The Evolution of the Strowger Dial

Some Highlights of the Development of the AutomaticElectric Inc. Dial. Excerpts From a Paper Presented Before the Society of Automatic Telephone Engineers at Chicago, on Thursday, March 3rd

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WHEN the automatic telephone user operates the dial on his telephone, he seldom gives thought to the years and years of experimentation, trial and development that has produced this seemingly simple and practically trouble-proof device. Even if he does think about it at all, or wonders how it works, he probably fails entirely to realize the importance of this little mechanism, and that it must do a number of things with scientific exactness and with absolute uniformity over its entire lifetime of many years, without any attention. The fact is that years of research and experimentation have been necessary to produce, by practical manufacturing methods, a dial which is capable of performing its necessary functions reliably over long periods of time without attention.

The history of the development and perfection of the automatic dial, from its crude beginnings to its present state of perfection, as exemplified in the Type 24 dial, is one of the most interesting stories in the whole field of automatic telephony.

In this paper are described and illustrated some of the outstanding improvements that have characterized the development of the dial by the engineering staff of Automatic Electric Inc.

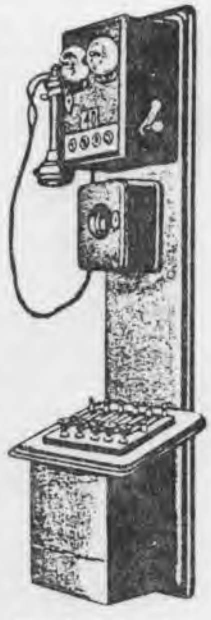


Fig. 1—One of the First Automatic Telephones, Showing the Push Buttons For Calling.

In the earlier days of the history of the Strowger Automatic telephone system, both the vertical and rotary motions of all central office switches were directly controlled by dial impulses. It was not until the year 1899 that the rotary motion became automatic.

The first public installation of Strowger equipment took place in 1892 at La Porte, Indiana, 400 years after the landing of Columbus. Figure 1 shows the type of calling device used in the first installation. This consisted of a series of telegraph sending keys; reading from left to right they were thousands, hundreds, tens, units and release. In calling a number, for instance, 232, the hundreds button was pressed twice, the tens button three times and the units button twice. There was no time element as to the rate of impulses, as the magnets were operated directly from the push buttons. In order to release the switch, the release button was depressed for an instant, thereby restoring the switch to its normal position, the receiver hook merely controlling the local battery talking circuit.

Figure 2 illustrates the first dial type of calling device made, which employed an oscillating motion as well as governing means to control the speed of the impulses. This type of dial was made in the year 1895 and was installed in Wilwaukee, Wis. The finger dial consisted of a cast brass plate having perpendicular fins which were called "finger holds." When the dial was in a normal position the abbreviation "TEL." was visible through the slot of the stationary portion of the dial, which served as a finger stop. When the first digit was dialed, the action of the ratchet wheel (known as the "star" wheel), shown in the rear view, moved the segment bearing the word "TEL." to another position and the word "hundreds" appeared. When the next digit was dialed the ratchet wheel advanced to another position, when the word "tens" appeared. Dialing the final digit of the number revealed the word "units."

This dial was operated by means of a clock spring using the escapement type of governor, the latter constituting one side of the impulse circuit. The platinum foil, seen on the left arm of the governor, made contact with the spring shown just below it. In order to disconnect the switches it was necessary to restore the receiver to the hook, simultaneously restoring the star wheel to its normal position, the word "TEL." again

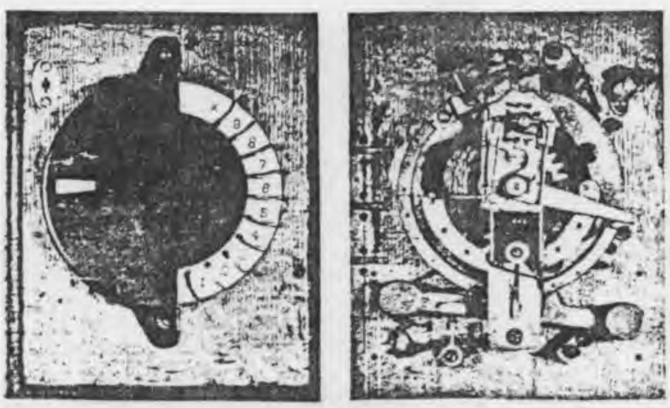


Fig. 2—The First Dial—1895.

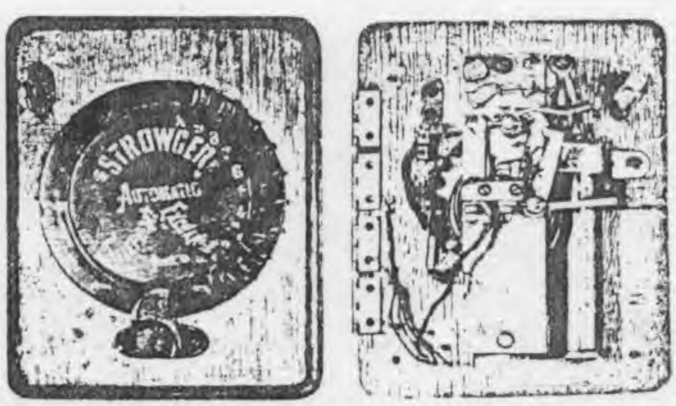


Fig. 3—The 1896 Dial.

Fig. 4—The First Dial With Friction Governor—1897.

becoming visible through the opening. This was the first dial made in which the finger was used to call a number, and in which the impulses corresponded to the figures dialed. The patent was broad enough to prohibit anyone making a dial so operated.

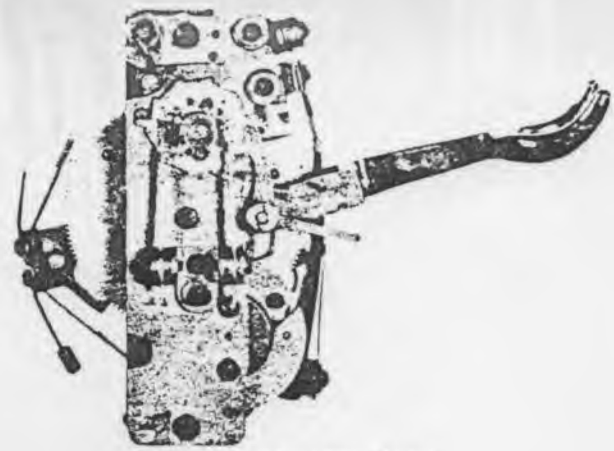


Fig. 5—The 1899 Model.

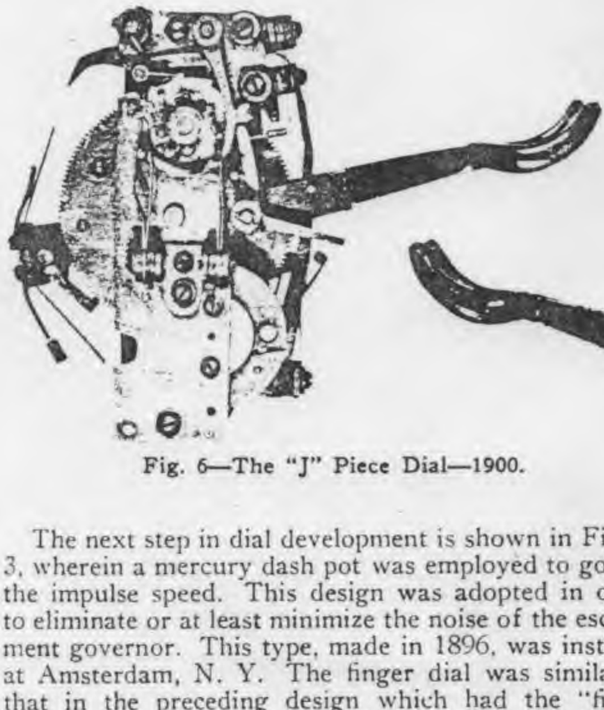
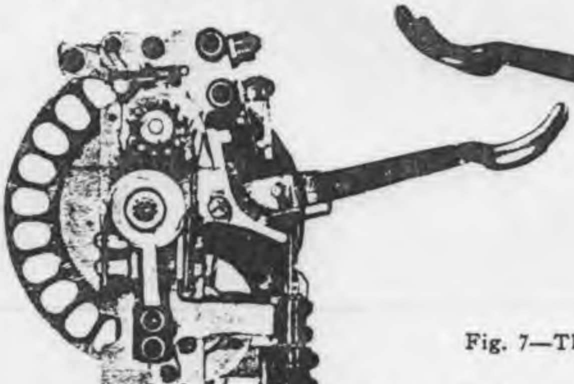


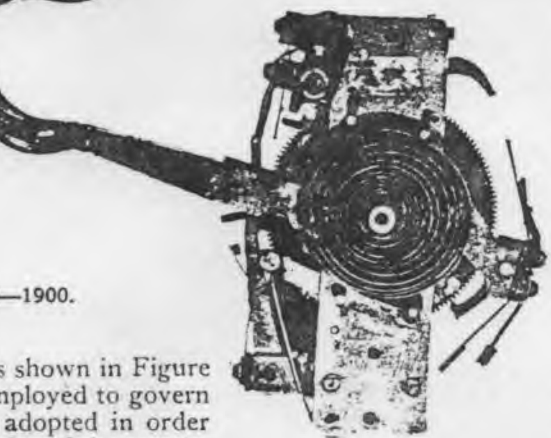
Fig. 6—The "J" Piece Dial—1900.

The next step in dial development is shown in Figure 3, wherein a mercury dash pot was employed to govern the impulse speed. This design was adopted in order to eliminate or at least minimize the noise of the escapement governor. This type, made in 1896, was installed at Amsterdam, N. Y. The finger dial was similar to that in the preceding design which had the "finger holds," and was made of cast iron and japanned. The impulses were made by an oscillating type of cam operating in one direction only, that is, upon the return stroke. The star wheel arrangement, controlling various circuits, will be noted.

Figure 4 shows the first friction governor type of dial, brought out in 1897 and installed at Augusta, Ga. The finger dial of this calling device was the same as the one illustrated in Figure 3, and impulses were secured in a similar manner. However, a gear-driven friction governor was used to control the impulse spe[illegible]d. It will be noted that th[illegible] receiver hook has an exceptionally long stroke, the [illegible]rpose of which was to secure sufficient releasing ti[illegible] [illegible]or the switches, as the latter at that time were re[illegible] by first energizing the rotary



magnets, holding them energized, and then energizing the vertical magnets. The switches had neither relays nor release magnets. They consisted of a pair of rotary magnets, a pair of vertical magnets and a private magnet, the releasing of the switch being accomplished by a cam action which became effective when the rotary member was held in an operated position. Thus, when the vertical magnet was then operated, the vertical pawl did not engage with the ratchet teeth, but unlocked the double dog and thereby allowed the shaft to be returned to its normal position by means of the rotary spring and gravity.



At that time, the first automatic desk phone was made by taking the wall telephone, which is shown in Figure 4, and mounting it on a pedestal.

The year 1899 witnessed some marked changes in the Strowger system. Up to this time there had been no automatic selection of trunks. In this year, also, relays were added to the

Fig. 7—The "Fall River" Dial—1901.

switches so that the dial impulses did not directly operate the magnets bu[illegible] [illegible]perated the relays, which in turn operated the m[illegible] [illegible]s. The release magnet, too, was added to the St[illegible] [illegible]r switch, and, though it may at first seem that the [illegible]ch became complicated at this time, it was in realit[illegible] [illegible]plified in its mechanical action.

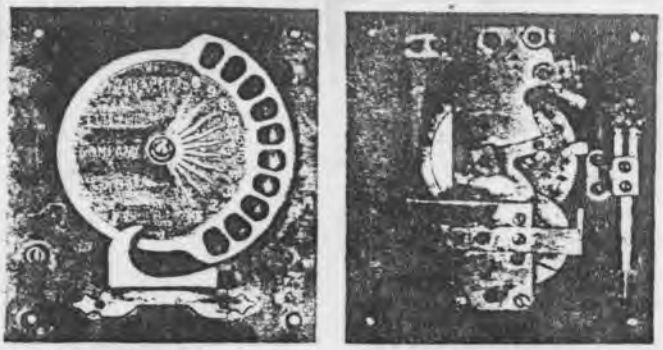


Fig. 8—The Dial First Installed at Dayton—1903.

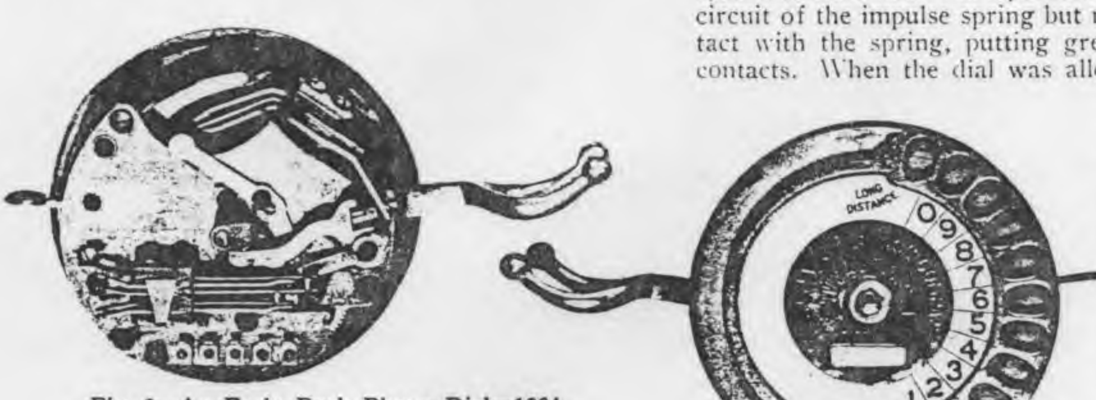


Fig. 9—An Early Desk Phone Dial—1904.

Figure 5 shows the dial made in this year and installed in Berlin, Germany, and in Ithaca, N. Y. In order to secure automatic selection of trunks, "0" was dialed after the first figure. For instance, if number 212 were being called, the digits 2012 were dialed, the "0" being used to deliver ten impulses for the selector rotary action. If the first trunk were not busy, the nine remaining impulses would not move the switch, but it was necessary to dial or call the "0" in case the nine trunks were busy. It will be noted in referring to Figure 5 that the receiver hook is under control of the same governor controlling the dial impulses, the slow release not proving entirely satisfactory in the model shown in Figure 4.

A further change of importance in the Strowger system occurred in the year 1900. This provided for the automatic selection of trunks without the dialing of an additional digit over the called number in order to secure automatic rotation of the switch shaft. This dial is shown in Figure 6 and was known as the "J piece" dial, because the arm which functioned in order to start the rotating of the switch was similar to the letter "J" in shape. This type of dial was installed at New Bedford, Mass.

Figure 7 shows the type of dial made in 1901 and installed in Fall River, Mass. A commutator was substituted for the "J" piece, performing the same function in a more reliable manner. The finger dial, it will be seen in this picture, was a die casting with elongated holes. The impulsing arrangement was controlled by means of a long impulse spring operated by an impulse disc which had ten prongs each bent at an angle, so that when the dial was operated it did not break the circuit of the impulse spring but merely came into contact with the spring, putting greater pressure on the contacts. When the dial was allowed to return to its normal position, the impulse spring was moved away from its stationary contact by the impulse segment.

Figure 8 shows the dial made in 1903 and installed at Dayton, Ohio, and Chicago, Ill. The springs shown in this dial were not complete, but the essential parts are shown. The impulsing arrangement was similar to that used in the preceding model, and automatic rotary movement of the switches was accomplished by means of a long spring similar in form to the impulse spring which made a circuit and broke it once for each digit called. This replaced the commutator which had been used for the same purpose.

The first desk phone of any consequence was made in the year 1904 and naturally called for a redesign of the dial in order to comply with the requirements of a desk instrument. This dial is shown in Figure 9.

Fig. 10—The Three-Wire Dial Which Immediately Preceded Two-Wire Development—1905.

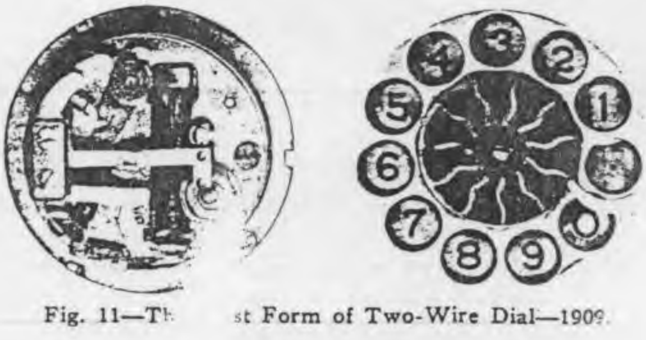


Fig. 11—Th[illegible]st Form of Two-Wire Dial—1909.

The finger dial was a brass stamping and 11 finger holes were used in order to separate "long distance" from the "0." However, the ten impulses could be delivered by the "0" or by "long distance." The holes were separated to avoid confusion on the part of the subscriber when calling a number which contained "0." This dial had two "normal" positions, with the receiver removed from the hook, the lever, which is shown on the rear of the dial, remained in its normal position, thereby locking the ringing button lever, so that it would not be possible for it to ring before a number was called. When the dial was displaced from the normal position, as in calling a digit, the first-mentioned lever moved about one-quarter inch in an upward direction and remained in this position while the other digits were being dialed. While in this position, it freed the ringing lever so that after calling the desired number the push button became operative, thus establishing the ringing. To release the switches, the receiver was restored to the hook and, during the last quarter inch of its stroke, the locking lever became disengaged causing a slow release which could not be forced. The locking lever was also under control of the governor, which was of the friction type.

Figure 10 shows a later type of three-wire dial. This was made in the year 1905 and was similar to the one shown in Figure 9, except that the locking lever was eliminated and the busy button separated from the dial

Fig. 12—A Later Form of Two-Wire Dial, the Forerunner of the Present Models—1911.

Fig. 13—The First Two-Wire Dial Featuring the Separate Shunt Spring Group—1918.

and mounted on the base, in the desk models, and on the front of the wall models. The reason that the two-wire type of dial cannot be applied to three-wire operation in the wall and desk phone is because, due to the slow release necessary for the three-wire switches, the receiver hook must be under control of the governor, which is rather difficult of accomplishment with the two-wire dial.

The first two-wire dials were modified three-wire dials similar to that shown in Figure 8; however, production of two-wire dials on a commercial scale did not take place until the year 1909. The outstanding feature of the dial shown in Figure 11 is that it was non-forcing. The finger dial was operated in a clockwise direction only. When the finger approached the finger stop, another lever just below hole "1" was automatically carried along to the finger stop locking the dial, against release until it had performed its cycle of operation. When this was completed the auxiliary lever returned to its normal position, freeing the dial for further calling. This dial was a forerunner of our present model and contained two fundamental principles which our experience has proved to be correct in dial operation. These are:

First—the uni-directional impulse cam.

Second—the high-speed, worm-driven governor.

The uni-directional impulse cam gives the most uniform impulses due to the fact that the wear is uniform throughout its entire life. In the earlier models the segment type of cam, having a total of ten segments, was used. It can readily be seen that the first segments were used considerably more than the tenth segment. As a result the first impulse could not remain the same as the tenth impulse due to unequal wear. In addition, the friction governor was driven by spur gears and was of considerable weight. The worm gear type of governor was chosen in order to obtain a uniform, uninterrupted drive. High speed is essential for sensitive governing. The worm drive exerted the greatest back pressure of any of the governors when an attempt was made to force the dial. The impulses on this dial were obtained by the cup-shaped cam which raised and lowered one of the impulse springs allowing it to be displaced from, and again brought into contact with, its mate spring.

In order to simplify the dial shown in Figure 11, as well as to make it more reliable, in 1911 it was redesigned to that shown in Figure 12. The finger dial reverted to some of the principles applied to the very earliest models, that is, it was an oscillating type. However, the uni-directional cam was retained, naturally

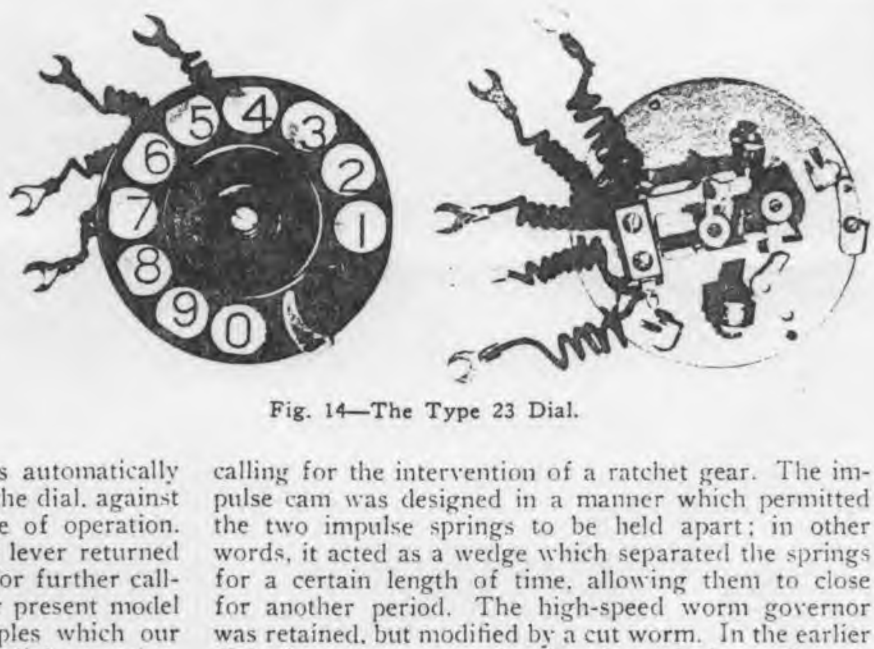


Fig. 14—The Type 23 Dial.

calling for the intervention of a ratchet gear. The impulse cam was designed in a manner which permitted the two impulse springs to be held apart; in other words, it acted as a wedge which separated the springs for a certain length of time, allowing them to close for another period. The high-speed worm governor was retained, but modified by a cut worm. In the earlier dials the worm was made of a piece of piano wire spiralled around the shaft. This was a rather difficult construction from a manufacturing standpoint.

In 1918 further improvements were made. In Figure 13 it will be seen that the shunt spring group was separated from the impulse spring group. This was done to avoid the critical adjustments between a shunt spring and its corresponding impulse spring, as in the shown in Figure 12, in which the lower shunt spring made contact with the upper impulse spring. The ratchet arrangement of the main gear was also changed, the clock spring was eliminated and a hardened dog held by a phosphor bronze spring was substituted. In addition, the finger holes in the finger plate were enlarged to one-half inch in diameter (the previous holes were $\frac{13}{32}$ inch), to permit of more convenient operation of the dial, as well as greater visibility for the numbers.

Still more improvements were brought about in 1923; the laminated worm wheel and ball-bearing governor were introduced. This model is shown in Figure 14 and is known as Type 23. The earlier models of the small type used a jewel bearing to counteract the thrust of the worm. In order to secure a more uniform type of thrust bearing, and to eliminate the difficulties encountered by soft jewels and uncertainties of jewel bearings in general, the ball-bearing type was substituted. The thrust bearing consisted of a ball race, hardened, highly polished and concaved, and a single very high-grade steel ball held loosely in position between the hardened, highly polished end of the worm and the ball race. This type of bearing has been subjected to innumerable tests one of which represented over seven hundred million revolutions, proving it to be the most suitable type of thrust bearing for this purpose.

The design of the governor wings was also altered, phosphor bronze formed in a cup shape being used, and the fly balls made of brass with an insert of fiber. This construction entirely eliminated any abrasive action between the fly balls and the governor cup. The laminated type of worm wheel was substituted for the solid bronze type. This consisted of two bronze discs inclosing a fiber disc. After being cut the worm wheel was subjected to a temperature high enough to exclude moisture, and then treated in oil in order to prevent further absorption of moisture. The laminated worm wheel absolutely prevented sticking between the worm and worm wheel, which was important since a dial is expected to operate satisfactorily for a great number of years without additional lubrication. The main spring was changed to a uniform diameter throughout its entire length, and the lever arm for the shunt springs was altered in order to secure a more positive action, as well as to make it easier to tension the main spring. It will be seen, also, in referring to Figure 14, that the escutcheon for mounting the escutcheon cards was improved.

In 1926, the Type 24, which is shown in Figure 15, was produced, and has proved to be the most easily operated, most quietly running dial ever manufactured. The design incorporates features which prevent any tampering with the mechanism, as the design is such that the dial cannot be taken apart without first removing the escutcheon. In order to do this it is necessary to know how it is done, as there are no visible means to indicate the method used. The escutcheon ring cannot be pried off. The finger dial is made of brass punched and formed to shape, which results in a very strong, light-weight finger dial. The same type of governor and laminated worm wheel is used in this dial as in Type 23. The impulse cam, as well as the impulse and shunt springs, have been improved, having been changed to [illegible] position perpendicular to the face of the dial, [illegible]hereby minimizing trouble from dust as well as [illegible]wing greater visibility for making adjustment[illegible] [illegible] addition, screw terminals are used on the s[illegible], eliminating the soldered cords used on the ea[illegible] [illegible]odel. The impulse cam is punched and shaved f[illegible] [illegible] fiber; by this method all cams

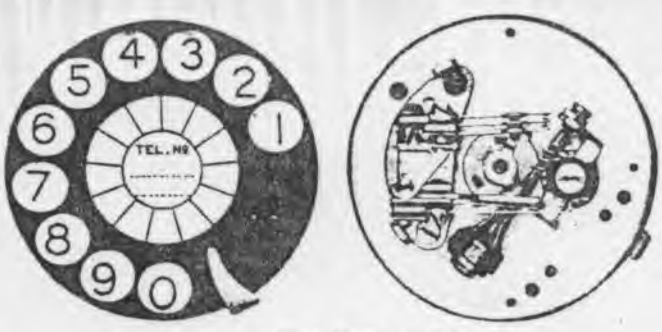


Fig. 15—The Type 24 Dial.

are exactly alike as they must conform exactly to the contour of the die. The pinion bearing has been made in the form of a bridge and riveted firmly to the base plate, making it impossible for this bearing to get out of line. The springs are mounted on a detachable unit, doweled to the base plate, and held by means of two screws. The picture shows a Type 24 delayed impulse dial.

That the Type 24 delayed impulse dial has approached more nearly to what might be termed practical perfection has already been amply proven by both everyday use and laboratory tests. In a series of exhaustive tests made upon Type 24 dials drawn from manufactured stock, some very remarkable records were established. Of three dials tested, by being turned mechanically from "0" to the finger stop and then released, delivering each time the equivalent of ten impulses, one withstood more than 5,000,000 operations, one more than 6,000,000, and the third accomplished more than 7,000,000 operations when the test was stopped and the dial dismantled for inspection. These dials were tested exactly as received, with no additional lubricant or special adjustments at any time. As several countries now specify 500,000 operations from "0" without failure, as the minimum standard of performance for stock dials, it can be seen how much superior to ordinary standards the Type 24 dial is.

A great amount of development work has been crowded into the thirty-five years which have elapsed since the first automatic telephone was made. Those who are engaged in the work are by no means convinced that the next three decades will not see further important changes, but in its basic elements the design of the dial seems to have arrived at a point where it can be said that the major problems have been brought to their ultimate solutions and where the difficulties which confronted the pioneers have been overcome for all practical purposes.