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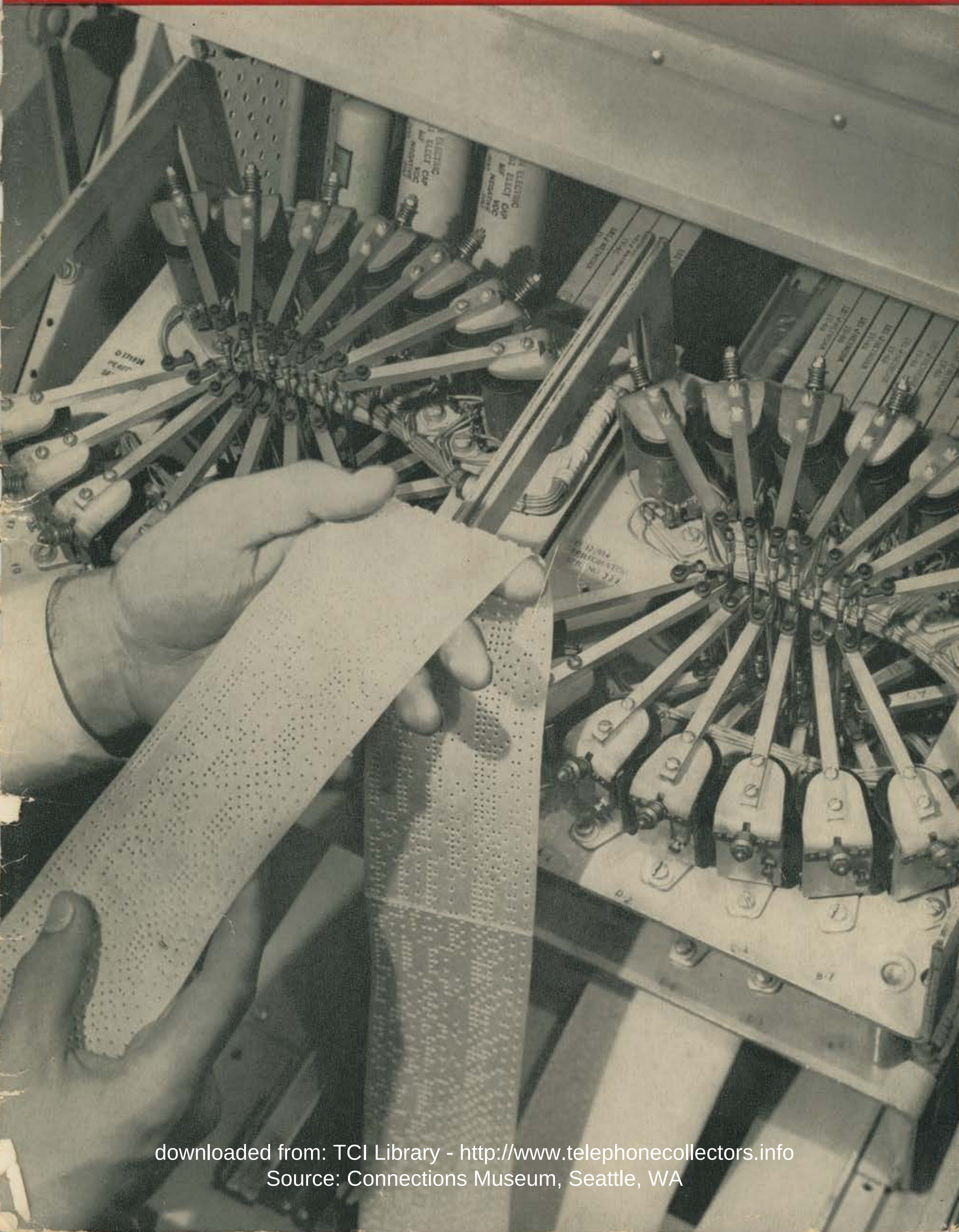

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Reprinted from

BELL LABORATORIES RECORD

Contents

The articles reprinted in this booklet describe features and operating methods which were standard at the time the articles were written. Some of these features and methods are out of date and no longer standard.

Automatic Message Accounting

C. F. SEIBEL
Switching Systems Development

Within the past few years, the Automatic Message Accounting (AMA) system has been placed in commercial service by the Bell System in a number of metropolitan areas. These systems record in the central offices all the data required to charge for subscriber-dialed telephone messages, both local and toll, and process this record in accounting centers through computing, sorting, summarizing, and printing machinery. Both the recording and processing arrangements employ many novel circuit and apparatus components. The use of the system will permit wide expansion of direct subscriber dialing to nearby and more remote points, with resultant increased speed, and convenience to telephone customers. Although AMA is the first system to carry out automatically both recording and accounting for toll calls, it is not the first step in this direction but is rather the culmination of a long line of developments.

During the early years of the telephone, subscribers were charged exclusively on a flat monthly or yearly basis but since the end of the last century, message rate service has been available in most of the larger cities. Initially the record of such calls was in the form of tickets prepared by operators. This method was later supplemented by the use of a small electromagnetic counter, called a message register, associated with each message rate line and operated once for each call made. As the metropolitan areas grew larger and subscribers began to call regularly beyond their local areas, zone registration was adopted. It provides circuits that, on each call beyond the local area, operate the message register the proper number of times to represent the cost of the call. Thus

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The photograph at the top of the page shows part of the Automatic Message Accounting center at Philadelphia.

if the charge on a call was 20 cents and each message register operation represented a charge of five cents, the register would be operated four times for this particular call.

Although zone registration is an economical method of charging for short toll calls, it does not, of course, leave any record of the details of the various calls. For calls requiring more than five or six message register operations, it has generally been felt preferable to have a record not only of the point to which the call was placed but of the day and time it was made. To secure such a record, and at the same time to obtain the economies and increased speed possible from automatic operation, an automatic ticketing arrangement* was developed some years ago for step-by-step areas. With this system a toll ticket is automatically printed for each toll call, and thus all essential information pertaining to the call is permanently available.

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*Record, *July*, 1944, *page* 445.

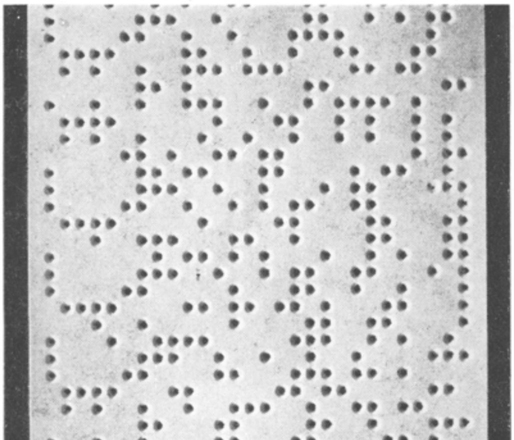

Fig. 1—A section of AMA tape after it has been perforated.

The alternative to all such methods, of course, is to bring in an operator for each such call and to have her make out a ticket. This is a less economical method of handling the call in many areas, however, and may delay its completion. It has of necessity always been used for calls beyond the range of the available automatic charging methods. The writing of a toll ticket, moreover, is only part of the work of charging for calls. Before subscribers can be billed for their calls, the thousands of tickets from hundreds of operators must be brought together and sorted out according to subscriber, computed, and totaled, and then the bill must be prepared. This work is extremely laborious and represents an appreciable item of expense.

It was recognized for some time that the entire process of recording calls and preparing the customer's bills could be done mechanically. One of the early suggestions was to provide an automatic accounting system that would supplement the automatic ticketing system, using the automatically prepared tickets as the basic information. Problems encountered, however, indicated that it would be desirable to record the information pertaining to the calls in a different manner. As a result, a completely new system from recording to billing was projected.

As now developed and being put into use, the automatic message accounting system, besides providing automatic accounting of messages, records the information pertaining to calls in an entirely different form from any used before. The potential usefulness of the system, moreover, has greatly increased with the prospect of nationwide subscriber dialing, since to take full advantage of nationwide subscriber dialing, an automatic method of recording billable information on calls dialed must be available.

In this new automatic message accounting system, the information pertaining to all calls requiring a charge is perforated in code on an oil impregnated paper tape three inches wide. A specimen of the section of the tape after perforation is shown in Figure 1. There is space for twenty-eight holes across the tape, which is used for recording six digits, each representing a single item of information. Adjacent rows are about one-tenth inch apart, and either four or six rows of information are required per call. The items of perforated information are automatically read and interpreted at the accounting center at a rate of over 80 digits per second.

The recording machines are installed in cabinets like those shown in Figure 2. They are associated with the outgoing trunks in the No. 5 crossbar system and with the district junctors in the No. 1 crossbar system. One recorder serves 100 trunks or district junctors. Together with their associated equipment, they are installed in the individual telephone central offices. Each day at about 3:00 a.m. the tapes in all the recorders are automatically prepared for cutting by perforating a readily recognized pattern to indicate the section where the tape is to be manually cut. After cutting they are transported to the accounting center for processing. This accounting center may handle the tapes from many central offices and may be remote from any of them.

Since each tape from a recorder includes the information for all calls handled by a group of 100 trunks or district junctors, calls from a particular subscriber may be distributed over a number of tapes, and the information for any one particular call, although on a single tape, will not usually be on adjacent lines of the tape. Certain of the information is recorded as the call is dialed or shortly thereafter, but the time the called subscriber answers, which is the beginning of the charge period, is somewhat later, and in the meantime information relating to other calls may have been recorded on the same tape. The time the conversation is completed will in general be considerably later, and thus there will be information pertaining to many calls between the recording of the beginning and the ending of any particular call. Each tape, moreover, will include information on calls that are charged for in entirely different ways. For calls that are billed in bulk, it is not necessary to record the office and number of the called subscriber, since the duration of the call and other billing information provided in the call record is sufficient to determine the charge. This is the type of call that requires only

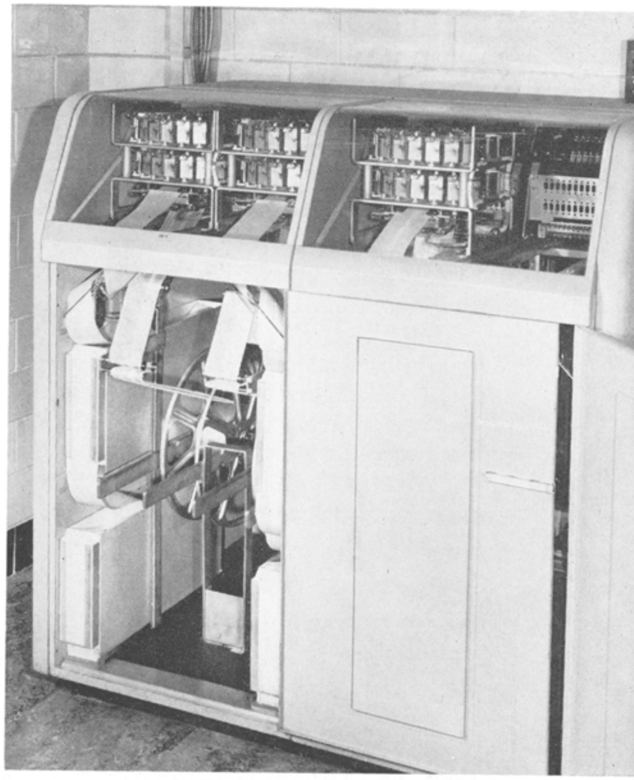

Fig. 2—Two tape perforators with their supplies of used and unused tape are mounted in a single cabinet.

four lines on the tape, while six lines are required when information pertaining to the called subscriber must be recorded.

In the accounting centers, the work in general consists in automatically assembling the information pertaining to each call, computing the conversation time for each call, sorting as to type of call—that is, toll calls, those that are bulk billed, and miscellaneous types—and then grouping the calls according to the subscriber. A list of toll calls, and a summary of bulk-billed calls, made by each subscriber during the billing period is then automatically printed. The total bill, including local, toll, other services and credits, is at present produced manually at the accounting center.

Because of the entirely new character of the AMA system, and the need for great accuracy in recording the calls dialed by the subscribers and in processing this information at the accounting center, it was concluded that a fairly large amount of this equipment should be observed in actual operation prior to placing it in regular service.

That part of the system which is located in the telephone central offices was installed in a 5,000-line No. 1 crossbar office at Washington, D. C., that had not yet been placed in service. Many hundreds of carefully controlled test calls were put through this equipment, and the recorded output of the AMA equipment checked against the known input of test calls. The result was extremely gratifying.

About this time the No. 5 crossbar system and the AMA accounting center developments were nearing completion. The No. 5 system was designed with provision for AMA, and AMA equipment was included in the first No. 5 installation at Media, Pa. The associated AMA accounting center was installed at Philadelphia. Before the Media office was cut into service an extended test run was made similar to that at Washington. The Media tape recordings were processed at the Philadelphia accounting center. The performance of both the central office and accounting center AMA equipment was very satisfactory.

A number of other AMA equipped offices and their associated accounting centers have since been installed around the country. AMA is particularly attractive in areas where a large number of short haul toll calls is originated, and where it is economical to permit the subscribers to dial such calls directly. The use of the system will further increase as steps are taken toward nationwide subscriber dialing.

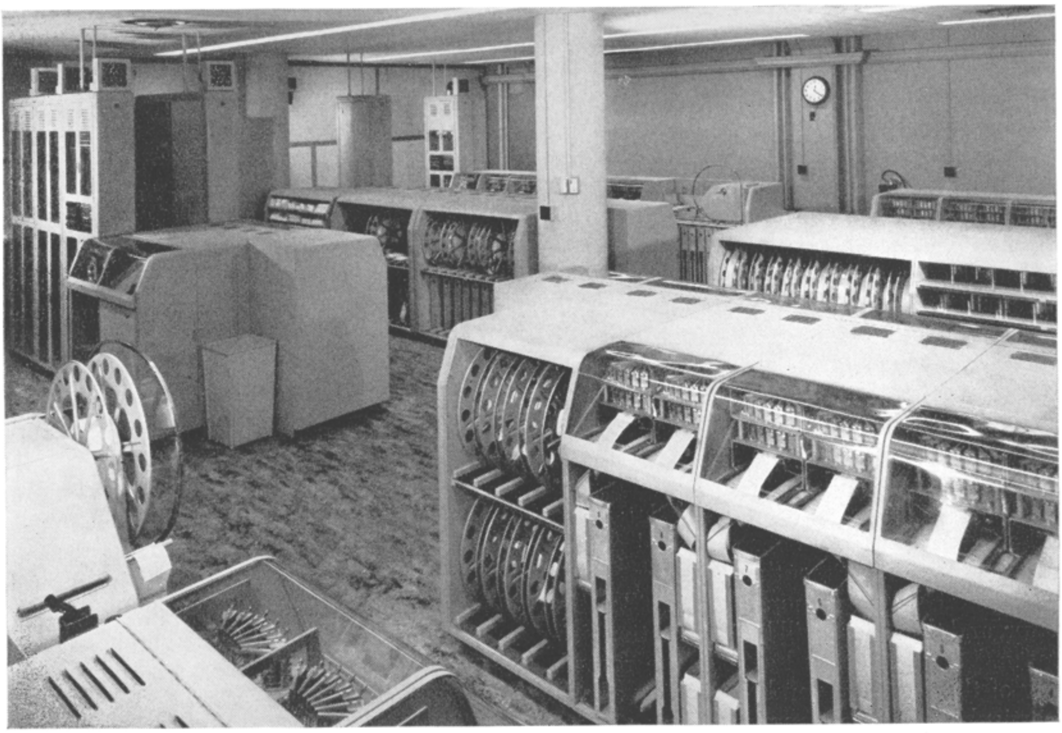

Fig. 3—A view of part of the AMA accounting center at Philadelphia.

Code Patterns in Telephone Switching and Accounting Systems

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Switching Systems Development

In telephone switching and accounting systems certain information regarding each call must be transmitted and recorded quickly and accurately. In many cases, moreover, the same information must be transmitted and recorded many times. Most of this information is in the form of decimal numbers, of which the component parts or digits may have any of 10 values. The telephone number CH3-1074, for example, is equivalent to the decimal number 2431074, since as a glance at a standard dial will show, C is one of the three letters that is represented by 2, and H, one of the three letters represented by 4. Much other information regarding each call is also represented by decimal numbers. The physical location of each line in the switching equipment, for example, the trunk and other parts of the switching system used on the call, and the rate of charge, are all represented by decimal numbers. It is obvious, therefore, that the transmitting and recording of decimal numbers by electrical and mechanical means is very important in telephone systems.

In transmitting decimal numbers from place to place, each of the ten possible values of a digit must be represented by a unique electrical or mechanical condition. Both the mechanical and electrical representations of a digit are used in the familiar dial. The number of degrees in the arc through which the dial is mechanically rotated for a specific digit is proportional to the value of the digit—"one" being the smallest arc, and "zero" being the largest. The arc representing 0 is ten times that of the arc representing "one". The values "two" to "nine" are represented by arcs of intermediate value. When the dial is released by the calling subscriber, it produces, on its return to its normal position, a number of electrical impulses corresponding to the length of the arc through which it rotates, one impulse for the value "one", two impulses for "two", and so forth, with ten impulses for "zero".

In the central office, electrical and mechanical devices respond to these impulses and take one of ten positions dependent upon the value of the digit dialed. Thus a decimal number, such as 2431074, is transmitted from a subscriber station and recorded in the central office by means of a simple code, each digital value being represented by a discrete dial arc, a number of impulses, and a position of the recording device.

TABLE I—A FOUR-ELEMENT CODE USED FOR SOME PURPOSES IN THE BELL SYSTEM TO REPRESENT DECIMAL DIGITS. THE ELEMENTS OF THE CODE USED TO REPRESENT A DIGIT ARE INDICATED BY X'S: ELEMENTS NOT USED ARE INDICATED BY —

Decimal Digit Represented	Code Elements 1	2	4	5
1	X	—	—	—
2	—	X	—	—
3	X	X	—	—
4	—	—	X	—
5	—	—	—	X
6	X	—	—	X
7	—	X	—	X
8	X	X	—	X
9	—	—	X	X
0	—	—	—	—

This simple decimal code is frequently used to pass a number from place to place within a central office by providing ten conductors per digit between the two places and closing current to one and only one of these conductors. It is also used to transmit all or part of a decimal number to a distant office by means of electrical impulses similar to those generated by a dial.

Where transmitting and receiving devices must be simple, as in station equipment, this code is suitable. There are many cases, however, where more complex codes are used for purposes of economy, accuracy, or speed. The decimal code has ten elements, one for each of the ten values to be indicated. It is possible, however, to represent ten values with a code of fewer than ten elements by using combinations of two or more of the elements to indicate the ten values. A code having four elements, where a single element or a combination of two, three, or four elements are used, can represent as many as sixteen values, and, of course, ten of these sixteen can be used to represent a decimal digit. One practical code of this nature has its four elements designated 1, 2, 4 and 5, and the ten digital values are represented in Table I.

TABLE II—ANOTHER FOUR-ELEMENT CODE USED IN THE BELL SYSTEM

Decimal Digit Represented	Code Elements 1	2	4	8
1	X	–	–	–
2	–	X	–	–
3	X	X	–	–
4	–	–	X	–
5	X	–	X	–
6	–	X	X	–
7	X	X	X	–
8	–	–	–	X
9	X	–	–	X
0	–	–	–	–

It will be noticed that the sum of the elements equals the value of the digit. Another four-element code, shown in Table II, is also used, and again the sum of the elements equals the value of the digit.

Each of these two codes has certain characteristics which are desirable for specific purposes. In panel and crossbar No. 1 systems, for examples, the 1, 2, 4, 5 code is used for all digits except the thousands digit, which uses the 1, 2, 4, 8 code. There is an advantage in using 1, 2, 4, 8 for the thousands digit and 1, 2, 4, 5 for the hundreds digit because this facilitates translation from these two decimal digits to the incoming brush, incoming group, and final brush selections used in the panel system and *vice versa*.

Four-element codes such as the above have been in use in telephone switching systems since about 1914, when the call-indicator systems were installed in New York City for completing calls from the Metropolitan toll office in Walker Street to the various manual "B" switchboards throughout the city. Four impulses or spaces are transmitted for each digit. These impulses (or spaces if the impulse is omitted) are nominally 0.070 second in duration; so that 0.280 second is required for the transmission of each digit. Each of the four impulses or spaces is one element of the code. By suitable receiving equipment the decimal value is reconstructed. The higher average speed of the four-element code, compared with the ten-element code, permits more efficient use of the common

TABLE III—IN RECENT YEARS A FIVE-ELEMENT CODE HAS COME INTO EXTENSIVE USE

Decimal Digit Represented	Code Elements 0	1	2	4	7
1	X	X	–	–	–
2	X	–	X	–	–
3	–	X	X	–	–
4	X	–	–	X	–
5	–	X	–	X	–
6	–	–	X	X	–
7	X	–	–	–	X
8	–	X	–	–	X
9	–	–	X	–	X
0	–	–	–	X	X

control devices.

The four-element code is also used to pass a decimal number from place to place within a central office. This is usually accomplished by providing four conductors for each digit between the two places concerned. This is a substantial reduction over the ten conductors required for the simplest code, and, although wires are not very expensive, the contactors and means for actuating them to establish multi-conductor connections between parts of a system are costly. Each of the four wires and the four devices actuated by them are the four code elements, and are used in the patterns shown.

In 1942, a five-element code came into use in telephone systems. The five elements are given the designation 0, 1, 2, 4, and 7,

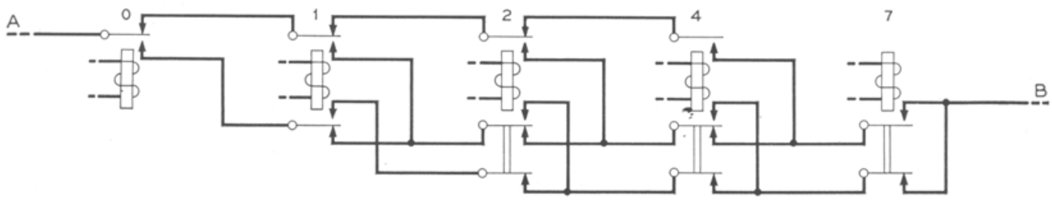

Fig. 1—One form of checking circuit used with the new five-element code.

and each digital value is represented by two of the elements, as given in Table III.

It will be noticed that for the values 1 through 9, the sum of the element designations is equal to the value which the combination represents. There are only ten combinations of five elements taken two at a time, and thus the remaining combination, 4 and 7, must be used for zero.

The principal advantage of this code is that devices can be readily designed to receive decimal numbers in this code, check for errors due to equipment or line faults, and to call attention to the trouble. Systems using the four-element code check intra-office wiring by an indirect method, which is somewhat slower than the direct method used with the five-element code. Inter-office pulsing using the four-element and similar codes is not self-checking. Checking with the five-element code is accomplished by arranging the transmitting or receiving device to demand that exactly two of the code elements are actuated for each digit. A lost element or an added element indicates trouble. Figure 1 shows a commonly used configuration of relay contacts, which assures that exactly two of the five relays are operated. The electrical path from A at the left to B at the right will be closed if any two relays, no more and no less, are operated for the digit. The path is, of course, extended through similar contact configurations for other digits of the decimal number, so that, if an error appears in any digit, circuit action is stopped, and trouble reported.

One use of the five-element code is for transmitting a decimal number from one office to another. Power supplies of five distinct frequencies are available at the originating office for use in combinations of two. The frequencies used and their corresponding code designations are:

0	1	2	4	7
700 cycles	900 cycles	1100 cycles	1300 cycles	1500 cycles

Thus, to send the numeral three, frequencies of 900 cycles and 1100 cycles are transmitted. At the receiving office, filters separate the component frequencies, and actuate two of the five detectors.

For transmitting a number within an office, five conductors are used for each digit, two of the five carrying current to convey the required numeral.

In the Automatic Message Accounting (AMA) systems,* the details of calls are perforated on a paper tape. Much of the information is in the form of decimal numbers, and is recorded in the five-element code. For each decimal digit, spaces are provided for five perforations, and, to record a particular numeral, the AMA recorder perforates two of these five spaces.

The above examples illustrate how widely the five-element (two-out-of-five) code is utilized in modern telephone switching and accounting systems. Because of the simplicity and speed of the self-checking facilities that can be designed for it, this code is being used wherever practical.

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* See page 5.

Basic AMA Central Office Features

D. H. PENNOYER
Switching Systems Development

Automatic Message Accounting* not only takes the place of message registers and zone registration equipment, but in addition furnishes all the information necessary for the conventional detailed billing of short haul toll calls. The circuits act so quickly that there is no delay in the normal completion of the calls. In fact the subscribers would be unaware of the existence of the new facilities except that they are no longer required to place these calls with an operator. These new accounting facilities are available in both No. 1 and No. 5 crossbar offices; the fundamental features are the same in the two systems although some of the details vary due to differences in the two systems. All the necessary information pertaining to a call is perforated on a paper tape by common AMA control circuits with holding times in the order of 0.1 to 1 second.

A simple block diagram showing the various circuits associated with an AMA call in a No. 5 crossbar office is given in Figure 1. The digits dialed by the subscriber are temporarily stored in the originating register and then transferred to the marker as for a non-AMA call. The marker, through the line and trunk link frames, prepares a path to an idle AMA trunk. It also transfers to an outgoing sender the information needed for completing the call and for making the AMA record. This includes the calling subscriber's line location and party identity, the number of the recorder serving the selected trunk, and a digit known as the message billing index. This digit is determined from the class of service of the calling subscriber together with the office to which his call is directed, and constitutes the basis for determining the charging rate on bulk billed calls where the called number is not recorded on the AMA tape. The sender now signals the transverter connector for connection to a transverter, and transfers to it all the foregoing information.

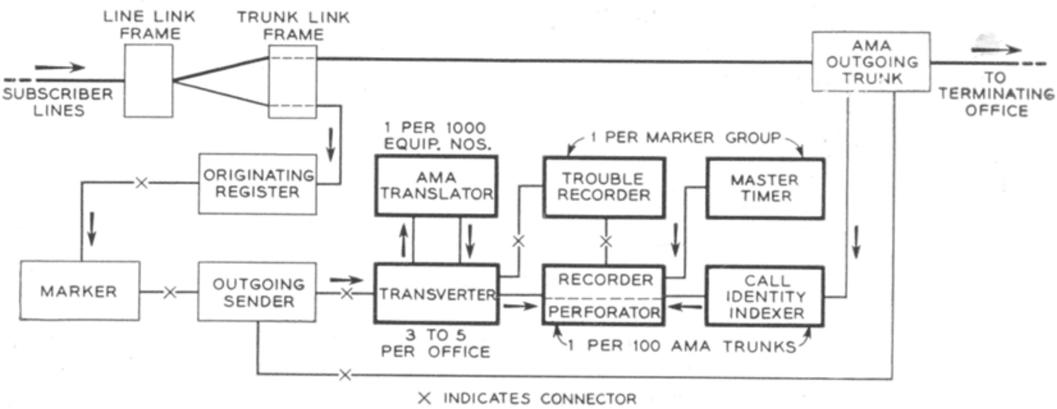


Fig. 1—Block diagram of the circuits associated with an AMA call in a No. 5 crossbar office.

From the message billing index, the transverter determines whether the call is to be bulk billed on a message-unit basis

* See page 5.

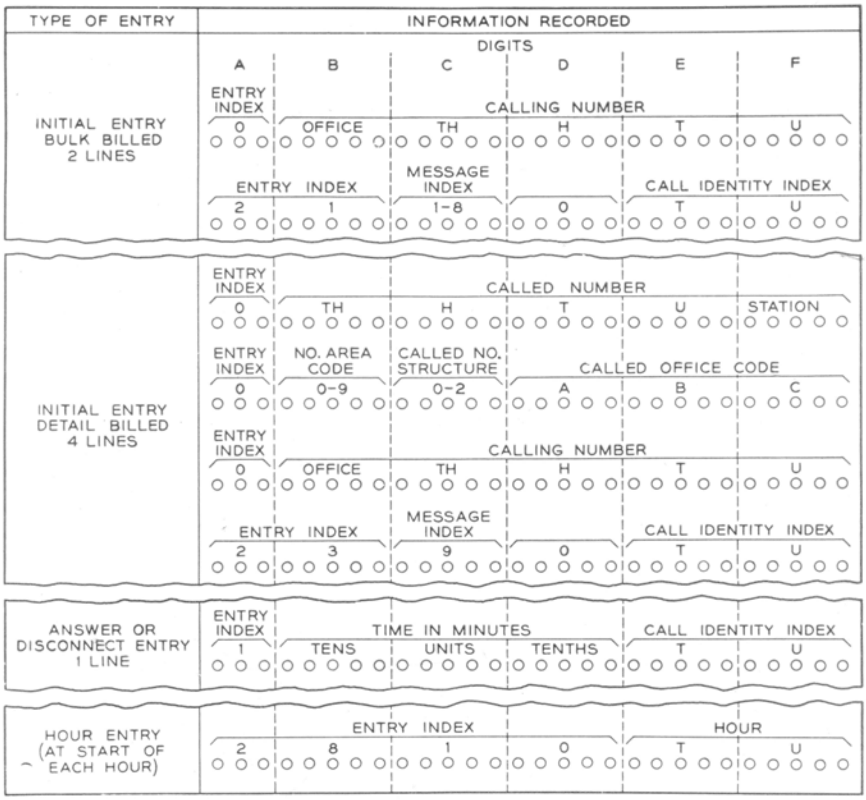


Fig. 2—Arrangement of the more common entries on an AMA tape.

or detail billed to include the called number; for a bulk-billed call a two-line initial entry is adequate, while for a detail billed call, a four-line entry is required. The transverter then summons the translator and obtains from it the directory number corresponding to the calling subscriber's line and party assignments. The transverter also causes the call identity indexer to furnish the call identity index to the recorder. This completes the information required for the initial entry. Primed with this information, the transverter engages the recorder assigned to the outgoing trunk selected, and causes it to operate the proper perforator magnets one line at a time. The actual perforation of the tape is accomplished by a perforator which is individual to the recorder circuits. This initial entry is normally recorded while the switching circuits are completing the connection to the called subscriber's line in a distant office.

The arrangement of the information on the central office tape for the more common entries is shown in Figure 2. Six digits are recorded in each line in positions designated A to F from left to right. For the A digit, one of the three punch positions is perforated to designate digits 0, 1, or 2, while for the digits B to F, two out of five punch positions are perforated to designate digits 0 to 9. The first few digits of each line comprise the entry index, and indicate the type of information the line contains.

At a central office, the lines are perforated in the order from top to bottom of Figure 2. At the accounting center, on the other hand, the tapes are read in the opposite direction, and thus for a two-line initial entry, the accounting center will first read the line whose entry index is 21. This index indicates a two-line entry, and the zero entry index in the next line identifies the second or supplementary line of this entry. The message billing index, or message index, appears at the right of the entry index, and may be any digit from 1 to 8, inclusive. Next is an unused digit zero, and beyond it are the tens and units digits of the call identity index, which in the No. 5 crossbar system is the trunk number. Two digits are adequate, since no more than one hundred such circuits are associated with a single recorder. In the second line of the initial entry, a single digit suffices to designate the office in which the calling subscriber is located since no more than ten offices are served by a common group of originating equipment, known as a marker group and identified elsewhere on the tape as described later. The calling subscriber's directory number appears in the remaining four digits of this line.

Below the two-line initial entry of Figure 2 is a four-line initial entry used for detail billed calls. The first two lines, in the order read by the accounting center, are similar to those of the two-line entry except that the entry index of the first line is 23 to indicate three additional or supplementary lines, and the message index is always 9. The last two lines of this four-line initial entry both have zero as the entry index, and contain the called office code and the number dialed, a numbering area digit, and a called number structure digit. Since the called office may be outside the local area, it is necessary to identify the area as well as the office, and the called area digit is used for this purpose. Calls to outside areas require special prefix digits for control of the switching equipment, and these digits cause the proper numbering area code to be perforated. The called number structure digit serves to indicate whether the numerical portion of the called number is made up of three digits, four digits with or without a party letter, or five digits as in numbers above 9999; this digit is used by the accounting center for proper printing of the called number.

At the start of conversation, the call identity indexer, under control of the trunk, brings the recorder in on the connection a second time to perforate the time of answer. At the end of conversation, the process is repeated for the purpose of entering the time of disconnect. One of these

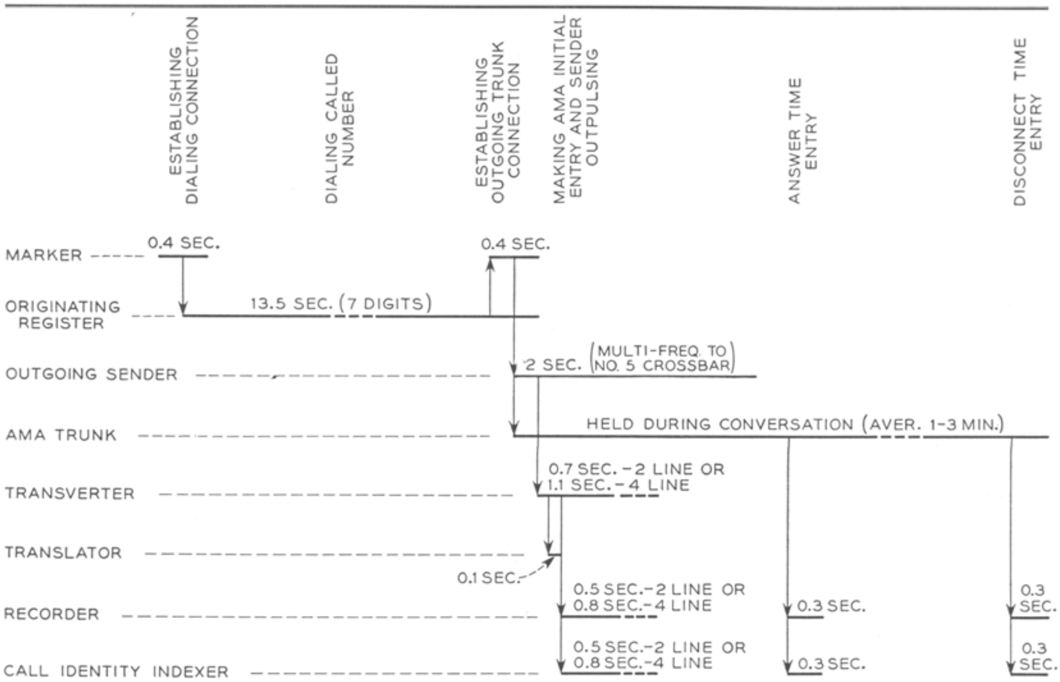


Fig. 3—Holding sequence of the circuits on an AMA call in a No. 5 crossbar office. Circuit holding times are approximate.

entries is shown in Figure 2 below the four-line initial entry. The entry index for this line is a 1, which indicates to the accounting center that the line is an answer or disconnect entry, no differentiation being required between the two. The B, C, and D digits in this line show the time at which the recording was made in terms of tens and units minutes and tenths of a minute past the hour. Digits E and F contain the call identity index for later use by the accounting center in associating this entry with the proper initial entry.

Since the answer and disconnect entries show only the number of minutes past an hour and do not specify the hour, it is apparent that some record of the hour is needed. This is obtained at the turn of each new hour by automatically recording the new hour on the tape of each recorder. Such an entry, with the identifying entry index 2810 followed by the tens and units digit of the particular hour is shown in the last line of Figure 2. The hour information is obtained from the master timer.

An interesting feature of the AMA equipment is its high speed of operation. This is important to insure against delay in the normal completion of calls and also to obtain short holding times for the common control circuits to permit a small number of these circuits to handle all the AMA traffic for an entire central office or group of offices. Figure 3 shows the time sequence in which the various major circuits come into play for both the switching and the AMA tape recording of a call in a No. 5 crossbar office. Approximate circuit holding times are indicated, and (for the AMA control circuits) range from approximately 0.1 second for the directory number translator to 0.7 second for the transverter in handling a two-line entry. A four-line entry engages the transverter for about 1.1 seconds. Between the common control circuits are connectors (not indicated separately in Figure 3) which follow conventional patterns and use preference and chain relay features to avoid interference between simultaneous calls.

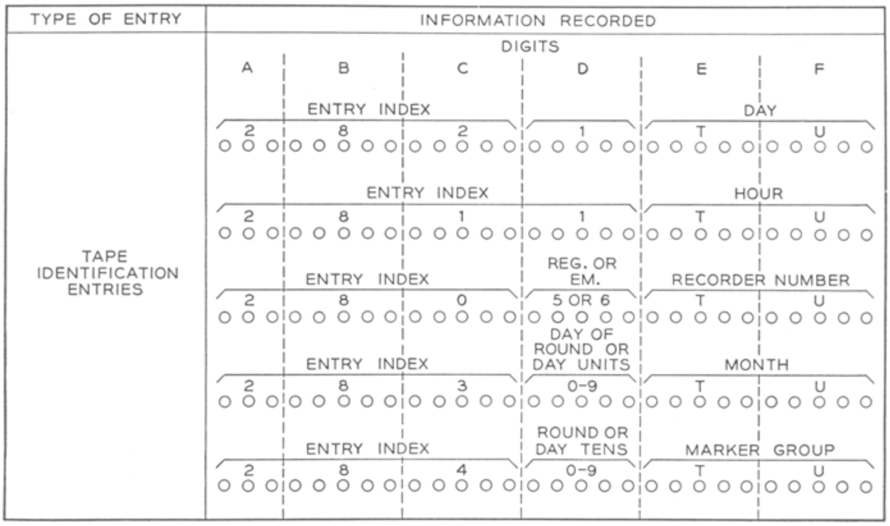


Fig. 4—Tape identification entries, which are perforated on a tape before and after cutting.

The principal function of the master timer is to keep a running record of time in steps of six seconds. This record includes the month, day, hour, tens and units minutes digits, and the tenths of a minute digit. A running record of the time within each hour is delivered to each recorder where it is always available for the recording of answer and disconnect entries. With the turn of each hour, the timer directs the perforation of an hour entry on all recorder tapes as previously mentioned.

Once a day, at 3 A.M. when the traffic is low, a series of special lines is recorded on all tapes to permit cutting them preparatory to transportation to the accounting center. These special lines start with one set of tape identification entries as shown.

in Figure 4, and are followed with about six feet of a uniform "splice" pattern. A second set of the tape identification entries completes the 3 A.M. record. With this arrangement the tape may be cut anywhere in the splice pattern, and the tape identity information will be available on both sides of the cut.

As shown in Figure 4, the lines of tape identification entries are characterized by three-or four-digit entry indexes, each starting with a 28 and followed by a digit 0 to 4 which identifies the particular line in the entry. These lines, in the order read by the accounting center, start with the one whose entry index is 284. The D digit, together with a corresponding digit in the following 283 line, identify the day on which the tape is perforated, either in terms of calendar day, or round and day of round. A round is a group of consecutive days the business for which is handled as a unit in certain parts of the accounting processes. In some accounting centers it is used in place of the more conventional calendar day. The marker group data is carried by the E and F digits of the 284 line and identifies the unit of common control equipment known as a marker group, which serves one or more offices in the same building. The identity of this unit, together with that of the particular recorder in the unit as provided in the 280 line, will completely identify any recorder tape in an entire accounting center area for a particular day. The D digit in the 280 line is a 5 on regular recorder tapes and a 6 on the tape of the emergency recorder which may be substituted for any regular recorder in trouble. In the latter event, the recorder number shown is that of the regular for which the emergency is substituted. The 282 line records the day, while the 281 line records the hour. The D digit in the 282 line is not used, and its position is filled in with a 1, since every position must have a digit or a trouble will be recorded. In the 281 line, however, the D digit, which is also a 1, forms part of the entry index, which is thus 2811. There are thus two types of hour entries that may be found on a tape: the one just described with an entry index

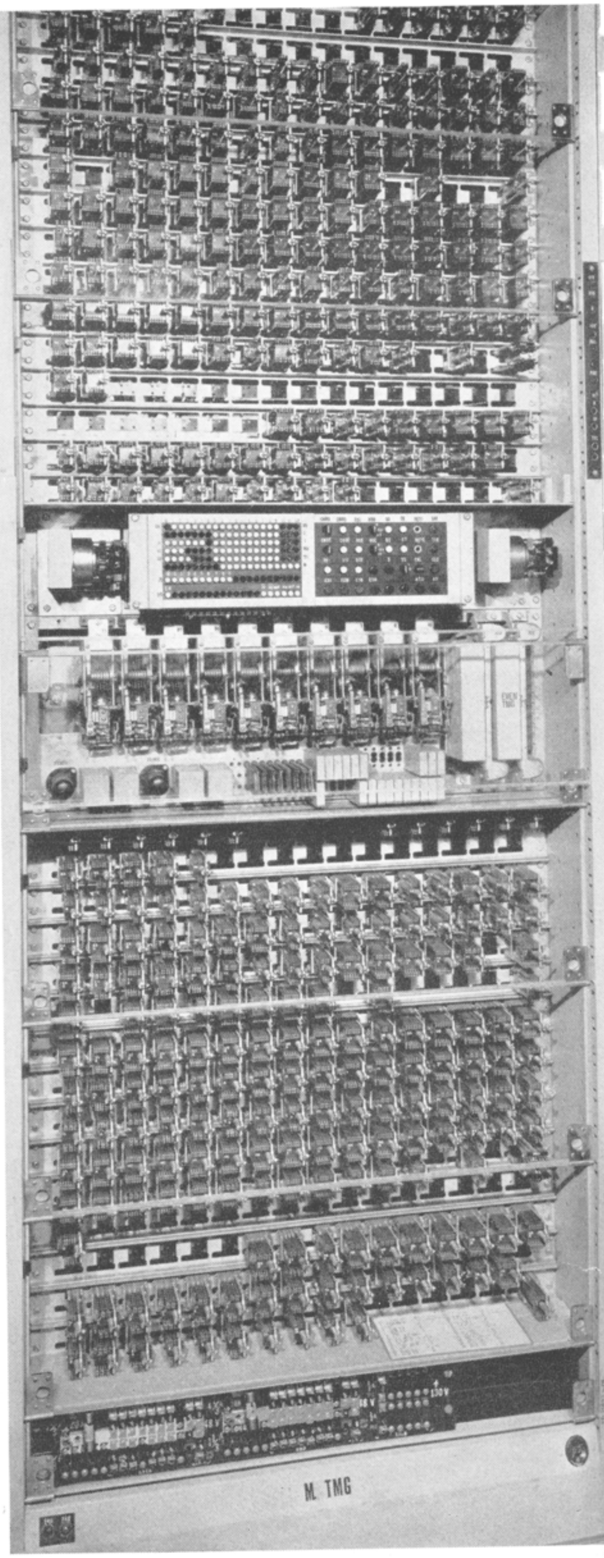


Fig. 5–The AMA master timer.

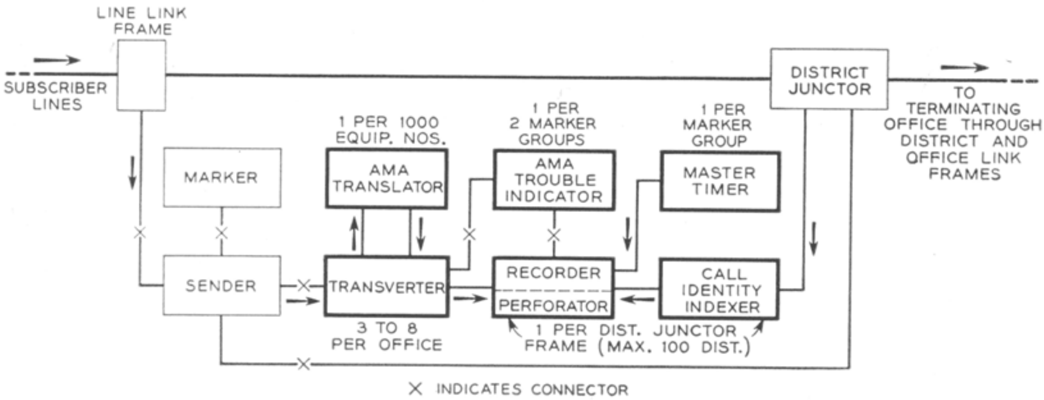
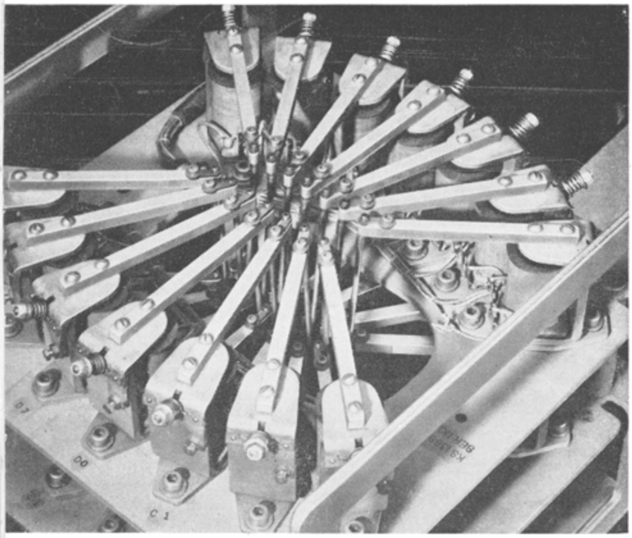


Fig. 6—Block diagram of the circuits associated with an AMA call in a No. 1 crossbar office.

2811, and the one described in connection with Figure 2, with an entry index 2810. Since these two hour entries may require different treatment at the accounting center, they are differentiated by 0 or 1 as the fourth digit of their entry index.

Many safeguards are designed into the AMA circuits to insure against incorrect charging in the event of equipment failures. For example, digit information is conveyed by the "two out of five" method, and a check is made to determine that no more or no less than two leads in the group of five are grounded before the information is accepted. Critical leads are checked for opens, crosses, and false grounds. If a trouble is encountered, the trouble recorder is summoned and a trouble card is produced showing the condition of the significant relays at the time of failure. In addition to the ability of detecting trouble on service calls, there is provision for making test calls on all the service circuits.

The above description has been specifically concerned with AMA in a No. 5 crossbar office. In No. 1 crossbar, the basic equipment and circuit features are similar but some of the details are different because of differences in the detailed circuit operations of the two systems. The AMA tapes are identical in the two types of offices, as indeed they would have to be to avoid the need for dissimilar handling at the accounting center. Figure 6 shows a block diagram of the principal circuits involved in AMA recording in a No. 1 crossbar office. In this system the subscriber's dialing is registered directly in the sender instead of initially in a register as in No. 5. Also, the transmission circuit is a district junctor instead of a trunk. In both systems the sender seizes a transverter via a transverter connector, and the operations of the AMA circuits in recording the data on tape are the same.



The AMA Tape Perforator

P. B. DRAKE
Switching Apparatus Development

One of the basic devices of the Automatic Message Accounting system* is the tape perforator. Its function is to perforate holes in paper tape in a coded pattern, and it is used both in central offices and in accounting centers. In central offices, it records the pertinent information for each call, while in accounting centers, it provides new tapes as the data are processed for use in preparing the customers' bills. The machine consists essentially of 28 perforating magnets, a drum, and a paper advance mechanism. The magnets, each with an armature arm carrying a perforating pin, are mounted on a two-level steel frame as shown in Figure 1. The drum and paper advance mechanism, together with a number of auxiliary units are mounted on the underside of the machine. The steel frame, consisting of two duplicate halves, is designed to protect the parts mounted on it from damage when the machine is resting on any side, and at the same time to provide handles by which the perforator may be moved about.

In early studies of the AMA project, it was decided to use a tape three inches wide, and to record six coded digits in each line of perforations across the tape. Since one of the digits requires space for three perforations, and each of the remaining digits requires space for five, a total of 28 perforating positions is required. Allowing for suitable margins along each edge of the tape, this gives only a tenth of an inch between the centers of adjacent perforations. Since the perforating pins themselves are about a tenth of an inch in diameter, and the armature bars that operate them are appreciably wider than that, it was obvious that all 28 pins could not be lined up in a single row across the tape. The arrangement adopted is indicated in Figure 2.

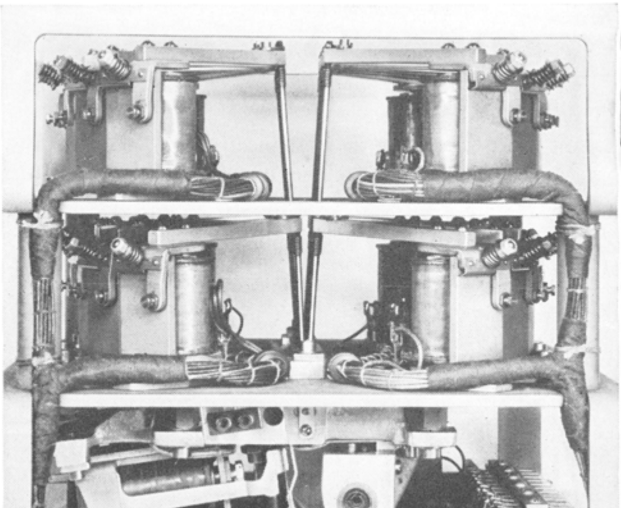


Fig. 1—Side view of the perforator used in accounting centers.

* See page 5.

The perforating magnets are divided into four groups of seven each and mounted on two levels; on each level seven magnets are mounted in an arc near the front edge of the frame, and seven in a similar arc near the rear edge of the frame. The fourteen pins operated by magnets along the rear of the frame are lined up over alternate perforating positions in one row, and those operated by magnets along the front end of the frame are lined up over alternate perforating positions in the adjacent row. This is indicated in Figure 3, where the positions are numbered from 1 to 28 across the tape, and the rows are numbered in the order in which they pass through the perforator. The first "line" of codes perforated use the even numbered holes in Row 1 and the odd numbered holes in Row 2. The second "line" perforated use the even numbered holes in Row 2 and the odd numbered holes in Row 3, and so on for successive "lines" of information. Although in descriptions of the AMA system reference is always made to

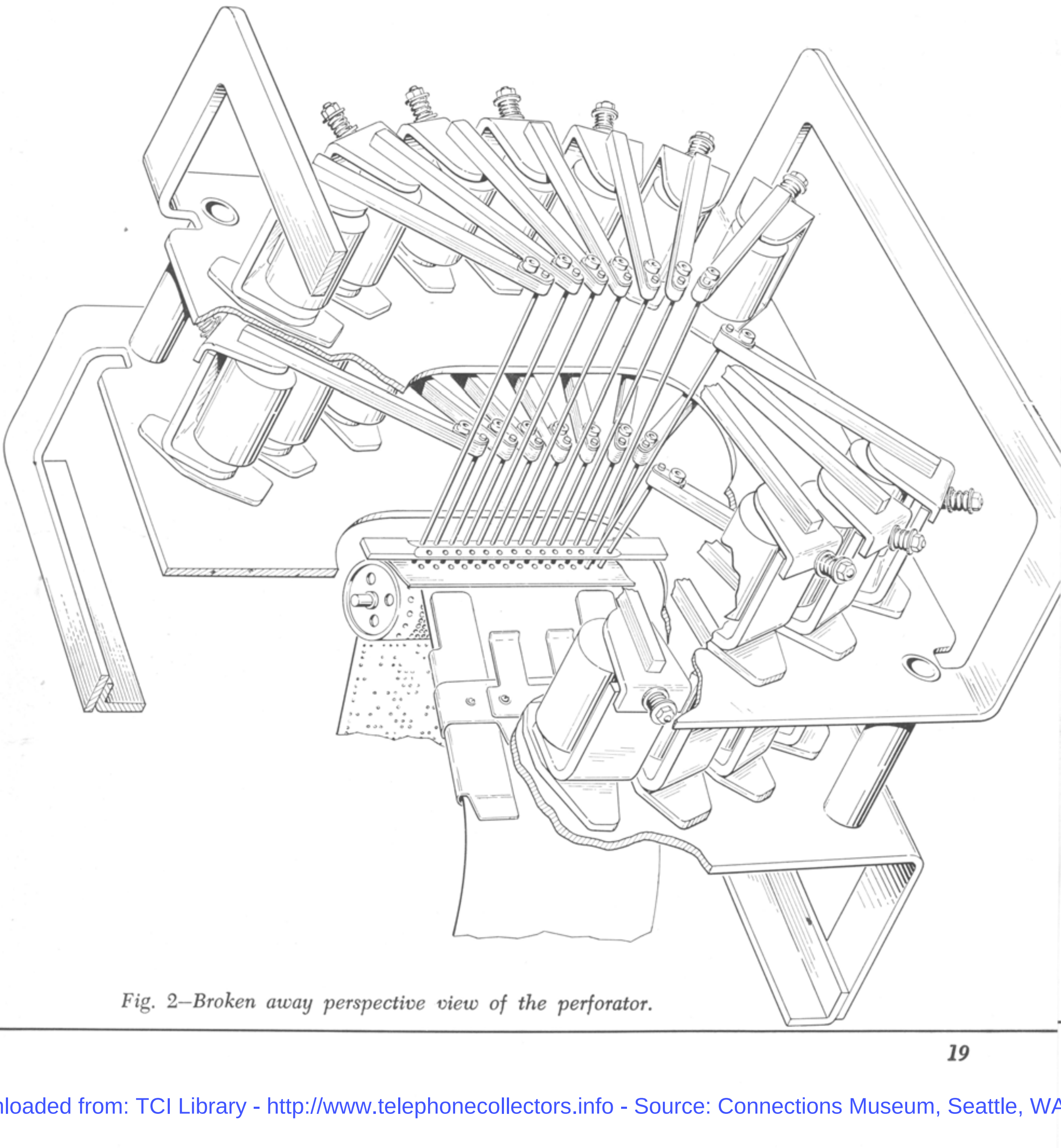


Fig. 2—Broken away perspective view of the perforator.

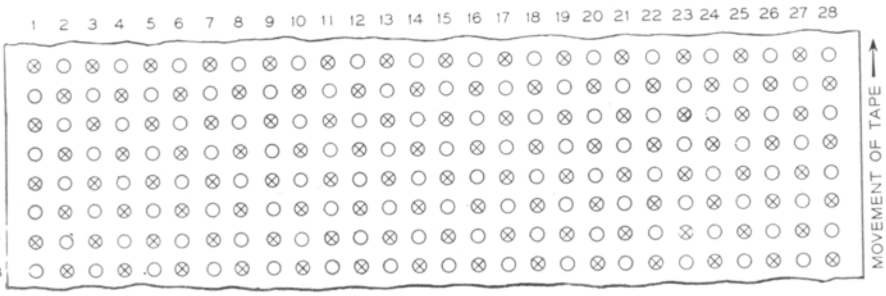


Fig. 3 – Pattern of the holes that are punched in tape by the perforator.

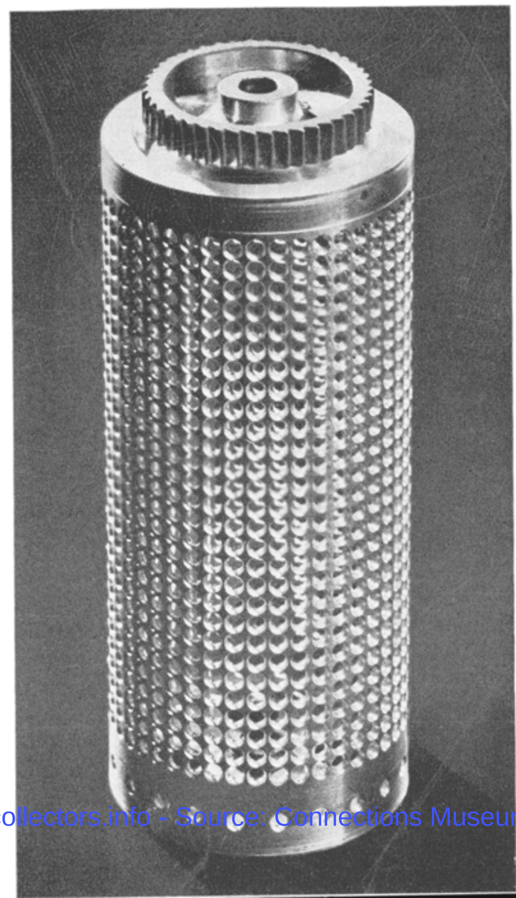
the information carried by a "line" of holes, the holes comprising such a "line" are physically the alternate holes in adjacent rows.

One of the most difficult undertakings in the design of the perforator was the drum on which the paper rests while being perforated. This drum is approximately 1½ inches in diameter and 3⅝ inches long and has 1232 holes (44 rows of 28 each). The holes are countersunk so as to conform to the conical ends of the perforating pins. Extreme precision is necessary in drilling these holes to permit the perforating pins to seat properly in them without binding in the guide. Also, the perforated tape is later passed through a reader at the accounting center, and the conically shaped perforations must fit accurately in the holes of the drum of a reader while the tape is being read. Since the machine was designed, moreover, to perforate 20 lines a second, and thus for each perforating operation the drum must be started, rotated a little over 8 degrees, then stopped, and still leave sufficient time for the perforating operation, all within 0.05 of a second, it had to be made very light to limit the force of inertia. It was therefore made from aluminum tubing with a wall about 1/16 of an inch thick. One of these drums removed from the machine is shown in Figure 4.

In operation, the tape is fed into the chute just under the bottom level of the frame, evident in Figure 2. This chute directs the paper under a curved metal guide plate, also evident in Figure 2, that holds the paper against the drum and guides it out of the machine. This guide is drilled with two rows of clearance holes to permit the perforating pins to pass through. Just above this guide is a second guide, similarly drilled, but with slightly smaller holes that guide the perforating pins into the proper holes in the drum. When the pins are up, their points are just below this upper guide, and when a magnet operates, the conically shaped point of the pin passes through the hole in the lower guide, perforates the tape, and forms a paper cone in the tape that seats in the countersunk hole in the drum. As the pin is retracted, the paper cone remains in the drum, and it is by means of these cones that the tape is drawn as the drum is rotated.

The paper-advance mechanism consists of a magnet and an armature carrying a

Fig. 4–An AMA drum.



pawl which engages the teeth of a ratchet attached to the drum, evident in Figure 4. When the magnet is electrically energized the pawl is withdrawn from a ratchet tooth and positioned to engage the next tooth. A retaining pawl prevents the drum from rotating when the driving pawl is withdrawn. When the magnet is de-energized, the spring-driven armature causes the pawl to engage the ratchet tooth and rotate the drum to advance the paper tape one row of holes. Each time the perforating magnets perforate holes in the tape, the paper-advance mechanism operates and advances the tape one step.

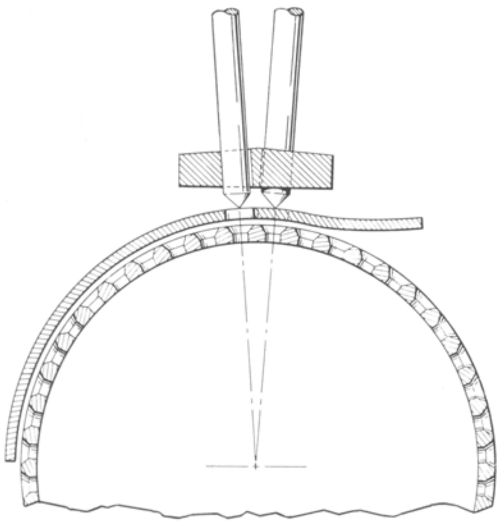


Fig. 5–Diagram showing relative positions of perforating pins and drum.

Each perforating pin moves along the line passing from the center of a hole in the drum to the axis of the drum, and thus the pins for the two rows of holes slant inward as the sides of a V that would intersect on the axis of the drum. This is evident in Figures 1 and 2 and in more detail in Figure 5. Since the pins must move essentially in a straight line, while the ends of the armature bars travel in an arc, a flexible coupling is required between them. This is accomplished by the construction shown in Figure 6. It consists of a steel ball held firmly between a cup-pointed set-screw and the top of the perforating pin by a helical spring. One end of the spring is held by the screw threads of the set-screw, while the other end is set into a groove in the pin. This coupling readily permits the slight rocking needed when the magnet operates. These springs are evident in Figure 1, which also shows the springs at the rear of the magnets that return the armatures to their normal positions, and thus withdraw the perforating pins when the operating current is interrupted.

To provide a continuous tape for the perforators, the end of one tape is spliced to the beginning of another. In this splicing operation the two tapes are overlapped for a short distance, and since the perforating pins cannot consistently penetrate the double thickness of tape, each perforator is equipped with a splice indicator, which detects an approaching splice and causes a special pattern to be perforated on the tape for a short distance each side of the splice.

At the time the splice is made, a rectangular hole, called a splice window, is cut in the tape across the splice as shown in Figure 8. The splice indicator itself consists of a flat finger (just below the middle of the drum in Figure 9) that rests on the tape a short distance back from the drum. When the splice window comes along, this

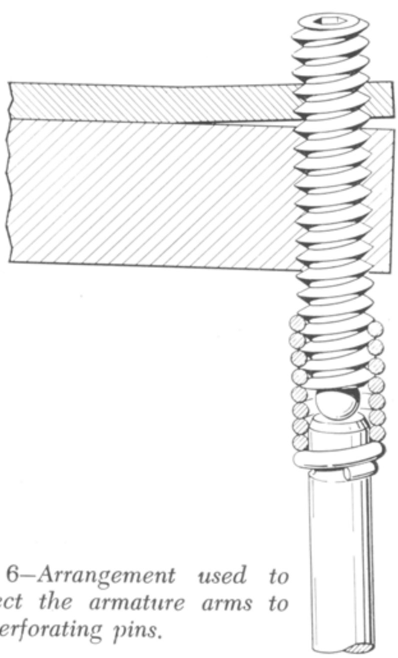
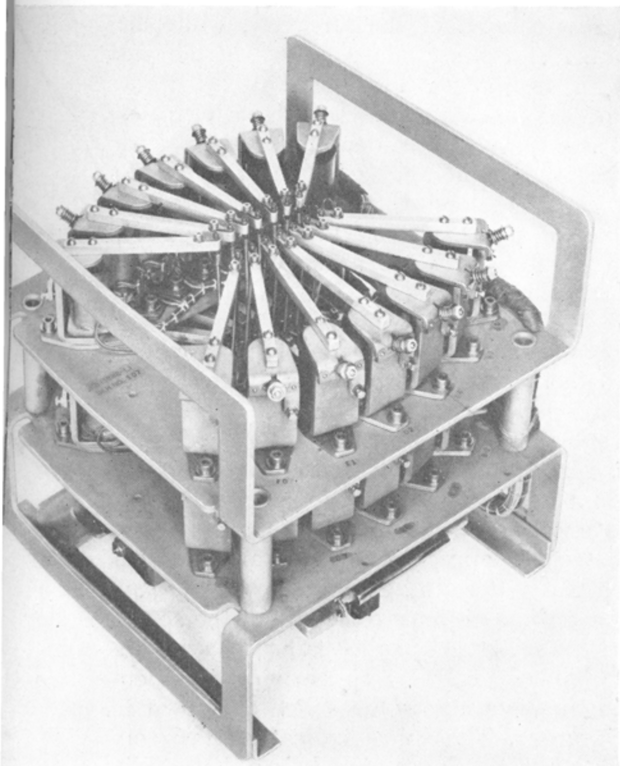


Fig. 6–Arrangement used to connect the armature arms to the perforating pins.



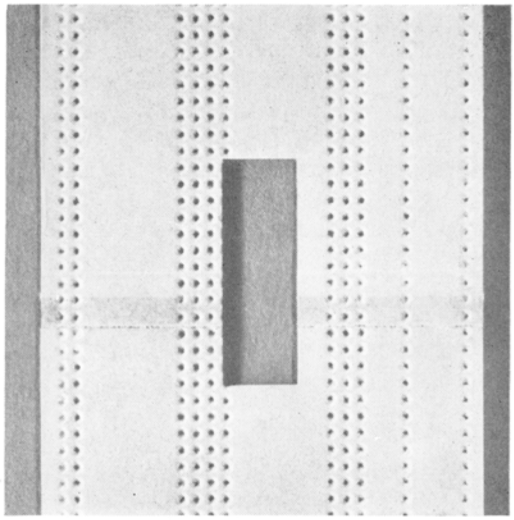


Fig. 8—A section of the tape showing a splice window and a splice pattern.

Fig. 7—View of the AMA perforator showing the two duplicate halves of the frame assembled to provide a two level structure for supporting the perforating magnets.

spring driven finger moves up a short distance through the splice window and in doing so permits a micro-switch to operate, causing an associated circuit to direct the perforator to produce a splice pattern—also shown in Figure 8. For the brief period while this splice pattern is being perforated, the machine is unavailable for perforating message information, and thus there is avoided the possible mutilation of information pertaining to a call because of the perforating fingers' being unable to penetrate the double thickness of paper at the splice. At the accounting centers, the circuits recognize the splice pattern, and no information is recorded until the splice pattern has passed through the reader.

Besides these various features of the perforator that are common to the machines used in both central offices and accounting centers, there are a few auxiliary features used only in the central office machines or only in the accounting center machines. In central offices the tapes are cut only once a day, and to allow space for cutting, the recorder – at about 3 a.m. – automatically perforates several feet of splice pattern on the tape together with tape identification codes on each end of the splice pattern. Tape may then be cut anywhere within this splice pattern at the convenience of the operating staff.

At accounting centers, on the other hand, the tapes are cut more frequently and at irregular intervals. To simplify this cutting, an electrically operated paper cutting mechanism is attached to the machines used in the accounting centers. It consists of a longitudinal section of a cylinder, shown just above the perforating drum in Figure 10, that when rotated by a solenoid, shears the paper from one side to the other against a stationary knife edge. The cutter is push-button controlled, and thus permits the tapes to be quickly cut by the attendants whenever the required amount of information has been recorded.

At the accounting center, the perforated tape is allowed to fall into a bin. It was found during the development stage that at times, particularly during the winter months, the paper in passing through the

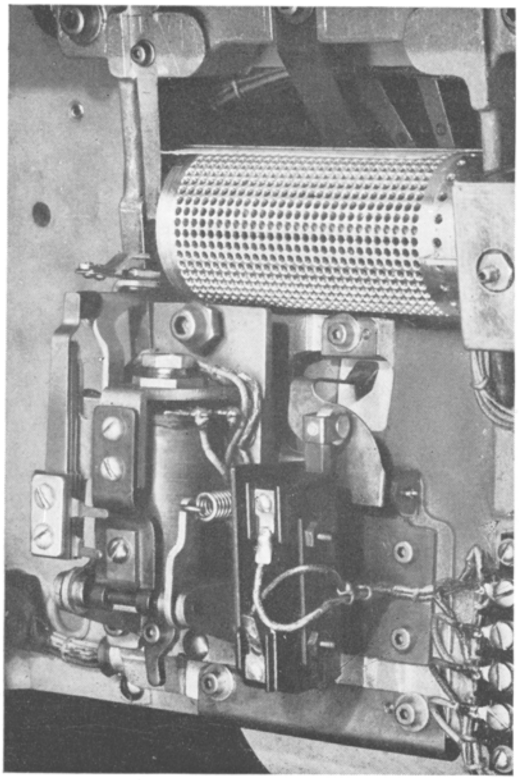


Fig. 9—View of the underside of a central office perforator showing the splice detecting finger just below the middle of the drum.

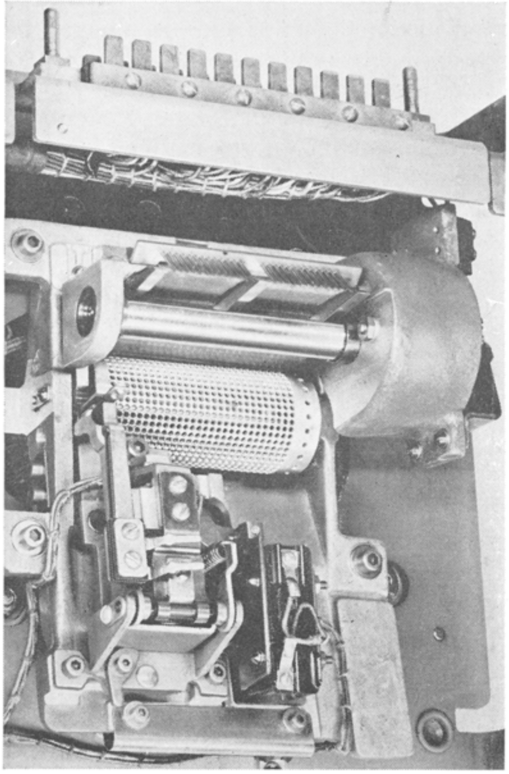


Fig. 10—Underside of an accounting center perforator showing the cutting mechanism and the static eliminator just above the drawer.

perforator collected sufficient static electricity to cause the tape to cling to the storage bin. This drastically reduced the amount of tape that could be deposited in a bin. To alleviate this, a static eliminator consisting of a series of needle points was designed and mounted on the paper cutter frame to dissipate the static electricity as the tape leaves the perforator. This static eliminator is also evident in Figure 10. There is no need for it in the central office machine where the perforated tape is wound on a motor-driven drum.

Although the machines in central offices do not have either the paper cutter or the static eliminator, they, in turn, are equipped with a drum-advance check that is not used in accounting centers. It consists of a small relay having a finger on its armature to "peck" at the drum. Special holes around the periphery of the drum on one end, shown in Figures 4 and 9, are arranged so that at every other step of the drum one of the holes is brought into alignment with the finger of the relay. Each time that the perforating magnets are electrically energized, the relay is also energized so that its finger will strike the periphery of the drum or engage one of the drum holes. When it engages a hole, the relay armature is permitted to complete its operating stroke and to close its contacts. When it strikes the drum, however, the motion of the armature is restricted and the relay contacts do not close. Continuation of this sequence indicates to the associated circuit that the drum advances after each operation of the perforating magnets. A failure of the sequence at once gives an alarm so that the operation of the perforator can be checked.

The electrical components of the perforator are connected by a local cable to a plug mounted on the underside of the perforator, partially evident in Figures 9 and 10. This plug contains 44 terminals arranged on two levels and is so designed and mounted that it may be plugged into the properly positioned jack to which the associated circuits are connected.

In designing the perforator, a number of parts manufactured for existing telephone apparatus were used, and modified where necessary to keep down the development and manufacturing expense. The perforating magnets, for instance, contain the same coil assembly and pole pieces used on 263-type relays. The paper advance mechanism utilizes the magnet, armature, pawl, and framework of the 206-type selector. Perforators used in accounting centers are known as KS-13882, List 1, while those for use in central offices are known as KS-13882, List 2 perforators.

These perforating machines are at present being manufactured by the Teletype Corporation in Chicago.

Fig. 11—AMA perforators in central office recorders.

Recording on AMA Tape in Central Offices

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Switching Systems Development

With the new Automatic Message Accounting system*, the basic information that will later be used in the accounting center for computing and printing subscribers' bills is recorded on AMA tapes in the various central offices. These tapes are punched by perforators but the perforators are controlled by a "recorder" or by a recorder and a transverter working together. For each call, three separate entries are made on the tape. The first entry includes all the information needed except the time for the beginning and ending of the call; the second gives the time the conversation begins; and the third, the time the call ends. Each entry requires only a fraction of a second of the recorder's time, and since each recorder may serve as many as 100 trunks, the three entries pertaining to any one call may be separated by entries pertaining to other calls. Each entry includes the number of the trunk involved, and it is this trunk number, that identifies the three entries for any one call.

The information perforated in the tape for these three types of entries is indicated in Figure 1. For the initial entry, either two or four lines are required: four when the office and number of the called subscriber is required, and two when it is not. In a two-line entry, the first line includes the calling office and number, while the second line includes the message index and the call identity index, which is the trunk number in the No. 5 system, and the district junctor

* See pages 5 and 12.

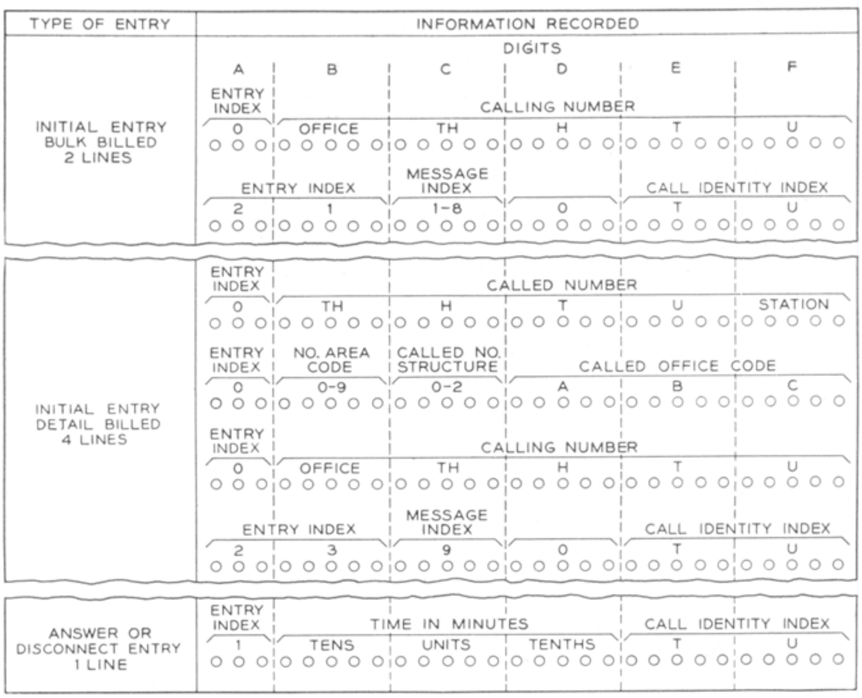

Fig. 1—The three types of entries perforated on a central office tape for each completed call.

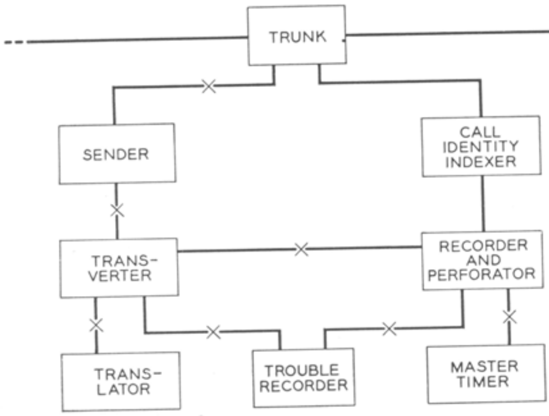

Fig. 2—Block diagram of circuits used for AMA recording in central offices.

in the No. 1 system. In a four-line entry, the called-line information is given by the first two lines; the last two lines include the information contained in a two-line entry. The two time entries for each call are identical except for the time indicated.

A block diagram of the circuits employed in making these recordings in a No. 5 crossbar office are shown in Figure 2. When a call is placed, a marker establishes a connection from the calling line to a suitable trunk, associates a suitable sender with the trunk, and transfers to the sender all the information it will need in handling the call. After the sender has recorded this information, it seizes the transverter, and transmits to it the identification of the calling line and certain other information. This identification of the calling line is in terms of the position of the line on the line link frame, however, and since this identification is not suitable for billing purposes, the transverter seizes a translator* to secure the directory number of the calling line. Having secured this information, it then seizes the recorder to make the initial entry.

If this initial entry requires four lines, the sender as well as the transverter will be used in controlling the recorder. The method employed is indicated in simplified form in Figure 3. Six groups of leads—five of five leads each, and one of three—connect the transverter with the recorder, and eight groups of five leads connect the transverter to the sender. As soon as the recorder is seized, relay C4 in the transverter is operated, and connects through to the sender the five sets of leads that will control the perforation of the last five digits of the first line. Relays in the sender are already operated to close two leads of each set of leads to cause the perforation of a thousands, hundreds, tens, units, and station digits of the called number. The A digit of the entry is controlled by contacts on relay C4 in the transverter, and serves to indicate that the line being perforated is not the last line of the entry.

Immediately after this line of digits has been perforated in the tape, the recorder will release relay C4 in the transverter, and operate relay C3. Digits A, B, and C will be controlled directly by relays in the transverter, while the leads for digits for D, E, and F will be closed through to the sender, where relays, already operated, will close two out of each set of five leads to indicate the three digits of the called office code. As before, digit A indicates that the line of entry is not the last line. Digits B and C give the number area code and the called number structure, and relays in the transverter will have already been operated by the sender to indicate the proper digits that are to be used.

As soon as this line has been perforated, the recorder will release relay C3 and operate relay C2. The six digits for this line are the entry index, the calling office number, and the thousands, hundreds, tens, and units digit of the calling number. Relays in the transverter have already been operated by the translator to record the proper values for these digits.

Perforation of the fourth line follows at once by the release of relay C2 and the operation of C1. The first four digits of this line are determined by relays in the transverter. These are the entry index, which requires two digits, and indicates the last line of a four-line entry, the message index, and a zero to fill up a position not required. The E and F digits of this line are the tens and units designation of the trunk. The leads that control the perforation of these latter two digits are cut through from the call-

* See page 30.

identity indexer by a relay in the recorder that is operated at the same time as relay C1 in the transverter. Immediately after this four-line entry has been perforated, the recorder is released by the transverter and is ready to proceed with another call.

A call identity indexer is permanently associated with each recorder, and identifies the trunk through a group of tens and a group of units relays to indicate the tens and units digits of the trunk. These relays in simplified form are indicated at the lower right of Figure 3. When a trunk has been seized, and while the first line of an initial entry is being perforated, the trunk grounds its DJ lead to the call identity indexer. Through a back contact of a tens auxiliary relay, this causes one of the tens relay T0 to T9 to operate and lock, thus identifying the tens digit of the number of that particular trunk. The operation of the tens relay places ground on the proper tens leads on a two out of five basis to the perforator, and also operates the tens auxiliary relay through one of whose back contacts it has been operated. When the auxiliary relay operates, it closes the ten DJ leads to the group of units relays, and one of them

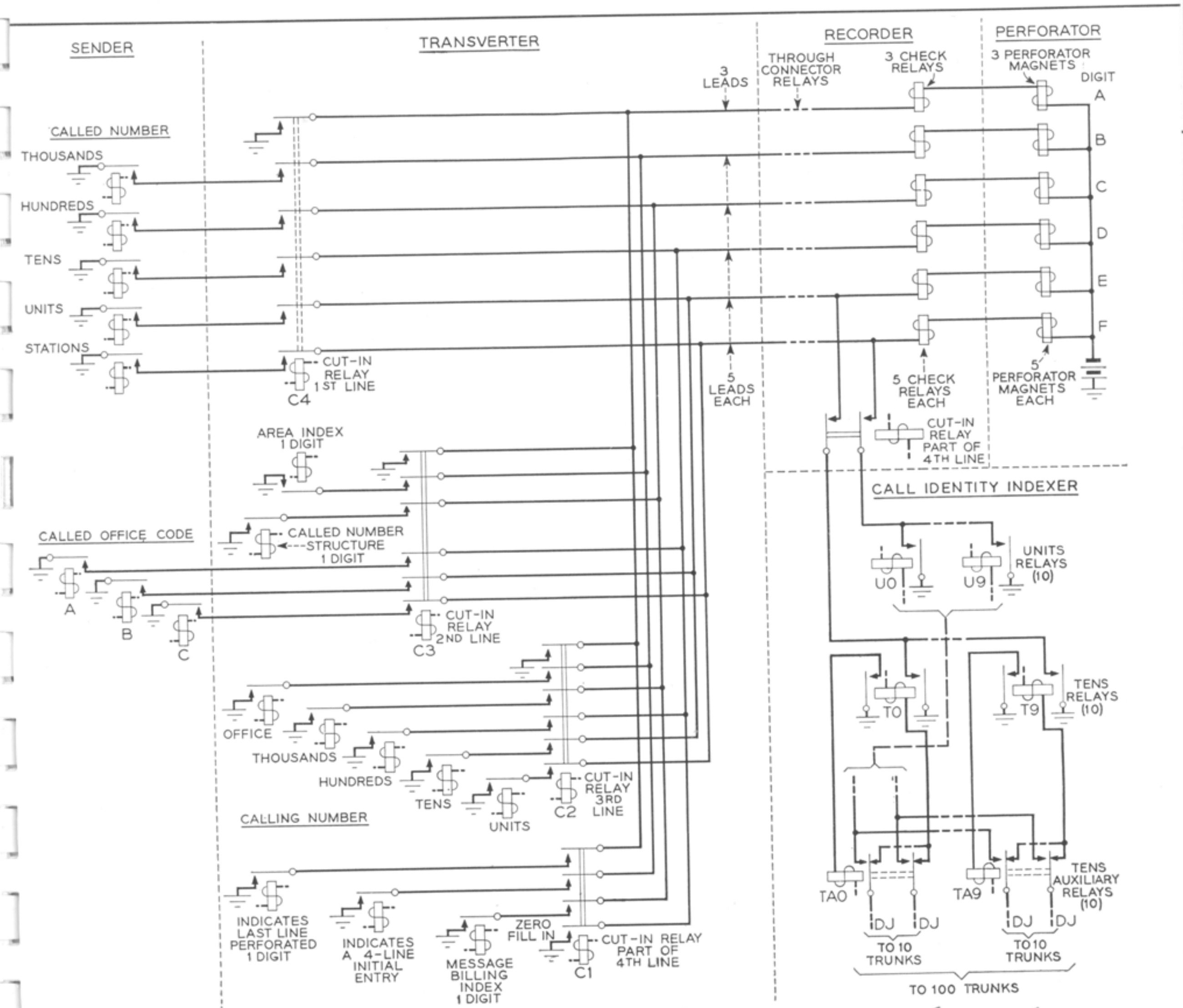

Fig. 3—Simplified schematic of circuits used in perforating initial entries.

operates and places ground on the proper units leads to the perforator. The connection to the DJ lead in the trunk will then be opened, but the tens and units relays will remain locked until after the cut-in relay to the recorder has been operated and the trunk number has been perforated.

For answer entries or disconnect entries, the operation of the indexer relays is the same. For these entries, however, the start signal over lead DJ is under control of the supervisory relays in the trunk instead of relays in the transverter, and the recorder makes the answer or disconnect entry in response to the operation of the relays in the call identity indexer.

The rapid perforation of four lines of initial entry outlined briefly above is accomplished by a relay circuit of which the principal components for perforating three of the four lines are shown in simplified form in Figure 4. Relays C4, C3, etc. of this diagram are the cut-in relays in the transverter already referred to in connection with Figure 3, but for simplification the six sets of leads that are cut through by their contacts have been reduced on the diagram to one lead for each relay.

When the recorder is connected to the transverter, ground on a spring of relay PT0 operates relay P4 in the transverter. Relay P4 holds itself operated through a front contact on one of its springs, and through ground on another spring, and through a back contact of P4A, operates C4. This perforates the first line as already described.

Through another contact, C4 also operates PTC in the recorder, which in turn operates the paper advance magnet and closes the operating circuit of PT0. Since this latter is a slow operate relay, there is a short interval before it operates. Operation of the paper advance magnet pulls back the pawl on the operating drive of the paper so that when the operating magnet is released, the paper will be advanced one line.

When the perforating magnets operate as a result of the operation of C4, relay CK is operated, thus closing a connection over lead P1 to the transverter and opening the connection over lead P. Circuit PT0 is given slow-operate characteristics to allow a short

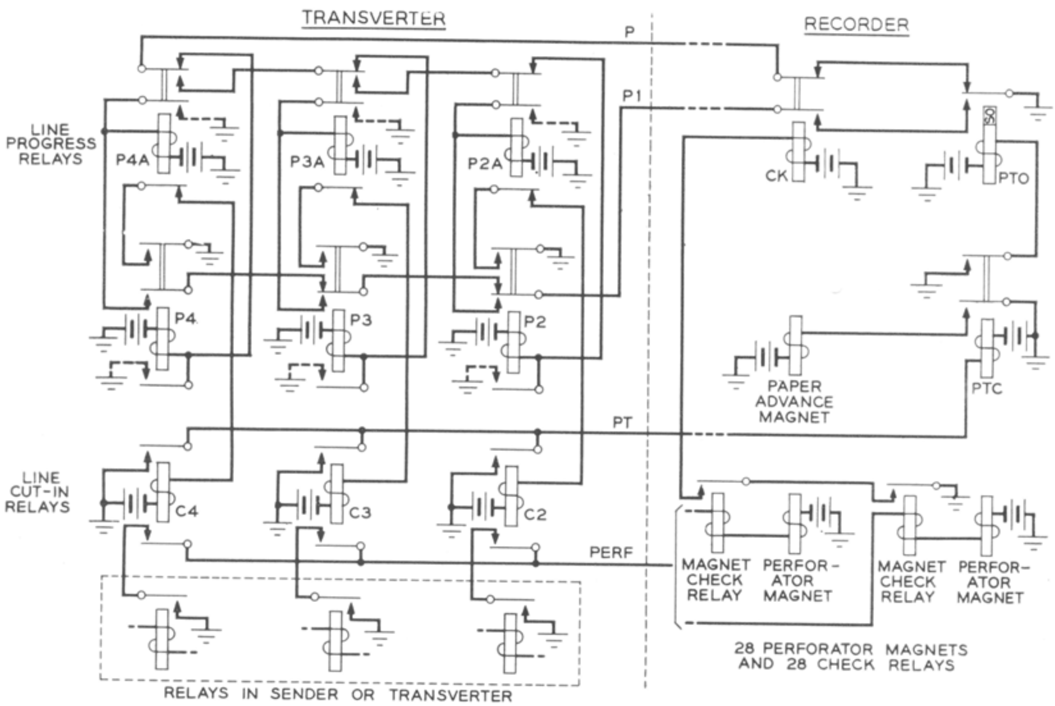

Fig. 4—Simplified schematic of line progress control circuit.

time interval to insure that the perforating magnets have time to operate fully. When PTO operates, ground is applied to lead P1 and this operates P4A in the transverter through back contacts of P2, and P3 and a front contact of P4. As P4A operates, it locks itself in and releases C4, and this in turn releases PTC in the recorder. This releases the paper advance magnet and thus advances the paper one line and also releases PTO, thus again placing ground on lead P to the transverter and removing it from P1. In the meantime, the release of the perforating magnets has released the CK relay.

Since relay P4A is now locked operated, ground over lead P operates relay P3. The sequence of operations resulting in the perforation of the second line is now exactly similar to that of the first line, and in a similar manner, after the second line has been perforated, relay P2 is operated and the third line is perforated, and so on for the fourth. After the last line, the recorder is released.

The sequence of operation of the various relays is given in the time chart shown as Figure 5. Relays P4, P4A, P3, and P3A, etc., once they are operated remain operated until the sender is released, but the other relays are operated for brief intervals only to carry out the various steps in the process. For calls requiring only a two-line initial entry, relays C4 and C3 are not operated. Whether or not these two relays are used depends on the information given to the transverter by the sender.

For the two time entries of each call, the transverter is not employed at all. At the proper moment, the trunk signals the recorder through the call-identity indexer—operating the cut-in relay shown in Figure 3—so that the trunk number may be recorded in the last two positions. The perforation of the A digit, giving the entry index, is controlled by the recorder, and digits B, C, and D—giving the time in tens, units, and tenths minutes—is also controlled by the recorder using information passed to it by the master timer. The hour is not required because a separate hour entry, giving tens and units digits for the hour, is perforated on the tape at the beginning of each hour under control of the master timer. A set of switches in the recorder carries a running record of the time in tens, units, and tenths minutes, and when a time entry is to be made, this group of relays controls the perforation of the B, C, and D digits. Each tenth of a minute, the master timer transmits a pulse to each recorder and thus maintains the proper indications on the time switches in the recorder.

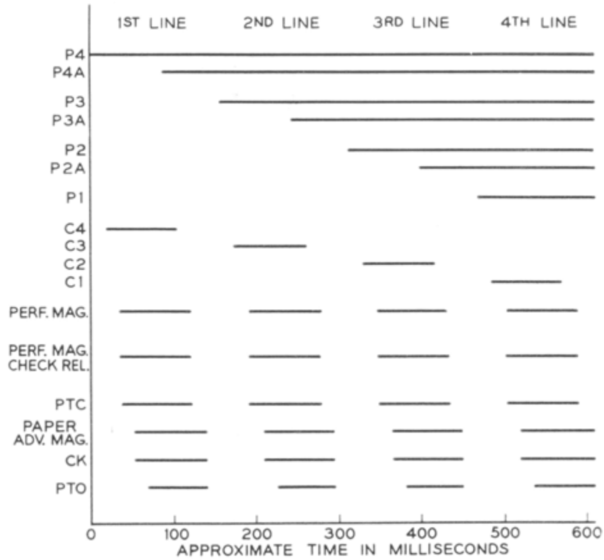

Fig. 5—Time diagram for operation of the relays of Figure 4 in perforating a four-line initial entry.

The AMA circuits are designed so that they are self-checking to a large extent. The recorders, for example, include means for checking the closure of two-out-of-five perforator magnet leads as well as detecting opens, crosses, and trouble grounds. If trouble is encountered, a trouble recorder circuit is brought in and a trouble record card is perforated, which will aid in locating the trouble. Under some conditions a trouble entry is placed on the central office tape for the use of the accounting center equipment. In addition to the ability of the circuits to detect trouble on service calls, there is also provision for making various test calls. A circuit called the master test frame has direct access to the transverters for miscellaneous tests and for checking translator frame cross-connections. Also built into the master test frame are facilities for testing the transmittal of AMA information through the senders and transverters, and for checking the associated trunks for the start signal in preparation for an answer or disconnect entry.

No. 5 Crossbar AMA Translator

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Switching Systems Development

In the No. 5 crossbar system, the subscriber lines terminate on verticals of crossbar switches on the line link frames. They are identified for switching purposes by the number of the frame on which they appear and their position on that frame. This position on the frame is defined by specifying the horizontal group, and the vertical group and file in which the vertical is found. The scope of the divisions of the frame is shown in Figure 1. There are ten horizontal groups and from six to twelve vertical groups on each line link frame. Each vertical group consists of five vertical files.

The series of numbers specifying the line link frame, vertical group, horizontal group, and vertical file, is known as the equipment number, but there is no fixed relation between this equipment number and the directory number. The reasons for this lack of relationship have to do mostly with keeping an even distribution of traffic through the frames and with providing flexibility for changes in assignment of directory numbers.

Since the marker obtains the equipment number in the process of handling an originating call, it is readily available to the AMA equipment. However, directory numbers rather than equipment numbers are required by the AMA equipment in billing the charges for a call. A translator is therefore required to convert the equipment number to a directory number. This translator is an electrical directory with the equipment numbers appearing in an orderly array each with its associated directory number.

After a subscriber picks up his handset to place a call, the marker seizes the calling

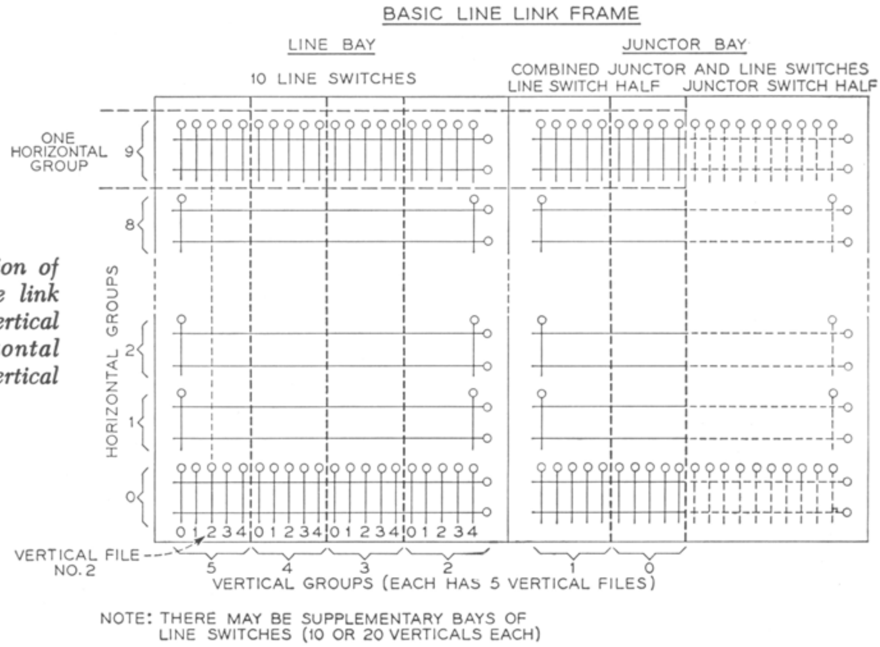


Fig. 1 — Division of lines on a line link frame into vertical groups, horizontal groups, and vertical files.

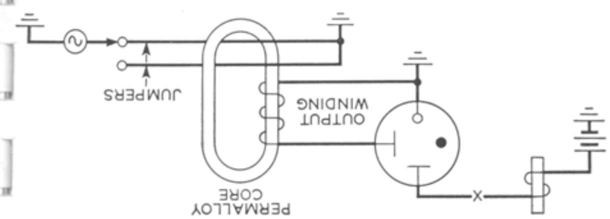


Fig. 3—Simplified diagram indicating method of using the coil shown in Figure 2 for translating.

line link frame, finds the calling line, connects it to an originating register, and tells the register the equipment number. The register records this number and, if the call is from a two-party line, determines whether the tip or ring party is calling. After the subscriber has dialed, the register obtains a marker and gives it the calling equipment number, including tip or ring party identification, and the called directory number. The marker in turn passes this information to the outgoing sender, which records it. After the marker completes this job, the sender controls the selection of the called number and at the same time obtains a transverter, which is part of the AMA equipment, and gives it the information. The transverter uses this information to obtain a translator to which it passes the equipment number. From this information the translator determines the directory number and returns it to the transverter, which causes it to be placed on the AMA tape in the form of five digits: one to indicate the office, and one each to indicate the thousands, hundreds, tens, and units digits of the subscriber's directory number.

The new element of the translator is the coil shown in Figure 2 and is shown schematically as applied to a circuit in Figure 3. The winding of the coil is connected to the control anode of a gas filled tube. If a surge of oscillating current is sent through one of the jumpers, an oscillating voltage is induced in the winding. This voltage ionizes the tube, thus allowing it to pass current between the cathode and the main anode, and operate the associated relay.

The method of using these coils in the AMA translator is shown in Figure 4. At the top of this figure is the surge circuit which generates the jumper current. Below is a relay tree that selects one of the terminals in the equipment number terminal bank. There is one terminal in this bank for each equipment number.

From each terminal, a jumper is threaded through one coil in each of the five rows of coils and terminated in ground. The coil used in the top row indicates the number of the office in which the calling line is located. The coils used in the other four rows are

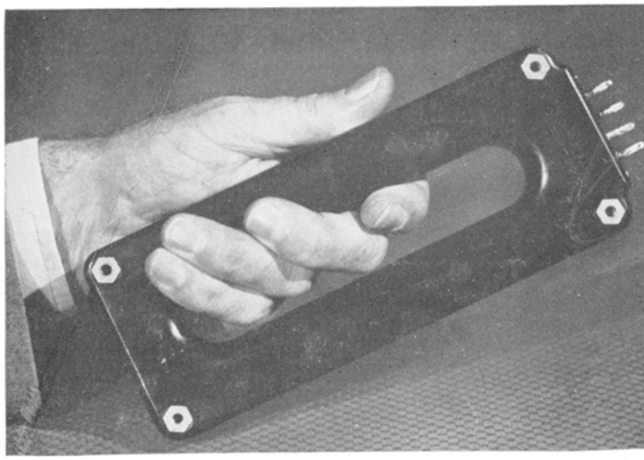


Fig. 2—The coil used with AMA; one of the essential elements of the "Dimond" ring translator.

chosen in accordance with the thousands, hundreds, tens, and units digits of the associated directory number.

When the transverter is connected to the translator, it operates relays in the relay tree which select one of the thousand equipment number terminals and connect it to the surge circuit. When this connection is made, a path is closed from ground through the jumper, the relay tree, and the back contact of relay SST. This ground suddenly changes the potential of point A from minus 48 volts to ground. This voltage change is carried through a coupling condenser to the control anode of the SST tube which is caused to pass current, thus operating relay SST. Relay SST now closes a discharge path for the oscillatory discharge of capacitor C through inductance L to ground. The discharge circuit is closed by the mercury contact relay SST rather than by the contacts of the tree circuit because the high current (about 3 amperes peak) in the surge might damage ordinary relay contacts, especially if there is any contact chatter. Any chatter which occurs in the relay tree contacts subsides during the operating time of relay SST.

The surge current in the selected jumper induces a voltage in the output windings of the coils through which the jumper passes. The associated gas-filled tubes fire from this voltage, and cause relays in the transverter corresponding to the directory number to operate. The translator connector then releases, disconnecting the transverter from the translator.

The relay tree is shown schematically in Figure 5. By using the line link frame number and the vertical group number, the transverter grounds one of the twenty G leads to operate the proper G relay. Tip parties and ring parties are assigned to separate translators. The transverter also operates one of the VF relays corresponding to the vertical file number of the calling line, and operates horizontal group relay in accordance with the horizontal group number.

The G relay uses fifty contacts to select from the thousand equipment number terminals the particular fifty of the vertical group of the calling line. The VF relay selects ten of the fifty terminals selected by the G relay, and the horizontal group relays select one of the ten terminals selected by the VF relay. Thus, by this process, one terminal out of 1000 is connected to the surge circuit, whereupon the operation proceeds as above.

Since the jumpers are changed rather frequently and since the terminals in the equipment number terminal bank are fairly closely spaced, it is felt to be worthwhile to design the translator so that inadvertent shorts between adjacent terminals will not cause severe reaction. With all the jumpers connected to a common ground bus as indicated at the bottom of Figure 4, such a short might result in the failure to translate the equipment numbers for a large number of lines, and the fault might be difficult to find. Suppose, for example, there were a short between the equipment number terminals for jumpers A and B. An attempt to translate the equipment numbers associated with either of these terminals would, of course, give the translation of both because of the short. This in itself is not too serious since only two lines are involved and the trouble could soon be located. The serious feature of such a short is that the short forms a closed loop consisting of the two jumpers. As a result, a surge in any jumper passing through one or more of the coils threaded by either of the shorted jumpers will induce a surge in the closed loop and thus besides operating the proper tubes for the translation will also operate those associated with the jumpers of the closed loop. With the short between jumpers A and B, for example, when jumper D is energized, a surge voltage is induced in jumper A because it threads tens-coil No. 6 in common with the D jumper. A current is therefore induced in the A and B jumpers, which energizes several coils besides the desired ones. This does not cause charging irregularities, however, because the transverter recognizes the operation of more than the correct number of tubes as a trouble condition. It would not accept the translation but would call in a trouble recorder. The fault would be difficult to locate, however, because the equipment number of the line that caused the trouble recorder to be called in may not be anywhere near the equipment numbers whose terminals are shorted in the bank.

To avoid such a situation, the formation of closed loops by shorts must be prevented. To this end, ground is provided through a bank of 1000 terminals physically arranged just as are those of the equipment-number terminal bank. Jumpers are run between corresponding terminals of the two banks. The method of supplying ground to the terminals of the ground bank is indicated in Figure 6. The ESW relay is operated by the horizontal group relays of the relay tree whenever the equipment number being translated is in an even horizontal group. Similarly the OSW relay is operated if the horizontal group is odd. The VF relays are the same relays as the VF relays shown in the relay tree. When a translation is to be made, the ESW or OSW and VF relays together supply ground to only a certain fifty of the thousand ground-supply terminals, and no two of these fifty are adjacent. ESW and VFO, for example, ground the even terminals in the bottom row of Figure 6.

With this arrangement there can be no

closed loops due to shorts between adjacent terminals in the equipment number terminal bank. If the shorted terminals are horizontally adjacent, then one must be in an odd horizontal group and the other in an even and, therefore, only one of the jumpers can be supplied with ground because of the ESW and OSW relays. If they are vertically adjacent then only one can be supplied with ground because only one VF relay is operated, and each horizontal row of terminals is supplied from a different VF relay. With no closed loops there can be no tubes falsely operated, and therefore the circuit will translate satisfactorily in spite of the short.

Not only does this scheme prevent false operation, but it causes a trouble record to be made indicating that a short exists. If jumpers A and B are crossed either in the equipment-number or ground-supply terminal banks, then when the A jumper or any other jumper on the same ground sup-

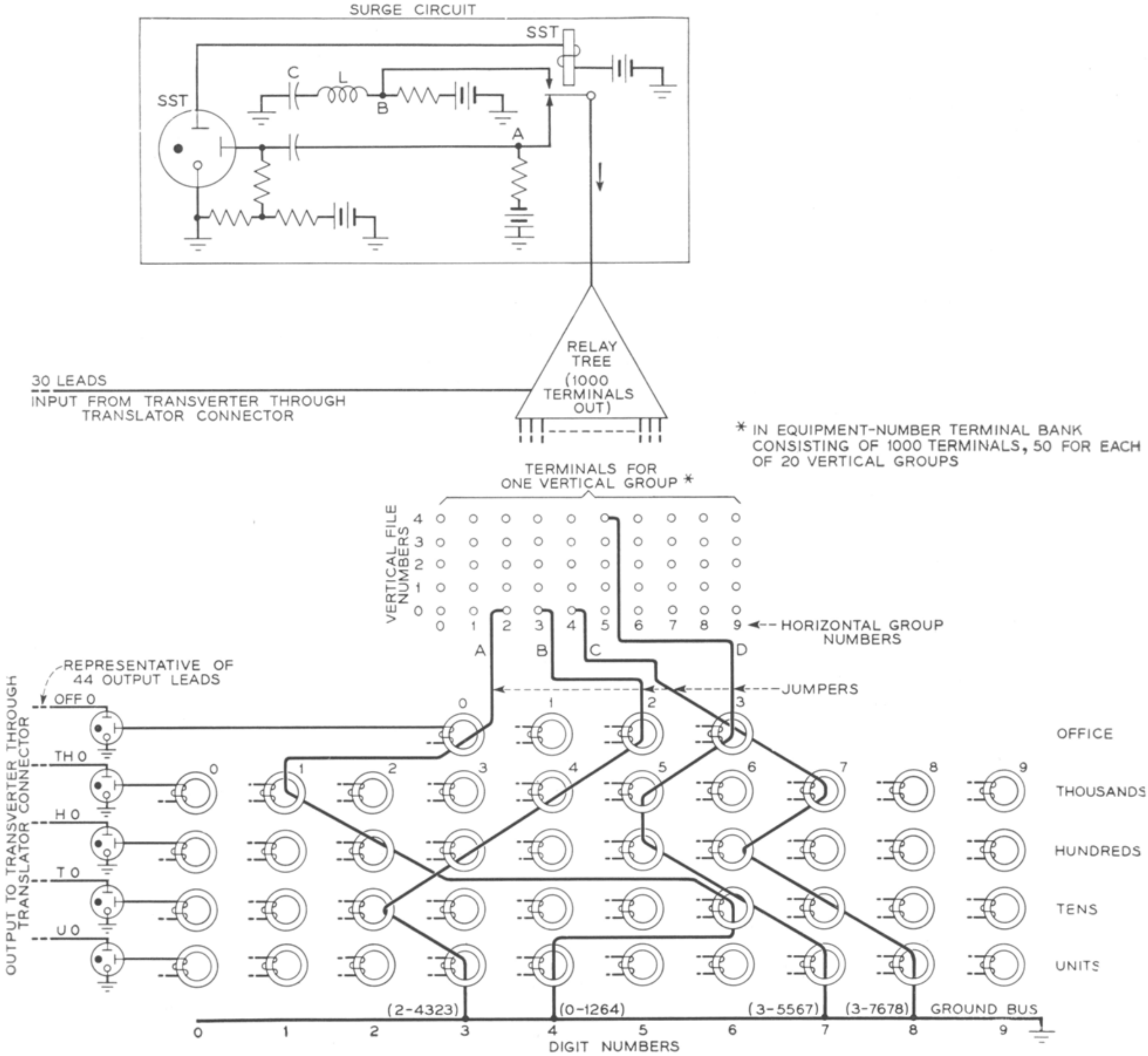


Fig. 4—Simplified circuit schematic of the AMA translator. This schematic shows jumpers set up to identify terminals of directory numbers 2-4323, 0-1264, etc.

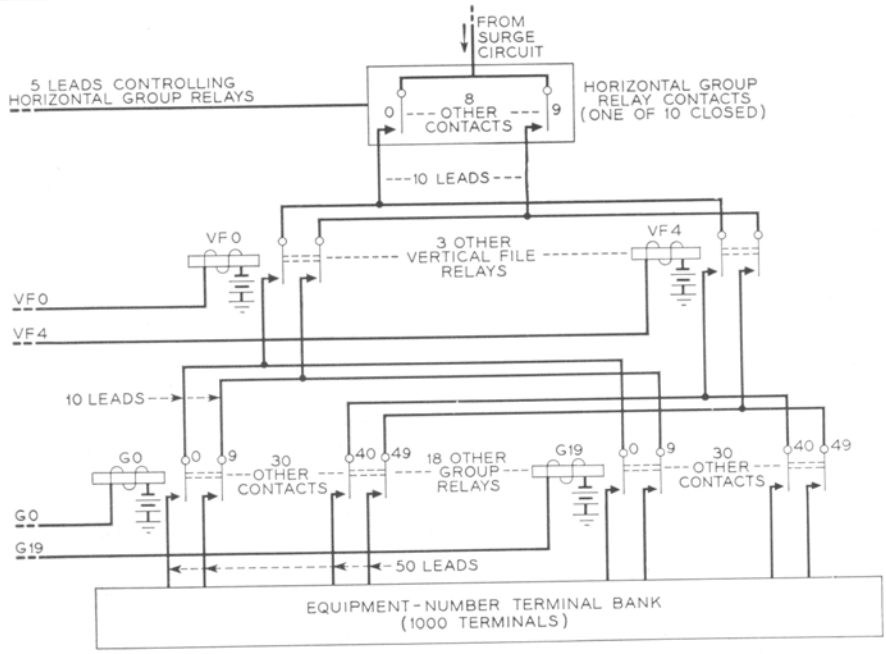


Fig. 5—The relay tree of the translator, which distributes the surge to the terminal for the equipment number that is to be translated.

ply lead is selected, the ground furnished by the VFO and ESW relays will close a circuit through the short and through the back contact of relay OSW to operate the cross-detecting relay in the transverter. This causes a trouble record to be made but does not interfere with the translation.

It may be wondered why it is necessary to indicate when a short exists since it does not interfere with the translation. The answer is that a single short cannot cause a closed loop but two shorts may. For this reason it is desirable to indicate a short as soon as it occurs so that it can be cleared

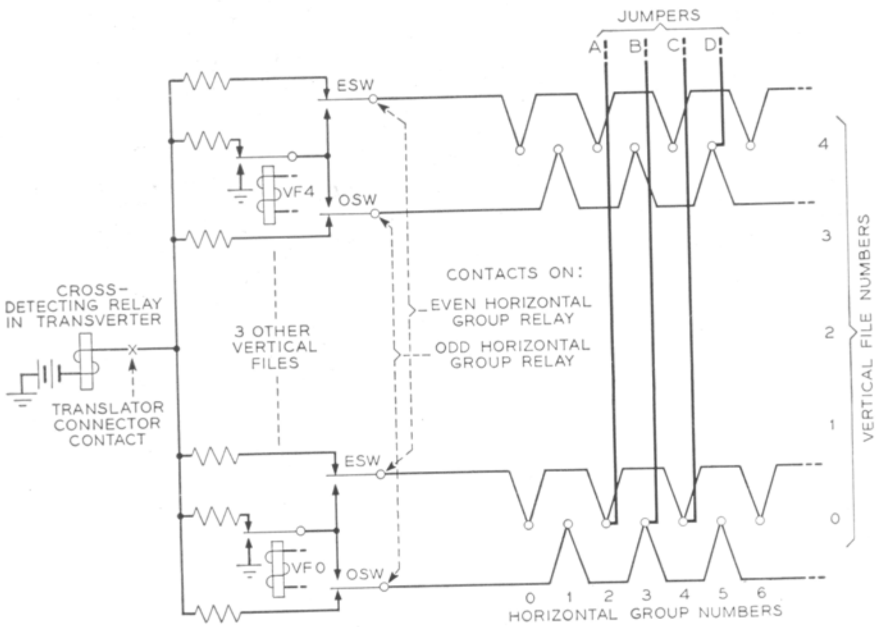


Fig. 6—Simplified sketch indicating the method of distributing ground to the terminals of the ground bank.

before another occurs which, in combination with the first, might cause translation failures on a large number of telephone lines.

A translator frame is shown in Figure 7. At the top, not shown in the photograph, is the translator connector, which has a capacity for five transverters. In the middle of the frame are the relays making up the relay tree. The bulk of these are the multicontact G relays. Below the relays are the terminal strips making up the equipment-number terminal bank. The coils are mounted next. The tubes are mounted immediately behind the coils. Near the bottom is the ground supply terminal bank. The whole assembly of coils and terminals is within easy reach of a maintenance man standing on the floor.

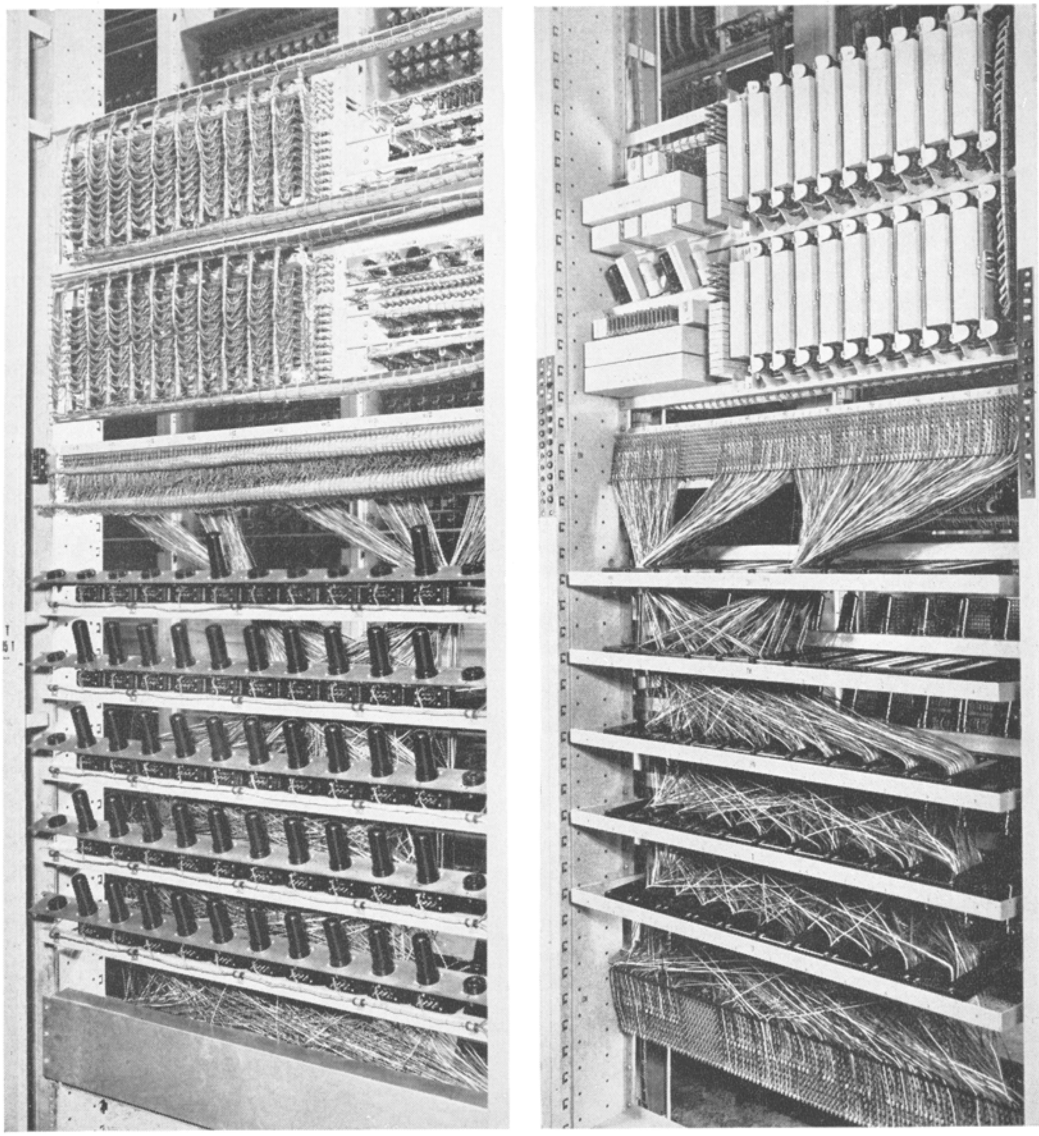


Fig. 7—Lower part of a translator frame; tube side at left, and coil side at right.

One of the difficult equipment and apparatus problems was the design of the coil structures and the general layout in such manner that the jumper could be readily removed. With the arrangement finally devised, the jumper can be removed by loosening both ends and pulling. One reason for terminating the jumpers in the same relative locations in both terminal banks is to make this possible without tracing the jumper through the coils to find its ends. The coils, one of which is shown in Figure 2, are enclosed in bakelite cases with smooth rounded jumper windows to reduce friction. It was found that an oblong window accommodates more jumpers than a round window of the same area. The maximum that can be placed in the coil is 600.

As a further aid in changing jumpers, the terminals in the equipment number and ground supply banks are of a new solderless type. These are shown in Figure 8. Each consists of a slit punching into which the stripped end of a jumper is slipped. A complete turn of the jumper is then made around the terminal so that any movement of the jumper will not disturb the electrical connection. The pressure between the jumper and terminal is very high, insuring a good, low resistance contact. Tests show that this terminal allows a reduction in connection and disconnection time.

The basic type of translator employing the kind of coil described above is known in the Bell System as a ring translator because of the shape of the coil. Its main advantage over more conventional types of translators is that it reduces the number of jumpers and connections. This saving in jumpers represents appreciable savings to the Telephone Companies because on the average each jumper is removed and re-run once each three years.

The same translator circuit as described above is used in the No. 1 crossbar system, although the equipment details are slightly different. The basic ring translator scheme has also been applied to computers.

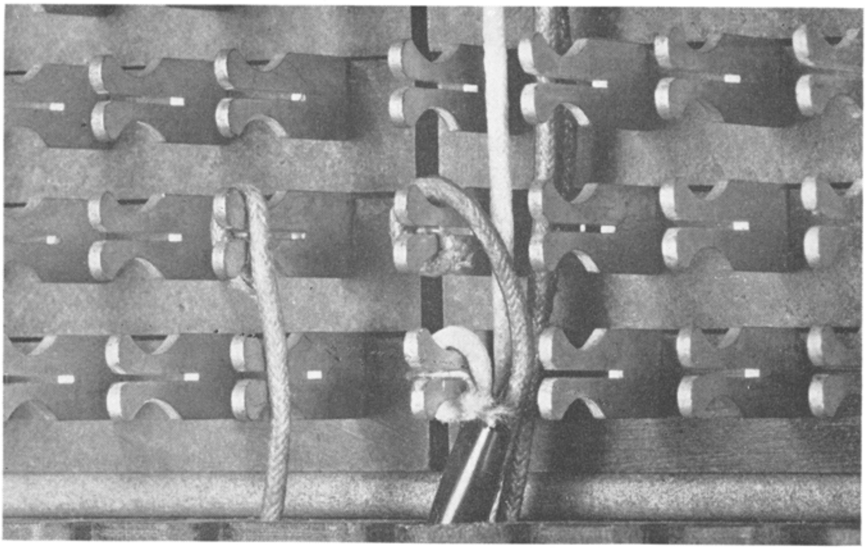
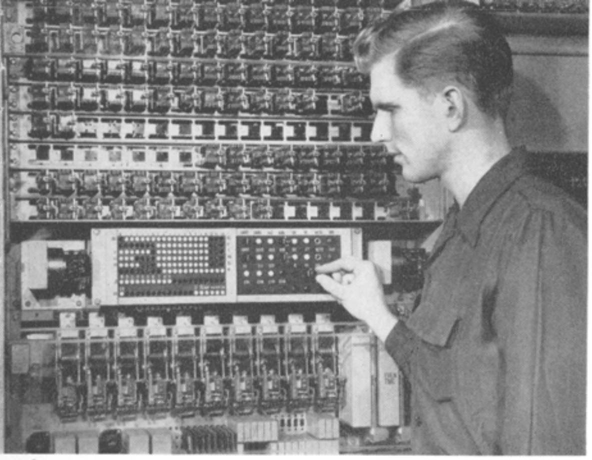


Fig. 8—A close-up of one of the terminal banks of the translator showing the new type of terminal employed.



The AMA Timer

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Switching Systems Development

Automatic Message Accounting*, as its name implies, is a system that automatically records, sorts, computes, and summarizes the required information for subscriber dialed telephone messages to determine the service charges. The original information recorded includes the time of the beginning and end of each call, and thus a dependable source of time must be associated with the recording equipment. This is provided by the AMA timer, and two of them—called the "even" and "odd" timers—are furnished for each AMA office. Both maintain a continuous record of time and check each other every minute for synchronism, but only one of them is "in control" at a time. Only one of them at a time, in other words, is supplying time information to the recorders, but each has certain checking and testing functions to perform whether "in control" or not, and either may carry out all functions when the other is out of service.

Each timer has a small synchronous motor, driven from the commercial power supply, that serves as the basic source of time. This motor drives a cam shaft with two cam-operated switches. Every six seconds one of the switches is closed for a brief interval, thus sending a pulse to the control circuit. This sequence of six-second pulses operates a chain of 206-type rotary selectors on which the various time units

* See pages 5, 12, 18, 25 and 30.

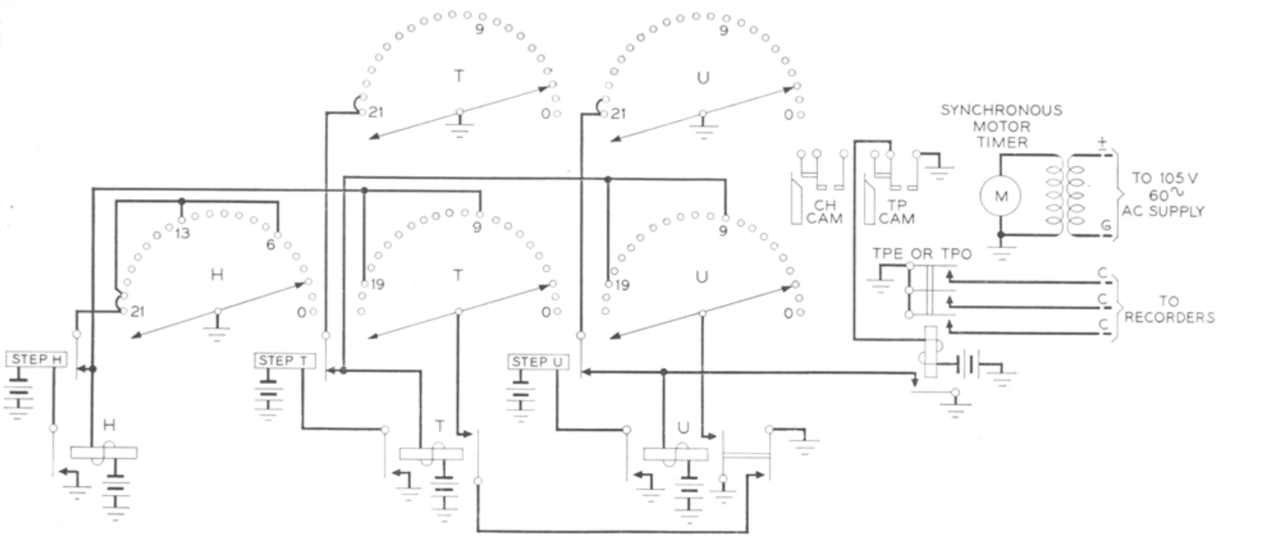

Fig. 1—Method of operating the U, T, *and* H, *selectors in the timers and recorders.*

are recorded. One of the selectors, designated U, records the six-second pulses themselves—each pulse moving the selector one step. The next, designated T, operates one step for each ten of the original pulses, and thus moves one step each minute. The third, designated H, operates one step for each ten steps of the T selector, and thus makes one step every ten minutes. Operated in a somewhat similar manner, there are also the HU, the HT, the DU, the DT, and the M selectors, operating one step for each hour, each ten hours, each day, each ten days, and each month, respectively.

To insure a continuous record of time even during failure of the commercial supply, means are provided for automatically transferring the timing motors to an emergency ac supply. This consists of a rotary converter, driven by the central-office battery, which is started automatically whenever the voltage on the commercial ac lines drops to 85 per cent of its normal value. When the voltage returns to 90 per cent, the motors are automatically transferred back to the commercial supply.

Besides operating the chain of selectors in the timer, the sequence of six-second pulses from the timer "in control" is also transmitted to each recorder in the office, and each recorder includes a U, a T, and an H selector, and thus has available within itself the information needed to control the perforation of the time of answer and disconnect on the tape. For the hour entry and the tape identification entry, however, the time comes from the master timer in control. The hour entry is made on each tape at the turn of each hour, and includes a tens and a units digit to identify the hour of the day. Six time digits are used for the tape identification entry: the month tens, month units, the day tens, the day units, the hour tens, and the hour units. The tape identification entry is made at 3 a.m. each morning, and at certain other occasions, such as at each splice, and each time a recorder is made busy or is returned to service.

The method of operating the time selectors is indicated by the simplified schematic diagram of Figure 1. Each pulse from the timing cam operates a relay that repeats the pulse over a number of branch leads—some going to the recorders and one to the associated timer circuit. Over this latter lead the stepping magnet of the U selector is operated, and on release, the selector moves ahead one step. A lead multipled to the 10th and 20th contacts of the U selector runs to the step magnet of the T selector. During each six-second pulse, ground is applied to the lower brush of the U selector, and every tenth pulse this ground, through a contact of the U selector, operates the T selector, and thus moves it one step. In a similar manner the H selector is operated every 10th contact on the T selector.

The 206-type selectors have six semicircular arcs each of 22 contacts, and since the brushes are double ended, the 23rd operation brings a brush again to the first contact. On the selectors such as the U selector just described, where a succeeding selector is operated every ten steps, the circuit is arranged—through connections on one of the other arcs of contacts—so that the selector moves automatically from the 21st contact to the first contact. Various other combinations of automatic stepping are also used as required for some of the subsequent selectors. One, two, or even three of the arcs may be used to control the operation of subsequent selectors, while some or all of the remaining arcs are em-

DIGIT	PERFORATING POSITIONS 0	1	2	4	7
1	×	×	○	○	○
2	×	○	×	○	○
3	○	×	×	○	○
4	×	○	○	×	○
5	○	×	○	×	○
6	○	○	×	×	○
7	×	○	○	○	×
8	○	×	○	○	×
9	○	○	×	○	×
0	○	○	○	×	×

Fig. 2—Translation of the "2-out-of-5" code. Positions perforated are marked with a cross.

ployed for some of the other functions that the timer performs.

All digits carrying charging information are recorded on the tape in a "2-out-of-5" code: five perforating positions are available for each digit, and each of the ten possible digits from 0 to 9 is represented by a particular pair of perforations. The code is readily translated by assigning the five perforating positions the numbers 0, 1, 2, 4, and 7 from left to right. Then the digit perforated is equal to the sum of the numbers assigned to the two holes punched. The only exception is the digit 0, which is represented by positions No. 4 and No. 7. This translation is shown in Figure 2.

Two of the arcs of each selector are used to translate the digit represented by the position of a selector to the "2-out-of-5" code. There are five output leads from the pair of translation arcs of each selector, and for each position of the brushes of the selector, ground will appear on the proper two leads. How this is accomplished is indicated in Figure 3. A relay that is operated whenever a time digit is to be perforated on a tape supplies ground to the brushes of the two translator arcs of each selector. As a result ground will appear on two out of the five code leads from each selector to give the correct code corresponding to the position of the selector. These code leads are

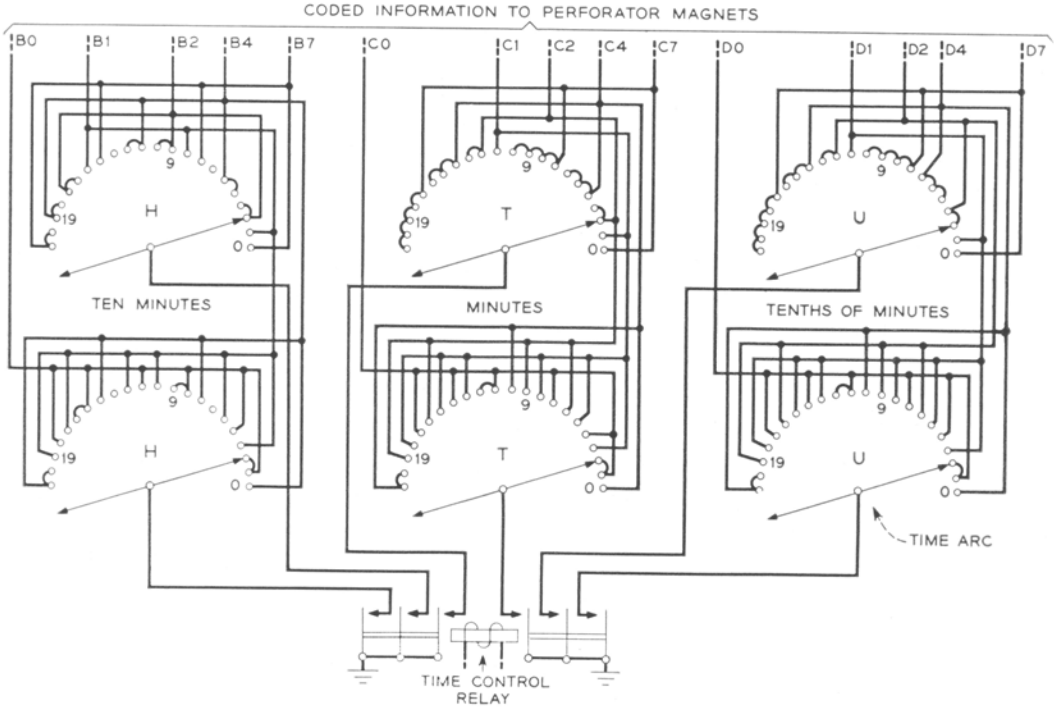

Fig. 3—Simplified diagram of the coding circuit of the selectors.

connected to the perforator by the recorder in the same general manner as other information, which has already been described*. In recording the time of answer or disconnect, the codes are taken from the selectors in the recorder, as already mentioned, but for the hour and the tape identification entries, the codes come from the selectors of the timer, since this information is not available in the recorders.

Besides keeping a running record of time and supplying it to the recorders, the master timer in control, also makes a check every minute to see if the corresponding selectors of the other master timer and of all the recorders are in step with its own. Other arcs of the selectors are used for this purpose by a circuit indicated in Figure 4.

* See page 25.

The No. 4 arc of the U selector controls this test, over a lead multipled to its No. 9 and No. 19 contacts, by supplying ground to a check relay. The actual test is made through contacts of the No. 6 arc. The No. 6 arcs for the U selectors only are indicated in Figure 4, but a similar circuit is provided for all of the timing selectors.

The second cam driven by the timer motor, designated CH in Figures 1 and 4, closes, and remains closed for about 3.5 seconds, one second after each six-second pulse. Between every 9th and 10th six-second pulse, ground on the brush of the U4 arc holds the check relay operated, and thus when the cam-operated CH contact closes following the 9th six-second pulse, relay CK operates. This supplies ground to the No. 6 brush of the U selector of the master timer in control at the time. The brushes of the No. 6 arcs of the corresponding selectors of the other master timer and of all the recorders are connected to relays marked U on the diagram, and if all these brushes are on the same contact as that of the master timer in control, the U relays all operate. At the end of the 3.5 second period, when the cam-operated contact CH opens, relay CK is released. No other action has taken place since all the selectors are in step.

If one or more of the selectors had been out of step, however, one or more of the U relays would not have operated, and as a result ground would have been applied to the CK relay to hold it operated after the CH cam contact had opened. Under these conditions, the next closure of the cam-operated TP contact, which gives the six-second pulses, would operate relay SSF through a front contact of CK. This would sound an alarm to call attention to the fact that at least one of the selectors was out of step. To

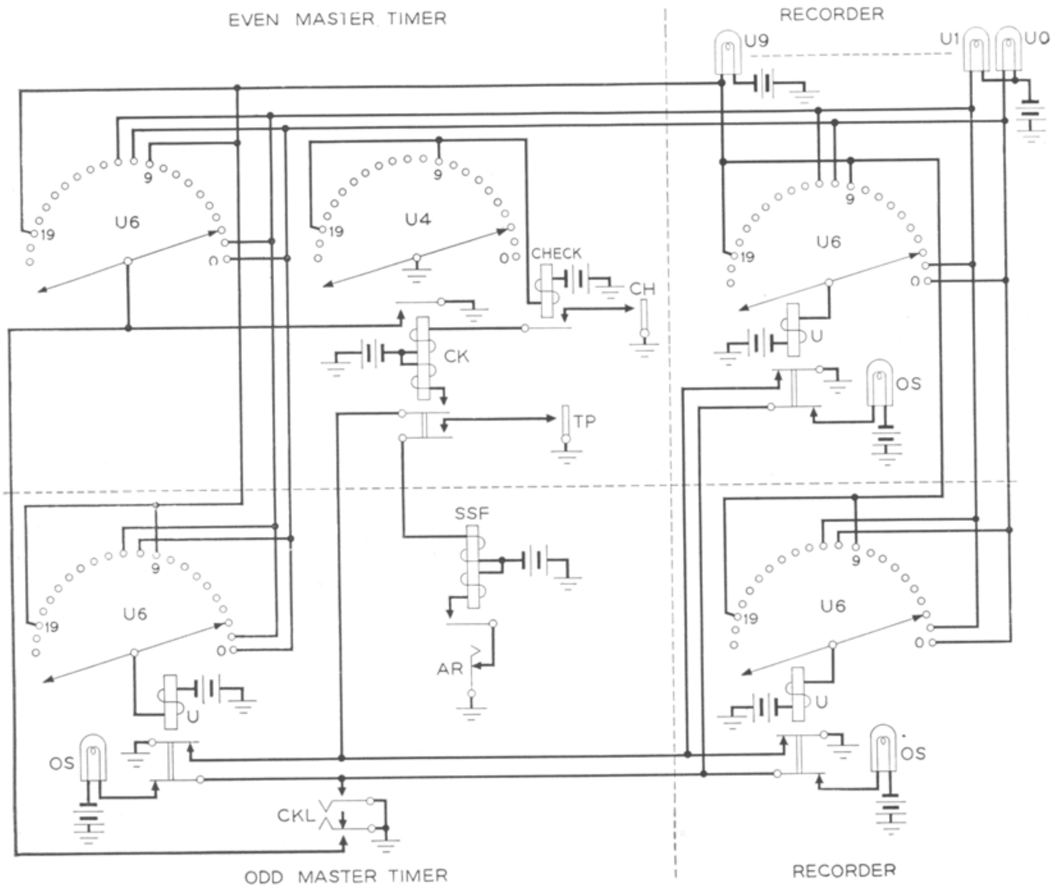

Fig. 4—Simplified diagram of the synchronizing test circuit of the timer.

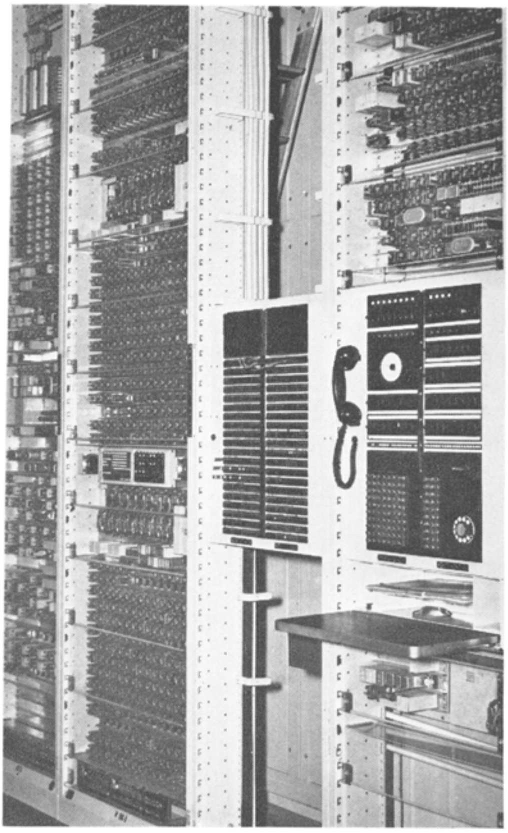

Fig. 5—A master timer frame in the No. 5 crossbar office at Englewood, N. J.

determine which selector it is, the CKL key is operated. This lights a lamp associated with any recorder that has a selector out of synchronism, since as long as a selector is not in synchronization, its U relay will be unoperated.

The No. 6 arcs of the selectors are also used to give a lamp indication of the position of each selector in the master timer "in control." A lamp with one lead connected to battery has its other lead connected to the lead multipling one of the contacts of all the No. 6 arcs of the selectors. Each contact of all the arcs has such a multipling lead with a lamp connected. When the CKL key is operated, ground is applied to the brushes of the selector at the master timer, and thus the lamp connected to the lead from the contact on which the brush is resting will light. As long as this key is operated, successive lamps will light as the selectors step around.

Besides providing these tests every minute to insure that all timing selectors are in step, the master timers are also used to test the operation of the recorders. These latter tests are under control of the odd timer and proceed automatically, but they are started by a key operation. Should trouble be encountered, the test will block, a trouble record will be provided, and a recorder trouble lamp will light. Restoration of the test circuit to normal will then be accomplished by another test key operation. On either normal completion or irregular completion of a test cycle, a test identification entry is perforated in the recorder tape at the end of the cycle. This entry provides information to the accounting center which enables it to skip the test perforations when processing the tape, since some of the test perforations resemble information provided as part of the subscriber call records.

A master timer for a No. 5 crossbar office is shown on the second bay from the left in Figure 5. The lamps below the middle of the bay include the lamps that display the selectors when the CKL key is operated. Below these lamps is the even master timer, and above them, up to and including the 206-type selectors, is the odd master timer. Above it is the equipment for the recorder test and the common relays that transfer control from one timer to the other.

Central Office Equipment for AMA

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Switching Systems Development

Automatic message accounting equipment in a central office comprises seven major units. These, with their interconnections, are indicated in solid lines in Figure 1. AMA equipment is available for both No. 1 and No. 5 crossbar offices, and except for the transverter and the transverter connector, these major units are the same in both types of offices. The frame constructions, however, are different for the two types of offices, and the association of the AMA equipment with the central office circuits also differs. In No. 1 crossbar offices the association is with district junctors and subscriber senders, while in No. 5 offices it is with outgoing trunks and senders.

For the AMA circuits in a central office, the transverter* performs a common control function much as the marker does in the central office switching system. It is brought in on all AMA calls by the sender acting through a transverter connector, the number of transverters being dependent on the amount of message rate and subscriber-dialed toll traffic. Usually there are not less than three transverters, with a maximum of five in No. 5 offices and eight in No. 1 offices. Each transverter has access to all recorders and translator frames. †

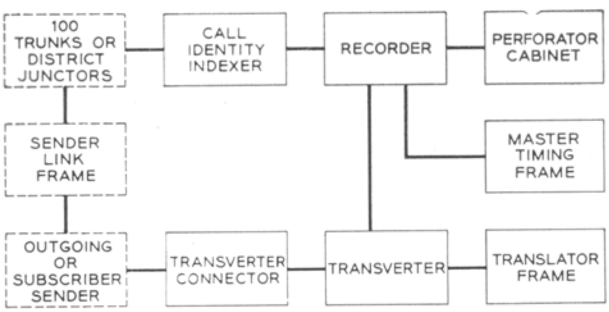


Fig. 1—Seven major equipment units, indicated by solid lines above, comprise the AMA equipment in a central office.

Each recorder has a perforator‡ and a call identity indexer directly associated with it, there being one such group for each 100 trunks in a No. 5 office, and for each district junctor frame of 100 district junctors in a No. 1 office. The outgoing trunks in the No. 5 system appear on the trunk link frames, which makes it possible to limit the AMA equipment to particular trunk groups having sender access and arranged for message rate traffic. The major portion of the flat rate traffic is routed over other trunk groups not equipped with AMA recorders. In No. 1 offices, the district junctors appear directly on the line link frames, where it generally is not feasible to segregate the message rate traffic. All non-coin district junctors therefore must be arranged for AMA, and this is done by assigning a call identity indexer, recorder and perforator to each district frame. The No. 1 crossbar system being arranged for 20 district frames may have 20 regular recorders supplemented by an emergency recorder. In the No. 5 crossbar system, the maximum provided for is ten regular recorders and an emergency recorder.

In a No. 5 crossbar office, the call identity indexers and recorders mount on two-bay frames called recorder frames, Figure 3. The equipment for these two circuits is assembled in shop-wired and shop-tested units, the recorder unit extending across both bays of the frame, and the call identity indexer unit across one bay. Two call identity indexer units thus occupy the space of a recorder unit. The initial frame in an office is equipped with three recorder units, emergency and two regular, and with two call identity indexers associated with the two regular recorders.

The perforators for the recorders are mounted in a steel cabinet, two in each cabinet, along with a supply of paper tape

* See page 25. † See page 30. ‡ See page 18.

and facilities for storing the perforated tape output. The paper tape is supplied in folded form rather than on reels or spools so that there will always be a continuous supply available to the perforators. This is done by storing the folded paper in two bins placed one above the other, each containing 3,000 feet of tape. By splicing the bottom end of the tape in the top bin to the top end of the tape in the bottom bin, there is available to each perforator a total of 6,000 feet of tape. When the supply in the top bin is exhausted and while there is still paper in the bottom bin, the latter is moved to the top position, and a fresh carton of paper is added in the second bin. This bin is then placed in the lower position and the two lengths of paper spliced together. The output from the perforators is stored on reels that are rotated automatically by motors as slack develops with the operation of the perforators. Figure 2 shows a central office cabinet enclosing two perforators in the upper portion behind a clear plastic cover. Below the perforators on either side of the cabinet are the paper input bins, and between them are the motor-driven reels for storing the output tape from the perforators.

The transverter circuit occupies the frame shown in Figure 4. Besides the register, check, progress, and recorder start relays comprising the basic part of the circuit, there are facilities that enable the transverter to connect with a particular translator frame and terminal on that frame, as determined by the calling subscriber's line location number. A cross-connecting field in the lower portion of the frame provides flexibility in the assignment of the translator frames to the lines as they appear on the line link frames. A minimum size group of three transverters is usually furnished so as to provide for maintenance and trouble conditions.

The transverter connector frame provides connecting paths over which the AMA information registered in the outgoing senders is transferred to the transverters. Each connecting path, called a transverter connector, is common to five senders in a No. 5 office. There are three connectors on each frame, thus providing transverter access for a maximum of 15 senders.

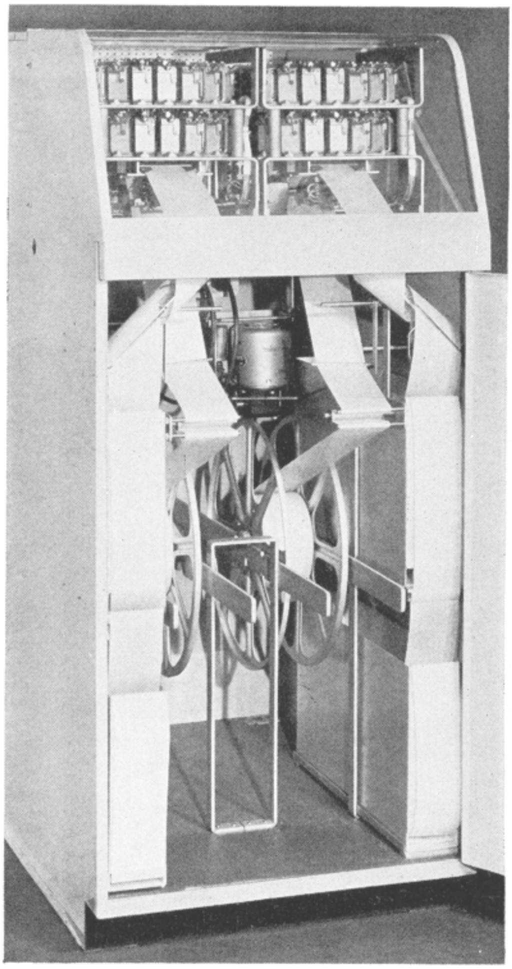
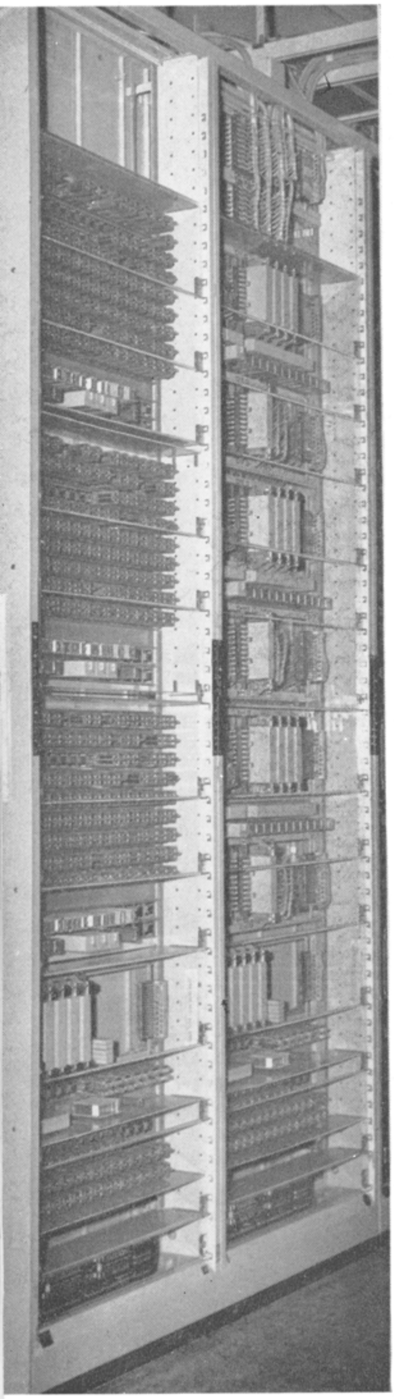
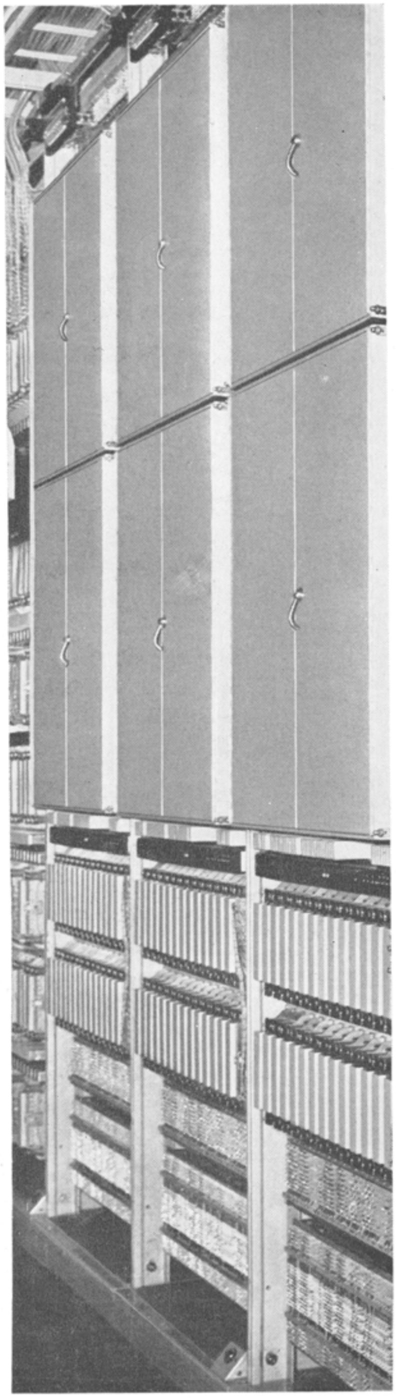


Fig. 2—A perforator cabinet houses two perforators and their tape supplies. Below the perforators on either side are the paper input bins, and between them are the motor-driven reels for storing the output tape from the perforators.

A single master timing frame* shown in Figure 5 serves all the recorders associated with a transverter group. Each frame includes two master timing circuits, designated even and odd, either one of which may be used to supply six-second pulses to the recorders and perform other functions such as periodically checking their timing circuits for synchronization, causing a time entry to be placed on the tape of each recorder at the turn of the hour, and controlling the entry of the end of tape pattern. Also included on the frame are transfer





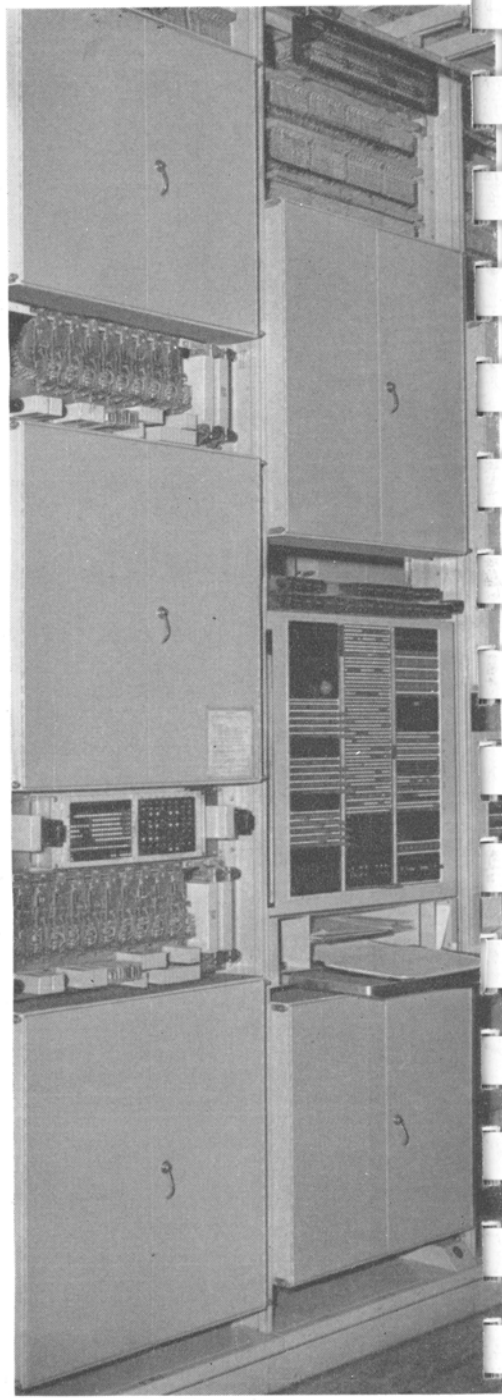
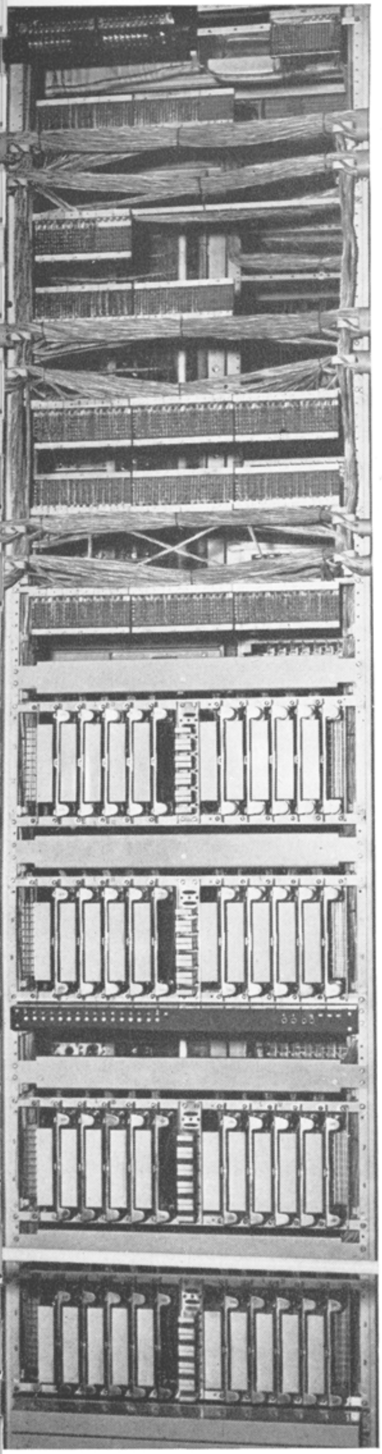


Fig. 3 (left)—A recorder frame in a No. 5 crossbar office in Englewood, N. J. Three recorders occupy the upper three quarters of both bays of the frame, while two call identity indexers are at the bottom of the frame—one call identity indexer in each bay. Fig. 4(center)—Three transverter frames in the No. 1 crossbar office at Hackensack, N. J. Fig. 5 (right)—The master timer frame at the left and the transverter trouble indicator frame on the right in the No. 1 crossbar office at Hackensack.



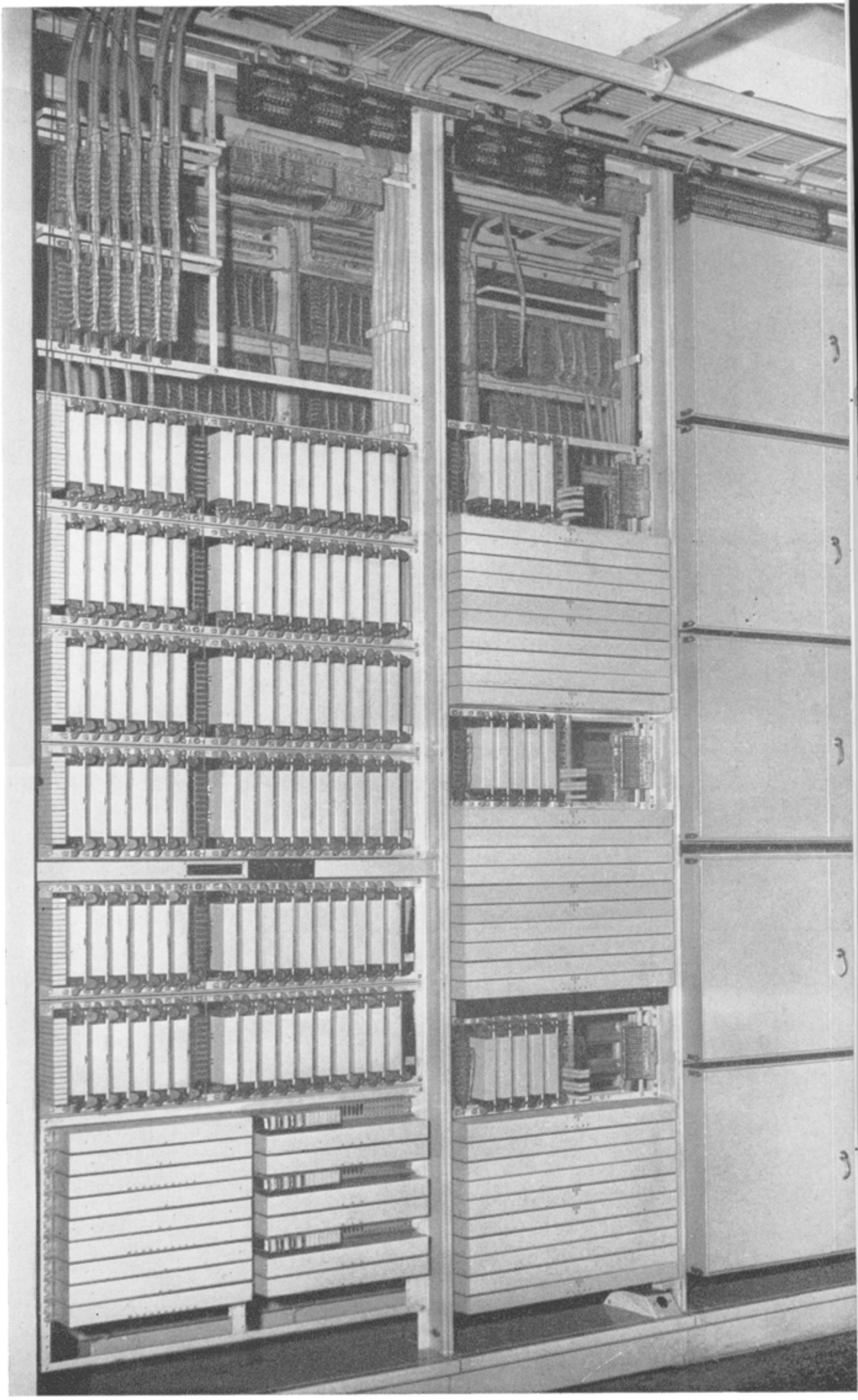


Fig. 6 (left)—A district group connector frame which is required only in No. 1 crossbar offices.

Fig. 7 (right)—A transverter connector bay at the left, a calling line register bay in the middle, and a bay of senders at the right in the Hackensack office.

facilities between the even and odd timing circuits, and means for testing the recorders in making initial, answer, and disconnect entries. Between the even and odd timing circuits in the lower and mid portions of the frame, respectively, are the two motor-driven timers, also a key, lamp, and jack panel used in making synchronization checks. The upper portion of the frame is occupied by the transfer and recorder test functions.

Of the above equipment, the call identity indexer, recorder, translator and master timing circuits are common to both No. 5 and No. 1 crossbar, as already mentioned, but are assembled on sheet-metal frames for No. 5 offices and on bulb-angle frames for No. 1 offices. The transverter is different for the two systems, primarily because of a difference in the translator selection feature, brought about by a difference in the way the subscriber's line is identified.

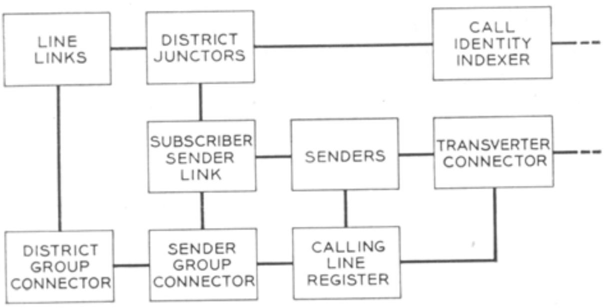


Fig. 8—Auxiliary equipment in a No. 1 crossbar office to transmit information from the line link frames to the senders.

Another frame that is different for the two systems is the transverter connector frame. In No. 5 crossbar, the transverter connector serves five senders and completes a path of 150 leads to the transverter, while in No. 1 crossbar it serves a maximum of ten senders and connects through 120 leads. The difference in sender capacity is brought about by the use of multi-frequency out pulsing senders in No. 5 offices. These have a much shorter holding time than the revertive out pulsing senders used in No. 1 crossbar system, which, as a result, reduces the number of senders that can be accommodated in a single transverter connector.

In No. 5 offices the calling line number is registered in the marker in the normal course of handling a call and accordingly is available to the outgoing senders on AMA calls. In No. 1 offices arranged for AMA, on the other hand, auxiliary equipment must be added to transmit this information from the line link frames to the senders. This takes the form of a district group connector frame, a sender group connector unit, and a calling line register frame. This arrangement is indicated in Figure 8. From and including the call identity indexer and the transverter connector, the AMA equipment is as shown in Figure 1. Included on the calling line register frame, shown in Figure 7, are 25 relays used for registering the calling line number as received from the line link frame. In the No. 5 system these register relays are mounted with the sender, but in No. 1 offices it is necessary to locate them exterior to the sender. There is one district group connector frame, Figure 6, for each 16 line link frames and a calling line register frame for each 30 subscriber senders. One sender group connector and one call identity indexer is furnished for each district junctor frame. These two units therefore are grouped on a separate frame in No. 1 offices, designated a call identity indexer frame and having a capacity of four district junctor frames. The recorders in No. 1 offices appear on recorder frames, four recorders to a frame.

Supplementing these AMA frames in the No. 1 central office are two maintenance frames: a maintenance recorder frame and a transverter trouble indicator frame. The maintenance recorder frame together with a perforator and reader located in the perforator cabinet and a teletype printer located in the maintenance center is used to make a printed record of calls to permanent signal holding trunks, line verification test calls, and sender test calls. The transverter trouble indicator frame, by means of a lamp display, indicates trouble or irregular operation encountered in the transverter, recorder, and master timing circuits. In No. 5 offices the functions of these two frames are performed by the trouble recorder and master test frame.

* See page 37.

Basic Features of the AMA Center

JOHN MESZAR
Switching Systems Development

Although the charging information for telephone calls is recorded in the individual central offices, all the work of telephone message pricing, billing, and bookkeeping for the Bell System is concentrated at about a hundred accounting centers. When one recalls that the Bell System has upwards of twenty-five million customers, and that the total number of accountable messages per month is close to two hundred million, the truly impressive proportions of the message accounting job are readily appreciated. In addition to its magnitude, this message accounting job has, of course, very exacting requirements of accuracy and promptness. Perhaps the most challenging factor in message accounting is, however, the need for the highest efficiency, since the accounting costs must add but a negligible amount to the low price of billable telephone messages, about 65 per cent of which are priced at fifteen cents or less.

Fig. 1—Above, A view of the AMA center in Philadelphia.

These basic characteristics of the message accounting job had a controlling influence on the design of the machinery for the AMA center, which is generally in or readily accessible to the existing Accounting Centers. As has been brought out in preceding articles*, the original message data for the AMA system are recorded in central offices as patterns of perforations on paper tapes. These tapes are then sent periodically to the accounting center where machinery performs the various data-processing tasks peculiar to message accounting. The ultimate AMA objective is, of course, the development of completely mechanized data-

* See pages 5, 12 and 25.

processing techniques to deliver printed customer-bills. However, the initial phase of the development had a more modest goal, and the machines that are at present available carry the automatic processing only part of the way toward this ultimate goal.

The processing technique is based on putting the central office data sequentially through different types of machines, each of which has been designed for a specific purpose. All of the machines receive their input information on tapes perforated in the preceding stage. Each machine "reads" its input tape, performs its assignment, and perforates its output on fresh tapes. The exception is the last machine whose output is in the form of typed alphabetical and numerical characters for use by the accounting center personnel.

A typical accounting center machine is shown in Figure 2. The low cabinets contain the input tape reader with its tape reeling mechanism, and the output tape perforators with their fresh tape supply and perforated tape receiving bins. The taller cabinets house the functional circuitry of the machines. Each machine has only one input tape reader, but the number of output perforators and the size of the functional circuitry varies from machine to machine. The principal machines, in the order of their usage, are the assembler, the computer, the sorter, the summarizer, and the printer.

After it is received at the accounting center, the reel of central office tape is first put into the reader of the assembler. As was brought out in the articles on central office AMA recording techniques, the billing data for thousands of telephone calls are perforated on this tape in the order in which the data became available. The data for a particular call are thus interspersed with corresponding data on other calls. The first step in the accounting center is therefore to assemble all the recorded data on each call, so that subsequent processing can deal with complete information per

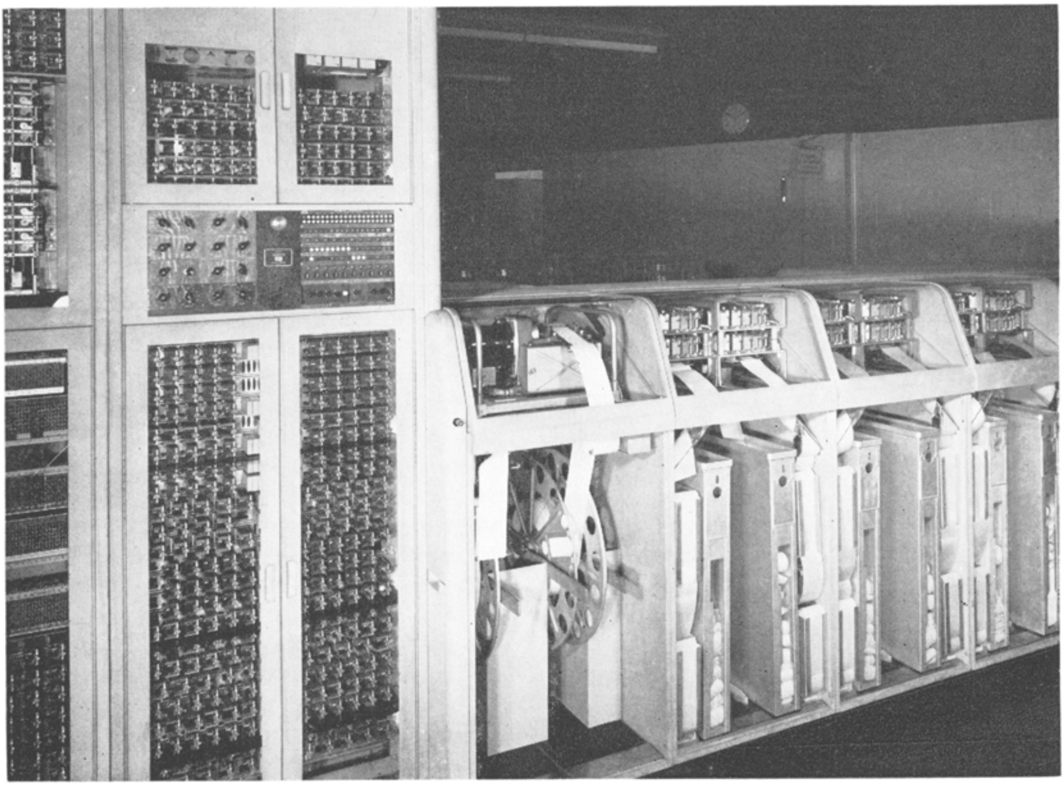


Fig. 2 — An accounting center machine showing relays and miscellaneous equipment in the tall cabinets at the left, a reader in the first low cabinet, and perforators in the other low cabinets.

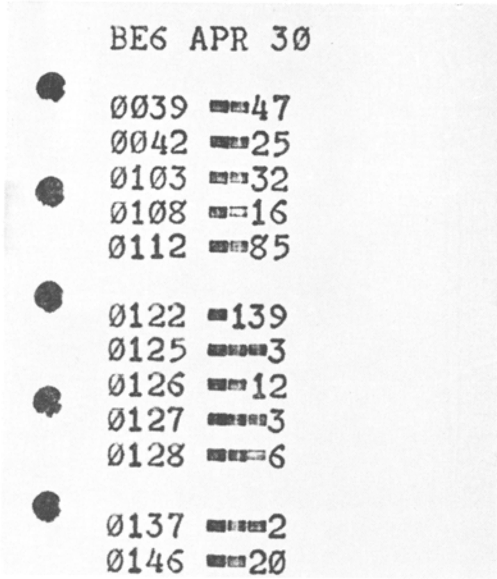


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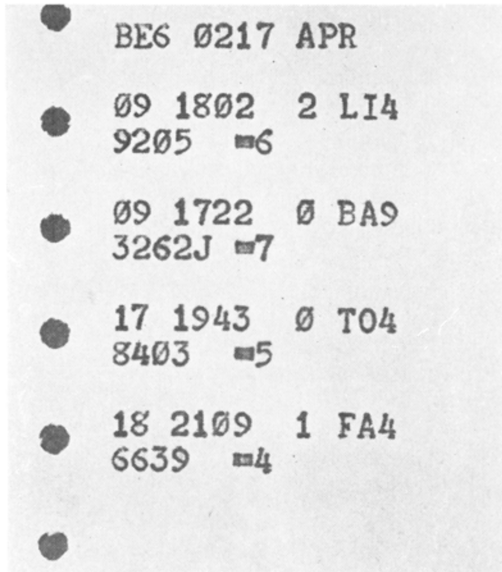
Fig. 3—A message-unit summary list as it comes from the AMA printer.



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84Ø3 ▬5

18 21Ø9 1 FA4
6639 ▬4

Fig. 4—A toll slip from the printer for telephone number BE 6-0217 for April.

call. This is accomplished by the assembler which perforates assembled messages on its output tapes. Assembling is basically a two-stage sorting process. The fragments of information belonging to a particular call are identified by a two-digit call identity index number and their time sequence on the central office tape, and the assembler sorts the fragments in accordance with these call identity indexes without disturbing the chronological order of the calls.

After the calls have been assembled, the required computations can be conveniently carried out. This is done by the computer into which are fed the output tapes of the assembler. For toll or detail-billed messages, the computer at present only computes the "chargeable interval" in minutes. For local or bulk-billed messages, the computer evaluates the chargeable time into "message units," in accordance with the applicable rate structure. Uncompleted calls are of course automatically discarded. The computer perforates separate output tapes for the local or bulk-billed messages and for the toll or detail-billed messages. It also perforates other miscellaneous output tapes for calls whose segregation is desired for various reasons.

Since the objective of the accounting center processing is to determine the total charges applicable to each telephone customer, the computed messages are next arranged by the sorter according to the telephone numbers of the calling customers. On the output tapes of this machine the calling customers' telephone numbers appear in ascending order, and all the messages originated by the same customer are perforated adjacent to each other. Sorting is a four-stage process, one stage of sorting being required for each of the four digits of a telephone number. Local and toll messages are sorted at different times.

After all the local messages chargeable to a customer have thus been brought together, it is feasible to summarize their message unit values for bulk billing. This is accomplished by the summarizer, which perforates on its output tape the total number of message units chargeable to each customer for a designated period.

The last machine of the existing accounting center series is the printer. Since the accounting work beyond this stage is to be done by the staff of the accounting center, the main function of the printer is to present the output of the AMA system in a form readily understandable by human beings. Accordingly, the printer types a message-unit summary list from the message-unit summary tape. A segment of such a list is shown in Figure 3. In the AMA system, zeros are printed with a slant line through them to distinguish them from the letter O. At the top of the summary list is the calling office and the last day included in the list. The four-digit numbers in the left column are the subscriber numbers, while the figures in the right hand column represent the total number of message-units billable to each subscriber.

Besides these message-unit summary lists, the printer types toll slips for each customer. These show the pertinent billing information on each customer's toll messages. The messages are presented in order of date, and the slips are automatically stacked by the printer in the order of the customer's telephone numbers. A toll slip with the record of four messages is shown in Figure 4. The subscriber's telephone number and the month are given at the top of the slip, while the data for each call are given by a two-line entry. In the upper line of each entry is the day of the month, the hour and minute of the day, the called area, and the called office, while the lower line gives the called number and the chargeable time in minutes. The time of day is given on a 24-hour basis, and thus the 1722 of the second entry represents 5:22 p.m.

A diagram of the over-all accounting center processing scheme is shown in Figure 5. Each of the accounting center machines will be described more fully in succeeding articles. Their most outstanding characteristic is accuracy. Features are incorporated in each machine which enable it to continuously check its own internal actions. One basic checking principle is to insure that circuit components—such as relays—always act in a designated pattern. If, for instance, a group of ten relays is used to represent the ten values of a digit (decimal code), the machine checks that in every use of

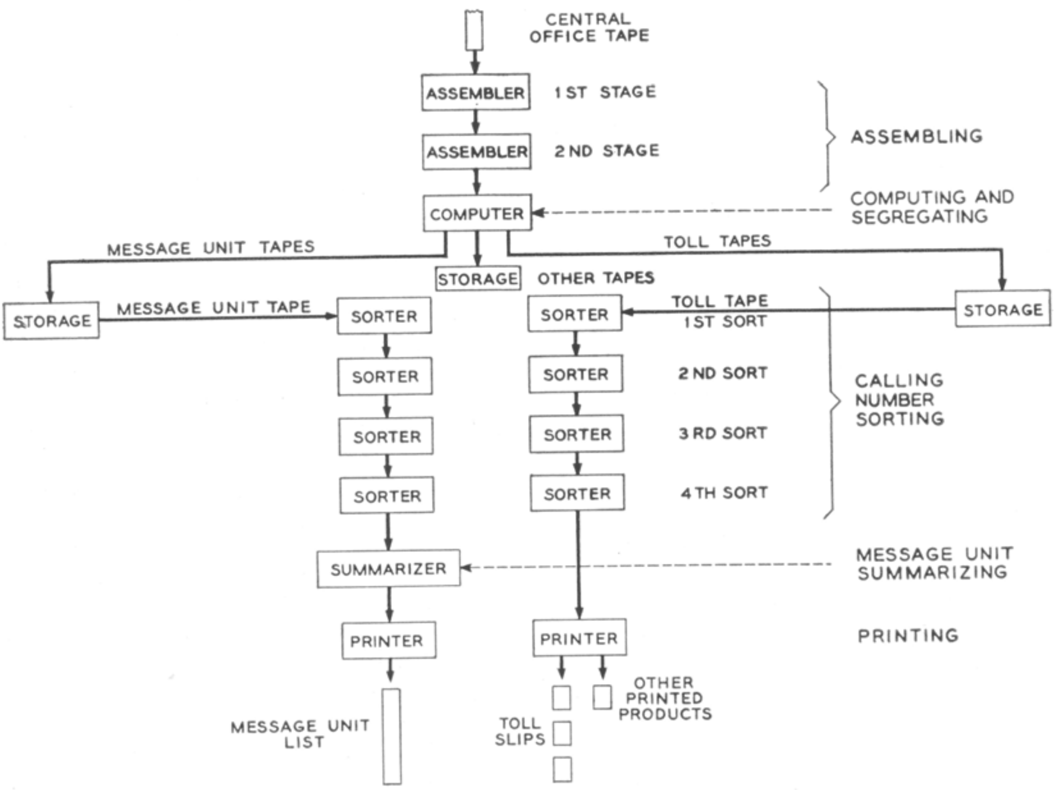

Fig. 5—Block diagram of an accounting center.

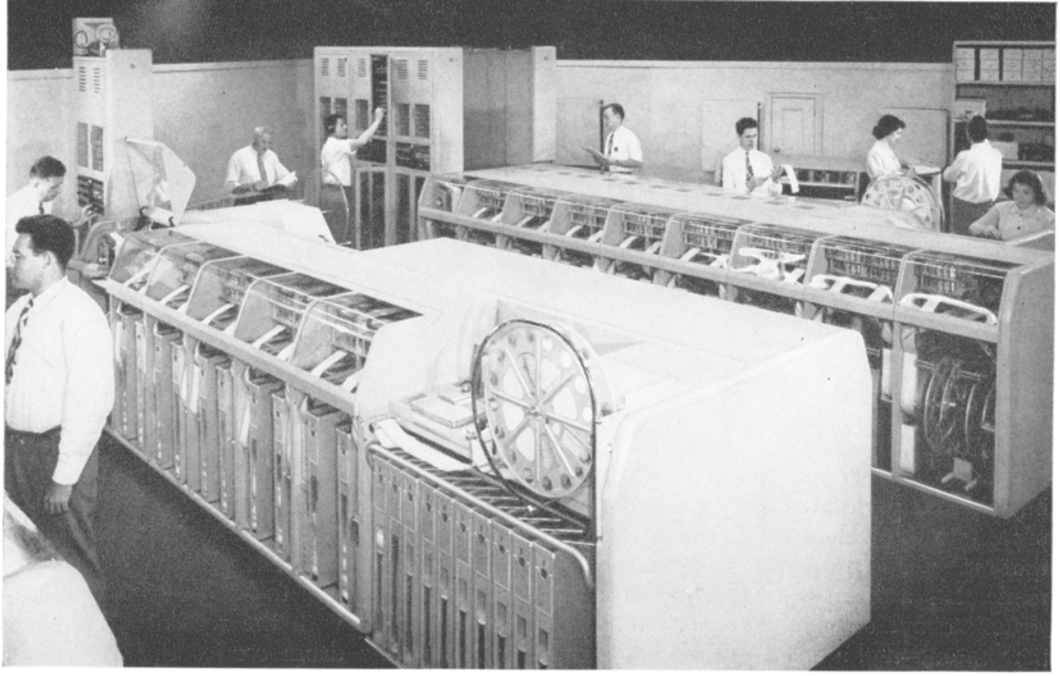

Fig. 6—Testing AMA machines at the Laboratories.

this group of relays one and only one relay is activated. Or, if the digit is represented in the so-called 2-out-of-5 combinational code, the machine checks that in every use of the five relays two and only two are activated. These and other types of rigorous self-checking features are woven throughout the whole circuitry of each machine, and include also an examination of the perforation pattern of the input tapes. If any internal irregularity or tape defect is experienced by the machine, it stops and signals the attendant to take appropriate corrective action. The machines are even capable of discovering human operational errors. For instance, if the wrong tape is put into a machine, it refuses to proceed with the processing. Accuracy tests run on the system have shown not only that the number of errors is extremely small, but that the few that are made result in an undercharge rather than an overcharge, which was one of the objectives in designing the checking features.

A second important characteristic of the machines is their reliability. This has been obtained simply by the use of time-proven central office type of apparatus and circuit design techniques.

The third notable characteristic of the accounting center machines is their speed of operation. With the exception of the printer, all the machines are capable of reading their input tapes and performing their required functions at the rate of approximately 1000 tape-lines per minute. The average speed of the computer—and to a smaller extent of the assembler—is a function of the types and relative quantities of the various calls, and is, of course, somewhat lower than its capability. The printer's speed in turn is determined by its output typing mechanism, which is rated at 100 words per minute.

One more common characteristic of the accounting center machines worthy of emphasis is their load capacity. All of them have been designed with input and output tape capacities sufficient for several hours of unattended running. Once an operator loads and starts a machine, it requires no further attention until the processing of the load is finished, at which time the machine shuts itself off and signals the operator both audibly and visually.

These are some of the primary attributes of the accounting center machines. Over and above these important physical characteristics, however, is the amount of built-in intelligence such machines possess. A little reflection on their main functions—reading, writing, computing, summarizing, sorting, checking, etc.—brings out the sharp similarities between the doings of such machines and human activities classified as intelligent.

The AMA Reader

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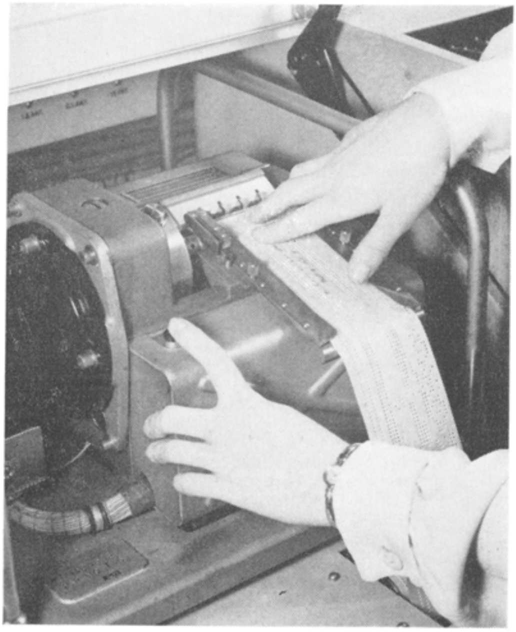
Switching Apparatus Development

For each of the successive operations in an AMA Accounting Center*—assembling†, computing, sorting, summarizing, and printing—a reader is required to transform the information perforated on the input paper tapes into equivalent electrical information that may be properly processed. Each reader has a drum—similar in general construction and arrangement to that of the perforator‡—and a set of twenty-eight reading fingers properly lined up with the holes in the drum. The input tape is fed over the drum through guides from the front in such a way that the small paper cones forced out in perforating the tape at the central office fit into the holes in the drum. Sixteen times a second, the reading fingers move in toward the drum and each finger will either be stopped by unperforated tape or will pass through a perforation in the tape. Each finger has associated with it a pair of twin contacts, and these are closed if the corresponding finger passes through the tape but are held open if the fingers meet unperforated tape. After each line is read, the fingers are withdrawn and the drum is rotated just enough to bring the next line of holes in line with the reading fingers. In rotating, the drum carries the tape along with it.

* See page 47.
† See page 59.
‡ See page 18.



Inspecting tape in the AMA reader at the Newark accounting center.

As shown in Figure 1, each reader is mounted in the upper part of a cabinet similar to that used for a perforator. In the lower part of the cabinet is space for two reels: one for the input tape and the other for the tape that has been read. The reader drum, shown in Figure 2, like that used in the perforator, has twenty-eight holes in each row along the face of the drum parallel to the axis. It differs from the perforator drum, however, in having thirty-six of these rows instead of forty-four, and is thus smaller in diameter. It differs also from the perforator drum in having cylindrical instead of conical holes, and there is a double rather than a single row of step-checking holes around the rim. Since there are thirty-six rows of holes, a ten-degree rotation of the drum is required for each advance. Provisions are made both for stopping the advance of the drum and for allowing it to be rotated freely, as may be desirable when a tape is being removed.

Besides the twenty-eight reading contacts and the two check advance contacts that are operated with them, the reader has sixty others, all twins, that are also closed and opened sixteen times a second. These sixty contacts are arranged in four groups: one of thirty for controlling the operation of a perforator, designated the P contacts, and three of ten contacts each for control purposes, designated the H, K, and J contacts respectively. The twenty-eight read-

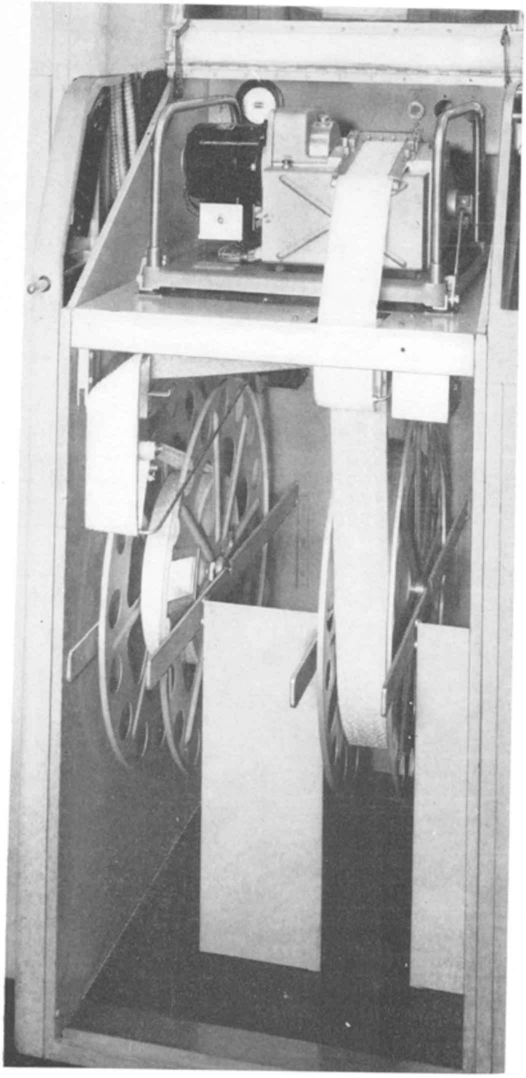


Fig. 1—Each reader cabinet includes a reader in the upper compartment and reels for the input and output tapes in the lower.

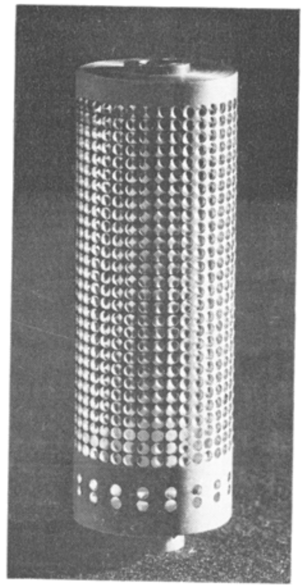


Fig. 2—The reader drum has thirty-six rows of twenty-eight cylindrical holes each. The two rows of holes in the rim are for checking the advance of the drum.

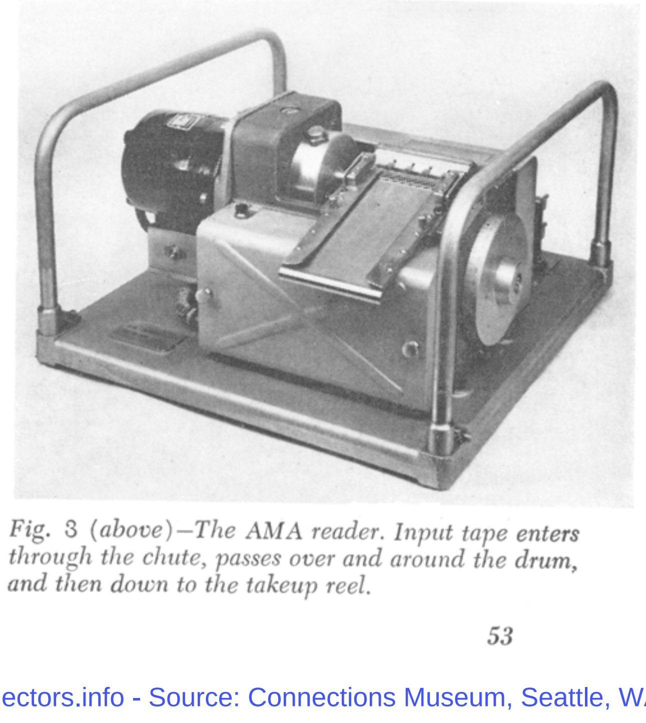


Fig. 3 (above)—The AMA reader. Input tape enters through the chute, passes over and around the drum, and then down to the takeup reel.

ing contacts, and the two advance-check contacts, close at the same time, if not restrained by blank tape or the drum, and they all open at the same time. All the perforator contacts open and close together, while in each of the H, K, and J groups, six contacts are closed while four are open, and vice versa. The P, H, K, and reading contacts are all in phase: the contacts opening and closing at the same time. The J contacts are phased to operate about fifty-two degrees later than the others. All ninety contacts, however, are operated once for each revolution of the cam shaft.

The reader is shown in Figure 3, and a diagram indicating the arrangement of the various components is shown in Figure 4. A small ac motor that runs continuously drives the cam shaft of the reader at 960 rpm. There is a reduction gear between the motor and the cam shaft, and the latter, through another set of gears, drives the stepping mechanism, whose input shaft also runs at 960 rpm. On the cam shaft are five cams, which, through rocker arms with rollers riding on the cams, operate the reading fingers and the four sets of contacts already referred to. One rocker arm operates the group of thirty perforator contacts, three of them operate the three groups of control contacts, while the fifth, at the right-hand end of the cam shaft, operates the reading fingers and their associated contacts.

The cam shaft runs continuously, and thus the reading fingers move in and out and the contacts close and open sixteen times a second. The motion of the drum, however, depends on actions in the stepping mechanism. Advance of the drum is under control of the reader circuits, and is at the rate of sixteen lines per second continuously or intermittently as required for the proper processing of the tape. The timing of the advance, when it is made, is always properly phased with the cam shaft so that the advance is made while the reading pins are fully withdrawn.

The stepping mechanism, shown in Fig-

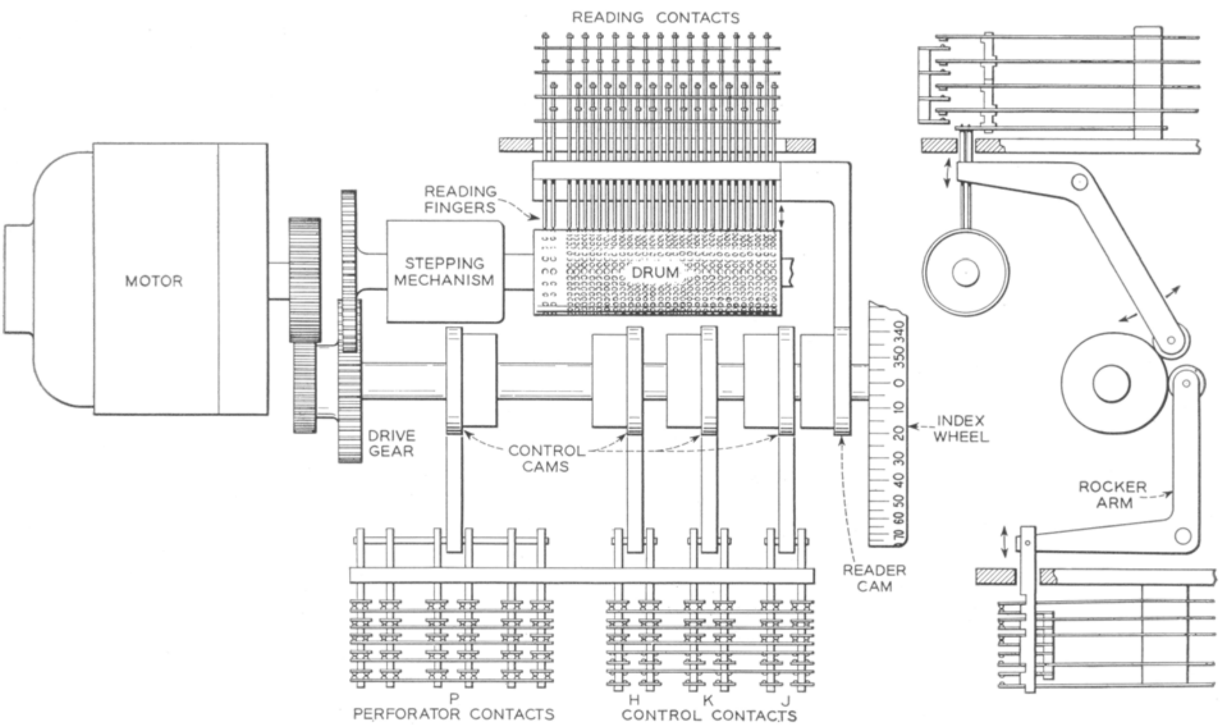


Fig. 4—Diagram of the reader showing the relationships between the major components.

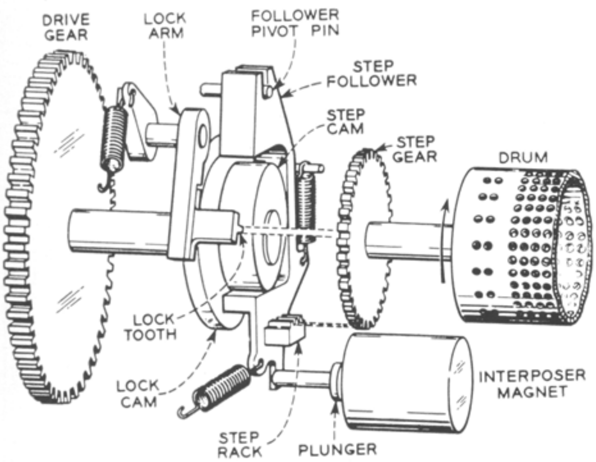


Fig. 5–Over-all view of stepping mechanism.

ure 5, has an input shaft driven through 1:1 ratio gearing from the cam shaft, and an output shaft that carries the reading drum and a thirty-six tooth gear. In the actual machine, the step gear on the output shaft is directly above the step rack, but in Figure 5 it is shown moved away from it to reveal more detail of the mechanism.

Stepping is brought about by the action of the step cam on the step follower, to which the step rack is fastened. Its action can be seen more clearly in Figure 6. The follower is U-shaped, and pivots on the follower pivot pin. Two of its inner surfaces, marked A and B, are held against the step cam by the engage spring and the step spring. The step cam, which is mounted directly on the input shaft, is so designed that in rotating, it first pushes the follower down so as to disengage the step rack from the step gear, then moves the follower to the right, then allows the engage spring to pull the follower up so that the rack engages with the step gear, and finally, allows the step spring to pull the follower to the left and thereby rotate the drum just enough to bring the next row of holes in line with the reading fingers. This cycle is repeated each revolution of the step cam, and thus a total of sixteen steps of the drum are made every second.

To secure this type of cycle, the step cam has two opposite 135 degree (3 times 45 degrees) sectors of constant radius, and two opposite 45-degree sectors of changing radius. The constant-radius sectors are A and C in Figure 6. Sector A has a greater radius than sector C; the difference between them is just enough to allow the rack to move the drum one line. Sectors B and D make the transition from large to small and small to large radius. When sector D reaches surface B of the follower, it forces the follower down and disengages the rack from the gear. This requires one-eighth of a cycle, or forty-five degree rotation of the cam. For the next one-eighth cycle, the follower remains still because its A and B surfaces are riding on constant radius sectors of the cam. At the beginning of the

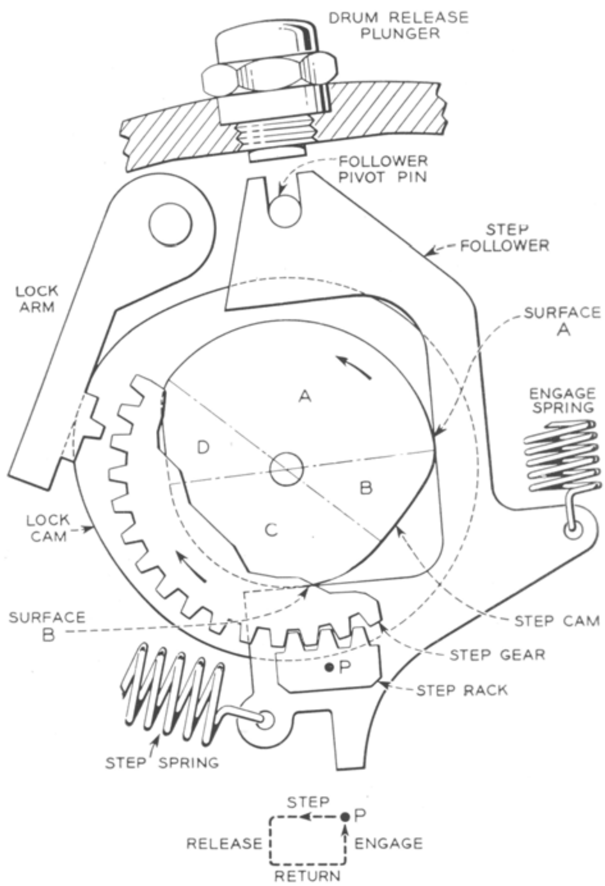


Fig. 6–Step cam and follower from drum end.

next one-eighth cycle, however, sector D has reached surface A and moves the follower to the right. After another one-eighth cycle of no motion of the follower, sector B reaches surface B and allows the follower to move up so that the rack engages the teeth of the step gear. Another one-eighth cycle of rest follows, and then sector B, having reached surface A, allows the follower to move to the left under the pull of the step spring, and advances the drum one line. The motion of the step follower, as illustrated by point P, is produced at practically constant acceleration and deceleration by the shape of the step cam. The performance is quiet and free from shock and thus long life is achieved.

In proper phase with the step cam, another cam, marked LOCK CAM in Figure 6, holds a lock tooth in mesh with the step gear except during the one-eighth cycle while the drum is being stepped. This prevents any possible motion of the drum while the reading fingers are in the drum.

The interposer magnet, shown in Figure 5, provides the means by which the control circuit can prevent the drum from stepping. When this magnet is released, its plunger moves forward behind a finger on the follower and prevents the follower from being pulled to the left by the step spring. When the interposer magnet is released, therefore, the follower will move up and down following the step cam, and the lock tooth will move in and out in the proper phase, but the follower will remain in its extreme right-hand position, and the drum will not be stepped.

A non-locking tape-feed key mounted at the left end of the control contact housing permits the interposer magnet to be operated by the attendant, thus allowing the drum to advance continually. This key is used principally when a new tape is being inserted in the reader.

Just above the follower and passing through the housing of the stepping mechanism is a drum-release plunger by which the follower may be pushed down to disengage the step rack from the step gear. If this is done at the middle of the step period, while the lock tooth is disengaged, the drum is left free to turn. This is taken advantage of in inserting and removing the tape.

Mounted on the cam shaft at the right is a flywheel (index wheel), evident in Figure 2, marked along the inner edge of its periphery with a degree scale from 0 to 360 in five-degree steps. This is used during adjustments and tests to set the cam shaft to any position of the operating cycle. Built into this flywheel is a ratchet which prevents the reader from turing backwards as the reader comes to a stop. This ratchet is of the centrifugal throw-out type, and is disengaged when the reader is running. It thus produces no noise or wear under operating conditions. It may also be disengaged by inserting special pins in the flywheel to permit the reader to be turned by hand in either direction for servicing.

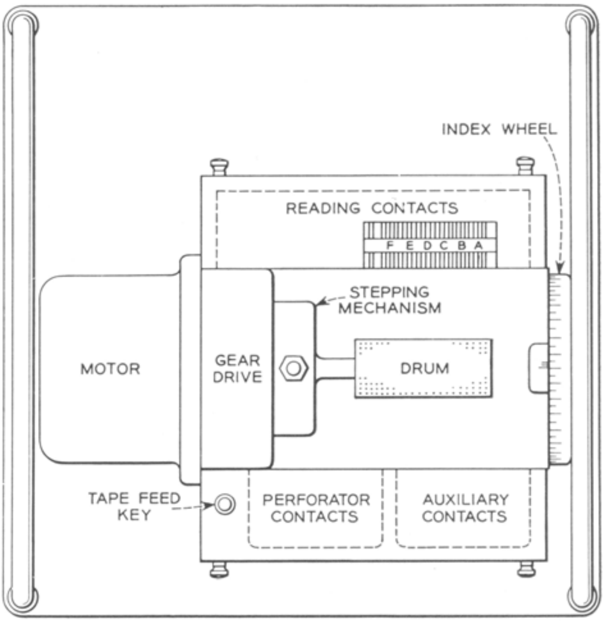


Fig. 7—Simplified diagram of the reader.

All of the contacts of the reader must be adjusted to close and open within fairly narrow limits. With the drive motor stopped, the opening and closing positions of the various contacts may be checked at any time by rotating the dial and reading its position as the various contacts operate. The relationships between the markings on the dial and the mean values for the closing and opening of the various sets of contacts are shown in Figure 8. The zero position on the dial corresponds to the middle

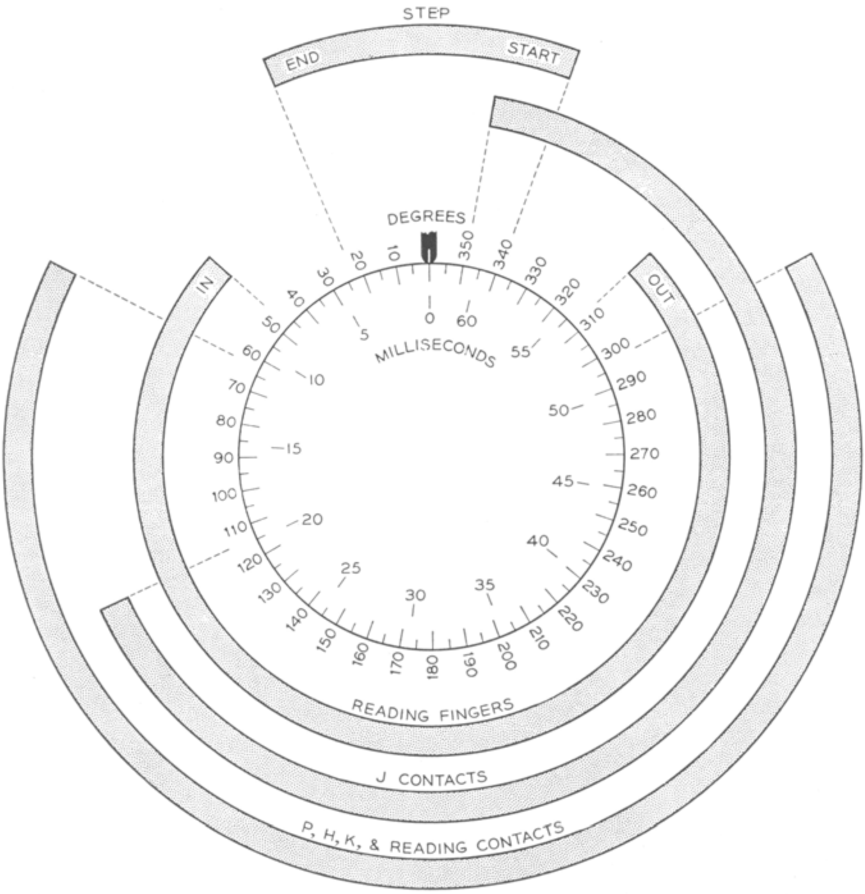


Fig. 8—Time-angle diagram for the reader shown in relation to the degree scale on the flywheel.

of the stepping period. Inside the degree scale of Figure 8 a time scale in milliseconds is marked—each revolution of the cam shaft requiring 62.5 milliseconds.

The contact assemblies, shown in Figure 7, are mounted to the frame of the reader with four screws and in addition are doweled in place with locating pins so that they are readily removable and can be remounted without disturbing the adjustment. Easily removable sheet metal covers protect the contacts from dirt. The cover for the reading contacts has a lucite window through which the positions of the reading fingers can be observed. An adjacent scale, marked A to F to designate the six digit-positions on the tape, permits the code being read to be directly observed.

The reading, perforating, and control contacts and the interposer magnet are connected by local cable to a plug mounted at the rear of the reader as may be seen in Figure 9. This plug contains terminals on two levels, and is designed to plug into a jack in the reader cabinet to which the associated circuits are connected. The motor is separately connected in its own switch box to a power receptacle to which 110-volt ac supply is connected under control of the reader circuit.

There are three additional versions of the basic accounting center reader. Two of these are used as test readers for maintenance of both the central office and accounting center perforators. They are geared to operate at twenty-four cycles per second, and are equipped with only one group of control contacts. The fourth is a maintenance recorder reader used in the No. 1 crossbar central office. It operates at the same speed as the accounting center reader but is equipped with the same contacts as the test reader. These readers are manufactured by the Teletype Corporation, and their basic design was carried out at Bell Laboratories by F. M. Thomas formerly a member of the technical staff.

Since the reader is in use many hours each day, it is necessary that the adjustments be held over long periods of use. Tests have shown that the reader is stable in adjustment, and that substantially trouble-free operation can be expected with occasional lubrication and maintenance.

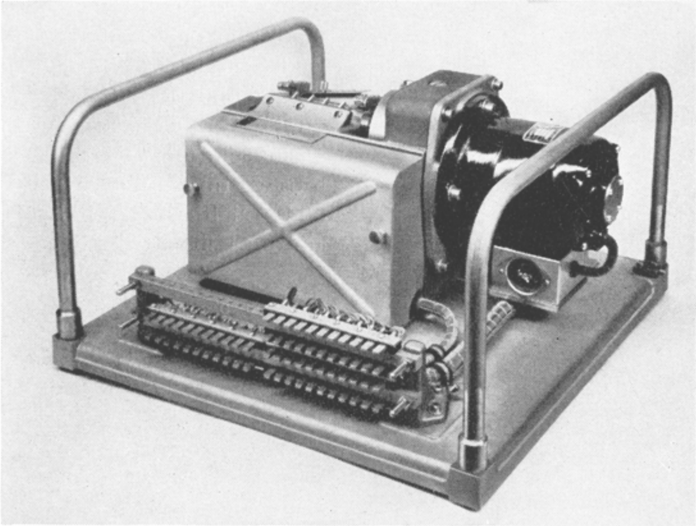


Fig. 9—A rear view of the reader.

The AMA Assembler

GLEN G. DREW
Switching Systems Development

In central offices employing automatic message accounting, a recorder perforates a tape for all AMA calls handled by a group of 100 transmission circuits—trunks in the No. 5 crossbar, and district junctors in the No. 1 crossbar system. Such tapes are sent periodically to a common accounting center* so that bills may be prepared from the information perforated on them. The information pertaining to any one completed call is contained in three entries—a disconnect time entry, an answer time entry, and an initial entry. Typical initial and timing entries are shown in Figure 2. The entries for any one call are usually interspersed with similar entries of other calls and the first step in the accounting center is to bring the entries pertaining to each call together. This is done by the assembler, which consists of a reader, a relay circuit, and ten perforators, as shown in Figure 1. Only one of the ten perforators is used at a time, but the control circuit of the assembler, guided by information it reads on the input tape, can choose which perforator to use for recording each entry found on the input

* See page 47.

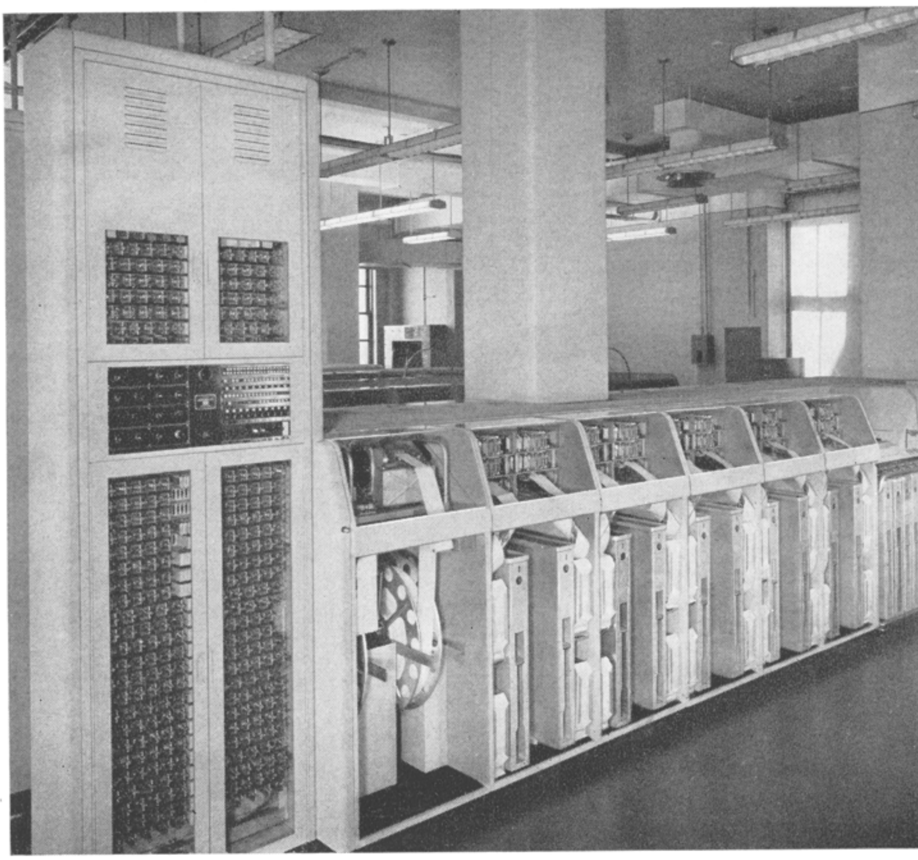


Fig. 1—An AMA assembler consists of a reader, a relay circuit and ten perforators.

tape. The result of this assembling process is an arrangement of call records and time indications that is the same as would result if a separate perforator had been provided at the central office for each transmission circuit and then the resulting tapes had been joined together in numerical order.

Each of the entries pertaining to a call on the central office tape carries a call identity index (CII), which is a two-digit number identifying the trunk or junctor that is being used for the call. Although each of these transmission circuits may be used for many different calls recorded on the same tape, it will of course serve only one at a time. In an accounting center, the tapes are read in reverse time order, and thus if a call was completed, the first entry for it encountered by the reader will be the disconnect entry. The other two entries for this particular call would be the next two encountered that carry the same CII as the disconnect entry. It is this fact that the assembler takes advantage of to bring the entries for each call to adjacent positions on the output tape.

In general the process consists in bringing together on the output tapes all entries carrying the same CII, and since these entries are perforated in the same time sequence in which they appear on the central office tape, the entries for each call will always be grouped together. Such an assembling is brought about by a double sorting process, using first the units digit of the CII and then the tens digit. For the first stage sort, the units digit of the CII, which is the F digit on the tape, is used to select one of the ten perforators for recording the entry. The perforators are designated from 0 to 9, inclusive, and all entries with an F digit zero are recorded on the number zero perforator, all with an F digit 1 on the number 1 perforator, and so on. After the proper perforator has been selected, the entry is recorded on it exactly as it appears on the central office tape.

After the input tape has been completely sorted in this manner, the ten new output tapes are spliced together in numerical order and then used as the input tape for the second stage sort. Exactly the same process is again carried out except at this time it is the tens digit of the CII, the E digit of the entry, that is used to select the perforator used for recording the entry. A chart

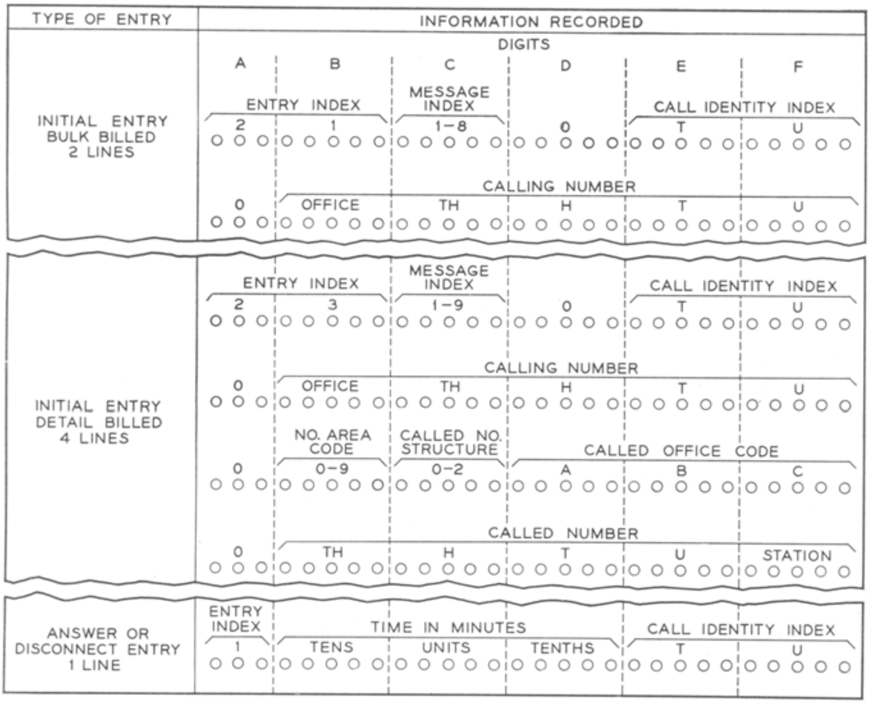


Fig. 2—Three entries are associated with each completed call: an original entry, an answer time entry, and a disconnect time entry. The answer and disconnect time entries are identical in type and differ only in the time recorded. Two types of initial entries are employed: one for bulk-billed calls and one for detailed billed calls.

indicating how the two stages of sorting distribute the entries is given in Figure 3 for a simplified section of a central office tape. It shows the information recorded on the central office tape and on the various output tapes of the assembler. The information is indicated by a letter to give the type of entry—I, initial; A, answer; and D, disconnect—followed by two digits representing the call identity index. At the left of the tape is an identifying number. On the input tape these run in sequence from 1 to 27, but they will be rearranged on the various output tapes. The ten output tapes from the second sorting stage are spliced together and serve as the input tape for the computer, which takes the next step in the accounting center procedure.

Besides the entries for each call, the input tape includes certain other entries to identify the particular group of calls it includes and to indicate the hour of the day. The perforators at the central office place a tape identification entry at each side of a splice, and these entries will thus appear at the beginning and end of each tape. In addition, at the beginning of each hour they perforate an hour entry on the tape. All of the information in the central office tape identification entry is not needed on the output tapes of the assembler, but certain additional information is needed. The assembler, using some of the data read on the central office tape identification entry and supplying the other information itself prepares a new tape identification entry of seven lines. These two tape identification entries and the hour entry are shown in Figure 4. The hour entry and the new tape identification entry must be perforated on all ten output tapes of the assembler. This process is called "spreading" the entry. When an entry to be spread is encountered, the advance of the reader is stopped, and a sequence circuit causes the entry to be perforated on one output tape after another until all have been perforated. The reader is then allowed to advance.

A block schematic for the assembler is given in Figure 5. Although assembling the entries for each call is its chief function, there are other operations that it must carry out to insure accuracy, which is essential throughout the accounting process. For this purpose the assembler is provided with circuits that check the accuracy of both the input and output of the machine. As indicated by the diagram, input checking features connect to the reading relays and parts of the control circuit, and check that the proper number of holes is detected in each line of the input tape, that the reader drum

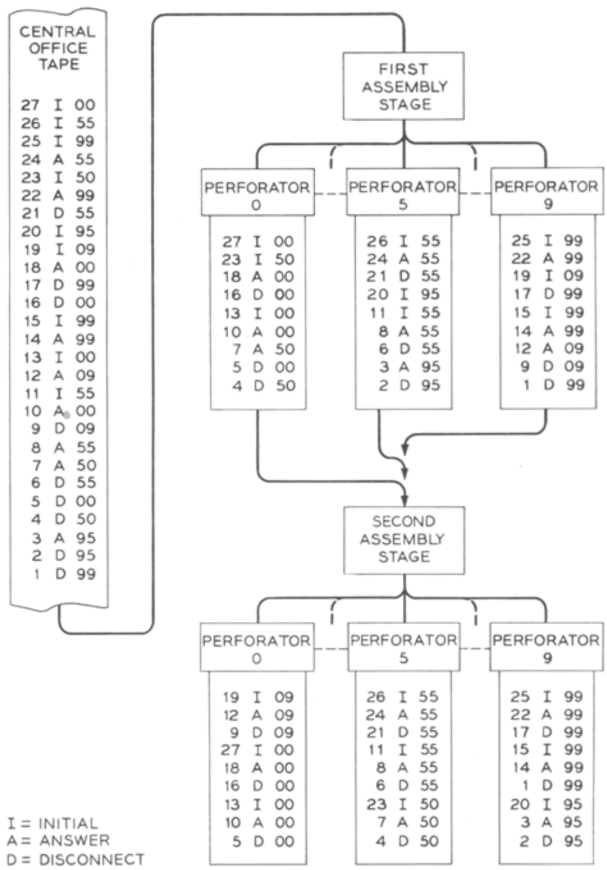


Fig. 3—Simplified chart indicating how the entries are distributed on the ten output tapes by the two sorting stages.

advances one line each time it is instructed to, that no line of an entry is either omitted or repeated, and that the proper tapes are fed into the assembler in the correct order. Output checking features insure that the proper number of holes is perforated in each line, that the perforation takes place on only one perforator at a time, and that the perforator tape advances after each

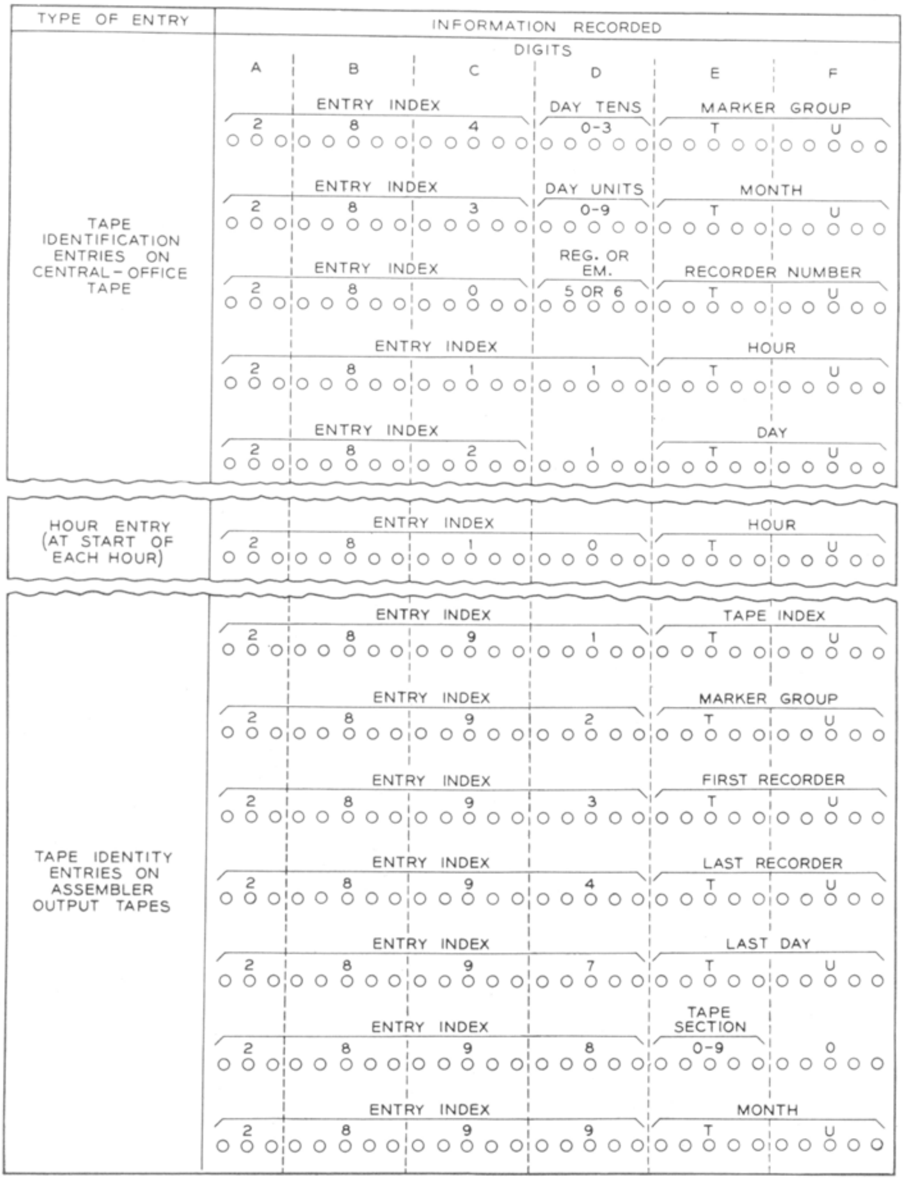


Fig. 4—A central-office tape identification entry, above; an hour entry, center; and below, the tape identification entry put on by the assembler.

perforation. Failure of any of the above checks will cause the operation of the machine to stop with an alarm lamp indicating the type of trouble.

These checks are provided for by wiring, through various relay contacts, circuits that will not be closed unless the proper conditions exist. Through the contacts of the reading relays for the various digits, for example, circuits are wired that are closed when two and only two of the reading relays for digits from B to F, inclusive, are operated. To make sure that only the proper tapes are being processed at any one time, somewhat similar circuits are wired through contacts of the reading relays and also through contacts of some of the dial switches on the control panel. On this control panel, there is one dial switch to indicate the assembly stage, either the first or the second, two to indicate the marker group in tens and units, a tens and units dial for both the first and last recorder of the group for which the tapes are being processed, a tens and units dial for the month, and a tens and units dial for the last day of the period for which the tapes are being processed. Before the assembler is started, these dial switches are all set in accordance with the particular tapes to be processed. If the assembler, in reading the tapes, finds that the various tape identification entries do not correspond with the settings of these switches, the reader stops and an alarm is given.

To accomplish these tests, a group of series circuits are established through the contacts of the various reading relays and through the contacts of the various dial switches on the control panels in such a way that a closed circuit is established only when the information indicated by the operated reading relays corresponds to the information set on the dials. Figure 6 indicates the conditions for a closed circuit for one particular line of identification information. The A, B, and C digits of each such line indicate the type of information carried by the remaining digits of the line. If the A, B, and C digits are 284, for example, the D digit will carry the day tens digit, and the E and F digits will carry the marker group tens and units digits.

When the A, B, and C reading relays indicate 284, therefore, a path is established to the contacts of the D reading relays. There are five relays for each digit except A, and since the information is recorded in a "2 out of 5" code, two of the relays will be operated. Circuits through the contacts of the five relays of the D digit are used to translate from "2 out of 5" to decimal code in such a way that ground on the single input lead will be extended to one of four output leads depending on the digit indicated. These four output leads run to the last-day tens dial switch on the control panel, and the ground on one of the leads will pass through the switch only if the dial is set to that particular digit. From this switch, a lead runs to the contacts of the E reading relays. Here again the circuit translates from "2 out of 5" to decimal code, and the ten output leads run to the tens dial switch for the marker group. The single lead from the arm of the marker group tens dial switch runs to the contacts of the F reading relays. These similarly translate the "2 out of 5" code on the F relays to decimal code, and the 10 decimal leads leaving the F relays run to the ten points on the marker-group units dial switch. From the arm of this switch, the lead runs to the reader step control relay, which will operate and allow the reader to advance only if a closed circuit has been established through the entire chain. For other codes conveyed by the A, B, and C digits, similar circuits are established through the D, E, and F reading relays and other dial switches on the control panels.

In addition to these various checking features, it is necessary also to dispose of certain erroneous or mutilated entries on the input tape. Recorder circuits in the central office have checking features that enable them to detect irregularities in the perforation on any line of the tape, and to detect other conditions that would cause false charging. When any such condition is found, an entry is perforated by the central office recorder to indicate that an irregularity has occurred, and as far as possible to give the nature of the trouble. If it has been determined that more or less than two holes had been perforated for

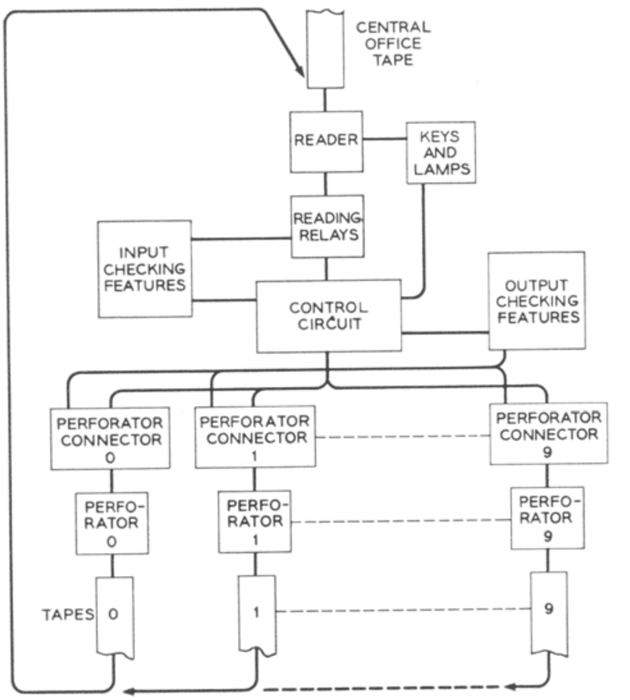


Fig. 5—Block schematic of the assembler.

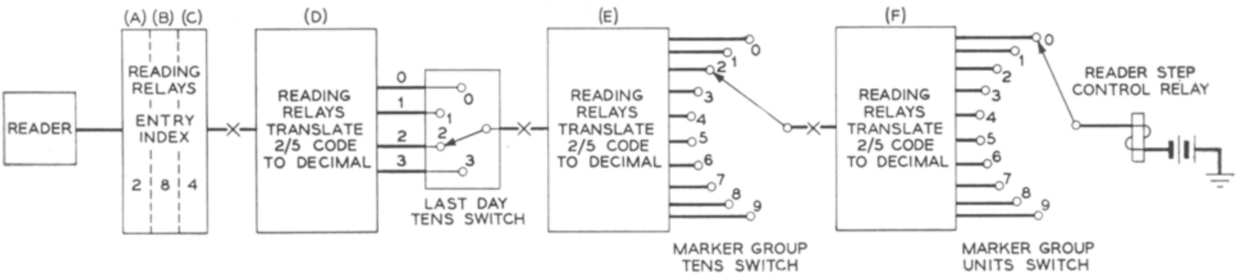


Fig. 6—Block diagram of part of the circuit used in checking the input tapes against information set on the control dials.

any digit on any line of an initial entry, a cancel entry is perforated as the next line. The assembler upon reading the cancel entry (reading the central office tape backward) will skip over the line which was found in difficulty, and any other lines of the initial entry already perforated. The faulty entry is thus thrown out at the first assembly stage.

Provision is also made in the assembler to care for mutilated entries for which no cancel entries have been perforated at the central office. Such mutilations may occur due to weak spots in the tape through which the reading pins project. The circuit is arranged to stop with an alarm at these conditions, and the machine will not start until the attendant takes appropriate action.

At sixteen lines per second about one-half mile of central office tape can be processed through the first assembly stage in an eight-hour day. This represents from 50,000 to 90,000 calls, depending on the type of traffic in the office.

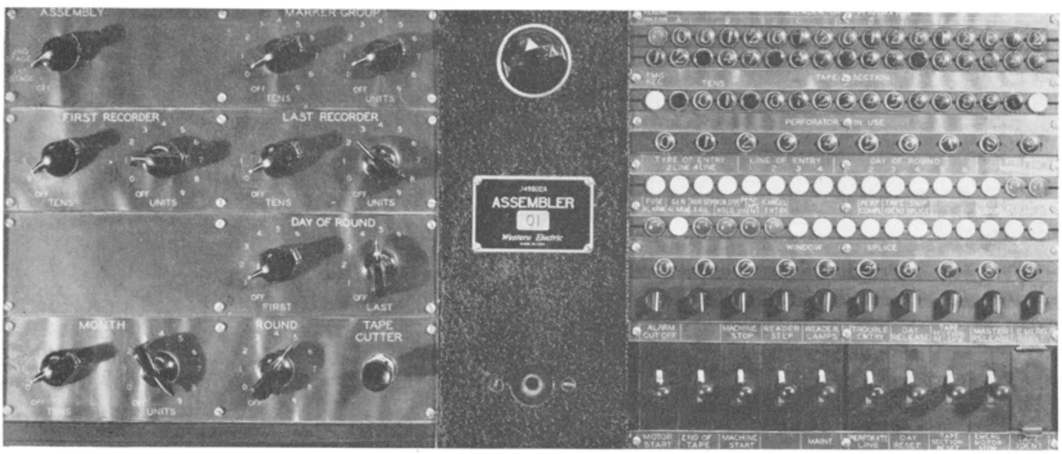


Fig. 7—Key and lamp panel of the assembler unit.

The AMA Computer

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Switching Systems Development

Of the various circuits in an Automatic Message Accounting Center,* the computer, which follows the assembler† in processing order, is the largest and most complicated. Its chief functions are to compute the chargeable time for detail-billed calls and the number of message units for bulk-billed calls, to discard "don't answer" and "busy" calls, to sort out the calls according to type, and to perforate condensed output entries from which all unessential information has been excluded. For these various functions it requires four cabinets of relay equipment with lamps and control panels, a reader,‡ and fourteen perforators – two in each of seven cabinets, as shown in Figure 1.

The input tapes of the computer come

* See page 47. † See page 59. ‡ See page 52.

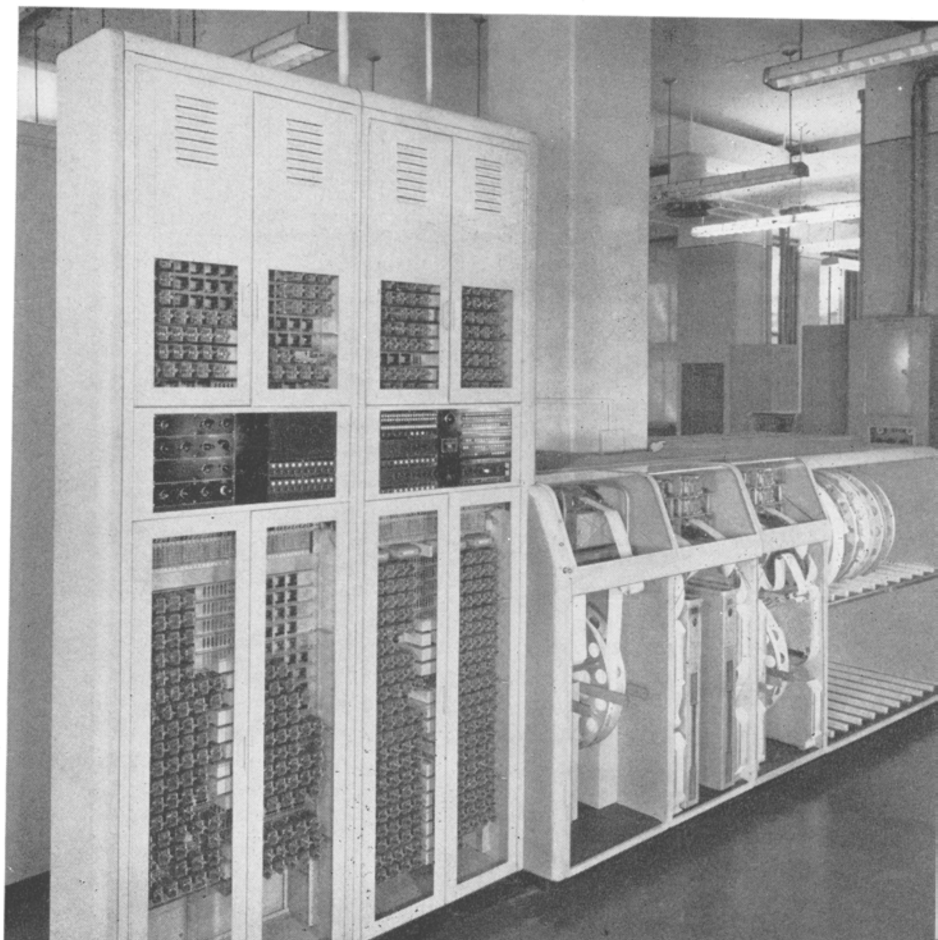

Fig. 1 – The AMA computer includes, from left to right and back-to-back, four cabinets of control equipment, a reader, and fourteen perforators, two in each of the seven cabinets.

from the assembler which, as the first in the series of accounting center machines, receives the tapes perforated at the central office. These central office tapes contain the initial, answer time, and disconnect time entries of each call. All three entries for any one call are marked by the same call identity index, and are in chronological order but intermingled with similar parts of other calls. Reading the central office tapes in reverse, for a purpose to be explained later, the assembler rearranges the entries in such a manner as to bring together the scattered elements of each call in consecutive lines on one of its output tapes. These become the input tapes for the computer.

From the disconnect and answer entries the computer calculates the chargeable time, and for message unit calls calculates in addition the number of message units chargeable for the call. Once these calculations have been made, the disconnect time entry is no longer needed in the accounting procedure, and the answer time is used only with detail-billed calls to serve as an additional identification for the call. The call identity index, having been used by the assembler, is also no longer needed. As a result, these items can be eliminated, and the entries to be perforated on the output tapes of the computer can be correspondingly compressed. For bulk-billed calls where the number of message units is not greater than nine, only a single line is required for the output entry, which includes one digit for the number of message units and four digits for the calling telephone number. When there are more than nine message units, a two-line entry is perforated, with the calling telephone number in one line and the number of message

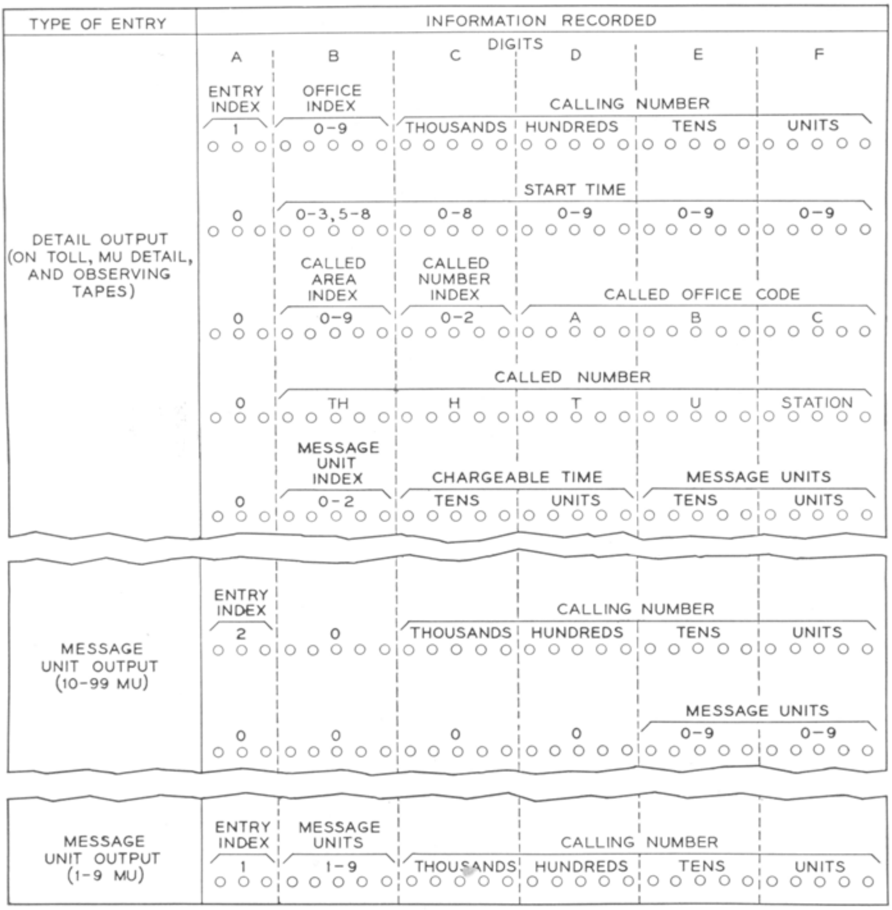

Fig. 2 — The three major types of output entries perforated by the computer.

units in the other. Output entries for all telephone calls that are recorded in detail are reduced to a single entry of five lines from the four-line initial entry and two one-line time entries on the central office tapes. The significance of the various lines and digits in this five-line output entry is shown in Figure 2.

One of the important processes in the accounting center consists in sorting or grouping messages according to type. Part of this sorting process is performed by the sorting operation reduces by one stage the amount of work to be done by the sorter, which processes the tapes after they leave the computer and brings together all the messages dialed by the same calling line within a given period.

A block schematic indicating the major components of the computer is given in Figure 3. In general, the process consists in reading the lines of the input entries pertaining to each call one after another, recording the information contained in each line in the appropriate registers, computing the chargeable time and, in the case of bulk-billed calls, the number of message units for the call, and then perforating an output entry on one of the fourteen perforators. An overlap operation is provided, however, so that an output entry may be perforated while the next input entry is being read. This is indicated in Figure 4. For message unit entries, where the output entry consists of only one or two lines, there is no delay at all due to output perforating.

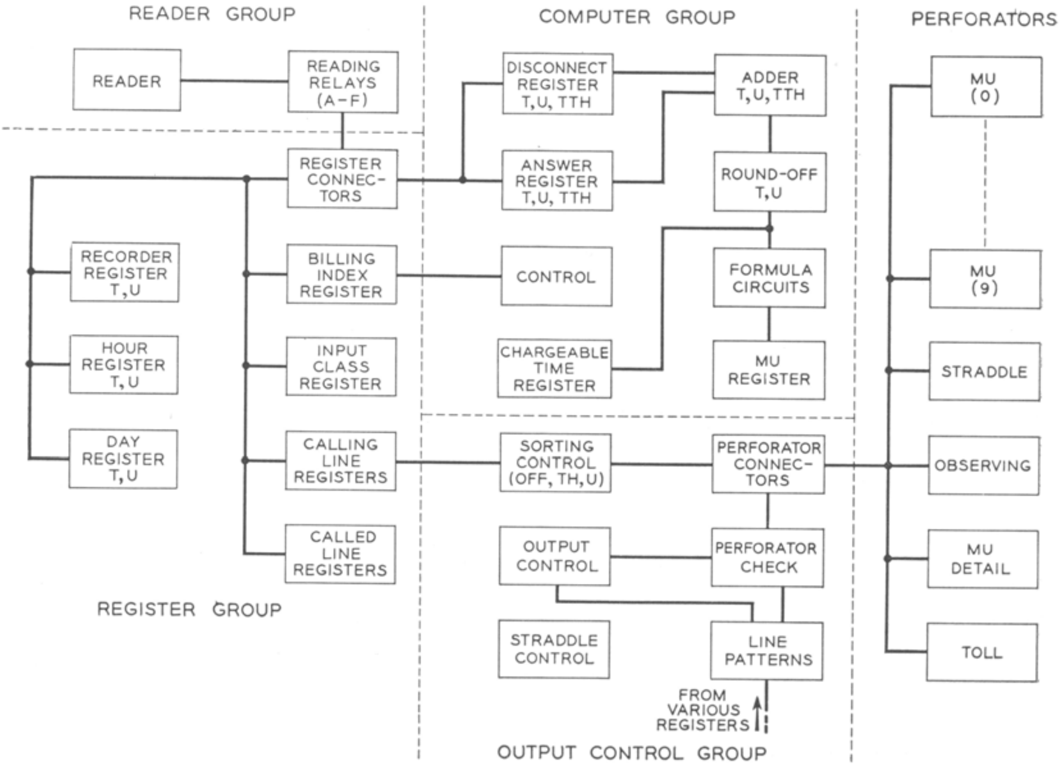

Fig. 3—Block schematic of the computer.

computer, which classifies its output entries as toll, message unit, message unit detail, etc., and then further sorts the message unit calls according to a digit of the calling line number. The office digit of the calling line number is used for sorting whenever the input tapes include calls from more than one central office served by the same marker group. When only one central office is involved in the marker group, the message unit calls are usually sorted according to the units digit of the calling line number. This

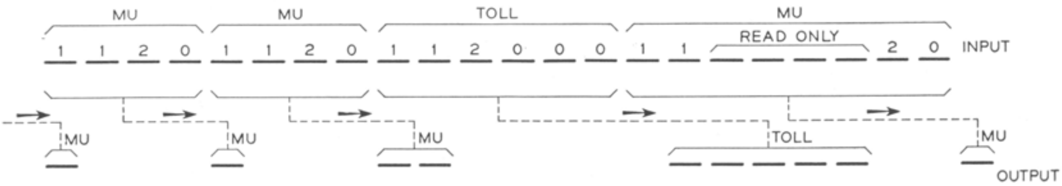

Fig. 4—Overlap operation in the AMA computer.

The input entries are read line by line in continual succession and the complete output entry for one call is perforated while the timing entries for the next call are being read. While the five-line output entry of a detail-recorded call is perforated, the progress of the input tape is held up four timing intervals, or a total of one quarter of a second, to permit the output entry to be completed before the input tape is advanced to read the initial entry of the succeeding call.

The timing intervals just referred to are determined by the motor-driven interrupter of the reader. Sixteen times a second the reading fingers move in to read the tape and a group of contacts are closed. The resulting pulses guide the operation of the computer and the perforation of the output tapes. Normally the reader is advanced on each pulse, but when a five-line output entry must be perforated, the advance of the reader is held up; the reading fingers move in and out and the contacts close and open but the input tape remains stationary.

The first entry of a call encountered on the input tape is the disconnect time in tens, units, and tenths of minutes relative to the hour, which is registered as a separate item from hourly entries on the tape. Next comes the answer entry, and then the initial entry, this inverse sequence being produced by the tape reversal at the assembler stage in order that computation may proceed without awaiting the initial entry. As the disconnect time entry is read, it is recorded at once in the disconnect register, and the input tape is advanced to the next line, which is the answer time entry. As the latter entry is read, it is at once recorded in the answer time register. Both of these registers are in the computer section of the circuit, and as soon as the answer time has been recorded, the computer subtracts it from the disconnect time to determine the elapsed time. This elapsed time is then passed to the "round off" circuit where a definite amount is subtracted to allow for any possible delays in recording the disconnect time at the central office. The remaining interval is then rounded off to the next higher minute to produce "chargeable" time.

In the meantime, the reader has advanced to the first line of the initial entry of the call. This includes the entry index showing the general class of the call – message unit or detail – and the billing index, which provides the final distinction regarding the specific type of the call and also indicates the particular rates to be used for the initial and overtime periods of message unit calls. As soon as the latter index is read, it is recorded in the billing index register, which interprets it and passes the resulting information to the control circuit of the computer. If the information indicates a detail-billed call, the computer passes the rounded off or chargeable time to the chargeable time register for later use in perforating the output entry. If the billing index signifies a message unit call, the control circuit of the computer selects the appropriate one of a number of formula circuits, of which there is one for each combination of initial and overtime rates in use. The chargeable time is then passed to this formula circuit, where a single stage translation evaluates the time in terms of message unit charges. This one operation is the equivalent of dividing the total chargeable time into initial and overtime periods, evaluating each in terms of message units, and adding the two results together to give the total number of message units chargeable for the call. This number is then transferred to the message unit register.

If the call being processed is a message unit call, the next line read by the reader will be the second or last line of the initial entry. This includes the calling office and line number, which will be recorded in the calling line register. For such a call, all the information needed for perforating the output entry is now in the registers of the computer. During the next impulse from the reader, therefore, while the disconnect entry for the succeeding call is being read, one line of the output entry is perforated on one of the ten perforators, as shown in Figure 4. Which perforator is used depends, as has already been stated, either on the office number or on the units or thousands digit of the line number.

For detail recorded calls there will be three lines of the initial entry to be read after the receipt of the message billing index has allowed the chargeable time to be transferred to the chargeable time register. Only after these three lines have all been read and the information recorded in the proper register can the output entry be started. Actually, however, one additional pulse period of the reader is allowed before the output entry is started. This is to make sure that the next line on the input tape pertains to the next call and is not a repeated line of the call just being processed. Thus in the call sequence shown in Figure 4, perforation of the output for the toll call does not begin until the answer entry of the next call is being read on the input tape.

After the disconnect and answer entry of a call have been recorded and the elapsed time calculated, the disconnect and answer registers can be released, and are thus available for recording the corresponding entries of the next call. This permits the overlap operation already illustrated in Figure 4. Here, short horizontal lines represent the pulse periods of the reader — each one-sixteenth of a second long. Since the third call indicated is a toll call, its five-line output entry will require more time to perforate than the reading of the next two timing entries. As already stated, output perforation of the toll call begins after the disconnect entry of the next call has been read. While the next four lines of the output entry are being perforated, therefore, the input tape is not allowed to advance. Four pulse periods must be allowed before the input tape is again started and the remaining part of the next entry is accepted by the registers.

One of the major sections indicated in Figure 3 is concerned with perforating the output tapes. There are connectors for each of the fourteen perforators, and there are selecting circuits to determine which one is used. The ten-message unit perforators are selected either by the calling office or the calling line number as already noted. Three of the remaining perforators, the toll, message unit detail, and observing all have the same type of input entries, and which perforator is selected depends on either the entry index or the message billing index, or both. Message unit detail calls are

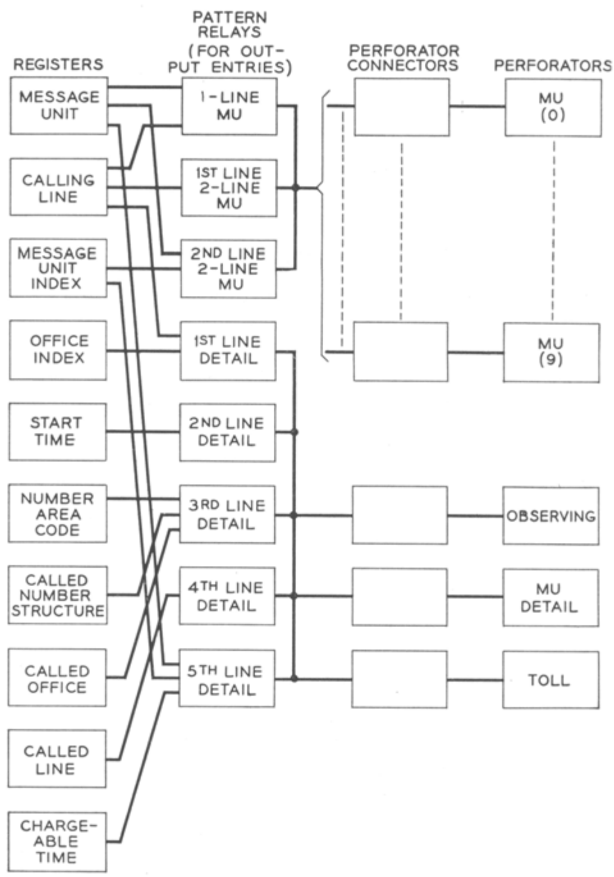

Fig. 5—Block schematic indicating some of the line pattern relays and their association with the registers and perforator connectors.

billed on a message unit basis from output entries perforated on the regular message unit tapes, but an additional output entry for each such call is perforated on the message unit detail tape to preserve the details of the call, including the message unit charges and the chargeable time. Service observing calls are those on which a check is being made by the operating personnel, and such calls have a detailed form of output perforated on the observing tape in addition to the regular output on one of the other tapes. On the straddle perforator are recorded those calls whose entries are not all contained on the tapes being processed. Some part of each such call will be on the tape in question, while the rest will be found on the tapes of the preceding or following period. Entries on the straddle tape have to be assembled later as a separate step.

Besides selecting the proper perforator, the output control circuit must also select a line-pattern relay for each line perforated on an output tape. These line pattern relays are connectors that establish paths from various registers to the perforator connectors. There is one pattern connector for each type of output line that may have to be perforated. In simplified block form, Figure 5 indicates their association with the registers and perforator connectors for detail and message unit calls. Other combinations of line patterns are used for straddle calls. A comparison of Figure 5 with Figure 2 will show that the line pattern relay for each output line connects the registers containing the information for that line through to the proper perforator connector.

"Don't answer" and "busy" calls (except those in the service observing category) are discarded by the computer. Such calls will have an initial entry on the input tape but no preceding disconnect or answer entries. When the computer receives an initial entry without having previously received the disconnect and answer entries, it releases its registers and the reader proceeds to the next entry, discarding the uncompleted call.

The computer includes a large number of checking features, as do other circuits of the AMA system. Among the elementary checks are those to insure that two and only two reading relays are operated for each digit, that the reader and perforators advance when they should, that the proper perforating magnets are operated for each output entry, and so on. However, a major consideration in the design of the computer has been the prevention of overcharging. Extensive additional checks have therefore been provided to insure that all elements relating to charging, particularly those requiring cancellation of all or part of the charges, have been taken into account before the output proceeds. If all conditions are not met, the machine stops and gives an alarm.

The AMA Computer:

Chargeable Time and Message Unit Computations

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Switching Systems Development

Although the computer of the AMA system has many functions, the one from which it derives its name, and its chief one, is computing. The computing operations are all related to the determination of charges for calls, and include: the calculation of the conversation time, the deduction of a fixed allowance from the calculated conversation time to compensate for recording variations, the rounding off of the net conversation time to whole minutes, and, for calls that are to be bulk billed, the conversion of chargeable time into message units.

The computations are based on information found in the three entries that the computer receives for each completed AMA call. From the answer entry and the disconnect entry, the conversation time can be calculated. After this conversation time has been adjusted and rounded off, it becomes chargeable time. How this chargeable time is used depends on whether the call is a message-unit call or a toll call. This information is contained in the initial entry. Message-unit calls are rated by the computer in terms of message units, and the charges for all such calls are lumped together at subsequent stages of processing and appear as one item on the subscriber's

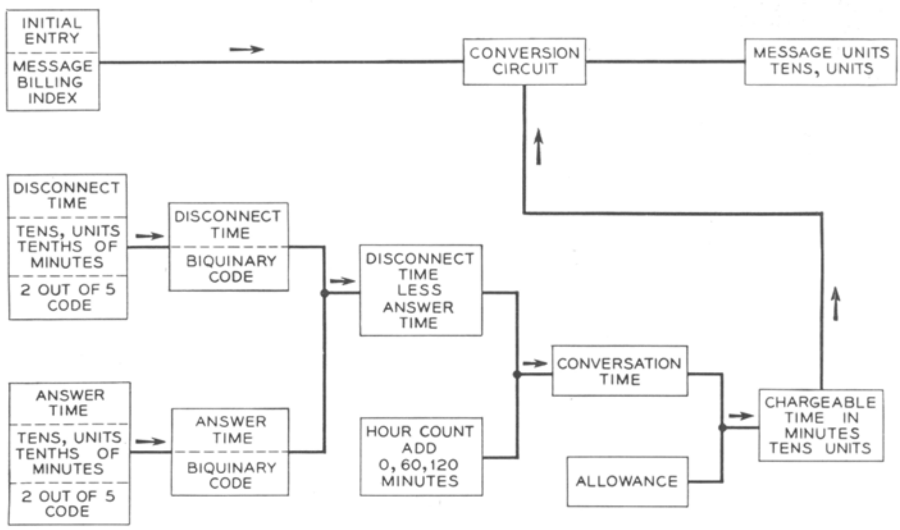

Fig. 1—Block diagram of the computing operations.

Table I — The Two-Out-of-Five and the Bi-Quinary Codes.

Decimal Digit	*Two-out-of-Five*		*Bi-Quinary Bi*	*Equivalent Quinary*
0	4	7	0	0
1	0	1	0	1
2	0	2	0	2
3	1	2	0	3
4	0	4	0	4
5	1	4	5	0
6	2	4	5	1
7	0	7	5	2
8	1	7	5	3
9	2	7	5	4

bill at the end of the month. Toll calls are rated at a subsequent accounting stage after the computer has determined the chargeable time, and all of these calls will appear individually on the bill that is sent to the customer.

A diagram of the computing operations is shown in Figure 1. The first step in the computations is to translate the disconnect and answer times from the "two-out-of-five" code in which they were originally recorded to the "bi-quinary" code, which is to be used for computing. The "two-out-of-five" and "bi-quinary" codes are given in Table I. Although there are many codes available for use in computing, the "bi-quinary" most nearly meets the requirements of the situation. These are: easy translation to and from the "two-out-of-five" code, which is employed in AMA, easy translation to and from the decimal code for the convenience of accounting and maintenance personnel who work with the machine, relatively simple computing networks, economy of apparatus—only seven elements are required to represent the ten decimal digits—and the ability to be made self checking.

The computation of conversation time requires the subtraction of the answer time from the disconnect time. Since both times are recorded in tens, units, and tenths of minutes after the last hour, this amounts to the subtraction of one three-digit number from another. Although a direct subtraction operation might have been performed the "complements adding" process, which has been fully described previously*, is used for calculating the conversation time.

In calculating conversation time, the computer must also take into account the passage of hours. Entries are recorded at the beginning of each hour and are registered and checked by the computer as has already been described†. To compute conversation time, it is necessary to know how many hours have passed between answer and disconnect times. The computer has an "Hour Count" circuit which supplies this information, and, after the answer time has been subtracted from the disconnect time,

Table II — Representative Charging Plans in Use in the Bell System

Billing Formula	*Initial Charge in Message Units*	*Initial Period in Minutes*	*Overtime Charge in Message Units*	*Overtime Period in Minutes*
A	1	5	none	. .
B	1	5	1	5
C	2	5	1	3
D	3	5	1	2
E	4	5	1	2
F	5	5	1	1
G	6	3	2	1
H	6	4	1	1
J	7	3	2	1
K	7	4	2	1
L	8	3	2	1
M	3	3	1	1
N	4	3	1	1
P	5	3	1	1
Q	4	5	1	1

an adjustment is made for the passage of hours. Let us assume a call that was answered at 17.3 minutes after an hour and disconnected at 35.7 minutes after an hour. Subtracting the answer time from the disconnect time gives a result of 18.4 minutes. If the hour count shows that no change has taken place in the hour between the answer and disconnect times, then 18.4 minutes is the conversation time. If the hour changes once, the answer being at 9:17.3

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* Record, *December,* 1946, *page* 457.

† See pages 65 and 77.

and the disconnect at 10:35.7, for example, then sixty minutes must be added to get the conversation time of 78.4 minutes. Similarly, if the answer had been at 8:17.3 and the disconnect still at 10:35.7, the hour would have changed twice, i.e., from 8 to 9 and then from 9 to 10, and 120 minutes must be added to get the conversation time of 138.4 minutes.

After the conversation time has been calculated, a small time allowance is made to cover any delay that might have occurred at the central office between the actual disconnect and its recording on the tape. The conversation time adjusted in this manner is then rounded to whole minutes. With an allowance of 0.1 minute, a call with conversation time of 18.4 minutes would fall in the interval 18-19 minutes (designated by 19) while a call with conversation time of 18.1 minutes would fall in the interval 17-18 minutes (designated by 18).

The subsequent treatment of this chargeable time depends on the message billing index, which was registered as part of the initial entry. If the billing index indicates that the call is a toll call, the chargeable time is registered and the computing operation is completed for the call, since the charges will be determined at a later time. If, however, the billing index indicates that the call is of the bulk billed variety, message unit charges must now be computed according to the billing formula designated by the billing index.

There are many billing formulas in use throughout the Bell System, and the conversion of chargeable time to message units depends on which billing formula applies to the particular call. Each formula specifies an initial time interval and the charge in message units for this interval, and also the length of and the charge for the overtime interval. Some typical billing formulas are listed in Table II. The message-unit charge for each length of chargeable time from zero to thirty minutes for eight of these billing formulas is given in Table III. If a call lasted for fourteen minutes, for example, and billing formula C applied, the charge would be five message units.

In calculating the number of message units applicable to each call, the computer employs circuits that are equivalent to a set of tables, like Table III, but with a chargeable time running from zero to ninety-nine minutes. Calls which last longer than ninety-nine minutes or for which the charge is more than ninety-nine message units are recorded on a special output tape and are rated manually.

The circuit for converting chargeable time to message units may employ any number of billing formulas up to a total of eight. Although there are many more than eight formulas employed in the Bell System, there will not ordinarily be more than

TABLE III — MESSAGE UNIT CHARGES FOR THE BILLING FORMULAS OF TABLE II AND FOR CHARGEABLE TIME UP TO THIRTY MINUTES

Chargeable Time	Billing Formula A	B	C	D	E	F	G	J
00	01	01	02	03	04	05	06	07
01	01	01	02	03	04	05	06	07
02	01	01	02	03	04	05	06	07
03	01	01	02	03	04	05	06	07
04	01	01	02	03	04	05	08	09
05	01	01	02	03	04	05	10	11
06	01	02	03	04	05	06	12	13
07	01	02	03	04	05	07	14	15
08	01	02	03	05	06	08	16	17
09	01	02	04	05	06	09	18	19
10	01	02	04	**06**	07	10	20	21
11	01	03	04	**06**	07	11	22	23
12	01	03	05	**07**	08	12	24	25
13	01	03	05	**07**	08	13	26	27
14	01	03	05	**08**	09	14	28	29
15	01	03	06	**08**	09	15	30	31
16	01	04	06	**09**	10	16	32	33
17	01	04	06	**09**	10	17	34	35
18	01	04	07	**10**	11	18	36	37
19	01	04	07	**10**	11	19	38	39
20	01	04	07	11	12	20	40	41
21	01	05	08	11	12	21	42	43
22	01	05	08	12	13	22	44	45
23	01	05	08	12	13	23	46	47
24	01	05	09	13	14	24	48	49
25	01	05	09	13	14	25	50	51
26	01	06	09	14	15	26	52	53
27	01	06	10	14	15	27	54	55
28	01	06	10	15	16	28	56	57
29	01	06	10	15	16	29	58	59
30	01	06	11	16	17	30	60	61

eight used in the area covered by an accounting center, and the computers for each center are equipped only for those formulas that apply to the local area.

Chargeable time, after being computed as described above, is registered on two groups of relays: one group representing the tens digit, and the other, the units digit. Leads from the contacts of these relays together with leads from the register for the message billing index run to the conversion circuit as indicated in Figure 1. At the output of the conversion circuit there are twenty message unit relays—ten for the units digit and ten for the tens digit. The function of the conversion circuit is to operate the proper tens and units message unit relays to give the number of message units corresponding to the chargeable time and the message billing index.

A diagrammatic over-all view of this conversion circuit is given in Figure 2. There is a CP relay corresponding to each billing formula for which the computer is equipped, and each relay is operated over one of the eight leads from the message billing index register. The operation of the CP relay connects the ten tens leads from the chargeable time register to a group of TA and TB relays. As shown in greater detail in Figure 3 there is a TA and a TB relay for each

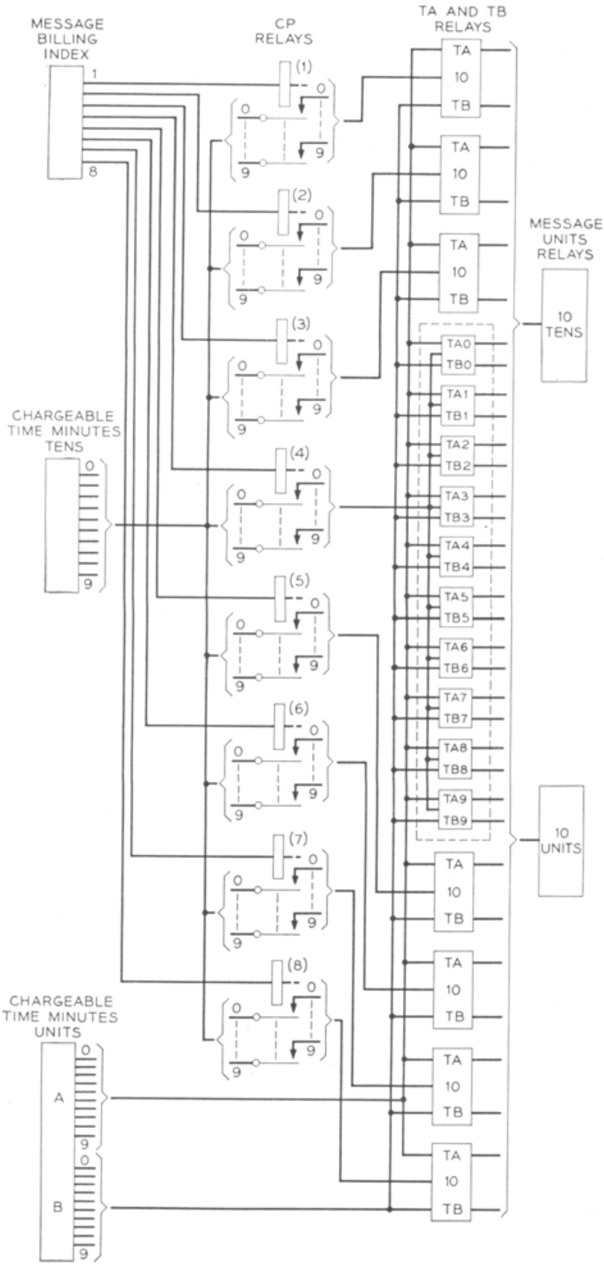


Fig. 2—Simplified schematic of the circuit that converts from chargeable time to message units.

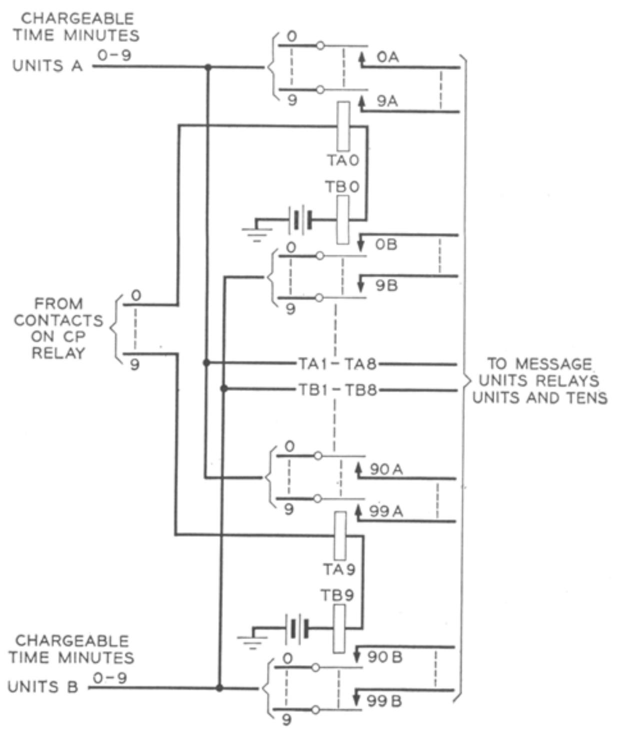


Fig. 3—Schematic showing the arrangement of the TA *and* TB *relays associated with each* CP *relay.*

of the ten tens leads coming from each CP relay, but for the sake of simplicity Figure 3 shows only the TA and TB relays associated with one CP relay.

Each units digit in the chargeable time register is represented by ground on two leads. There are thus two groups of ten leads for the units digit of chargeable time, and one lead in each group will be grounded for any one units value of chargeable time. One of the groups of leads multiples to springs on all the TA relays, and the other, to springs on all the TB relays. The front contacts of the TA and TB relays connect respectively to the windings of the units and tens message-unit relays, Figure 2, in accordance with the billing formula represented by the CP relay with which the particular TA and TB relays are associated.

When a CP relay is operated, the ground on one of the tens digit leads of the chargeable time register will operate the correspondingly numbered TA and TB relays in series. As a result of the operation of a TA relay, the ground on one of the units digit leads from the chargeable time register will be connected through to one of the message-unit units relays, while as a result of the operation of the TB relay, ground will appear on one of the message-unit tens relays. Figure 4 shows the circuit involved when the CP relay number 3, corresponding to billing formula D, is operated and when the tens digit of chargeable time is one. Had the tens digit of the chargeable time been other than one, a different pair of TA and TB relays would have been operated. A similar circuit is controlled by each of the seven other CP relays.

It will be noticed that Figure 4 corresponds to the parts of two columns of Table III set in bold face type; it covers all message-unit charges for formula D when the tens digit of the chargeable time is one. Contacts 10 to 17, inclusive, of the TB relay are all multiplied together and connected

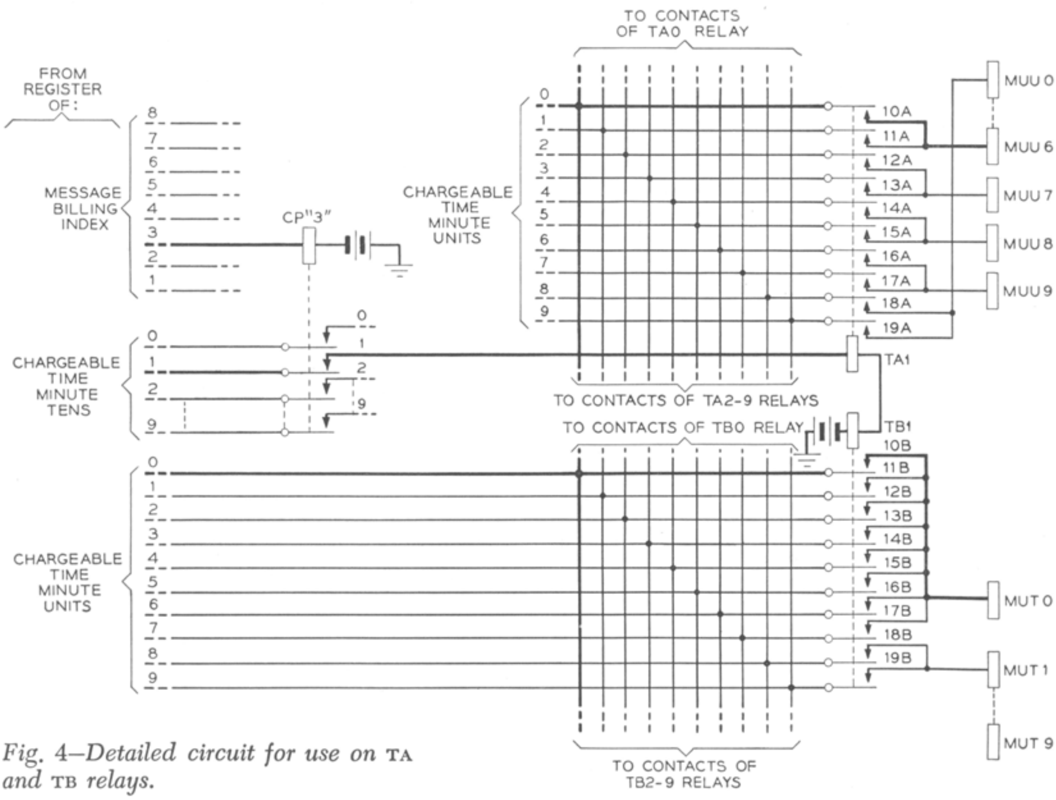
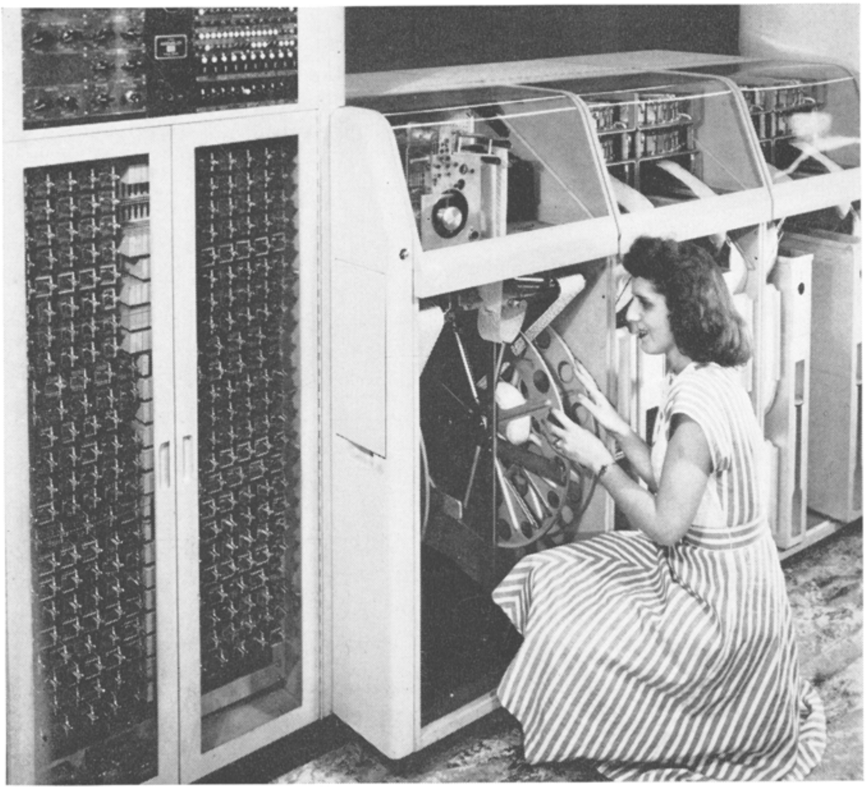


Fig. 4—Detailed circuit for use on TA *and* TB *relays.*

to the "zero" message-unit tens lead, while the 18 and 19 contacts connect to the "one" message-unit tens lead. Contacts of the TA relay are multiplied in pairs; contacts 10 and 11 connect to the number six message-unit units relay; contacts 12 and 13, to the number seven message-unit units relay, etc.

The fully equipped conversion circuit corresponds to a table, like Table III, extending to ninety-nine minutes of chargeable time. Each of the CP relays corresponds to one of the eight lettered columns, and each pair of TA and TB relays associated with a CP relay, correspond to ten lines of the column.

When chargeable time has been converted to message units, the computing functions are completed. The total time required to make the computations for the call is approximately one tenth of a second. This time, small though it is, includes time to check at each step of the computations that the required result has been obtained. Checks are made throughout the entire AMA system, but they are nowhere more important than here where the actual charges for calls are calculated. The proof of the efficiency of the checks is the fact that from July, 1949 to March, 1951, almost two years of AMA operation, during which time more than 100 million calls were processed by AMA computers, there was no known case of a call being wrongly charged due to misoperation of any of the computing circuits described in this article.



Adjusting tape take-up mechanism in the AMA accounting center in the Philadelphia office.

Tracing Time Backward In AMA

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Switching Systems Development

In central offices operating under the automatic message accounting system, the entries pertaining to calls are perforated in the AMA tapes in their proper time sequence. The initial entry, containing the basic information for identifying the call, will be perforated first, then the time the called subscriber answered, and finally the time of disconnect. In the accounting centers where these tapes are processed, on the other hand, they are read backwards. Of the three entries pertaining to any one completed call, the disconnect entry will be read first, the answer entry next, and the initial entry, last. An advantage in processing in reverse order is one of convenience in tape handling: the free ends of the tape on the reels received at the accounting center from the central office can be fed directly into the first machine–the AMA assembler. For subsequent machines, the intervening splicing and rereeling routines set up, preserve the reverse order. There are, however, more basic reasons.

When, for example, the check circuits in a central office detect that an error may have occurred in the perforation of an entry, they cannot erase what has already been perforated, but they can and do provide a subsequent cancellation or correction entry. By reading in reverse at the accounting center, this warning entry is encountered first, and the machine thus knows in advance how to act when reading the entry with the suspected error.

In Figure 1, for example, is a sequence of entries in the order in which they might have appeared on an AMA tape. This tape was perforated from top to bottom: the (g) entry was perforated first, the (f) entry next, etc. At (c) is an initial entry that was suspected of being faulty by the central office circuits. As a result, a cancellation entry, (b), was perforated immediately afterward. When the tape reaches the accounting center, it is read backward, that is, in the order (a), (b), (c), etc. The (b) entry is thus encountered before the (c) entry, and thus the accounting center machine will know how to deal with a faulty entry when it reaches it.

There are, however, two other important advantages from reading the tape backward by the AMA computer. With this order of reading, the disconnect time and the answer time are both read before the initial entry, and thus the answer time may be subtracted from the disconnect time while the initial entry is being read from the tape. A set of three such entries for the same call is shown at (d), (e), and (f) of Figure 1. They were perforated at the central office in the order (f), (e), (d), but they are read after assembling it in the accounting center in the order (d), (e), (f), and thus the timing entries may be processed while the initial entry is being read.

By reading the tape backward, it is possible also to recognize the initial entries of calls without timing entries (calls to busy lines, unanswered, or free calls) immediately upon reading the first line of the initial entry and thereby avoid the further registering and analyzing of the entry by the AMA computer. Such an initial entry is shown at (g) of Figure 1. Since the immediately preceding entry was also an initial entry, the absence of intervening disconnect and answer entries shows that (g) was unanswered, and it may be discarded.

As a result of reading the tape in the reverse direction, however, the progress of time must be followed backwards. Time manifests itself in two ways in the results of the AMA process. First, there is the elapsed time on the messages, which is used directly for charging purposes, and second there is the date and time of day

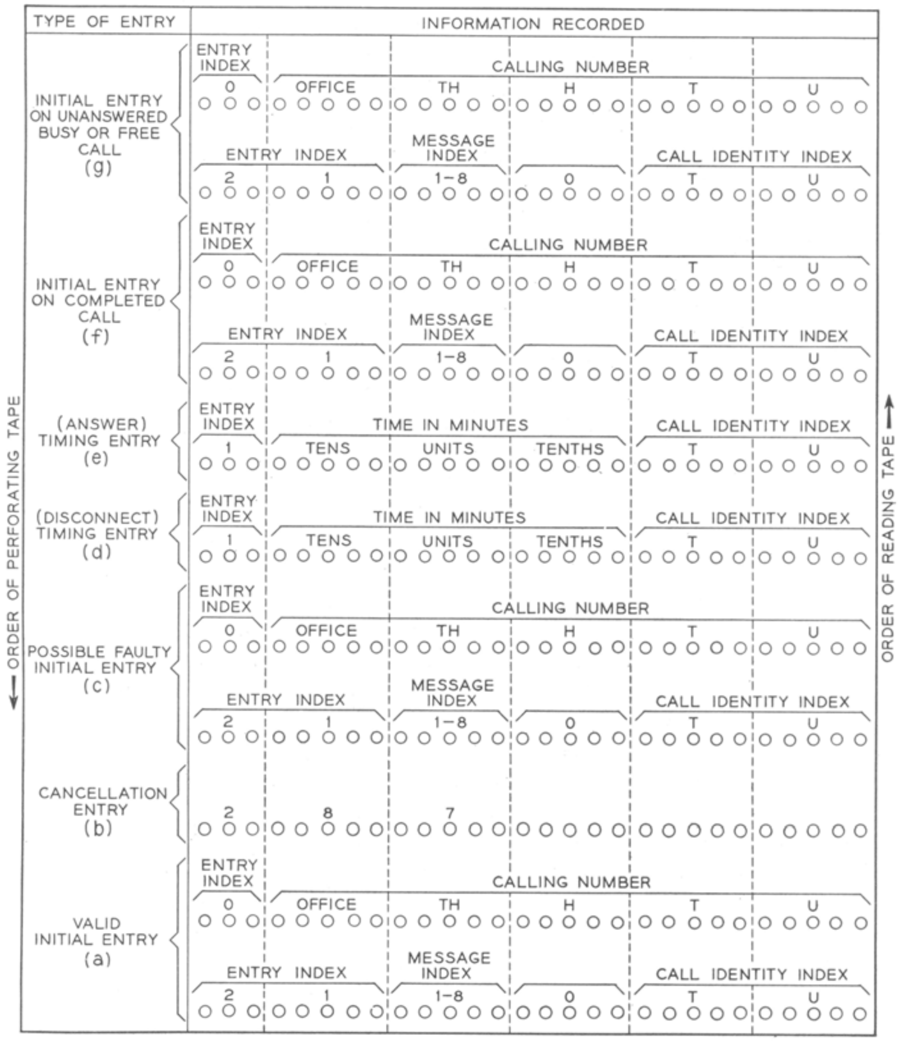


Fig. 1—A sequence of entries of various types that might appear on an AMA tape.

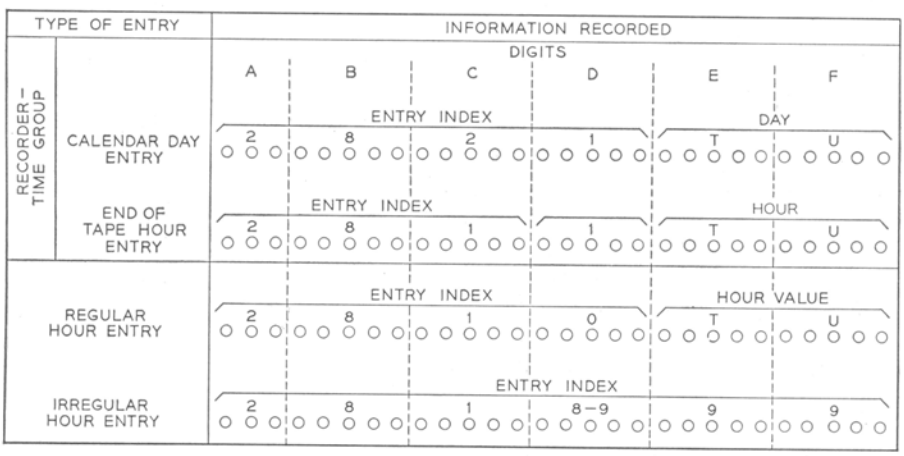


Fig. 2—Various types of hour and day entries that appear on the AMA tapes.

each call is answered, which is provided on detail-billed records for determining the rate and for use in any discussion of the call with the customer.

The principal accounting machine involved in these uses of time is the AMA computer. All entries recorded on the central office tape for individual calls are brought together by the AMA assembler. The answer and disconnect timing entries indicate only the minutes of the current hour. Interspersed among these call entries are the single-line hour entries, which are perforated each hour in the central office tape. These identify the hour by tens and units digits, which appear as the E and F digits on the tape, while the entry index 2810 occupies the A, B, C, and D digits. There are also two other hour entries known as "irregular hour entries" which have entry indexes of 2818 and 2819, and a 9 as the E and F digits. In addition, there are the end-of-tape entries which also include an hour entry with an entry index of 2811. These latter entries were originally perforated in the central office but have been copied on the output tape of the assembler. Unlike the regular hour entries, they do not indicate a change in the hour, and thus they are treated differently from the regular hour entries by the computer. These various types of hour entries are shown in Figure 2.

One or more of these hour entries may, of course, be found between the disconnect and initial entries pertaining to any one call and will thus affect the hour to be associated with the tens and units minutes digits of the answer and disconnect times. The computer must thus maintain a correct record of the hour at all times, and this it does with the hour circuit. A schematic of the hour circuit is shown in Figure 3.

This circuit consists of two principal registers: the "earliest hour register" and the "disconnect hour register." Associated with these are several connectors and subsidiary registers and an hour-counter circuit. Since the tape is read by the computer in the reverse time order, each regular hour entry received will be the hour following the hour that applies to the call entries read from the tape before the next regular hour entry is encountered. Thus prior to reading a disconnect entry that occurred at 9 hours 52.6 minutes, the computer will have read the hour entry 10. The call entry includes only the minute figures 52.6, and for the proper computation of the charges on the call the hour 9 must be associated with them. Since the previous hour received by the computer was 10, an important part of the hour circuit is a "less one connector," which subtracts one from each regular hour entry before registering it.

A schematic of this "less one connector" circuit is shown in Figure 4. At the right are the ten units leads and the three tens leads from the reading relays, and at the left are the equivalent output leads that go to the earliest-hour register. Each time a regular hour entry recorded on the reading relays is to be transferred to the earliest-hour register, ground is placed on the lead marked 2810 at the right of Figure 3 and on one each of the units and ten leads. Ground on the 2810 lead operates the HO relay and also—if relay CTO is not operated—operates the NC relay. None of the other relays will operate except for input hours 00, 01, 10, 11, 20, and 21. Under these conditions, the hour appearing on the output leads will be one less than that on the input leads. By the operation of HO each input units digit is connected to the next lower digit lead on the output side, and each tens digit input lead is connected to the same valued output lead.

When the input hour is 00, 01, 10, 11, 20, or 21, however, the translating procedure is a little different. When the input units digit is 1, and the tens digit is not 0, such as 11, or 21, the NC relay is operated at the same time as the HO relay, and the translation is to one lower number on the output leads as before. Thus 11 is translated to 10, and 21 to 20. Ground on the 0 lead of the units output group, however, operates relay CTO. This causes no change at the moment because NC holds itself operated, and CT cannot be operated because of an open back contact of NC. When the reading relays are subsequently disconnected from the less-one connector, however, HO and NC release but CTO remains operated until after the reading relays have been again connected to the less-one connector to record the next hour entry. When this occurs, since CTO is now operated, NC will not operate because operating circuit is open at CTO. Instead relay CT will operate, and thus the output leads will record 09 or 19 with input 10 or 20.

When the input hour is 01, relay NC will operate with HO as before, and the translation will be made to 00. After the HO and NC relays have been operated, however, both CTO and CTU will operate because of the grounds on the 0 units and 0 tens output leads. Both of these relays hold operated after HO and NC have released, and thus when the reading relays are connected through for hour 00, relays CTU1

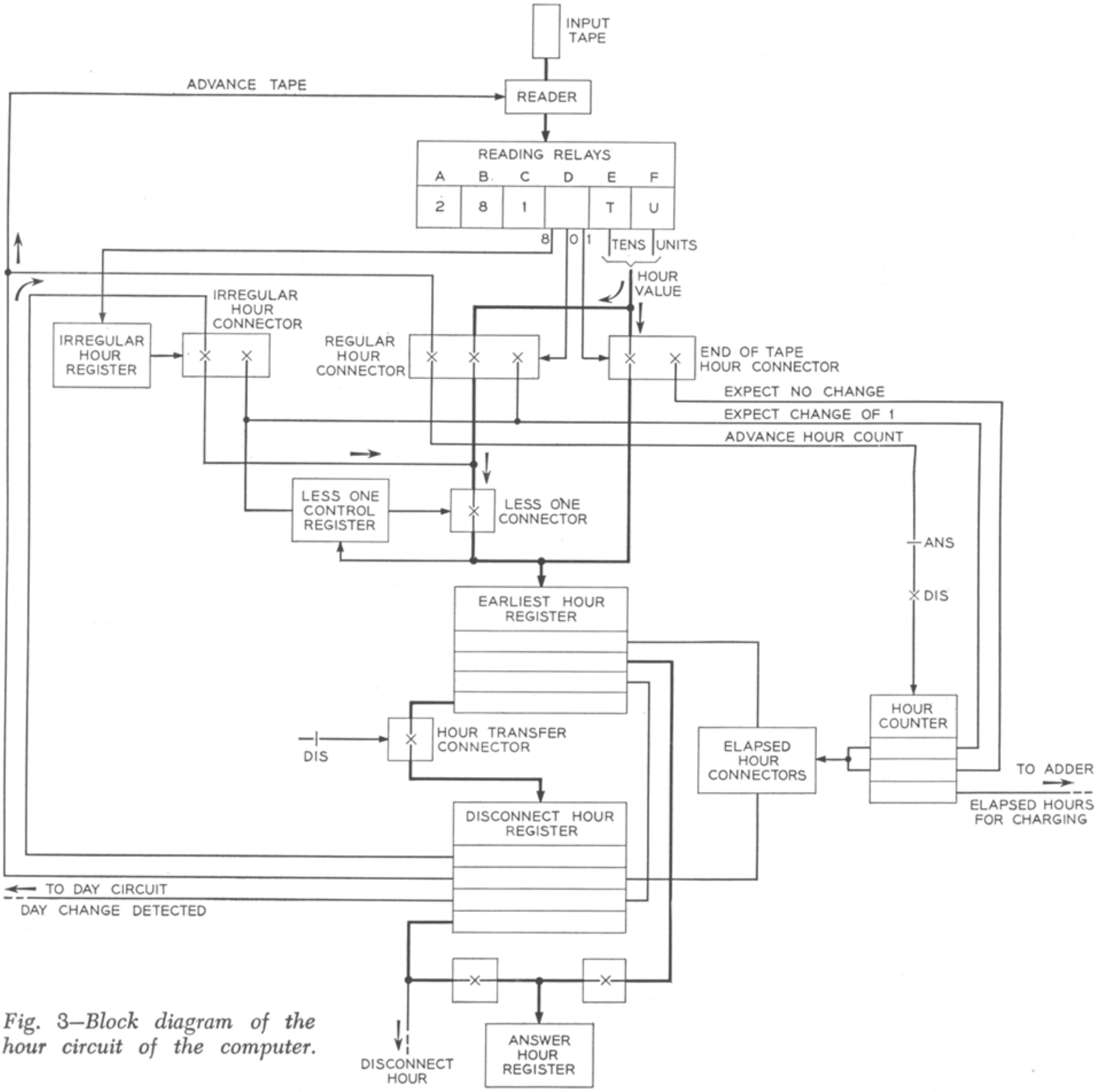


Fig. 3—Block diagram of the hour circuit of the computer.

and HO will operate simultaneously. With CTU1 operated, the input 00 is translated to 23 at the output. This scheme of operation and translation is shown in Table I.

When beginning the processing of a new tape, an end-of-tape hour entry is the first hour entry received. It is identified by the entry 2811, and when such an entry has been recorded by the reading relays, the end-of-tape hour connector is operated. The E and F digits of the reading relays are transferred to the earliest hour register through the end-of-tape hour connector instead of passing through the less-one connector. Since there is no hour value registered at this time in the disconnect hour register, the hour value in the earliest hour register is immediately transferred to it. Since this entry is made after a regular hour entry, it will be correct for application to call entries read subsequently because the tape is read in reverse time sequence. With an end-of-tape hour entry made at 3:30 A.M., for example, the hour value will be 03. This hour will be correct for all call entries made during the preceding half hour, and this—since the tape is read backwards—for all calls encountered prior to the next regular hour entry. The end-of-tape hour entry recorded on the earliest hour register is, therefore, immediately transferred to the disconnect hour register, and the earliest hour register is released after a check is made that the hour value now in the disconnect hour register agrees with the earliest hour value recorded.

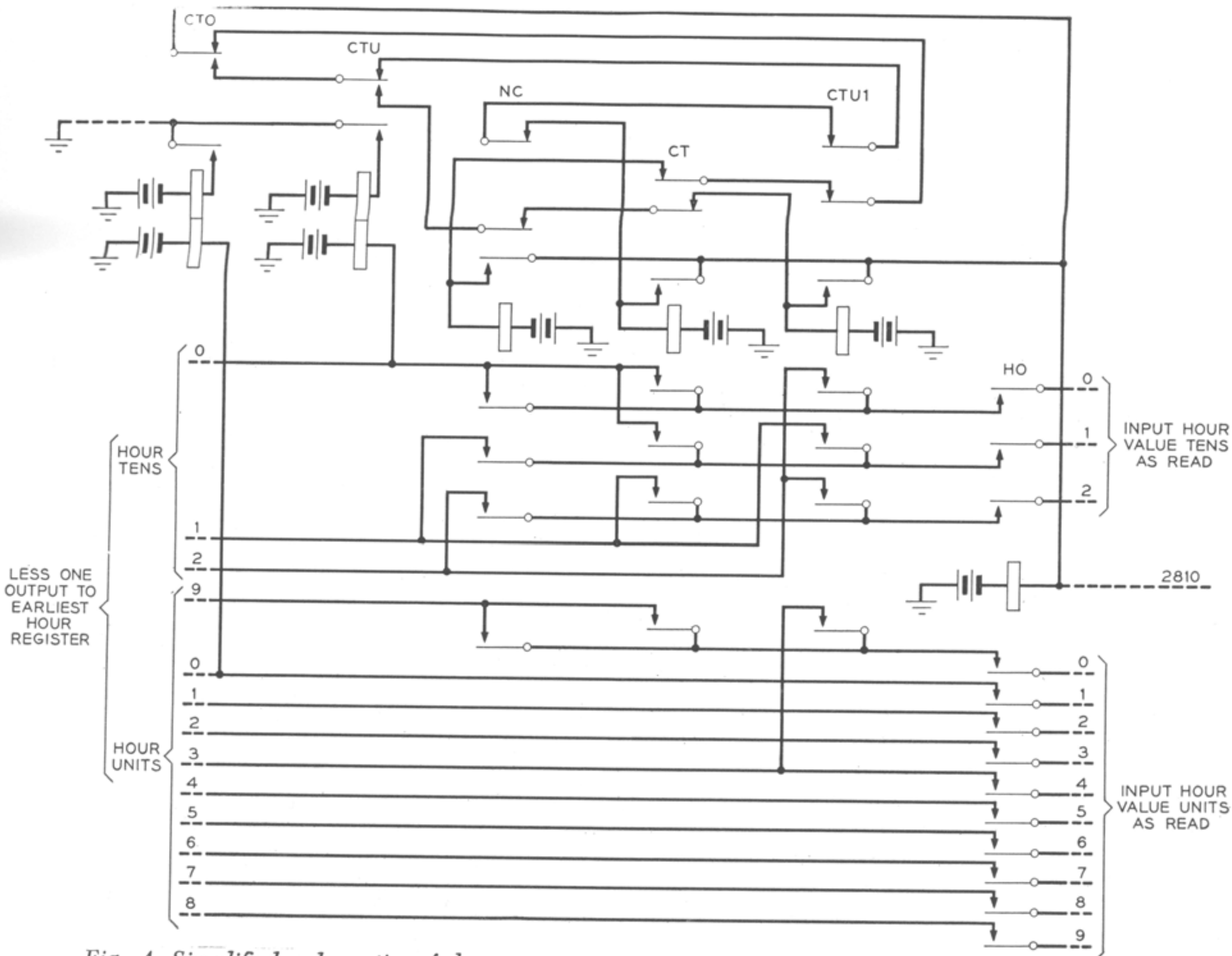


Fig. 4—Simplified schematic of less-one connector circuit.

Whenever the reader of the computer encounters a 2810 entry index, indicating a regular hour entry, and has recorded the entry on the reading relays, the regular hour connector is operated. This connects the E and F digits of the reading relays through the less-one connector to the earliest hour register.

Each time an hour has been recorded in the earliest hour register, the hour counter circuit checks it against the hour recorded in the disconnect hour register, and then, if the difference between the two registers is correct for the conditions, allows the reader to advance to the next line. At this time also the hour will be transferred from the earliest hour to the disconnect hour register, unless a call entry has been received in the meantime. Once the first, or disconnect, timing entry has been read from the tape and stored in another part of the computer, the hour circuit is prevented from performing the transfer of the hours from the earliest hour register to the disconnect hour register. The hour circuit is then arranged to start counting the hours whenever a regular hour entry has been registered in the earliest hour register and checked.

Should it happen that a regular hour entry be received prior to the receipt of the answer timing entry on this call it would be registered – less one – in the earliest hour register and checked. At the same time the hour counter would count one hour, and this count would change the number of expected elapsed hours should another hour appear before the answer timing entry is received. As long as one timing entry has been registered, the succeeding hourly entries are registered only in the earliest hour register—each new one displacing an old one. It is for this reason that it is called the "earliest hour register," since during a call it contains the earliest hour value that has been received and interpreted by this circuit. The disconnect hour register contains the hour value as it was at the time that the disconnect timing entry was received. If new hour entries are received by the earliest hour register the elapsed hour connector is arranged to expect the difference between the earliest and disconnect hour register in accordance with the hour count thus far recorded. The advance of the hour counter when registering new earliest hours during a call is permitted only after the elapsed hour check has been made on the value as received.

When the answer timing entry is read from the tape, all hour counting ceases since the hours counted between the disconnect and answer timing entries are the only ones to be used in the computation of the elapsed time. At the same time the answer hour register is used to record the hour value at the time the answer timing entry was read. If no hour occurred between the disconnect and answer timing entries the answer hour registration is taken from the disconnect hour register. If, however,

TABLE I—TABULATION OF RELAY OPERATIONS IN THE LESS-ONE CONNECTOR CIRCUIT

Input Hour	*HO*	*CTO*	*CTU*	*NC*	*CT*	*CTUI*	*Earliest Hour Register*
01	x			x			00
		x	x				
00	x	x	x			x	23
23	x			x			22
22	x			x			21
				x			20
21	x	x					
20	x	x			x		19
19	x			x			18
12	x			x			11
11	x			x			10
		x					
10	x	x			x		09
			x				
09	x		x	x			08
			x				
08	x		x	x			07
01	x		x	x			00
		x	x				
00	x	x	x			x	23

one or more hours have intervened between the disconnect and answer timing entries, then the answer hour is to be found at this time in the earliest hour register.

The result of the hour count is passed on to the portion of the computer where elapsed time is calculated. The hour counter is arranged to count a maximum of only three hours since calls with more than three elapsed hours are beyond the capacity of the elapsed time calculation. On such calls it is necessary to obtain both the answer and disconnect hour values from the hour circuit. The answer hour is registered as previously described and the disconnect hour is taken directly from the disconnect hour register.

Means are provided in the central office for placing entries on the tape to indicate that difficulty is being experienced in placing the proper hour value on the tape for the regular hourly entries. In this case irregular hour entry 281999 will appear on the central office tape and is passed to the accounting center for correcting the information in the hour circuit. The 281999 irregular hour entry indicates that a difficulty was experienced in recording the regular hour entry and that what has been recorded should be skipped. This skipping operation was performed by the assembler which in turn placed an 281899 irregular hour entry on its output tapes. This entry may appear on the central office tape if

Fig. 5—A computer installation at the Philadelphia accounting center. It consists of four relay bays, a reader cabinet and seven perforator cabinets.

an equipment trouble prevents a regular hour from being perforated, and the assembler reperforates the entry without change. The computer in receiving an irregular hour entry 281899 first registers this fact in the irregular hour register. If there is no call in the computer circuit at this time, the earliest hour register is normal and the irregular hour register takes action to connect the output of the disconnect hour register through the irregular hour connector and the less-one connector to the earliest hour register. In this way the hour circuit boosts itself by its own boot straps to produce artificially from the hour already registered, the new hour which was missing or mutilated on the central office tape.

If a call is in progress, the irregular hour register is prevented from performing this self-correcting action since the disconnect hour may not be the succeeding hour value. In this case the irregular hour register controls the hour circuit so that it may be brought up to date when the next regular hour is read from the tape. When the next regular hour value is read between the disconnect and answer timing entry, the irregular hour register arranges the controls so that the regular hour entry is first read in as an end-of-tape hour without subtracting one. This in effect brings the hour registration up to date and will permit the proper subtraction of one hour from this hour value when it is next read through the regular hour and less-one connectors. In this way once again the hour circuit lifts itself up by its boot straps so that the correct hour progression passes through the earliest hour register and the correct subtraction can thus be made.

The end-of-tape hour entry is perforated on the tape at the central office and reperforated by the assembler on the tape that goes to the computer. Such an entry is placed on the tape each day between 3 and 4 a.m. to provide the time information at the point where the tape may be cut for transmission to the accounting center. These entries may also appear on the tape at any point where regular recording was stopped or restarted. In this case further recording is usually continued by an emergency recorder on a different tape section.

Should end-of-tape hour entries occur during processing, the first of these to be received is checked to see that it agrees with the previously registered hour. In this case the elapsed hour connector expects no change in the hour value. Succeeding end-of-tape hour entries are registered without checks since they may be the start of new processing which takes place after a central office trouble of indefinite length.

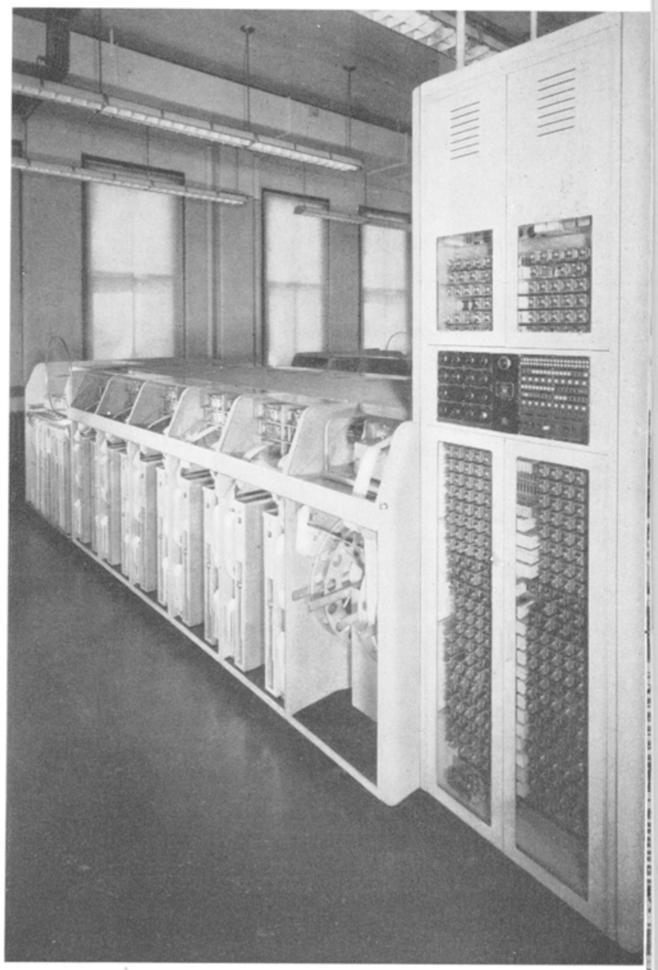
The timing and dating of calls requires the day and month to be traced backward in much the same manner as described above for the hour records. For this purpose a day circuit is provided in the computer which together with appropriate portions of the tape identification circuits insures that the correct calendar day appears on all detail call records. The hour circuit aids in this function by providing the day circuit with an indication when the midnight hour entry is registered. The AMA printer and tape-to-card converter also must interpret the calendar day and tape identification records to print or control the punching of the proper month value.

The Sorter for Automatic Message Accounting

F. N. ROLF
Switching Systems Development

At some stage in the telephone message accounting process* it is obviously necessary to bring together all the messages chargeable to a particular customer for the billing month. In the AMA system this is the function of the sorter which receives the tapes from the computer† described previously. The sorter consists of a reader, ten perforators‡ (two in each of five cabinets) and a relay rack containing about 300 relays together with a key and lamp panel. The input tapes for the reader are those prepared by the computer, and are of two general types. One type includes only message unit calls and has a mixture of one-line and two-line entries; the other type includes only detailed calls, and its entries all have five lines. Each entry of either type includes the number of the calling subscriber, but the telephone numbers are in random order. The function of the sorter is to prepare new tapes containing the same entries that were on the input tapes but arranged in the order of the calling subscribers' numbers.

Sorting is accomplished in four stages: one stage for each of the four digits of the calling subscriber's number. The first stage sorts the entries according to the value of the units digit; the second stage, according to the tens digit; the third, according to the hundreds digit; and the fourth according to the thousands digit. Assuming a set of four-digit numbers arranged in random order, as in column 1 of Table I, the arrangement of the numbers after the first, second, third, and fourth stages of sorting would be as in columns 2, 3, 4, and 5, respectively. Digits 3, 4, 5, and 6 have been omitted from the numbers of Table I to simplify the tabulation. It might seem off-hand that sorting should begin with the thousands rather than with the units digit. If this were done, however,



The sorter includes an enclosed relay rack, the reader cabinet, and five perforator cabinets.

* See page 65. † See page 65. ‡ See page 18.

the numbers after the four stages of sorting would be in order when read from right to left instead of the normal order of from left to right. Column 6 of Table I gives the numbers in the order in which they would be found had the sorting started with the thousands digit.

Sorting in the various stages is brought about by using each of the ten perforators for recording the entries with a particular value of the digit being sorted at the time. The perforators are designated 0 to 9, and during the first sorting stage, all entries with a units digit 0 in the calling number will be perforated by the number 0 perforator. All entries with the digit 1 in the units place will be perforated by the number 1 perforator, and so on. This is indicated by the bracketing of the various columns in Table I.

At the end of the first stage of sorting, the tapes are removed from all ten perforators and spliced together in numerical order. This composite tape then becomes the input tape for the stage two sorting. It is placed in the reader, and the sorting is carried out exactly as for the first stage, except that now it is the digit in the tens place that determines the perforator to which each entry is allotted. At the end of each successive stage, the newly perforated tapes are spliced together in order, and become the input tapes for the next stage. The composite tape resulting from the fourth stage becomes the input tape for the following stage in the accounting center procedure. After the tapes have been used to control the next sorting stage, those resulting from the first, second, and third sorting stages may be discarded. Only the original input tape and the composite tape resulting from the fourth sort are retained as records.

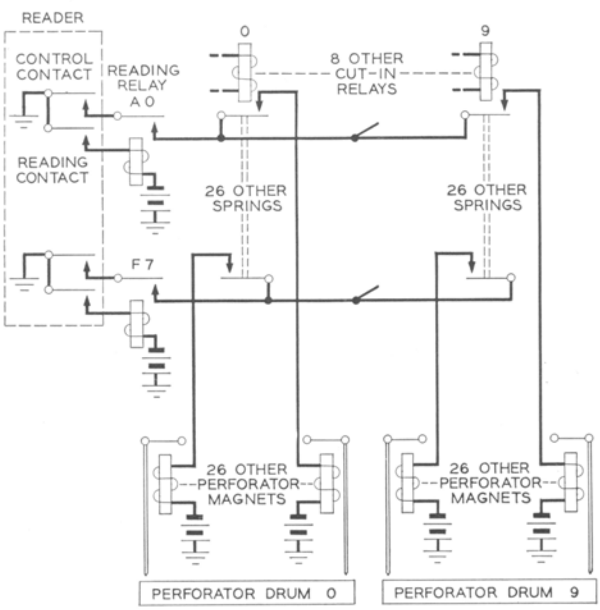


Fig. 1—Simplified schematic of that part of the sorter circuit used in perforating an output tape with the same information that appears on the input tape.

So far as each entry of the input tape is concerned, the function of the sorter is to cause the perforator to reproduce the same entry on an output tape. The sorting function comes in only in selecting the particular one of the ten perforators to be used for perforating each entry. Reproducing functions of the sorter require that leads from the contacts of the 28 reading fingers be associated with the 28 perforator magnets of a perforator so that each reading contact that closes will cause the corresponding perforating magnet to operate. The essential circuit elements by which this is brought about are indicated in Figure 1. For each line of an entry, one of the ten cut-in relays will be operated as described later. As soon as the cut-in relay operates, ground from control contacts in the reader is extended through front contacts of all operated reading relays, and through corresponding front contacts on the cut-in relay that has been operated, to operate the associated perforating magnets of the perforator. In this way the complete line of the entry on the input tape is duplicated on the output tape of one of the ten perforators. Following this, both the reader and the perforator are allowed to step ahead one line.

Which perforator cut-in relay should be operated for each line of the input tape depends on one of the digits of the calling subscriber's number. The calling-line number always appears as the C, D, E, and F digits in the first line of an entry, as indicated in Figure 2. These digits are perforated in the 2-out-of-5 code used through-

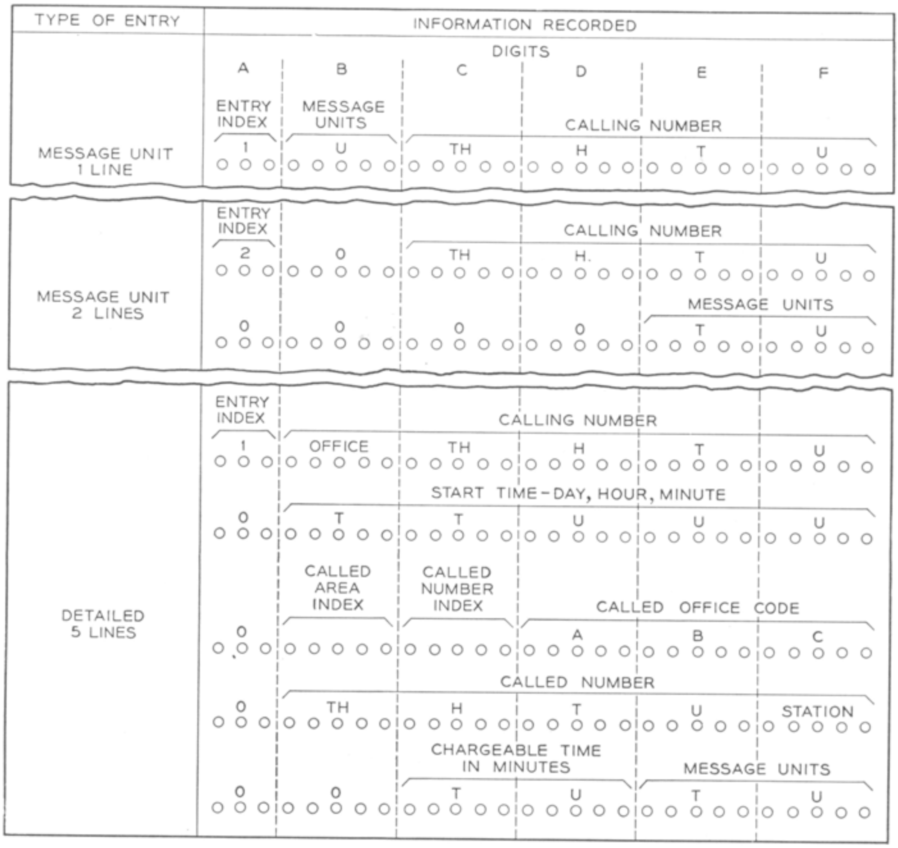


Fig. 2 — The three types of entries that appear on the input tapes for the sorter. Message unit tapes have both one-line and two-line entries, have five-line entries.

out the AMA system, and indicated in Table II on page 90.

A set of springs on the five reading relays associated with each of the digits C, D, E, and F is wired in such a way that ground applied to a single input lead will appear on one of a group of ten output leads. The ten output leads are numbered 0 to 9, and the circuit is so arranged that for any particular pair of relays operated, the ground appears on the output lead indicated by the translation table of Table II. One form of translating circuit of this type is shown in Figure 3.

For each stage of sorting, under control of a key set at the beginning of the sort, ground from a control contact of the reader is applied to the input lead of the translating circuit of the digit that is to control the sort. Similarly, the ten output leads from that translating circuit are connected to the cut-in relays of the perforators. If, for example, the tens, or E, digit is to control the sorting, ground will be applied to the input lead of the translating circuit on the E digit reading relays when the reading contacts close. If for the particular entry encountered, the second and fourth holes were perforated, which have the values 1 and 4, respectively, ground would appear on the number 5 output lead, and as a result the cut-in relay for the number 5 perforator would be operated. By means of the circuit shown in Figure 1, the complete information on the line being read would be perforated by the No. 5 perforator.

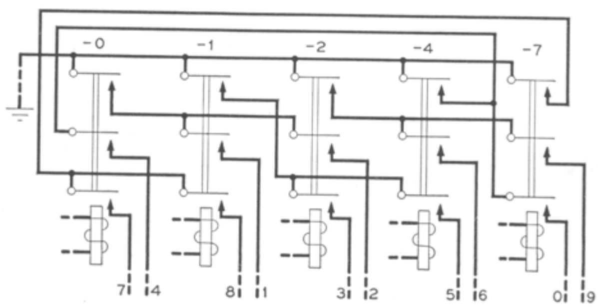


Fig. 3—One of several possible forms of circuit for translating from a "2-out-of-5" to a decimal code.

Table I — Twenty Four-Digit Numbers in Random Order in Column 1 Are Shown in Columns 2, 3, 4, and 5 as They Are Arranged After the 1st, 2nd, 3rd, and 4th Sorting Stages. Column 6 Shows the Order in Which the Numbers Would Be Arranged After Four Sorting Stages if They Were Carried Out in Reverse Order

1 *Random Numbers*	2 *After Units Sort*	3 *After Tens Sort*	4 *After Hundreds Sort*	5 *Completely Sorted*	6 *Sorted in Reverse Order*
9190	**0** 9190	**0** 8802	**0** 1009	**0** 0217	**0** 9110
0277	8780	2807	2018	0277	8780
8780	9110	7908	7077	0281	9190
1829	**1** 0281	1009	8091	0789	**1** 0281
0281	8091	**1** 9110	**1** 9110	**1** 1009	8091
9192	**2** 9192	0217	9190	1829	**2** 8802
7908	9722	2018	9192	1929	9722
9722	8802	**2** 9722	**2** 0217	**2** 2018	7282
7077	7282	1829	0277	2807	9192
8091	**7** 0277	1929	0281	**7** 7077	**7** 2807
1009	7077	**7** 0277	7282	7282	0217
7798	2807	7077	**7** 9722	7798	7077
2807	0217	**8** 8780	8780	7908	0277
8802	**8** 7908	0281	0789	**8** 8091	**8** 7908
2018	7798	7282	7798	8780	2018
1929	2018	0789	**8** 8802	8802	7798
9110	**9** 1829	**9** 9190	2807	**9** 9110	**9** 1009
7282	1009	8091	1829	9190	1829
0217	1929	9192	**9** 7908	9192	1929
0789	0789	7798	1929	9722	0789

If all entries consisted of only a single line, the two circuit arrangements just described would be all that would be required except for certain checks and safeguards that must be included. There are two general types of input tapes. One includes only bulk-billed calls, and its entries have either one or two lines. The other includes only detailed billed calls, and all its entries have five lines. There is no need for the sorter circuit to automatically distinguish between these two types of tapes, except to block and give an alarm if the wrong type of tape is inserted, since switches on the control panel are operated manually before the beginning of a sort to indicate the type of tape that is being used.

It is necessary, however, to distinguish automatically between one-line and two-line entries on the message unit tapes, and to perforate the two lines of a two-line entry on the same perforator. With detailed billed calls, it is necessary to make sure that all five lines of an entry are perforated by the same perforator. These various types of entries are indicated by the A digit of the first line, and the sorter uses this index to guide its operating procedure.

On the message unit tapes the entry index of a one-line entry is 1, and when this entry index is encountered on a message unit tape, the circuit recognizes a one-line entry. When 2 is encountered as the A digit, the circuit recognizes a two-line entry, and the second line of the entry, which will have an A digit of 0, will be perforated by the same perforator. With detailed billed tapes, the entry index 1 of the first line indicates—as with message unit entries—the line that will determine which perforator to use, and all the following lines of the entry, which have 0 for the A digits, will be perforated by the same perforator. An A digit of zero always indicates a supplementary line with any type of entry and thus may be used as an indication that the same perforator should be used for recording it. In addition, however, a counting circuit is brought in to count the lines of an entry to make sure that the proper number of lines is recorded.

A very much simplified diagram indicating the over-all action of the sorter is given in Figure 4. Besides the translating circuits wired through contacts of the C, D, E, and F reading relays, already referred to, there are circuits wired through other springs of all the reading relays that will be closed when two and only two of the B, C, D, E, and F group relays are operated, and when one and only one of the three relays of the A digit group are operated. These various check circuits are indicated in block form on the diagram.

When the cam-controlled reading fingers move in to read a line on the input tape, 11 of the 28 reading contacts will close (one for the A digit and two each for the B, C, D, E, and F digits). All the control contacts, marked P on the diagram, will also close as will the K contacts. Ground through the

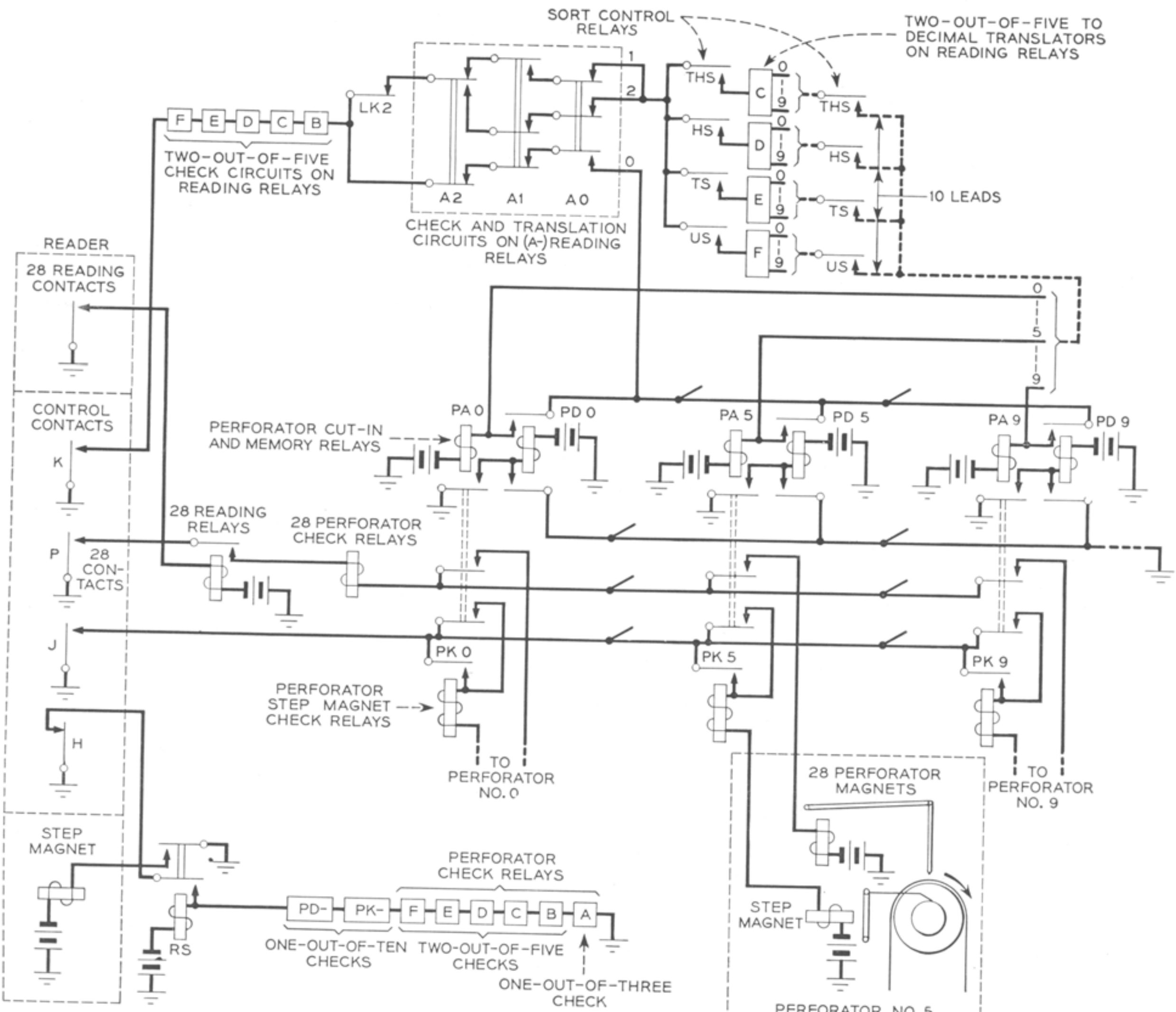
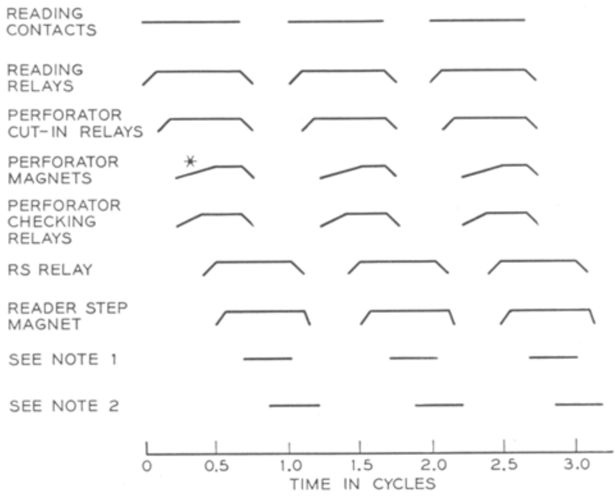


Fig. 4—Simplified schematic of the sorter.



* PUNCH MAGNET IS OPERATING AND PERFORATING PAPER.

NOTES:

1. READER DRUM STEPS DURING THIS INTERVAL PROVIDED STEP MAGNET HAS BEEN OPERATED.
2. PERFORATOR DRUM STEPS DURING THIS INTERVAL PROVIDED PERFORATOR ADVANCE MAGNET HAS PREVIOUSLY BEEN OPERATED AND IS PERMITTED TO RELEASE.

Fig. 5—Time diagram of the sorter operation.

K contact will be passed through the check circuits on the springs of the reading relays, and, if the A digit is one or two, to the translation circuit on the reading relays for the digit that is to control the sorting. As a result, the ground will appear on the lead to the cut-in relay, PA, for the proper perforator. This operates the cut-in relay, and the proper perforating magnets will be operated from grounds on the control contacts P. Ground from the J contact of the reader passes through a spring on the cut-in relay, through a PK check relay, to operate the step magnet of the selected perforator.

In series with each perforating lead is a check relay, and the groups of check relays for each of the six digits of a line have circuits wired through their springs that will be closed only if the proper number of relays in each group is operated: two for the B, C, D, E, and F digits, and one for the A digit. The closure of these circuits indicates that current is flowing to the proper perforating magnets. As shown at the lower left of Figure 4, ground is passed through these check circuits, through a checking circuit on the PK relay that is closed if one and only one of the PK relays is operated, and through a similar check circuit on the PD relays, to be described later, to operate the RS relay and prepare the reader for stepping to the next line. Relay RS locks itself operated until the next reading cycle begins.

The contacts of the reader are operated and released sixteen times a second by a power drive, and the circuit operations described above all take place in about 40 milliseconds. When the reading and perforating contacts open at the end of a reading cycle, the operated reading relays, the operated PA relay, and the perforating magnets release. Contact J of the reader, however, does not open until shortly after the other contacts, and thus the stepping magnet of the perforator is not released until after the perforating magnets have been released and the perforating pins have had time to withdraw from the tape. A time diagram showing the operation of the various relays for a succession of reading cycles is given in Figure 5.

To take care of multiple line entries, a PD relay is associated with each PA relay and is operated by it. If a message unit tape is being sorted and the entry index of the line being read is a 1, the PD relay will release when its associated PA relay releases, and the circuit action will be as described above. If the entry index had been a 2, however, indicating a two-line entry, the holding ground for the PD relays would have been closed by circuit elements not shown, and the LK2 contact, shown at the upper left of the diagram, would have opened as the reader stepped to the next

TABLE II— KEY TO THE "2-OUT-OF-5" TO DECIMAL TRANSLATION

Pair of Holes Perforated in Tape	*Corresponding Decimal Digit*
0 and 1	1
0 and 2	2
1 and 2	3
0 and 4	4
1 and 4	5
2 and 4	6
0 and 7	7
1 and 7	8
2 and 7	9
4 and 7	0

line. Because of its holding circuit, relay PD would therefore remain operated after its PA relay had released. This in no way affects the perforation of the line just read, but when the reader contacts close on the next line, the path to the translation circuit is opened at contact LK2. If the A digit of this next line is O, however, as it normally would be, a circuit through the check circuit on the A reading relays will be closed, and over it the same PA relay will be operated through a front contact of its associated PD relay that had been held operated. A similar action takes place when sorting entries of a detailed message tape. In both cases, the counting circuit already referred to counts the lines, and after the proper number has been recorded, the PD and LK2 relays are released, and the sorter is ready for a new entry.

Besides the checking circuits described above, others are so arranged that troubles encountered in reading the input tape, whether sorter troubles or mutilations in the tape, prevent a perforator cut-in relay from operating. The sorter stops and sounds an alarm, and the operator can read the line on which it stopped by means of twenty-eight reading lamps associated with the reader to determine whether the tape or the sorter is at fault. When a line is read properly, but because of some other trouble it is not properly perforated, the RS relay fails to operate and the sorter stops. In this case, since perforation has taken place, the perforator step magnet is prevented from releasing until the trouble is corrected. This guards against the repetition of any line on the output tape and is an important safeguard. As a further precaution, this feature of the sorter is automatically checked at the beginning and end of each sorting stage. Other lamps are provided on the control panel to assist the operator and the maintenance personnel in the event of trouble. When a stoppage occurs, the operator is able to tell immediately whether it was caused by a faulty input tape or by an internal sorter trouble which requires maintenance action. In the latter case, the lamps give an adequate indication to the maintenance personnel of the exact nature of the trouble.

Every AMA tape has a section of "splice pattern" at each end. This is a series of identical lines conveying no information, used to permit feeding the tape into the reader and to permit splicing without interfering with call entries. Between the call-entry section and the splice pattern at each end of the tape is a series of "tape identity" entries which completely identify the tape as to central office, date, type of tape, and the stage in the accounting process where it was produced. All this information is automatically checked by the sorter by matching it with the switches on the control panel set by the operator, to insure that the proper type is being used. When the input tape to the sorter consists of a number of sections spliced together, the sorter counts the sections, checking that they are all present and that they have been spliced in the correct order.

The AMA Summarizer

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Switching Systems Development

Since local calls are billed to the customers monthly as a single item, instead of individually as are toll calls, they pass through a stage in the automatic message accounting system that is not required for toll calls.

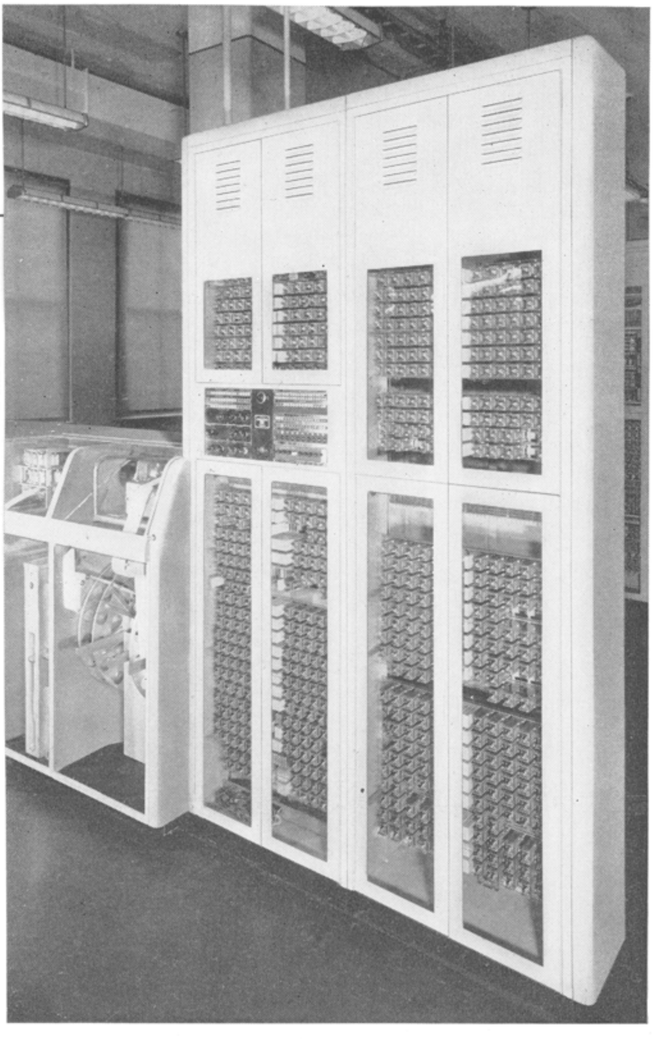

Fig. 1—A summarizer includes a tape reader, a tape perforator, and two cabinets of control equipment.

This stage is the summarizer, which is the fourth stage in handling local calls. In the three preceding stages,* the entries pertaining to each call are brought together as adjacent lines on the output tape of the assembler, the chargeable time for toll calls and the number of message units for local calls are calculated and placed on separate output tapes of the computer, and all the messages for each calling number are brought together on the output tapes of the sorter. The output tapes of the sorter serve as the input tapes for the summarizer, which adds the message units for the group of calls made by each subscriber and produces an output tape with a two-line entry for each calling number, giving the total number of message units chargeable to it.

The summarizer consists of a tape reader, relay control equipment, and a tape perforator as shown in Figure 1. Although adding is its major function, the summarizer must be able to discriminate between different calling subscriber numbers since only the message units for one number are added together. It thus includes two major circuits: one for comparing the calling numbers, and the other for adding the message units. The number comparison must be made first since whether the associated message units are added to the previous total or used as the start of a new total depends on whether or not the new calling number matches that of the previous entry. The calling number comparison circuit includes two sets of registers, and the calling numbers of successive entries are recorded alternately in them. Circuits are wired through the contacts of the register relays in such a way that if the

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* See pages 59, 65 and 85.

same number is recorded in both registers, the adding circuit will add to the previous sum the message units indicated in the last entry. If the calling numbers are not alike, the advance of the input tape is stopped momentarily, and the previous calling number and the total message units chargeable to it are perforated on the output tape. Immediately after this has been done, the input tape is allowed to advance and a new sum is started for the new calling number. Both the number comparison and the adding circuits carry out their operations so rapidly that the input tape is stepped along from line to line without interruption at the rate of sixteen lines per second as long as the calling number does not change.

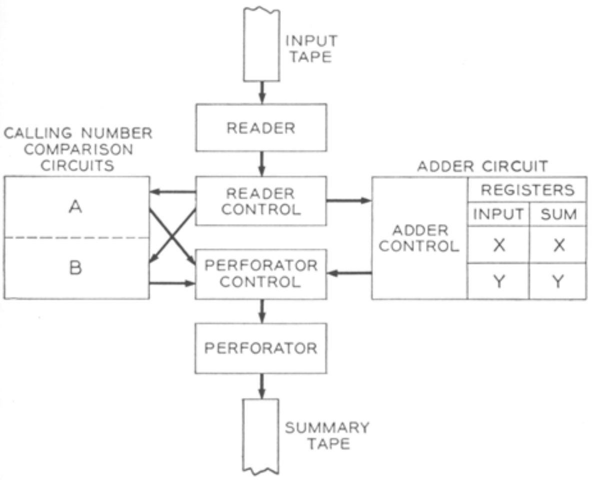


Fig. 2—Block schematic of the summarizer circuit.

The adding circuit includes two input registers and two sum registers, and the message units of successive entries on the input tape are recorded alternately in the two input registers. The message units of the first entry of the input tape will be recorded in the X input register, and immediately transferred to the X sum register, thus releasing the X input register. The message units of the second input entry will be recorded in the Y input register, and – if the calling number is the same as for the first entry – will be added to the number in the X sum register and then the sum will be recorded in the Y sum register, after which the Y input and X sum registers are released. This recording in an input register, adding to the total in the sum register of the opposite name, and recording in the sum register of the same name continues alternately back and forth as long as the calling numbers remain the same. When the calling number of an entry is found to differ from that of the preceding entry, the process is momentarily stopped after the message units for the new number have been recorded on the input register, and the previous calling number and the total of message units recorded in the sum register are used to control the perforation of an entry on the output tape. Immediately after this is done, a new summation is started for the new calling number.

A block schematic of the summarizer circuit is shown in Figure 2. As the entries are read, the calling numbers are recorded alternately in the A and B registers of the number comparison circuit, and the message units are recorded alternately in the X and Y input registers of the adder circuit. If the number of a new entry recorded in the B register is the same as that already recorded in the A register, the A register will be released and the number of the next entry will be recorded in it. If this is the same as the number in the B register the latter will be released, and so on as long as the number remains the same. In step with these operations, the message units will be recorded alternately in the X and Y regis-

Table I—Tabulated operation of the summarizer for four entries for line number w with associated charges of a, b, c, and d message units respectively, and one entry for line number z with e message units. Time flows across the table from left to right, and downward from top to bottom.

Entry	*Calling Number Comparison Registers*		*Input Registers*		*Sum Registers*	
	A	*B*	*X*	*Y*	*X*	*Y*
1	w	o	a	o	a	o
2	w	w	o	b	a	o
	o	w	o	o	o	a+b
3	w	w	c	o	o	a+b
	w	o	o	o	a+b+c	o
4	w	w	o	d	a+b+c	o
	o	w	o	o	o	a+b+c+d
5	z	w	e	o	o	a+b+c+d
	z	o	o	o	e	o

ters. A message unit figure recorded in the Y input register will be added to the total in the X sum register, recorded in the Y sum register, and the Y input and X sum registers will be released. The next message unit figure will be recorded in the X input register, added to the total in the Y sum register, recorded in the X sum register, and the X input and Y sum registers will be released. Only when a new calling number is encountered will this back and forth action be stopped long enough to perforate a total on the output tape.

This action is indicated in Table 1 for a series of input entries for calling line number w, and then for an entry for calling line number z. The number of message units for the various entries are indicated by the

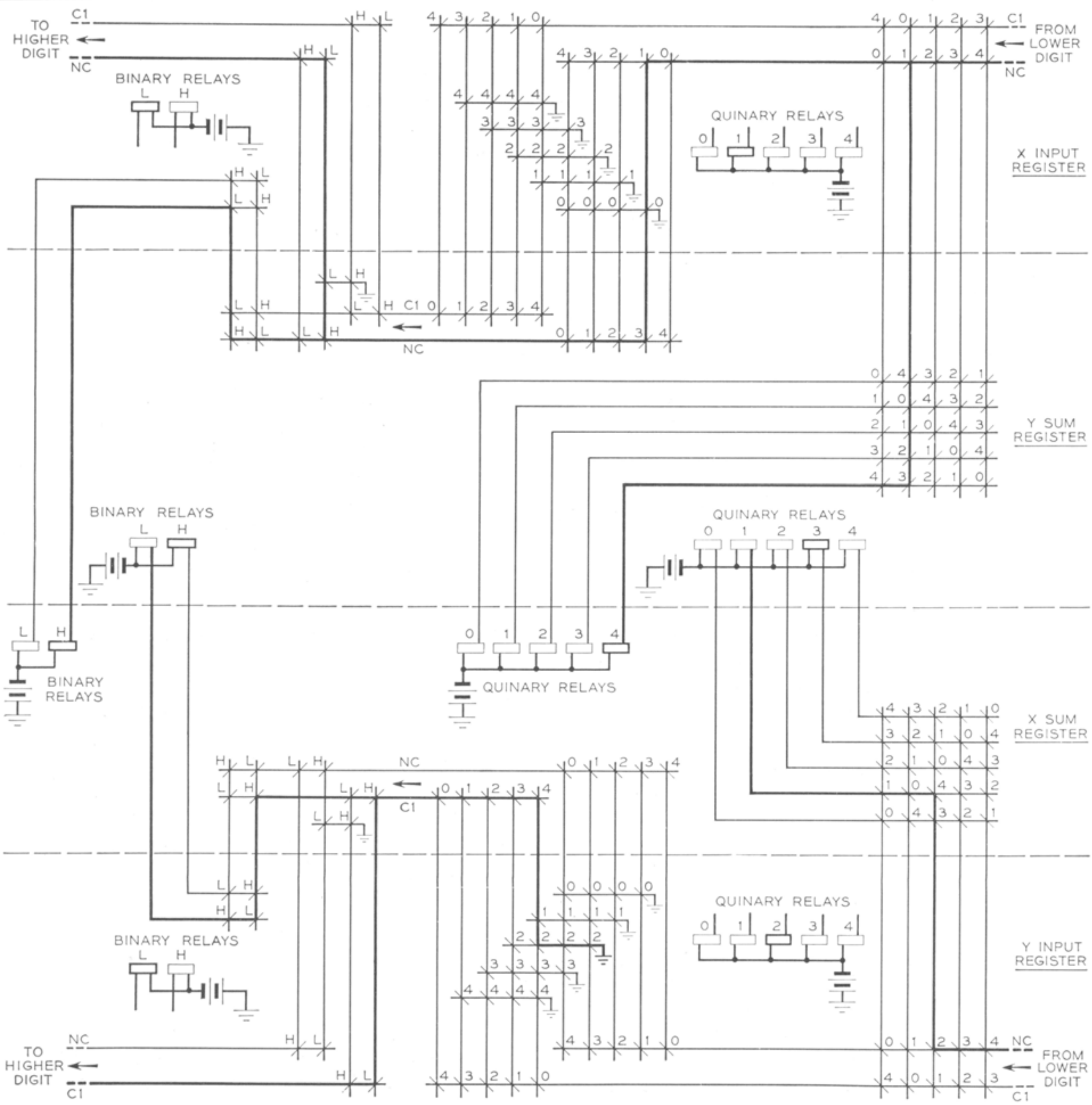


Fig. 3—Simplified schematic of the adding circuit for the tens digit only.

Table II—Relationships between the decimal, 2-out-of-5, and biquinary codes.

Decimal	*2-out-of-5*	*Biquinary*
0	4+7	L0
1	0+1	L1
2	0+2	L2
3	1+2	L3
4	0+4	L4
5	1+4	H0
6	2+4	H1
7	0+7	H2
8	1+7	H3
9	2+7	H4

letters a, b, c, etc. Time flows downward from the top of the diagram, the top line representing the first input entry. A small circle represents that the circuit is released.

Each of the four circuits of the adder – the X and Y input and the X and Y sum – is arranged to register and add three digits – units, tens, and hundreds – and thus the complete circuit will handle up to 999 message units. At the thousandth message unit, a carry-over signal from the hundreds circuit causes an entry for 1000 message units to be perforated on the output tape. Thereafter the circuits add as before until another 1000 message units have been added, when another 1000-message unit entry will be made. When a new calling number is encountered, the sum remaining on the adder will be perforated as an additional output entry for the preceding calling number. When there are more than 999 message units, therefore, there will be two or more output entries for the calling number that is involved.

A simplified circuit diagram for the tens digit of the adding circuit is shown in Figure 3. The circuit for the units digit is the same except that it will not have a "carry 1" (C1) lead coming in from the right. The circuit for the hundreds digit is the same as Figure 4 except that the "carry 1" lead extending out at the left, instead of being used to increase the next higher digit, will be used to initiate the perforation of a thousand-message-unit out-put entry.

The message unit digits recorded in "2-out-of-5" code on the input tape are translated to a biquinary code before they are transmitted to the input registers of the adder. In this latter code each digit is recorded by operating one of two binary relays and one of five quinary relays. The binary relays are designated L and H, to indicate "low" and "high," and the quinary relays are designated 0, 1, 2, 3, and 4. If L is understood to represent zero, and H, 5, the digit in the biquinary code is the sum of the operated relays in the two groups. The relationships between the decimal, "2-out-of-5", and biquinary codes are given in detail in Table II.

In Figure 3, the short slant lines at the intersections of the various leads represent contacts on the binary and quinary relays of the section of the circuit with which they are associated. With digit 1 recorded in the X input circuit, for example, register relays L and 1 will be operated, and thus all contacts marked L or 1 of that circuit will be closed. The Y input and sum circuits are identical to the X input and sum circuits, but both are shown in Figure 3, so that their interaction may be followed.

Assume that when the digit L1 (1) is recorded in the X input register, a digit H3 (8) is already recorded in the Y sum register. If there is no carry-over from the next lower digit, there will be ground on the NC lead at the upper right corner of the diagram. Since the NO. 1 relay of the X input register is operated, this ground is extended through the NO. 1 contact on the NC lead, down to the NO. 3 contact on the Y sum register, which is also closed, and thence to the NO. 4 relay of the X sum register.

Ground on the NC lead will also be extended through the second NO. 1 contact on the NC lead down to the NO. 3 contact on the NC lead of the Y sum register, and thence to the left to the two operated H contacts. Through the first of these, it passes up and then through the closed L contact of the X input register to appear on the NC lead running to the hundreds digit. Over the second H contact on the NC lead of the Y sum register it passes up and through another closed L contact in the X input register and thence down to operate the H relay of the X sum register. These paths are indicated by heavy lines on the diagram. In this way number L1 in the X input register has been added to H3 in the Y sum register to give H4 in the X sum register. Expressed in decimal code, this is $1 + 8 = 9$, with no carry-over.

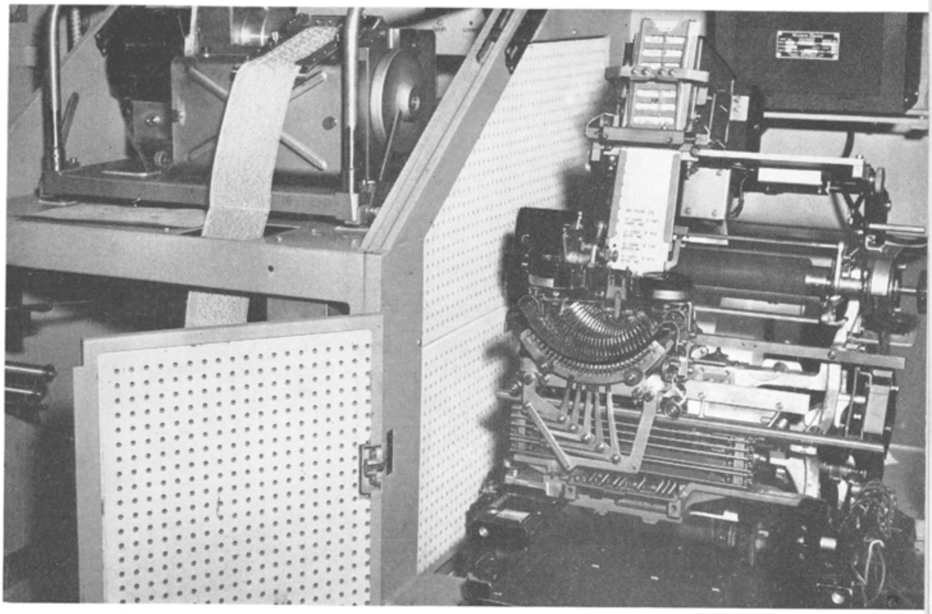
If the next entry is for the same calling number, the message units will be recorded in the Y input register. Assume that the tens digit is two with no carry-over from the units digit. Under this condition L2 will be recorded in the Y input register, and the heavy lines on the lower part of the diagram show how this would add to the H4 just placed in the X sum register to give L1 in the Y sum register (which had been released after H4 had been recorded in the X sum register) and the "carry 1" to the 100's digit. In decimal terms $2 + 9 = 11$, but the 1 in the tens place is carried to the next higher digit.

The two rectangles of contacts, five contacts square, at the right of the sum registers, together with the two parallel rows of contacts on the NC and C1 leads in the input registers, perform the quinary part of the addition, while the rectangles, two contacts square, at the extreme left of the input and sum registers perform the binary part of the addition. The remaining part of the circuit is involved in the No-carry and "carry 1" operation – both from the quinary to the binary sections of the digit and forward to the next higher digit.

For billing purposes, the message unit summaries for an entire month are required. Each month, however, is broken up into a number of processing periods, and a summary tape is perforated for each. To obtain a cumulative summary, the summary tape for the first period is sorted with the message unit tapes for the second period. The summary tape for the second period then contains all of the message units for the first two periods. This summary tape is sorted with the message unit tapes for the next period, and so on until the end of the billing month. The summary tape for the last period will thus contain the message units for the entire month.

Reeling and splicing tape AMA at the Philadelphia accounting center.

The AMA Printer



T. A. MARSHALL
Telegraph Systems Development

In all the automatic message accounting processes described in previous issues of the RECORD, the information is in the form of numbers perforated in "2-out-of-5" code in paper tape. The original information was recorded in this form in the central offices, and it has been assembled, computed, sorted, and summarized in the accounting center, and new tapes have been prepared in the same 2-out-of-5 code. Before the bills representing these various charges can be made out, this information must be translated from a sequence of digits in 2-out-of-5 code into the corresponding words and numbers, and then printed for use by the accounting center personnel. It is this translation and printing that is the major function of the AMA printer.

As may be seen from Figure 1, the printer consists essentially of a regular AMA reader for obtaining the information from the tape, relay circuits for interpreting and translating the tape information, and a teletypewriter for printing the call records. This equipment is mounted in six cabinets: the printer itself is in the left hand cabinet, the reader in the next cabinet, and the relay equipment, in the four taller cabinets. The printer proper, shown in greater detail in Figure 2, is a standard 15-type teletypewriter modified by the addition of arrangements for cutting the typed paper strip into toll tickets and stacking them in the ticket box, evident on the top of the machine, and by a few other changes. The reader is the standard AMA reader already described in the RECORD*, but the control circuits differ somewhat from those used with the reader in the other stages of the accounting process. Just above the middle of the first relay cabinet is the control panel on which dials are set to identify the particular tape being processed. These are shown in greater detail in Figure 3.

Although the printer is designed for processing and recording tapes of several different types, its general method of operation can be indicated by describing the processing of the two types of input tapes that comprise the main bulk of the work of an accounting center. One of these, which is prepared by the summarizer, contains all calls charged for on a message unit basis. These calls are grouped according to the central offices, and for each central office are arranged in numerical order of the call-

* See page 52.

ing number. For each calling number there is a two-line entry giving the calling number and the total number of message units chargeable for one accounting period. For these message unit tapes, the output of the printer takes the form shown in Figure 4. It is a strip of paper three inches wide and folded every eleven inches. At the top is printed the central office name and the date, and below, in numerical order, are the calling line numbers with the number of message units chargeable to each during that month. In all cases the printer uses a zero with a slant line through it to represent a significant zero, and a dash to represent a non-significant zero. A list including every subscriber in a 10,000 line office would require about 180 feet of paper, and would fold to form a pack eleven inches long and about 200 sheets thick.

The other of the two most important types of tape supplied to the printer includes all toll calls, which are perforated as a 5-line entry, also in order of the calling number under each central office. For these tapes, the output of the printer takes the form shown in Figure 5. These are slips of paper three inches wide and five inches long, and are thus of the same size as the slips prepared manually by operators for calls beyond the dialing range. This equality in size facilitates correlating the slips in preparing the subscriber's bills. Each such slip records the calls of only one subscriber, and may record as many as nine calls. When there are more than nine calls for a subscriber, more than one slip is required. At the top of the slip is placed the subscriber's office name and line number, and also the month. Each call is represented by two typed lines. The first gives the day of the month, the hour and minute the call was answered, the called office area index, and the called office abbreviation, while the sec-

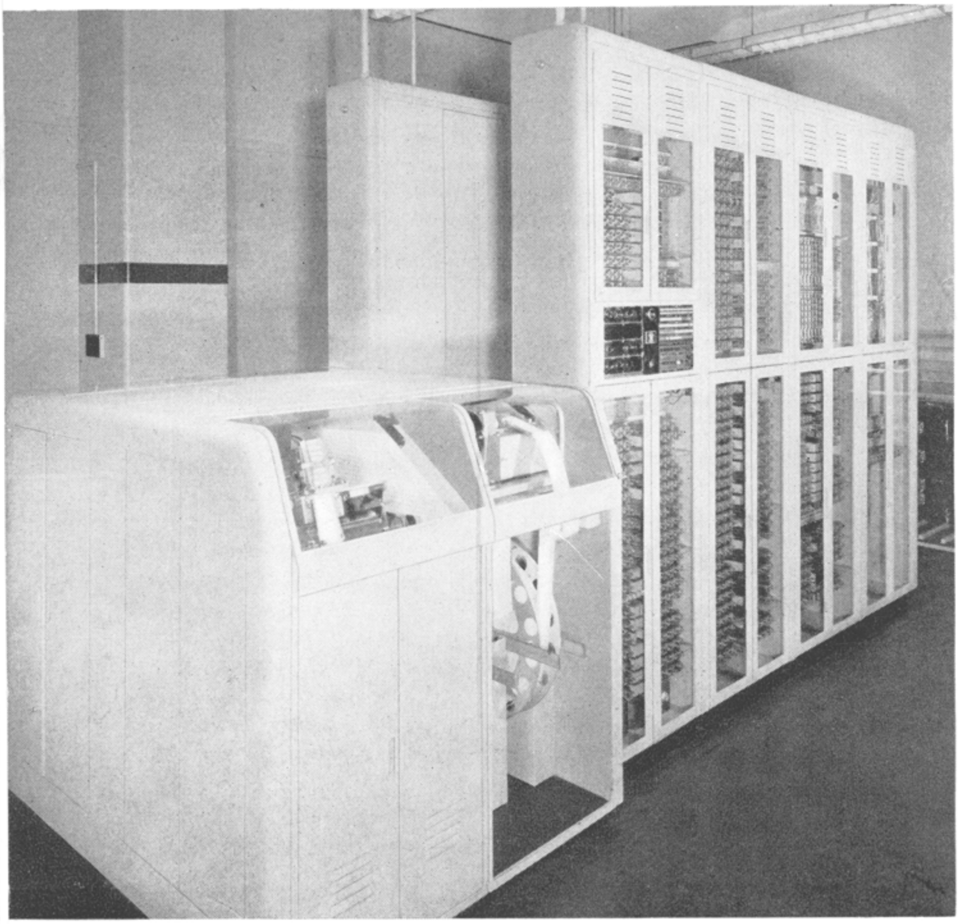


Fig. 1 — An AMA printer includes, from left to right, a printer, a reader and four bays of relay equipment.

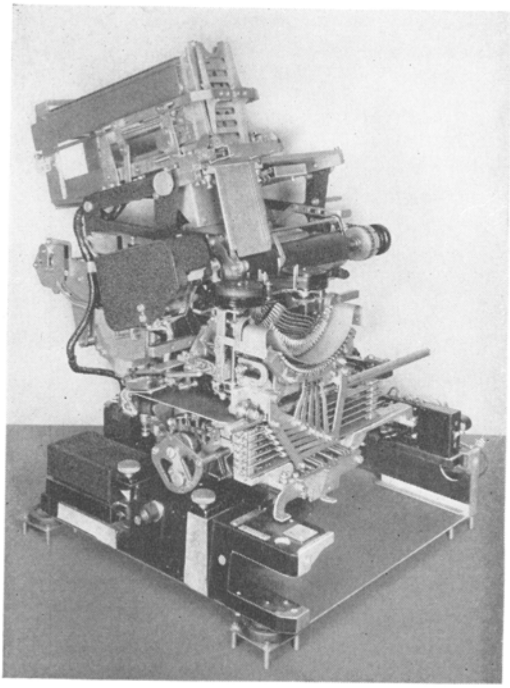


Fig. 2—For printing the output tapes and tickets, a standard 15-type teletypewriter is employed with a cutter, a stuffer, a ticket box, and a few other items added to it.

ond line gives the called line number and the chargeable time in minutes. The time the call was answered is given on the basis of a 24-hour clock: the first two digits represent the hour, ranging from 01 to 24, and the last two digits give the minutes after the hour and range from 00 to 59.

The reader is capable of reading and advancing the input tape at the rate of sixteen lines per second, while the teletypewriter operates at a speed of 600 operations per minute, or ten characters per second. Each entry on the message unit output tape requires ten operations, including the carriage return, as may be seen from Figure 4, and thus requires about 1 second, while the corresponding input entry can be read in one-eighth of a second at the most. A similar discrepancy exists for the toll tapes. An entry on the output toll slip requires about two and one-half seconds, as may be estimated from Figure 5, while the corresponding input entry can be read in five-sixteenths of a second. For both types of tape it thus requires about eight times as long to print the output entry as to read the input entry. As a result, the reader is operated intermittently instead of continually. The circuits of the printer include a number of storage circuits, and each line of the input tape is registered in one of them as it is read. After a complete entry has been received, the reader is stopped, and is not started again until the printer is ready to begin printing the next entry.

In processing a two-line message unit entry, the printing begins as soon as the first line is registered in the proper storage circuit. The second line will be immediately registered in its proper storage circuit. Then the reader will step the tape to the first line of the next entry and wait for the printer to finish the entry. Simultaneously with the return of the type basket of the teletypewriter to the left margin of the paper, the information in the line being held in readiness by the reader will be

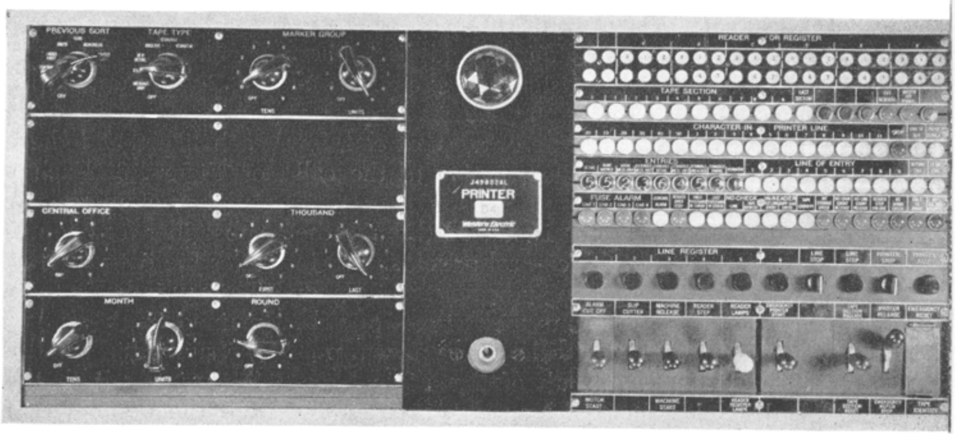


Fig. 3—The control panel for the printer includes dials for setting the type of tape, the marker group, the central office, and the month and day to which the tape applies.

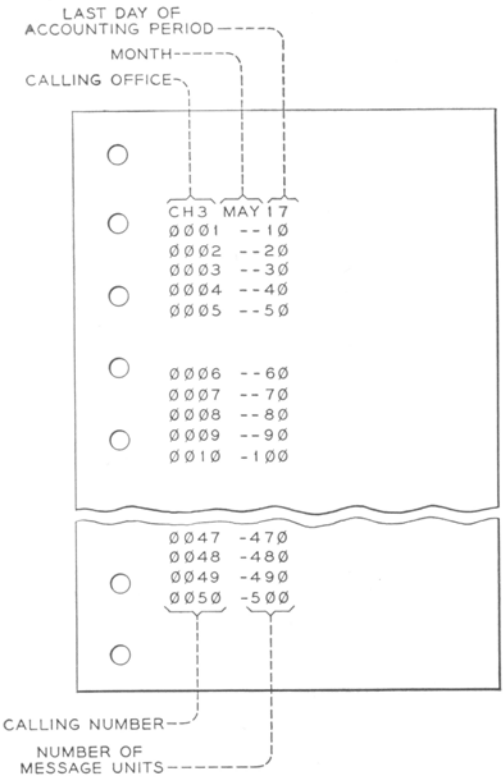


Fig. 4—An output tape for message unit calls is headed by the central office name and the date, and carries all the message unit calls made on that date as single line entries for each subscriber.

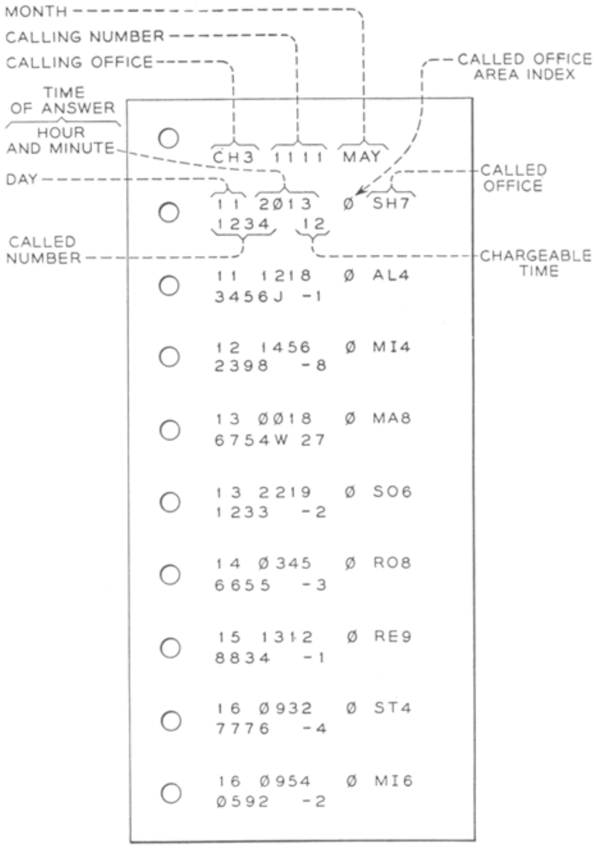


Fig. 5—Each toll ticket is five inches long and may carry as many as nine calls. It is headed by the central office name, the calling line number, and the month.

passed to its storage circuit so that the printing of the second entry may begin without hesitation.

Likewise, in processing the five-line entries of the toll ticket tapes, printing starts with the storage of the first line of the entry. The second, third, fourth, and fifth lines are immediately registered in their respective storage circuits and the reader waits, ready with the first line of the next call, for the completion of the printing of the call information.

Before a new tape is started through the reader, dials on the control panel, shown in Figure 3, are set to indicate the type of tape, the marker group that serves the calls, the central office in which the tape was prepared, and the month of the original record. Each tape carries an identification entry that was perforated in it by the computer to give this and other information. As the tape is started through the reader, the control circuit compares the tape identification entry with the information set on the dials, and gives an alarm and stops advancing if there is any irregularity.

Message unit input tapes to the printer consist of a sequence of two-line entries each like that indicated in the upper part of Figure 6. Each entry gives the total number of message units chargeable to a subscriber for one month. The printer identifies the entry by the entry index in line 1. The MU index in the B digit in line 2 has remained in the entry from previous use in the summarizer and is of no significance in the printer. Both the calling line number and the number of message units are re-

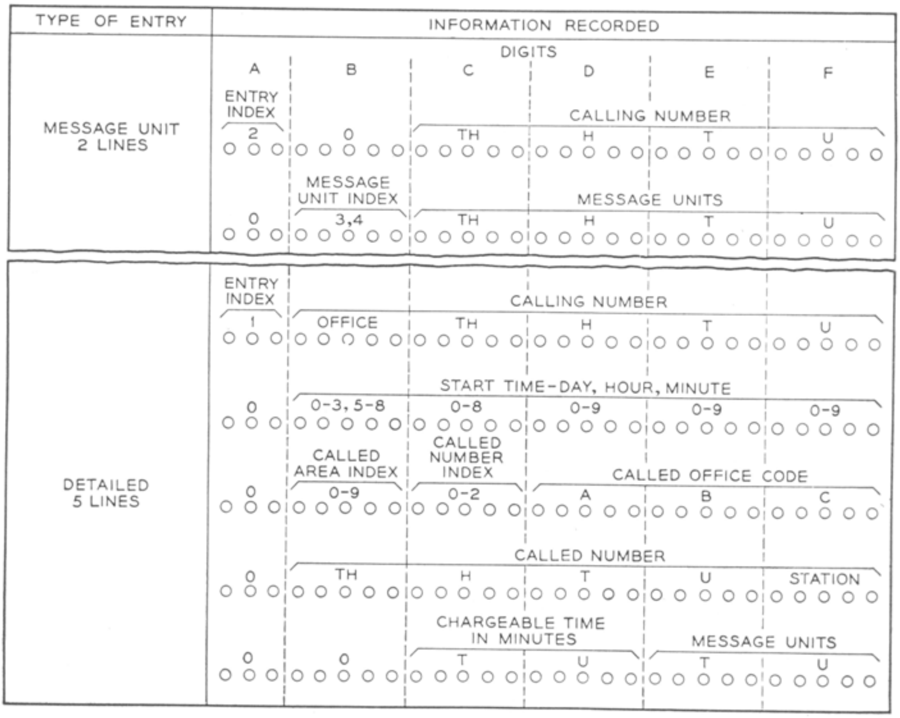


Fig. 6—Arrangement of the two types of call entries on the input tapes to the printer.

corded in the input tape in 2-out-of-5 code, but, in transferring them to the storage circuits, they are translated to decimal code. The information in the first storage circuit controls the printing of the first four characters of each line of Figure 4, while the information in the other storage circuit controls the printing of the last 4 characters of the line. Not more than 1000 message units will be recorded in one entry by the summarizer. If the number of message units chargeable to a particular subscriber is greater than 1000, the additional units will be recorded in a second entry for the same subscriber.

For these message unit tapes, the calling office and date, which appear at the top of the tape, are taken from the control dials shown in Figure 3. The name of the central office of the calling subscriber is translated from the two-digit marker group number and a single digit office designation to the familiar two letters and single numeral by the marker group translator. The three-letter month abbreviation is derived from two digits by the month translator, while the day of the month is translated from the day tens and day units dials.

For the toll tickets, the calling office number and the month, which appear at the top of each ticket, also are taken from dials on the control panel. The day of the month appears as one of the items of each entry since the calls appearing on a single ticket were not necessarily made on the same day. All the calls indicated on the toll ticket, however, are made by the same subscriber, and thus the calling line number is placed at the head of the ticket as one of the identifying marks. This is taken from the call entries on the input tape, one of which is shown in the lower part of Figure 6. These entries are grouped on the input tape according to subscriber line numbers, and successive entries will be placed on the output ticket being printed until a new number is encountered.

Each of the five lines of an input entry is read and registered in one of the storage circuits of the printer. The calling number appears in the first line, and, as soon as it has been recorded, the printer either uses it in printing the heading of a new ticket, or recognizes it as the same as the number of the ticket being printed and proceeds to print the new entry.

The first six characters of a toll entry on the output ticket are the day and answering time of the call and are translated from the five digits of the second line of the input tape. This day, hour and minute information has gone through several metamorphoses in the preceding AMA circuits. It was recorded as three separate entries in the central office tapes. The day was placed in the tape identification entry as a tens and a units digit; the hour, in the hour entry, also as a tens and a units digit; the answering time appeared in the answering time entry as three digits: minutes tens, minutes units, and minutes tenths. A total of seven digits are thus used on the central office tape to convey this information. The minute tenths digit is eliminated in the computer, and the remaining six digits are compressed by coding into five so they may be put in a single line on the output tape of the computer. This is possible because only four digits are required for the day tens digit (zero to three inclusive); only three digits for the hour tens (zero to two inclusive); and only six for the minute tens digit (zero to five inclusive). The total number of possible combinations of the three tens digits is thus $4 \times 3 \times 6 = 72$, and since 72 things can always be represented by a two-digit number, a code has been devised by which the day tens, hour tens and minute tens digits are recorded in the output tape of the computer by a two-digit number. The day units, hour units, and minute units each require one digit and thus the entire information is represented by five digits. As a result the printer must reconvert these five digits to the six digits that are actually printed on the first line of each entry of the output ticket. The four digits designating the called office area index and the called office itself, which also appear in the first line of the output ticket, are translations of the B, D, E, and F digits of the third line of the input entry. This is a more complex translation which will be described in a subsequent issue of the RECORD.

The second line of the output entry includes the called number and the elapsed time. Either four or five digits or four digits and a letter are required for the called line, and these are translated from the fourth line of the input entry. The elapsed time is given as one or two digits, and is taken from the C and D digits of the fifth or last line of the input entry.

Besides reading the input tape, recording the information in storage circuits, making the many translations required, and printing the output tickets, the printer carries out many checks throughout its operation. It checks the tape identification entries against the settings of the dials on the control panel, it checks every line read for complete registration in all digits, it checks many other operations, and stops operating and reports trouble on a bank of lamps whenever an irregularity is encountered. These many and varied operations call for a large and complex circuit, and, according to a *Science News Service* release of June 6, 1950, the patent* covering the printer is one of the largest on record.

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* Patent No. 2,510,061 granted to D. E. Branson, G. A. Locke, and T. A. Marshall on June 6, 1950. See BELL LABORATORIES RECORD, *March*, 1950, *page* 515.

The AMA Called-Office Name Translator

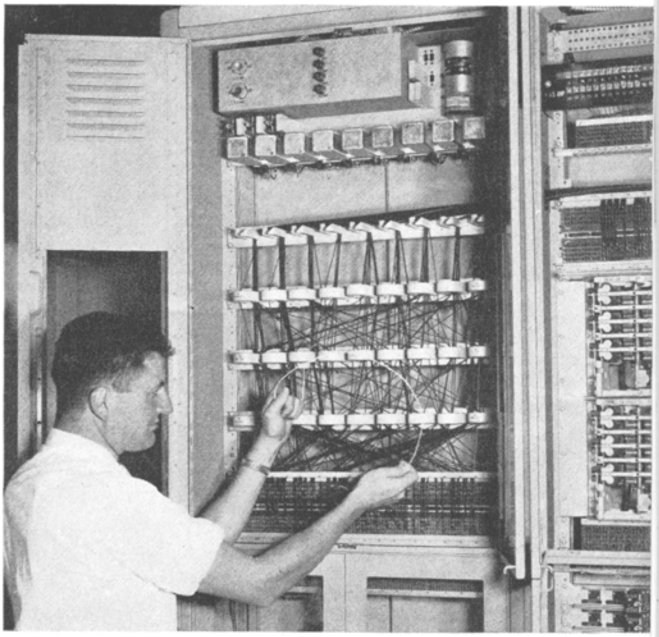
D. E. BRANSON
Telegraph Systems Development

Part of the information required for customer billing by Automatic Message Accounting equipment is the designation of the central office to which each call is directed. This information is supplied to the AMA equipment as a sequence of three digits, and a special circuit is provided to translate it to the familiar sequence of two letters and a numeral in the final presentation.

In an AMA accounting center, the information required for subscriber billing is processed through a number of stages as described in previous issues of the RECORD*. In one of these stages, all the calls to be charged to a particular subscriber in a billing month are assembled by a Sorter, and then passed to a Printer circuit where the information is translated and printed in a form that can be utilized by accounting center personnel. Most of this translation is relatively straightforward and has been described in previous articles. The designation of the called office, indicated on the third line of a typical detailed entry as shown in Figure 2, however, requires a more elaborate translation.

The more complex nature of this translation can be illustrated by a specific example: a subscriber dials the FUlton-9 central office in Philadelphia as FU-9 but this information is recorded on the AMA tape as 389. Reference to any telephone dial will show, however, that the 3 in this sequence might represent a D or an E as well as an F, and the 8, a T or a V as well as a U. The FU then, is only one of 9 possible letter pairs which can be formed by selecting one of the letters D, E, F and adding a T, U, or V. These 9 pairs are indicated in Table I. This situation is further complicated by the fact that an AMA center may serve a relatively large geographic region which might well include several central offices designated by the same number sequence. In this example, 389 refers to the FUlton-9 exchange in Philadelphia while

Fig. 1 — Called office name translator as set up at Bell Telephone Laboratories, West Street, with W. B. Groth threading the ring coils.



the same sequence designates the EVergreen-9 office in New York. These AMA regions, therefore, are divided into a number of dial areas identified by a digit referred to as the called area index, and within each area, a particular three-digit sequence has a unique translation. The Philadelphia area in this example is arbitrarily designated by the index 0 and the New York area by the index 1. A series of four digits is thus required on an AMA tape to specify the called office: one to indicate the dial area, and three to designate the particular central office within that area.

To carry out the translation, the called office name translator, illustrated in Figure 1, has been developed. This translator serves as an accessory to the Printer, and converts each four-digit sequence to a dial area index and called office designation: a numeral, two letters, and a numeral. The translation is then transmitted to the Printer where it is used to print the called office abbreviation on toll slips.

When a called office name translator is used in an accounting center serving only one dial area, a called area index is not required and the task of the apparatus is to translate a three-digit sequence to a pair of letters followed by a numeral. If the New York area were the only one served, for example, the sequence 389 would always be translated as EV-9. Since the first and second digits of a sequence can each have any one of eight values corresponding to the positions two through nine on a telephone dial, 64 two-letter central office abbreviations are possible. The third digit of a sequence, however, can have any of ten possible values for the central office numeral, and the 64-letter

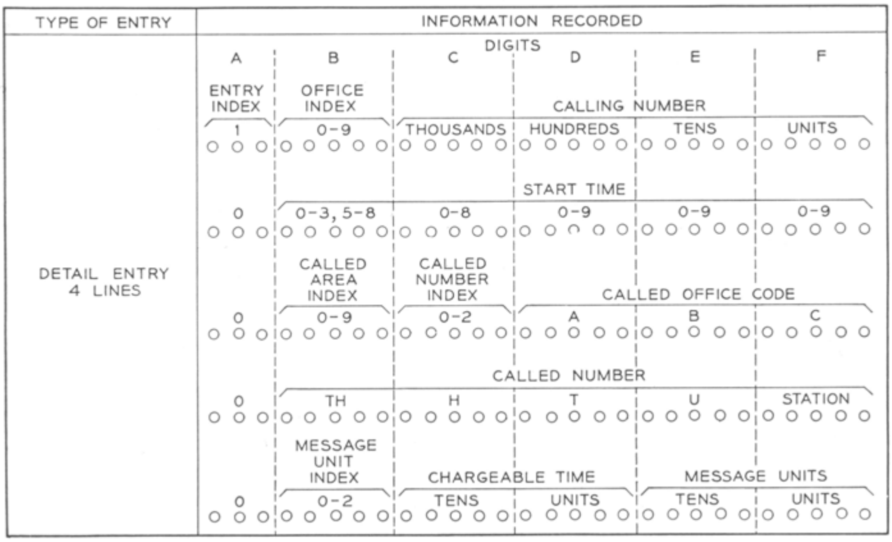


Fig. 2 — Typical detailed output entry perforated by the computer.

pairs and ten numerals provide a total of 640 possible combinations. The translator must provide a means whereby a three-digit sequence on an AMA tape can select the proper one of these combinations.

Eight horizontal rows and eight vertical columns on each of two 10 x 10 crossbar switches having five contacts per crosspoint are used in this translator to provide the 640 unique positions required to represent the possible central office designations, and a particular three-digit sequence selects one of these positions. To accomplish this, the first digit of the sequence causes the select magnets of the horizontal rows corresponding to its value to operate. As illustrated in Figure 3, the first digit 3 causes the operation of the number three crossbar select magnets. The second digit 8 of the sequence completes a circuit to the hold magnets corresponding to its value on both switches. In the illustration of Figure 3, the digit 8 closes a path to the number eight hold magnets, and thus the 3-8 crosspoints are chosen. Only one

DIGIT 8 LETTER GROUP	DIGIT 3 LETTER GROUP		
	D	E	F
T	DT	ET	FT
U	DU	EU	FU
V	DV	EV	FV

TABLE 1—THE NINE POSSIBLE LETTER PAIRS FORMED BY ONE LETTER FROM THE GROUP D, E, F, AND ONE FROM THE GROUP T, U, V

of these two crosspoints is actually closed, however, and this choice is governed by the third digit. If this digit has any of the values zero through four, the hold magnet for the indicated vertical on the first switch is operated. If the value lies in the range five to nine, however, the corresponding crosspoint on the second switch is closed. The third digit in the example 389 indicates that the 3-8 crosspoint on the second switch should be closed as shown in the diagram.

Each of the crosspoints is equipped with five individual contacts. On the first switch, the five contacts at crosspoint 3-8 represent the sequences 380 through 384 and the contacts on the corresponding crosspoint of the second switch represent the sequences 385 through 389. The third digit of a sequence causes a ground to be applied to all the switch contacts corresponding to its value. In Figure 3, the ground is applied to all the number 9 contacts. Since the 3-8 crosspoint on the second switch is the only one closed, however, contact 389 provides the only complete path for ground. In this way, a three-digit sequence selects a unique position of 640 possibilities.

To complete the translation process, an AMA printer must be directed to print the central office designation corresponding to the selected switch contact. The 24 printer character relays corresponding to the letters on a telephone dial are divided into eight groups of three each as they are arranged on the dial. The first digit of a sequence, in addition to activating select magnets, closes a path to its corresponding group of printer character relays. As shown

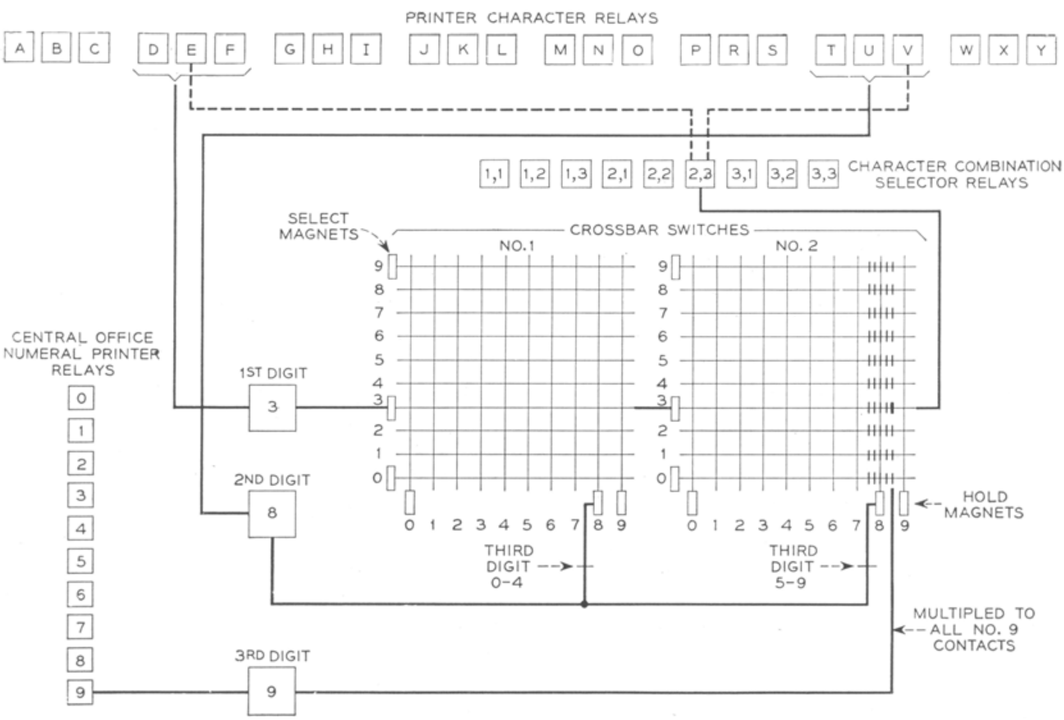


Fig. 3 — Block diagram of called office name translator as used for single area translations.

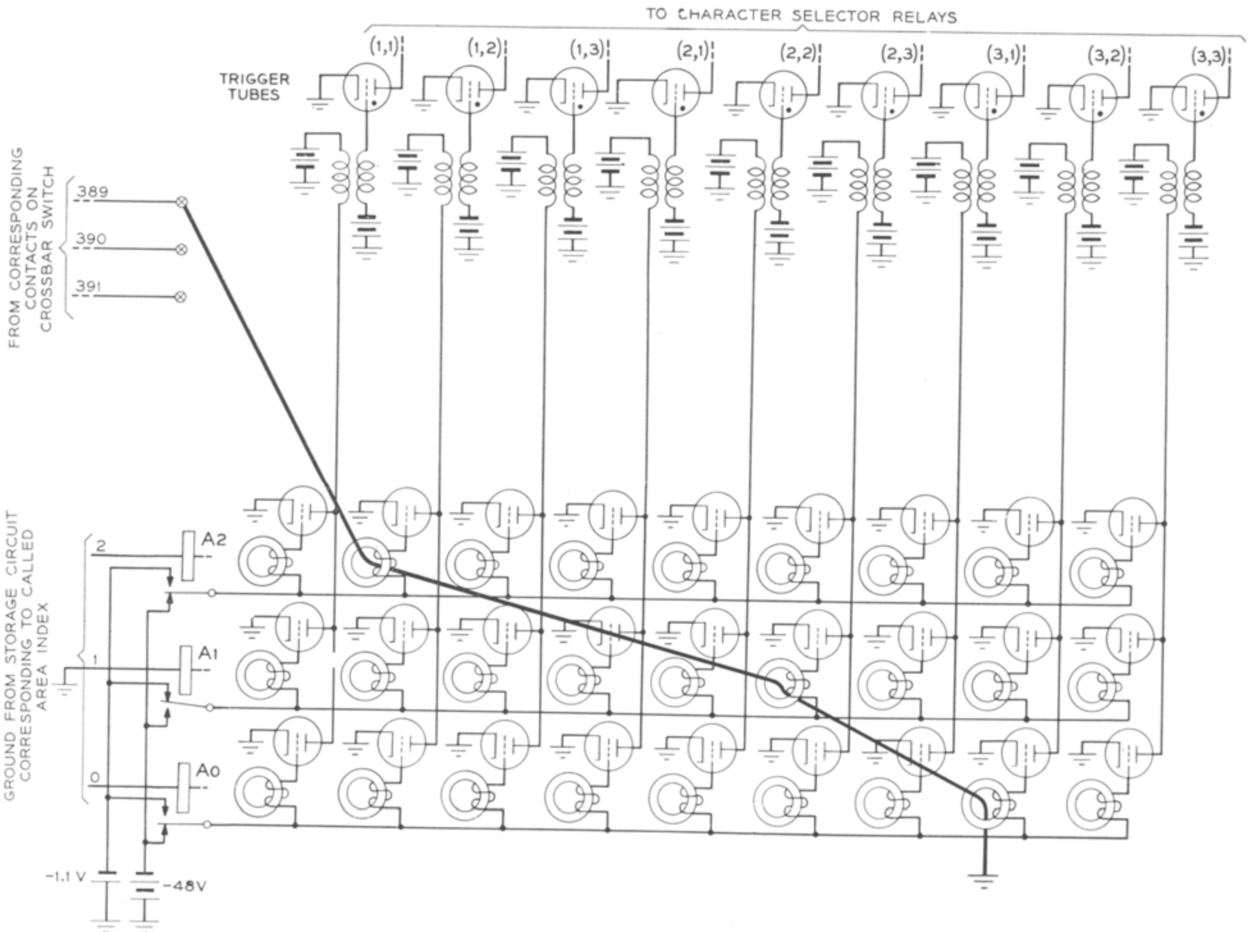


Fig. 4 — Nine ring coils corresponding to each of three dial areas with the line from the 389 contact on the crossbar switch threading one coil in each group.

in Figure 3, the digit "3" closes a path to the characters D, E, and F. The second digit similarly closes a path to the printer character group corresponding to its value. In this way, two of the eight possible relay groups are selected.

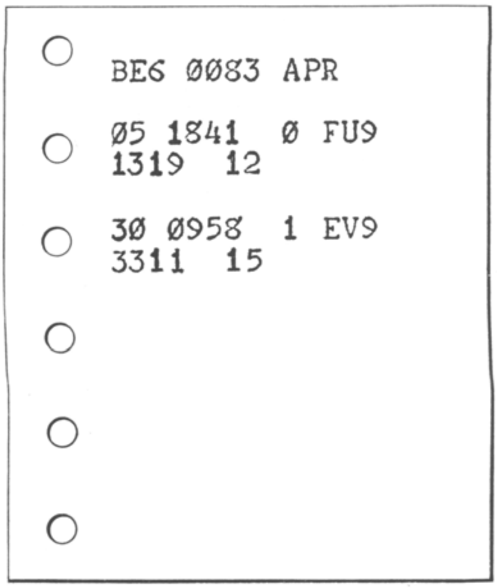
In the remaining step, the correct letter-pair of the nine possibilities provided by the six characters in these two groups must be selected. This is done through the use of one of nine character combination selector relays. Each of the 640 contacts in use on the crossbar switches is cross-connected to one of these nine relays and they, in turn, are connected to the printer relays in such a way that they direct the printing of the desired one of three characters in each of two groups. Since circuit paths to only two of the groups have been completed by the first two digits in the sequence however, the characters indicated by the combination selector relays in these groups are the only ones that operate. The crossbar switch contact 389 in Figure 3, for example, is wired to the selector relay "2, 3." This relay applies ground to the second character in the first group and the third character in the second group. In this way, the character relays EV are activated. The third digit of a sequence causes the central office numeral to be printed directly, and the translation is thus completed.

The preceding account describes the use of the called office name translator in accounting centers which serve only one dial area. The process is considerably more complicated, however, in the more typical situation of several areas served by the same center. In actual practice, as many as three dial areas are involved and it is possible for the same three-digit sequence to occur in two or three of them. The translator must then include a provision for supplying a different translation of the same sequence for each dial area in which it may appear, and the choice of the particular translation is governed by the called area index. The apparatus required to select the proper translation consists essentially of an additional group of relays, a set of ring coils* with associated amplifiers, and a set of gas tubes.

The operation of a called office name translator in regions including more than one dial area is an extension of that previously described. In a multi-area application, however, the circuit is so arranged that the third dialed digit causes an alternating current rather than a ground to be placed on the selected contacts of the crossbar switch. In the example of Figure 3, ac is supplied to contact 389. From the switch contact, the signal follows the path indicated in Figure 4 to the character combination selector relay rather than the direct route shown in Figure 3 for a single area translation.

The diagram in Figure 4 illustrates the arrangement of ring coils, amplifiers, and trigger tubes used in a translator serving three dial areas. As shown, there are nine ring coil-amplifier combinations for each dial area with one combination per area connected to each character combination selector relay. This ring coil array is also evident in the open rack at the left of Figure 1.

A lead from each crossbar switch contact is threaded through a coil corresponding to the Selector relay that yields the desired translation for each dial area. In Figure 4, the lead from contact 389 passes through a coil in the dial area zero group that is associated with relay "3, 2." The same lead encounters the coil for relay "2, 3," in the area 1 group, and that for the relay "1, 2" in area 2. The grids of the amplifier tubes associated with the ring coils are normally maintained at a potential of 48 volts below ground and hence the associated trigger tubes illustrated in the figure are kept far below their operating threshold. A storage circuit, containing the called area index, however, applies ground on a lead to operate one of three relays, A0-A2. This relay, A0 in the case of the 0 Philadelphia dial area or A1 for the number 1 New York area, changes the grid potential on the 9 amplifiers in the bank of coils corresponding to its area, from –48 to –1.1 volts. For the four-digit sequence 1389, relay A1 is operated to raise the grid potential of the 9 amplifiers for area 1 to –1.1 volts.


BE6 ØØ83 APR

Ø5 1841 Ø FU9
1319 12

3Ø Ø958 1 EV9
3311 15

Fig. 5 — Sample toll slip from printer showing calls to the FUlton-9 and EVergreen-9 offices.

The ac signal on the lead from contact 389 induces a voltage in the ring coils it encounters but this voltage has no effect on the associated amplifier tubes that have grid potentials of –48 volts. The ac signal, however, will be amplified with a grid potential of 1.1 volts. The ac on the lead from contact 389 in Figure 4 does not affect the

* See page 30.

amplifier-coil combination through which it passes in the area 2 group since this grid potential remains at –48 volts. Similarly, the combination in area 0 is unaffected, but the induced voltage in the area 1 coil makes its associated amplifier tube conducting and this fires trigger tube "2, 3". This tube, in turn operates Character Combination Selector relay "2, 3" which directs the printer to type EV-9 as previously described. The dial area index is typed by the printer circuit directly.

If the FUlton-9 central office in the Philadelphia dial area had been called, the four-numeral sequence would have been 0389, differing from the EVergreen-9 sequence only in the dial area index. In this case, relay AO would have raised the grid potential of the amplifiers, in its bank and activated Character Selector relay "3, 2". This directs the circuit to operate the third character relay in the first set, the F, and the second in the second set, the U, and the designation FU-9 is then printed. Figure 5 shows a sample toll slip on which the called office name translator has directed the printer to type the combination 0FU9 from the sequence 0389 and 1EV9 from 1389.

Several variations in translation are provided for in this apparatus since it may be necessary to convert central office designations of one numeral, of one letter, of two numerals, of one letter and one numeral, and of two letters. For these, additional coils and their associated relays are required.

A very thorough check feature is incorporated in this circuit which requires the operation of one and only one relay in a group before the typing of any character can proceed. Any improper functioning of this circuit or improper recording of a central office designation operates a trouble alarm.

Throughout the Bell System, accountable telephone messages in the order of about 200 million per month must be recorded, priced, and billed. The immensity of this message accounting job, one that must be done under exacting requirements of accuracy and promptness, made it particularly desirable to mechanize much of this work. Complete mechanization is the ultimate goal, and the present AMA system is making strides in this direction. The tape-to-card converter is one of these steps.

Card column assignments on the IBM control panel of the AMA Tape-to-Card Converter are checked by W. B. Groth.

A Tape-To-Card Converter for Automatic Message Accounting

W. B. GROTH
Switching Systems Development

Billing data for customer-dialed local and toll telephone messages are now recorded and processed by means of the automatic message accounting (AMA) system in the areas of eight principal cities in the Bell System network. This system records the information required for billing the customer in the form of perforations in paper tape in the central office. Recordings are made while the switching machinery is establishing connections between telephone lines, and while the messages are in progress.

These perforated paper tapes are cut daily and forwarded to an accounting center where the information is processed through a series of machines, each of which, except the last, produces new paper tapes. Individual message records are assembled, and chargeable message units or chargeable time, in the case of toll messages, are determined. Individual message entries are sorted by calling line number, message units for a given billing period are added, and finally message unit summaries and individual customer toll slips are printed. The printed output of the AMA accounting center is used by clerical personnel in producing toll service statements and customer bills.

Statement

B

130 2868

New Jersey Bell Telephone Company

TOLL SERVICE STATEMENT

DATE	PLACE CALLED	AMOUNT
1-16	PR 7	.10
1-18	NYEV 4	.15
1-18	PA 6	.15
1-18	PA 6	.15
1-21	NYSL 6	.15
2-8	NYUL 7	.35
2-11	PA 6	.20
2-11	PA 6	.15
2-13	UN 6	.10
2-15	NYSL 6	.15

PLEASE SEE YOUR DIRECTORY FOR CENTRAL OFFICE NAMES AND ABBREVIATIONS OF NEARBY POINTS

U. S. TAX SCHEDULE
TOLL CALLS
UNDER 25¢ . . . 15%
25¢ and over . . 25%

TOTAL U. S. TAX .28
TOTAL CARRIED TO BILL 1.93

A 2486 (11-51)

PLACE CALLED	DATE	AMOUNT	CALLED AREA	CALLED C. O.	CALLED TELEPHONE NO.	CONNECT TIME	MINUTES	CLASS	
PR 7	1-16	10		777	3900	1045	3	1	130 2868
NYEV 4	1-18	15	1	384	3264	1727	1	1	
PA 6	1-18	15		726	0946	1704	3	1	
PA 6	1-18	15		726	0946	0757	5	1	
NYSL 6	1-21	15	1	756	2782	1046	3	1	
NYUL 7	2-8	35	1	857	4085	1132	13	1	
PA 6	2-11	20		726	0946	1324	6	1	
PA 6	2-11	15		726	0946	1221	2	1	
UN 6	2-13	10		866	5304	1157	1	1	
NYSL 6	-15	15	1	756	2782	1044	3	1	

CODE LL-LONG LINES — TOTAL U. S. TAX 28 — TOTAL CARRIED TO BILL 193

EXPLANATION OF CLASS CODES: 1. STATION DAY 2. STATION NIGHT 3. PERSON DAY 4. PERSON NIGHT 5. MOBILE 6. COLLECT 7. TELEGRAM 9. REPORT CHARGE

*0*0
*0*0

Fig. 1 — A Toll Service Statement as prepared is in two sections; a section, shown in the upper part of the illustration, is sent to the customer, while the one shown in the lower part of the illustration is retained by the Telephone Company.

It is hoped ultimately to make even this last step automatic. As a step in this direction, IBM machines using punched cards are now used to process toll calls. Designed to make the accounting procedure more efficient, this process is known as tape-to-card conversion and has had a marked effect upon the routines followed in the accounting center. Tape-to-card conversion, therefore, is not merely an adjunct of the AMA system, but a new process intended to supplement AMA in its previous form. A typical toll service statement for the customer is shown in Figure 1.

Since the processing immediately preceding the final preparation of the toll service statement is done with punched cards, it was necessary to develop suitable equipment to convert the information from the perforated tapes used during the earlier stages to punched cards that can be used in the later stages. The result is the tape-to-card converter, which first went into service in Newark in 1951. When this machine is used, the four sorting stages* and the printer that were formerly employed for toll calls are eliminated and the tape-to-card

* See page 85.

converter will take over from the output of the computer.

At its input, the tape-to-card converter employs a reader* to which the toll tapes from the computer are supplied. At its output is an IBM card punching machine which punches 3 by 7 inch cards, each card having space for all the essential information for one entry on the input tape. Other IBM machines carry out the rest of the accounting process to produce an individual Toll Service Statement for each customer.

The laboratory installation of the tape-to-card converter is shown in Figure 2. At the left is the card punching machine, next to the right is the reader for the input tape, while the bays at the extreme right comprise the relay equipment of the converter. In brief, the converter consists of a group of input registers for recording the data read from the input tape; a few translators to translate certain items of the input tape entry before they are placed on the card; a group of output registers on which are recorded the data to be punched on the card; and the card punch itself. These various units are indicated in the block schematic of Figure 3.

The information recorded for one entry on a toll tape is shown in Figure 4. Each line of an entry carries five digits of information – The B, C, D, E, and F digits – and the A, or index, digit. Digit 1 in the A position indicates the first line of an entry, and this prepares the converter to accept a new entry. Each of the succeeding lines of the entry will have a zero in the A position, and thus the next appearance of a 1 indicates that the preceding entry has been completed and that a new one is to begin.

Most of the information on such a tape can be transferred directly to the card, but for certain items, such as the calling office designation and the start time, a translation is needed. Only a single digit is recorded on the tape entry to indicate the office – the B digit in the first line. This is because a single tape records only calls handled by a single marker group, and such a group never handles the calls of more than ten offices. The marker group to which the tape applies is recorded at the end of the tape and is set up on the control panel of the converter before the tape is inserted in the reader, and from the marker group and the office index, the B digit of line 1, it is possible to derive the three digits identifying the calling office. This is one of the translations that the converter makes.

The start time of the call was originally recorded as six digits: day tens and day units; hour tens and hour units; and minute tens and minute units. As already described,* however, these six digits are recoded so as to require only five digits on the tape supplied to the converter. Another translation is therefore required to reconvert the start time to the original six digits. With these and some minor additional translations, all the information on the input tape is transferred to the card. The card is of the form shown on Figure 5.

Such a card has eighty columns and twelve horizontal rows. These rows are designated, from top to bottom, 12, 11, 0, and then 1, 2, 3, 4, 5, 6, 7, 8 and 9, while

* See page 52.

* See page 97.

Fig. 2 – W. B. Groth and L. J. Koos examine a toll message card punched by the AMA Tape-to-Card Converter.

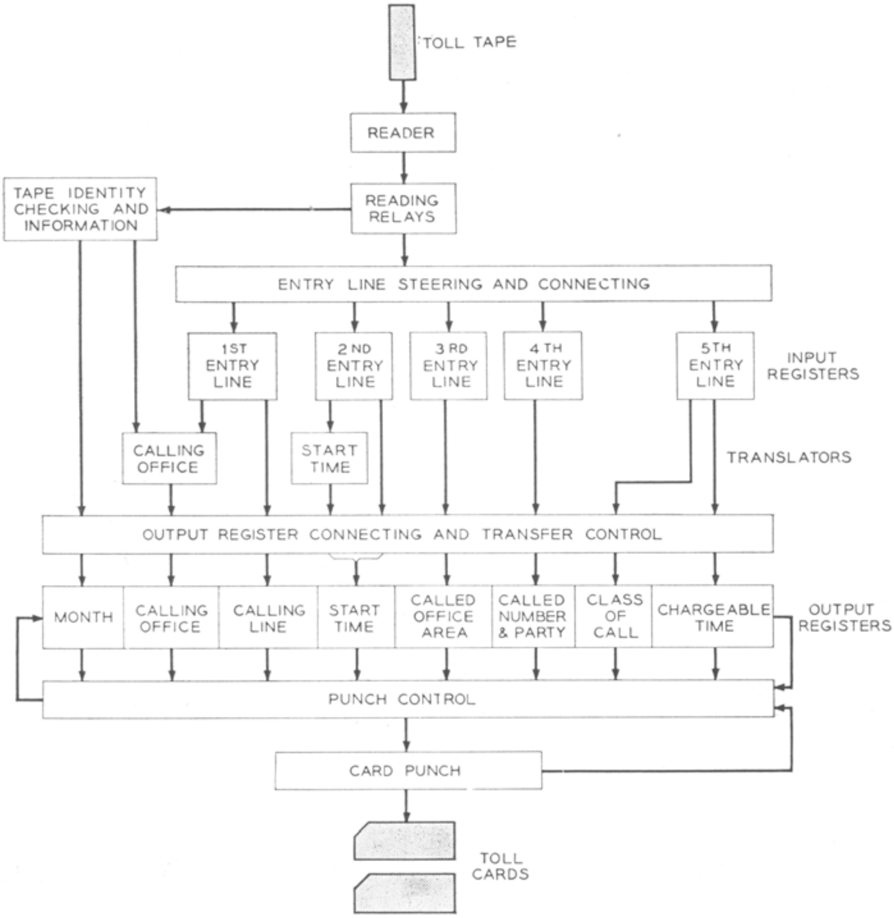


Fig. 3 — Block Diagram of the Tape-to-Card Converter.

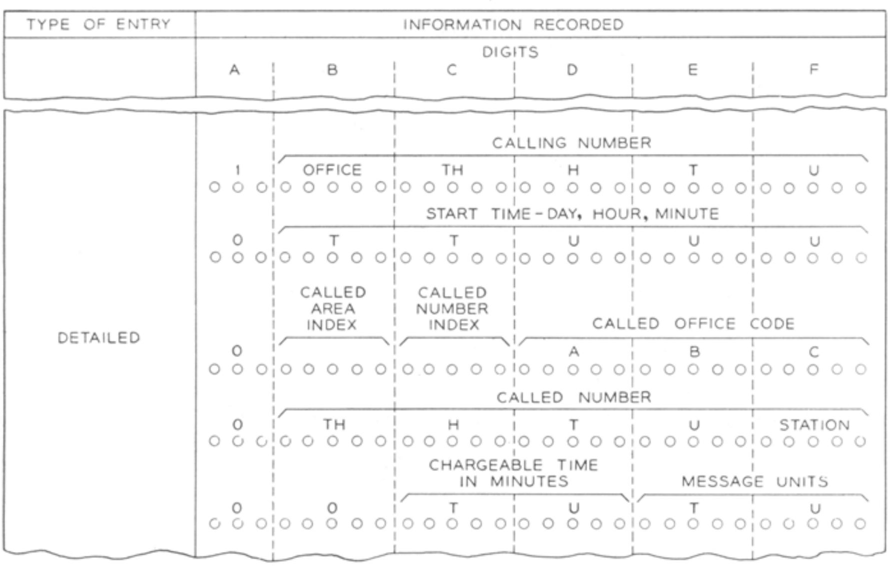


Fig. 4—A diagram indicating the spaces available for a toll entry on an input tape to the converter.

the eighty columns are indicated from left to right along the bottom of the card. Individual items of information are found in one or more columns. Information requiring three digits, for example, will be punched in three columns with one digit in each column. The particular card shown in Figure 5 was for a call from Office 236, and this calling office designation will be found in Columns 55, 56 and 57. An inspection of the card will show that in Column 55, the 2 has been punched out; in Column 56, the 3; and in Column 57, 6. A similar method is employed for all items. The called number for the card of Figure 5 was 1614J, and these digits will be found punched out in Columns 63 to 67, inclusive. Column 62, which is also one of the columns reserved for the called number, is used only in the comparatively rare cases when the number has a digit in the ten thousands place. Rows 11 and 12 at the top of the card are used only for special information such as the type of card and certain check information.

These cards move through the machine at right angles to their length. There are eighty punching magnets, one for each column, and Row 12 is punched first, Row 11 next, then Row 0 and so on. The various items of information are not punched one after the other but rather the zeros in all the items will be punched at one time, then the 1's in all items, and so on.

After all the information of one entry of the input tape is recorded in the input registers and translated where necessary, it is transferred to the output registers where it is then available in the correct form for the punching process. The procedure leading to punching may be followed with the help of Figure 6. A sequence circuit grounds twelve emitter leads one after the other, and following the grounding of each lead, one row of the card is punched and the card is stepped ahead ready for punching the next row. These twelve emitter leads are multipled to the output registers and are so associated with the register relays that a ground on the zero emitter lead, for example, will pass through contacts of the

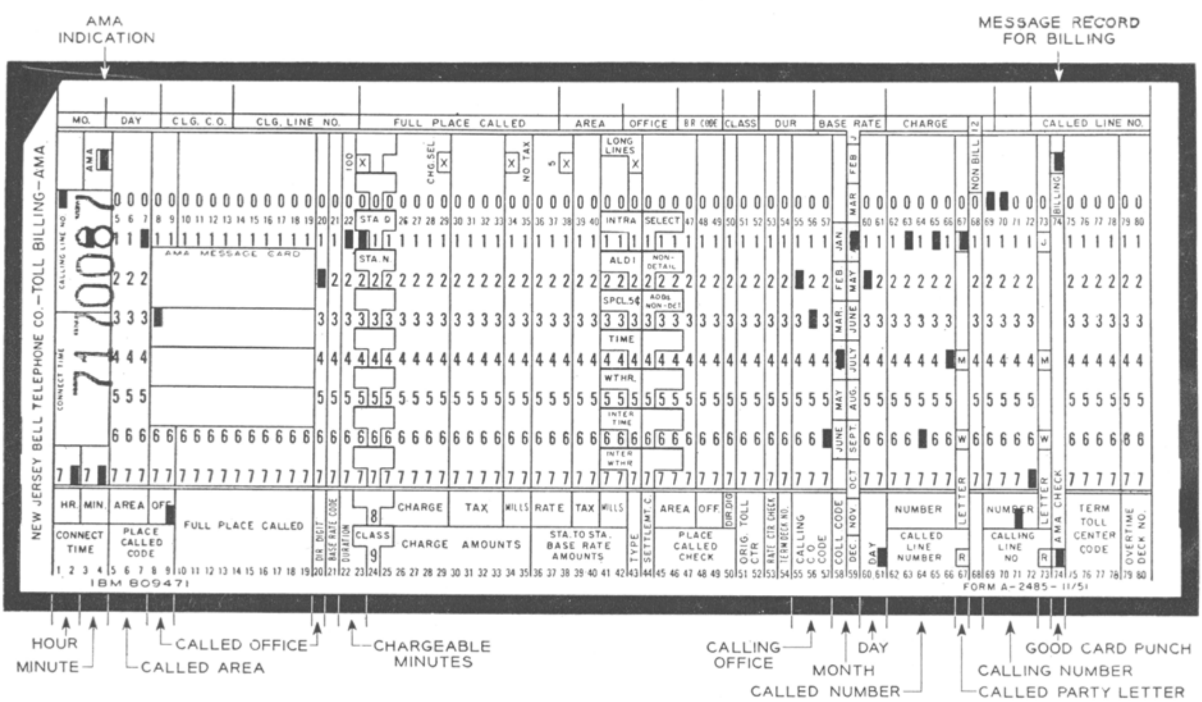


Fig. 5 — A toll card as punched by the tape-to-card converter.

relays of all registers that have a zero recorded to operate a check punch relay and a punch relay in series for each digit of information. Following this, a circuit breaker operates and sends current through the contacts of all the operated punch relays and thus operates the proper punch magnets. The punch relays are released following the punching, but the check punch relays are held operated until the card has been fully punched.

After the sequence circuit has grounded the number 9 emitter lead, all of the check punch relays required for that entry will be

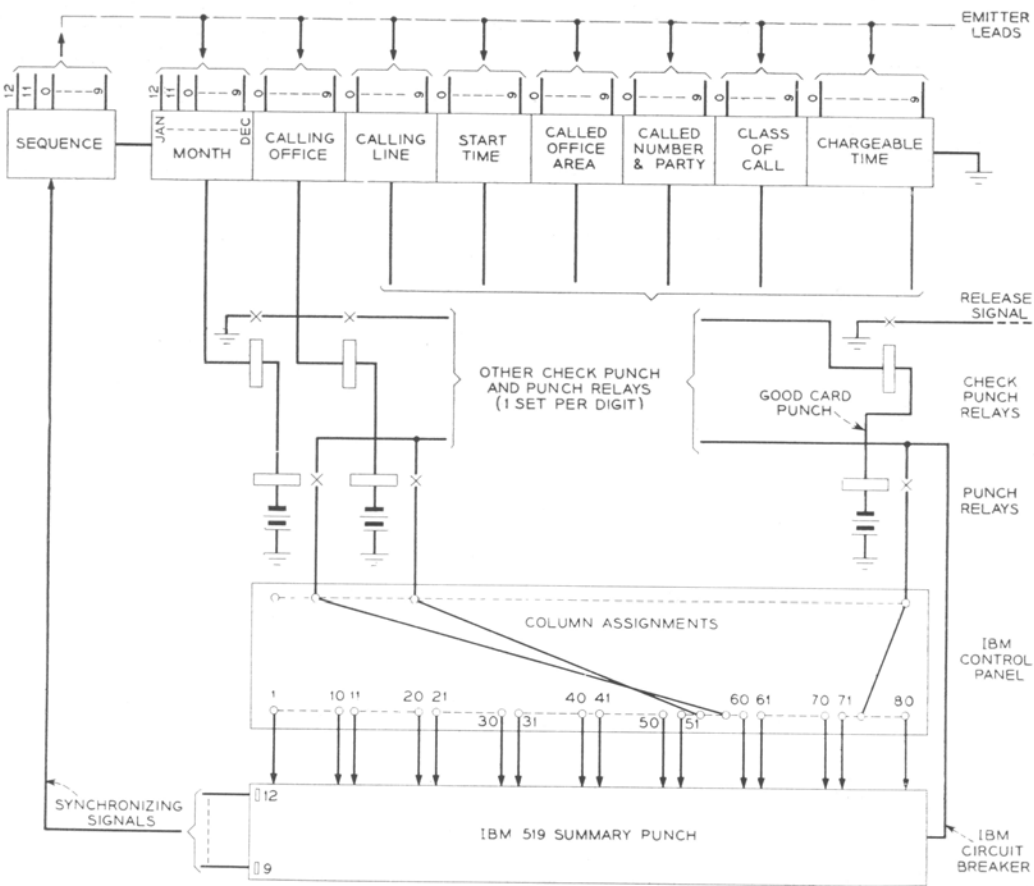


Fig. 6 – Simplified diagram outlining the punching procedure.

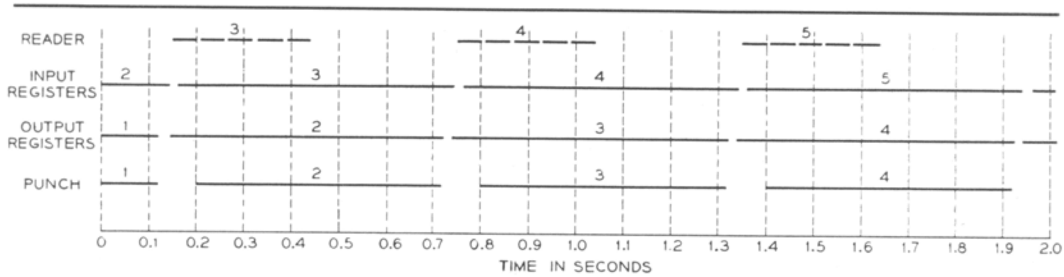


Fig. 7 – Time chart showing overlap operation of the converter. Successive entries are indicated by numerals over the lines indicating the operated condition.

Fig. 8 — L. J. Koos removes toll message cards punched by the AMA Tape-to-Card Converter.

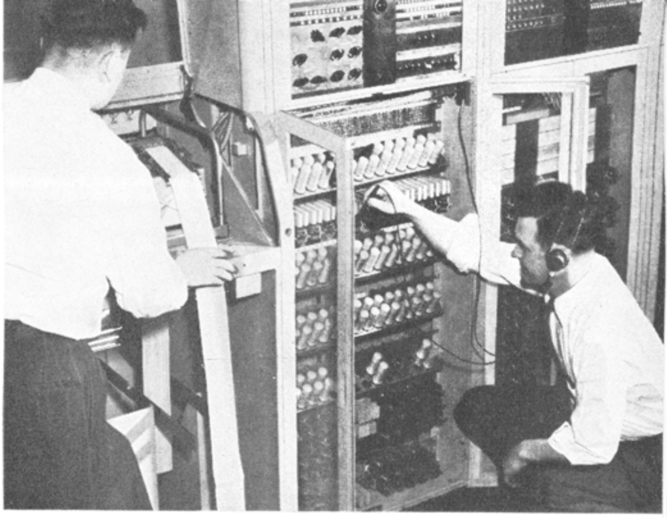


Fig. 9 — W. B. Groth and L. J. Koos test for trouble in laboratory model of the Converter.

operated, since as already mentioned the check punch relays are held operated after the punch relays are released. At the time the last check punch relay is operated, therefore, a circuit will be closed to the good-card punch relay. As a result when row 9 is punched a punch is made in column 74, designated AMA check on the card, to indicate that the correct number of punches has been made in the card. The operation of the check relay for the good-card punch has closed a circuit to the release control, and through it — after the No. 9 row has been punched — the output registers and the check punch relays will be released and the card will be automatically advanced in order to allow a new one to take its place.

The card machine is capable of operating at the rate of 100 cards per minute, and thus only 0.6 second is required to punch the twelve lines of one card. Since the reader operates at sixteen lines per second, it reads the five lines of an entry in only a little more than half of the time required to punch the card. To permit operation at the full capacity of the punch — 100 cards per minute — an overlap operation is provided. Entry No. 2 is being read while the card for entry No. 1 is being punched, and so on. This is indicated in Figure 7. After the last row of a card is punched, the output registers are released and immediately afterward the input registers transfer their information for the next entry to them. A check circuit of the output registers then releases the input registers. This starts the reader, which reads the five lines of the next entry and then ceases to advance until the input registers are again released.

The printing on the cards and the type of information put in the various columns may differ at different accounting centers because of local conditions. To permit this flexibility, the contacts of the punch relays and the leads to the punch magnets are connected to jacks on the control panel of the punch machine. Plug leads are used to associate the various punch relays with the punch magnets.

After a card is advanced in the punch beyond the punching stage, it is sensed to insure that the correct number of punches has been made. This is called double punch and blank column detection and may be assigned to columns on a flexible basis through the IBM control panel.

The card may be end printed with quarter inch characters in the next station of the card punch. Connect time and calling line number, selected by control panel wiring, are shown end printed at the left side of Figure 5. These items are used for visually selecting certain message records.

The end printing completes the over-all tape-to-card conversion process. Cards punched by the tape-to-card converter are then processed in a punched card machine system where they are sorted by called place, gang punched in certain of the blank columns with rate and called place information, sorted by calling line number, and finally used in a tabulator for printing the toll service statement. This statement then becomes available for sending to the customer.

Test Tapes for Automatic Accounting Centers

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Machines of the automatic message accounting center*—assemblers, computers, sorters, summarizes, and printers—are of a type unique in telephone systems in that they function without benefit of interconnecting leads to pass intelligence from one to another. In place of the more usual wire connections, these machines read holes which have been perforated in paper tapes to gain the information necessary to their jobs, and all of them provide a physical output in the form of other punched tapes, printed call tickets, or summary sheets.

Four of the machines, the assembler, computer, sorter, and summarizer, perforate other tapes to furnish information to subsequent machines in the processing series, while the printer makes its output in the form of typed records. In all cases, all operations of each machine are fully determined by the punched hole information on the tape which is fed into it. Similarly, for every punched paper tape fed into a machine, there can be only one correct output whether in the form of tapes or printed matter. Such machines can best be tested by means of specially prepared test-tape inputs and by checking the machine's output against master output tapes or lists, provided this checking or comparing process can be carried out with sufficient speed and accuracy.

Since each line of an AMA tape is in the form of coded six-digit numerals, the tapes used to feed the test information to each machine, and also those used for comparison with the machine's output, are designed by preparing lists of numbers to

* See pages 47, 52, 59, 65, 85 and 92.

Fig. 1—The test tape perforator includes a reader, two key sets on a table, and a small relay cabinet evident just below the table top at the right.

represent the information to be punched into the tapes. These numbers are tailored to the operating peculiarities of each machine so as to provide as complete testing as possible with a minimum number of entries. The number lists also carry information for key manipulations and some other special operations required of the test man.

Copies of these number lists are also used by the test man in locating trouble when the machine stops during testing. For this reason the lists are also made to carry as many "sign posts" as possible to facilitate analysis of troubles when they occur. Several expedients are used for this purpose: digits that do not affect the operation of the machine on particular tests are arranged in ascending numerical order; deliberate errors are introduced into the tape to cause machine stoppages at predetermined points; and meaningless repetitive entries are used to mark certain positions on the tape by producing visually recognizable punched hole patterns.

After the number lists have been designed, the test tapes represented by these number lists must be manufactured. To facilitate this operation, a test tape perforator was developed. As shown in Figure 1, this consists of two key sets mounted on a table on which is also mounted a small cabinet for the register and relays that control the operation of a perforator of the type used in other AMA machines.* In perforating a test tape, two operators are used, and each is furnished a copy of the test tape number list. Each operator writes the entries on her list on her own key set. Since the lists are identical, the operators should be writing the same number at each writing. The associated relay circuits monitor the results of the two operators' keying for each line of six numbers by a match check similar to that described later in this article for the tape comparer. If the numbers match, the relay circuit causes the associated perforator to perforate the number corresponding to the identical key setups. The keys of both operators are then automatically restored, and the operators proceed to write the next line. If any lack of agreement in the key settings is found, the circuit refuses to perforate the line until the operator at fault corrects the error.

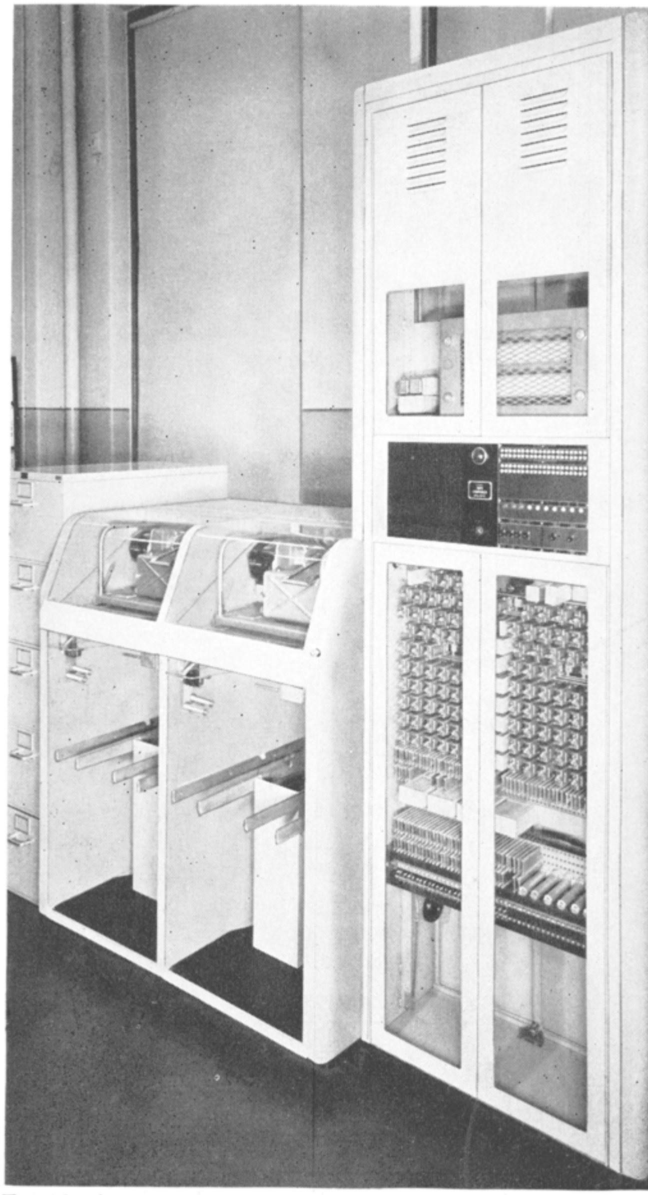


Fig. 2—A tape comparer employs two readers, a large cabinet of relays and other control apparatus.

In addition to the design and manufacture of the test tapes and test tape lists, there still remains the problem of making the comparison with the machines' outputs sufficiently rapid and accurate. In the case of the printer, a visual check of the output is unavoidable. This check, however, has been made as convenient as possible by showing the expected output in printed

* See page 18.

form on the input test-tape number lists alongside the entry line numbers.

A different sort of problem is posed by the assembler, computer, sorter, and summarizer. The output tapes from these machines contain thousands of lines of punched holes which must be compared with previously prepared output test tapes to determine if they are exact hole-for-hole duplicates. To provide a speedy and accurate means of tape comparison, a tape comparer was developed. It is used also for comparing new test tapes with the originals. Since the test tapes are paper, their life is limited. Thus new tapes must be made rather frequently, and these reproduced test tapes must also be compared line-for-line before the worn originals may safely be discarded.

The tape comparer, shown in Figure 2, employs two standard tape readers, and the tapes to be compared are fed into them. Relays in the comparer so control the line stepping of the two readers that the tapes are compared for identity line-for-line; the machine stops and sounds an alarm whenever any lack of identity is noted or whenever either tape violates the code system used by having too many or too few holes on either tape.

Included in the relay cabinet at the right of the two readers are two relay registers, one for each reader. As each line is read, the six-digit number is recorded on the associated register. A circuit is wired through the contacts of the register relays in such a way that unless the same numbers are recorded on both registers, and unless, for each 2-out-of-5 digit, two and only two of the five relays are operated, the circuit will not be closed and the two readers will not be stepped to the next line. The portion of this circuit for the last digit of the line is shown in Figure 3.

To obtain the highest speed of operation and to provide reliability, it was found necessary to operate the two readers in synchronism with each other. In view of the fact that the readers are driven by induction motors and fixed gear trains, this provided an interesting problem. The solution was found by taking advantage of the fact that, with a fixed load, induction motor slippage can be made to vary slightly with

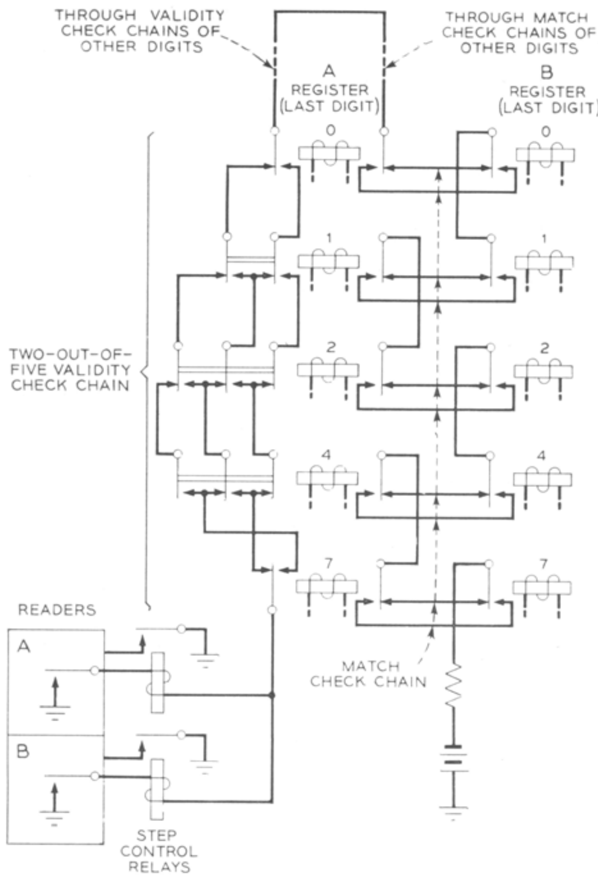


Fig. 3—A simplified schematic of the comparer circuit for one digit. Only if the same digit is read on both, will the two readers be allowed to step.

the applied voltage. The reader motors are required to drive only a relatively light and fairly constant load consisting of the reader gear train and tape reading and moving mechanism. It was found that the insertion of a fixed resistor into the power feed of one reader motor after it had reached running speed was sufficient to guarantee that it would run somewhat slower than the other reader motor and still leave sufficient reserve power for all reader operations. Control over the other reader for synchronizing purposes was obtained by periodically cutting in and out a resistance in series with its power circuit. The control arrangement used is shown in the simplified diagram, Figure 4.

To understand the operation of this circuit arrangement, assume that readers A

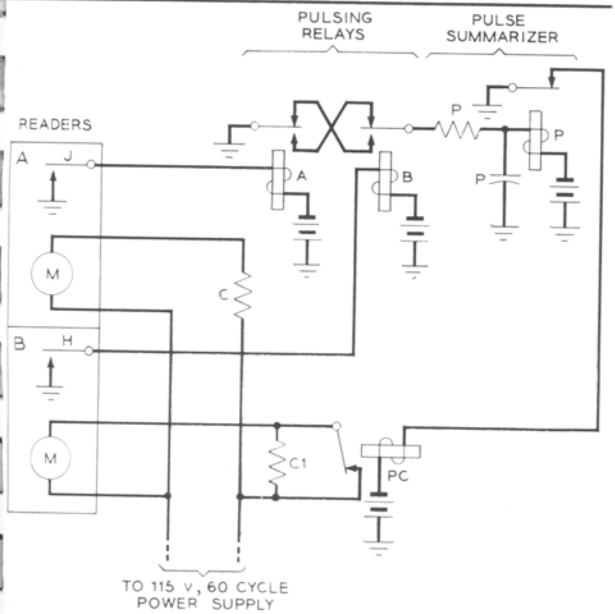


Fig. 4—Simplified schematic of control circuit that keeps the two readers operating in synchronism.

and B are running with their respective cam contacts J and H momentarily in synchronism. Relays A and B operating from these contacts will also be in synchronism and there will be no tendency for relay P, which is in series with the reversed transfer contacts, to operate. Reader B however, is running faster than reader A because of resistor C in series with the reader A motor. Contact H and its relay B, will, therefore, become slightly out of phase with contact J and its relay A. With relays A and B slightly out of phase, ground pulses are delivered to the 8-mf condenser P through resistor P at the beginning and end of each reader cam cycle. As the out of phase relationship increases, these ground pulses discharge condenser P to the point where the difference between the potential on condenser P and the 50-volt supply becomes sufficient to operate relay P. The operation of relay P causes the release of the power control relay PC which in turn introduces resistor C1 into the power leads to the reader B motor. This relatively high resistance in its power leads causes the motor of reader B to lose speed, thus bringing contact H back into phase with contact J. This brings relays A and B also back into phase with each other, thus ending the ground pulses to the pulse summarizing condenser P.

The ending of these ground pulses permits the potential to build up on condenser P to the point where relay P releases, re-operating relay PC. With the re-operation of relay PC, the speed of reader B is once more increased because of the removal of resistor C1 from its power leads, and the speed control cycle, just described, repeats itself. This arrangement provides a degree of synchronization sufficient to keep both readers stepping reliably on each line read and to avoid the loss of time which would otherwise result from each reader waiting for the other when out of synchronism.

Because of the flexibility of the test tape method of testing, it has been possible to impose upon each machine a much greater number of testing conditions than would have been practicable with specially designed test sets or manual testing. Also, since test tapes are made to conform in general with the requirements for the regular processing tapes, their use permits some of the routine testing to be done, if desired, by the regular operating forces.

A Test Unit for AMA Perforators and Readers

A. R. BONORDEN
Switching Systems Development

To simplify the testing and adjusting of perforators and readers used in the AMA system*, the test unit shown in Figure 1 was developed by the Laboratories as part of the maintenance facilities for accounting centers. It consists of a cabinet type relay bay, which houses the relay equipment of the test circuit and a rectifier for supplying 50 volt dc power, and a table carrying a control turret and mountings for a reader and a perforator. These mountings incorporate jacks through which the reader or perforator is electrically connected to the test circuit. The perforator mounting at the left, rides in a sub-base and turn table so arranged that after a perforator is plugged into the test circuit and fastened, it may be tilted and rotated to expose any face toward the attendant for adjustment purposes. The design also permits the bottom face of the perforator, which carries the paper advance mechanism, to be so exposed, as indicated in Figure 2.

Immediately behind the perforator mounting, rests an oscilloscope used to check reader contacts under dynamic conditions for chatter and phase difference. This instrument, being portable, is also available to the maintenance force for use outside of the test room. Floating fluorescent lighting fixtures are located above each of the machine mountings. The fixture over the reader carries a 5-inch magnifying lens which provides an excellent aid to vision when checking and adjusting the reader

* See pages 5, 18, 47 and 52.

Fig. 1—Perforator and reader test unit.

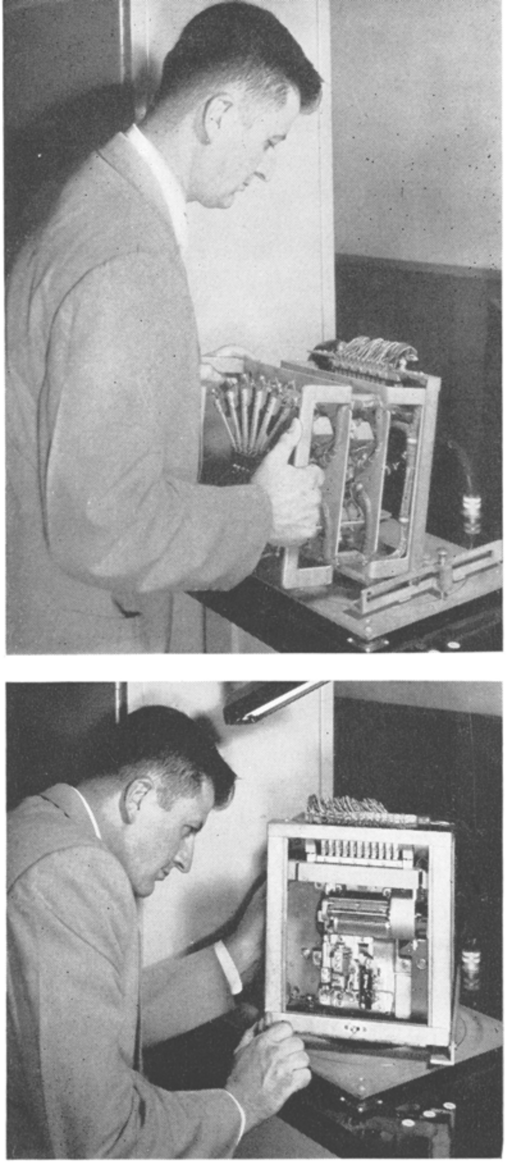


Fig. 2—By tipping up the perforator, sliding back and then rotating its mounting, its undersurface is exposed for inspection or adjustments.

contact springs. Below the table, provision is made for holding blank paper tape for the perforator and perforated tape for the reader, and for collecting the output tape from each machine in metal bins.

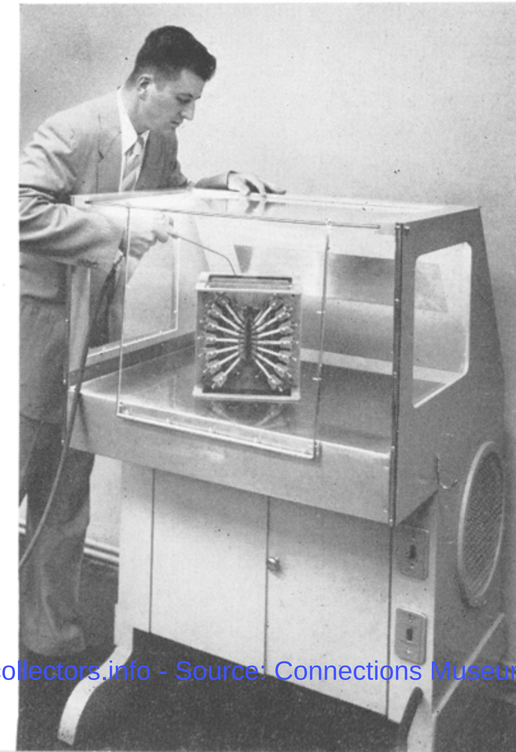
Also associated with the test unit is a cleaning cabinet, shown in Figure 3, which provides compressed air and a suction pump for removing accumulation of paper fibers and dust from the machines before adjusting, lubricating, and testing.

Each accounting center reader has twenty-eight reading pins with their associated spring contacts, two advance checking fingers also with their associated contacts, and sixty other pairs of contacts arranged in two groups: a perforating group and a control group. These three sets of thirty pairs of contact springs are driven by separate cams on the drive shaft and are phased differently.

In the lower part of the control turret there are three banks of thirty lamps on the right, and three banks of similarly arranged jacks on the left side of the turret. During a test, the lamps are associated with the three groups of contacts in the reader: thirty associated with the twenty-eight reading pins and the two advance check pins, thirty with the perforator contacts, and thirty with the control contacts. The jacks give access to the reader contacts and also to the perforator magnets. Above the lamps and jacks are two meters and a group of keys used in controlling the various tests. One of the meters is a dc voltmeter for indicating the output voltage of the rectifier; the other is a pulse-per-second meter used for indicating the running speed of the reader.

Certain sub-groups of contacts on the reader make and break at different points of the reading cycle, and one of the static tests of the reader is made to determine that each contact makes and breaks within specified angular limits of the drive shaft. In

Fig. 3—Perforator being cleaned with compressed air in the cleaning cabinet.



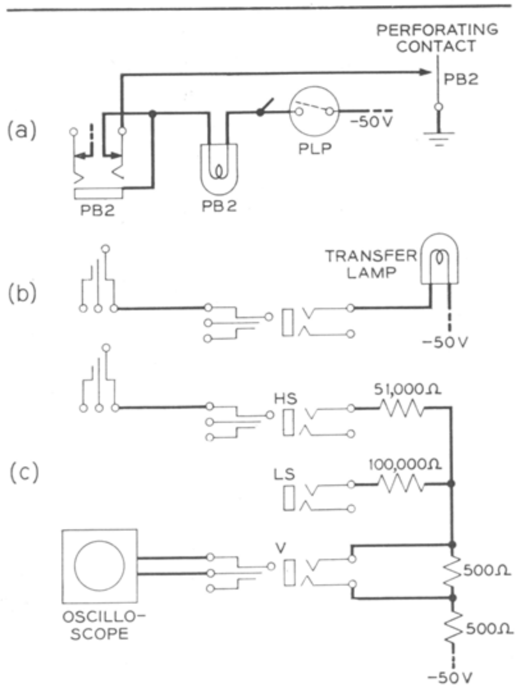


Fig. 4—Each contact of the perforator group of the reader is associated with a jack and lamp as indicated at (a) and through its jack may be associated with a lamp in the top of the test table, as at (b) or with an oscilloscope, as at (c).

making this test, the index wheel of the reader* is set to precise position while watching the lamps associated with the contacts to see that all those in each group light or go out within prescribed angular settings. When it becomes necessary to work on an individual contact spring, the strain of watching one lamp in a group is eliminated by a simple patch between the jacks at the turret. This patch connects the desired contact directly to a lamp located in the table top near the reader where its condition, whether lighted or not, is readily evident even though the eye is focused on the index wheel marking.

The association of the lamps and jacks with the contacts of the perforating group is indicated by the top drawing of Figure 4. Somewhat similar arrangements are provided for the other two groups of contacts. The lamp in the table top used for checking individual contacts is also associated with a jack, and it may be substituted for the lamp in the turret by use of the patch cord indicated at (b) of Figure 4. It will be noticed that the reader contact is connected to the tip of the jack, and this is true of the equivalent circuits for all three groups.

Among the dynamic tests of the readers are those for contact chatter, phase difference of contacts, and false closure on blank tape. For the first two tests, the oscilloscope is patched through a simple jack circuit, indicated at (c) in Figure 4, to the reader contact to be tested. With the reader running, each closure impresses a small voltage across the input of the vertical sweep amplifier in the oscilloscope to cause the trace to move upward. When the horizontal sweep is synchronized with the reader speed, the two horizontal lines of the repetitive trace, representing the make and break portions of the cycle, will readily indicate any chat-

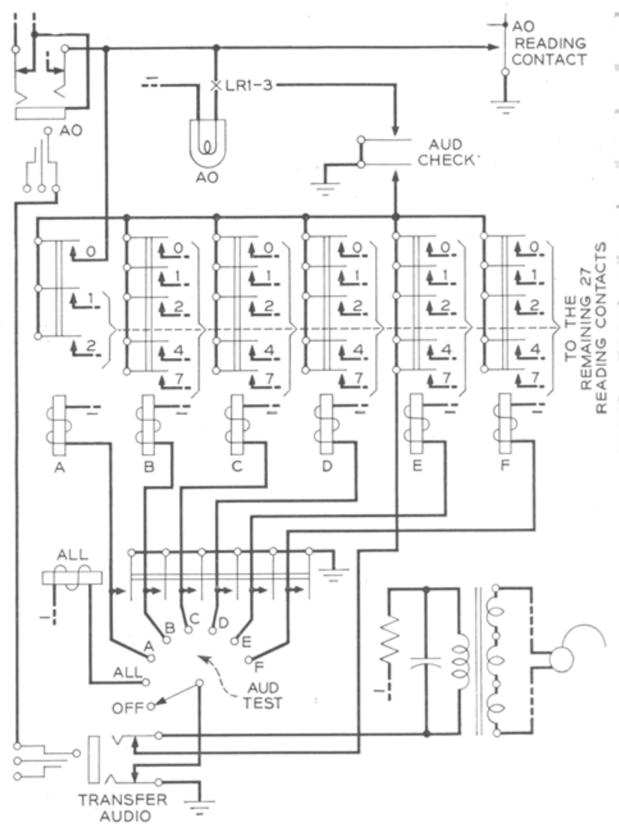


Fig. 5—Auditory test circuit employed to detect false closures of reading contacts sensing blank tape.

* See page 52.

ter or bounce during the cycle. By means of patching in a second reader contact to jack LS, it is possible to see the phase difference between the closure or openings of the two contacts. The second contact when closed alone provides a vertical deflection half that of the first, and when both are closed together, the deflection becomes one and one-half times that of the first alone. With one cycle of the trace spanning thirty-six divisions on the oscilloscope screen, out-of-phase conditions greater than five degrees are readily detected.

A telephone head receiver plugged into jacks in the front apron of the table is used to detect false closure of any of the twenty-eight reading contacts with the reader running and reading blank tape. Such contact closures are not necessarily cyclic and are difficult to observe on the oscilloscope screen. The telephone receiver provides a convenient method, and its sensitivity is excellent for this purpose. The usual varistor is connected across the receiver to limit the intensity of the audible clicks emitted on closure and opening of a contact.

The circuit arrangement used is shown in Figure 5. Three of the twenty-eight reading contacts are associated with the A digit of a line of perforations on an AMA tape, and five contacts are associated with each of the five remaining digits designated B to F inclusive. The contacts for each of the six digits of a line of the tape are connected to the test circuit through a separate relay, and which relay is operated depends on the position of the AUD TEST rotary switch. The first position of this switch, by operating relay ALL, connects all twenty-eight contacts to the test receiver. The lamps associated with the contacts are not connected to the circuit unless the LRI-3 relays are operated from the AUD CHECK key.

Before making the test, however, it is necessary to make sure that the test circuit itself is not defective. With the reader running without tape, the AUD CHECK key is operated and released after observing that all twenty-eight reading lamps flash, which checks the paths between contacts to the lamps. The AUD TEST switch is then turned to the ALL position and the AUD CHECK key again operated and released after observing that the same lamps light steadily, which assures that all contacts are connected to the test circuit. The receiver will now be emitting clicks. The actual test for false closures now consists in inserting blank tape into the running reader and noticing its effect on the output of the receiver. With blank tape in the reader none of the reading contacts should close and therefore all clicks should be eliminated.

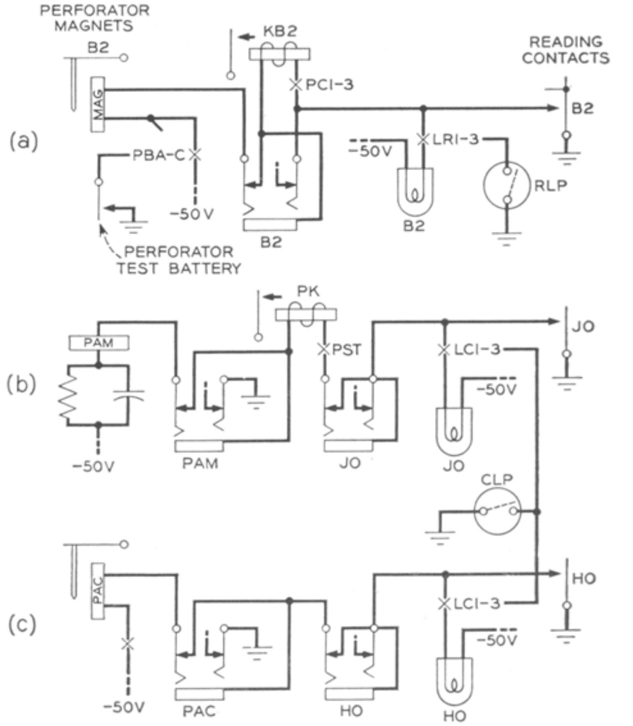


Fig. 6–Connecting paths of perforator magnets.

Should false closures be detected on the receiver with the AUD TEST switch on the ALL position, the switch is advanced step by step through the succeeding six switch positions. Each position leaves connected to the receiver one of the A to F groups of reading contacts. When the location of the contact failure has been narrowed to a particular group, the receiver circuit is then extended through a patch cord to each of the test jack tip springs individually in that group to locate the contact at fault.

For a static test of the perforator magnets, the circuit indicated in Figure 6(a) is employed. The jack indicated here is that for

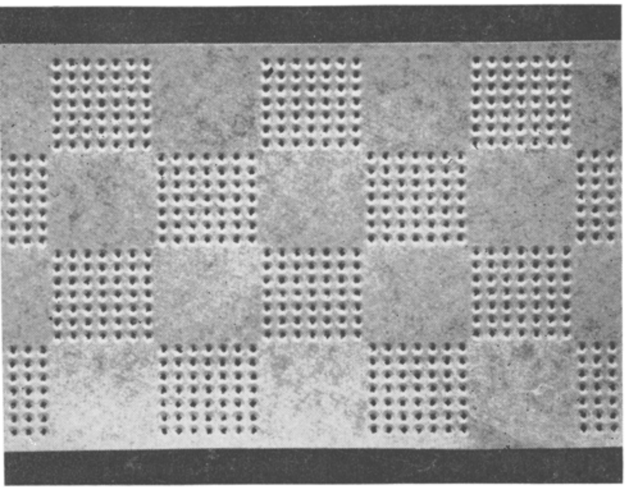


Fig. 7—Test pattern on tape used in over-all test.

one of the reading contacts, and like all the jacks has a reader contact connected to the tip. All the jacks for the twenty-eight reading contacts, however, have one of the perforator magnets connected to their ring contacts. When no plug is inserted in the jack, and relays PCI-3 have been operated for a perforator magnet test, there is a path through the winding of the check relay KB2 to the ring contact of the jack. The magnet may be operated individually by a patch from this ring contact to a ground jack or to a 35-type test set*, which permits the current flow tests.

During the adjustment of the perforator advance mechanism, it is necessary to have eleven of the perforator magnets operated. This is accomplished by rotating the reader index wheel by hand until the reading pins have completed their advance toward the drum on which has been placed a short piece of tape having a splice pattern. This allows eleven contacts to close and operate eleven magnets through check circuits like that of Figure 6(a).

Two additional jack circuits shown at (b) and (c) of Figure 6 provide electrical access respectively to the perforator advance magnet (PAM) and to the perforator advance check magnet (PAC) when equipped. As an aid in effecting and checking adjustments of the associated mechanisms, these two magnets may be conveniently operated by means of remote control keys (32A-test set) patched to jacks PAM and PAC.

* RECORD, *April*, 1940, *page* 134.

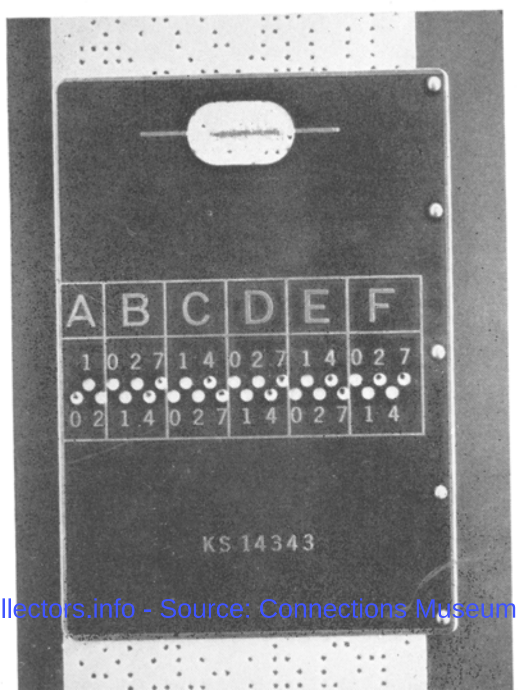
A final over-all operation test is used in which the reader under test reads a test pattern test tape, shown in Figure 7*, and drives a perforator known to be in good adjustment. Similarly a perforator under test is arranged to be driven by the test reader.

The test reader runs at a higher speed than service readers. It provides contact make and break periods which are representative of the shortest periods encountered by perforators serving in accounting center machines. The test pattern test tape provides a six foot length of "checkerboard pattern" preceded and followed by one foot of splice pattern. During the passage of this test tape through the reader the perforator is caused to perforate the pattern line by line as read, each magnet being operated from the corresponding reader contact over a test jack circuit such as Figure 6(a).

Just before the end of the test tape reaches the drum of the reader, the reader is stopped, the test tape is removed, and the leading end of the output tape from the perforator is inserted into the reader to initiate a "feedback" test. The reader is again started and allowed to run for five minutes during which time the perforator reproduces eight or nine complete test pat-

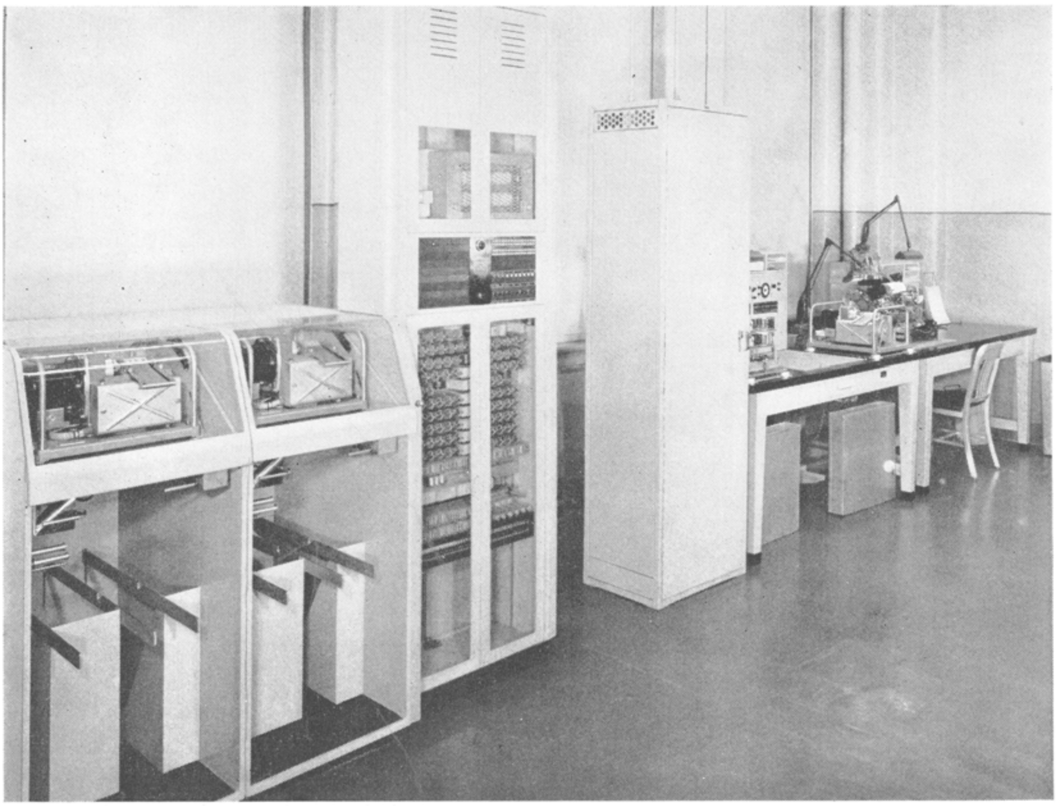
* *Specification* X-64669B, *List* 1.

Fig. 8—The KS-14343 tape reader in position on a tape disclosing a good line.



tern test tapes in tandem as a continuous output tape. Inasmuch as each such test tape is derived from the preceding test tape, any tendency toward malfunctioning in reading or perforating very often provides a cumulative worsening of any defective perforation through the reproduction stages so that these conditions are readily noticed when making a visual examination and comparison of the last and first test tapes in the output. Easily noticed also are missing lines and extra lines indicative of a failure of the drum to advance in the perforator and reader respectively.

The duplication at the test table of test tapes for the processing machines of the accounting center is also an important function and is accomplished as explained above for the initial reproduction of the test pattern tape. If errors exist in such input test tapes, they must be previously located and marked with the aid of the KS-14343 tape reader, Figure 8, so that the reader may be stopped a few lines ahead of the line containing the error. Control means then permit alternately stepping to and perforating each good line, and with dummy plugs and a patch cord the error may be corrected in reproduction or the bad line may be perforated correctly hole by hole.



Test room at Newark showing tape comparer unit, perforator and reader test unit, and printer test unit.

Performance Studies of AMA Readers and Perforators

H. T. DOUGLASS
Switching Systems Development

Perforators and readers, used in the accounting center of the AMA system, may be subjected to 25,000,000 and 250,000,000 operations per year, respectively, and in spite of their heavy operating schedules, they must perform reliably and require a minimum time-out-of-service for maintenance purposes. This goal has been achieved not only by rugged design of the machines but also by obtaining a thorough knowledge of the operating capabilities of the apparatus through intensive laboratory studies, thereby permitting the machines to be used at their optimum capability in the various circuit applications. These studies of readers and perforators were undertaken for three general purposes; first, to determine the operating characteristics of the reader or perforator as manufactured; second, to recommend changes in design to improve speed, assure reliability, lengthen maintenance-free service periods, and to increase circuit operating margins; and third, to establish working limits and field test requirements for the final product to insure the maximum service interval before readjustment is necessary.

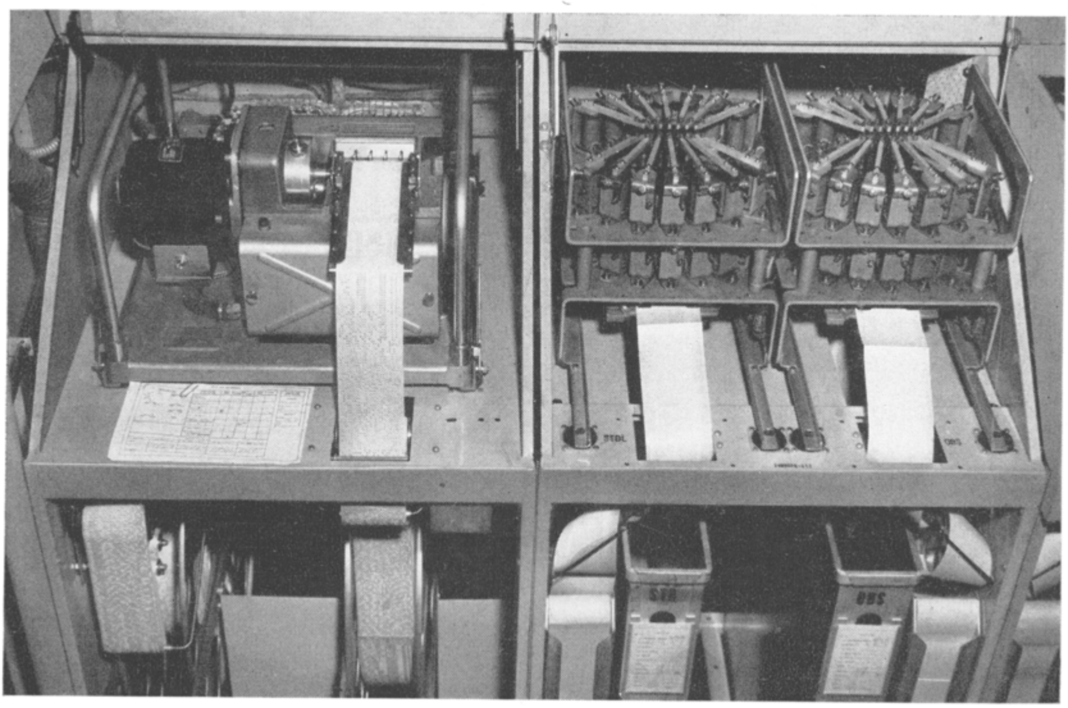
The physical characteristics of the paper tape used for recording call data have considerable influence on the reliable operation of readers and perforators. The texture of the tape must be such as to permit it to be readily punched by the perforator, yet strong enough to resist penetration by repeated impact of the reading pins when the tape is stationary in the reader. Oiled perforator tape paper four thousandths of an inch thick was selected as providing the best over-all performance. This is a No. 1 grade (best quality) sulphite bond paper made without the clay loading usually used in sulphite papers to render them more opaque and to make the surface more satisfactory for writing or typing. Clay loading is considered objectionable in AMA tapes because it increases abrasiveness of the paper.

The tape, three inches wide, is supplied in approximately three-thousand foot lengths, which are fan-folded into a nineteen-inch package approximately eleven inches high. Folding in this manner permits the tape to be withdrawn from the container without excessive drag, and makes a continuous supply of tape available for the perforator, since the trailing end of one package can be readily spliced to the leading end of the next package.

The early experimental models of readers and perforators were designed and constructed under the direction of W. W. Carpenter. To establish the range of operating capabilities, the models were tested under limiting conditions, simulating extremes of actual operating conditions. To do this a special laboratory test frame was constructed which provides facilities for repetitive or start-stop operation of a group of perforator magnets at various speeds and circuit closure intervals. The circuit, shown in Fig. 1, is arranged so that pulse-machine closures operate a group of fifteen mercury-contact relays each of which, in turn, when operated, closes a ground to operate one of the perforating magnets. Jacks and keys provide facilities for operating the perforator magnets in any desired combination, as well as the paper advance magnet. The mercury contact relays provide chatter-free impulses, and adjustment of the timing potentiometer permits the operate and release times of the relays to be made equal so that no distortion of the impulses is indicated when the pulse trace is observed on an oscilloscope. The impulse which controls the paper advance mechanism may be delayed in continuously variable amounts up to nine milliseconds by the condenser-timed delay relay. Controlled variations in the speed and the ratio of make-to-break intervals of the pulse machine provide means for establishing the limiting conditions under which satisfactory operation of the perforators may be obtained.

For satisfactory perforator operation, all magnets, when operated in groups of fourteen, must produce well centered, fully embossed, uniform perforations, and the advance of the tape through the perforator must be accomplished without observable irregularity. The over-all operating capability of the perforator is thus limited either by the perforating magnet having the poorest capability or by the paper advance magnet. In making these tests, the effects on over-all capability of series check relays, of variations in mechanical adjustments of the individual perforating magnets, and of variations in lead resistance and voltage are also determined. The variations investigated include adjustments of armature travel, distance of perforating pins from tape, armature restoring spring tension, and similar factors. Proper consideration is also given to the effects of magnetic interaction and the vibration of the parts under repetitive operation at various speeds.

To determine the capability range, impulses of a selected speed were applied to the groups of perforating magnets, and the ratio of the open and closed periods of the impulses was varied in small steps until the perforator either failed to advance the tape properly or until inspection of the perforated tape disclosed light, missing, or off-center perforations. When this point had been determined, the make-break ratio of the operating impulses was adjusted until satisfactory perforations and advance of the tape were obtained and the maximum and minimum settings were recorded as the limiting capability at the selected speed. Similar data were obtained at speeds ranging between five and twenty-five impulses per second. To estimate the anticipated life of the perforators, the models were operated continu-



A reader at the left and two perforators at the right as used in an AMA accounting center.

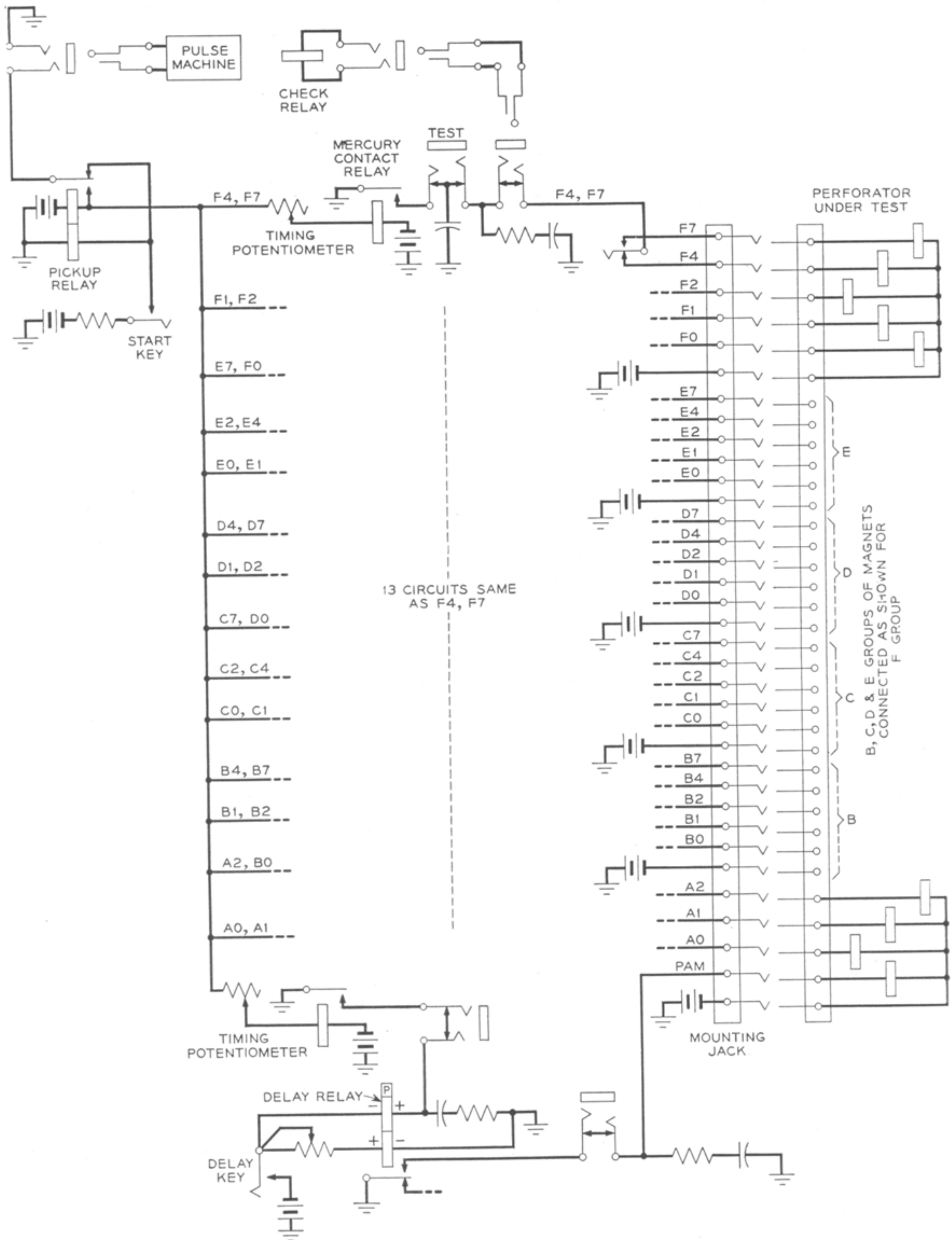


Fig. 1—Perforator testing circuit.

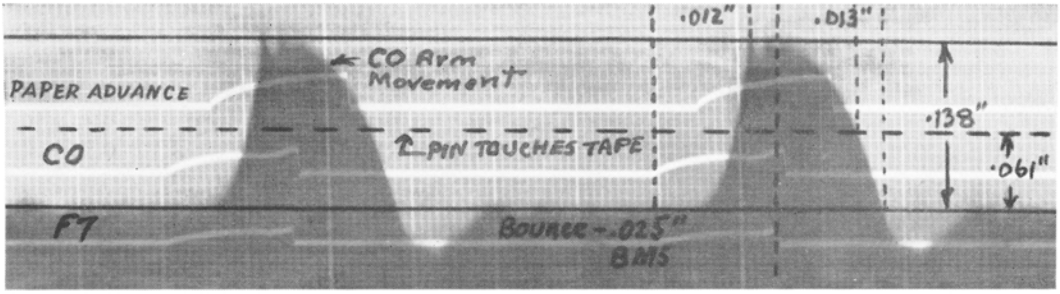


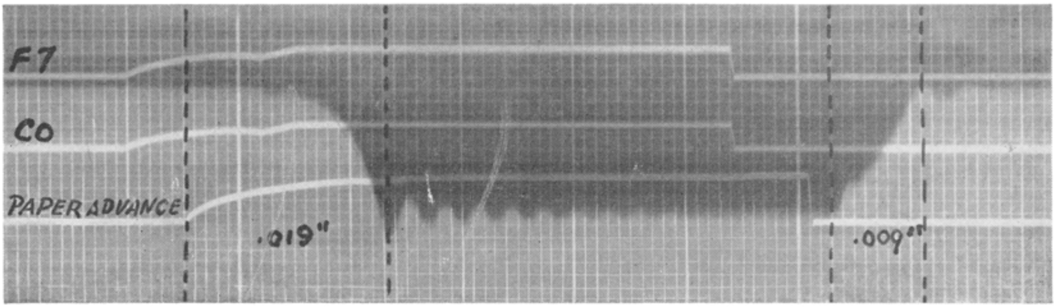
Fig. 2—Shadowgram showing movement of the CO perforating arm.

ously with frequent inspections to determine the wear and adjustment changes.

The results of the tests outlined above indicated that the design was functionally satisfactory. The need for modifications of the original design to reduce wear, increase reliability of operation, and facilitate manufacture and field maintenance, however, was also indicated. Some very effective tools for determining and recording the various motions are the stroboscope, the shadowgraph, and the high-speed motion picture. A preliminary analysis of the motions of the various parts was obtained by operating the perforators at various speeds and circuit-closure times from an interrupter, and observing the motion of the parts using a stroboscope. In this manner critical motions were located and selected for more detailed study and analysis. By means of the stroboscope, the apparent motion of the various parts may be slowed or stopped and the action of the parts under operating conditions observed visually.

For more detailed study of the motion of individual parts and the relation of this motion to the current flow through the magnets, the rapid record oscillograph equipped with a shadowgraph attachment was used for obtaining a photographic record of the time relation of the events involved. Figure 2 shows a typical shadowgram illustrating the movement of the perforating magnet arm, and Figure 3 is a similar illustration showing the motion of the arm of the paper advance magnet. The electrical circuit of the magnet is connected to the oscillograph string in such a manner that a deflection proportional to the current through the magnet is reproduced on the sensitized paper. Superimposed on this current record is the shadow showing the motion of a point on the arm as it moves from the unoperated to the operated position. The trace of the current operating the perforating magnet is marked CO on both oscillograms, while that for the current to the paper advance magnet is marked PAPER ADVANCE. Trace F7, which is in synchronism with CO, may be neglected. The fine vertical lines of the figures are spaced one millisecond apart, thus providing a positive measurement of the time of application of the operate current and the motion of the arm. By this means the speed of motion of critical parts was determined for establishing final requirements. High-speed motion pictures of the action of various parts under repetitive operation con-

Fig. 3—Shadowgram showing motion of the armature of the paper advance magnet.



tributed further to the determination of the capability of the perforators, and disclosed interactions that could be eliminated by modification either in mechanical adjustment or in the associated control circuits.

After analyzing motions of various parts of many typical perforators by the method described above, a composite chart of the seconds passes before the magnet begins to operate, and about twelve milliseconds more is required for the perforating pin to complete its travel. These figures are averages; the maximum and minimum are both indicated on the diagram. A dwell period of about four milliseconds is then allowed to insure a crisp, fully embossed perforation

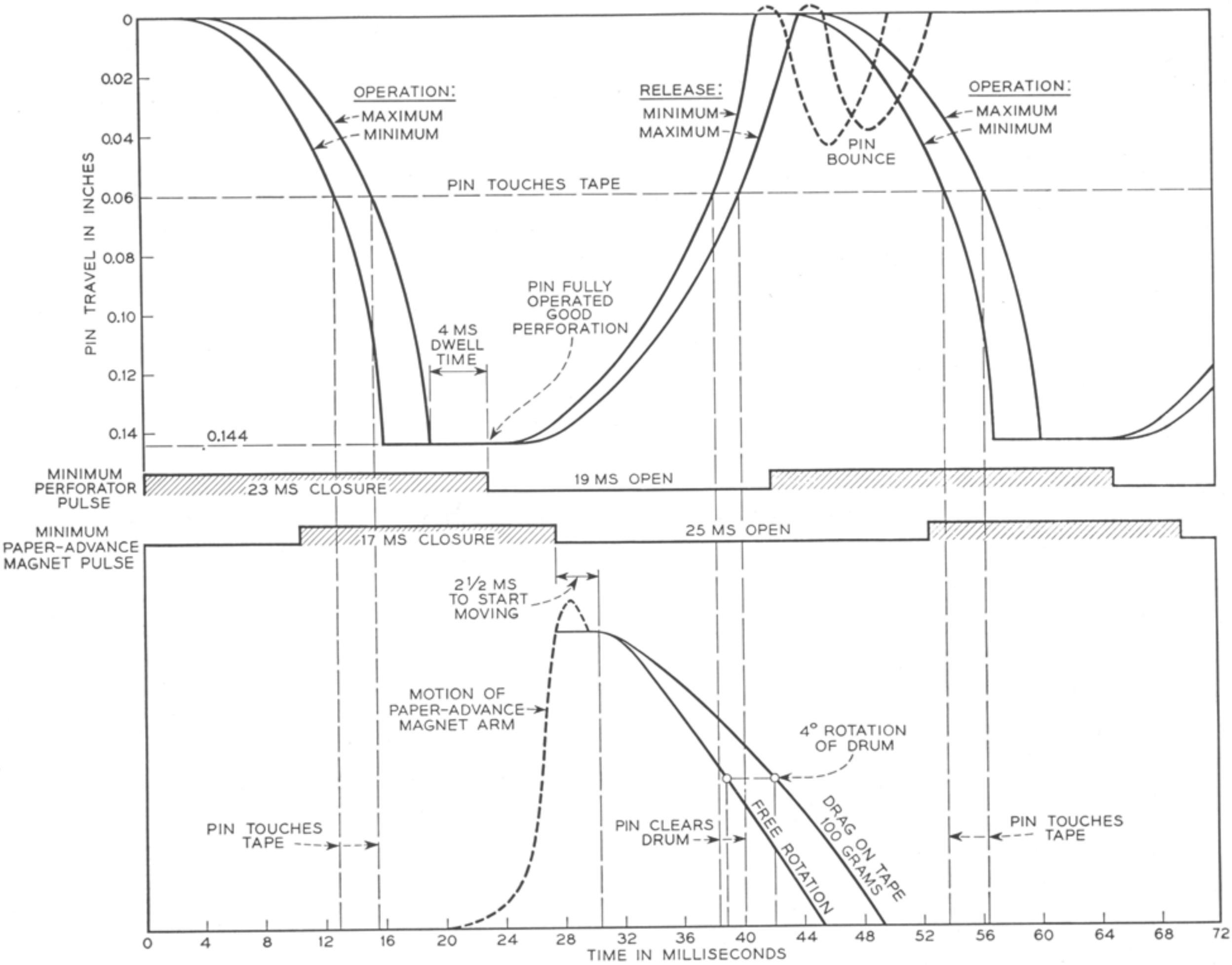


Fig. 4—Maximum operating limits of the KS-13882 perforator.

perforator operation was prepared and used to establish limits of operation from which maintenance and manufacturing requirements were set. This type of chart is illustrated in Figure 4 for the limiting capability of the perforator. The circuit to the perforating magnet is closed at the left end of the upper diagram and remains closed for twenty-three milliseconds. About six milli- before the circuit to the magnet is opened and the perforating pins are retracted. A horizontal line indicates the point where the pin touches or leaves the paper tape.

The circuit to the paper advance magnet is closed about eight milliseconds after the circuit to the perforating magnet has been closed. Tape advance is accomplished, however, on the release of the paper advance magnet, and the circuit to the magnet is not opened until after the perforating pins have started to retract. Because of the conical ends of the perforating pins, indicated in Figure 5, rotation of the drum may be begun before the perforating pin has completely left the paper. Actually nearly half the rotation has been made by the time the tip of the perforating pin leaves the upper surface of the paper.

Figure 6 shows the test limits established for the perforators to insure proper operation in service based on a testing speed of twenty pulses per second. Service operation is at a speed of sixteen pulses per second, twelve milliseconds being added to the closed contact intervals to provide time for the operation of associated circuit control relays before the perforating pulse is applied to the magnets.

Mechanical requirements applying to the various moving parts were selected to insure maximum over-all speed of operation and fully embossed uniform perforations. Variations of such adjustments as perforating-magnet armature travel, retractile spring tension, and operated armature gaps were explored, and limits were established that would insure most effective operation of the perforators. For example, the retractile spring tension of the perforating magnet must be sufficiently high to insure proper withdrawal of the pin, but must not be high enough to require excessive current through the magnet or to increase the maximum operate time of the magnet beyond the limits imposed by the over-all operating conditions. Oscillographic records of operate and release times obtained with various retractile spring tension adjustments supplied the basic information for establishing the ultimate requirement.

To show the full satisfactory operating range of the perforators and the relationships of the various test points to this range, plots like that of Figure 6 were employed. The duration of an operating cycle, which is the reciprocal of the operating frequency, consists of a break period, b, and a make period, m, of the circuit to the operating magnet; and the break period as a percentage of the total, p, is thus 100b divided by m + b. When the break period is too short, the drum will not advance properly because the pins will not have sufficient time to withdraw. When the break period is too long, on the other hand, the make period will become too short to allow the pins to perforate the paper properly. There is thus both a lower and an upper limit for the per cent break period at any frequency, and these are indicated by the two curves of Figure 7.

The per cent break is readily varied for test purposes by changing the make-to-break ratio of the interrupter supplying the operating magnets. The lower curve of Figure 7 was obtained by adjusting this ratio at various operating frequencies until the shortest break period was found at which the perforator would advance properly. Similarly the upper curve was determined by increasing the per cent break until the make period was just long enough to give satisfactory perforation. If the minimum break period were the same at all frequencies, the lower curve would be a straight line with the equation $p = 100bf$. As may be seen from Figure 7, the lower curve is a straight line and gives a break period of about 17.6 milliseconds. Similarly if the same minimum make period was required at all frequencies,

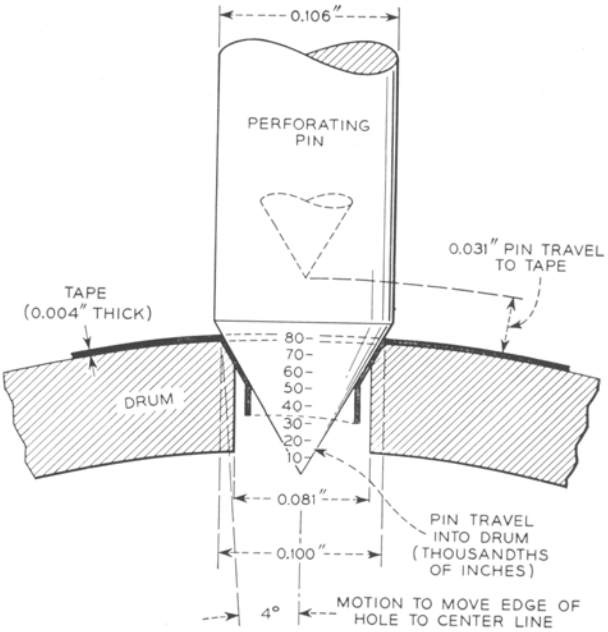


Fig. 5—Cross section of a perforator pin and part of the drum (ten times actual size).

the upper curve would be a straight line with an equation p = 100 (l-mf). This curve also is seen to be straight, and gives a value of m of 16.3 milliseconds. The maximum operating frequency, which is the reciprocal of m + b, is thus 29.5 cycles. This, it will be observed, is the frequency where the curves intercept.

Any combination of per cent break and frequency that lies in the space enclosed by these two curves is within the limiting overall capability of the perforator. The normal operating point is indicated by a circle, while the field test point is indicated by a triangle. Shop test points for minimum break period and minimum make period are also indicated.

The primary function of the accounting center reader is to translate the perforations in the tape into contact closures of proper duration to cause the associated relay circuits and perforators to function and thus accomplish the assembling, sorting, computing, and billing functions incident to processing the tape. Auxiliary contacts, operating either in synchronism with the reading contacts or at a predetermined interval later, provide for circuit control, paper advance, and perforator operation.

In the accounting operation, each line of information on the input tapes must be accurately read and recorded before the tape is permitted to advance to the next line. The paper advance mechanism of the reader is held locked in position under circuit control until the associated circuit indicates that the line has been accurately read and recorded. At this point the drum locking feature is released permitting the reader to advance to the next line. Critical time margins are involved in these operations, and laboratory studies established release times adequate to insure proper movement of the tape during circuit operation.

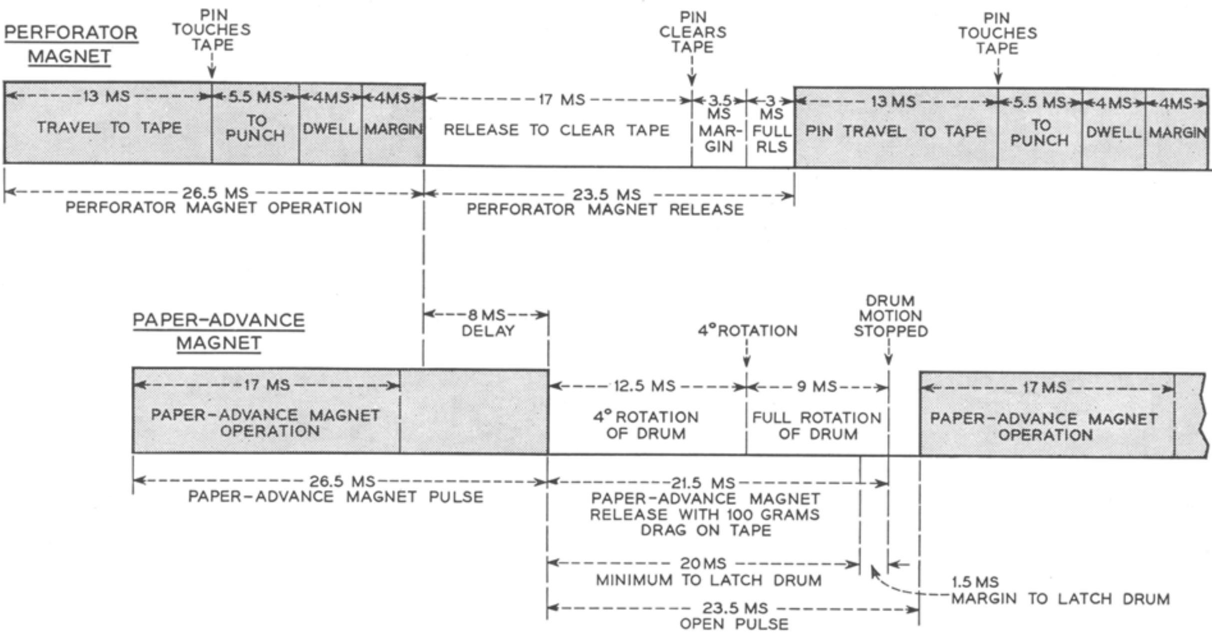


Fig. 6—Operating-time chart for perforator test at twenty cycles per second.

The permissible variation in phase of the reading and control contacts, the effect of instantaneous speed variation on the reader pulses, and the effect of the drag on the input tape were explored and the design of the readers and the associated control circuit coordinated to insure adequate margins for accurate reading.

Laboratory studies on the current readers were concerned chiefly with the determination of the operational characteristics of the various parts of the reader mechanism and the over-all coordination of these characteristics with the circuit conditions imposed by the associated circuits. Items considered in the laboratory studies included contact phasing and chatter, margins for preventing false closure on unperforated tape, interposer magnet operate and release characteristics, relation of drum motion to reading pin motion, and the resistance of tape to false perforation under repetitive impact of the reading pins. As in the case of the perforator, the stroboscope, the rapid record oscillograph, and high-speed motion pictures were used to obtain data for use as the basis of establishing requirements for maintenance and for recommended improvements in reader design.

The initial commercial installation of the AMA system was put into operation in Philadelphia during 1948. Subsequent installations have been made in Newark, Chicago, Detroit, and other locations. The performance of the readers and perforators in these installations has been outstanding, and has clearly demonstrated the value of thorough analysis of the inherent capabilities of the apparatus in its application to the proposed circuit arrangements. Laboratory studies of the readers and perforators, with the resultant improvements, contributed materially to bring about the reliable record of operation of these machines.

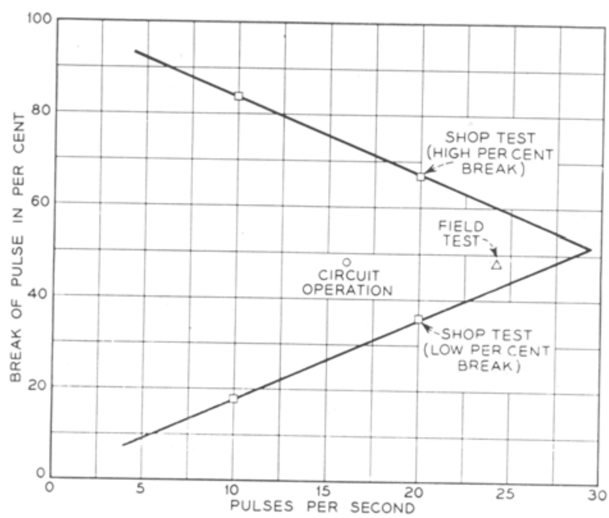


Fig. 7—Operating range of the perforator in terms of frequency and of the ratio of the break period to the length of the operating cycle, which is the reciprocal of the operating frequency.

Accuracy Provisions in AMA

G. V. KING
Switching Systems Development

Although a high degree of dependability is sought and maintained in all telephone circuits and operating procedures, it becomes of dominant importance in the automatic message accounting system. If the bills presented monthly to customers are not accurate, the system producing them cannot be justified regardless of any favorable features it may possess. This need for accuracy was recognized at the very beginning of the development of the AMA system, and has been the guiding influence throughout.

Other articles have described various features built into the central office equipment to assure accurate central office tapes. Such features are provided in the individual relay circuits, which tell what is happening on each call, in the circuits for electrically transferring charging information through the numerous central office paths, in the timing circuits, and in the equipment for perforating the information in the central office tapes. Trouble entries are automatically made when an irregularity has been detected that might affect charging, and special testing facilities are furnished to aid in locating and clearing troubles. In accounting centers, which process the output of many central offices, accuracy provisions play an even greater role. Earlier articles on accounting center equipment have indicated some of these, and others are described in the present article.

Undoubtedly the most important accuracy aid is the 2-out-of-5 code. It is used extensively in both central office and accounting center design, and it has merits for electrical storage and transfer of information similar to those afforded in recording on paper tape. As has been described earlier, the records on the central office tapes, and on the numerous tapes prepared in the course of accounting center processing, consist of coded numbers perforated in successive lines across the tape. There is space for six digits in each line, and all except the first, or A digit, which is used only to aid in identifying information carried by the rest of the line, are perforated in the 2-out-of-5 code. In the space allowed for each digit there is room for five perforations, but of these possible five, two and only two are used to represent a digit. All the accounting machines are arranged so that during the reading, recording, or perforating of information they check that there are two and only two elements for each digit. Practically every type of trouble that could arise, such as defective paper, relay contact failures or open, and crossed or grounded leads, will result in fewer or more than two elements for a digit. This use of the 2-out-of-5 codes thus makes practically certain that the information on the tape is correct.

Another and very important over-all accuracy requirement is the proper identification of all AMA tapes. In the central office where the original tapes are made, a group of recorders perforate tapes for all calls handled by a marker group, which may serve more than one central office. There may be as many as twenty recorders in a group, and each recorder will perforate upward of 100 feet of tape a day. These tapes are removed from the recorders and sent to the accounting center periodically, and for a maximum recorder group there may thus be twenty reels with a total of nearly half a mile of tape for each day's business.

After each processing stage in the accounting center, new tapes are perforated until the printer is reached, which – as a final re-

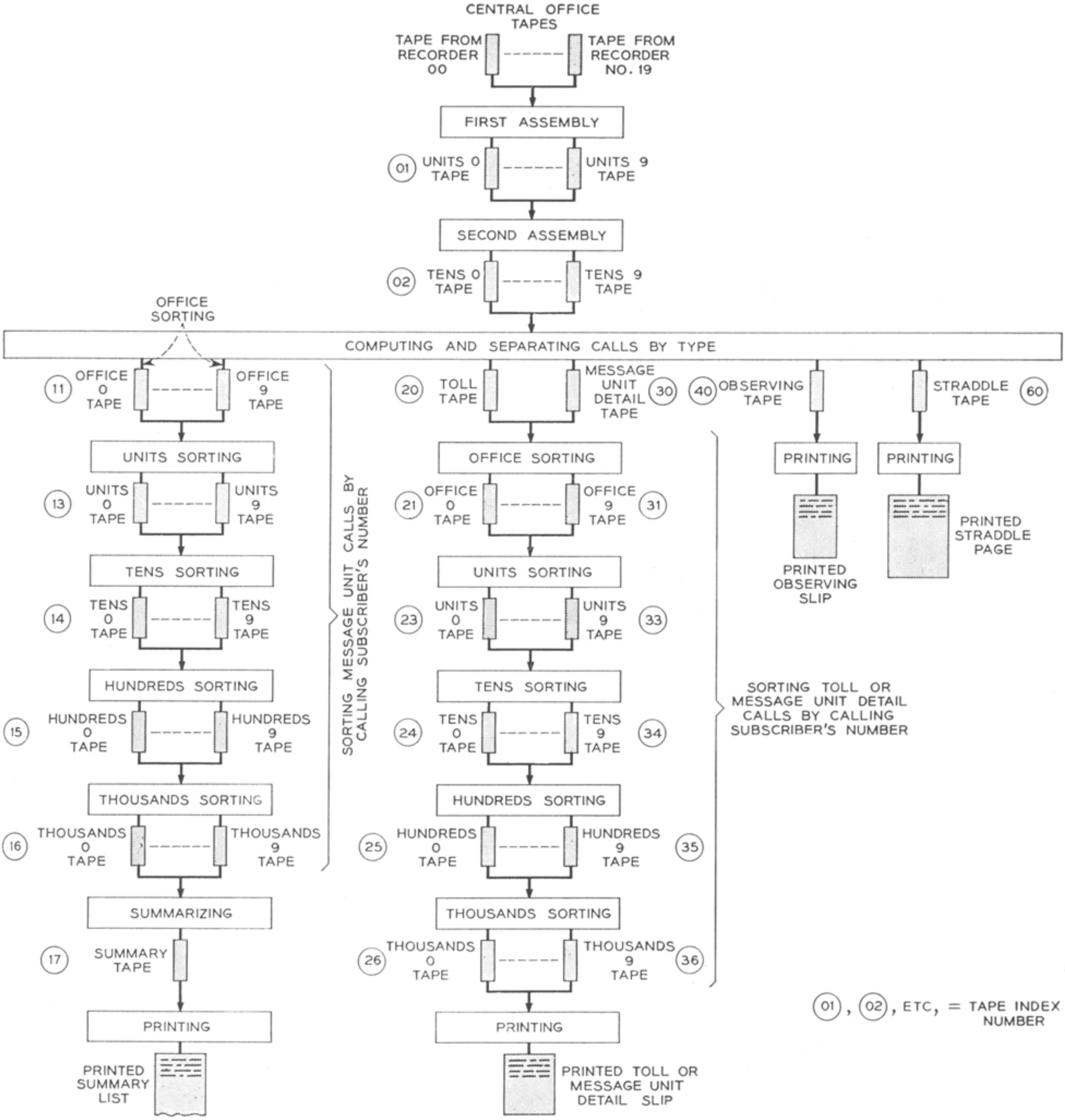


Fig. 1—Diagram showing the various stages in the accounting center process.

sult – prints a list by subscriber number of all calls made during the accounting period. The various stages in the accounting center process are indicated in Figure 1. The central office tapes are spliced together consecutively in order of their recorder numbers, and are then processed through the first assembly stage. The ten output tapes of this stage are spliced together in order and processed through the second assembly stage. This operation produces ten new output tapes on which all of the elements of a call are adjacent. These ten tapes are then spliced in 0 to 9 order and processed through the computing stage, which computes chargeable time on all calls, and message units on local calls. The output of this stage consists of ten message unit tapes, one toll tape, one message-unit detail tape, one observing tape, and one straddle tape.

Each of the message unit tapes containing calls from one central office are processed separately through the remaining stages. This consists of sorting by the calling subscriber's number, summarizing all the message units for the billing period for each subscriber, and printing a list of message units chargeable to each subscriber. Each of the other tapes from the computer contains calls from all of the offices in the marker group. The observing and straddle tapes go to the printer without sorting. The toll and message unit detail tapes are sorted by calling office and by the calling subscriber's number, and then go to the printer.

Since there is a tape from each recorder of each marker group for each collection period, and tapes from each accounting stage, there is a very large number of tapes in an accounting center all the time. The need for the proper identification of each tape is therefore obvious. This identification is of two forms. To permit the accounting center attendants to identify the tapes so that the proper ones will be supplied to the proper machines at the proper time, each tape is marked on its outer end by a rubber stamp or by an associated tag. The other or more basic identification of the tape, however, is carried by a group of identification entries perforated at each end of each section of tape. In general, this information is required to make sure, when processing calls made by a particular group of subscribers in a particular period of time, that all tapes containing such calls are included, that no tape is processed twice, and that tapes containing calls made at another period or by other subscribers are excluded. The machine attendants get their instructions as to which tapes to process from assignment slips, which also give information

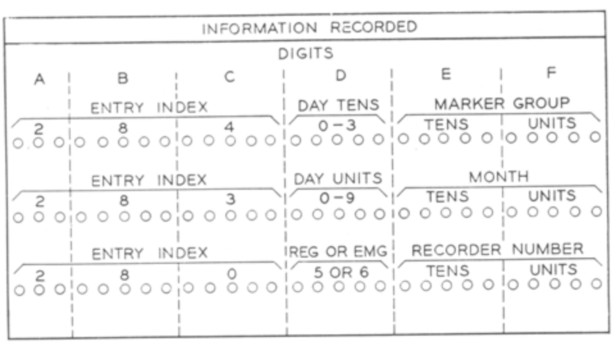


Fig. 2–Tape identification entries punched in the tapes at a central office.

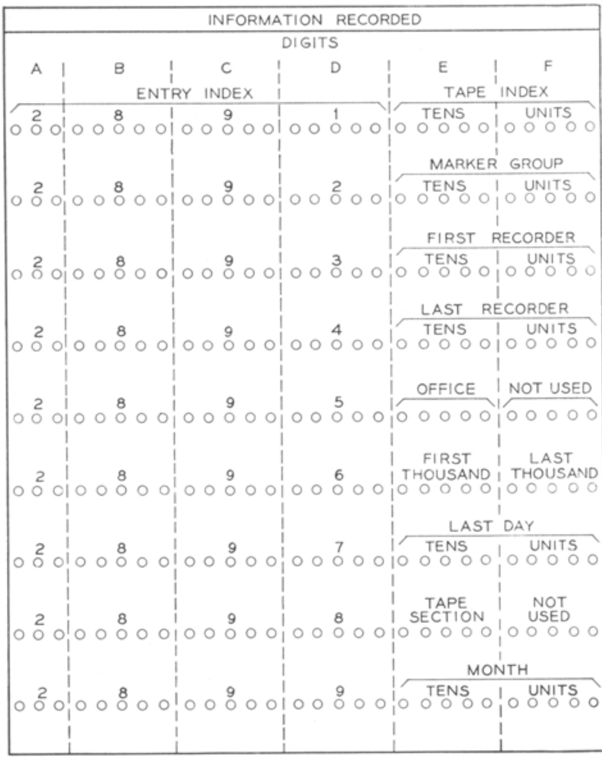


Fig. 3–Tape identification entries punched in the tapes in an accounting center.

as to the settings of the various checking dials on the processing machines. As the tapes are "read" by the various machines, their identification entries are checked against the information set on the dials, and should the information be found not to check, the machine will stop and give an alarm. By this means all tapes are checked for marker group, month, and day. The central office tapes and the assembler tapes are also checked for recorder number. In addition, the accounting center tapes are checked for stage of processing and, after office sorting, for the office index.

Tape identification entries are of two general types: one is perforated in the tape at the central office and is used only at the first assembly stage; the other is perforated in all tapes made at the accounting center. The central office tape identification entries, shown in Figure 2, are characterized by a three-digit entry index each starting with 28, which defines the nature of the information in the remaining three digits. The D digit of the 284 line together with the 283 line identifies the day and the month during which the calls recorded on the tape were made. The E and F digits of the 284 line identify the marker group in which the calls originated. The identity of the marker group together with the recorder number, which is perforated in the 280 line, completely identifies any central office tape for a particular day.

These identification entries are used by the assembler only for the first assembling stage. In perforating new tape, however, the assembler and all the other accounting center machines perforate an identification entry of the type shown in Figure 3. Here a four-digit entry index beginning with 289 and comprising the digits A to D, inclusive, is employed to indicate the information carried by the E and F digits of each line.

The stage of processing, or tape index, is indicated by entry 2891 of Figure 3. This is a two-digit number. The first digit indicates the type of tape – message unit, toll, etc. – while the second digit gives the processing stage. These tape indexes are marked beside the various stages in Figure 1.

To insure that all tapes are included and that no tape is processed twice, each machine requires that the tape sections which it reads be in numerical sequence. The central office tapes are checked for recorder number sequence (280 entry) and the accounting center tapes, for tape sections 0 to 9 (2898 entry). If complete agreement is obtained during the tape identity checking, the machine proceeds, otherwise it stops and signals the attendant, who then takes corrective action.

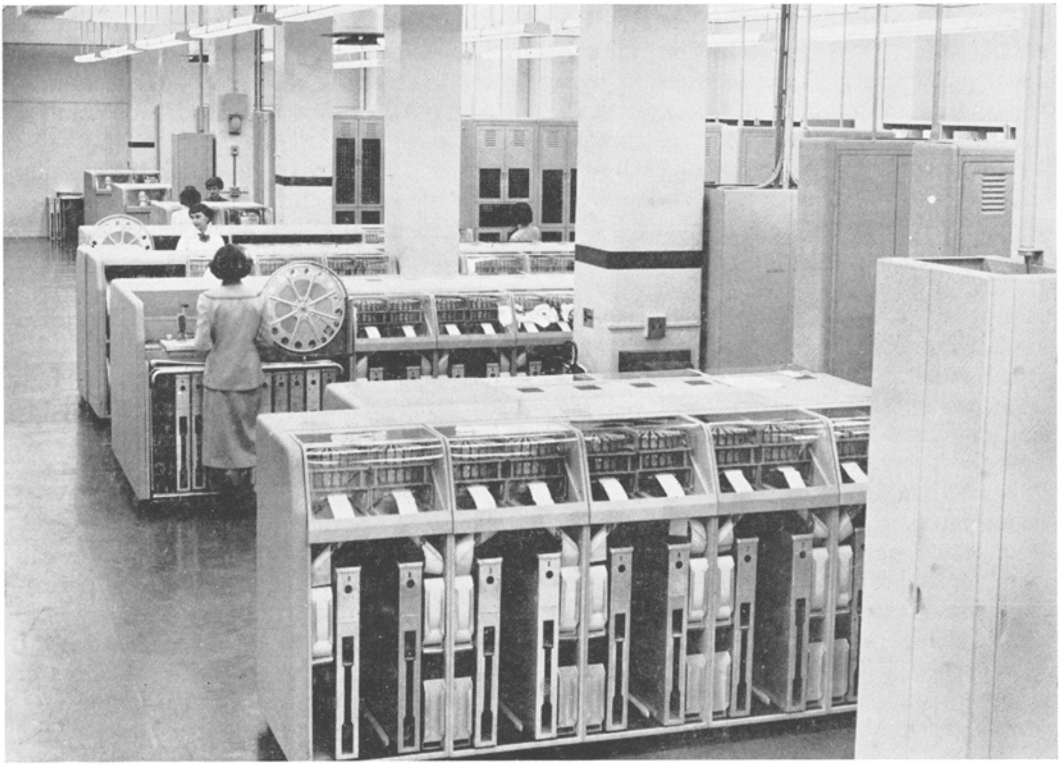
Operating procedures have been set up which further safeguard accuracy. All central office tapes for each marker group are spliced together in recorder-number sequence. Accounting center tapes which are to be processed as one run are also spliced together. This splicing tends to prevent tapes being processed twice, since a long tape, after it has been read, will have its starting end toward the inner or center of the reel and could not be processed again without rereeling. A short unspliced tape might not be on a reel, and processing it again could be done in error.

Other checks are made which are peculiar to the type of machine. The computer deals with individual elements which make up a call: the initial entry, the answer and disconnect entries, hour entries, and various entries that indicate cancelled or straddled conditions. Since many of these entries are not always present on a particular call, failure to register any of them and hold the information until needed would not be detected, and would result in inaccuracies unless safeguards were introduced. The loss of the answer, the disconnect, or an hour entry would result in loss of revenue if the call lasted longer than the initial charge period. Since the purpose of the cancel entry is to prevent the computer from charging for the particular call or for overtime, the loss of such an entry might overcharge the customer. To prevent these inaccuracies, the computer registers this type of entry in two places, completely independent of each other. In one place it merely registers the type of entry, but in the other the actual information contained in the entry. The circuitry is such that when the information is to be used, if an entry is registered in one place it must also be registered in the other or the machine will not proceed. If the entry had been registered in only one place, a circuit failure such as an open lead, might have dropped it out, and the machine would have no way of knowing that this had happened. The probability of two faults that would drop out both entries is negligibly small, however.

In printing the information in the final stage, the standard teletypewriter code is not used since it is a five-element code using from one to four elements to represent a digit. It thus lacks the advantages of the 2-out-of-5 code. A new code was devised for the printer, therefore, in which each digit was represented by two elements.

In addition to the self-checking features, test tapes are provided for each machine. These consist of input tapes which contain entries and combinations of entries for checking all the operating features, and output tapes which contain the entries that would be perforated by the machine if it were in perfect working order when the input tape was processed. To test a machine, the input test tapes are processed, and the output tapes thus obtained are automatically compared in the tape comparer with standard output tapes. If the tapes are identical the machine has done its job accurately and correctly.

As a result of these provisions for insuring accuracy, the report on the accuracy test of an installation in Philadelphia stated: "There were no overcharges of any kind. Undercharges occurred amounted to 0.78 per 10,000 messages, or 0.0078 per cent."



General view of a section of the accounting center in Newark.

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