A Throwdown Machine for Telephone Traffic Studies

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(Manuscript received December 3, 1952)

In order to study the traffic-carrying characteristics of the No. 5 crossbar switching system, a machine has been built to simulate the operation of the system. This machine, known as a throwdown machine, is controlled by a team of four operators. Its input is a statistically accurate representation of telephone traffic and its output is a detailed record of the course of each call through the system. This paper discusses the design principles of the throwdown machine, its operation, and the type of results obtained.

INTRODUCTION

Existing analytical methods are inadequate for investigating many statistical problems in which a large number of variables and their interactions must be considered. The problem of evaluating the performance and traffic capacity of a large automatic telephone switching system is one example. Others involve logistics, air and highway traffic control, and certain phases of military and naval strategy. All these require the assimilation of large quantities of data, processing the data according to certain procedures which are often empirical, and producing final information from which performance of the system or the excellence of the procedures can be judged.

These problems fall in the general category of "systems evaluation." The types of systems considered are those that are capable of a large number of variations depending on the nature of the input data, and must be judged on a statistical basis. One method of study might be to operate and observe an actual system. There are a number of objections to this. Operation may be so slow that the accumulation of sufficient data may require excessive time or, as in the case of a telephone switching system, so rapid that it is impractical to make the necessary observations. Operating the system under controlled conditions in these cases may be too expensive or indeed impossible. Then, too, the system may be proposed only and not yet exist.

One solution is to devise a method of simulating the performance of the actual or proposed system which through the use a suitable time scale will permit the necessary information to be obtained. The simulation may be done entirely on paper by recording each state of the system and modifying this state with each bit of input information according to the system plan, as though a log were being kept of the performance of the actual system.

Since the general problem involves large quantities of input data which are statistical in nature, all possible variations cannot be studied. A sufficient number of typical situations must be tried to obtain statistically reliable results. These methods have been extensively used in telephone traffic studies and are called "throwdown" studies. The name stems from the use of dice in the early study of telephone traffic problems. Each die is designated to represent a particular independent event and the faces of this die are designated according to the probability of the event taking place. By repeatedly "throwing down" a number of such dice and observing the results, the probability of a particular combination of events taking place can be estimated. Other similar methods based on selections from lists of random numbers have been used in telephone traffic studies for a number of years. Recently, mathematicians, using digital computers, have employed similar statistical methods in problems relating to the diffusion of gases, electron ballistics and the solution of certain types of differential equations. They have called this the "Monte Carlo" method.

Various mechanical aids can be used in running a throwdown study. This paper will discuss the techniques of throwdown studies and will describe a semi-automatic throwdown machine which was constructed for studies of the new No. 5 crossbar switching system used in local telephone central offices. A general view of this machine is shown in Fig. 1. It is a system of electrical switching circuits, signal lamps and mechanical devices which simulates a large telephone switching system and its associated subscribers. The machine is controlled by a team of four operators. Artificially generated telephone traffic is processed by this machine in a manner analogous to the action of the actual system. Detailed records are made of the progress of each call and the traffic situations encountered. After a sufficient number of calls have been processed, the recorded information can be analyzed by statistical methods to obtain desired information. The action of the system is simulated in sufficient detail to insure that results are representative of actual

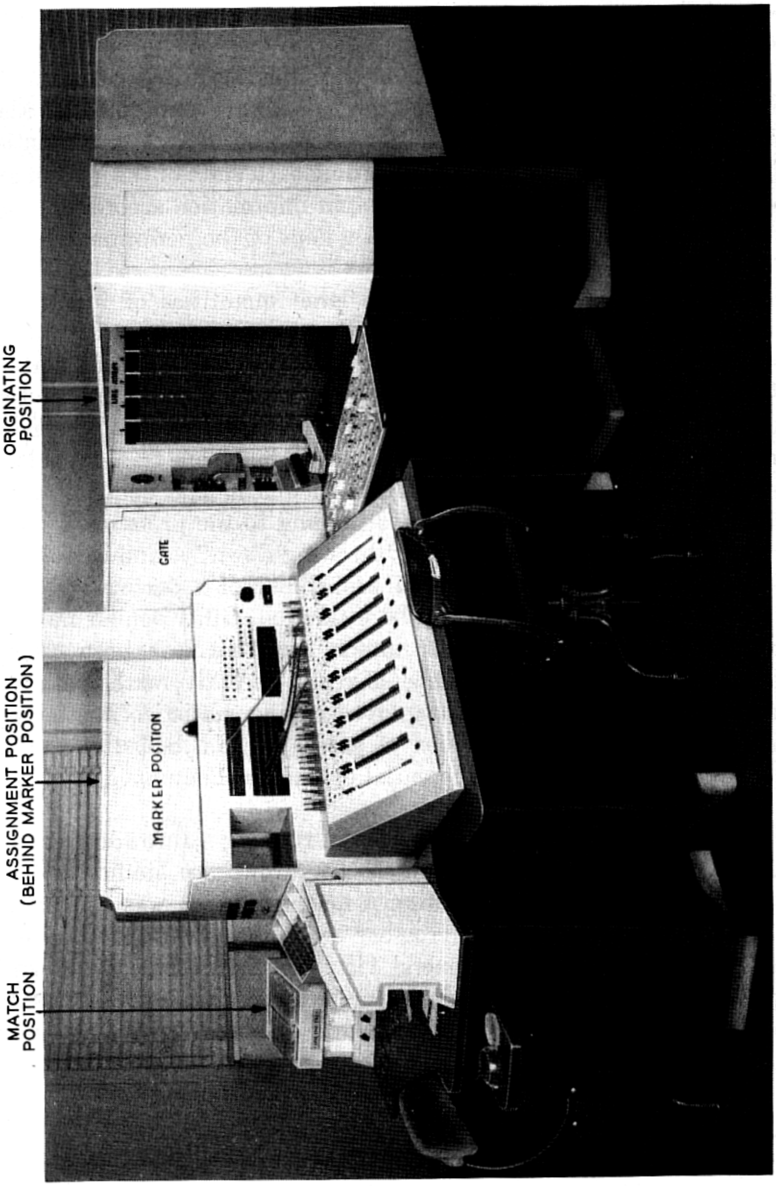


Fig. 1—General view of No. 5 system throwdown machine.

system performance. The level and character of submitted traffic can be varied, and a wide range of system sizes with varying quantities of control circuits can be tested.

Before the throwdown machine was built a "paper" throwdown trial of a small No. 5 crossbar system installation had been conducted by Mr. R. I. Wilkinson. This was run by a team of girls using card files, ledgers and written records, and using dice to make certain random decisions. The machine is basically a mechanization of these early methods to make possible the testing of larger installations in a reasonable time. The methods of generating data for the machine were developed by Mr. Wilkinson and many of the decisions relating to telephone traffic and statistical problems which were encountered in designing the machine were solved in consultation with him.

THE TELEPHONE TRAFFIC PROBLEM

A large automatic telephone switching system of the common control type is not a simple mechanism nor is evaluating its performance and traffic carrying capacity a simple problem. The economy of these systems depends upon the efficient use of relatively small groups of circuits on a time-sharing basis to serve a large number of subscribers. Each group of circuits is specialized to perform certain of the functions necessary in establishing a connection, and circuits from several groups must co-operate to handle every call. A sequence of actions with appropriate alternatives at several stages where busy conditions may be encountered is completely prescribed for every call. However, this sequence is subject to interference due to simultaneous requests to use the same control circuits. Competition is resolved by preference arrangements which cause some requests to be delayed while others are being served. Delays will increase the holding time of circuits with the possibility of causing traffic congestion at other points in the system.

With a number of subscribers originating calls at random, it becomes difficult to predict what the reactions of the system will be at various traffic levels. Although some parts of the problem can be solved by analytical methods employing probability theory, it is doubtful that mathematical means, beyond rough approximations, are available for evaluating the performance of an entire system.

Where systems have been built and placed in operation, the performance can be judged from observations of the working system. There are obvious weaknesses in this procedure. Only by collecting large quantities of information can the performance at various load levels be determined. Practical systems, as a matter of economy, are not equipped with indicating mechanisms to show performance at all stages. Events take place rapidly and the causes leading up to a particular traffic situation cannot be easily observed. Traffic loads cannot be repeated under controlled conditions. Size of installation and quantities of working equipment can be varied only by small amounts in a working office. To test offices of various sizes requires that these offices be built and installed. Variations in the system operation require actual changes in a working system. This can be done only to a limited extent.

In the case of newly developed systems, estimates of performance can be made on the basis of engineering judgment and experience with older systems of a similar type. This can be followed by a trial installation of a working system of a modest size which will test the system for flaws in design as well as provide information on traffic capacity which can be extrapolated to indicate approximate quantities of equipment for larger installations. At best this is a slow and expensive process and engineering data must be continually revised as experience is gained with larger installations. When the system is to be used extensively in installations of various sizes, methods of evaluating system performance in advance of actual construction are desired. This situation occurred in the development of the No. 5 crossbar system and was the occasion for building the present throwdown machine.

THROWDOWN TECHNIQUES

Since throwdown techniques have played an important part in the development of telephone traffic theory, a brief discussion of the basic principles will be given.

A single throwdown test will indicate the performance of a system under a specific set of conditions. In a typical telephone traffic study, a given traffic load would first be assumed and a simulated system installation to handle this load would be engineered on the basis of the best available information. The test run then will show the performance of the system under these particular conditions, and indicate both the adequacy of the initial engineering procedures and possible improvements. To obtain a proper balance between equipment quantities and traffic load may require several additional runs, varying the equipment quantities, traffic load or both.

The procedure in a throwdown study is to first obtain data representing the traffic to be handled by the system. The traffic data can be generated artificially by the use of random numbers. The method is based on a knowledge of the statistical behavior of the various factors entering into the composition of real traffic. Random numbers are drawn for each factor. These numbers are assigned values according to frequency distributions obtained analytically or from field observations. The regulating data are combined to produce a description of a sample of traffic which would be encountered under the assumed conditions and then processed by methods which simulate the performance of the actual system.

As a simple example of the throwdown procedures, suppose that it is desired to determine how often on the average an "all trunks busy" condition will occur in a particular group of trunks handling inter-office calls. A certain period of time is first selected and the number of calls expected within this period is determined. Two random numbers are then drawn for each call. One random number specifies the time, within the period, of origination of the call. The other random number, weighted according to an exponention distribution which will be discussed later, gives the holding time of the call.

With the data of call origination times and holding times prepared, the throwdown run can be started. The calls are listed in the order of their originating times. The first call is assigned to the first idle trunk. A record that this trunk is busy is made and the time at which it will become idle determined by adding the assigned holding time to the time of origination. This is also recorded. The call which follows in time of origination is then assigned to the next idle trunk and the process continued for succeeding calls. Before each call is established the release times of all busy trunks are scanned to determine whether any busy trunk should be made idle. In setting up each call idle trunks are chosen from the group in the same order of preference that would be used in the system being simulated.

Thus, the performance of an actual system is reproduced with considerable accuracy and detailed records of this performance can be made. From a study of these records the desired information can be determined. The probability of encountering an "all trunks busy" condition can be found, the average number of trunks busy can be determined, or a frequency distribution chart showing the percentage of the time the number of busy trunks is above any given number can be constructed. If proper records are kept such information as the average number of trunks searched over in locating an idle trunk can be determined. If the trunks were reached through a graded multiple or if they were in subgroups with a common overflow group, simple extensions of the above procedures would be followed.

This particular problem can be solved by analytical methods and is presented here only to illustrate the application of throwdown techniques. However, as problems become more complex it becomes increasingly difficult to apply analytical methods. Even in relatively simple systems the interplay of variables may be so involved that existing theoretical methods are entirely inadequate. Various simplifying assumptions must be made and there is often the doubt that some important factor has not been overlooked in formulating the mathematical theory.

The most fruitful use of throwdown methods has been to check results obtained by theory and to obtain data upon which mathematical theories can be based. Throwdown techniques, of course, can be used to obtain direct results, but the functioning of a system will be better understood if there is at least some attempt to develop a theory which explains how various forces act together to produce observed results. Such theories may suggest modifications of the system which will improve its performance.

It can be seen that the planning of a throwdown study requires a thorough knowledge of both the functioning of the system being simulated and the characteristics of the input data being processed by this system. The validity of results will depend upon the faithfulness with which the artificially prepared input data represent real data and the accuracy with which the throwdown routines represent the real system performance. The following two sections of this paper will describe the No. 5 crossbar system and the characteristics of the subscribers using this system. Later sections describe the methods used in the machine for simulating the dynamic performance of an operating system with its subscribers.

THE NUMBER 5 CROSSBAR SWITCHING SYSTEM*

No. 5 crossbar is a marker-controlled system designed primarily for local central office application in the residential sections of large cities and the fringe areas surrounding these cities.

In regions of this type a relatively large proportion of all calls are completed to subscribers within the same office. Since the surrounding offices to which connection must be made are likely to be of widely diversified types, the system is designed to interconnect with any existing type of central office. No. 5 is also capable of serving isolated centers from about 3,000 lines up, and multioffice areas including the largest

* F. A. Korn and James S. Ferguson, *Trans. A.I.E.E.*, **69**, Part 1, pp. 244–254, 1950.

metropolitan business exchanges. Although the system includes facilities for toll and tandem switching, these were not included in the throwdown studies and will not be discussed.

The Switching Network

The No. 5 system is built around an interconnecting network consisting of two types of switching frames utilizing crossbar switches and known as line link frames and trunk link frames. This is illustrated in block diagram form on Fig. 2. Each frame is double-ended and provides means for connecting any point on one side of the frame to any point on the other side. The connecting paths are known as links.

All subscriber lines in the office connect to one side of the line link frames, each of which can serve, roughly, 300 to 500 lines; and all trunks connect to one side of the trunk link frames, each of which has 160 trunk appearances. The other sides of line and trunk link frames are connected together in such a manner that each line link frame has access to all trunk link frames over several paths.

These interconnecting paths are known as junctors. The basic maximum number of line link and trunk link frames is 20 and 10 respectively, and this is the size embodied in the throwdown machine. However, in practice, multipling arrangements can be employed to double the number of frames to give greater subscriber and traffic capacity.

With the system described above, any subscriber line can be connected to any trunk over one of several paths, each consisting of two links and a junctor and known as a channel. On connections to outgoing or incoming trunks, a single channel is required; on connections through intraoffice trunks (connection between two local subscribers), two channels, one from each end of the trunk, are required. The method of combining links and junctors to form channels will be described later.

Dial Registration—Originating Registers

The circuits that receive and store the dialed signals from the subscriber are known as originating registers. These circuits, in quantity as determined by desired quality or grade of service, are distributed over the trunk link frames as equally as possible. A connection between subscriber and register is set up through the switching network just as between subscriber and trunk. The registers call in control equipment for setting up the subscriber's connection when dialing is completed.

Common Control Circuits—Markers

The switching of all connections in the office is performed by a group of common control circuits known as markers, any one of which may be utilized on a particular call. The principal functions of the marker are (1) to determine or receive the specific location of a calling circuit; (2) to translate input signals into the specific location of a called circuit or group of circuits; (3) to test for availability and seize a called circuit or one of a group of circuits; (4) to locate, test and seize a switching path between calling and called circuits; (5) to set up the connection; and (6) to take alternative action in case of trouble or busy conditions. A marker performs these functions in a very short period of time so that a few circuits can handle the requirements of an office. In the original design of No. 5 crossbar, a single type of marker handled all connections. This was the arrangement specifically handled by the throwdown machine. Later design has introduced three types of markers; dial tone, completing, and combined.

As an example of the function of the control circuits, when a subscriber originates a call, a connection is automatically established from the subscriber line circuit on a line link frame via a marker connector to an available marker. The marker identifies the location of the line and establishes the fact that it is a new call requiring a register. It tests all registers and trunk link frames and chooses an idle frame with idle registers. The marker then gains access to the correct line link and trunk link frames via the frame connectors, chooses an idle register, tests all usable channels, picks a particular channel and operates the crossbar switch magnets to close the connection between line and register. After storing the line location in the register for later use, the marker disconnects itself.

When the subscriber completes dialing, the register connects itself to an idle marker via the marker connector. It transfers to the marker the location of the originating line and the called number. If the call is local to the office, the marker determines the location of the called line from the number group circuit (a translating device) and tests and chooses an intraoffice trunk. The marker then gains access to the link frames through the frame connector, tests the called line for busy, picks a channel, and establishes the connection, thereafter removing itself and the register from the connection.

During the course of the foregoing events, a call may encounter various delays beyond the minimum circuit operating time in setting up the connection. Delay may be caused by meeting a temporary busy condition of markers, registers or the particular number group link frames required. Busy condition of lines or trunks may result in rerouting the call. In general, the grade of service is measured by the delay in connecting a subscriber to a register (dial tone delay) and the probability of not finding an idle trunk or channel.

Intraoffice Trunks

The intraoffice trunks, used on locally originated and completed subscriber connections, include the supervisory, charging and ringing functions. The trunk is held on a connection for the duration of the call in distinction to markers and registers which have short holding times.

Outgoing Trunks and Senders

Calls to other offices are completed via outgoing trunks which incorporate the supervisory and charging functions. In order to transmit information to the distant office, an outgoing sender is connected to the trunk for a short period of time by means of an outgoing sender link. In establishing the call, the marker first connects itself to the sender via the sender connector in order to register in the sender the called number, and then sets up the trunk-sender linkage. When the sender, which may be one of several varieties depending upon the type of signaling required by the distant office, has transmitted the number to the distant office, it drops off the connection.

Incoming Trunks and Registers

Calls from a distant office are completed through an incoming trunk, which includes supervisory and ringing functions. In order to receive signals from the distant office, the trunk connects itself to an incoming register by means of an incoming register link. When the register, which again may be one of several varieties, has received the called number, it obtains a marker through the marker connector for setting up the connection. When its functions have been accomplished, the register disconnects.

Tone Trunks

This group of trunks includes those to which calls are routed when line busy or all trunk or channel busy conditions are met. Subscriber error or excessive delay in dialing also result in routing to these trunks. The tone trunks return distinctive tone signals to the subscriber. If the marker is unable to set up a connection to a tone trunk, the originating register is able to return the tone signal.

Number Groups

Each number group is a translating circuit which provides terminating information for a consecutive block of 1000 directory numbers. When a marker transmits the called line number to a number group, it receives back the line location on a line link frame, the type of ringing required, whether or not the line is in a PBX group, and certain minor information. The number group also includes facilities for selecting an idle line in a PBX group. As with link frames, only one marker can connect to a number group at a time, but markers can connect to different number groups simultaneously without interference.

Connectors

The marker connector, providing access from line link frames and register to markers, include circuits which assign preference of all line link frames and registers for specific markers. This helps distribute marker usage.

In addition, when several line link frames and registers are competing simultaneously for busy markers, a gating arrangement allocates the order of service to reduce excessive delays. Although shown as one block on Fig. 2, the marker connector circuits are provided one per line link frame and one per sub-group of ten or less registers.

The frame connector, which provides access from markers to link frames, includes preference and lockout features since only one of several competing markers can connect to a given frame at one time. Although shown as one circuit on Fig. 2, the frame connectors are actually distributed over the frames.

Outgoing senders of a particular type are divided into two groups and the sender connector permits connection from two markers, each to one sender in each group simultaneously. Preference and lockout features obtain.

The number group connectors, provided one per number group, are similar to frame connectors and give access from markers to number group.

Handling a Typical Call

An understanding of the operational intricacies of a telephone switching system cannot be gained by a discussion of components and can only be developed by a study of the course of events in setting up calls through the system. As has been intimated earlier, the establishment of calls is largely a matter of marker operation. In order to illustrate the marker functions, Figs. 3 and 4 show two charts indicating the order of events in establishing a connection, first, between a calling or originating subscriber line and a register, and second, after dialing, between two subscriber lines within the same office. These two types of connection are known as a dial tone call and an intraoffice call, respectively.

Figs. 3 and 4 are drawn as sequence charts with time flowing downward. There is no attempt to maintain an accurate time scale; the x marks on the vertical line merely represent the relative order in which important control functions take place. In actuality, of course, the time between x marks is known with fair precision. Brief descriptions of the control functions are listed to the left of the vertical lines. The call illustrated is presumed to encounter no difficulties in completion. However, points at which blocking might occur are marked with an asterisk to the right of the lines. If any of the difficulties noted were to develop, the marker would have to take alternative action which will be illustrated later. Also shown to the right of the lines are potential points of delay, where a call may have to wait until a connector, a marker, or a desired frame becomes idle. It must be remembered that during moderate or heavy traffic, several or all of the markers are working simultaneously and tending to interfere with each other.

In a well-balanced and soundly engineered central office, the aggregation of parts are nicely adjusted to give on the average no more than certain preassigned values of delay and blocking at some average busy hour traffic level chosen as a base. A typical example of permissible delay is no more than 1 per cent of calls having a dial tone delay greater than three seconds. When traffic is heavier than the engineering base, the percentages of delay or blocking will increase.

A summation of all the possible alternative sequences which a marker may have to take when trunk busy, line busy and channel busy conditions are encountered becomes extremely complex. Although no attempt will be made to discuss this in detail, a chart showing the operational variations of a marker on an intraoffice call is presented on Fig. 5. Even this figure does not include all possible variations since, for example, the contingency of all tone trunks being busy is not shown on the diagram. This chart, similar in form to Fig. 4, will later be found useful in discussing the throwdown machine. In order to simplify the presentation, some of the control events are combined in time with the frame seizure which precedes the event. The normal course of a call

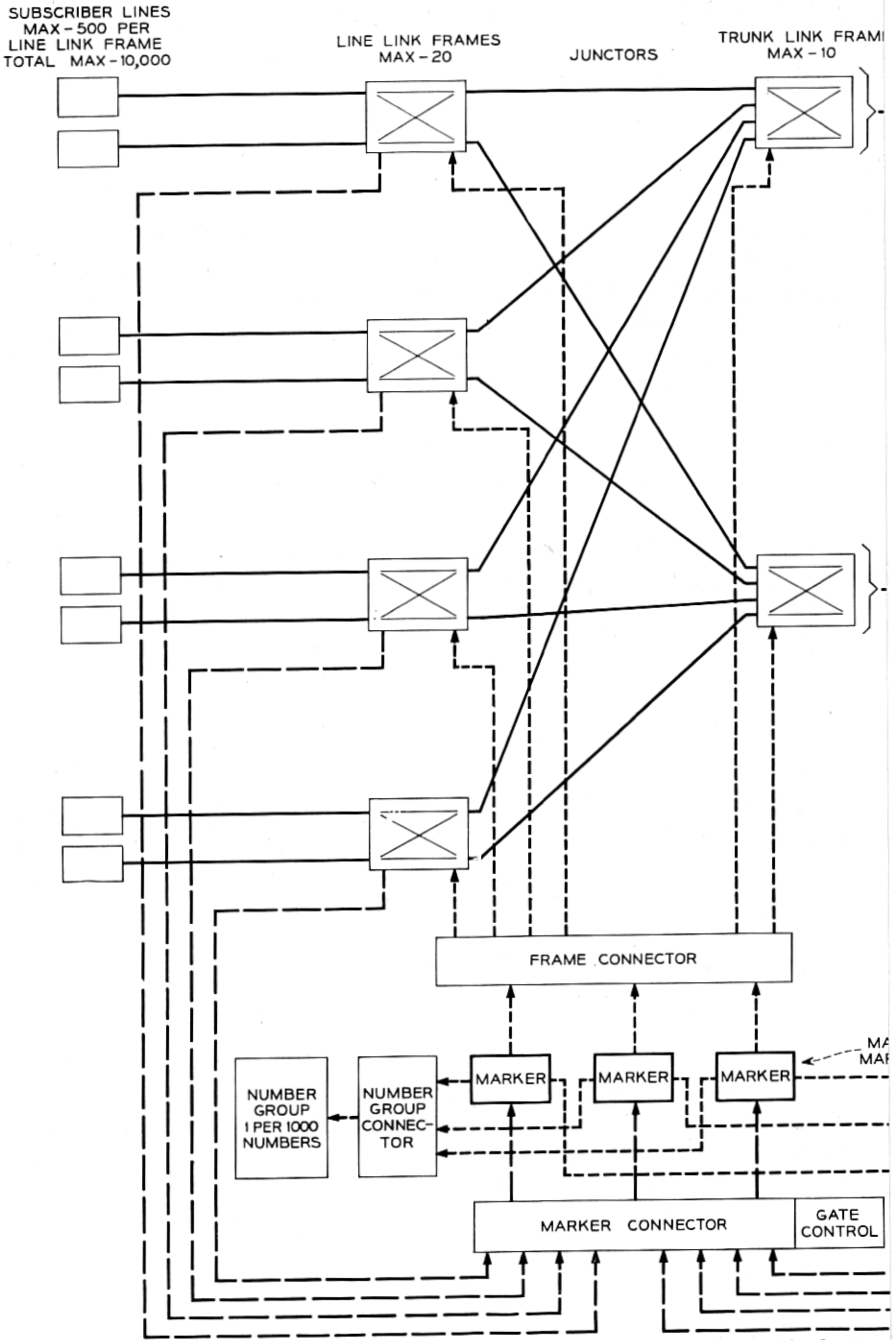
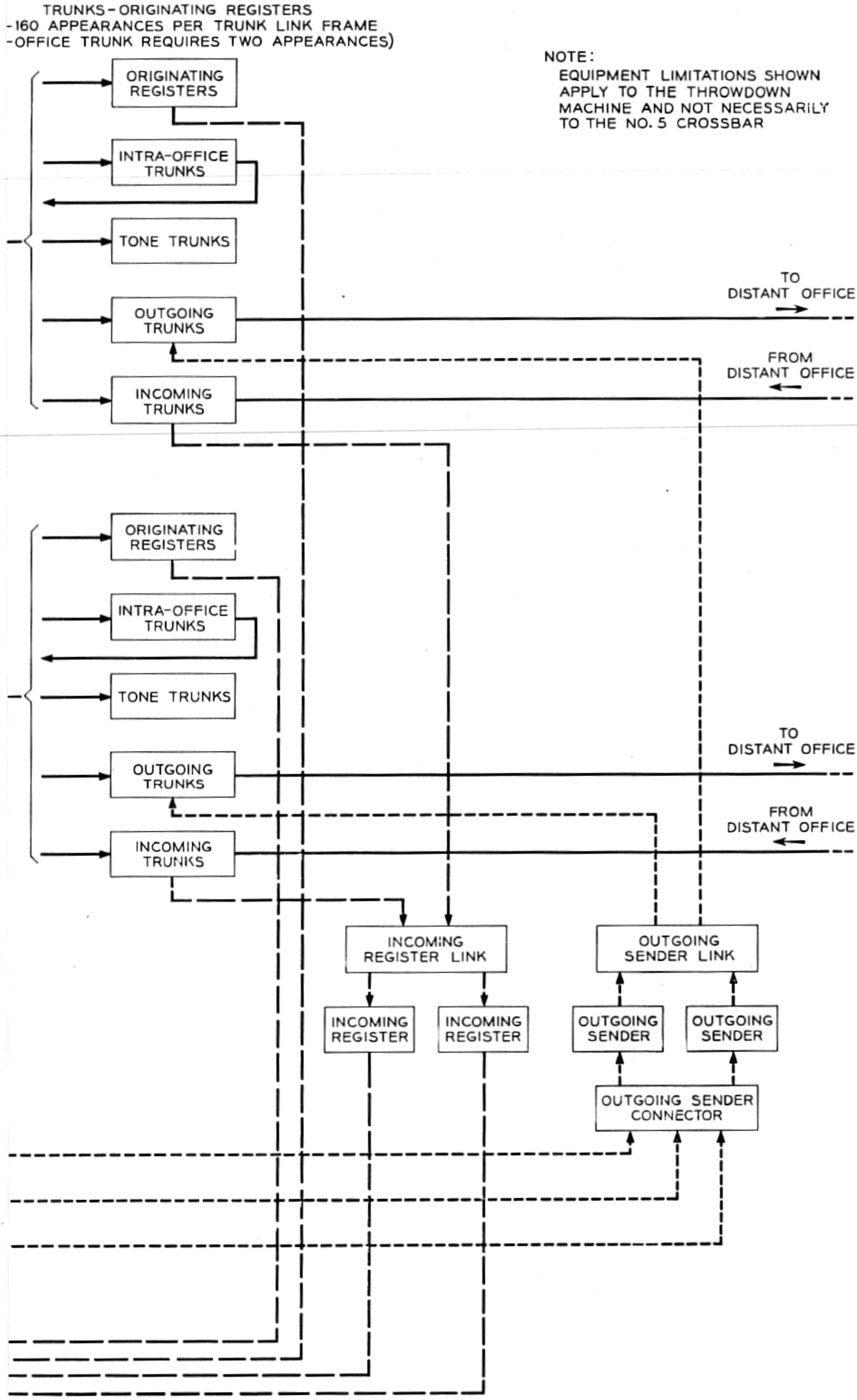


Fig. 2—Principal comp



5 crossbar office.

is in a vertical direction and it is only when a busy condition or a special function such as PBX hunting is encountered that the call shifts to the right or left. On a particular call, the only control functions performed are those marked with an x.

In the situation illustrated, the size of the office is assumed to be such that two groups of intraoffice trunks are provided. The marker makes a more or less random choice of the first group to be tested, and, if this group proves to be all busy, will automatically test the second group.

This brief description of the Number 5 Crossbar System is not intended to be exhaustive. It discusses only the important features of the system and those which will help make the description of the throwdown machine more intelligible. Certain more involved items will be discussed in greater detail in later sections concerned with the functioning of the throwdown machine.

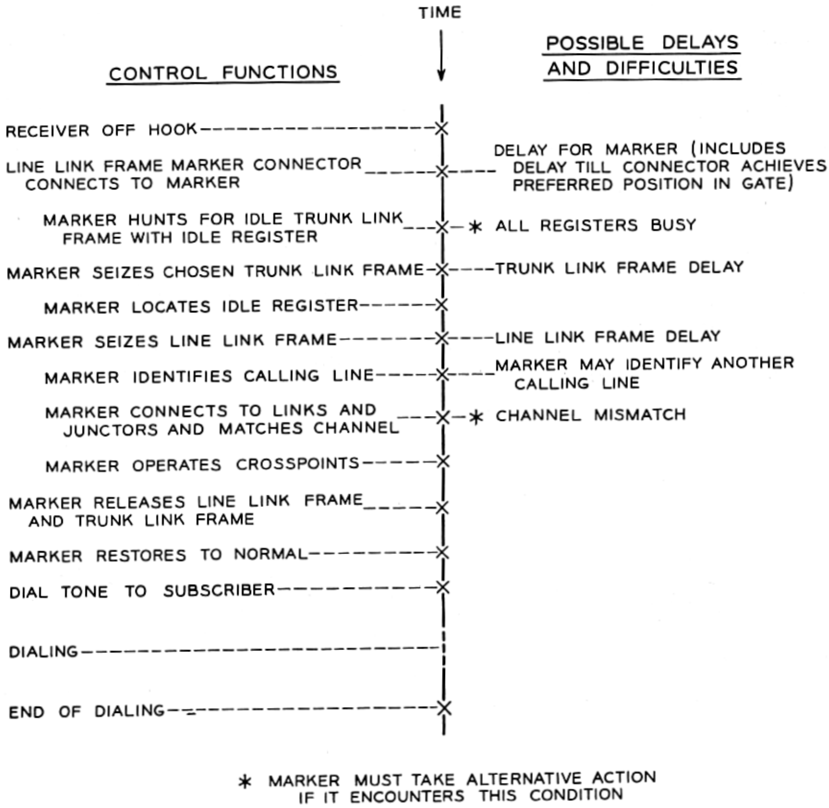


Fig. 3—Establishing a dial tone call.

CHARACTERISTICS OF SUBSCRIBERS AFFECTING DATA

Since the purpose of the throwdown machine is to evaluate performance and traffic capacity of a simulated switching system under conditions met in service, subscriber data fed into the machine must represent, as nearly as possible, the characteristic actions of real subscribers. Fortunately, telephone subscriber characteristics can be studied in working switching systems which are similar to the one under throwdown evaluation. Little error is introduced by such subscriber data

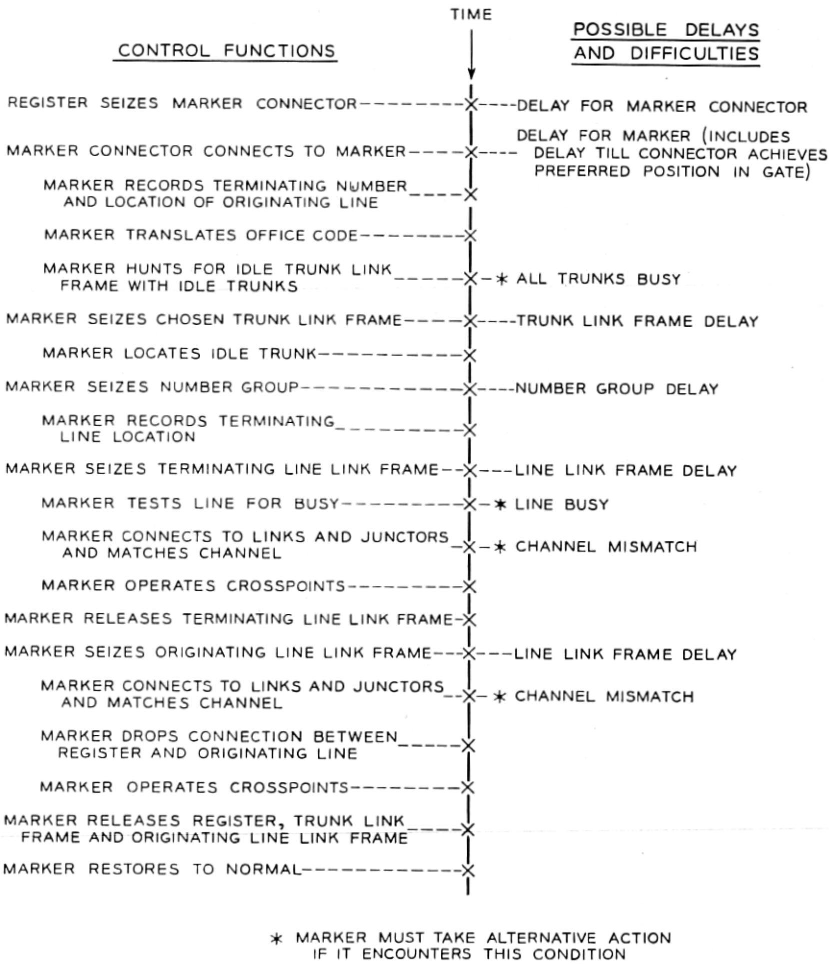


Fig. 4—Establishing an intraoffice call.

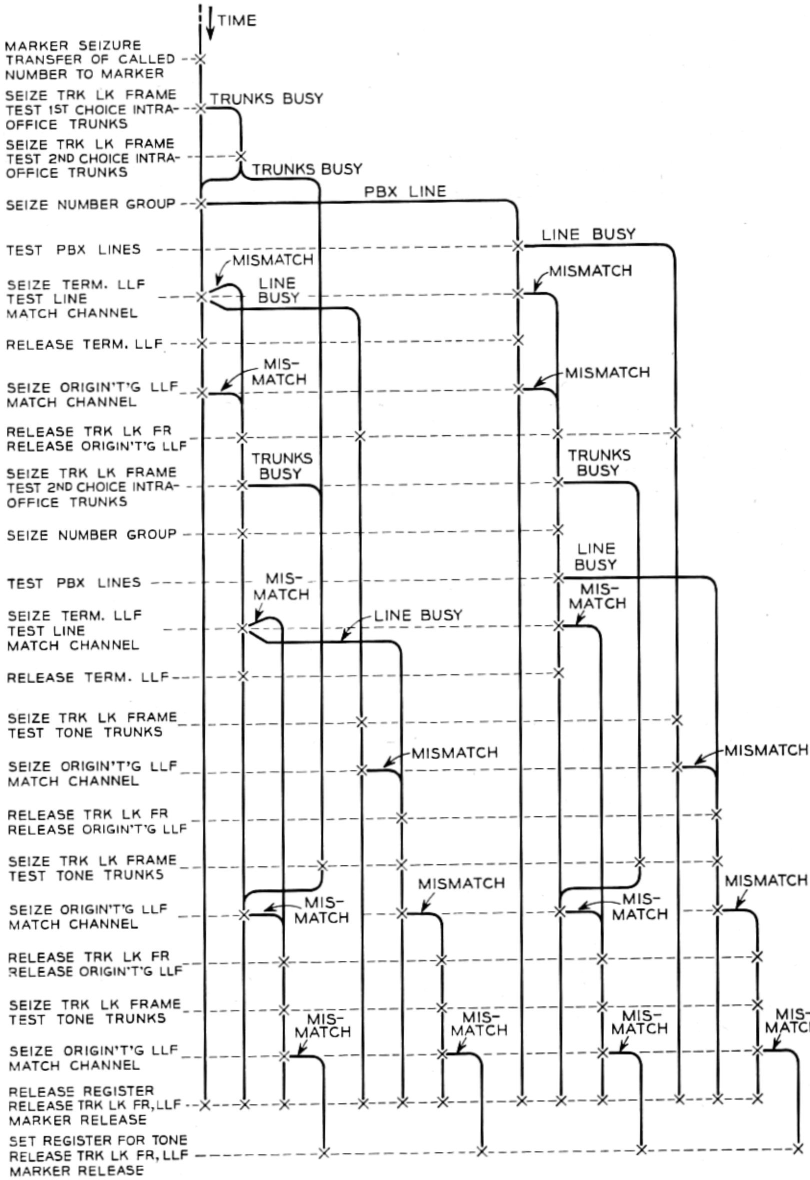


Fig. 5—Possible variations in handling an intraoffice call.

inasmuch as subscriber behavior is very slightly influenced by the type of system serving their telephones.

Subscribers, although they are individuals, exhibit many "group characteristics" dictated not by the requirements of telephone communication but by their mode of life. This fact allows statistical treatment of many observed action distributions without introduction of significant error. However, these group actions also present problems of congestion in telephone plant which require detailed throwdown study for solution.

As an example of group characteristic, subscribers do not originate a steady barrage of calls over the twenty-four hours of the day. During mid-morning and mid-afternoon hours traffic is built to a peak value, whereas during certain of the remaining hours it is reduced to a minimum. In some residential areas peak traffic may also occur during the early evening. Throwdown evaluations of simulated switching systems, however are primarily concerned with the busy hour, the hour in which the greatest number of calls are originated, regardless of its actual time of day occurrence.

Useful datum obtained from busy hour field observations is the calling rate per subscriber (calls per hour) which can be used to set up traffic load conditions on the simulated switching system. The calling rate characteristics can be measured as average calls per hour placed by subscribers in a number of group classifications. An example used in a particular throwdown study of simulated system response to a given traffic load is given in Table I. The values given in this table represent average day to day calling rates. Weather conditions, pre-holiday periods or special events have been found to raise substantially the average calling rate in affected classifications. Values adjusted for these conditions are useful in projecting percentage of overload that can be offered to systems engineered for average daily loads.

Subscribers, however, in originating calls, act independently within their classified group in maintaining the average calling rate. Originating times of calls, therefore, occur at random within the hour. Throwdown input data representing subscriber originating time behavior are produced by assigning to each call, of the total within the studied hour, a six digit number from a list of random numbers. If the hour is divided into one million parts the assigned random number determines the millionth part of the hour in which each call will originate.

Observations made in the field have shown that subscribers, upon receiving dial tone, do not always follow through to dial a full code. Among possible causes are failure to hang up after completion of a call, answering the wrong telephone where two or more are adjacent, dialing

TABLE I

Group Classification	Average Calling Rate Per Subscriber During Busy Hour
Heavy demand individual line subscribers (such as doctor and professional services	5.0
Medium demand individual line subscribers (such as small business and some residential subscribers)	0.85
Light demand individual line subscribers (mainly residential subscribers)	0.02
P.B.X. line subscribers (such as large businesses, hotels, railroads, etc.)	3.0

before dial tone, and forgetting the number. Such actions produce waste usage of equipment within the switching system, and their study is pertinent to producing throwdown data. To simplify this study, all subscriber actions involving the alerting of central office equipment are designated "subscriber starts" and divided into four categories as given in Table II.

Since "no dials" and "partial" dials are largely due to subscriber errors in properly originating calls, many of these calls will be originated upon discovery of the error. False starts, on the other hand, are attributed to accidental origination with no intent to place a call. A flow chart illustrating these actions is shown in Fig. 6. The importance of this subscriber behavior is indicated by the percentage of waste usage calls (FS, ND, and PD) to ultimate good calls. Pen recorder tapes taken at particular central offices showed waste usage calls at 30% and good calls at 80.5% of ultimate good calls. For these specific cases false starts represented 7.5%, partial dials 7.5%, and no dials 15% of ultimate good calls.

TABLE II

Category	Description
Good calls	Calls on which the subscriber waits for dial tone and then dials the required full code
False starts	Calls, on which a sender or register is seized, but which are abandoned in less than two seconds without dialing
No dials	Calls lasting longer than false starts but on which no dialing occurs. These calls may exceed a certain length "time-out" period and be given a distinctive tone
Partial dials	Calls on which less than the required full code is dialed. These calls may be held beyond a certain length "time-out" period and be given a tone

It was also found that approximately 90% of the partial dials and the abandoned no dials were reoriginated. These percentages are quoted only to illustrate subscriber behavior under certain conditions of central office load at a particular office. Type of service, load conditions on the central office, and location can effect these percentages. For a more detailed analysis, see "Dialing Habits of Telephone Customers."*

Fig. 6 illustrates only the group behavior of subscribers. Individually, the subscribers will hold equipment on abandoned no dials, abandoned partial dials, and false starts for varying amounts of time. These varying individual holding times can be quantized into several average values which are equally likely to occur, or may be averaged to one value as shown on Fig. 6 depending upon the throwdown study requirements. The holding times on calls receiving tone are usually assumed to cease a few seconds after tone is received.

Subscribers, as individuals placing ultimate good calls, spend varying amounts of time, after receipt of dial tone, before start of dialing and

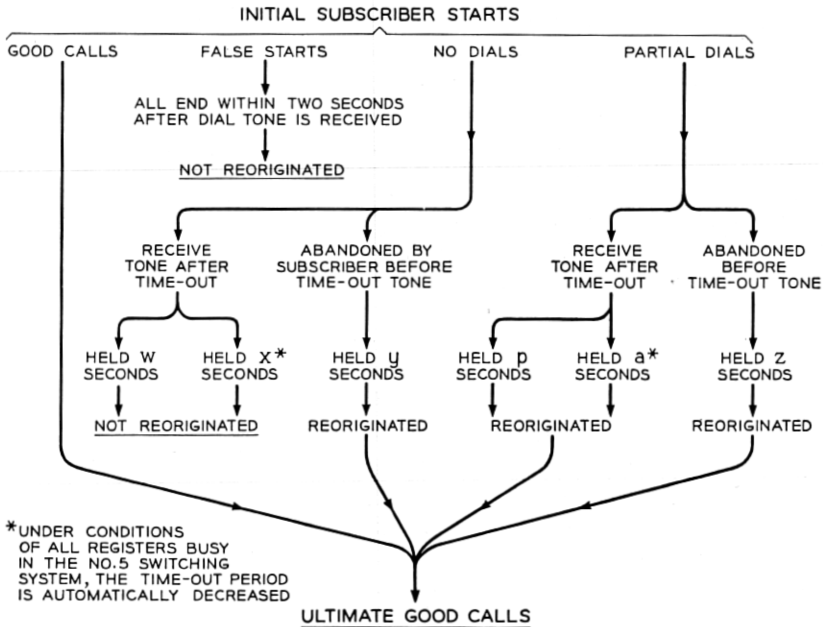


Fig. 6—Simplified characteristic action of subscribers in converting initial subscriber starts to ultimate good calls.

* Charles Clos and Roger I. Wilkinson, "Dialing Habits of Telephone Customers," Bell System Tech. J., **31**, pp. 32–67, Jan. 1952.

in dialing a full code. This behavior affects the holding time of registers receiving the dialed digits and must be considered in throwdown studies. Data collected on combined waiting and dialing time characteristics show a frequency and time distribution that can readily be quantized into a number of values, each equally likely to occur. When the number of values for a particular throwdown study are determined, each quantized dialing time is represented by a number. Each ultimate good call is then assigned a number from a random list of the representative numbers to establish the dialing time of the call.

Ultimate good calls will develop one of three terminating conditions attributable to subscriber behavior: 1) DA, called subscriber does not answer, 2) busy tone because of called subscriber line busy, or 3) answer by called subscriber. It is assumed from analysis of "don't answer" studies that, for certain throwdown evaluations of the switching system, approximately 10% of the ultimate good calls meet the DA condition. The number of busy tone terminations, of course, will develop during the throwdown study as a result of the average originating and terminating calling rate per subscriber served by the system.

Most subscribers, upon encountering a line busy condition make subsequent attempts to reach the called line. The number and frequency of attempts made depend upon the individual characteristics. A detailed analysis of this characteristic, suitable for use in throwdown studies, has appeared in a paper by Charles Clos.*

When calls are answered by called subscribers, the connections will be held for varying amounts of time. It has been determined from field observations that the frequency distribution of these holding times is closely approximated by an exponential distribution. For throwdown purposes a simplifying assumption can be made that holding time is not a continuous variable but is quantized so that a particular holding time will have one of several values. To determine these values an exponential distribution having the proper average is plotted as shown in Fig. 7. The area under the curve is then divided into the required number of equal parts (ten, for this example). A central value of holding time is determined to represent each subarea. Ten holding times are thus produced which are weighted according to the exponential distribution and which are equally likely to occur. These holding times can be designated 0 to 9 and assigned to the calls by choosing one-digit numbers at random for each call.

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* Charles Clos, "An Aspect of the Dialing Behavior of Subscribers and Its Effect on the Trunk Plant," Bell System Tech. J., **27**, pp. 424–445, July, 1948.

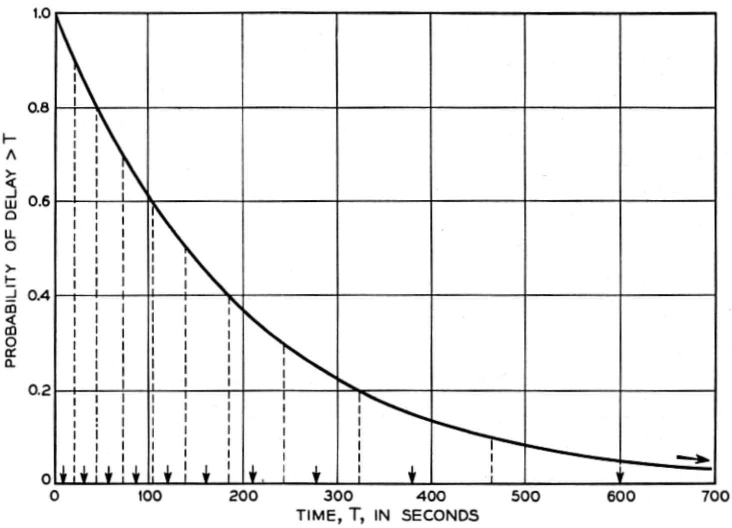

Fig. 7—Distribution of holding times.

GENERAL PLAN OF THE MACHINE

The broad plan of the throwdown involves a division of work between the team of operators and the circuits of the machine. The circuits keep track of system events, resolving complex sequences of actions concurrently taking place. Their chief purpose is to present signals to the four operators so that they will be able to perform the right actions at the proper time and thus dovetail together the events for a large number of calls in progress.

The operators keep manual records of the busy-idle states of items which occur in large quantities, such as lines, trunks and links. They also perform the searching operations necessary to locate these items when they are required to be made busy or idle.

In general the circuits signal the operators to perform actions; the operators in turn signal the circuits that the action is completed or some appropriate alternative taken. The circuits then determine the next action and present corresponding signals to the operators. Thus the circuits largely control the sequencing of events. However, in some cases where the sequencing would require extensive circuitry, the operators assist in determining sequence. For example calls returning to the control circuits after a subscriber completes dialing are interleaved with new calls according to written records maintained by the operators. Releasing connections are also placed in proper time sequence by the operators according to written records.

The actions of the operators are checked electrically in many cases. An improper setting of certain switches, which is inconsistent with the state of the system at the time will in some cases give an alarm and in others, block the progress of the machine until the error is corrected. Certain actions performed by the operators involve the insertion of plugs into jacks. Where alternative actions are possible in response to a given signal, separate groups of jacks correspond to the several alternatives. Insertion of a plug into a particular group will signal the circuits as to which alternative is taken. The circuits make one of several keys effective and the operator must then depress this key (corresponding to the action she has taken) before the circuits will advance.

Where several operators must cooperate to perform a given action, signals are passed between the operators by means of keys and all operators must respond before the circuits can advance. Wherever possible, overlap operation is employed. Signals are presented to several operators simultaneously and each operator starts the indicated action, signaling the circuits when it is completed. When the signal from the last operator is received, the circuit advances. In some cases an operator is allowed to start a particular action before the stage has been reached at which this action is required. For example the information necessary to choose links and determine a suitable path through the interconnecting network of the No. 5 crossbar system is available before it is necessary to establish the connection. Since this search is time consuming, the operator is allowed to start as soon as the information is available. At the proper time she is given a signal to complete the record of this connection, or if the call has been blocked before reaching this stage, she is given a "back out" signal instructing her to restore her records to their previous condition. Since this is a rare condition occurring less than one time in 100 tries, little useless work is done and the overall action is speeded up.

A block diagram showing the relations between the operators and the various major components of the machine is shown in Fig. 8 The CLOCK controls the flow of time in the machine and gives an indication of simulated present time in the traffic run being tested. The TIME DETECTORS, of which three are used, provide a means for the operators to indicate a future time at which some action must be taken and be signaled when this time arrives. The block labeled CONTROL CIRCUITS, which present action signals to the operators, represents the main body of circuits which maintain a current record of the states of the various complex units of the system, such as markers. The GATE provides a means for operators to feed traffic into the machine and determines the order in which each working item of traffic is taken up by the control circuits. The RANDOM CIRCUIT is an electronic "roulette wheel" which permits the operators to make random choices in disposing of certain traffic items. It provides random selections varying from one out of three to one out of ten.

The individual record of each call is made on a card of the form shown in Fig. 9 which is called a "call slip." These are of various types identified by distinctive designations and colors for the several varieties of calls which may occur. The basic types are: dial tone, intra-office, incoming, and outgoing.

As the call progresses through its various phases the slip is passed from one operator to another, each operator retaining the slip while it is in the phase under her control and recording on it in designated spaces the nature and time of the events taking place. When the call is completed, the slip carries a complete record of the call including the designation number and time of seizure of the various circuit units used in establishing the connection and the nature and duration of any delays encountered.

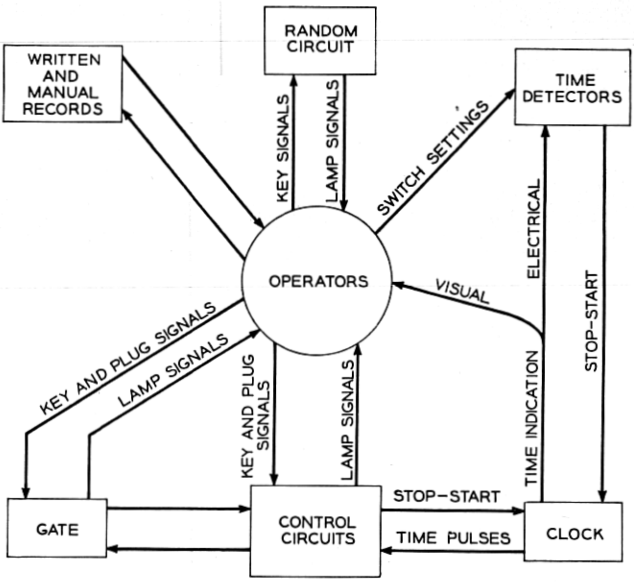

Fig. 8—Communication between the machine components and the operators.

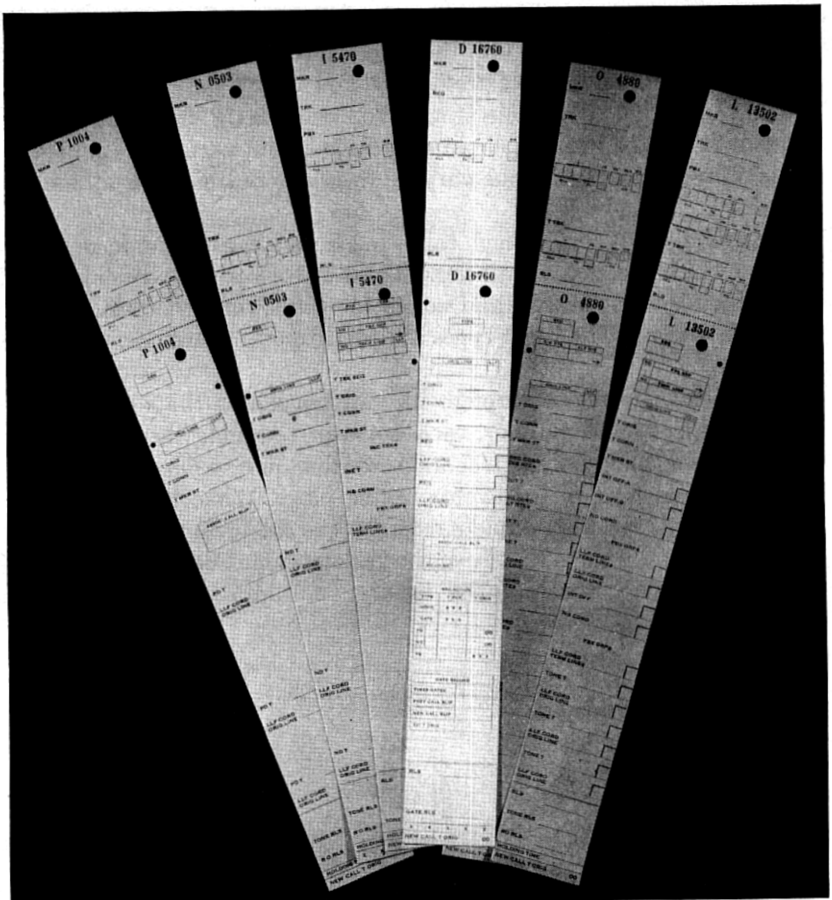

Fig. 9—Call slips on which records are made in the throwdown machine.

DESCRIPTION OF POSITIONS

The throwdown machine consists of five positions as shown in the plan view of Fig. 10. A photograph showing all but one position appears on Fig. 1. This division into positions results from the requirements of simulating the components of the No. 5 crossbar system and equalizing the work load on the attending operators. The arrangement of positions, as shown, provides a continuous clockwise flow of records and other items that must be passed from operator to operator. The five positions are known as: originating position, gate position, marker position, match position, and assignment position. Four operators attend the five posi-

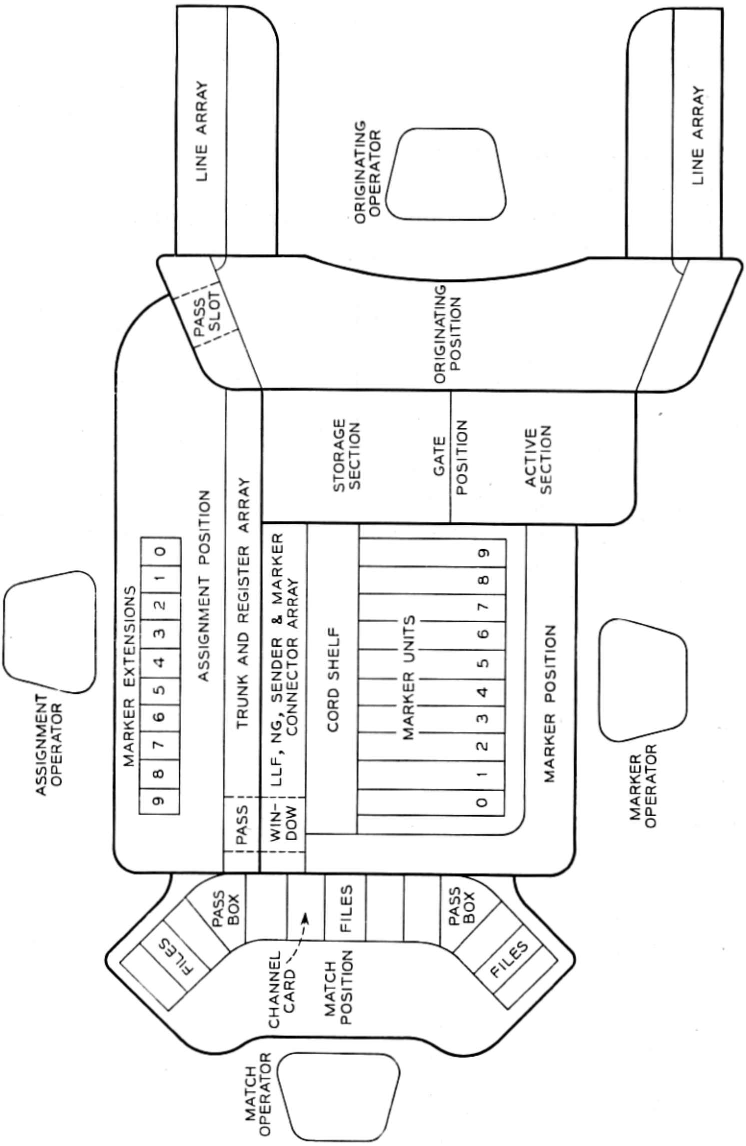

Fig. 10—Plan view of throwdown positions.

tions, the gate position being jointly served by the operators stationed at the originating and marker positions. Each operator is given the same name as the position at which she is stationed.

The general plan of traffic flow is such that all calls are originated or restarted at the originating position. For this reason, the major equipment items of this position include: the subscriber line array, which represents by pegs all of the subscriber lines associated with the switching system under throwdown evaluation; the trunks incoming to this system; and certain of the system components associated with incoming calls. The call slips, sorted in sequence as to originating times, are stored at the originating position for use in originating calls.

Means are provided for presetting the times at which the next originated or restarted calls will enter the throwdown machine. When actual time coincides with a time thus preset, the system stops and signals the originating operator to serve the waiting item. The originating position does not provide for actually entering an item into the machine, but indicates the time of entry, stops the machine, and supplies the items to be entered. For example, the operator, when signalled to originate a dial tone call in accordance with information furnished on the call slip, selects, from the line array, a peg representing the subscriber line, associates it with the call slip, and passes the two items to the gate for entry.

Since the means for determining the busy or idle condition of a subscriber line are provided by the presence or absence of that line's peg in the array, the originating position also enters into the operation on incoming and intraoffice calls.

The gate position, which simulates the marker connectors of the No. 5 crossbar system, serves as the entry point for all calls. The originating operator inserts call slips and pegs into the gate position from one side to start the call. The marker operator removes them at the other side for processing in the marker position. Relay circuits associated with the gate position control the flow of traffic through the gate in accordance with actual No. 5 crossbar operation.

The marker position provides means for associating the call slips with the individual simulated markers of the switching system. Since these markers control processing of the calls, the principle records of the calls' progress are obtainable through this association. The records are kept as time entries on the call slip and marked adjacent to action lamps determining these entries.

At the top of each marker unit in the marker position are cords which provide access to the switching system components under control of the marker. These components are line link frames, number groups, sender subgroups, and marker connectors. As the call progresses, the marker operator will connect and disconnect the marker with these components as directed by the action lamps provided.

The principle purpose of the assignment position is to provide equipment for test and choice of a trunk on each call. A trunk jack array which includes all trunks and registers of the switching system therefore appears on the face of this position. Since, in the actual No. 5 crossbar system, testing and choosing of trunks are performed by the markers, an extension of each marker also appears in the assignment position. The assignment operator, when required, makes a visual test for idle trunks to the proper destination. She then chooses and associates one of these idle trunks with the active marker by means of a marker cord which is plugged into the trunk jack.

In addition to this principal function of trunk choice, the assignment position is equipped to determine the disposition of calls when the marker has finished setting them up. Means for ascertaining conversation time, dialing time and other types of holding times is provided.

The positions so far described have simulated only the two ends of a connection, the subscriber line and the trunk or register. To complete the connection a channel must be set up between these ends. In the actual switching system the marker matches a line link, a junctor, and a trunk link to form the channel. The match position is provided to simulate this action. The match operator, through visual inspection of a set of channel cards, tests and makes busy the channels for each connection. Information as to the originating subscriber line reaches her through the pass box in the form of the upper portion of the call slip, Fig. 9. Information as to the trunk or register choice is passed verbally by the assignment operator. Since this operation is a function of the marker, marker extensions appear at the match position. These extensions are provided with action lamps to guide the match operator and with keys to inform the simulated marker circuits of the results of the match.

A pass window is cut between the marker position and the assignment position for passage of the call slip and originating peg at the time of marker release. Similarly, a pass box is provided for passing the upper portion of the call slip (match ticket) from the match operator to the assignment operator. The assignment operator is charged with the disposition of these items.

THE TIME SYSTEM

The timing system of the throwdown machine is based on a start-stop system of time pulses. Pulses generated by the clock, Fig. 11, drive indicators which display time and also drive circuit elements which count time units to cause events to occur in the proper sequence. When these time counters reach a stage where some action is to be performed by the operators, "stop-time" signals are produced. These signals lock in and cause the clock to halt. Simultaneously, action signals are displayed to the operators. When each operator completes the indicated action she depresses an appropriate key at her position which extinguishes the action signals and removes the stop-time signal. When the last operator has responded, all stop-time signals are removed, the time lock is opened and the clock again advances. Thus the clock, in effect, takes time-out while the operators perform the various manual searching and recording actions necessary to simulate and tabulate the performance of the crossbar system.

In the throwdown machine, each clock pulse represents one millionth of an hour or 3.6 milliseconds. This quantitization of time is based on two considerations. The first is that it is convenient to represent a particular time during an hour by a six-digit decimal number. The second is that the time represented by one time unit (3.6 milliseconds) is well under the average acting time of the relays and switches used in the system being simulated. Thus the events taking place in the actual system can be reproduced in sufficient detail. Some events of longer time duration

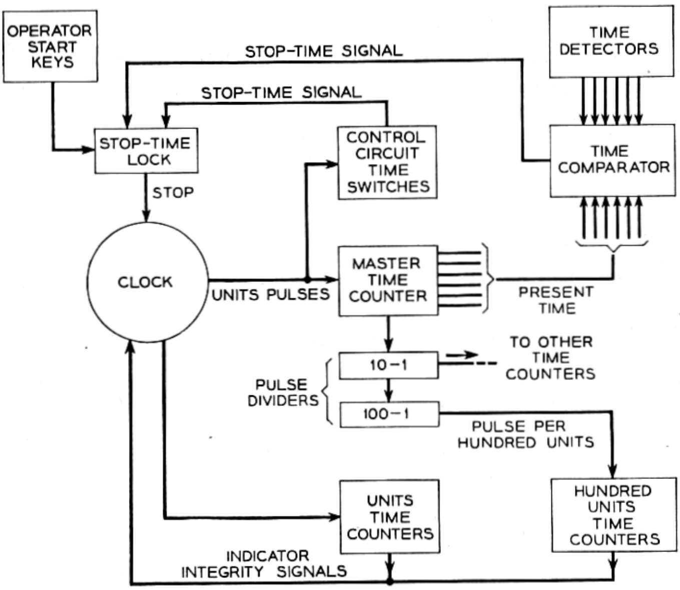

Fig. 11—Block diagram of the time system.

are timed in less detail. For this purpose the clock is also arranged to deliver pulses at one tenth and at one hundredth of the basic pulse rate.

The clock, circuit wise, is a form of free running relay pulse generator. It consists of a series of relays in which the first, in a released condition, causes the remainder of the series to operate in sequence. When the last relay of the series operates, it causes the first relay to operate. The remainder then release in sequence. When the last relay releases, it causes the first relay to release. This cycle, if not interfered with, is repeated continuously to produce pulses representing units of time. Time, thus, can be stopped by the simple expedient of allowing the stop time signals to hold or "lock" the first relay in the operated state.

Time is visually indicated in units and hundreds of units at the operators' positions by a group of telephone type message registers termed the *time counters*. Certain of the registers indicate present machine time for action recording purposes. Others are set at a specified number of units ahead of present time to indicate future times at which held items will be released or re-entered into the system:

To drive these counters and to safeguard their integrity, the counters are substituted for the last relay in the clock pulser relay series. The operating windings of all *units counters* are connected in parallel. Contacts, which make on each counter when the individual counter is advanced, are all connected in a series circuit to form the last relay contact. Failure of any units indicator to advance will, therefore, interrupt the pulse generator cycle and stop time until the trouble is cleared.

The integrity of the hundred units time counters is guarded in the same manner. On each hundred pulse when these counters are advanced, their windings and contacts also form a part of the pulser circuit.

The basic pulse repetition rate of the clock is approximately four pulses per second, being determined by the acting time of the counters and the various circuit elements which the clock pulses must drive. Since each pulse represents 0.0036 seconds, the ratio of basic machine time to real time is in the order of 70 to 1.

The clock pulses, Fig. 11, are counted by two types of time switches. One type, the control circuit time switch, is associated directly with the component control circuits of the throwdown machine. These time switches are not continuously driven but are automatically connected to the clock as required to time events in the progress of a call. The control circuit time switches, as discussed in more detail later, are returned to zero after each usage in preparation for timing the next event.

The second type of time switch, designated the *master time counter*, is continuously driven by the clock. This counter records simulated present time throughout the entire running of a throwdown test.

The master counter does not, in itself, generate stop time or action signals. Its primary purpose is to furnish correct present time to the time comparator circuit where such signals are generated. It also controls a pulse divider which furnishes pulses at one tenth and at one hundredth the basic pulse rate.

Since failure of the master time counter to advance on each pulse would introduce present time errors which are cumulative over the throwdown run, the integrity of this circuit is rigidly guarded. Checking circuits verify that each basic clock pulse advances the master time counter. The checking circuits, not shown on Fig. 11, upon detecting a failure to advance, produce a stop-time signal and an alarm signal which can be released only after the counter is brought to correct time. The master time counter consists of pulse driven rotary switches arranged so that each switch represents one decimal digit of time. To count one hour of simulated time, as provided in the master time counter, six switches are necessary. These switches record 000000 to 999999 units of 0.0036 seconds.

Means are provided for presetting such items as subscriber originating times, incoming call originating times, and hold release times by the *time detectors*. When a time so set coincides with simulated time, the clock is stopped by a stop-time signal and an action signal indicates that a call is to be originated or a held item released.

The time detectors consist of sets of ten-position manually controlled switches with each switch representing a decimal time digit. Since simulated time is divided into millionths of an hour, these switches are preset to the millionth interval, say 003162, in which an event is to occur. Information from each switch is transmitted to the *time comparator*, Fig. 12. Also transmitted to the time comparator, from the master time counter, is the simulated machine time, say at present, 003159. When the master time counter advances to a time 003162 which coincides with the detector time, the time comparator generates a stop-time signal to stop the clock. An action signal, associated with this particular time counter in coincidence is also lighted. The operator, after taking the appropriate action, resets the time counter to a future time—the time of the next waiting item in the category—and depresses the start time key. Checking circuits prevent advancement of the clock should the time detector accidentally be set to a time value which has already passed in the throwdown run, in the example, to a value less than 003162.

Three time detectors are provided in the throwdown machine. One each is used for setting originating times of subscriber starts and of incoming calls. The third is used for releasing held items. Since the holding times of these items are measured in hundreds of time units the last two digits of the time interval are dropped, and only four switches are required.

It has been mentioned that the ratio of basic machine (clock) time to real time is in the order of 70 to 1. However, in operation, the flow of time is halted frequently to permit actions by the operators. The average interval between stops in the traffic runs which have been processed is less than 10 time units. Thus the machine time is only a small fraction of the time consumed in processing a traffic sample. The ratio of total processing time to real time has turned out in practice to be between 1000 and 2000 to 1 depending on the nature of the traffic sample being tested.

GENERAL PLAN OF THE CONTROL CIRCUITS

The major part of the throwdown machine circuitry is associated with the marker sequence and timing controls and the gate preferencing arrangement. The circuit plan followed in these two cases will be briefly described in order to illustrate how the throwdown functions were implemented.

The gate circuits simulate the action of the marker connector circuits of the No. 5 crossbar system which control the access of line link frames and registers to the markers. These circuits assign traffic to idle markers according to the preference rules used in the actual system. The circuits resemble corresponding circuits of the system. They employ two relays per connector and one relay per marker and are arranged with cross-connection terminals so that the preference order and number of connectors can be varied as required.

Each call handled by a marker consists of a series of events occurring in time sequence with time intervals between events corresponding to the "work time" consumed by the marker in performing required functions. The sequence of events is not fixed at the start of a particular call but may be altered from stage to stage depending on the particular busy and idle conditions encountered. A block diagram of the control circuits used for simulating this action is shown in Fig. 12. They consist of a number of individual circuits provided on the basis of one per marker together with common circuits whose use is shared by all markers.

The fundamental plan is based on the use of two rotary stepping switches. One of these, the sequence switch, determines the sequence in which events take place, while the other, the timer switch, measures work time between events. In the throwdown machine each possible event which may occur in setting up a call is represented by a position on the sequence switch. Circuits through the switch cause action signals for the event represented by its position to be displayed to the operators. All of the events for one type of call are arranged in order on the switch terminals so that by omitting certain positions (events) all of the variations of this type of call can be represented. At the conclusion of an event the switch is directed to the position corresponding to the next appropriate event according to the setting of "memory" relays located in each marker unit. These relays operate at various stages of the call in response to key signals from the operators indicating the conditions they have encountered in attempting to respond to action signals. Thus, significant events are recorded in order to control the future progress of the call.

To provide for all types of calls it was found necessary to furnish three sequence switches for each marker. These switches have 22 positions and six arcs. Five arcs are used for displaying signals and for control while the sixth arc is used in conjunction with the timer switch to control the time at which signals are displayed. A timer switch is individual to each marker. It is a 22-position, six-arc switch arranged with auxiliary relays to count a maximum of 105 clock pulses. Terminals of the timer switch

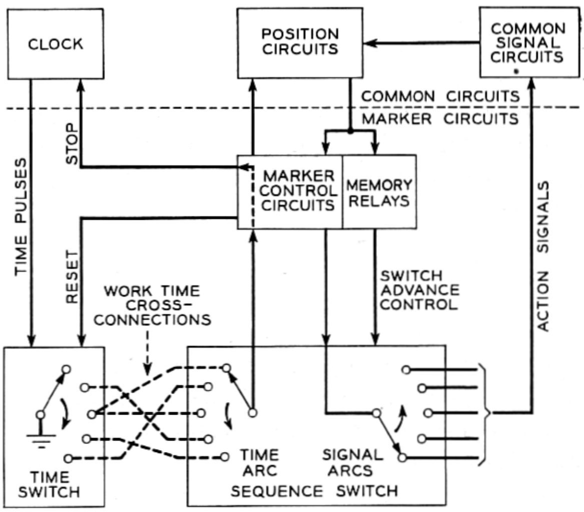

Fig. 12—Block diagram of marker progress circuits.

are cross-connected to the time arc of the sequence switch to fix the work time preceding the event represented by each sequence switch position.

In the general operating scheme, the sequence switch stands at a position representing the next event to take place. The timer switch is started from normal and counts clock pulses until it reaches the terminal cross-connected to the position on which the sequence switch stands. This initiates signals which stop the clock and cause action signals to be displayed. When the operators respond, the sequence switch advances to the terminal for the next event in the call, the time switch returns to normal and the clock restarts. The time switch then counts time units leading to the next event. Since several markers may be in use at the same time in different stages of their calls, two markers can reach an action point during the same clock pulse. A lockout circuit insures that only one marker at a time displays its action signal. At any time that a marker stops the clock, the timer switches of all other markers halt but continue their count when the clock is restarted. Thus, relative time relations are maintained while a true count of time consumed by an operating system is obtained.

The circuit action can be illustrated by a discussion of the events in a dial tone call. This call represents an attempt by a marker to establish a connection from an originating subscriber line to a dial register. The possible sequences of events are diagramed in Fig. 13. As indicated, this class of call employs eight sequence switch positions in addition to the normal position.

The call starts when the gate circuit assigns an idle marker to a call which has been originated at the proper time and placed in the gate. The assigned marker is prepared to process this type of call by the operation of an associated "class" key which selects and advances the sequence switch which carries the events of a dial tone call. Advance of the switch is from normal to Position 1 to control, at the proper time, signals for the first event, namely, seizure of a trunk link frame and selection of a register. The timer switch is set at zero and in a condition to step one terminal at a time in response to clock pulses. Terminal 1 of the sequence switch time arc is cross-connected to a terminal of the timer switch representing the marker work time between the time the marker is first seized and the time it attempts to seize a trunk link frame.

The operator in control of the marker now operates a START key and the clock starts pulsing, each pulse causing the marker timer switch to advance one step. When the specified work time has elapsed the timer switch reaches the terminal connected to Position 1 of the sequence switch. This passes a signal from the timer switch through the sequence switch causing the clock to stop and the signals associated with Position 1 of the sequence switch to be displayed. Signals at the assignment position identify the particular marker and instruct the assignment operator to obtain a trunk link frame and a register. Three conditions may occur: (1) a trunk link frame frame and register may be idle and available, (2) a register may be idle but the frame on which it appears is busy, being held by another marker, or (3) all registers may be busy.

In condition (1) the assignment operator obtains the frame and register according to the operating procedures and operates an OK key at her position. This extinguishes her signals and passes a signal to the marker operator instructing her to record the present time in the space provided for trunk seizure on the call slip. The proper space is indicated by one of a row of lamps beside the call slip. The marker operator then operates the START key for this marker causing the marker timer to return to normal and the sequence switch to advance to Terminal 2. The clock starts if no other marker is waiting to display signals.

In condition (2) the assignment operator observes that there will be a delay in obtaining a trunk link frame. She inserts a connector cord for this marker in a "delay" jack and operates a DELAY key. This extinguishes her signals and passes a signal to the marker operator to record

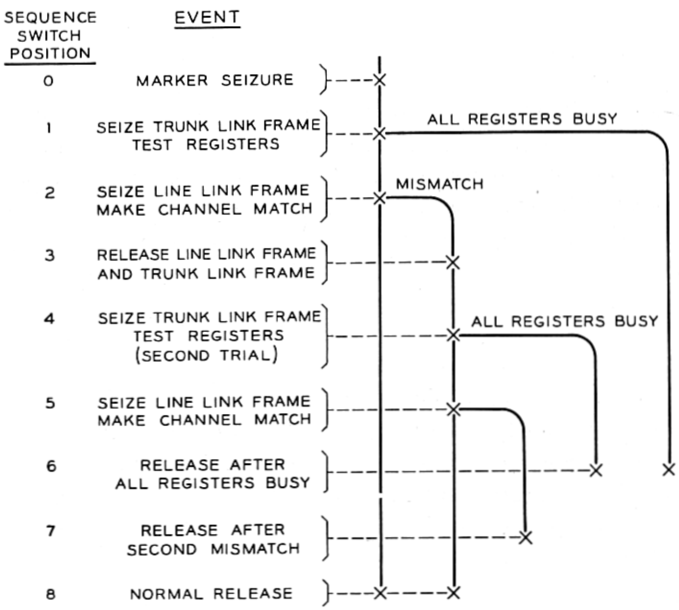

Fig. 13—Possible sequences of a dial tone call.

on the call slip that a delay has been encountered. The marker operator then operates the START key for this marker. This returns the timer to normal but since a delay condition has been established in the marker circuit by the actions of the assignment operator it does not advance the sequence switch but allows it to remain in Position 1. The marker in a delay condition does not permit its timer switch to step but removes the halting signal from the clock to allow time to advance and other markers to be served. All signals for this marker are extinguished during this time. As time advances some other marker will release a trunk link frame. This passes a signal through the delay jack to the delayed marker causing it to display again the signals requesting a trunk link frame and a register associated with sequence switch Position 1. The operators and circuits then proceed exactly as when these signals were first displayed.

In condition (3), the assignment operator observes that all registers are busy and operates her ALL BUSY key. This operates a memory relay in the marker circuit recording that the all busy condition has been encountered and that the future progress of the call should follow the sequence indicated in Fig. 13 by the side branch at Position 1. With all registers busy it is impossible for the marker to establish a connection. As the side branch shows, the alternative is to release and restore to normal. (Later attempts to serve this subscriber will be made until an idle register is obtained.) Thus, with the all busy condition recorded on the memory relays, the circuit will cause the sequence switch to advance, running over positions representing intermediate actions and coming to rest in Position 6 where it is prepared to display signals for the release of the marker. The operation of the ALL BUSY key also started the clock and restored the timer switch to normal so that it could measure suitable work time before displaying release signals.

The call progresses through successive events in a manner similar to that described above. After obtaining a trunk link frame and a register as in condition (1), the sequence switch stands in Position 2 while the timer switch counts work time preceding a request for a line link frame. During this time other markers may request service causing the clock to halt, interrupting the advance of time in all circuits until the operators have completed the required actions. After this marker has counted the specified time, a signal is passed through Position 2 of the sequence switch causing a request for a line link frame to be displayed at the marker position. A delay is handled as before, the marker waiting until the busy frame is released by some other marker. When the frame is obtained, a signal at the match position requests that operator to match

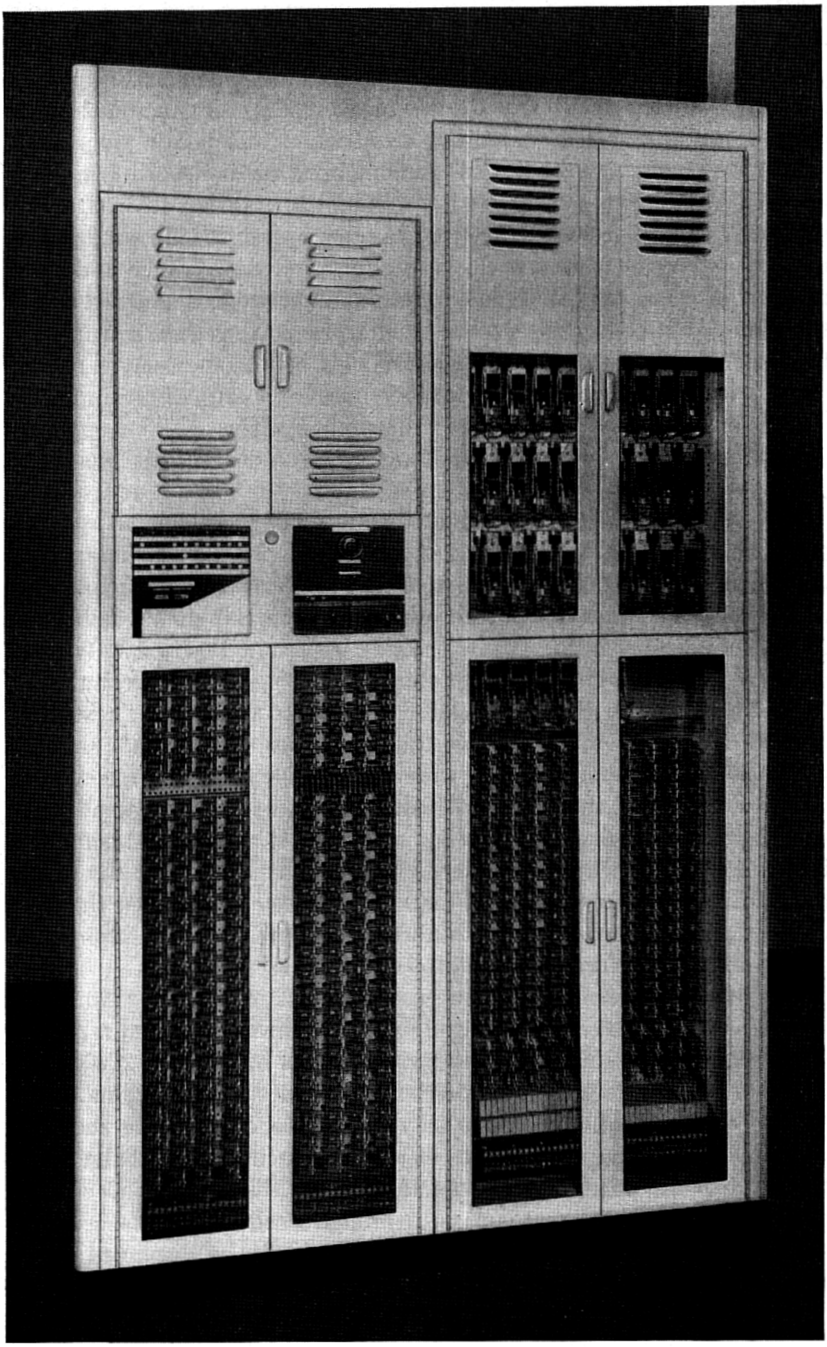

Fig. 14—Relay and switch cabinets.

a channel before allowing time to advance. In case of a mismatch the match operator depresses a MISMATCH key. This operates a memryo relay which will cause the marker to follow the alternate sequence indicated by the side branch at POSITION 2 in Fig. 13. As a safety precaution, the MISMATCH key is made effective only at the time a request for a match is made so that accidental operation at other times will not disturb the circuit action. With a mismatch recorded, the sequence switch advances to Position 3 and at the proper time displays signals to release the line link frame, trunk link frame and register. Thus the call advances with the possible alternates of all registers busy at Position 4 or a second mismatch at Position 5. The call proceeds to one of its possible conclusions where frames are released and the marker becomes idle.

The dial tone call which has been described is the least complex call handled by the machine. The intraoffice call which was diagramed in Fig. 4 is the most complex. It requires 22 sequence switch positions to represent events and may have 92 possible sequences depending on conditions encountered. To take care of variations in sequence in all calls a total of nine memory relays is provided in each marker.

The circuit equipment consists, largely, of telephone type electromagnetic relays and rotary stepping switches. Approximately 800 relays are used. The total number of switches is 57. Of these 47 are of the 22-position, 6-circuit type while the remainder are of the 44-position, 3-circuit type. This equipment is mounted in the two cabinets shown in Fig. 14 and in additional units located within the operating positions. Time indications are given by four-digit message registers, approximately 40 being used. The random circuit consists of a gas tube counting ring with several control relays. Output indications are given by miniature neon lamps. Signals are given to the operators by telephone switchboard lamps, 822 being used. Manual equipment used by the operators in signaling to the circuits consists of keys, switches and telephone plugs and jacks. The machine contains 187 keys and switches, 60 cords equipped with plugs and 509 jacks.

PREPARATION FOR A THROWDOWN RUN

There are two phases in the preparation for a throwdown run. One of these is the tentative engineering of an office of the size to be tested. The other is the preparation of data to represent traffic handled by this office. The first of these follows rather closely the general procedure that would be used in planning the installation of a new switching office.

The chief difference is that preliminary decisions concerning the size and general characteristics of the office to be tested will be made. For example it may be decided to test an office in the twenty line link frame size range serving mixed business and residential subscribers with a high percentage of calls completed within the office. Based on general knowledge of subscriber behavior, the number of subscribers necessary to present a suitable traffic load to this number of link frames will be determined. Values for average holding time and calling rate associated with these subscribers must also be developed. These may, in part, be determined from estimates or specific knowledge of the traffic capacity of the line link frames, taking care that the figures are typical of such a group of subscribers as determined by field observations. Since we are usually concerned with determining the maximum safe capacity of the system, full load or overload conditions will be assumed and the usual margins for future growth considered in engineering an actual office will be omitted. Decisions will also be made as to the number of other offices to which this office has trunks and the percentages of the total traffic originated and terminated in each of these offices.

Having made these preliminary assumptions concerning the nature and environment of the office to be tested, the office is then engineered according to the best available information. The numbers of registers and markers are determined and arranged in connector groups according to standard procedures. The sizes of the trunk groups to various connecting offices are determined and the placement of trunks on the trunk link frames chosen according to the usual practice. All similar factors concerning quantities and arrangement of equipment are determined. The throwdown machine is then set up to simulate this office. This will involve crossconnections in the gate circuits and arrangement and designation of the facilities provided for keeping the busy-idle records of such items as lines, trunks, registers and links.

The second phase in the preparation is to produce data representing calls presented to the system during the time interval to be studied. This is accomplished by choosing a random number for each call. This number must contain a sufficient number of digits to specify all the pertinent data necessary to describe the call. These digits are assigned to represent certain factors. For example, the first six digits represent the time of origination. The next two digits specify the type of call. This is done on a percentage basis. For example, if 40 per cent of the traffic is to be locally completed, the numbers 00 through 39 in these places would indicate an intraoffice call, if 25 per cent is to be outgoing to other offices the numbers 40 through 64 would indicate this type of call, and so on for the remaining types of calls. If divisions of less than one per cent are to be made, three or more digits could be used for this purpose.

The meanings of certain of the remaining digits will depend upon the type of call. If the call is originated within the office, the next five digits will give the identity of the calling line in terms of its frame location. If the call is incoming from another office certain of these five digits will be used to specify the office of origination and the trunk number. This again is on a percentage basis depending on the fraction of total incoming traffic expected from each office. Five other digits give the identity of the called line if the call is completed within the office; if outgoing they specify the terminating office. Other digits give the percentage of calls which will result in partial dialing by the calling subscriber. Since, as will be discussed later, there is a possibility that these will be re-originated later as good calls, all of the information for a good call is also determined for these calls. Additional random numbers determine various other aspects of the call such as the identity of the number group which will be used. As a suggestion to those who would undertake a throwdown study, it is advisable to include a number of surplus "utility" digits in the original random number. It invariably happens that some factor is overlooked in the initial planning or arises during the course of a test and these digits can be used in making decisions in these cases.

It should be noted that the random circuit is used for making certain random decisions in the course of a call at the time that a need for these decisions arises. For example, the holding time of an established connection and the probability of the called subscriber not answering is determined by this circuit. This circuit could have been eliminated by including digits in the original number for every possible situation of this type which might be encountered. This would cause much useless work in preparing the data since all situations are not encountered on every call.

A quantity of random numbers must be drawn to provide the desired load on the office. This is not a simple process of determining the number of calls expected during a given period and drawing this number of random numbers. One factor is that in generating data by the above procedures it will be found that certain numbers will represent calls originated by lines which are busy at the indicated time on a connection established previously. The number of such cases can be estimated from the expected number of busy lines in the office and a corresponding number of additional numbers drawn. When this situation is encountered in the course of the run the call is discarded. The other important factor is a "feedback" effect due to the calls meeting a situation which prevents successful completion and the probability that these calls are originated later.

A simple example is where the called line is found busy. As previously mentioned, there is then a possibility that subsequent attempts will be made at a later time. All attempts make use of circuits and control equipment and should be considered in determining the load capacity of the office. Other situations which produce this effect are illustrated in Fig. 15. Lines entering the figure at the left represent classes of calls which enter the system. A certain number of calls will be partial dials, no dials and false starts regardless of the performance of the system at the time the call is originated. The partial dials represent cases where the subscriber makes an error in dialing or does not wait for dial tone and dials a digit before he is connected to a register. These may be abandoned before the register obtains a marker or may "time out" in the register and be connected to an overflow tone trunk. In either case the subscriber may re-originate the call later. The probability of re-origination has been estimated from field data and the dotted lines in the figure represent these reoriginated calls.

In the throwdown machine the random circuit is used to determine which calls will re-originate and the elapsed time before the second at-

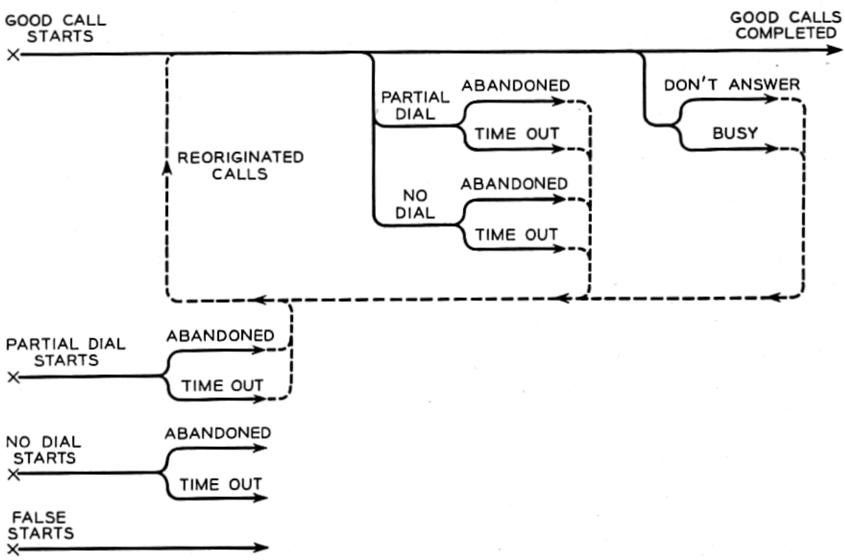

Fig. 15—Composition of the load on a crossbar office.

tempt. No dial starts represent such situations as a change of mind by the subscriber after lifting the receiver or accidentally removing the receiver and are not considered to be correlated with later trials. The same is true of false starts which are momentary start signals often hard to explain. A certain number of partial dial and no dial calls are the result of dial tone delays which may occur during heavy load conditions. These branch from the "good call" line in the figure and are due to the subscriber not waiting for dial tone and dialing part of the digits or even the entire number before being connected to a register. The probability of this occurrence will depend on the extent of dial tone delay. After dial tone delay on each call is known, successive uses of the random circuit determine whether the call is partial or no dial type and if the call is to be re-orginated at a later time. Rough estimates of the quantity of this type of traffic could have been made and included in the original traffic data. However, since they depend on the performance of the system there is a tendency toward a "snowballing" effect and it was thought best to handle it as described in order to detect this effect.

It can be seen that the exact load on a system is difficult to estimate on the basis of initial starts. The procedure then is to make the best possible estimate of initial starts necessary to produce a given load, taking into consideration all important known factors and, at the conclusion of a run, make a count to determine the exact number of calls of various types handled.

When the data for the various calls have been determined from the random numbers, the pertinent information must be transcribed on the call slips. For most calls originated in the office this will requre two call slips. One of these is for the dial tone stage of the call and is used in establishing a connection to a register. The other represents the later stage of the call where the register connects to a marker after dialing is completed and an attempt is made to establish an intraoffice or outgoing connection. The initial time of origination and the calling line number will be recorded on the dial tone slip. The slip for the second stage of the call will carry the calling line number and the called line or outgoing trunk number, but will not carry a time of origination. This is a function of dialing time and is determined at the conclusion of the dial tone stage by the random circuit. It is recorded on the second call slip at that time. The two slips are associated by recording the serial number of the associated slip on the dial tone slip. Incoming call slips carry the origination time, the calling trunk, and the called line numbers. Call slips for partial dial and no dial initial starts carry information similar to that on the dial tone slips.

In preparation for a run all slips bearing initial time entries are stacked in order of their times of origination. Slips for the second stage of a call are kept in a separate stack. At the conclusion of a dial tone action when the time of origination of the second stage is determined, the associated call slip is located, the time is entered on this slip and it is inserted in proper order in the stack of originating calls. In the case of re-originated calls, the information from the old call slips is recopied on a new slip with the new time of origination and these slips are placed with waiting calls in the proper time order.

Detailed Description of Equipment and Functions of the Operating Positions

THE ORIGINATING POSITION

The originating position, in relationship to the rest of the throwdown machine, appears to the extreme right of Figs. 1 and 10. Detailed views of the two wings of the position are shown on Figs. 16 and 17. The principal features of this position are arrays of jacks and wooden pegs representing subscriber lines and incoming trunks, together with associated time counters and detectors. The chief function of the originating operator is to enter all calls into the system at appropriate times. This requires that the stacks of call slips, visible in Figs. 16 and 17, be held at this position. These call slips are arranged in order of their originating times, with latest time on top, and carry the originating line identification number so that line peg and call slip can be associated when the call is to start.

The line array, split into two wings, contains jacks and pegs for all subscriber lines in the office. The jacks which are simply holes with no electrical function, are arranged in a coordinate grid to assist in quick location. Twenty frames are provided, each holding 500 lines for a total of 10,000 lines.

The array is divided into 20 horizontal sections, running across the two wings, each representing a line link frame. Each frame is divided vertically into 10 subgroups of 50 lines, each representing a horizontal group. Since the directory number assigned to a subscriber line in a crossbar office is purely arbitrary and has no physical significance, it is not used in the present case for line identification. Rather, an equipment number, which represents the location of the line on a line link frame, is used. This is a five digit number, stamped on the peg, and made up

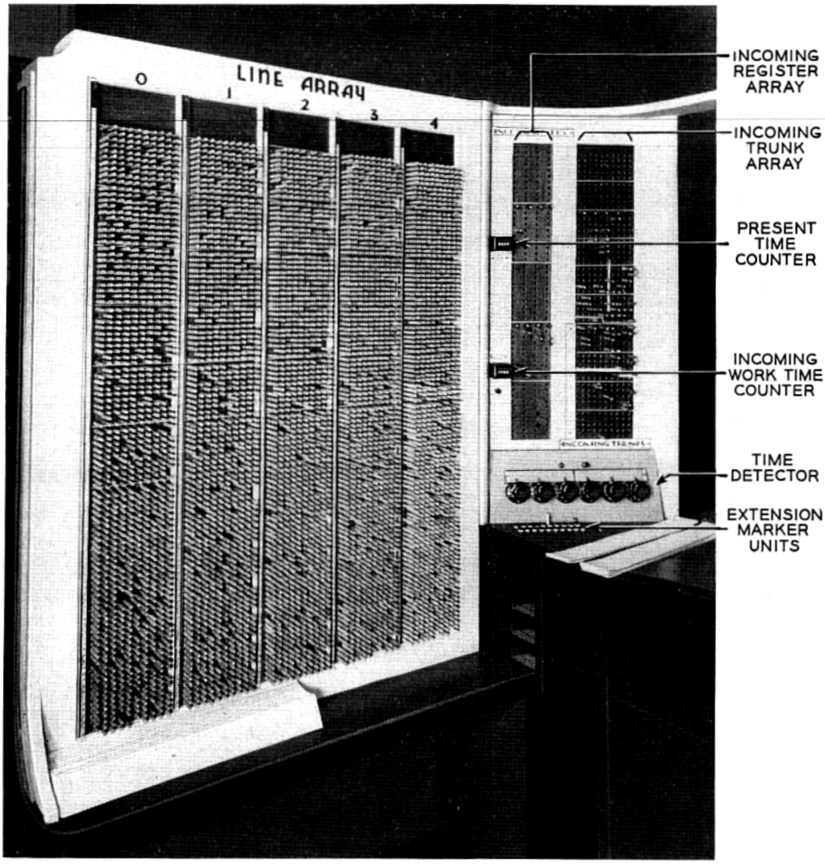

Fig. 16—Originating position—left side.

as follows:

HG—LLF—L

where HG—horizontal group No. 0–9
LLF—line link frame No. 00–19
L—line No. 00–49

The right upper five lines in each horizontal group of a frame (lines 45–49) are reserved for PBX use. A PBX can be assigned to line jacks occupying the same relative location in a vertical row (20 line link frames-same horizontal group). The pegs in a PBX group are marked with a distinctive color to facilitate hunting.

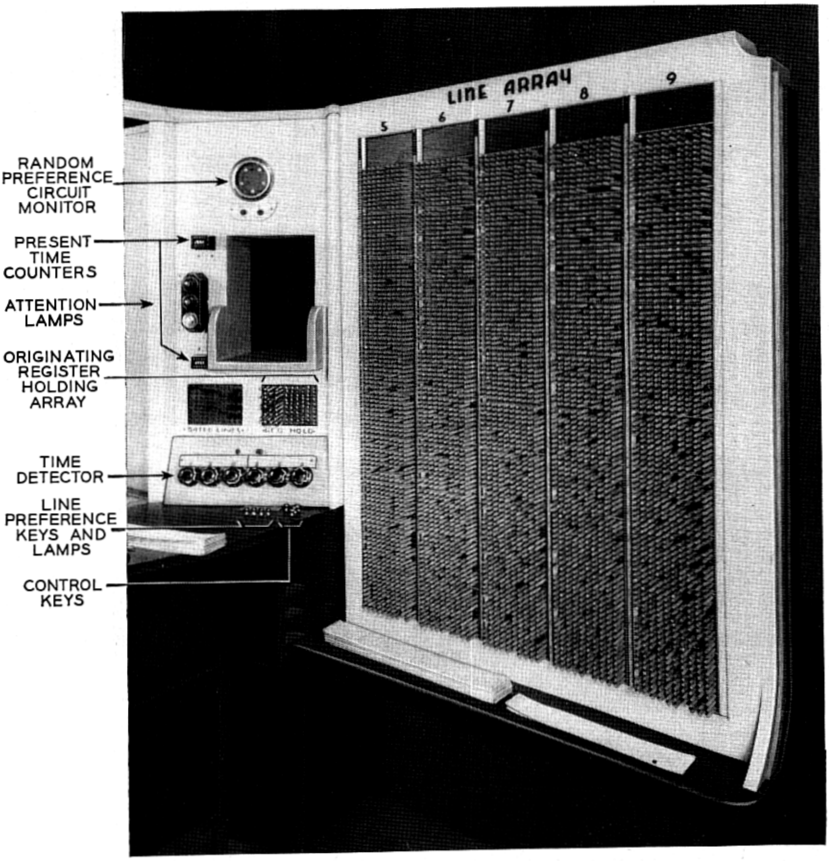

Fig. 17—Originating position—right side.

Line pegs are removed from the array while they are occupied on a call. The jack thus remains empty during the busy interval. The originating operator utilizes a line peg and a call slip in originating each dial tone call.

The incoming trunk and register arrays are located on the left column at this position as shown on Fig. 16. The incoming trunk array consists of pegs and jacks arranged in accordance with the trunk groups. The primary horizontal grouping is assigned a route number which is used only for identification purposes. The horizontal rows within a route represent the number of the trunk link frame switch on which the trunk is located. Vertical rows represent trunk link frames. Provision is made for a maximum of 400 incoming trunks. Trunk identification is a four-digit number made up as follows:

R—TLF—SW

where R—route No. 10, 11, 12, 13
TLF—trunk link frame No. 0–9
SW—switch No. 0–9

Jacks representing these same incoming trunks also appear at the assignment position.

The incoming registers consist of short sleeves which can fit over the trunk peg. When a call is originated by a particular trunk as indicated by the time on a waiting incoming call slip, the trunk is associated with the correct type of incoming register by slipping the sleeve corresponding to the latter over the trunk peg. The peg and sleeve then accompany the call slip into the system. Appropriate times for each action are entered on the call slip.

The incoming register sleeves are held on arrays adjacent to the trunks. They are identified by a three-digit number:

CONN—REG

where CONN—marker connector No. 0 or 1
REG—register No. 00–19

Waiting holes are provided at the register array for holding trunks if all registers are busy.

MARKER CONNECTOR OR GATE

This is a bridging position between the originating position and marker position. Through it must pass all call slips and pegs requiring marker service. The originating operator places call slips and pegs in the gate from one side and the marker operator removes then at the other.

The gate, shown on Fig. 18, provides jacks for pegs and slots for call slips arranged in blocks corresponding to the individual marker connectors for line link frames, originating registers and incoming registers. It is divided into two sections, a storage section in which calls wait for an idle connector, and an active section in which calls wait for an idle marker and removal by the marker operator. An associated relay circuit controls the flow of traffic through the gate, simulating actual No. 5 operation, and indicates by lamp the appropriate action.

When a call slip is ready to enter the gate, the originating operator obtains the corresponding line or register peg and places the peg and slip in a jack and slot, respectively, in the correct connector block of the storage section of the gate. The connector block number is ascertained from the peg identification or from the call slip. If the connector is free a CONN READY (R) lamp lights to indicate that the peg and slip should be advanced to the connector block in the active section of the gate. If the connector is not ready, the lamp will light at some subsequent time and the connector delay time will be noted on the call slip. If several calls pile up in a particular storage connector block, means are provided for maintaining correct preference for entry into the active section in the case of registers. With line originations, a random line preference circuit under key control at the right side of the originating position key shelf picks, on a random basis, the next entry into the active section of the gate (except in the case of preferred lines whose pegs will have a distinctive marking) and which have precedence over ordinary lines. Keys for a choice of one out of two, three, four or five are provided. With

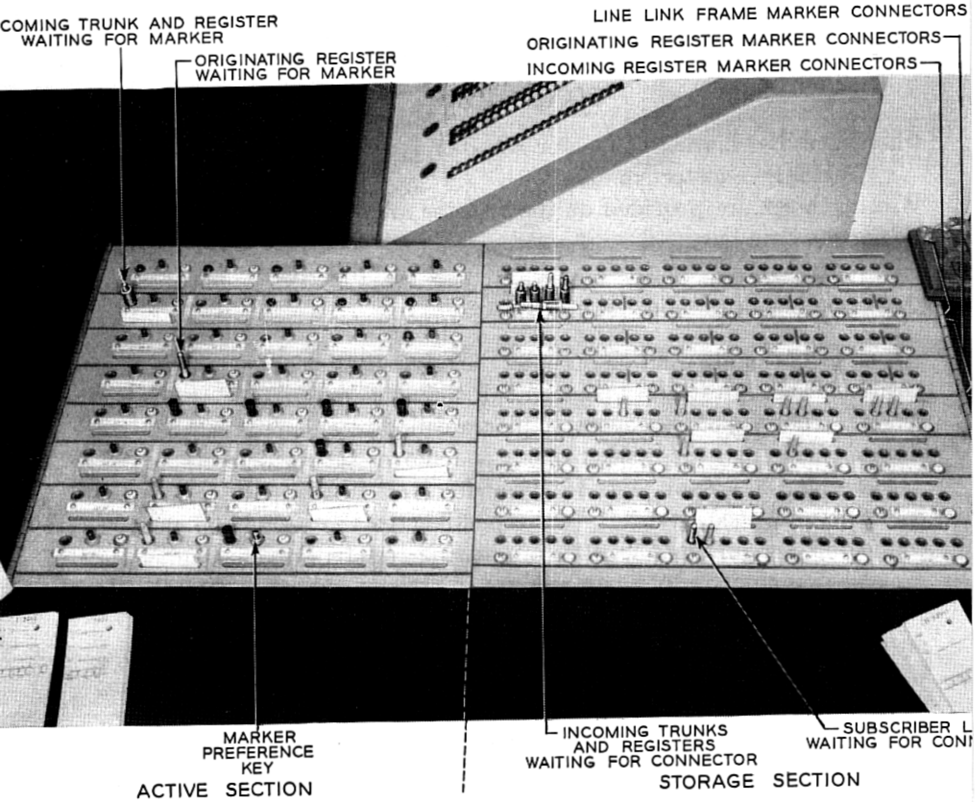

Fig. 18—The gate for control of marker connector preference.

register originations, the operator controls the preference with the assistance of a lamp signal per connector and a written register preference record.

Once in the active section of the gate, a call awaits an idle marker. When correct preference conditions are met, a CONN CLOSED (C) lamp lights, together with an attention lamp, to indicate to the marker operator which is the next call to be served. The marker operator depresses the MKR PREF key in the connector block to lock in a signal at the marker position indicating the marker to be used on this call. The operator then removes the call slip and peg from the gate and inserts them in the correct unit of the marker position. The match ticket portion of the call slip is torn off and passed to the match operator. On originating register controlled calls, the register match ticket will have been attached to the call slip and this also is passed to the match operator.

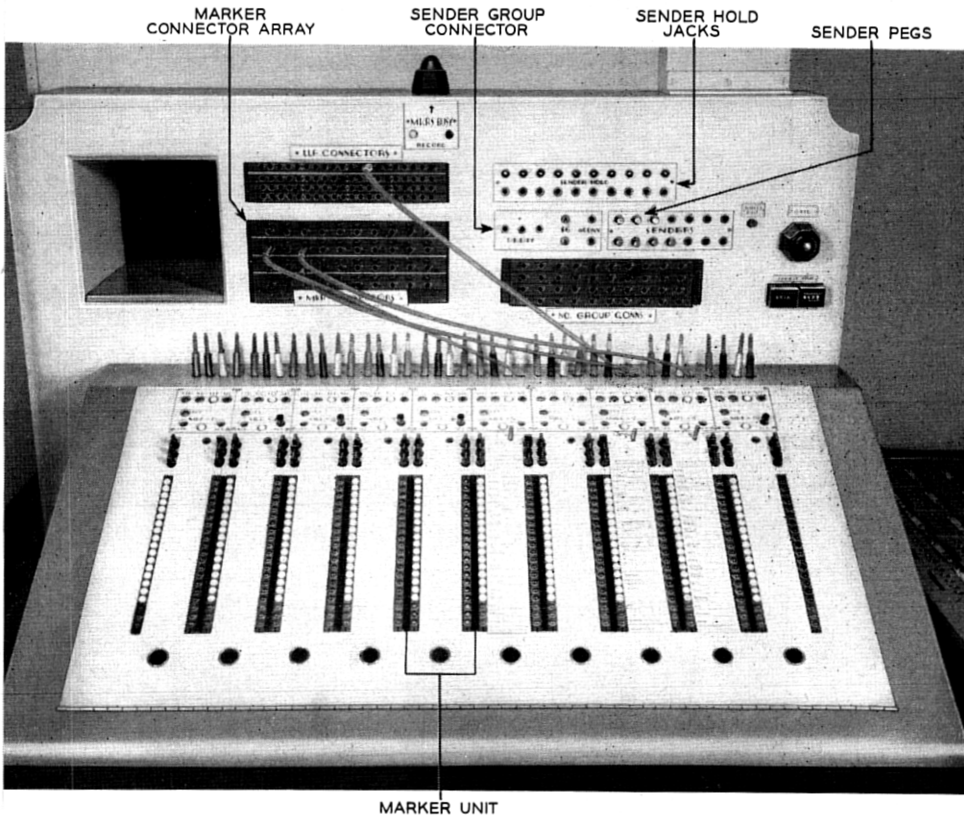

Fig. 19—Marker position.

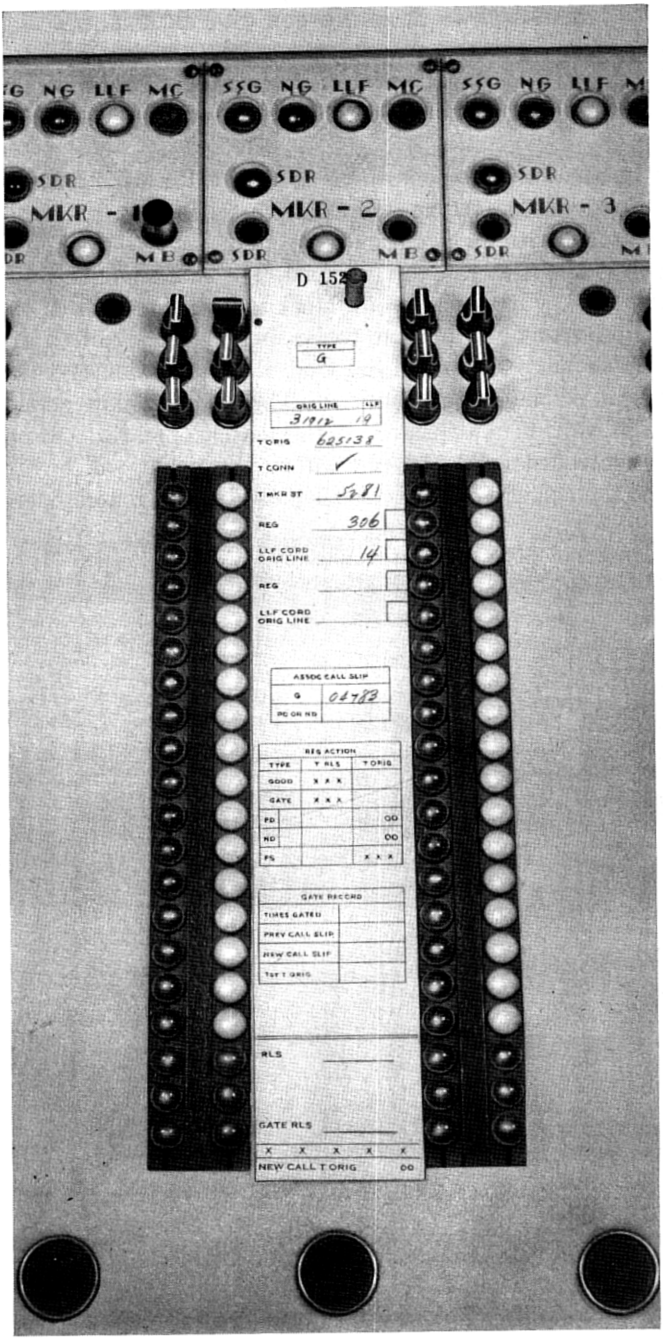

Fig. 20—Call slip in marker unit.

The circuit associated with the gate assigns all calls and markers according to No. 5 preference arrangements and provides the correct gating action. This preference is set up on cross-connection field located within the position and may be changed to correspond to any desired system arrangement.

MARKER POSITION

A photograph of the marker position is shown on Fig. 19. The individual marker units, of which ten are provided, are disposed on the sloping work panel. On the array panel are jack arrays representing the line link frames, the number groups, outgoing sender subgroups and senders, and the marker connectors. Connections to these jacks are made by means of plugs and cords located at the top of each marker unit.

The call slip for dial tone class of call is shown inserted in a marker unit on Fig. 20. At the top of the slip, in the TYPE and ORIG LINE boxes and opposite T ORIG and T CONN, are typical entries as made by the originating operator. The marker operator has also made three time entries.

The heavy dot at the top edge of the call slip indicates which of the six class keys to turn. The class keys condition the marker circuit to handle each type of call correctly. The hole at the top of the slip lines up with a jack and is used to store temporarily the line peg (register or incoming trunk peg in the case of other types of call) as received from the gate; it also serves to locate and hold the call slip in the correct position.

On the lower portion of the slip are spaces corresponding to all marker actions requiring association with other frames or circuits. These spaces line up with lamps on the marker unit which signal when and what action should be taken and indicate whether or not the time should be entered on the call slip. If a delay is encountered at any point, a check is put in the associated delay block to assist in subsequent computations involving the call slip. The left hand row of lamps lights to indicate when a direct action should be taken and a time written down. For example, when the third lamp from the left hand top lights (opposite LLF CORD) the operator places the line link frame cord at the top of the unit in the correct jack in the LLF connector array, and writes down current time in the space opposite the lamp. If the LLF jack is occupied by another marker, the operator plugs the LLF cord in a preference delay jack associated with the line link frame jack and places a check mark in the delay block.

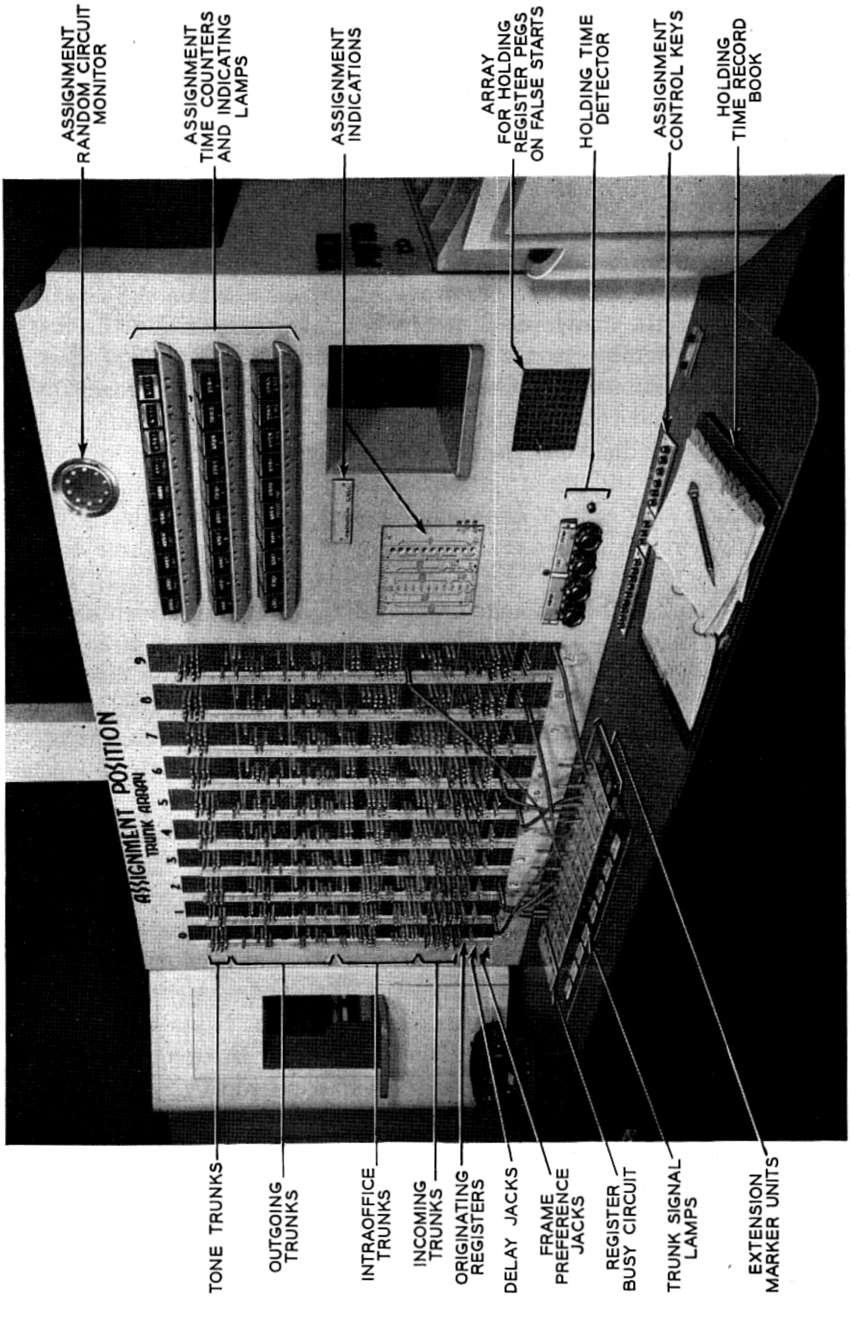

Fig. 21—Assignment position.

As discussed previously, certain marker functions are located at the assignment, originating and match positions. The choice of trunk link frames and trunks, for example, is made at the assignment position. Therefore certain lamps at the marker position light only to signal the writing down of a time. This is true of the second lamp from top left which indicates register seizure. The lamps in the right-hand row are also used in conjunction with actions at other positions. They light only to indicate that a delay should be checked in the corresponding box.

At the time of marker release, both left and right lamps light opposite one of the release categories. The specific type of release determines partially the further disposition of the call.

The START key at the bottom of each marker unit is pressed after completing each action called for by the sequence lamps. Operation of this key puts out the lamp and permits the circuit to advance.

ASSIGNMENT POSITION

The assignment position, shown on Fig. 21, includes the trunk array, the register false start holding array, the traffic assignment equipment, the holding time book and counters, and individuals units representing extensions of the markers. The chief function of the assignment operator is to test and choose trunks on each call, to determine the disposition of certain calls which encounter excessive dial tone or busy conditions, and to ascertain holding times of originating registers and trunks.

The trunk array consists of jacks (holes) representing all the trunks, and jacks and pegs representing the registers. Line pegs are held in the jacks during conversation time to mark the trunks busy. The array is divided into vertical sections representing trunk link frames. The trunk groups are disposed in horizontal rows so that trunk jacks of each group or route occupy the same relative position in each frame section. Thus a trunk-hunting action consists of picking a horizontal level in the array and searching along the level to the first idle trunk as indicated by an empty jack. The array provides more jacks than the total number of trunks so that most small trunk groups can be set up on individual horizontal levels.

The trunk identification is a three or four digit number composed as follows:

R—TLF—SW

where R is route number 0–99
TLF is trunk link frame 0–9
SW is switch number 0–9

The route number in some cases is required only for location purposes since many trunk groups are identified by name. It is assigned to a common group of trunks, maximum 100, or 10 per frame. However, in the case of outgoing trunks, the route number is required to identify the specific trunk group desired. The route number for originating registers is the same as the marker connector number for each register and is unusual in that any route number from 0–9 represents the same register group.

The register jacks occupy the lower trunk level on the array and are supplied with pegs which are used to originate the second half of outgoing and intraoffice calls. During dialing time, the associated line peg occupies the register jack to mark it busy. The next higher level on the array is the group of incoming trunks. These are furnished on a two-jack per trunk basis and are, in effect, multiples of the incoming trunk array at the originating position. The two jacks are required to hold the terminating line peg and the incoming trunk peg. The route number for these trunks is significant only for the function of location since it is not necessary for throwdown purposes to segregate incoming trunks into groups as it is with outgoing trunks.

The intraoffice trunks are divided into an A- and a B-group since more than 20 trunks per frame are required. The No. 5 marker can only test up to 20 trunks per frame at one time. The machine automatically allots calls between the two groups. Two jacks per trunk are required for originating and terminating line pegs. Unlike the incoming trunk jacks each jack of an intraoffice pair corresponds to a different switch location, although only one switch number is used for identification purposes.

The outgoing trunk groups are disposed above the intraoffice trunks. For the most part, these trunks will be in small groups, each with its own route number. When a call is set up to an outgoing trunk, it is necessary for the marker operator to inform the assignment operator of the correct route number. Several of these trunk groups can occupy the same horizontal level to conserve space. Only one jack per trunk is required to hold the originating line peg.

Tone trunks (busy, overflow, partial dial, no dial trunks) are at the top of the array. Only one jack per trunk is required.

Within the trunk link frame, the preference order in which a No. 5 marker tests trunks and the manner in which the order shifts from call to call is rather complex. In order to reduce the load on the assignment operator in trunk hunting, the actual trunk preference is approximated by reversing the direction of hunting within a frame group from call to call on a substantially random basis. Thus, when the operator determines the trunk frame within which she will hunt, she observes the LEFT and RIGHT lamps below the array for the indication as to whether to hunt from left to right or vice versa.

TRAFFIC ASSIGNMENT

One of the important functions of the assignment operator is to determine the assignment of all calls at the time of marker release. For this purpose she is furnished with traffic assignment keys and indicators which appear to the right of her position. An adequate understanding of this feature requires a somwhat detailed explanation.

With the aid of the traffic assignment controls and indicators, shown to the right of Fig. 21, the assignment operator performs the following specific functions:

On Dial Tone Calls: The operator determines whether a call reaching a register should be classified as a good call (successful subscriber dialing), a PD call (partial dial—incomplete subscriber dialing) or an ND call (no dial—no subscriber dialing while connected to a register). A proportion of call slips are originally marked as PD or ND (and also FS or false start) and on these this determination need not be made. If the call is of the PD or ND type, the operator determines whether it should be subtypes PD1, PD2, PD3 or ND1, ND2, ND3. The subtype affects the assumed time until the subscriber abandons the call. If the call is classified as good type, the operator determines which of several dialing times should be used. If the call is classified as PD, ND or FS type, the operator determines when the call is abandoned and whether or not it is routed to a tone trunk.

On Calls Completed to a Subscriber: On calls completed via intraoffice, outgoing or incoming trunks, the operator determines whether the call is answered and which of ten holding times should be assigned for subscriber line and trunk.

On Calls Routed to a Tone Trunk: On calls which are routed to tone trunks or given a tone signal from the register, the operator determines the trunk or register holding time and whether and when the call is re-originated.

In making these determinations, the operator presses keys which cause a lamp to light either beneath a time counter or beside a designation strip. The time counter, set ahead of present time, indicates trunk release time, register return time, etc., while the designation strip classifies the calls. The determining factors include the magnitude of dial tone delay, probability, and whether or not all registers are busy. Where dial tone delay is concerned, it is determined by comparing the originating time of a dial tone call slip with three dial tone delay time counters. These counters give present time minus 1, 2 and 9 seconds respectively so that matching the time of origination against them indicates whether the delay was < 1 sec., 1–2 sec., 2–9 sec. or > 9 sec.

The probability factor is obtained from a circuit which is capable of lighting one lamp out of ten, one out of three, etc. on a random basis when a key is depressed. By means of the circuit, calls can be assigned to various categories in correct proportion in accordance with the best available traffic information. Whether or not all registers are busy is indicated by the all register busy circuit controlled by the assignment operator.

If the assignment for a trunk or a register is that it be held for a period of time and then released, the assignment operator makes use of the holding time book as described later. If the assignment is for a register to return with a bid for a marker, or a new call to return into the system (after encountering busy, for example), the time is noted on the call slip and the latter is passed to the originating operator for subsequent action. For new call return time, a letter designation associated with the signal lamp is also entered on the call slip. The letter is carried forward on the new call slip. If subsequent attempts of this same line meet busy or overflow, the letter designation is used to identify the same category of return time instead of using the random circuit.

When a trunk call is set up, the trunk and one or two lines must be kept out of service for one of several fixed holding times. There are ten different assigned holding times with an equal likelihood of an established call falling into any one of them as determined by the traffic assignment circuit. False start, tone trunk and don't answer connections provide four additional holding times.

The holding time counters provided at the assignment position indicate present time plus a fixed holding time. Thus each counter gives the time at which a connection, set up at present time and assigned to that particular holding time, will release its elements back into service.

Holding time starts for a given call at the time the release lamp lights at the assignment position marker unit associated with that call. At such a time, the assignment operator obtains the one or two line pegs of the call and plugs them in the trunk jack or jacks (identified by the frame connector cord), noting at the same time the trunk number. The operator then depresses a key which causes the traffic assignment circuit to light a lamp under one of the holding time counters, thereby assigning a release time. The trunk number and release time are recorded. At the end of the holding time, the operator removes the line peg or pegs from the trunk jacks and the pegs are returned to their home jacks. Presence of the line pegs in the trunk jacks during holding time marks the trunk busy.

The busy trunk numbers are recorded in a holding time book according to release times. Time units in the system represent millionths of an hour (0.0036 second). Each page of the holding time book covers 10,000 units of time and is divided into one hundred 100-unit blocks. An illustration of one page of the book is shown on Fig. 22.

Since the time unit is one millionth of an hour, each time unit in a one hour series can be represented by a six-digit number. Of these six digits, as far as the long holding times are concerned, the last two are unimportant since 100 units is only 0.36 second. If they are dropped, the first two digits of a four digit holding time release figure give the 10,000 time unit group or page number of the holding time book and the second two digits give the 100-block on the page. Trunk numbers are entered in the book on this basis with the page and block number obtained from the assigned holding time counter.

By this means the release times of all items appear in consecutive order in the holding time book. Holding time entries are always made several 100-blocks beyond the next release time, which eliminates con-

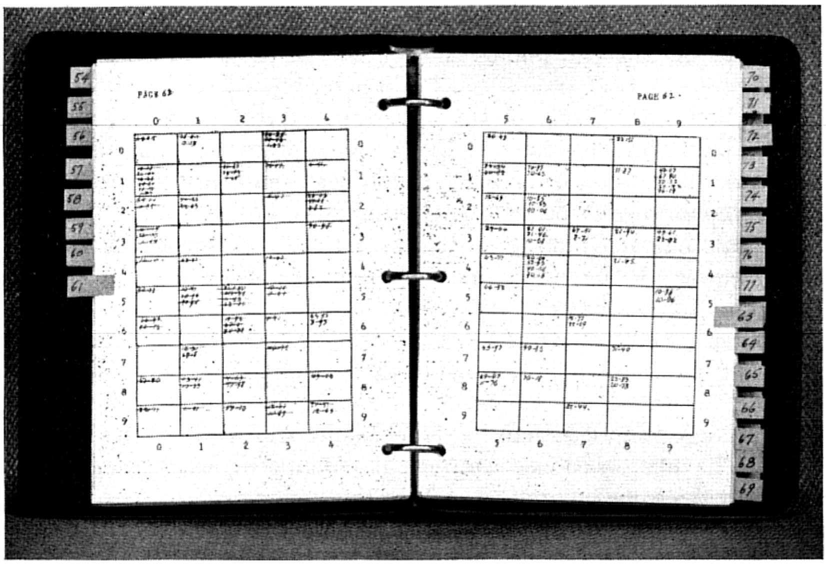

Fig. 22—Holding time book.

fusion. Following the simple numerical order of release times, the operator sets up the next release time on the holding time detector, similar to the time detectors at the originating position, which stops the system and signals when that time arrives. The operator returns the held items listed in that 100-block to normal, crosses out the block and sets up the next following time on the detector.

False start and register overflow release time entries are made in the same holding time book. A jack array is provided to hold the register peg until release time under these conditions.

Since the longest holding time is six minutes (100,000 units), the operator is never concerned with more than 11 pages at one times. With each page clearly labeled by a numbered margin tab, search time to make an entry is reduced to a minimum.

MATCH POSITION

The match operator performs the function of testing and making busy the switching channels through which each connection is set up. Her position includes ten marker units, each consisting of a group of lamps, and a set of files which hold the channel cards by means of which the channel records are kept. The position is shown on Fig. 23.

The No. 5 marker picks out a channel between a subscriber on a line link frame and a trunk on a trunk link frame by matching a line link, a junctor and a trunk link which are capable of being switched together to connect the two end points. A schematic of the system is shown on Fig. 24.

Each horizontal group of subscribers has direct access to a set of ten line links which connect to the ten junctor switches of the frame. Each link of the set can be given a number from 0 to 9 corresponding to the junctor switch on which it terminates.

Verticals on each junctor switch connect to junctors which are distributed over all the trunk link frames in the office. In a ten trunk link frame office, the ten verticals of each line link frame switch are distributed to all ten trunk link frames. This provides a set of ten junctors from each line link frame to each trunk link frame. If there are less than ten trunk link frames in the office, additional sets of junctors, perhaps comprising less than ten junctors per set, are provided between frames. The junctors connect between like-numbered switches and within a set bear the same number (0 to 9) as the switch.

The trunk links are similar to the line links except that twenty links connect from each trunk switch to the ten junctor switches. The twenty links are subdivided into left and right sets of ten which connect to the left and right halves of the junctor switches respectively. Within each set, the links are numbered in accordance with the junctor switches on which they terminate. The junctor switches are split horizontally as shown on Fig. 24 to provide for twenty junctor connections per switch (one from each of twenty line link frames). Thus a set of junctors terminating on the left halves of a junctor switch must be matched with a left set of links.

It can be seen on Fig. 24 that when the three sets of links and junctors capable of connecting a trunk and a subscriber are matched, the two No. 0 links and the No. 0 junctor go together, the two No. 1 links and the No. 1 junctor go together, and so forth. The marker performs the

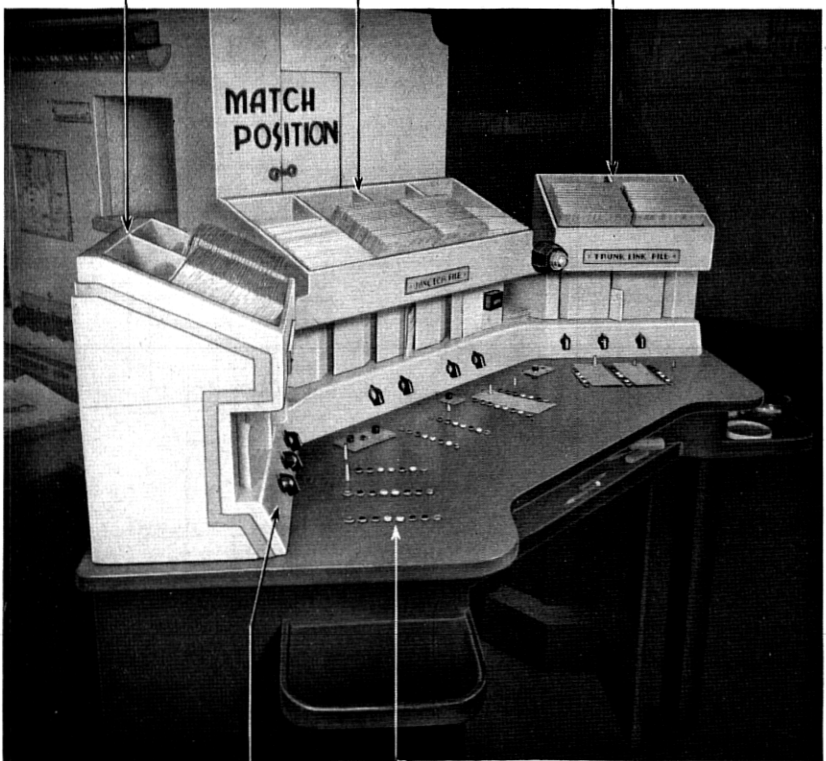

Fig. 23—Match position.

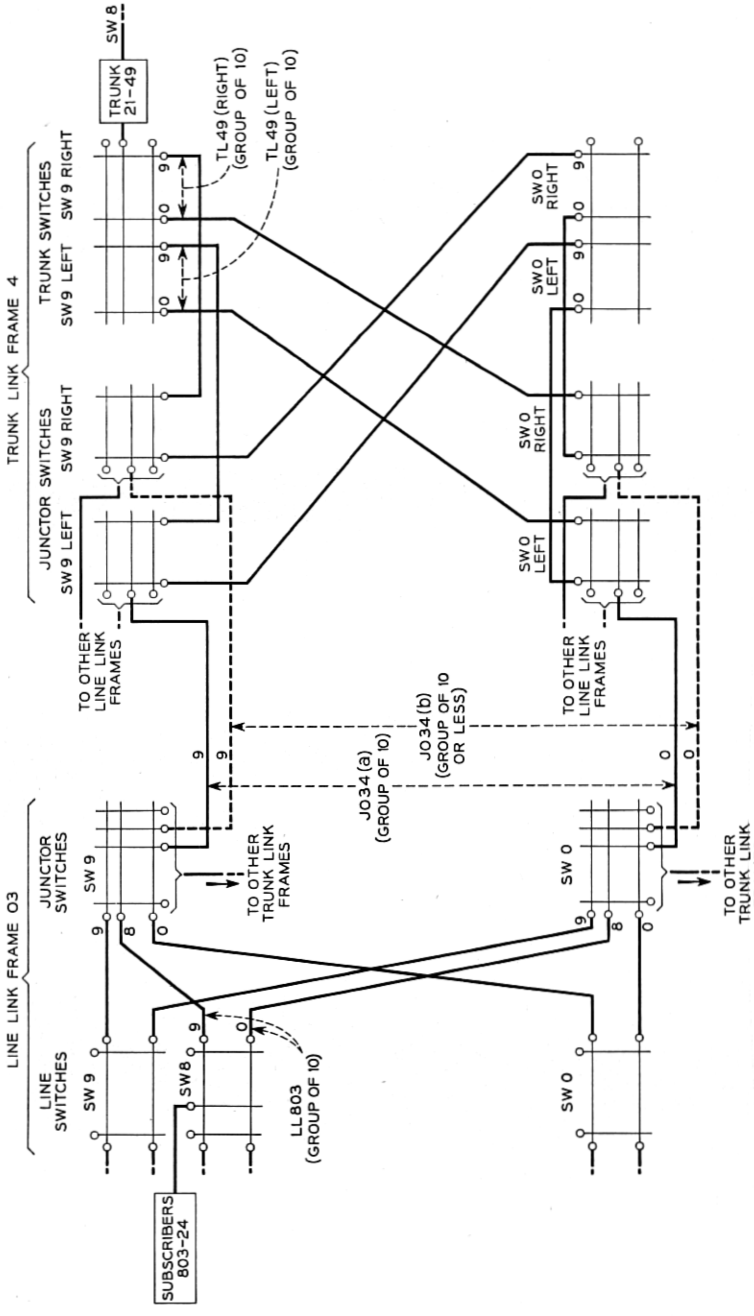

Fig. 24—Channel matching schematic.

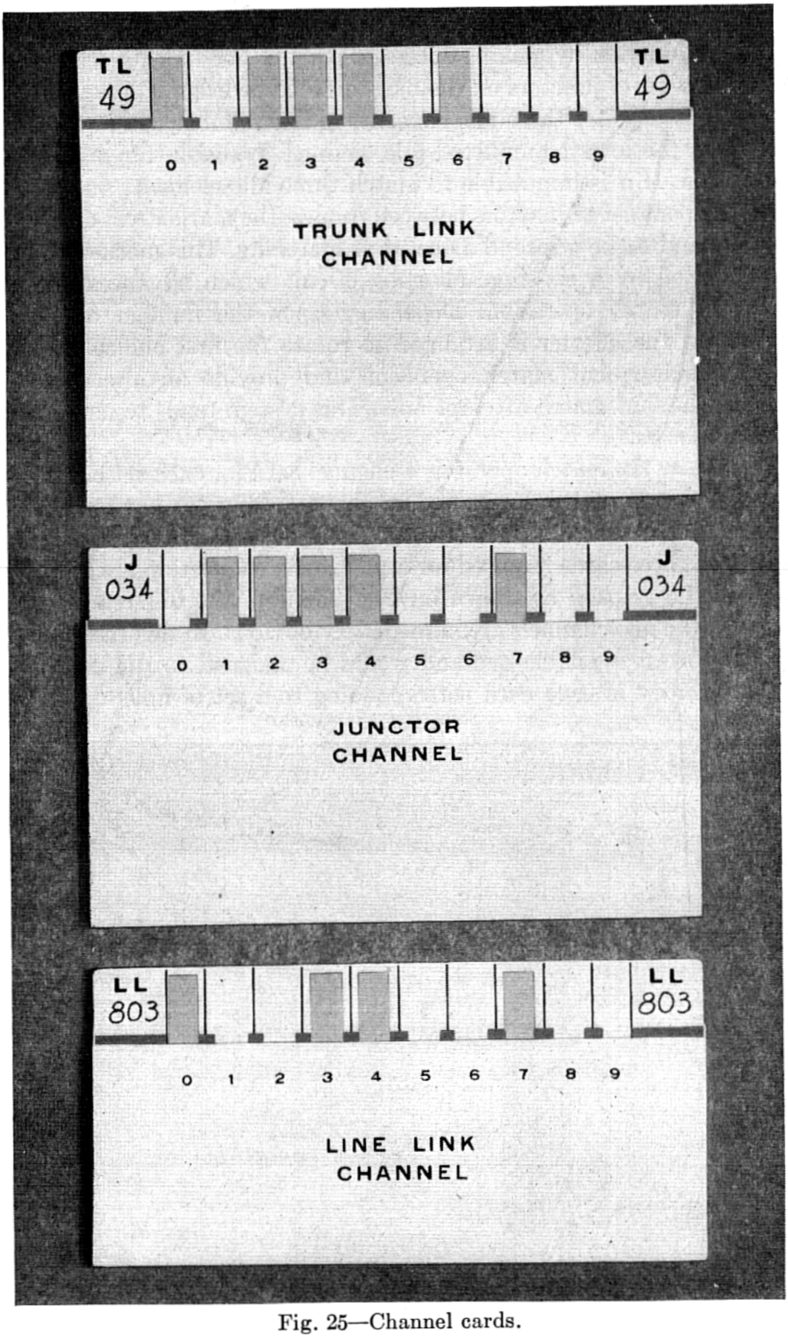

Fig. 25—Channel cards.

matching function by gaining access to a set of line links, a set of trunk links and a set of junctors on the basis of its knowledge of line and trunk location. It tests for three idle elements of like number within these sets and picks the lowest numbered idle channel available for making the connection. If it is impossible to match three idle elements and there is more than one set of junctors between frames, the marker will change the junctors and make a second attempt at matching. This marker function is performed by a six-stage allotting circuit which advances one step for every match operation. Depending upon the number of junctor subgroups, the allotter is arranged to rotate the first choice subgroup on each subsequent match operation and provide an alternate subgroup if the first match attempt fails. This system tends to equalize the use of junctors.

For use by the match operator, a channel card for each set of ten links or junctors is provided. Each card, as shown on Fig. 25, has ten pockets, one per link or junctor element, in which can be inserted a busy tab. When the three cards required for a particular connection are identified, they can be stacked as shown on Fig. 26 (note the difference in card size) and the idle channels are immediately obvious. In this case, channel 5 is the lowest available one and would be assigned to the call.

The identity of each card corresponding to a set of links or junctors

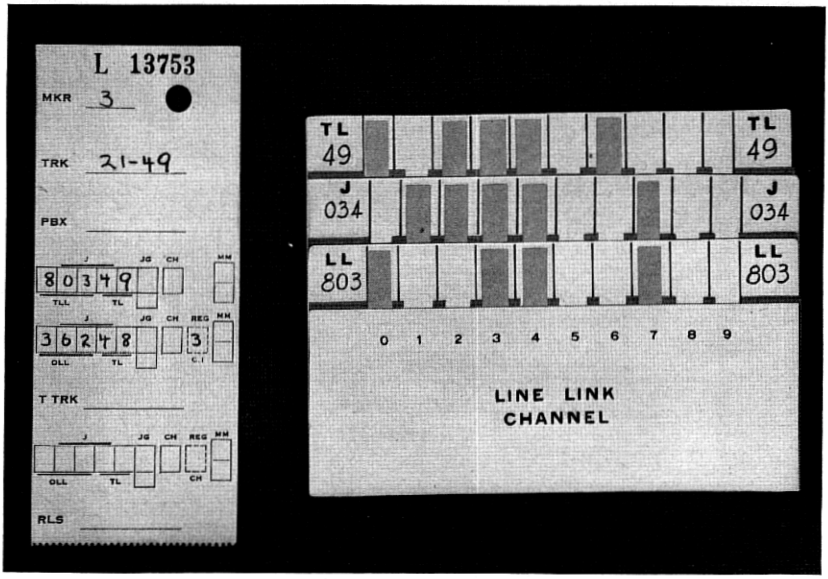

Fig. 26—Channel matching procedure.

is determined by switch and frame numbers. There are ten sets of line links per line link frame and a maximum of twenty frames. The identification of each set is a three digit number made up as follows:

SW—LLF

where SW—switch number (0–9)
LLF—frame number (00–19)
This provides for a total of 200 line link sets or cards.

The number of the line link set is incorporated in the line identification number so that from the latter can be determined immediately the particular line links available to the line. Note on Fig. 24 that line 803–24 must use the LL803 set of links (card shown on Figs. 25 and 26) for any connection.

There are twenty sets of trunk links per trunk link frame (ten left and ten right sets) and a maximum of ten frames. The identification is a two digit number plus a left or right indication. The number is composed as follows:

TLF—SW

where TLF—frame number (0–9)
SW—switch number (0–9)
and the left or right indication is, for convenience, one of two colors. This provides for a total of 200 trunk link sets or cards, 100 of each color. The link identification is included in each trunk number. Thus, on Fig. 24, trunks 21–49 must use trunk link set TL 49, either left or right.

The number and disposition of junctors are determined by the layout of line link and trunk link frames. In a 20 line link-10 trunk link frame office, there is one set of junctors between each pair of frames. For fewer frames there are more sets between frames to a maximum of five for a four-line link, two-trunk link frame office. The junctor sets or cards are identified by the two frame numbers involved, as

LLF—TLF

where LLF—Line Link Frame No. (00–19)
TLF—Trunk Link Frame No. (0–9)
If more than one set of junctors interconnect two frames, letters A to E are added to the base number. For a particular line and trunk, the junctor number is derived from a combination of the line and trunk numbers. For example, the essential parts of line number 803-24 and

trunk number 21-49 combine to give a number

80349

where the underlined digits represent the set of junctors (see Fig. 24).

In the general case, the junctors of a set may terminate on either the left or right half of a trunk link frame junctor switch. When the channel cards are made out preparatory to a throwdown study, the junctor numbers are assigned to cards of one of two colors (same as trunk link cards) depending upon whether it is left or right connection. Thus, in picking the three channel cards for a match, the choice of trunk link card depends upon, and must be the same as, the color of the junctor card.

Normally the channel cards are kept in filing sections at the match position as shown on Fig. 23. Before the matching operation is physically performed, the operator has available on a match ticket the line-trunk composite number. In the example shown on Fig. 26 this number is

80349

The digits 803 identify the line link card; the digits 034, the junctor card; and the digits 49, together with the junctor card color, identify the trunk link card. The operator removes the cards from the file, stacks them, and places them in a slot associated with the particular marker until the match signal is received. At that time, the operator picks the lowest numbered free channel in the stack, marks it busy and enters the channel number on the match ticket for record.

Each channel must be released at the same time that the line and trunk with which it is associated are removed from holding. Since release times for lines and trunks are entered on the assignment position holding time detector, this latter detector is used to signal release times to the match operator. The match operator maintains all her established match tickets in release time sequence with the earliest time on top of the pile. The lighting of a signal lamp indicates that the channel identified by the top ticket should be restored to normal.

A channel release condition which the match operator must recognize without a special signal occurs at the marker release time on intraoffice, outgoing, partial dial and no dial calls. At this time the register channel associated with the call must be dismissed. The operator will have received from the marker operator the register channel ticket involved and must restore the channel to normal before answering any new signal.

MASTER CONTROL PANEL

A master control panel for the throwdown machine is supplied on the relay cabinet shown on Fig. 14. This panel provides: means for turning the system on and off at the beginning and end of each day's operations; a centralized alarm indicating system; a bank of marker action lamps which indicate marker status during operation; and a present time counter with a units-to-seconds conversion scale.

The equipment operates on two battery supplies, one known as permanent battery and the other as day battery. Permanent battery is on continuously during a complete throwdown run in order to hold operated certain record relays. The day battery, however, is turned off during idle periods.

The equipment is arranged so that at the end of a working period all operator functions requested by signal lamps during the last working unit of time can be completed before the machine automatically stops. This is controlled by the DAY-NIGHT switch which is turned to the NIGHT position when it is desired to cease operation. The NIGHT lamp lights at this time. When the operators have extinguished the last signal lamp, the DAY POWER switch is turned to OFF.

Certain critical portions of the machine are provided with alarm circuits which automatically stop the machine and light lamps at the control panel. In most cases, the lighting of one or more of these lamps will require troubleshooting. When the trouble has been found, operation of the key associated with the lamp extinguishes the lamp and permits the machine to start again.

RESULTS OF THROWDOWN STUDIES

The throwdown machine has now been in operation for slightly less than four years. During this time 1383 seconds of equivalent central office time, divided among eleven runs, have been accumulated. The machine, of course, has not been in continuous operation, since the time required for preparation of a run and eventual analysis of output data exceeds the actual operating time for the run. In general, the same team of girls has handled both preparation and analysis of data and operation of the machine. Beyond this, there have been periods when no studies were in progress.

A detailed presentation of throwdown results is not properly within the scope of this article. However, a brief resume of the several runs with some mention of their primary objectives and typical results is necessary to conclude this picture of the throwdown machine.

It should be emphasized again that the principal function of a throwdown machine is to provide data, under controlled conditions, which can be used to develop and check a comprehensive theory of operation of a complex system. A secondary function is to study the reaction of the system to specific equipment or circuit arrangements. The No. 5 throwdown machine has been used for both purposes. All runs have furnished masses of statistical data which have been very useful in formulating traffic theories applicable to No. 5 crossbar. Some data, such as those on link matching, have a more general field of application.

All throwdown runs have employed a basic size office of twenty line link frames and ten trunk link frames, loaded by 9000 subscribers. On the first two runs, a traffic level designed to load these frames to their normal capacity was applied to the machine. This level can be called

TABLE III

Run	Duration	Quantity		System Loading	Primary Purpose of Run
		Markers	Orig. Registers		
	Seconds			*per cent*	
I	256	5	67	100	To load up machine and give normal load picture
II	216	5	59	100	To study effect of higher marker occupancy due to reduced number of registers
III	90	5	59	125	To study effect of 25 per cent overload
IVa	86	5	59	110	To establish response of system with original gate preference for comparison with run IVB
IVb	94	5	59	110	To provide data on response of system with reversed gate preference
V	65	6	65	—	This was an intermediate run in which traffic at high level was introduced in order to build up to system equilibrium at the 120 per cent load level
VI	108	6	65	120	To study system at high load level below saturation
VII	288	7	60	120	To study effect of situation where registers are more severe bottleneck than markers
VIIIabc	180	4	35	140	These three runs tested two proposed changes in the gate control circuit against the standard reversed preference arrangement. Identical traffic was used for each run

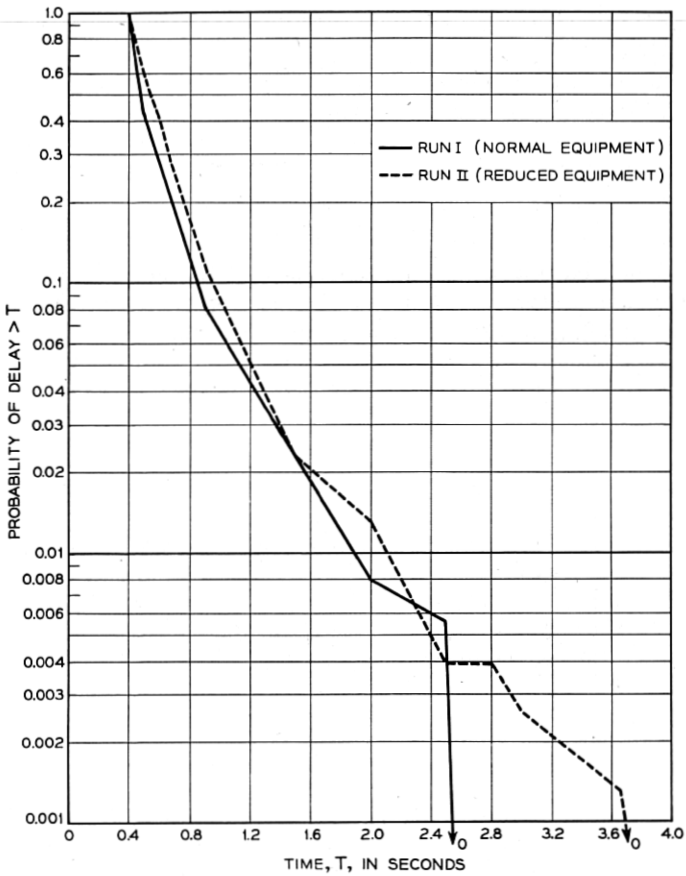

Fig. 27—Dial tone service with different equipment quantities as determined by the throwdown machine.

100 per cent load. In succeeding runs, an overload of varying amounts was utilized. In the several runs, the quantities of registers and markers were varied to obtain basic engineering data.

As the No. 5 system was originally engineered, the preference order in which markers were assigned by the gate control circuit to marker connectors during heavy loads was as follows: (1) line link frame marker connectors; (2) originating register marker connectors; (3) incoming register marker connectors. At a later date, this order was changed to put the line link frame marker connectors last in preference. In the discussion which follows, this arrangement will be known as "reversed preference."

The essential features of the throwdown runs to date are given in Table III.

The curves of Figs. 27 and 28 are representative of the type of data made available by the throwdown machine. Fig. 27 shows the overall dial tone service obtained during the first two runs. The slight degradation of service in Run II is caused by the reduction in number of registers. In both cases, however, service is very good.

Fig. 28 shows the spread of delays met by line link frames in obtaining a marker on dial tone calls during the same two runs. These curves are representative of the distributions of delays encountered at individual stages of handling a call. Other examples might be line link and trunk

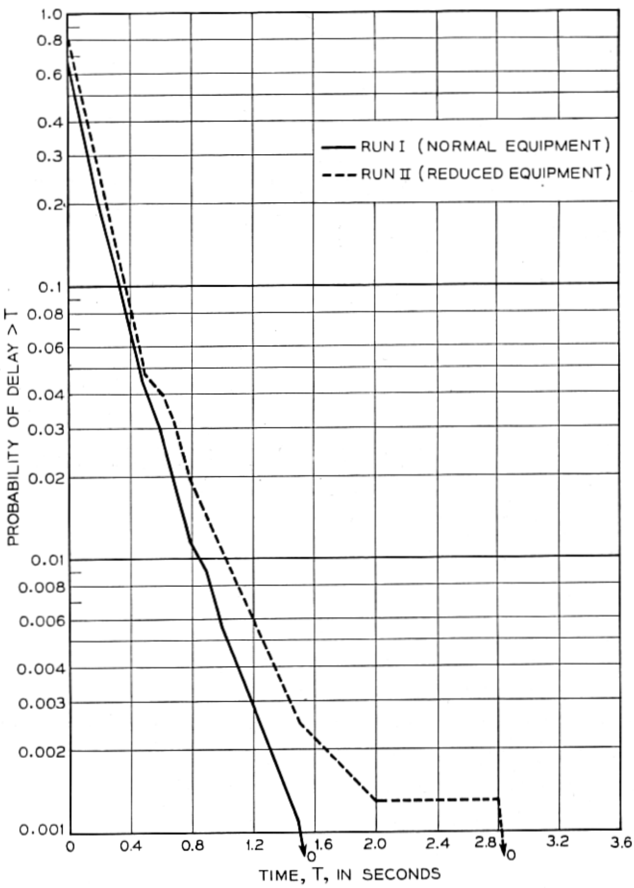

Fig. 28—Marker delays on dial tone calls with different equipment quantities as determined by the throwdown machine.

link frame delays. Taken together, these various delays determine overall grade of service.

An interesting example of the practical utility of the throwdown machine is furnished by the series of events which lead to the introduction of reversed gate preference in the No. 5 crossbar system. The changing quantities of line and register pegs in the gate position provide a graphic visual indication of the dynamic status of the system. After watching the gate for some time in the early overload runs, it was noticed that the register marker connectors were relatively less successful in gaining access to markers than the line link frame marker connectors. During all register busy periods, this reduced the call handling capacity of the system since registers were delayed in becoming available to waiting lines. The effect was compounded by wasting marker time in attempting to set up dial tone calls when no registers were idle.

It was felt that a change in gate preference, placing register marker connectors before line link frame marker connectors, would improve this. The new arrangement was tested and confirmed in throwdown run IV and is now a system standard.