Calling Subscribers to the Telephone

By L. J. STACY
Local Systems Development

SOME form of alternating current has been used since 1878 for calling subscribers to the telephone. In that year Thomas A. Watson devised the plan of connecting in series with the line at each station a polarized ringer — an electric bell polarized for operation on alternating current. Ringing current was provided by a hand-driven magneto generator. That arrangement was the best available for a number of years, but even when the resistance of each ringer was kept at a minimum, the resistance of a line with many stations was made great enough by the series connection to hinder the transmission of voice currents. In 1890 John J. Carty overcame that difficulty by connecting a subscriber set containing a generator for calling the operator and a high-resistance ringer across the line at each station, rather than in series. That plan was commonly known as the "bridging" bell system. On account of the low frequency of the ringing current and the high voltage it could be given, it was possible to use ringers whose impedance to voice currents was high enough for the requirements of speech transmission on the line.

In spite of the many changes that have since taken place in the telephone plant, the methods of ringing now used have developed directly from those of 1878 and 1890. The simplest conditions of today are presented on so-called rural lines — party lines with a large number of subscribers, usually in the country. On these lines the ringing system now in general use is that brought out by Mr. Carty. At each station a polarized ringer is connected across the line, or from one side of the line to ground, and when ringing current is applied, it flows through and operates all or half of the ringers, depending on the connection. A code is used, with an individual combination of long and short rings assigned to each subscriber. For comparatively short rural lines having a small number of stations, ringers of 1000 ohms resistance and hand gen-

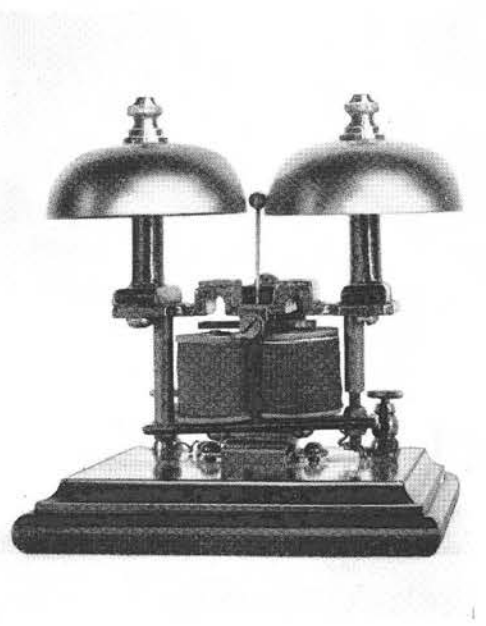

Fig. 1 — Watson's polarized ringer

erators having three permanent magnets are commonly used. If longer lines or more stations are involved, it is necessary to use ringers of higher efficiency, with 2500 ohms resistance,

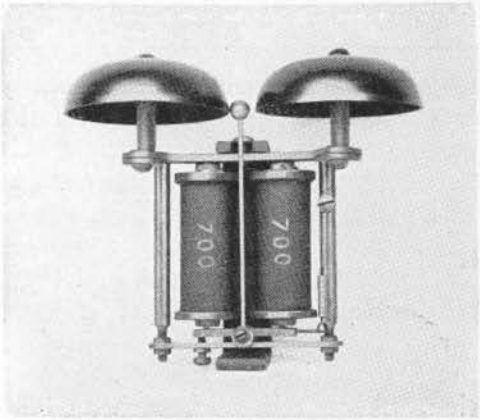

Fig. 2—A polarized ringer of today, 8-A

and hand generators built with five magnets, giving higher output voltage.

In larger offices, where it became desirable to use a battery common to all subscribers' lines for talking and for attracting the operators' attention, several changes in the ringing system became necessary. Normally the central-office battery is continuously connected to each line. With ringers connected directly to the line at the stations there would be a continuous flow of direct current, which if large enough would keep the line relay operated and the signal lamp in front of the operator lighted, just as if the receiver were left continuously off the hook. That was avoided, at first, by using ringers of sufficiently high resistance. Subsequently the constant flow of battery current was prevented by connecting a condenser in series with each ringer. Thereupon the ringers were adjusted to prevent tapping during the surge conditions accompanying charge and discharge of the condensers in the ringer sets.

At an early stage in telephone history selective ringing — ringing of one station only — was offered on two-party common-battery lines. Each ringer was connected from one side of the line through a condenser to ground; alternating current applied between ground and either side of the line passed through one ringer only. Semi-selective ringing was given on four-party lines by the same arrangement, but with two ringers connected from ground to each side of the line. Then ringing current sent out on one side of the line operated both of the ringers connected, and a simple code was used to indicate which of the four subscribers was wanted.

The first commercial system giving

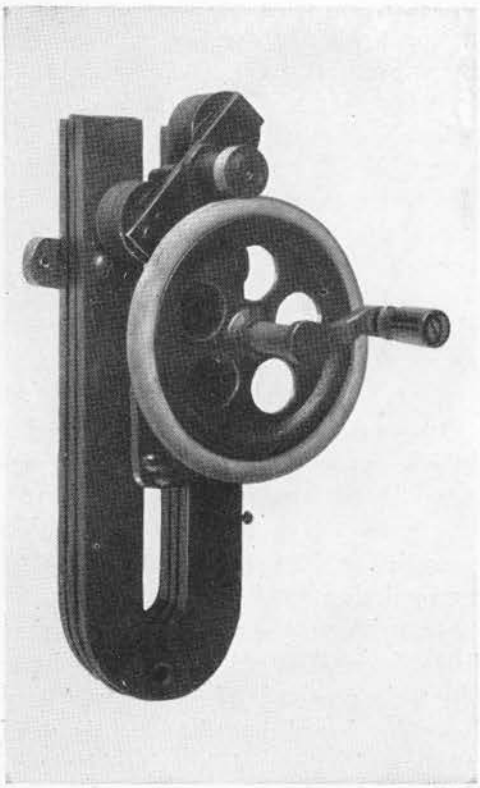

Fig. 3—Watson's hand generator

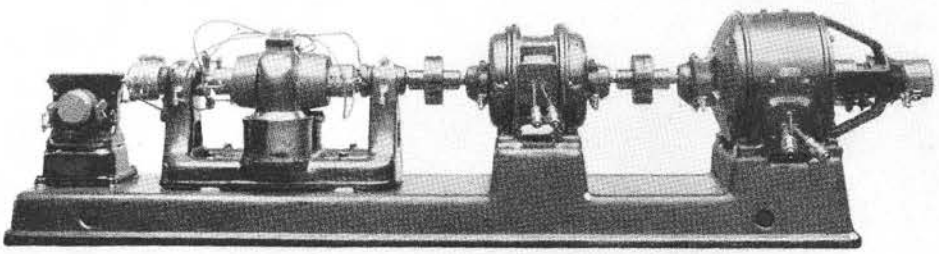

Fig. 4—A modern ringing machine

selective ringing for four-party magneto lines was patented in 1896 by Angus S. Hibbard of the Chicago Telephone Company. Two ringers were connected from each side of the line to ground as before, but the connections made to them were of opposite polarity, and ringing was accomplished by pulsating current — either the positive or the negative half-waves of alternating current. When pulsating current of either polarity was applied to one side of the line, it passed through both ringers to that side. On one ringer, suitably poled, each pulse pulled the armature against the tension of the biasing spring so that the clapper struck the gongs, but on the other ringer the pulses pulled in the same direction as did the spring, so that the armature remained at rest against the stop. When used on common battery lines a resistance was placed in series with each ringer to prevent operation of the line relay; there was however a leakage path for battery current at each station. Although still used to some extent in its original form on magneto lines, this ringing system is of interest principally as the forerunner of the better systems in use to-day.

To remove the direct-current path from each side of the line to ground through the ringers when applied to common-battery lines, a system using a relay at each station was devised in 1899 by G. K. Thompson. The ringer at each station was connected from line to ground through the contacts of a relay whose winding was connected across the line in series with a condenser. With the relays normal the ringers were disconnected, but when pulsating current was sent out the relays at all four stations operated and connected the ringers as in Hibbard's system; then the pulsating current flowed through the two ringers on one side of the line to ground and operated the ringer for which the pulsating current was suitable. In offices using this system, however, ringers on individual lines were connected across the line in series with a condenser, as before. Alternating current was used for these, since it is somewhat more satisfactory than pulsating current for operating ringers connected in series with condensers.

With the adoption of superimposed current, the need for alternating current in addition to the pulsating ringing current for four-party lines was

ended. The system of superimposed ringing, developed by T. C. Drake and patented in 1904, uses an alternating-current generator connected in series with batteries. The resultant current may be considered as alternating current with the neutral axis displaced from the center line of the wave by the amount of the battery voltage. The action, on four-party circuits, is the same as that of pulsating current. On individual and two-party lines, where a condenser is in series with the ringer, only the alternating current component can flow. Voltages of the a-c. and d-c. components of the ringing current are regulated at any particular office within limits which depend on the types of ringers in the area served.

Meanwhile the sources of ringing current and the means for its control had received attention and development, just as had the ringer circuits themselves. The demand for operating convenience with resultant economy made it necessary first to do away with the need for turning a generator handle. In the transition to a central source of ringing current, various devices were used, marking successive steps toward reliability and convenience. One of these, known as a pole changer, is used extensively today in the smallest offices. It is a relay with vibrating armature, the contacts of which connect alternately with battery contacts of opposite polarity. In larger offices, for many years the source of ringing supply has been motor-driven generators, to which the name "ringing machines" has been given. For alternating current the output was used directly, but when pulsating current was first used the generators were installed in pairs, each supplying current of one polarity only. Later one generator was made to do the work of both. It was equipped with a third collector ring divided into two equal segments, insulated from each other; one was connected to the alternating current ring, and the other to the ground collector ring. Two brushes 180 degrees apart then collected half waves of alternating current, one giving positive and the other negative pulsating current. For superimposed current no such construction is needed, but merely an ordinary alternating-current generator connected in series with batteries.

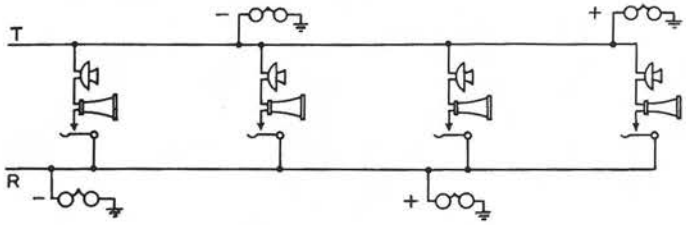

Fig. 6—A. S. Hibbard's circuit for full selective ringing

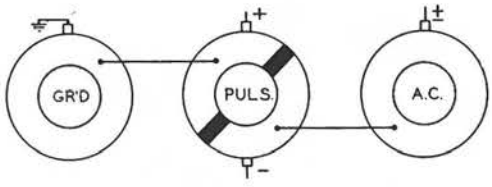

Fig. 5—Ringing machine connections to give pulsating current

When ringing machines came into use, the ringers in service had been designed to operate at the voltage and frequency given by hand generators. It was natural therefore that the voltage and frequency of the ringing machines were governed accordingly. Thus 75 to 110 volts at 16 2/3 cycles came to be standard. With a two-pole generator, this frequency corre-

sponds to 1000 revolutions per minute, a speed readily obtained with direct-current motors. When alternating current became generally used for power, it became desirable to use an alternating-current motor for driving

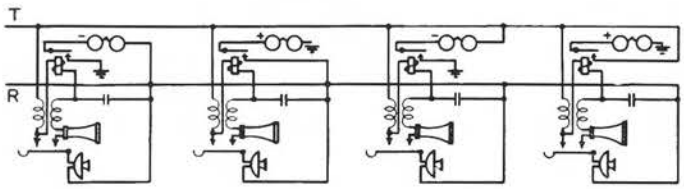

Fig. 7—The four-party circuit now used for full selective ringing

at least one ringing machine in each office. This was done by connecting the motor to the ringing generator with a belt, since with 60-cycle power it is impossible to obtain a speed of 1000 revolutions per minute directly. As before, a reserve machine was still furnished to be driven by the central-office battery.

The development of induction motors made it possible to build sets with the motor and generator connected directly rather than by a belt, if the ringing frequency were changed to 20 cycles. The maintenance and cost advantages of this change were so great that it was made about 1917, and the ringing machines directly connected to six-pole induction motors were standardized for new installations in place of the belt-driven sets. With 60-cycle power these operate at 1200 revolutions per minute and produce 20-cycle ringing current. To secure uniform frequency at all times, the reserve machines which operate on the central-office battery were also changed to give 20-cycle current. The actual frequency is somewhat less than the 20-cycle nominal value, since it is cut down about two-thirds cycle by the slip of the induction motor.

Regardless of its source, ringing current must be controlled for connection to the desired line. Even with hand generators, a ringing key was provided in each cord circuit for connecting the generator. Later there were commonly as many as five keys in the cord and trunk circuits of subscriber switchboards, for selective ringing on four-party lines with pulsating current, and ringing of individual lines with alternating current. In any case it was at first necessary for the operator to press one of the keys during each interval when ringing current was sent out, and thus to give the call a certain degree of attention for the duration of ringing.

This need was ended by "machine ringing", the system whereby ringing current is intermittently connected to a subscriber's line, either automatically

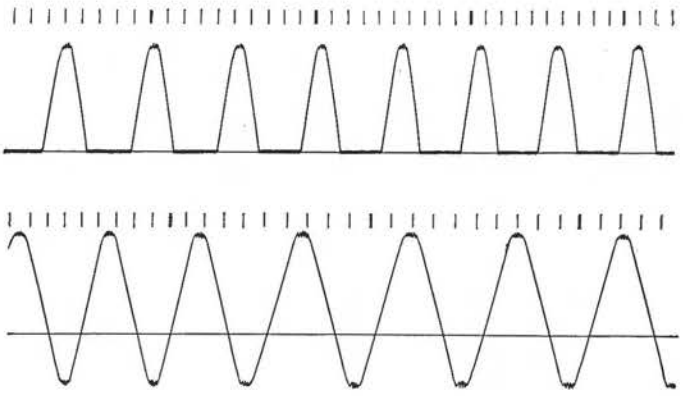

Fig. 8—(above) Pulsating ringing current. Fig. 9—(below) Superimposed ringing current

or by the momentary depression of a key, after the operator has plugged one of her cords into the jack of the called subscriber. Thereafter ringing current is connected to the line at regular intervals until the subscriber answers or the connection is taken down.

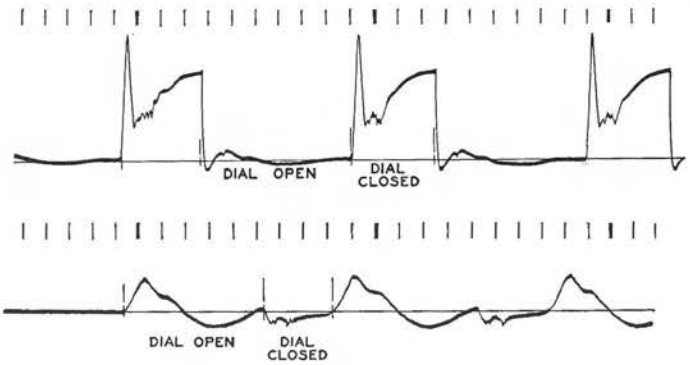

Fig. 10—(*above*) *Current in subscriber's line during dialing.* *Fig.* 11—(*below*) *Current in ringer during dialing*

During each revolution an interrupter mounted on the ringing machine connects ringing current to the line for two seconds, and connects direct current for four seconds. This direct current is supplied so that the called subscriber's answer—removal of his receiver—may be recognized immediately even though it comes during one of the silent intervals, and that the line may be ready at once for conversation to start.

To disconnect ringing current in a machine ringing system and to establish a through talking path, each ringing circuit is equipped with a tripping relay which operates on the increased current when the receiver is removed from the switchhook. These relays must all operate on direct current, and in addition on ringing current—some of them are designed and adjusted to operate on alternating current, some on pulsating current, and some on superimposed current—but they must not operate on any current passing through them before the subscriber answers. Such conditions are in themselves exacting, but they are made much more so by variation in ringing voltage and frequency, and by differences of several hundred ohms in the resistances of the various lines. Closer limits for voltage and speed of the ringing machines were therefore established to increase the assurance of reliable operation.

With the introduction of dial systems, further problems in ringing arose from the charging and discharging of the station condenser during dialing, and resultant tapping of the ringer. On party lines, and lines with extension telephones, this resulted at times in calling a person at one of the other stations. Ringers at dial stations, even for individual lines, were poled and adjusted to prevent tapping; as a result, it became much more difficult for them to operate on the usual ringing current. Voltages of the ringing machines were modified correspondingly, and new sets of limits established for panel and step-by-step offices. Superimposed current is used where full selective ringing is offered on four-party lines, and alternating current for ringing other lines. In new offices, in areas not having four-party selective lines, alternating current with a small amount of superimposed direct current is used to facilitate the operation of the relays which trip machine ringing. This direct current however has no effect on the ringers in these areas. In the older manual offices there will still be found all of the ringing voltages and fre-

quencies which have been standard, but in the newer offices the limits are the same as for the corresponding dial offices.

In many cases the line to which ringing current is applied will not have a ringer connected to it at all. It may be a line to a private branch exchange, or to a special operator's position, at which a visual signal is wanted. In such cases the ringing current must operate a relay controlling a lamp in front of the operator. These "ring-up" relays must operate under any normal ringing condition, and must not be operated by any other current flowing in the circuit during its use. Their story, however, like those of other pieces of ringing apparatus, belongs by itself rather than with a brief history of general ringing conditions.

Thus from the time when the first telephone switchboard was installed, the problem of calling subscribers has been to let them know positively and quickly that some one wished to speak to them. The signal must be distinct and reliable, so that there can be no doubt that it is genuine, and even on party lines there should be no tapping or accidental ringing to cause confusion or annoyance. The present polarized type of ringer has met the increasingly exacting demands of a rapidly expanding service, and while other forms of signals have been considered, none have been suggested that seem at all likely to replace it.