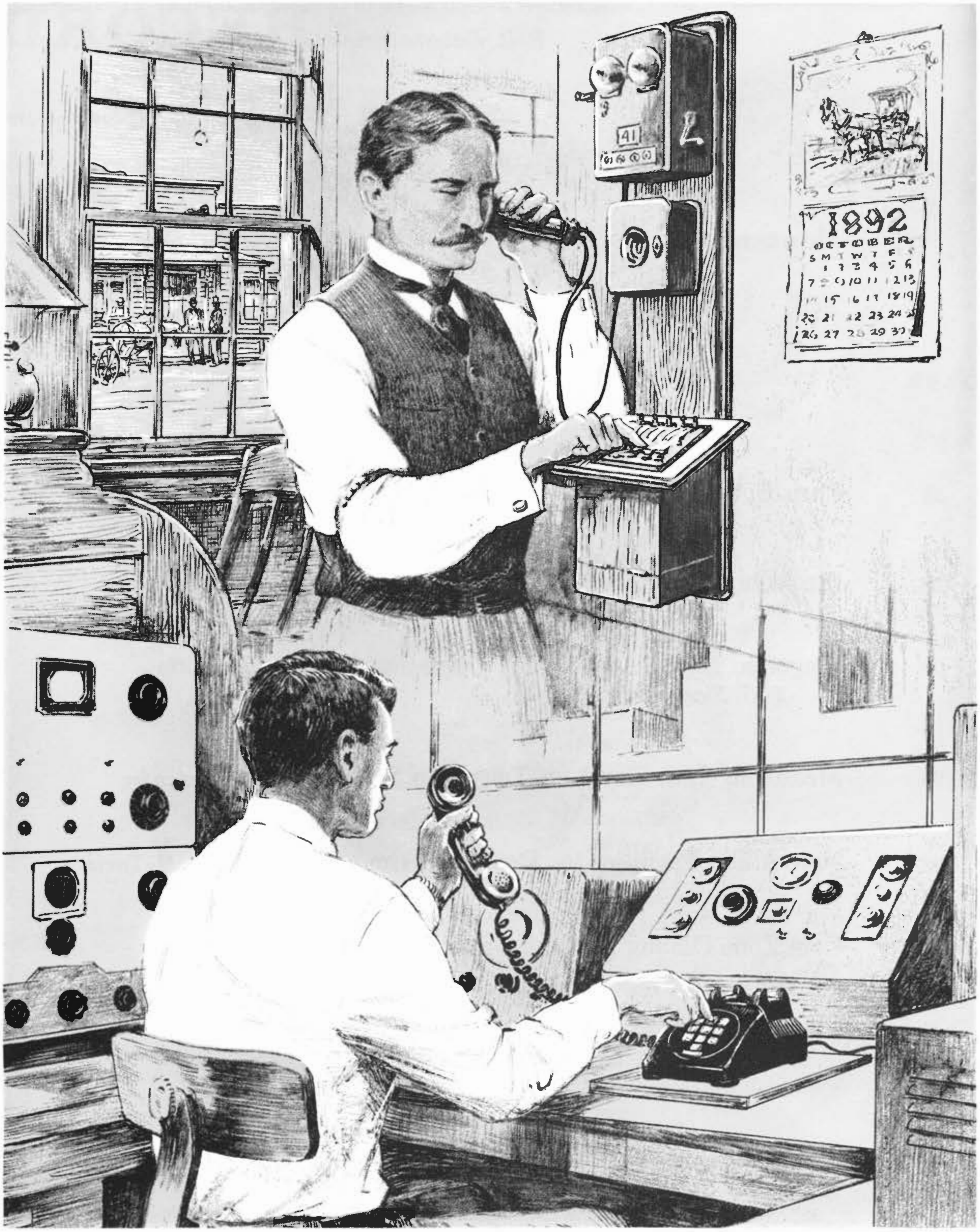


Push-button telephone in top sketch was the forerunner of the rotary dial. In 1892, customers used this key arrangement to send individually generated pulses to the first automatic exchange.

Today's version of the push-button telephone, now being developed at Bell Laboratories, sends a pair of distinct tones for each digit, and promises to make customer signaling easier and faster.

Bell Laboratories Record Vol 38

Push-button "dialing"—one of the most important concepts in future telephone service — has recently demonstrated its customer appeal in two field trials. Interestingly, many of the firm bases for this very modern method of customer signaling go back to early telephony.

H. F. Hopkins

PUSH-BUTTON "DIALING"

For four months last year, 200 customers in Hamden, Connecticut, and a similar number in Elgin, Illinois, used telephones equipped with push buttons instead of dials. This field trial was, at least, a partial implementation of an objective that has been sought over 60 years of telephone development. For even in the very early days of telephony, pioneer engineers recognized the need for automatic switching systems and, more importantly, for ways of easily and economically directing such systems from the calling station. Inventions aimed at the replacement of the well-known telephone dial have cropped up fairly regularly since before the turn of the century. Now, with the development of newer solid-state devices, a promising solution to simplified customer control of switching machinery appears within reach.

The results of this important trial of push-button signaling from the customer's telephone indicate that the development of push-button station apparatus may become increasingly important. With this fact as its basis, this article introduces some of the important concepts that underlie push-button signaling.

Very early in its history, the tremendous potential for growth of the Bell System became evident to those who were guiding its development. In his book, *History of the Telephone*, published in 1910, Herbert N. Casson wrote: "Already the Bell System has gone far in this direction by organizing what might fairly be called a 'Foresight Department' . . . Even in the city of New York, one half of the cable ducts are empty, in expectation of the greater city of eight million population which is scheduled to arrive in 1928." Telephone planners soon recognized that if the number of telephones increased at the expected rate, the problem of hiring and training enough operators to handle traffic manually would be just about impossible.

There were many who opposed the proposed solution to this problem—automatic switching systems with "customer calling". They predicted that such systems would be too complicated, and therefore unreliable and uneconomical; too expensive; and too inflexible, and therefore unadaptable to special services. Further, oppositionists felt that automatic switching was wrong from the customer's viewpoint. "The public will not tolerate doing its own operating," they said.

In spite of these pessimistic predictions, the first "step-by-step" system of automatic switching was put in service in La Porte, Indiana, in

1892. The stepping switches in this system were actuated directly by pulses generated by the customer at his station (progressive control). By 1908, step-by-step exchanges were in use in about 70 cities and towns in the United States.

Prior to 1896, customers on these automatic systems called the desired number by pressing push buttons. These buttons or more precisely, keys, can be seen on the early instrument in the sketch on page 82. On some versions of this early telephone there were three buttons on the "calling device," as it was commonly called. The button on the left was labeled HUNDREDS, the middle one TENS, and the one on the right UNITS. To call 143, for example, the customer would push the left-hand button once, the middle one four times, and the right-hand one three times. Customers using this system made many calling errors. Consequently, in 1896, a "contact-making machine," now commonly called a dial, was substituted for the push buttons. These governor-controlled dials were similar in principle to those in use today.

Another important advance, in both automatic switching and push-button signaling, came in 1910. This was the year the Western Electric Company developed the panel system of automatic switching. A semi-automatic system of 450 lines, the first switching system to use "common control," was set up for trial at what is now the New York location of Bell Laboratories. In 1914, a complete panel system of this type was installed in Newark, New Jersey.

With the semi-automatic versions of panel, the customer told the operator the number he wanted, and she completed the call with push buttons. Each operator's position had five vertical rows, each with ten push buttons, or "keys." This arrangement permitted the keying of decimal numbers up to five digits long.

In 1921, the first fully automatic panel system was installed in Omaha, Nebraska. Here, the customers were provided with dials. An "automatic caller," with five preset levers and an actuating arm, was also used at this time.

Early Rotary Dials

The governor-controlled rotary dials developed for the early progressive-control systems were well suited to the pulse-handling speed of the stepping switches. Also, a rotary dial with finger holes of adequate size requires only reasonable and easily applied wind-up forces to generate the mechanical energy needed for controlled-speed pulsing contacts.

On the contrary, it is difficult to generate this energy mechanically with push buttons, because the shorter stroke available requires rather high mechanical forces. Suggestions for reducing the mechanical loss due to the governor, or for using escapement mechanisms and schemes other than friction governors, have not borne fruit.

Dials were further suited to early switching systems because the time required by the customer to search for a following digit, plus the time required to wind-up the dial preparatory

Mrs. Carole Rustako of the Laboratories demonstrates the first step in dialing SH-1, one of the office codes used in the Elgin trial. She is using an exploratory model similar to those used in the actual trials.

Bell Laboratories Record Vol 38

to pulsing, add up to a satisfactory interdigital interval for activating stepping-type switches. Although many improvements have been made in dial mechanisms over the years, the basic design adopted in 1896 has withstood the test of time as the soundest method of manually applying the energy to generate selected, timed pulses.

Things are changing in the Bell System, however, and the time has come to look seriously for more effective methods for customer signaling. There are now nearly 60,000,000 telephones in the System and about 55,000,000 of these use dials. Instead of restricting dialing to local calls, the Bell System is rapidly extending the convenience of dialing by instituting customer dialing of toll calls in many areas. The number of digits to be dialed for some of these toll calls may be as high as 14. Furthermore, the calling rate, particularly on toll calls, has increased materially.

New types of switching systems have also been developed. Systems like No. 5 crossbar are capable of establishing telephone connections at speeds far greater than those of older systems. The experimental electronic switching system (ESS) (RECORD, *October*, 1958), now called the electronic central office (ECO), opens up even greater potentials for high-speed calling devices. These factors, along with the current flood of push-button devices in other fields, conspire to make this an appropriate time to consider the introduction of push-button calling to Bell System customers.

Actually, Bell System toll operators have used push-button calling, or key pulsing, for some time. This system, using voice-frequency pulses, was introduced in toll service in about 1940. The arrangement uses a two-out-of-six frequency code. But because they are all in the voice-frequency band, the signaling frequencies can inadvertently be imitated by speech or other sounds transmitted over the trunk. Therefore, special operating procedures have been adopted to prevent interference with the signaling process. These special procedures cannot practically be imposed on the customer, however, and a more sophisticated system for protection against voice-frequency interference had to be invented before practical voice-frequency signaling could be introduced to customers.

Efforts in this direction, using various signaling schemes, have been tested and in some cases commercially used, both in this country and abroad. In Europe, push-button calling systems have been developed, using dc signals obtained from combinations of polarity checks from the two sides of a telephone line to ground. This method involves the use of diodes to maintain proper signal direction. A trial installation, employing a modification of this principle was made at the Laboratories in 1943. Because of the possible inductive effects from extraneous sources, however, a grounded system of this kind is generally considered undesirable for the Bell System.

Telephones used in the 1948 trials of push-button calling. Pencil shows transducer that picks up tones from plucked reeds (fixed to the base behind the key levers). Note arrangement of buttons.

There have also been tests of a push-button pulsing scheme based on the dc voltage drop in the customer's loop. This system creates a problem in voltage regulation, and does not appear well suited for use in a large and complex telephone network. More recently, a pulse-position code with six positions was suggested and evaluated by the Switching Research Department in the early 1950's (BSTJ, *May*, 1952).

Station devices for generating dial pulses in a decimal code, similar to those produced by existing rotary dials, have also been investigated. Some of these devices were mechanical and some were electronic. Such schemes require waiting periods for both the transmission of the pulse train and the inter-digital spacing, and thus require self-discipline by the user. For high-speed systems, this self-discipline might be tolerable, but for the slower speeds demanded in current step-by-step switches, waiting would undoubtedly become a source of irritation to the customer.

The two-out-of-six frequency signaling system currently used by operators for toll keying is satisfactory from the standpoint of operating speed, but it requires improved pulse-receiving circuitry to guard against voice interference. Such circuitry has been developed, but the present analysis indicates that a new multifrequency signaling system has many advantages.

Bell Laboratories Record Vol 38

This new system — a four-by-four frequency scheme proposed by L. A. Meacham of the Station Development Department — seems to attain most of the objectives desirable in a push-button calling system for customers (BSTJ, *January, 1960*). A complete explanation of this system would itself take several articles. But briefly the proposed system uses one frequency from each of two bands (high and low) for each digit it transmits. The frequencies that are used minimize interference from harmonics. This permits instantaneous limiting in both frequency bands, and satisfactorily guards against possible voice interference.

To this point, we have been primarily concerned with the historical basis for push-button signaling and with some of the experimental and developmental efforts devoted to it. Because it has been broad and brief, this background has barely mentioned the most important parameter in any telephone system — the customer. This important consideration poses such questions as: Will customers like push-button calling? Can they learn to use it readily and accurately? Will "push buttoning" improve their service?

The Media Trial in 1948

To make a start on getting answers to such questions, Bell Laboratories in 1948 arranged a small-scale trial of push-button calling, limited to 35 employees of the Pennsylvania Bell Telephone Company. The trial was held in Media, Pennsylvania, the town in which the No. 5 Crossbar switching system was first introduced. This switching system had, in its registers, receivers that used the two-out-of-six multifrequency code. Registers are the units that store and then spill out the dialed digits as they are required by the switching mechanisms. These receivers thus made the No. 5 system very well suited to a trial of customer signaling with push buttons.

For the trial, the customers were given a special, mechanical push-button station mechanism. The unit had mechanical linkages that plucked two of six metal reeds, each tuned to resonate at a desired frequency. When the customer pushed any one of the ten buttons, two reeds would be plucked and transmit the code for the desired digit. A view of this mechanical arrangement and the external appearance of this experimental push-button telephone are shown on page 85. The frequency pulses were generated in coils by magnetic induction from the reeds. Although this mechanism was not handy by present-day standards for push buttons, the customers were enthusiastic. Their performance was reasonably adequate, according to both field and laboratory studies. This trial established the desirability of push-button signaling, from the customers' viewpoint. But the technical approach did not appear attractive, so further work on this form of signaling was deferred.

Recently, however, advances in technology, particularly in the fields of transistors, ferrites, and other solid-state electronic devices, have provided new tools for implementing the required signaling circuitry at both the station and at the central office. Furthermore, the conception of the four-by-four frequency system has made possible a relatively simple mechanical structure at the telephone set.

Concurrent with these electrical and mechanical developments, human-factors engineers at the Laboratories have made careful psycho-physical studies of customer preference and performance to determine the optimum arrangement, size, spacing, stroke and operating force for push buttons. These studies indicated that push buttons could facilitate and speed up customer calling without seriously increasing dialing irregularities. Encouraged by the results of work in both of these areas — solid-state technology and psycho-physical studies — the A.T.&T. Company and the Laboratories decided to go ahead with a moderate-sized field trial of push-button calling.

The main objective of the trial was to evaluate the customers' performance in using a modern push-button mechanism. A central-office receiver and converter were available in the form of a "black box" device developed for another purpose. Although not the ultimate in sophistication, this device would perform all of the necessary central-office functions. The black boxes were capable of repeating standard dial pulses, receiving multi-frequency (MF) signals, and converting MF signals to dial pulses for use by the switching equipment.

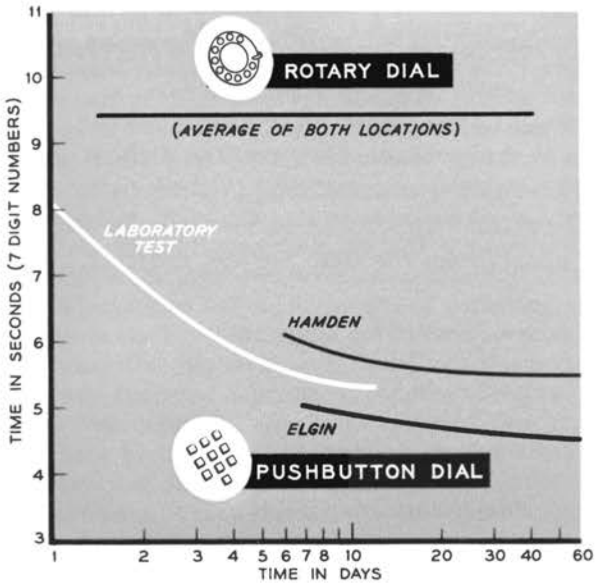
In the step-by-step trial arrangement at Hamden, Connecticut, the receiver-converters were installed between the first two elements in the switching network — the line finder and the first selector — in a segregated group of line finders. In the No. 5 crossbar office at Elgin, Illinois, they were put in between the trunk-link and register circuits. About 170 individual and two-party stations in each central-office area were equipped with push-button sets. In addition at each location about 30 key sets (telephones with several lines selected by buttons) and an attendant's position on a PBX were so equipped.

Even though trouble rates were relatively high due to the lack of refinement in apparatus design, customers in both areas were enthusiastic about the service. Speed and ease of use were the most frequently mentioned advantages. In a relatively short period, the customers with push-button sets were approaching the dialing accuracy they had achieved with regular dial telephones. Laboratories' engineers knew beforehand that irregularities with push buttons tend to be greater than those with the rotary dial — probably because of the ability of push buttons to operate at higher speed. There is every indication that this small increase in errors will be overcome with "learning," as is the case when a manual office is changed to dial.

The adjustment of an individual to the operational procedures of any new mechanical device requires a period of learning. The graph opposite compares learning curves, for speed of operation, for the Elgin and Hamden trials. These curves are also compared to an average rotary-dialing-speed curve for both locations. One might suppose, from a cursory look at the curves, that people in Elgin are faster dialers, or button pushers, than those in Hamden. It was found, however, that a large proportion of the calls in Elgin are to the local offices SH 1 and SH 2. In the push-button configuration used on the trial telephones *(see photograph on page 84)*, the buttons for dialing SH 1 are in bottom-to-top sequence in a vertical row, an arrangement well suited to fast operation. Dialing SH 2 is almost as readily managed. The rate of learning, however, is about the same in both areas.

Learning Rates

The curves show that several weeks were required for the customers to develop operating skill approaching their potential end-point performance. This is because most people make only a few telephone calls a day, and therefore get no concentrated practice. For a further comparison, a laboratory-measured learning curve is also included. These data were obtained at the Laboratories by testing twelve people who were asked to dial ten, seven-digit numbers each day for twelve days with the push-button set used in the trial. The numbers used in these tests are comparable with those encountered in Hamden, and no easily manipulated numbers such as those found in Elgin are involved. The facility of operation these subjects attained in a few days equals that attained by the Field-trial customers at Hamden in several weeks. Thus it is possible to get approximate evaluations of customer performance in a relatively short time in the laboratory. However, a full-scale trial of customer and equipment performance in the field is required to evaluate a new design fully.



Graph comparing speed of learning to dial with push buttons with average rotary-dialing speed. A laboratory-measured learning curve for ten calls a day shows how fast skill in push-button dialing can progress with more frequent practice.

From the customers' point of view, push-button calling is easier and faster than rotary dialing. At the present state of the art, however, the push-button station set is expected to cost more. Also, rather costly additional central-office equipment will be required in existing offices.

Why, then, is the Bell System interested in the possibility of providing push-button calling? One reason, of course, is that it is always interested in anything that provides better service to the customer. Another reason is confidence its ability to solve the technical and economic problems involved in this possible future service. Finally, a push-button device for voice-frequency signaling provides the customer with a potential (slow-speed) data transmitter.

The trials at Elgin and Hamden indicate that customer approval of push-button dialing is appreciable. The next step, which is already under way, is to progress from the exploratory equipment and apparatus designs used in these trials to more sophisticated prototype models. These models will then be used for additional larger trials to evaluate the potential marketability of push-button dialing and to explore in more detail the technical and maintenance problems. Trials of this type are scheduled for later this year.

Bell Laboratories Record Vol 38