## II. STEP-BY-STEP IMPROVEMENTS

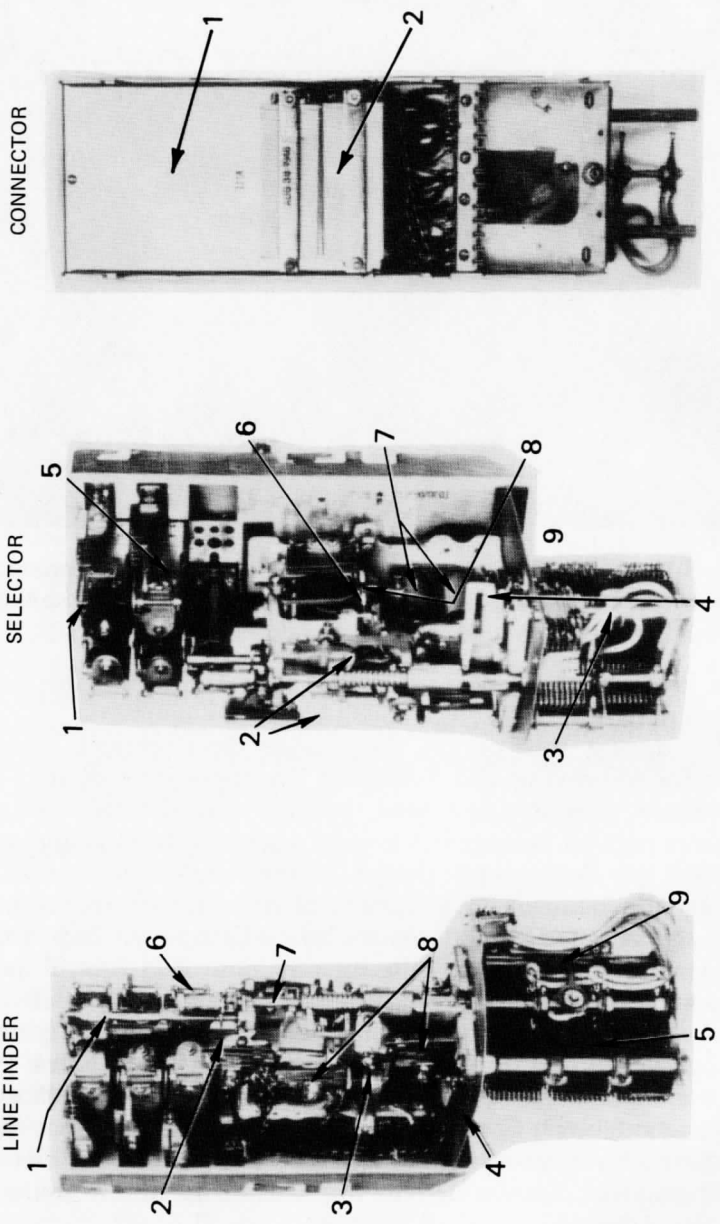
Although the Bell System decided in 1919 to adopt the step-by-step dial system for single and small multioffice exchange areas, Western Electric did not begin production of step-by-step equipment until 1926. During this period Western Electric installed equipment manufactured by Automatic Electric.

Once the step-by-step system was standardized by the Bell System, the Western Electric engineering department and its successor, Bell Laboratories, were engaged in an extensive program of improving the design and engineering of step-by-step equipment.[28] The list of improvements contributed by the Bell System is too long to discuss in detail. Fig. 3-12 shows some of the apparatus improvements made between 1926 and 1948. The principal thrust was to improve operation for short-haul toll dialing and to provide adequate inter-

faces between the step-by-step dial offices and operator access to the toll network.

Also during this period, long-range development plans were made for improving and extending the application of step-by-step equipment. For the first time, prepaid coin service features and message register arrangements were added to step-by-step systems. By 1925 the Bell System design requirements information for all step-by-step central office equipment had been established. These were also adopted by Automatic Electric Company. Included in the standard specification was the introduction of 11 foot, 6 inch high frames to the step-by-step system as designed by Bell Laboratories.[29] Previously the Automatic Electric Company equipment was arranged for 9 foot double-sided frames. In 1925, the first Western Electric-engineered job using equipment manufactured by Automatic Electric Company was completed (Champaign, Illinois). The first job engineered and manufactured by Western Electric was for Springfield, Massachusetts, and was completed in January 1927 (see Fig. 3-13).

Once Bell Laboratories engineers became thoroughly familiar with the state of the art in step-by-step switching, they proceeded to


CONNECTOR
1
2
SELECTOR
1
2
3
4
5
6
7
8
9
LINE FINDER
1
2
3
4
5
6
7
8
9

LINE FINDER

1. **Normal Post and Spring Assemblies**
   *Four changes, 1928-1940:* Redesigned post, springs, and operating cam.
   *Results:* 2,9,11.
2. **Vertical Off-Normal Spring Assemblies**
   *Five changes, 1926-1948:* Redesigned lever and springs.
   *Results:* 2,11,17.
3. **Rotary Armature**
   *Nine changes, 1926-1946.*
   *Results:* 5,9,11.
4. **Test Jack and Lower Cover Plate**
   *Eight changes, 1926-1948:* Redesigned test jack; hinged number plate holder.
   *Results:* 2,9,11.
5. **Wiper**
   *Six changes, 1925-1947:* Contour of tip; improved assembly; detachable guide; replacement spring; noble metal tip.
   *Results:* 2,6,11.
6. **Shaft Spring Assembly**
   *Two changes, 1931-1946:* Changed to helical spring.
   *Results:* 5,9,11.
7. **Shaft**
   *Three changes, 1928-1939:* Reduced varieties; improved construction.
   *Results:* 2,10.
8. **Interrupter Springs (Vertical and Rotary)**
   *Two changes, 1929-1942:* Bell crank design; improved design of spring.
   *Results:* 5,910.
9. **Commutator and Wiper**
   *Five changes, 1927-1947:* Redesigned spring; changed terminal and mounting.
   *Results:* 5,9,15.

SELECTOR

1. **"B" Position Relay**
   *Five changes, 1926-1945:* Redesigned bearing; 1:1 ratio armature.
   *Results:* 9,11,13.
2. **Double Dogs**
   *Three changes, 1931-1939:* Improved bearing; cover guide added.
   *Results:* 2,10.
3. **Wiper Cords**
   *Three changes, 1925-1929:* Termination at test jack; tinsel cords; solderless tips.
   *Results:* 2,10.
4. **Cam Springs**
   *Three changes, 1926-1928:* Eyelected studs; redesigned cam and bracket.
   *Results:* 9,11.
5. **Relays**
   *22 changes, 1928-1947:* Improved coil construction, bearings, and mounting; redesigned armatures.
   *Results:* 2,4,8,9.
6. **Vertical Armature**
   *Eight changes, 1926-1946.*
   *Results:* 5,9,11.
7. **Magnet Coils**
   *Four changes, 1926-1940:* Self protecting windings; filled coil construction.
   *Results:* 3,7.
8. **Banks**
   *Seven changes, 1928-1945:* Radial-sided contacts; mechanized assembly; solderless terminals.
   *Results:* 2,6.
9. **Release Mechanism**
   *Three changes, 1929-1947:* Redesigned armature and spring; redesigned armature and spring; redesigned release link.
   *Results:* 1,2,9.

CONNECTOR

1. **Mounting Plates and Covers**
   *Nine changes, 1925-1948:* Redesigned front and rear covers and mounting plates.
   *Results:* 2,10.
2. **Condensers and Networks**
   *Three changes, 1938-1948:* Developed smaller units; included in switch assembly.
   *Results:* 2,12,16.

**General Changes**

*Ten changes, 1928-1948:* Improved finishes and spring pileups; lubrication; increased pulsing range.
*Results:* 2,11.

**Results: Legend**

1. Easier Adjustment
2. Reduced Cost
3. Avoided Fire Hazard
4. Improved Capability (Capacity)
5. Improved Operation
6. Improved Service
7. Improved Stepping Capabilities
8. Improved Transmission
9. Longer Life
10. Easier Maintenance
11. Reduced Maintenance
12. Easier Rearrangements
13. Improved Release Time Capability
14. Improved Release Time
15. Easier Wiring
16. Simplified Wiring
17. Improved Operating Margin

Fig. 3-12. Improvements in step-by-step switching, 1926–1948.

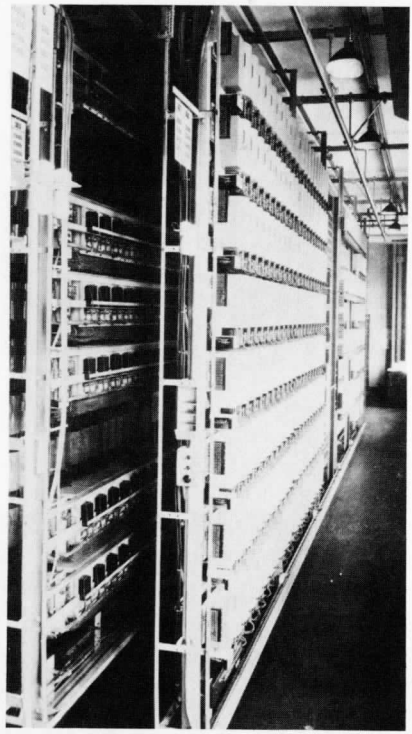


Fig. 3-13. Springfield, Massachusetts, 1927 installation of step-by-step equipment, the first job engineered and manufactured by Western Electric.

apply their creativity and standards to many parts of the system. From 1925 to 1927, most of the basic selector and connector circuits were redesigned. Not only were connectors and other circuits developed to provide for the superimposed selective ringing as used by the Bell System to some party lines, but provision was also made for automatic revertive calling on these lines. As shown in Fig. 3-14, new types of selectors were developed which for the first time provided for digit absorption.[30] These were used with discriminating selector repeaters in small offices,[31] but later proved most useful when the Bell System went to universal 7-digit dialing in the early 1950s (see Chapter 6, section 3.2).

Arrangements were developed to prevent wrong numbers due to preliminary pulses which might be falsely generated at the start of a call when the receiver is first taken off-hook.[32] This also resulted in the standardization of "11X" service codes as compared with "X11" for the panel system (see Fig. 3-15).

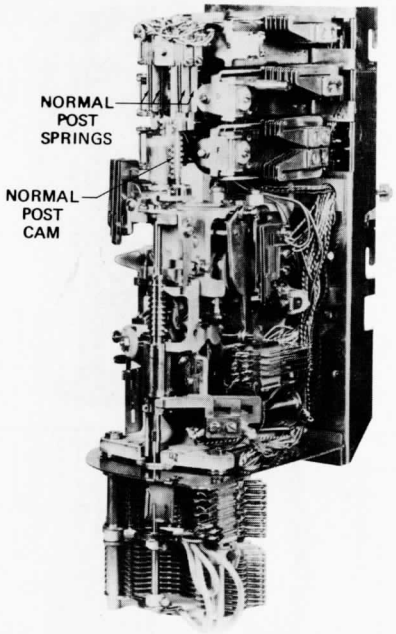



Fig. 3-14. Two-digit, digit-absorbing step-by-step selector.

In 1926 Bell Labs engineers adapted from the panel system the ideas of commutators and multiple reversals and applied them to the basic step-by-step switching mechanism, so that this mechanism could be used as a line finder to replace the individual or plunger line switches that had been standard to that time[33] (see Fig. 3-16). A simple arrangement was developed to allot idle finders with the shortest travel distance to serve calls from each level.

Due to the limited access inherent in each level of the step-by-step switch, much effort was expended to obtain efficient gradings[34] (see Chapter 5, section III). In addition, the concept of providing access greater than 10 was adopted. This was done by introducing an additional stage of 22 terminal switches, known as rotary out-trunk selectors (ROTS) to reduce the number of succeeding switches and trunks.[35]

At the terminating end of the switch train, new level-hunting connectors were developed that enabled the system to serve PBXs with more than ten trunks without the grading of the connector multiple, thereby obtaining better call completion.[36] New dial long line circuits and improved relays increased the subscriber loop range of the system.

The administrative and maintenance aspects of the step-by-step system improved. Test trains and dial and ringer testers that could

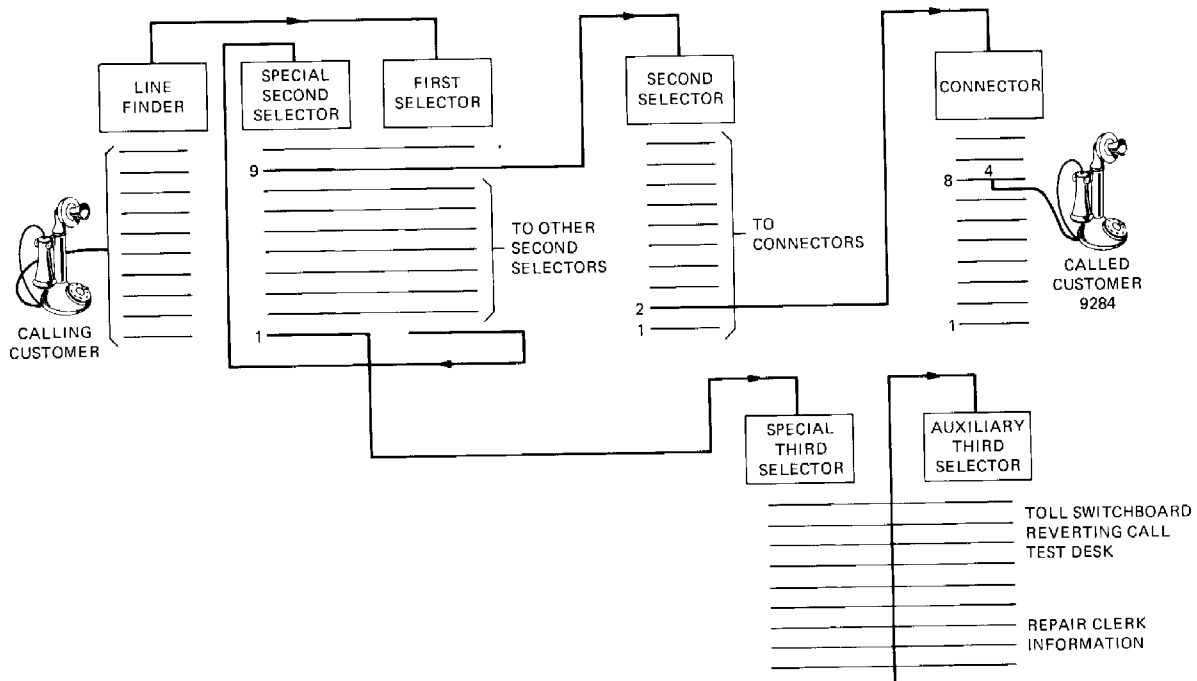



Fig. 3-15. Use of supplementary switches for preliminary pulses. (The boxes with ten underlines represent step-by-step switches.)

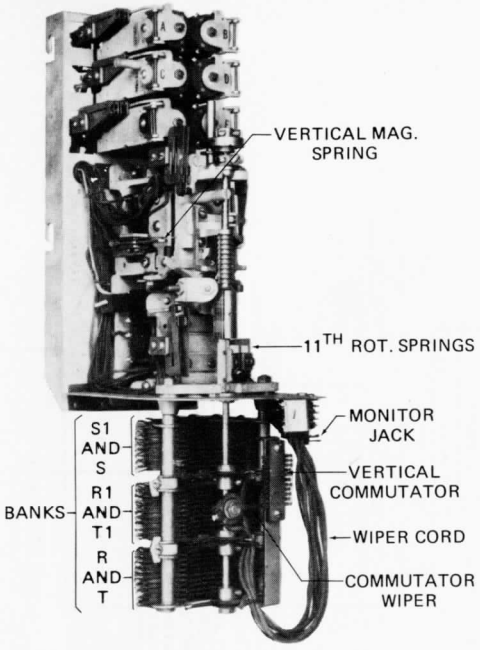



Fig. 3-16. Step-by-step switch adapted for use as a line finder.

be used by installers were added[37] (also for the panel system, as shown in Fig. 3-17).

The Springfield, Massachusetts office cutover in January 1927, was not only the first office completely engineered, manufactured, and installed by Western Electric, but it also contained many of the Bell Laboratories innovations to that date.

Early work on new applications of the step-by-step system to intermediate (tandem) offices was started in 1924 with the rehabilitation of the Los Angeles plant that the Bell System had consolidated in 1918. These changes, while not standardized, were placed in service in 1926 and paved the way for new standard developments for tandem and toll applications.[38] Until these improvements were made, all calls from within Los Angeles to the suburbs were treated as toll calls and were passed to toll switchboards. The new arrangements permitted "A" or dial system assistance (DSA) as well as toll switchboard operators to dial these points directly and complete the calls to distant offices. This method became known as "A-B Toll" and was applied to dial and manual completion.

These arrangements, which included improvements in signaling as well as new selectors and connectors, provided for toll grade transmission, improved pulsing range, and pulse repeating selectors that could be located in intermediate offices (see Fig. 3-18).

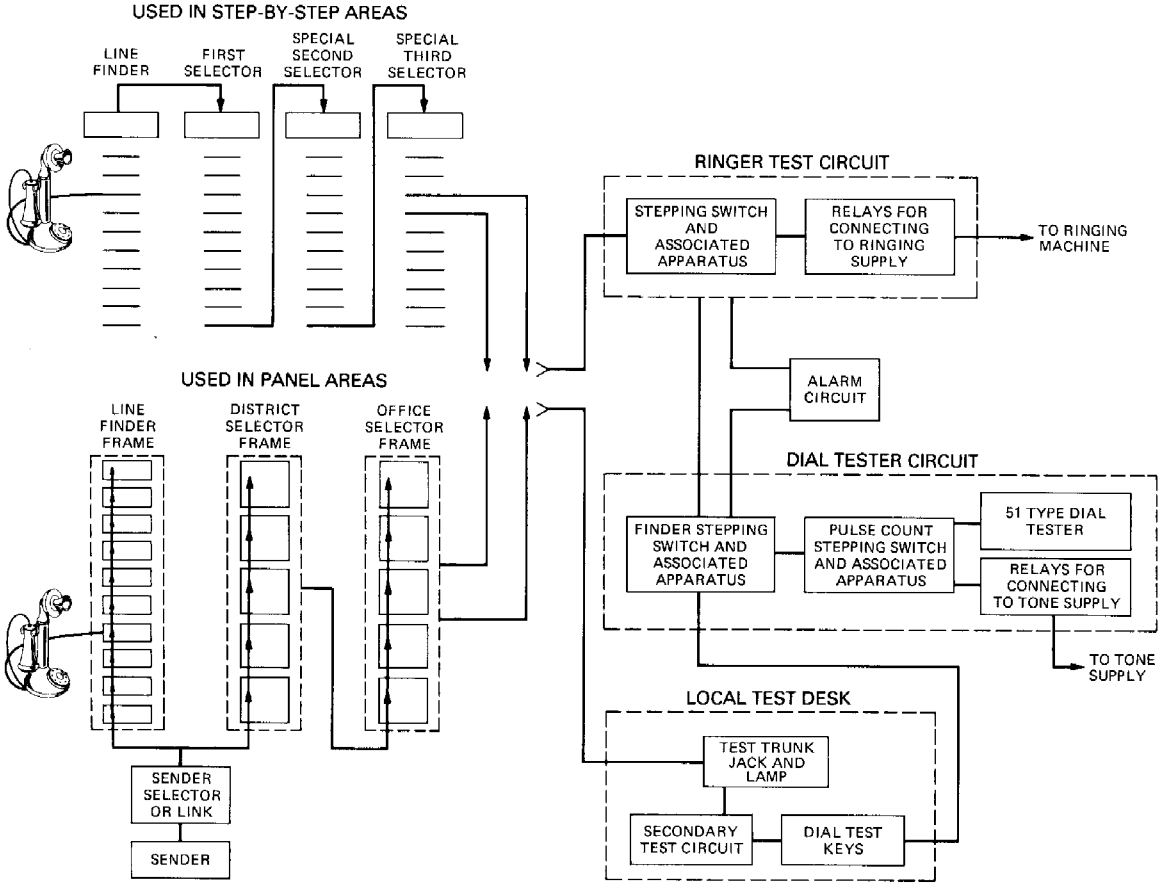



Fig. 3-17. Dial and ringer test circuits, applied to both step-by-step and panel systems.

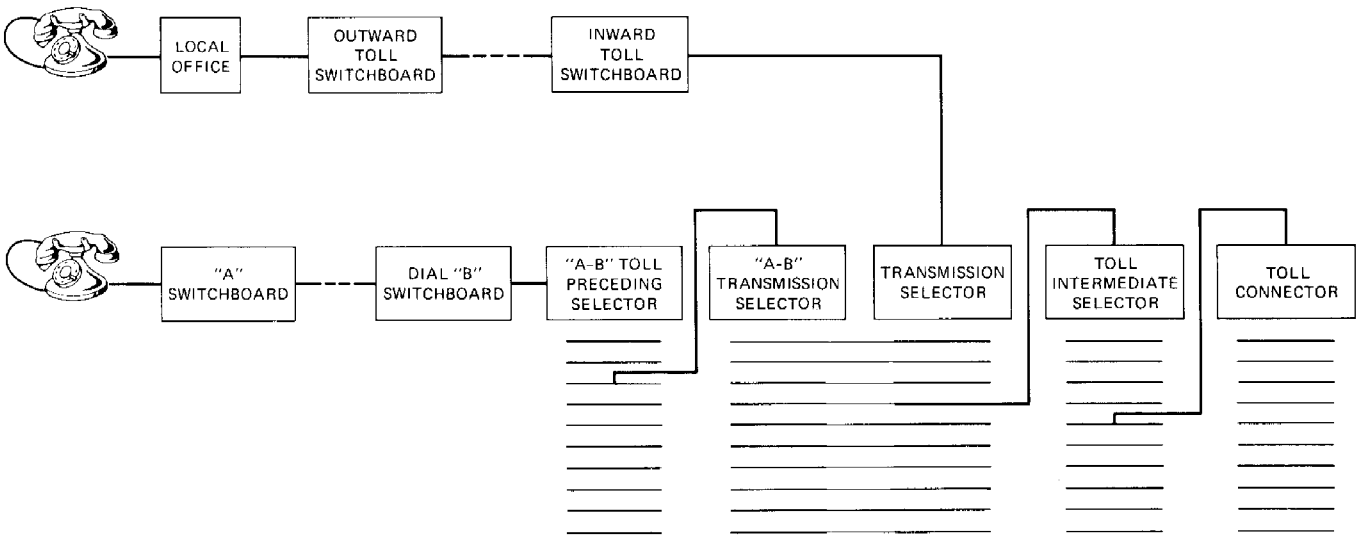



Fig. 3-18. The A-B Toll system used to improve step-by-step dial services over extended distances.

After a successful trial, the Los Angeles development was standardized in 1931[39] after being applied in most of the state of Connecticut in 1929,[40] and in Denver, Colorado, Albany, New York, and San Diego, California.

Since the Bell System was using the panel system for automating service in large cities, and since the 1919 decision assigned step-by-step the task of automating service in smaller communities, Bell Laboratories devoted some of its efforts to developing very small step-by-step offices. Here the operator functions were located remote from the switching office. The maintenance needs were so infrequent that resident craftspeople were not necessary. Fig. 3-19 shows a general schematic of such an office, which became known as unattended community dial offices (CDOs). The first one, later

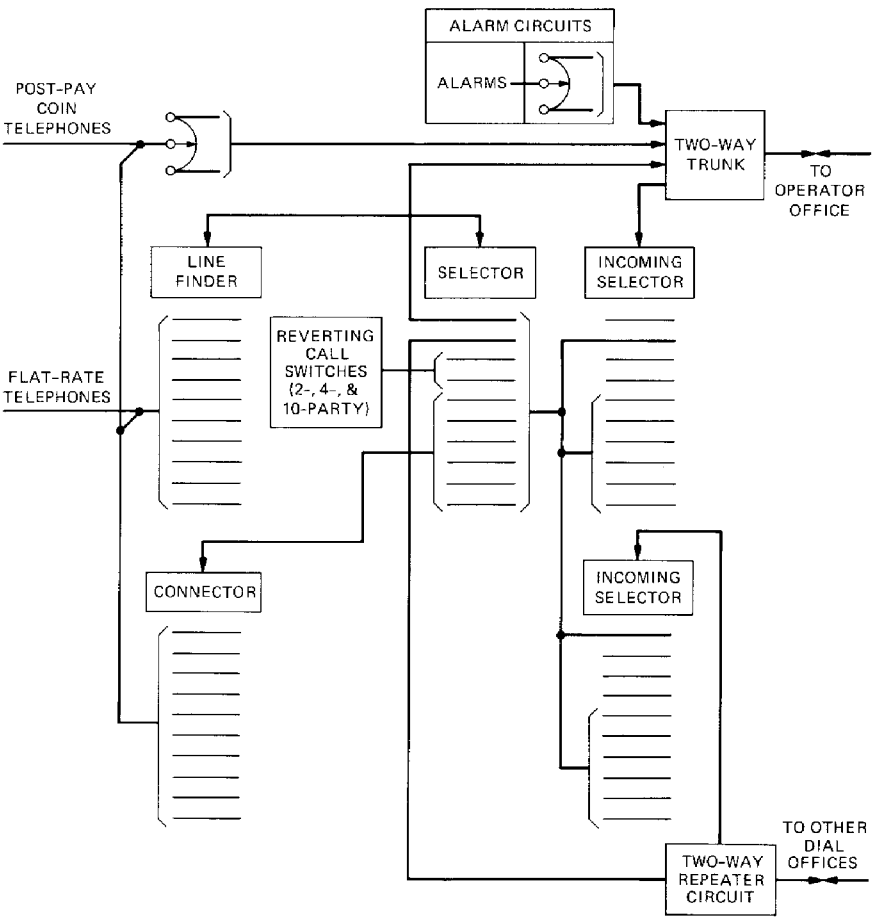



Fig. 3-19. Schematic of a typical step-by-step community dial office (CDO) with two-way dial and operator trunk group.

coded the 350A, was placed in service in San Clemente, California in July 1927.[41]

A trial of this system was held in Sinking Springs, Pennsylvania in 1926. The 350A, which has a maximum capacity of 1500 lines, was soon followed by the 360A with a capacity of only 500 lines[42] and the 370A and B (1932) with very small capacity (fewer than 100 lines), with selector connectors, and operating over two-way trunks[43] (see Fig. 3-20). A network of 14 of these offices was placed in Southern California by the end of 1929.[44]

Since the contract with Automatic Electric Company guaranteed a minimum production level, Western Electric suspended production of step-by-step equipment during the depression from 1932 to 1936. Community dial offices by Automatic Electric Company were introduced, most notably the system identified as 35E97. (Others were 375A/B, 385, 386, 32A32, 32A44, and 36A1.)

The Bell System acquired through purchase of independent telephone companies about 100,000 lines of step-by-step equipment of Automatic Electric Company manufacture prior to the 1919 agreement. Under this agreement, another 2.3 million lines of Automatic Electric Company manufactured equipment meeting Bell Laboratories specifications were placed in service in the Bell System. After

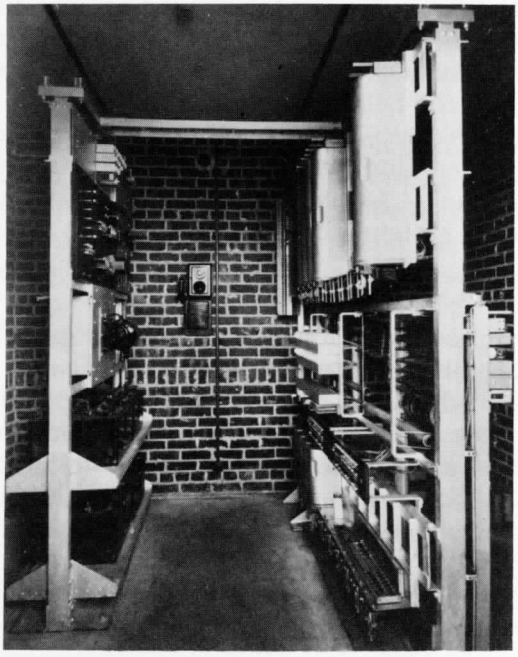


Fig. 3-20. Small-capacity 370B step-by-step office in Manakin, Virginia.

World War II when the Automatic Electric Company could not meet both the Bell System and independent telephone company needs, Bell Labs designed and Western Electric manufactured step-by-step equipment (initially manufactured by the Automatic Electric Company) for use as additions in Bell System offices.

The success of and demand for small offices after the depression stimulated a new equipment design with uniform-size frames and switch types that were packaged for easy engineering and installation. This system, developed by Bell Laboratories, was known as the "355A"[45] (see Fig. 3-21). Among the features was a new combined line and cutoff relay as well as a separate optional "line lockout" relay for use of lines with a high incidence of line faults.

The first installation was cut over in Batavia, Ohio in 1939. A total of about 3500 offices serving about 4 million lines demonstrate the success of this development. There is more of this code of switching system manufactured and placed in service in the Bell System than any other code at any time. After World War II an improved package known as the "356A" was developed but found limited success. As late as 1957, new equipment designs were being made for the still popular 355A CDO.[46]

Many individual innovations continued to be made in the step-by-step system. For example, an arrangement was added to provide for early detection and operator interception of permanent signals in 1963,[47] and also the timed disconnect of connectors when only the called party goes on-hook so that he or she may originate a new call.

Other improvements to maintain the step-by-step system as a viable member of the Bell System network are described elsewhere in this chapter. The step-by-step system provided automatic service for more Bell System lines than any other switching system when it reached its peak of 24,440,000 lines in 1973. (Later the same year the No. 5 crossbar system exceeded this number.)

## III. APPARATUS AND EQUIPMENT

From its beginning, switching has depended upon the availability of specific and unique apparatus designs that could perform with high reliability. Moreover, until the introduction of digital time-division electronic switching (see Chapter 12, section I), switching required apparatus or devices that went hand-in-hand with switching developments and generally preceded the design of new systems. The relays and switches, as well as the improvements referred to in the previous section, are examples of this close partnership. Not only was new apparatus developed to accompany system improvements, but existing apparatus in large-scale production was modified to reduce cost[48] and to improve performance.[49]

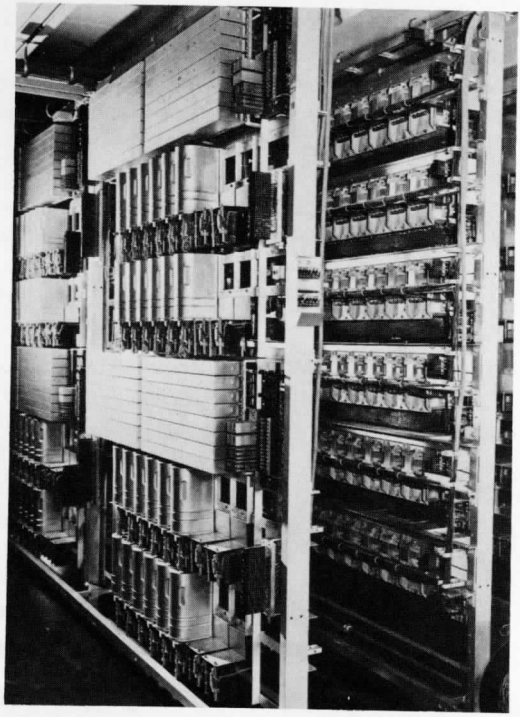


Fig. 3-21. Line finder equipment of a small step-by-step office, 355A design. This community dial office was produced in large numbers, beginning in 1939.

Other partners in the development of systems were the equipment designers. They had the knack of "putting it all together," so that the bits and pieces of a system were made into a whole when placed in the hands of the operating telephone companies. They also were responsible for documentation that described the generalities of the system before one plunged into its specific details. During the pre-World War II period at Bell Laboratories, many new system concepts as well as improvements reached the point where field testing or field trials were necessary. The Bell Labs equipment engineering organization headed by H. H. Lowry had separate departments for organizing, constructing, and implementing field trials. It was through this organization that many young engineers passed before becoming full-fledged equipment designers.

In the switching systems organization there was a similar department devoted to the construction and testing of laboratory models of systems. These system laboratories were established in separate buildings at the West Street location of Bell Labs in New York City,

where many young engineers learned about switching on the job. This included learning firsthand about the construction of switching equipment frames and the adjusting and testing of the apparatus.

The relays and switches used in the prewar systems all required adjustments. Fig. 3-22 shows the array of tools required to adjust step-by-step switches. A separate organization in the systems testing department provided engineering information for the apparatus codes for specific circuit applications of apparatus designed in the switching apparatus organization. It was here, also, that many young engineers learned the intricacies of switching circuit design.

A book covering switching technology during the electromechanical era would not be complete without recognizing the contributions made by Bell Laboratories apparatus engineers in understanding and applying the principles of electromagnetics in relay technology. Many designs were placed into production and continually improved. These designs were necessary to meet the changing and greater capabilities required by each succeeding generation of switching systems. Much of this progress has been recorded in ref. 50.

Fig. 3-22. Tools needed to adjust step-by-step switches.