotates at high speed on a mandrel inclined to a second mandrel, holding the discs, by an angle equal to the complement of the helix angle of the hob. Twelve discs are held in the machine and rotate at low speed, the hob moving slowly along a line parallel to the axis of the discs and cutting the teeth as it proceeds.

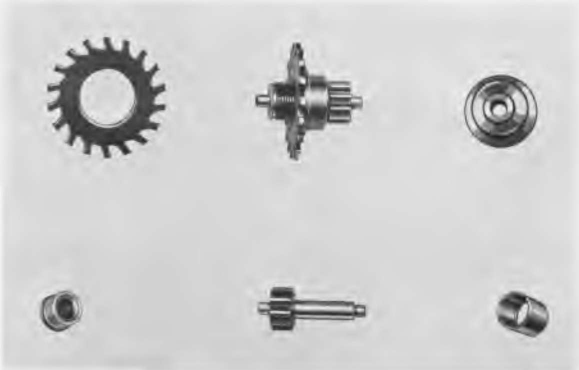

Fig. 4.—Star Wheel assembly and components.

Finger Plate.

The finger plate is pressed from stainless steel sheet, the use of this metal having been introduced by the Company several years ago, and since standardised by the British Post Office and overseas Administrations. Its advantages, now well-known, are not confined to appearance but are found also in the small mass, resilience and mechanical strength. The mechanical shock exerted on the mechanism, the product of mass and acceleration, when the finger plate completes its return motion, is substantially less than on a dial fitted with a heavy finger plate.

Governor Mechanism.

Production of most of the parts can be made on machines which at other times are used for other purposes but the star wheel and worm together with the pinion and clutch spring call for such specialisation as warrants the establishment of a separate department concentrating on these components.

Star Wheel.

The star wheel assembly and its components are illustrated in Fig. 4. A special hob (Fig. 5) cuts the star wheel itself out of phosphor bronze discs, six such discs being cut at once. The distinctive tooth profile is an innovation of the G.E.C. and is designed for true action of the governor mechanism. Each tooth is undercut so that the leading face is not radial but is very slightly offset. When meshing, therefore, with the worm, the whole face is not in contact, thus preventing the formation of the ridge which, produced by wear when teeth are of the normal type, gives rise to the tendency to stick.

Pinion.

The pinion is solid with its spindle and is cut by a hobbing process, the accuracy of the teeth, as in the case of the star wheel, being attributable to accuracy of the hob and care in setting up the machines.

Clutch Spring

The clutch spring is formed from steel wire, wound in approximately 4-inch lengths on a mandrel. The diameter of mandrel used is selected to suit the diameter of the wire in order that any variation between spools as received from the wire manufacturers shall be nullified. This precaution requires selection to be made from ten mandrels each of which

Fig. 5.—Special hob for cutting star wheel teeth.

Fig. 6.—Machine for testing main springs.

varies from the next by no more than .0005 in. From the 4-in. lengths, short lengths are cut to exact dimension, and, after heat-treatment, a rigid inspection passes only those springs which conform to close limits of diameter and length.

The remaining components of the star wheel assembly—the cup to which the wheel is secured, and the collar which is pressed on the pinion spindle—are made in this department to fine limits on automatic machines.

Inspection of Star Wheel Components.

All these components are tested for true running before assembly The gauges are similar in each case and comprise a sensitive plunger which is brought in contact with the periphery of the part under test and, by actuating an indicating pointer, shows any irregularities in running which may be present in an imperfect part. On the star wheel and cup, a variation from true running of .001 in. is permissible, whilst in the case of the spindle of the pinion, .0015 in. is allowed, any excess causing rejection of the part. The importance attached to rigorous inspection is shown by the fact that the personnel of this department is approximately equally divided between production and inspection.

Assembly of Star Wheel and Pinion.

Assembly of star wheel and pinion follows inspection of the components. The cup is spun-over to secure it to the wheel, the strength of the joint being confirmed by a wrenching action imparted by means of a special fixture. The pinion spindle is passed through the cup and the spring is slipped over a boss in the centre. A collar is placed over the spindle, and, fitting inside the spring, is then spun over to grip the spindle. If it were not for the presence of the spring, the star wheel would rotate freely on the spindle but when rotation is made in the direction of winding of the spring its internal diameter decreases, causing the spring to grip both the boss and collar, thus tightly coupling star-wheel and pinion. This is the direction of rotation during the return motion of the finger plate. The absence of backlash, that is to say, the instantaneous action of the clutch, is an indication of the accuracy of the parts.

The assembly is then tested for true running by means of a gauge similar to those used for testing the components. Of the small percentage of rejections, the majority are assemblies which, by chance, comprise components each of which approached the limits of permissible variation from true running.

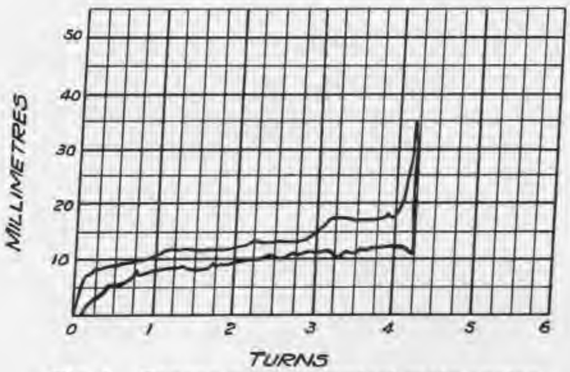

Fig. 7.—Torque curve of typical main spring.

Worm.

The worm is produced from steel rod, turned to size, on which the worm itself is cut. The end which takes the thrust when pressure is greatest, that is, when the clutch is operative during the return motion, is ground to a spherical shape to reduce wear. The worm is then case-hardened and the surfaces brought to a glass-like condition by a polishing disc for minimum friction when in contact with the teeth of the star wheel. A test for straightness follows, a variation of .0015 in. from true running causing rejection of the worm.

Main Spring.

Main springs are tested for smoothness of torque by means of a machine (Fig. 6) in which a spiral spring is loaded simultaneously with the winding of the spring under test. In testing a spring it is first oiled and then its cup is held in a chuck on the left-hand tailstock, the spring itself being anchored to the spindle of the right-hand stock. A crank enables the spring to be wound fully several times in order that the oil shall penetrate the coils. On the spindle of the right-hand stock is a disc with a slot in its periphery into which fits the end of a strip suspended from the spiral spring. By means of a second crank, turning the cup at low speed, torque is transmitted by the spring under test to the spindle of the right-hand stock, causing rotation of the disc and, therefore, elongation of the spiral spring. To the strip coupling the disc to the spiral spring is fitted a pen, which, as rotation of the crank continues, traces a curve on a paper cylinder, itself rotating by a drive from the tail-stock spindle. When the spring is fully wound the crank is turned in the reverse direction and a second curve traced back to the starting point of zero torque. Typical curves are given in Fig. 7, the almost vertical portion of the curve representing the annealed end of the spring. The curves are drawn in relation to axes of extension of the spiral spring and revolutions of the cup, and since the constants of the spiral spring are such that a load of 100 grms. causes an extension of 15 mm., the torque of the spring under test at any stage can easily be determined. The torque at the end of winding is required to exceed 3,600 gramme-millimetres and all springs used in G.E.C. dials meet this with a substantial margin. In the following notes on assembly is explained a precaution taken so that the spring is not worked near the limit at which the effects of annealing are seen.

Assembly.

Assembly and adjustment of the complete dial are made on a progressive basis, small tracks being laid down the centre of each bench, along which the dials proceed as each stage is completed. Prior to commencement of the main assembly, a

f e d c b a

Fig. 8.—Stages of assembly.

number of sub-assemblies are made in order to facilitate progression along the track. These consist of the governor spindle and cup, contact springs, mainspindle, finger plate with instruction card holder, and main spring.

In the completed dial the governor spindle is held at one end by a bearing in the case and at the other by a bearing in the governor cup. These bearings are in the form of small hardened steel discs which take the thrust, and which are pressed into the cup and into a hollow screw, subsequently positioned in a lip on the case.

Assembly on the track commences with the case, the bearing holes in which are previously reamered, whilst a tap is run through all screwed holes to remove any trace of nickel plating. The case is then placed in a fixture by means of which the lip which takes the pivot bearing of the governor spindle is adjusted to correct angle.

The progressive stages of assembly are illustrated in Fig. 8. The governor and main spindle are assembled (Fig. 8b), adjustment of the position of the two brackets seen in the illustration contributing to smooth running. The dial then moves along the track for inspection in order to confirm that the gears run silently At the next point on the track the main spring is added (Fig. 8c), a lip on the cup engaging with a keyway on the spindle, whilst the inner end of the spring itself is anchored in a slot in the centre bearing. By rotating the spindle the spring is fully wound and is then allowed to unwind to the extent of two revolutions of the spindle. At this point a screw is inserted in the gear wheel to engage with the stop on the case which limits rotation of the spindle, thus ensuring that the point to which the spring is wound for maximum rotation of the finger plate (digit 0) does not approach the unstable limit shown in the curves already given.

Further progress along the track is followed by assembly of impulse and slipping cams. Since the main springs are stored in an oil bath prior to being issued to the bench, more than a drop of superfine clock oil is unnecessary when assembly is made, and, after its application, the impulse cam, carefully cleaned on fine tissue paper, is placed on the spindle. Two of the thin steel washers are then placed over the spindle, to be followed by the masking cam and remaining two washers, all carefully cleaned and examined for the slightest sign of pitting. The cam assembly is completed (Fig. 8d) by addition of the star washer and its locating washer, the arm operating the off-normal springs, and two lock nuts.

With the addition of the number ring (Fig. 8e) held by a steel wire round its circumference, the finger stop screwed to the case, and the finger plate screwed to the gear wheel, assembly is complete (Fig. 8f) and the dial moves along the track for adjustment of the contact springs. This is done in the usual way with special pliers and bending tools.

Inspection.

The tests to which the completed dial is submitted cover speed of impulsing, ratio of make and break periods and smooth running. Small electrical test sets are employed in the first two cases, the speed and ratio being indicated, but the final test is one in which are employed only inspectors who, from several years of experience, have acquired a critical touch and sense of hearing. In rotating the finger plate, the feel of the mechanism affords a criterion to the experienced inspector, whilst the sound of the gears further indicates any slight error in adjustment which may have escaped previous inspection.

Life Tests.

In addition to regular routine tests in the course of production, numbers of dials, selected at random, are subjected to life tests consisting of continuous operation by the machine illustrated in Fig. 9. In the case of each dial, a plunger acts as a finger and rotates the finger plate. The majority of tests are on digit 9 but any digit can be dialled by means of a simple adjustment to the machine. Not only is the dial subject to correct treatment but it is also maltreated by the application of undue pressure on the plunger and interference with the return motion, thus simulating service conditions at the hands of careless subscribers. The number of rotations and the number of impulses per rotation are recorded, and each dial tested is required to send 500,000 trains of 9 impulses. Such a figure represents well over twenty years of life for all normal service telephones but an indication of the small amount of wear which has then taken place is provided by the fact that dials tested to *four million* trains of 9 impulses have still been in serviceable condition.

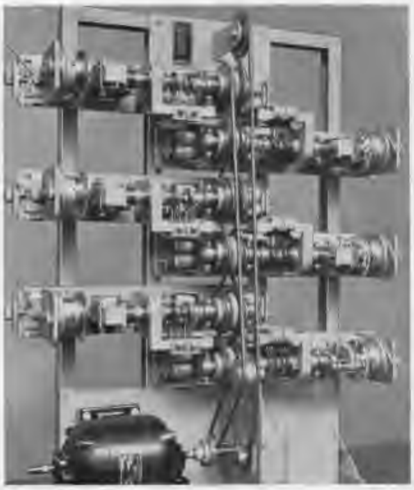

Fig. 9.—Dials under life test.

In conclusion, it may be said that the merits of the B.P.O. standard dial are primarily inherent in the design and then attributable to the manner of its production. Given the fundamentally good design, the care in manufacture and rigorous inspection described ensure that the initial and sustained accuracy characteristic of the G.E.C. product are maintained throughout an average production of 4,000 per week.