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COMMONWEALTH OF AUSTRALIA.

POSTMASTER-GENERAL'S DEPARTMENT.

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AUTOMATIC TELEPHONY.
COURSE "A."

THE MECHANICAL FEATURES AND DETAILS OF CONSTRUCTION OF THE DIAL.

It has been explained that the remote control of switches by the subscriber (which is fundamentally necessary in Automatic Telephony) is effected by means of " breaks and makes " of the current flowing through the subscriber's instrument, and in Paper No. 2 reference was made to the Dial as the means for generating the impulses.

As a dial must be fitted on each subscriber's instrument, there will obviously be a very large number used, and this, combined with the fact that they are installed in premises scattered over a considerable area, demands that they should be capable of working for a long time without attention or re-adjustment.

On account of the vital importance of the DIAL, much time has been spent on its development, and several different designs have been produced. An *ideal* dial should be :—

1. Cheap to manufacture.
2. Robust in construction and capable of standing heavy wear and tear and rough usage.
3. Simply constructed and cheap to maintain.
4. Constant in its action. The " impulse ratio " and " impulse speed " should not vary greatly with use.
5. Unaffected by dust or damp.
6. Designed so that the subscriber cannot see or interfere with any of the mechanism that can be damaged or thrown out of adjustment.

The progress made in dial manufacture has been very striking, and the design is approaching gradually nearer to the ideal. Before proceeding to a description of the mechanical construction of the Australian Commonwealth standard dial, let us consider the purpose for which it is constructed.

THE FUNCTIONS OF THE DIAL.

The chief functions performed by the dial may be summarized in the following manner :—

1. A train of impulses is sent out when the moving portion is released after having been displaced from its normal position.
2. The speed at which the impulses are sent out is kept constant by means of a governor.
3. Changes are produced in the subscriber's instrument circuit immediately the moving portion is displaced from its normal position. This is effected by means of " off-normal " springs.
4. By means of a " lost-motion " cam, it is ensured that a minimum time must elapse between the last impulse of one train and the first impulse of the succeeding train. This pause is required by the switch mechanisms for " hunting," that is, for searching for a free circuit. The necessity for this will be more readily understood when later papers dealing with the circuit operation of switches have been studied.

It is necessary to have these functions in mind when considering the parts of the dial and the purpose of each part, but it is probable that the student will more thoroughly appreciate the points whilst studying the work which follows.

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THE MECHANICAL DETAILS OF THE COMMONWEALTH STANDARD DIAL.

Fig. 1 is a drawing of the main elements of the standard dial as seen from the rear. This drawing should be read in conjunction with the photograph of Dial Auto. No. 10, accompanying Paper No. 2.

Dial Auto. No. 10 consists of a circular pressed steel case (DC), which fixes, by means of three lugs (LU) in a suitable mounting. In the case of the pedestal type of instrument, the dial is mounted in the base of the instrument, and in the case of the wall type of instrument the dial is mounted just below the transmitter. To ensure rigidity, the lower lug is furnished with a fixing screw. In the centre of the case, but out of view, is a bearing which carries the main spindle, the end of which is visible in the centre of the back view of dial. A spring, similar to the main spring of a watch, is arranged with one of its ends fastened to the dial case, and the other to the main spindle. The spring is situated behind, and is obscured by the impulse wheel (F). The spring returns the main spindle to its normal position when it is rotated and released.

In the front of the dial is a plate provided with ten holes. This plate (shown in the front view of the photograph accompanying Paper No. 2) is termed the finger-plate; it is fixed to the main spindle, and can therefore be rotated relatively to the dial case. The numbers that can be seen through the holes in the finger-plate are enamelled upon a number ring which is fixed to the dial case by means of a brass wire spring. The impulse arrangements are such that if the finger be placed in any hole, say, the hole through which the figure five is visible, and the finger-plate rotated until the finger is stopped by the finger-stop (U), then released, a train of five impulses will be sent out as the finger-plate is returned to its normal position by the main spring.

Situated behind the instruction label in the centre of the dial, is a screw which, when fully tightened, "fouls" at one point, a projection on the dial case, thus forming a normal position beyond which the finger-plate cannot be rotated in a counter clockwise direction. The screw also provides a means of applying an initial tension to the main spring. To set the spring, the instruction label is removed and the screw is turned until it clears the projection. The finger-plate is now turned in a clockwise direction until the main spring is felt to tighten, the finger-plate is allowed to return through one complete revolution when the screw is tightened.

IMPULSING AND "LOST-MOTION" FEATURES.

Fixed rigidly to the main spindle and located at the back of the dial may be seen the impulse wheel (F) and the change over arm (J). The latter keeps the "off-normal" springs (ON) separated when the dial is normal, and allows the springs to make contact when the finger-plate is rotated. The use of these springs will be fully dealt with when the circuit of the subscriber's instrument is being considered. The impulse springs (S) normally remain in contact due to the pressure applied by the impulse lever (M), which is a hinged strip—insulated—provided with a "bulge" that rests against the impulse wheel. The impulse wheel is provided with a number of indentations, and during rotation the bulge on the impulse lever drops into these indentations, thus permitting the contacts (S) to open. As the impulse wheel rotates, therefore, the springs open and close rapidly, and from this source a series of impulses are produced.

A cam (D) mounted upon the main spindle immediately next to the impulse wheel serves—

1. To prevent the impulse springs from opening when the finger-plate is being rotated from its normal position, but permits impulsing when the finger-plate is returning to normal under the influence of the main spring.
2. To provide a minimum time interval between impulse trains.

(D) is termed the slipping cam; it is not fixed to the spindle, but is pressed into intimate contact with the impulse wheel by the spring washer (X). The fibre washer (XW) between the spring washer and the slipping cam prevents excessive wear of the latter and keeps the retarding force constant. As the finger-plate is turned in a clockwise direction, the impulse wheel and slipping cam will move round (the direction will be counter clockwise if the dial is viewed from the back) until the projection (D1) encounters the forked stop (E), when the cam is stopped and commences to slip in relation to the impulse wheel. During the whole of this forward movement, the cam serves to screen the impulse lever from the indentations on the impulse wheel, thus preventing the transmission of impulses. When the finger-plate is released, the cam will move with the impulse wheel until the projection (D2) encounters the forked stop, when slipping takes place during the remainder of the motion. With the slipping cam in this position the impulse lever is not screened, and consequently the impulse lever will engage the indentations, and impulses will be produced. The portion of the return movement prior to this slipping, during which the cam screens the indentations, is termed the "lost-motion" period and provides the minimum time period necessary between impulse trains. The dial is so designed that the impulse wheel is screened while two indentations pass the impulse lever, thus the "lost-motion" period has a duration of about 0·2 secs. The time interval between successive trains of impulses, therefore, is equal to the time occupied by the subscriber in turning the finger-plate and releasing it, plus 0·2 secs.

By releasing a screw, the position of the forked stop can be altered so that the projection (D2) lies between the fork, and if secured in this position the scope of the slipping cam is materially reduced, being only sufficient, under these conditions, to allow such movement as will prevent impulsing during the forward operations of the finger-plate, but is insufficient to cause "lost motion" during the return of the finger-plate. This feature is introduced so that the dial may be used on Automatic systems where the "lost-motion" feature is not required (the Western Electric Company's Rotary system is a notable example). As the elimination of the "lost-motion" feature will introduce two additional impulses per train, owing to the fact that the impulse wheel is unscreened during the whole of the time that the finger-plate is returning to normal, a compensating arrangement must be provided. This is effected by moving the finger-stop to an alternative position such that the travel of the finger-plate is reduced by an amount equal to two impulses. A second set of holders for fixing the finger-stop are therefore provided which can be seen in the back view of the dial, near the edge of the dial-case, in the photograph accompanying Paper No. 2.

IMPULSE SPEED CONTROL.

This is effected by means of a spring-controlled friction governor. Immediately behind the finger-plate, and like it, secured to the main shaft, is a toothed wheel. This meshes into a pinion wheel, which in turn meshes into a worm on the governor spindle (GS). The teeth of the pinion wheel can just be seen in the back view of the dial.

The governor spindle carries two flat springs having brass weights at their ends. These pass inside a casing against which they are pressed by centrifugal force as the spindle rotates. The faster the dial tends to move, the more the weights try to fly out and the greater is the friction between them and the inside of the casing, thus tending to slow down the dial speed. By this means the speed of rotation is kept constant at a value depending upon the initial "set" or tension given to the governor springs. The normal speed of impulsing is ten impulses per second, but this will vary, of course, as the main spring loses tension or as the friction of the governor alters with use. Although the switches are capable of working with speeds of from 7 to 14 impulses per second, the dial speed should be kept between 9 and 11 impulses per second, in order to allow a working margin. If, under test, the speed is found to be outside this range, it can readily be corrected by bending the governor springs inwards or outwards according to whether the speed is "slow" or "fast."

DIAL AUTO. No. 24.

This differs from the Dial Auto. No. 10 in many ways, the following points being of particular importance:—

1. Includes a ratchet.
2. Governor rotates in one direction only.
3. "Lost motion" is at end of a train of impulses instead of before.
4. Impulsing by means of a two-lobed cam instead of an impulse wheel.
5. Has spiral spring to control return motion instead of clock spring.
6. Has no slipping cam or friction washers.
7. Ratio of 1·6 : 1 instead of 2 : 1.
8. "Lost motion" of 1 impulse instead of 2.

The plate accompanying Paper No. 2 shows a rear view of this dial. The shunt cam assembly which controls the operation of the auxiliary springs is definitely fastened to the finger-plate—a pressed metal stamping in this case—and on the forward motion in dialling this assembly moves its two cams, one allowing the two make springs of the "off-normal" assembly to operate as in the standard dial, the other cam allowing the impulse springs to come to a position so that the longer spring is in the path of the impulsing cam. The forward motion also winds up the spiral spring on the centre shaft and moves the ratchet pawl around the teeth to the desired position.

On the return motion of the finger-plate the pawl engages the ratchet to operate the governor and impulse cam which rotates to transmit the desired number of breaks. One more impulse than that pulled would be sent if it were not for the cam on the shunt cam assembly which comes into contact with the impulse springs before the final impulse is sent and pushes both springs away to continue the make period and put the long spring out of engagement with the impulse cam. The "lost-motion" time period is thereby given at the end of each train.

A governor is included which acts in the same manner as described for the Dial Auto. No. 10.

The above descriptions deal with two typical dials. Slight variations are made by the different manufacturers, but the information given above will serve as a basis for appreciating the action and construction of any make.

THE SUBSCRIBER'S INSTRUMENT.

In appearance the subscriber's instrument for use in an automatic area differs from the equivalent manual (central battery) subscriber's instrument only in the addition of the dial. As previously explained in the case of table type instruments, the dial is placed in an opening provided in the base of the instrument. With a wall type of instrument, the dial is fixed in a special mounting fastened to the front of the instrument immediately below the transmitter.

The functions to be performed by the subscriber's instrument are :—

1. To provide a means of signalling the exchange when it is desired to make a call.
2. To cause fluctuating currents to flow in the line when speech waves reach the transmitter.
3. To produce audible sounds in the receiver when fluctuating currents flow in the line.
4. To provide a means by which the subscriber can be rung when required.

With regard to 2, 3 and 4, the circuits employed are identical in both automatic and manual working, so that the only difference between them is with regard to 1, i.e., the signalling arrangements.

In manual working, the act of lifting the receiver completes a loop across the lines, operating a relay in the exchange and lighting a calling lamp. In automatic working, a loop is formed across the lines when the receiver is lifted. This loop results in the "seizing," of a switch, and it is then necessary for the calling subscriber to route his own call by breaking and making the current flowing round the loop, by means of the dial on his instrument. It is obvious, therefore, that the loop must pass through the impulse contacts of the dial, in order that the opening and closing of these contacts may make and break the current flowing. The simplest method of connecting the dial would be to connect the impulse springs in one of the lines, as shown in Fig. 3. This method, which has been used in practice, has several disadvantages, the most important of which are—

(a) Loud clicks would be heard in the receiver when dialling occurs.

(b) High voltages are produced between the line wires each time the contacts of the impulse springs open, owing to the self-induction of a signalling relay in the switch circuit. The current fed to the loop passes through the windings of this relay, and consequently a high back E.M.F. is produced every time the circuit is opened.

(c) In the case of table type instruments, a 4-wire cord would be necessary between the bell-box and the telephone.

The disadvantage under (a) can readily be overcome by providing spring contacts on the dial, which short-circuit the receiver immediately the finger-plate of the dial is moved from its normal position. In the description of the dial, reference was made to "off-normal" springs of this type. Various alternative schemes have been suggested to eliminate the disadvantages indicated under (b) and (c), some of which introduce other disadvantages such as :—

(d) Distortion of the ratio of "break" to "make" resulting in a decrease in the maximum length of line through which dialling can take place successfully. This matter will be dealt with at some length in a later Paper.

(c) Tinkling of the telephone bell during dialling. If the dialling conditions are as shown in Fig. 4 (which would be the case if the impulse contacts were connected in series with the transmitter, and the receiver disconnected during dialling by " off-normal " springs) the condenser would be rapidly charged and discharged during dialling, resulting in tinkling of the bell. As the pull on the armature of the bell is greater during the discharge of the condenser than during the charge, tinkling can be overcome to a certain extent by means of a spring (called a bias spring) which presses the armature of the bell against that pole piece to which it would be attracted by the stronger " kick." The bell will not tinkle unless the weaker " kick " is sufficiently strong to overcome the pull of the spring. Care must be taken in adjusting the tension of the spring under biasing conditions, to ensure that the efficiency of the bell, from the ringing point of view, is not impaired, and the disadvantages of this method of suppressing tinklings is that the margin of adjustment is not large.

The circuit finally made standard is shown diagramatically in Fig. 3, the actual connexions of a table set being given in Fig. 6. When the finger-plate is displaced from its normal position the " off-normal " springs make contact, thus short-circuiting both the transmitter and receiver. The manner in which the disadvantages of other circuits have been overcome by this circuit will be seen from the following :—

1. The receiver is short-circuited during dialling; thus there is an absence of clicks in the receiver.
2. It has been found that with the circuit shown in Fig. 4, the maximum voltage that is produced between the lines during dialling is 700 volts when the line resistance is very low. If the shunt across the dial contacts due to the bell and condenser be removed, the voltage rises to 900. If the bell is short-circuited, the maximum value falls to about 180 volts. It will be seen from Fig. 5 that with the standard circuit the dialling condition is practically equivalent to the bell being short-circuited, while the condenser (2m.f.) is connected across the dial springs. The maximum voltage on zero line conditions therefore is about 180 volts.
3. A 3-wire cord only is necessary between the table set and the bell-box.
4. Very little distortion occurs.
5. The bell does not tinkle during dialling, owing to the shunt formed by the low resistance windings of the induction coil.

It will be seen that the circuit adopted is satisfactory from all points of view.

The standard telephone, just discussed, provides for the most efficient transmission on lines, the D.C. resistance of which does not exceed 300 ohms. At this value of line resistance the current passing through the transmitter is approximately 50 milliamperes, and any decrease in this current value is liable to render the transmitter, and consequently the telephone, less efficient.

It may be accepted, however, that it is practicable to satisfactorily operate the standard automatic switching equipment which accepts the dialled impulses over lines of much greater resistance than the 300 ohms which gives the most efficient transmission.

Means for dealing with the special transmission conditions of lines beyond the resistance stated will not be discussed at this stage

FIGURE No 1.

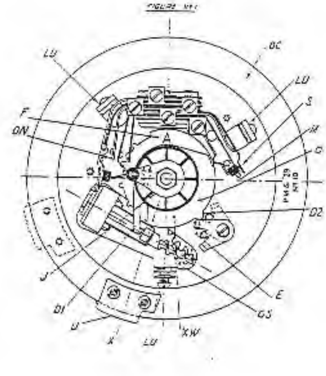
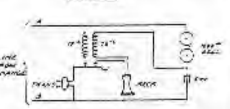
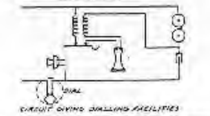


FIGURE No 2.



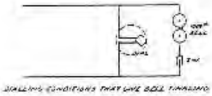
TRANSMITTING, RECEIVING & RINGING CONDITIONS IN AUTOMATIC & MANUAL 1925 CIRCUITS

FIGURE No 3.



CIRCUIT GIVING DIALLING FACILITIES

FIGURE No 4.



DIALLING CONDITIONS THAT GIVE BELL TINKLING

THE SUBSCRIBER'S INSTRUMENT.

The A.T.M. Co.'s series instrument has hitherto been considered, as its dialling conditions are equivalent to the dial contacts being connected across the lines. This circuit is not standard in Australia; a circuit identical as regards speaking, ringing, and listening conditions to the standard C.B. instrument has been adopted.

The standard telephone (Tele. with Dial Auto. No. 10) has already been described, and a diagram of the connexions has been given. The dialling conditions are reproduced in Fig. 3, which also shows the dialling conditions of the series instrument and the former post office standard instrument (the dial has a change-over off normal spring assembly generally termed the 4-point dial). It will be seen that in the case of the standard and the 4-point telephone which refers to the whole circuit associated with the 4-point dial shown in Fig. 3, the bell and condenser are connected across the lines, but that in the former the 26-ohm winding of the induction coil is connected across the bell coils.

The following table gives the impulse ratio figures for each instrument, with zero loop and 750-ohm non-inductive line :—

Table B.

—	Line Resistance.	A Relay Operating Lag.	Release Lag.	Per cent. make A Relay.	Amount of loss due to Distortion.
				Contact.	
Series	0 ohms ..	7 millisecs. ..	8 millisecs. ..	34	1 millisec.
Tele. 4 pt.	0 ,, ..	8 ,, ..	20 ,, ..	45	12 millisecs.
Standard	0 ,, ..	8 ,, ..	12 ,, ..	37	4 ,,
Series	750 ,, ..	9 ,, ..	5 ,, ..	29	4 ,,
Tele. 4 pt.	750 ,, ..	10 ,, ..	17 ,, ..	40	7 ,,
Standard	750 ,, ..	10 ,, ..	13 ,, ..	36	3 ,,

The tabulated results are also shown in graphical form in Fig. 4 covering a range of line resistances.

It will be seen that the series instrument gives the least distortion. The standard circuit gives a little more and the 4-point telephone gives the most of all. The reason for the distortion is due to the large release lags, especially in the last two cases. The operating lag is practically the same for all three, for when the impulse springs close they become practically identical, viz., a short-circuited line. Immediately the impulse springs open, the current will cease to flow in the case of the series instrument, but, in the other two cases, an unchanged condenser is suddenly connected across the lines, and consequently a charging current will flow for a short time, thus delaying the release of the impulse relay. The quantity of electricity required to charge the condenser must be the same in both cases, but with the 4-point dial circuit the bell is connected in series with the condenser, and the impedance of this will slow down the charging current. Consequently it will flow for a longer time in the case of the 4-point telephone circuit than in the case of standard circuit. The difference in the rate of "charging up" the condenser is shown by the release lag figures in the two cases, viz., 20 and 12 ms. respectively.