No. 1 ESS Master Control Center

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The No. 1 ESS master control center (MCC) serves as the interface between the switching system and operating telephone company personnel. It includes facilities for system test and control, alarm indication, maintenance of lines and trunks, recording customer billing information, and writing information on program store memory cards. The MCC is thus the central maintenance, control, and administration point of No. 1 ESS; it can be functionally divided as follows:

(a) maintenance teletypewriter (TTY) facilities, the primary communication facilities between the system and operating company personnel. Other TTY channels provide for communication between the system and a number of other operating company areas (such as traffic measurement, line assignment, etc.). The description of all of these TTY channels is included.

(b) alarm, display, and control circuitry to provide continuous indication of system status and permit maintenance personnel to control the system.

(c) trunk and line test (TLT) facility provided for maintenance of trunks, lines and service circuits. Included are facilities for dc loop testing, transmission testing, circuit make-busy, handling permanent signals on lines, etc.

(d) automatic message accounting (AMA) facility, providing a magnetic tape record of all data related to billing customer calls. The tape is processed in an accounting center to determine the customer charges.

(e) program store card writer used for periodically updating the program store translation information. This machine is described in a companion paper.

I. TELETYPEWRITER FACILITIES IN NO. 1 ESS

1.1 *Introduction*

To maintain and administer the No. 1 electronic switching system (ESS), communication facilities must be provided to exchange information between the switching system and operating company personnel. The flexibility and self-diagnostic features of No. 1 ESS are exploited fully[1,2,3] and result in an especially large volume of information exchange for effecting changes in subscriber service, reporting trouble conditions, etc. This makes it essential that the communication facility be flexible and convenient to use. The teletypewriter, together with the No. 1 ESS stored program and large memory capacity for storage of input and output messages, meets these requirements. Other major factors which influenced the adoption of the teletypewriter as the principal communication link with No. 1 ESS were:

(a) the teletypewriter is a standard device and relatively reliable because of the vast amount of development work already done in this field;

(b) the teletypewriter, with a standard English keyboard, lends itself readily to the large number of input-output messages required in maintaining and administering a large system such as the ESS;

(c) no particular training is required to use a teletypewriter for the vast majority of input messages to the ESS;

(d) the translation of English or English mnemonics to binary and vice versa is a relatively easy task for the ESS.

Keys and lamps are also provided as input-output devices for certain special or highly repetitive but simple functions.

1.2 *Maintenance Teletypewriters*

The two primary teletypewriter channels provided in the ESS are associated with the master control center (MCC). One of these teletypewriters serves as the basic communications channel between the ESS and maintenance personnel for normal everyday use. This machine is permanently mounted as part of the MCC; see Fig. 1. The second teletypewriter associated with the MCC may be located near the MCC or in some remote maintenance center or maintenance bureau. This second teletypewriter will always be located at some remote attended point if the central office is to be unattended at any time. This machine, besides serving as a communications channel for the maintenance men, also serves as the alarm broadcasting facility for the unattended office.

The normal output messages from the system will consist of alarm indications of various types, messages indicating troubles within the system, results of any self-diagnosis resulting from detected troubles within the system, and traffic overload conditions, as well as answers to questions asked of the system by the maintenance men.

Input messages to the system are of two general categories. First, the maintenance man may interrogate the system concerning a number of

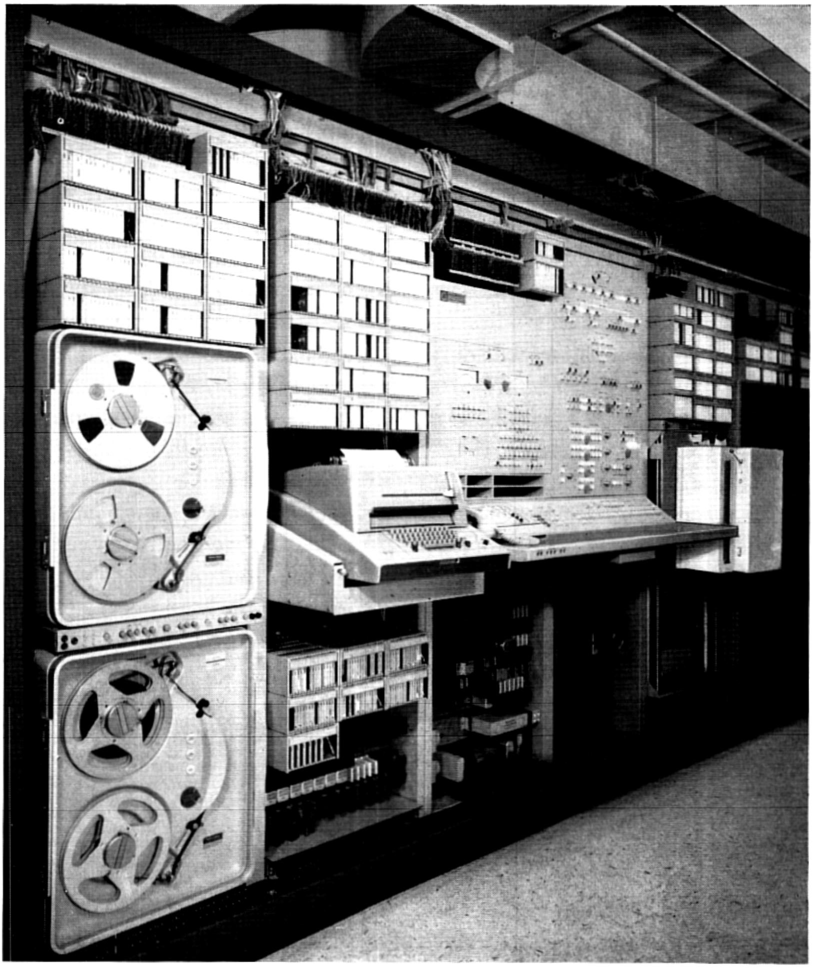

Fig. 1 — No. 1 ESS master control center.

specific areas. That is, he may ask the system to print out the contents of a particular memory location or to trace a call through the network from a particular line or trunk. He may also ask the system for the information in its memory concerning a particular line or a particular trunk. That is, he may give the system, for example, a directory number and ask the system to print out the equipment number that the directory number is associated with and all other information the system has pertaining to that directory number. Second, the switchmen may order the system to perform a diagnostic test on some part of the system.

1.3 *Service Order Teletypewriters*

A teletypewriter arrangement is also provided as the input channel for service order information. In this arrangement a teletypewriter tape reader is located in a remote service order bureau or any other location convenient for operating company personnel. This ESS teletypewriter channel accepts service order information in the field-oriented format used by any operating company. On receipt of the teletypewriter signals, the ESS edits the service order information insofar as it is able. For example, if a service order indicates that a directory number is to be assigned to a new customer's line and, in fact, the directory number is already in use, the system will detect this error. When any service order information appears to be in error, the ESS will ignore the information and will indicate the existence of the error and the service order number on the MCC teletypewriter. If the information is acceptable, the system stores the information until it is activated by operating company personnel. The service order is activated when telephone company personnel dial the service order number over a special telephone line, thus instructing the system to start using the translation information.

Provision is also made for another teletypewriter to be connected to this service order input channel and located near the main frame in the central office. When provided, this teletypewriter will receive the same service order information as received by the ESS from the remote point. The copy from this machine can then serve as the service order for main frame cross wiring.

1.4 *Traffic Usage Teletypewriter*

Another teletypewriter arrangement is provided in the ESS for indicating the contents of a large number of traffic usage registers. These traffic registers in the ESS memory are functionally analogous to the mechanical traffic registers used in all electromechanical switching systems. This traffic usage teletypewriter may be located at any point remote from the ESS. The ESS is programmed to identify each of these registers on the remote teletypewriter and to indicate its contents in summarized form. These register counts are reported periodically on the remote usage teletypewriter: the contents of some registers will be reported every half hour. In other cases, depending upon their function, some registers' contents will be reported every four hours.

This teletype channel and the associated ESS program are also arranged to permit traffic administrative personnel to interrogate the system concerning the contents of specific registers. Certain traffic overflow conditions encountered are also reported on this teletypewriter.

1.5 *Line Trouble Teletypewriter*

The final teletypewriter arrangement provided in ESS serves three purposes. This one-way channel is utilized by the system to transmit information to a remote maintenance bureau concerning permanent signals on lines, the results of automatic line insulation testing (ALIT) and the results of tests performed on pressurized cable contactor pairs. Permanent signal information is normally transmitted by the system periodically on a timed interval. However, in the event a large number of permanent signals occur in a short time, a printout is initiated as soon as information on them has been collected. The results of the ALIT tests and cable contactor tests are printed whenever failure information is available.

1.6 *Call Store Buffer*

In communicating with peripheral units, central control is able to transmit or receive a multibit word every 11 μsec.[1] By contrast, the teletypewriter can send or receive information at only one bit every nine msec. To bridge this speed barrier, a call store buffer is provided. The functional form of the buffer and its relation to the teletypewriter channels are shown in Fig. 2. It consists of two stages: a first stage provided on a per-channel basis and a second stage common to all channels.

The first stage of the buffer includes the teletypewriter channel buffer (TCB) and the teletypewriter channel control (TCC) registers. These registers are used to assemble and process both input and output messages. The TCB register can store up to 60 TTY characters. This corresponds to one line of type from the teletypewriter. As each incoming character is received from the teletypewriter, it is deposited in the TCB register by the control program. After the complete message has been assembled, it is withdrawn from the TCB register, converted to ESS machine language, and delivered to the proper client program. Records necessary for administering the TCB register are stored in the associated TCC register.

The second stage of the buffer is used as an assembly area for outgoing messages and is designated the "outgoing message buffer area" (OMBA). Records for the administration of the OMBA are kept in its administration area (AA). The OMBA has a capacity of 200 24-bit words. It contains two kinds of entries: a client request (CR) register for every output message and a data entry for clients requiring data storage. The destination channel, priority, and other output message information is stored in the CR register.

An output message from a client program is stored in the OMBA until

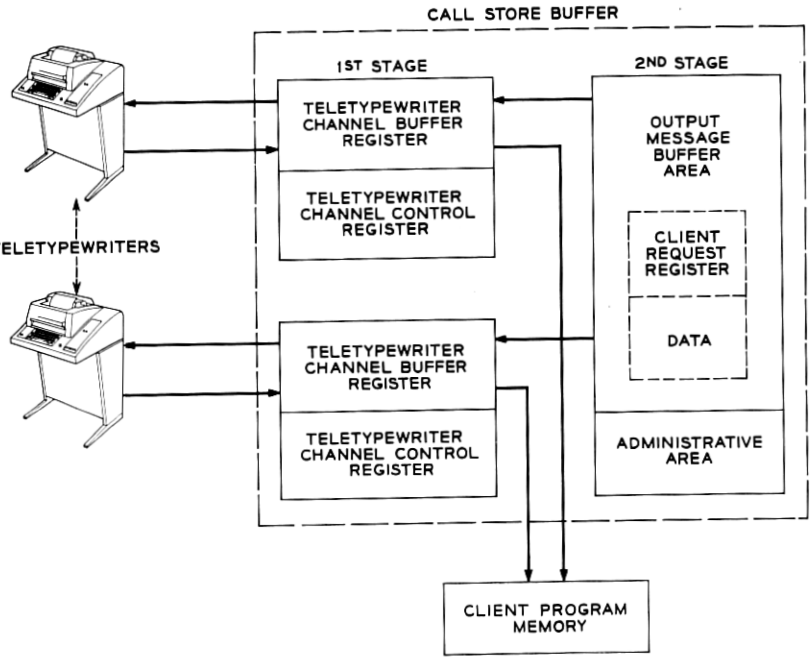

Fig. 2 — Call store buffer.

the desired destination channel is available. The message is then converted into TTY characters and loaded into the TCB register. Every 100 msec, the control program transmits a character stored in the TCB register to the teletypewriter. As this process continues, new characters are placed in the TCB register until the output message is completed.

1.7 *Input Message Control*

A special group of characters is used to instruct the program as to the proper treatment to be given each input message. Since these characters have control significance, they may not be used in the body of an input message. A partial list of the control characters and a brief description of the function of each are given below.

Dash (-): the dash is used as a part of the message identification code which precedes each input message to specify its destination and treatment. The message identification code consists of as many as 13 noncontrol characters and two dashes. The second dash indicates the end of the message identification code.

Execute (.): a period is typed at the end of each line to tell the program to execute that portion of an input message. The contents of the TCB register are then transferred to the client's memory and the carriage is returned to the left margin in preparation for the next input or output.

Checkput (?): the checkput is a printback of an input message that has just been typed. It is used to check that the No. 1 ESS has properly received the input message. The checkput is requested by typing a question mark at the end of each line of input message. If the printback is satisfactory, a period is typed at the end of the line to tell the program to execute the message.

Backspace (←): the backspace character is used to correct typing errors. Each backspace that is sent causes the program to discard the last character stored in the TCB register. The program also moves the carriage one space to the right so that the correct character can be printed to the right of the incorrect character.

Begin again (↑): this character is used to correct a full line of type. In this case, the program discards the entire contents of the TCB register and then returns the carriage to the left margin so that a new line may be typed.

Abandon message (@): input messages that have not been terminated by typing the execute character may be discarded by typing the abandon message character. In this case, the program returns the channel to the idle state and ignores the preceding message.

After each input message is typed in, a two-character acknowledgment is printed out by the program. The acknowledgment appears on the same line as the input and indicates what action has been or will be taken by the No. 1 ESS. Finally, after each complete input or output message, the program sends at least three nonprint characters to the stunt box (see Section 1.8), which repositions the carriage and unlocks the keyboard for the next input or output message.

1.8 *The Model 35 Teletypewriter*

The Teletype Corporation Model 35 teletypewriter has been adopted for use with No. 1 ESS. This newly developed machine has a four-row keyboard similar to the standard office typewriter. It operates at 100 words per minute using a new seven-bit code based on the American Standard Code for Information Interchange (ASCII) recently approved by the American Standards Association. Sixty-four code combinations are assigned to letters of the alphabet, numbers, and symbols; thirty-five combinations are used for control purposes; and the remaining twenty-nine combinations are unassigned.

The line signals generated and received by the Model 35 teletypewriter are shown in Fig. 3. Each seven-bit character is transmitted with a start bit, an unused bit, and two stop bits. Since the nominal bit interval is 9.09 msec, one character may be sent every 99.99 msec.

Like its predecessors, the Model 35 teletypewriter is equipped with a stunt box which is able to decode certain teletypewriter characters and activate a set of contacts. In No. 1 ESS, these contacts provide a convenient method of controlling external relay equipment. For example, the stunt box is used to actuate audible and visual alarms in the maintenance center when alarm messages are transmitted to the remote maintenance teletypewriter.

The Model 35 teletypewriter may also be equipped with an answer-back circuit. When triggered by a stunt box contact, this circuit sends a unique sequence of characters back over the signal line as an indication that the machine is able to transmit and receive information.

1.9 *The Transmit-Receive Unit*

Since the No. 1 ESS is a word-organized system, information is transferred between functional units in parallel form. To permit communication with the teletypewriter which sends and receives serial information, a transmit-receive (TR) unit is interposed between the central control and the teletypewriter. The TR unit accepts parallel information from central control and transmits it serially to the teletypewriter. Conversely, the TR unit receives serial information from the teletypewriter and converts it to a parallel form acceptable to central control.

The functional form of the TR unit is illustrated in Fig. 4. Serial-to-parallel or parallel-to-serial conversion of each TTY character is carried out by means of a shift register. Since full-duplex operation is not required, the same shift register is used both to transmit and receive information.

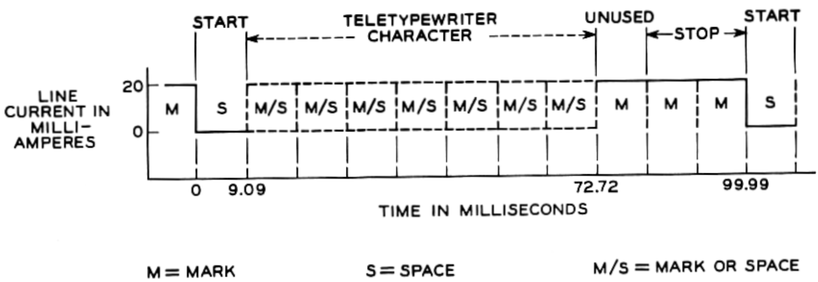

Fig. 3 — Model 35 teletypewriter line signals.

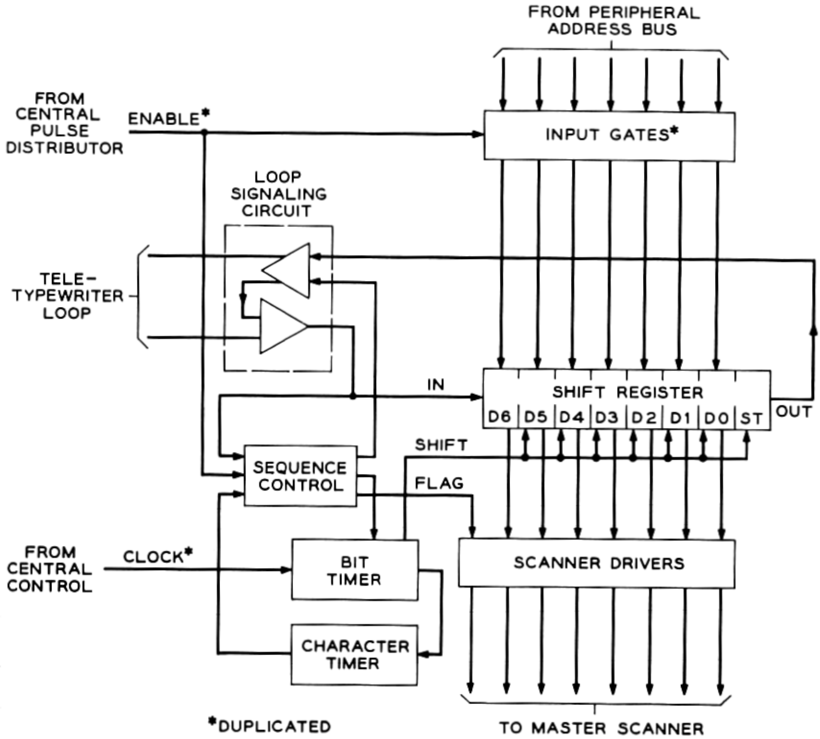

Fig. 4 — Transmit-receive unit.

The TR unit must also generate timing signals which define the duration of each bit and the end of each seven-bit character. This timing information is derived by counting down a clock signal supplied by central control every 71.5 μsec. These clock signals drive a binary counter (designated the "bit timer") which is arranged to recycle after 127 clock pulses or 9.085 msec. Each time the bit timer recycles, it increments another binary counter (designated the "character timer") which in turn recycles after the start bit and seven character bits have moved into or out of the shift register.

Parallel information from central control is delivered to the TR unit via the peripheral address bus (PADB).[4] Central control is able to transmit to the TR unit over either PADB by enabling the appropriate set of input gates. The enable signals are supplied from the central pulse distributor[5] over two private wire pairs.

Serial information from the teletypewriter is temporarily stored in the shift register and is available to central control via scan points in the master scanner.[5] The teletypewriter sends and receives information in the form of mark and space signals which appear on the signal line as 20 ma of current or zero current respectively. These signals are generated and detected in the TR unit by a transistorized loop signaling circuit. The detector has a decision threshold of 10 ma and a low-pass filter in its input to reject high frequency noise.

The operational sequences normally carried out by the TR unit are initiated by external signals received from either the central control or the teletypewriter. Resulting actions inside the TR unit are governed by the sequence control.

1.9.1 *Normal Operation*

1.9.1.1 *Receiving Sequence.* A receiving sequence is initiated by a start signal from the teletypewriter, which is detected by the loop signaling circuit. The sequence control times for half a bit interval and then samples the line signal. If the line signal is now a mark, the preceding space signal is interpreted as a hit due to line noise and the TR unit returns to its normal state. On the other hand, if the line signal is still a space, it is accepted as a legitimate start signal and the TR unit flags central control. At the end of the start bit and each successive bit, a shift pulse generated by the bit timer gates the line signal into the register and shifts each bit in the register to the next higher stage. At the end of the seventh character bit, the character timer recycles and the sequence control deactivates the flag ferrod, indicating to central control that a full character has been received. The sequence control then times for two more bit intervals, after which it returns to the idle state. During the receiving sequence, the TR unit inhibits the input gates from the PADB to prevent an improper read-in from the central control due to a false enable signal.

Central control scans the TR flag every 25 msec; after detecting the flag rise and fall, it interrogates the scan points which monitor the seven character bits stored in the shift register. The full TTY character remains stored in the shift register from the end of the seventh character bit until the end of the next start bit. After the character is read out, it is placed in a buffer register in the call store until the full input message is assembled.

1.9.1.2 *Transmitting Sequence.* Output messages are transmitted by the central control to the TR unit at the rate of one character every 100 msec. A transmitting sequence begins with an enable signal from central control. The seven character bits are gated into the shift register and an enable verify signal is returned to central control.

The sequence control now takes charge of the TR unit and begins to transmit information serially to the teletypewriter. The output of the last stage of the shift register is gated to the loop signaling circuit and the start bit transmitted by sending a space signal for 9.085 msec. Then each of the seven character bits is gated to the loop signaling circuit by a series of shift pulses generated by the bit timer.

The loop signaling circuit transmits a mark or space signal, depending on whether a one or a zero is stored in the last stage of the register. After each bit is applied to the signal line it is gated back into the first stage of the register. Thus, by recirculating the transmitted character, central control is able to check the TR unit's ability to properly transmit information.

After the last character bit is transmitted, the character timer recycles and the shift register is disconnected from the loop signaling circuit, leaving the signal line in a continuous marking condition. The sequence control times two more bit intervals and then returns to the idle state. During the transmitting sequence the input gates from the PADB are again inhibited to protect the information in the shift register from mutilation by a false enable signal.

Although teletypewriter signals can flow in only one direction at a time, there is still the possibility of simultaneous seizure of the TR unit by both the teletypewriter and central control. In this case, the TR unit favors the teletypewriter by permitting the start signal to override the enable signal from central control. The TR flag is activated and central control is able to defer its output message until the input message is completed. This same provision permits the maintenance man to interrupt central control at any point in a transmitting sequence simply by depressing the break key at the teletypewriter. This action produces a long space signal which fills the shift register with zeros and is recognized by central control as a request to send an input message. After the input message is received, central control resumes sending the output message previously interrupted by the break signal.

1.9.2 *Trouble Detection*

Central control periodically checks the TR unit's ability to transmit information by comparing the recirculated character with the character previously transmitted. If a discrepancy is found, central control activates a central pulse distributor point which places the TR unit in the quarantine mode. This mode is designed to permit fault recognition and diagnosis. While in quarantine, the TR unit is divorced from the teletypewriter, although the recirculation path is maintained and continuous marking current is supplied to the signal line. Five of the seven scan points that normally monitor the shift register are reassigned to critical points in the character timer and sequence control. The other two scan points continue to monitor the fourth and seventh stages of the shift register. Central control may then initiate a transmitting sequence and observe changes of state in the sequence control, recycling of the character timer, and signal flow through the shift register.

The ability of the TR unit to receive information is also checked on entering the quarantine mode by momentarily opening the input to the loop signaling circuit. The TR unit interprets this action as a valid start signal and executes a receiving sequence. At any time during a diagnostic routine, central control may monitor the full content of the shift register by returning the TR unit to its normal mode.

Fuse alarms, power removal, and abnormal supply voltage conditions are also reported to central control by means of scan point indications. During idle periods, central control may check the supply voltage monitors by artificially inducing high- and low-voltage conditions.

1.10 *The 105A Data Set*

Most of the teletypewriters associated with No. 1 ESS will be located at points remote from the central office. The permissible distance between the teletypewriter and its associated TR unit would normally be limited by the loop resistance of the connecting cable pair. To overcome this restriction, the dc teletypewriter signals are converted to ac tones by 105A data sets which are interposed between the teletypewriter and the TR unit as shown in Fig. 5.

Each data set consists of a frequency-shift modulator and demodula-

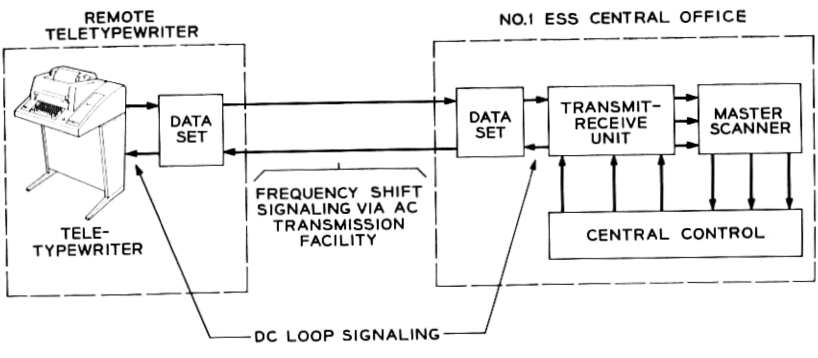

Fig. 5 — Remote teletypewriter channel.

tor. The modulator converts dc loop current or the absence of current into a continuous mark or space frequency. The demodulator detects the mark or space frequency and converts these signals to dc loop current or the absence of current. The data sets are arranged to transmit and receive in two different frequency bands, thereby allowing transmission in both directions simultaneously.

The strength of the carrier signal received by each data set is continuously monitored as an over-all check of the communications channel. If the received carrier falls below a predetermined level for more than 400 msec, the data set will change to its disconnect state and send a 750-msec space signal to the other data set. After timing the long space signal, this set will also change to the disconnect state. The loss of carrier is reported to the No. 1 ESS by means of a scan point in the master scanner activated when the data set is in the disconnect state. Loss of carrier on the remote maintenance channel is also reported as a major alarm by the data set in the attending maintenance center.

A special provision in the remote maintenance channel is the means to report a catastrophic failure of No. 1 ESS even though the system is unable to transmit an output message. In this case, the emergency-action timeout circuit in central control releases a relay which opens the transmission path between the two data sets. The subsequent loss of carrier is detected and reported as a major alarm by the data set in the maintenance center.

II. ALARMS, DISPLAYS, AND CONTROLS IN NO. 1 ESS

2.1 *Introduction*

The primary medium of communication between No. 1 ESS and maintenance personnel is the maintenance teletypewriter channels described in the previous section. When the system maintenance program detects a trouble, it diagnoses the unit and reports the location of the failure to the maintenance personnel via the maintenance TTY. After repairing the unit, maintenance personnel use the maintenance TTY to instruct the system to return the unit to service.

TTY communication, however, is not dependable when the system loses its self-organizing capability. When this occurs, the need to exert control over the system is imperative. To provide for this need, controls and displays are provided in No. 1 ESS equipment frames and on the alarm, display, and control panel at the master control center. An alarm system is used to alert maintenance personnel and direct them to the proper location for receiving data about the nature of the failure.

2.2 *Office Alarm System*

For any one floor in a building, the office alarm system (see Fig. 6) consists of an aisle pilot unit with a major alarm lamp for each equipment aisle, a group of three lamps for each main aisle, a vertical lamp holder near the exit with one lamp for each of the other floors in the building, and a panel containing four audible alarms and relay control equipment. Of the three lamps in the main aisle group, one is the main aisle pilot. This lamp indicates trouble in an equipment lineup off that main aisle. The remaining two are the "other floor lamps." These indicate the existence of troubles on other floors. The audible signal for major alarms is a tone bar and for minor alarms is a telephone ringer.

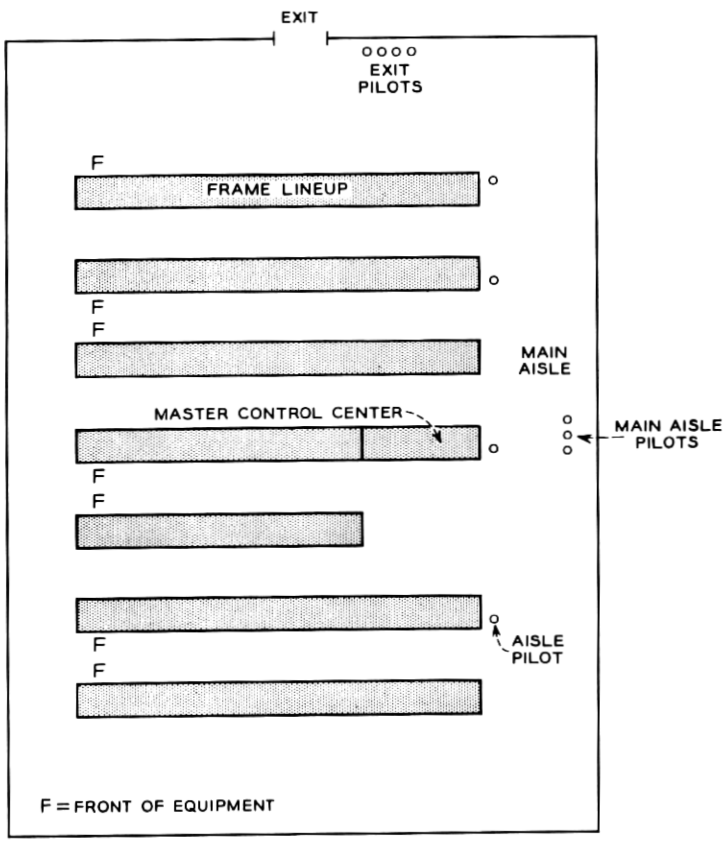

Fig. 6 — Office alarm layout.

The power room equipment does not contain a series of locating lamps, since it has its own alarm circuit providing both major and minor alarms. It is tied into the office alarm system, however, to the extent that for major alarms it lights the appropriate other floor lamp and rings a distinctive audible alarm on all floors. For a minor power alarm, it lights the appropriate other floor lamp and rings the regular minor alarm bell on the floor where power alarms are normally supervised. Either major or minor power alarms cause a separate exit lamp on each of the floors to light.

The office alarm system also contains an alarm circuit to indicate a failure in the supply that powers the alarm circuits themselves. A failure in the fuses that supply the alarm circuits causes a distinct audible alarm to be sounded, immediately indicating to the maintenance man the precise nature of the failure.

Each No. 1 ESS subsystem reports fuse failures via the office alarm system. Lamps located on the frame indicate the nature of the trouble. The maintenance programs, the most powerful diagnostic facility in No. 1 ESS, have access to the office alarm system at the MCC. When the program completes diagnosing a unit, it reports the failure to the MCC, which causes a signal to be placed on the alarm system. The maintenance personnel retire the alarm at the MCC and receive the dictionary printout[3] from the teletypewriter.

No. 1 ESS alarms are transferred to a distant office using a teletypewriter loop. The teletypewriter at the receiving office is integrated into the office alarm system by using teletypewriter stunt box contacts to activate remote alarms.

2.3 *Alarm, Display and Control Panel*

The alarm, display and control panel (see Fig. 7) is the centralized control point for No. 1 ESS. Lamps provide an over-all indication of the system status. Keys and pushbuttons provide means of exerting direct control over the system and its program. For convenience, this panel is divided into four sections. Each section will be described separately.

2.3.1 *System Status Display*

The lamps in this group display the status of individual units as classes of units. Whenever a trouble occurs, the maintenance man can quickly ascertain the seriousness of the failure by glancing at the lamp displays. Each central control has two lamps: one, labeled "TBL," lights when the unit is in trouble; the other, labeled "ACTIVE," lights when the unit

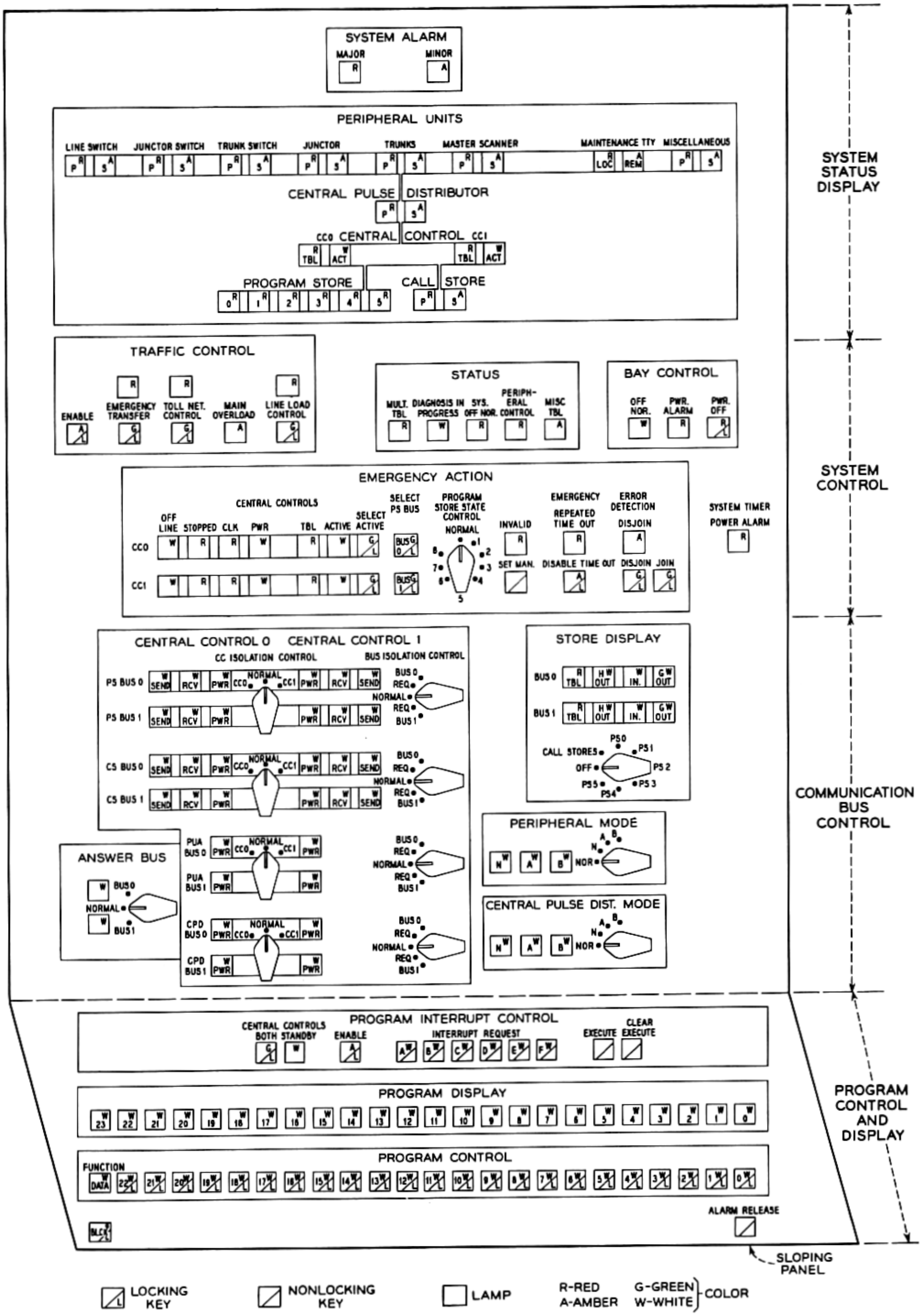

Fig. 7 — Alarm, display, and control panel.

is in active status. Each program store has a lamp that lights when the store is out of service. Two lamps are provided for line switch frames. The primary lamp P lights when both scanner controllers or both network controllers are in trouble in some line switch frame. The secondary lamp S lights when one scanner controller or one network controller is out of service in some line switch frame. Similar considerations apply to the other groups of units. In the call stores, the primary lamp lights when both copies of some information block are no longer available. The secondary lamp lights when only one copy of some information block is unavailable.

2.3.2 *System Control*

The system control is used to restore rudimentary self-adaptive capability to the system when the maintenance programs[3] cannot effectively restore order. The first indication that the system has lost program control comes when an emergency-action alarm is given. This alarm indicates that the system program has not passed prescribed check points within a given time interval. If this alarm is repeated several times (as indicated by the "REPEATED TIME-OUT" lamp), the system is deemed to have lost control. For instance, the system clock may have failed and a switch of central controls cannot be effected. When maintenance personnel are faced with this situation, they must take control over the system. Control is assumed via the "emergency-action" controls. Via these controls, the maintenance man can force a configuration of central controls and program stores, the basic data processing units in the system. He then starts the program. The program then attempts to recover an operational system. If the program cannot reestablish control it will again time out. Maintenance personnel then force a different configuration. This is repeated until the program establishes control.

Associated with the emergency action controls are lamps to provide feedback to the maintenance man. Points monitored include the clocks, power, active status, stopped, and trouble flip-flops in each central control.

2.3.3 *Communication Bus Control*

The keys and lamps in this group are used to control the interframe bus systems[4] and display their status. The lamps in this group display how the central controls (CC) are associated with the duplicated buses for program stores (PS), call stores (CS), peripheral units (PU) and central pulse distributors (CPD). For each CC, lamps indicate whether the

CC is transmitting to and/or receiving from the appropriate bus system. Each CC can also be isolated from any or all bus systems. Such control is desirable when the systems must be "split" for special test purposes. The buses can be isolated from each CC by operating the appropriate "BUS ISOLATION CONTROL" switch. Before control is applied the switch passes through an intermediate "REQ" position. This position, which is monitored by a scan point, gives the program an opportunity to mark the bus in trouble and take it out of service. This allows an orderly shutdown of the bus system.

2.3.4 *Program Control and Display*

Since the "software" in No. 1 ESS is significant in the operation of the system, some control over it is necessary. There exists a class of programs — system initialization, for instance — instituted by the maintenance man in emergency circumstances. The system can be forced into a number of these programs by operating the "program interrupt" keys.

The "program control" keys are used to insert data into the system. Conversely, the system can be requested to display data on the "program display" lamps. The program control keys are also used to control blocks of programs when the system program is being modified.

III. TRUNK AND LINE TEST PANEL

3.1 *Introduction*

The trunk and line test (TLT) panel, in conjunction with the MCC TTY, provides central office maintenance personnel with a facility for maintaining interoffice trunks, lines, and service circuits (e.g., dial pulse receivers, multifrequency transmitters, etc.).[6] The inherent ability of No. 1 ESS to perform logical actions under direction of a stored program suggests that the facility design should include a minimum amount of hardware. In general, the simplicity and flexibility of design in the TLT panel was obtained by exploiting the following:

(a) Compared to electromechanical switching systems, No. 1 ESS permits simplified trunk circuit design and, consequently, more trouble-free operation. Also, the types of trunk circuits required in the largest numbers are designed as plug-in modules for easy maintenance.

(b) No. 1 ESS is programmed to make a number of per-call checks on trunk circuits and service circuits in the process of handling a call. This arrangement allows the system to report circuits causing trouble via the maintenance TTY.

(c) If No. 1 ESS encounters trouble with a particular service circuit or trunk in the process of handling a call, it can in many cases complete the call by using another circuit and then determine the nature of the trouble and report it to the maintenance man via the TTY.

(d) Part of the simplicity in trunk circuit design stems from the fact that outgoing trunk (OGT) test jacks are not provided on a per-trunk basis. Test access to any trunk or service circuit is obtained by a switched connection through the switching network.

(e) Entire test sequences can be stored in the system program for various circuits and be rapidly initiated by the maintenance man from the TLT panel. The system can also be told to mark a trunk or service circuit busy in the memory, and consequently a make-busy key or jack per trunk is not required.

3.2 *General*

The TLT panel in conjunction with the local maintenance TTY adjacent to it serves as the major tool for the central office personnel for maintaining trunks and lines. The keys and lamps on the TLT panel are used for those tests and messages which occur most frequently in the course of maintaining trunks, lines, and service circuits. The same messages could as well be transmitted by the TTY, but the TLT panel provides a more rapid means of communication.

The block diagram in Fig. 8 shows the basic relationship between the TLT panel and the system. The equipment arrangement is shown in Fig. 9. A TOUCH-TONE key set, mounted on the key shelf, is used to transmit all information to the system. The output of the TOUCH-TONE key set reaches the system via the master test line (MTL) which appears as an ordinary TOUCH-TONE line on the switching network with a special class of service. The keyed information may consist of a trunk or service circuit number, a trunk number and a directory number to be outpulsed, etc. Once a trunk, line, or service circuit has been identified to the system via the MTL and the maintenance man has received appropriate supervisory or status indications (e.g., busy, idle, etc.), he can then exercise any of the test and maintenance features provided in the TLT panel.

3.3 *Trunk and Line Test Panel Features*

Trunk make-busy — If the maintenance man identifies an outgoing trunk by keying the proper identity number over the MTL, he can then, if the trunk is idle, operate a make-busy key to instruct the system to mark that particular trunk "maintenance-busy" in its memory. As long

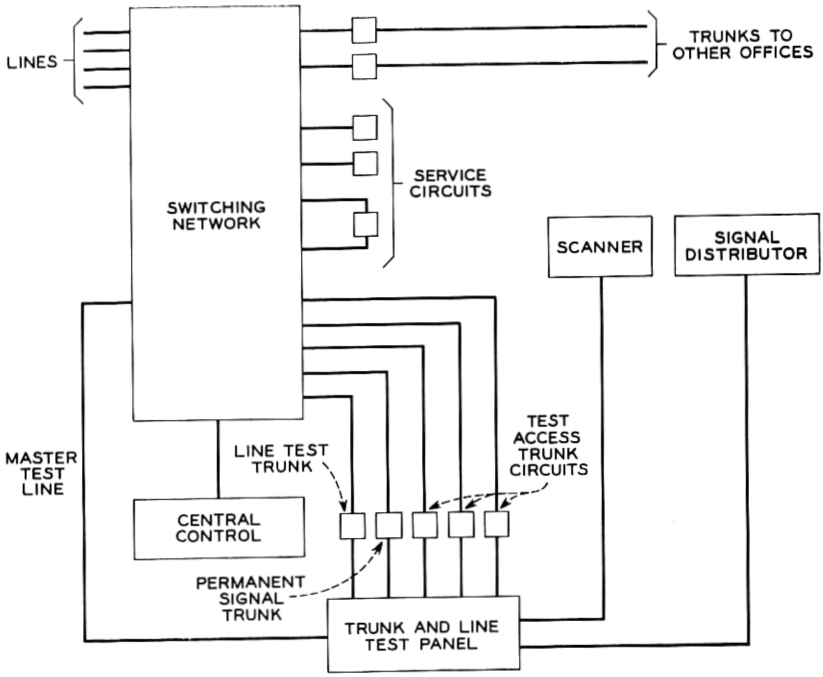

Fig. 8 — Block diagram showing basic connections between TLT panel and ESS.

as the trunk is marked "maintenance-busy," the system will not use the trunk for normal traffic. However, a connection can be established between the trunk and the TLT panel for test purposes. If the maintenance man identifies a trunk that is already in the "maintenance-busy" state, he can operate another key which instructs the system to restore that particular trunk to service. Whenever the system reacts to a make-busy or remove-busy order from the TLT panel, it also prints a message on the TTY identifying the trunk which was made busy or restored to service.

If the maintenance man wants to mark a trunk maintenance-busy but finds that it is traffic-busy, he can instruct the system to mark it maintenance-busy as soon as it becomes idle and to notify him by a message on the TTY. Thus, he can continue with other work until the trunk is available.

Test access trunks — Once a trunk or service circuit has been identified, the system can be instructed to connect it to any one of the three test access trunks. Thus, if the maintenance man identifies an outgoing trunk and causes the system to outpulse to a test terminal or test facility

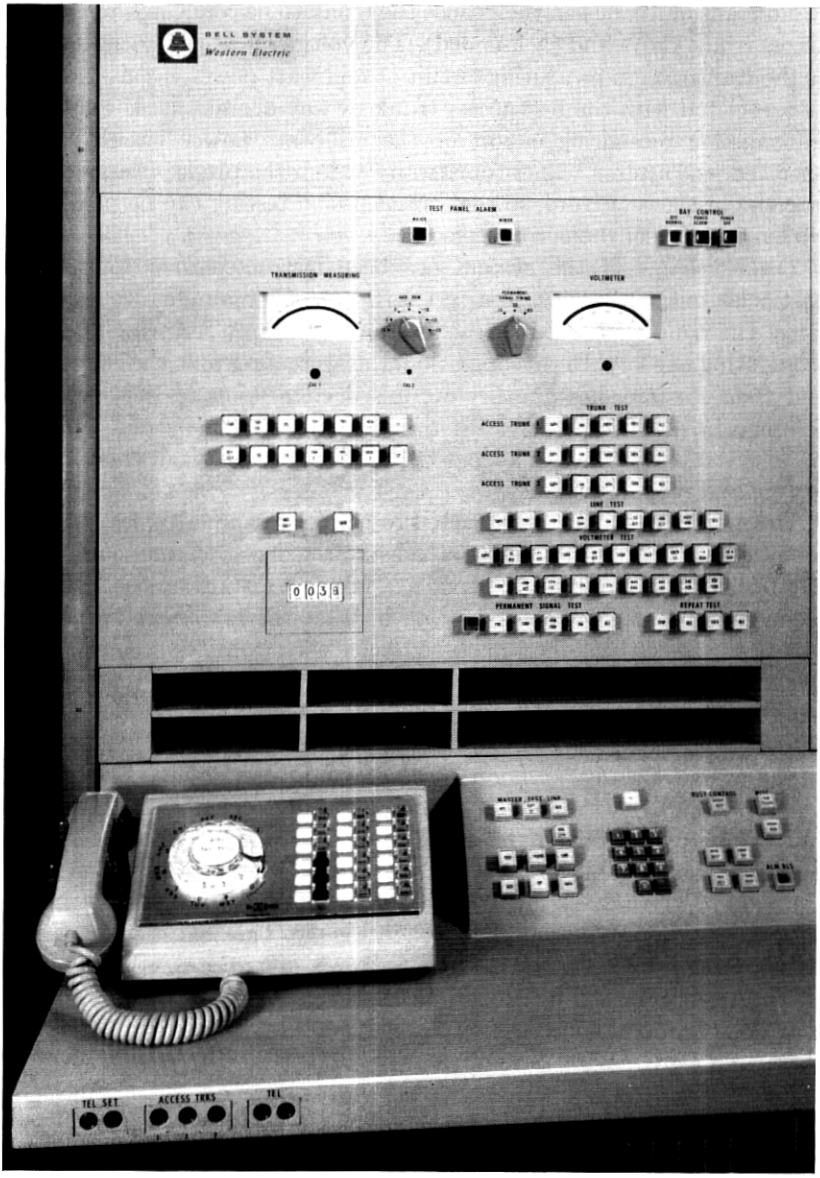

Fig. 9 — Equipment arrangement of TLT panel.

in a distant office, he can then cause the trunk to be connected to the test access trunk (key- and jack-ended). The voltmeter test facilities as well as the transmission measuring circuit or milliwatt power circuit can then be associated with the test access trunk by key operations. If either the transmission measuring circuit or the milliwatt power circuit key is operated, the system will automatically switch the proper resistive pads into the test access trunk so that transmission testing can be performed within 0.1 dbm of the correct reference level.

Trunk retest — If the system has been instructed to outpulse on a particular outgoing trunk to a test terminal, the maintenance man can retest the trunk to the same test terminal by simply restoring and then reoperating one key. In this operation, the system releases the connection and then reestablishes another outpulsed connection to the same test terminal in the distant office via the same trunk. The system will continue this retest operation as long as the maintenance man continues to restore and reoperate the key.

The system can also be instructed to perform a similar repeat test automatically. That is, if a test call is established to a permanently busy test terminal or an incoming trunk test line in a distant office, the maintenance man can, by key operation, instruct the system to repeat the test on the same trunk for a maximum of thirty-two times. Each time the system establishes a new test call, it will monitor the signals or tone being returned from the test terminal and report when a failure is detected.

Substitute trunk test — Loop pulsing trunk circuits in ESS are designed with a bypass state. That is, under system control, the trunk circuit can be completely bypassed or removed from the trunk. This feature makes it possible to switch a substitute test trunk circuit in place of a loop-type trunk circuit suspected of being faulty. The network connections for this operation are shown in Fig. 10. This feature can be used to help isolate troubles in a trunk. If the maintenance man cannot successfully establish a call through either the regular trunk circuit or the substitute trunk circuit, he has reasonable assurance that the trouble is not in the regular trunk circuit.

Line testing — The maintenance man can identify a customer line in the same way that he identifies a trunk or service circuit. Once the system has received the identity of a line from the TLT panel, it reports the busy-idle status of the line and displays the line's class of service (e.g., coin, noncoin, PBX). If the line is idle, the system will connect the line to the TLT panel via the line test trunk. The line test trunk is key ended at the TLT so that the voltmeter test circuit can be associated with the line. Keys are also provided for ringing the line, exercising coin

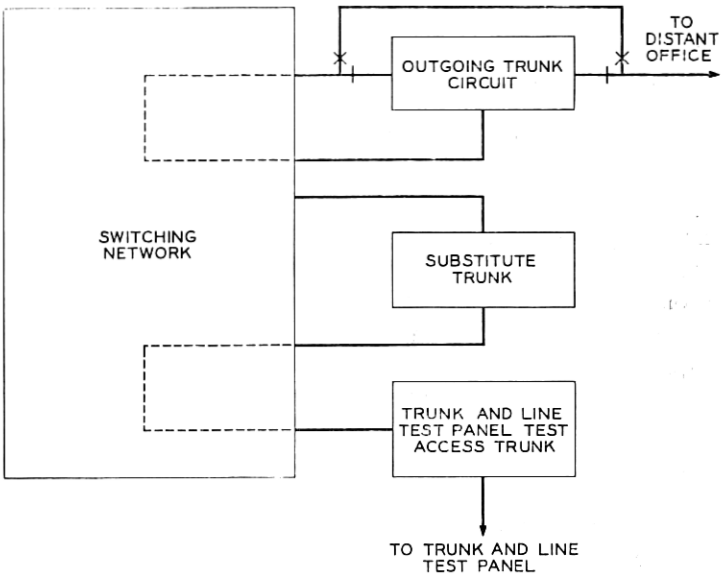

Fig. 10 — Network connections for substitute trunk.

control if it is a coin line, applying receiver off-hook (ROH) tone, and testing the ferrod associated with the line.

Monitoring — By key operation, the system can be instructed to establish a monitoring connection to any identified traffic-busy trunk, service circuit, or line.

Permanent signal holding trunk — When a permanent signal persists on an ESS line, the system sequentially connects the line to a recorded announcement, ROH tone, an operator trunk, and the permanent signal holding trunk appearing at the TLT panel. If the permanent signal condition ceases any time during this sequence, the line is restored to normal and the balance of the sequence is omitted. When the system connects a permanent signal line to the permanent signal holding trunk, it alerts the maintenance personnel by lighting a lamp associated with the holding trunk at the TLT panel. The system also indicates whether the line is serving a coin station, a PBX, etc. If the maintenance man takes no action on the permanent signal, the lamp will start flashing after a timed period and an audible alarm will be sounded.

The holding trunk is key ended at the TLT panel, and by key operation the maintenance man can challenge on the line, ring, or apply ROH tone. If these actions fail to clear the permanent signal, he may test the line with the voltmeter test circuit and instruct the system to disconnect the line from the holding trunk. When the system releases the network connection to the line, it causes the directory number of the line to be printed on the TTY and continues to scan the line. There is no network connection to the line during this scanning operation. However, when the trouble causing the permanent signal is cleared, the system will automatically restore the line to service and notify the maintenance man via the TTY that the line is now free of trouble.

Only one permanent signal holding trunk is provided, because the ESS has the ability to establish a queue of permanent signal lines which have been subjected to all parts of the permanent signal sequence except for being connected to the holding trunk. Consequently, if permanent signals exist on more than one line, the line that has been in the permanent signal queue the longest will be connected to the holding trunk as soon as the maintenance man releases the holding trunk. The system will notify maintenance personnel if the number of lines waiting in the permanent signal queue increases beyond a certain number, and on request will print via the TTY a complete list of all line directory numbers which are in a permanent signal state.

Test progress and errors — The system is arranged to inform the maintenance man of the progress on any test call that he has instructed the system to perform, and in addition alert him to many kinds of errors. For example, if an irregular code is keyed to the system or if any of the control keys are operated incorrectly, the system will flash a lamp at the TLT panel.

Register listing feature — All information transmitted to the system from the TOUCH-TONE key set via the master test line is stored by the system in a register until the MTL is released. The contents of this register include the identity of a trunk and the outpulsed number, etc. The maintenance man may at any time interrogate the system as to the contents of the MTL register by operating a key. The system will then cause the contents of the register to be printed on the TTY.

The preceding description illustrates the types of features that are included in the TLT panel. All of the features provided in the TLT panel, including those described here, provide the operating company personnel with a flexible and versatile tool for testing and maintaining lines, service circuits, and trunks.

IV. AUTOMATIC MESSAGE ACCOUNTING IN NO. 1 ESS

4.1 *Introduction*

The automatic message accounting (AMA) facility in No. 1 ESS collects and records all pertinent data related to the charging of customer calls. This information is later transported to an accounting center where it is used to determine the charges to be included on each customer's telephone bill. The entire operation can be divided into four parts:

(a) collection of the data on all calls for which charging information is required,

(b) assembly of data into coded format,

(c) data recording on a medium suitable for transportation to the accounting center, and

(d) data processing in the accounting center.

The first three of these function are performed by No. 1 ESS.

4.2 *General*

The major features of the No. 1 ESS AMA are:

(a) maximum use of the system data processing capability to minimize the amount of circuitry and hardware,

(b) data recording as a completely assembled entity for each call, and

(c) use of magnetic tape as the recording medium.

When the call processing program determines that an AMA record is required on a particular call, it stores the pertinent data in an AMA register located in call store (see Fig. 11). This information is then as-

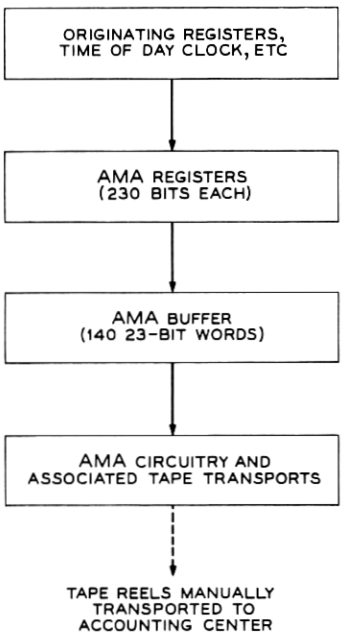

Fig. 11 — Simplified flow of AMA data.

sembled in binary-coded decimal format and stored in a temporary buffer storage area. When the buffer reaches its capacity, the recording procedure is initiated. An AMA program causes the data to be transferred one word at a time to the AMA circuit for recording on magnetic tape. Each tape is properly identified with labels for processing control.

Normally, each central office is provided with two AMA circuits and one block of buffer storage. One circuit serves as the active unit while the second serves as a standby. Each midnight, the system automatically switches the two units. Thus all AMA data during a 24-hour period are normally recorded on one magnetic tape. This complex of two AMA circuits and one block of buffer memory is capable of handling as many as 70,000 busy hour calls or about 100,000 calls on each reel of tape. In very large offices, four AMA circuits and two blocks of buffer memory will be provided. The two additional AMA circuits and the additional memory are required only when the traffic in a given office is greater than about 70,000 calls per busy hour or when the additional machines are desired so that tape changes will not have to be performed as frequently.

4.3 *Accumulation of Charge Information*

Before any chargeable call can be connected through the network, an AMA register must be associated with the call.[2,7] Once an AMA register has been associated with a call, all pertinent data available from the originating register are stored in the AMA register. The answer time and disconnect time are also stored when available as readings from the ESS time-of-day clock in hours, minutes, seconds, and tenths of seconds. When the call is completed, the information is organized into a binary-coded decimal format and stored in a buffer area.

Each AMA register has a 230-bit capacity (10 call store words), enough call store memory for almost any type of AMA entry. Facilities also exist for internal memory linkages with other registers to obtain extra storage area for types of calls requiring additional information. The extra memory is needed for calls such as those requiring operator assistance and the use of the traffic service position switchboard, or those calls requiring more than one billing entry for services such as dial conference and add-on.

Normally, only completed calls are recorded by No. 1 ESS. However, the call processing program is arranged to place a number of special marks in the originating register which also allow incomplete calls to be recorded. For example, if a calling line is arranged for service observing, an indication is placed in the originating register that this call may be service observed. If the call is being observed, an entry is made in the AMA register and the call is entered as a detailed entry regardless of whether or not it was completed. Complaint observing entries are also provided for message rate lines. In this case, a special mark indicates that charge information for all AMA calls originating from a particular message rate line is entered on tape as a detailed entry.

4.4 *Assembly of Information into AMA Entry*

The information in the AMA register must be coded in a standard binary-coded decimal (BCD) form for use in the Bell System data processing centers. Because of the large number of entry types in the ESS, AMA formats have been specified to allow for recording all types of calls in a minimum of call store space. The information in an AMA register is arranged in a format appropriate to the particular type of call after all disconnect timing has been completed.

At midnight, before the active unit is switched into the standby state, all completed AMA entries are placed on the tape so that the total AMA record for the day is on one tape. When an AMA register has been held through two consecutive midnights, a trouble alert report is printed by the maintenance teletypewriter and the call can be manually checked for validity.

4.5 *AMA Buffer and Control*

The AMA buffer provides intermediate storage for the AMA data in the call store. Buffering is required to collect sufficient AMA data to fill an AMA block of 100 words, each word consisting of five 4-bit characters. When the AMA buffer is filled, the transfer sequence is started for recording this block on magnetic tape. (See Section 4.10 for a detailed description of the recording process.) Each 100-word block contains from seven to 20 call entries, depending upon the type of calls being recorded. Overlap of an entry from one tape record block to the next is permitted.

The buffer actually consists of 140 call store words, but it unloads only 100 words at a time. The extra 40 words permit the full contents of an AMA register to be placed in the buffer even though only part of the call fits into the 100-word block. As the program empties the buffer, that space becomes available for loading with new data.

When handling normal AMA traffic, the AMA block contains approximately 11 call entries. Recording on magnetic tape is done at a rate of one 100-word block per second. This provides a recording capability of

25,000 to 72,000 complete AMA entries per hour. Large offices with predominantly message-rate traffic may be equipped with two AMA buffers and four AMA circuits. These would increase the total AMA entry capability to between 80,000 and 144,000 entries per hour.

4.6 *Tape Format, Labels, and Codes*

The AMA data is written on the tape in a format which usually includes the following:

(a) tape header label,
(b) call entries,
(c) tape trailer label, and
(d) tape mark.

The tape header label is recorded once every day at midnight to indicate the start of a day's call records. Its contents include the originating area code or building number, the ESS office identification number or office number, the date, and the tape transport number.

Each call entry consists of a start-of-entry code, a type-of-entry code, and the data field. The type-of-entry code indicates the precise type of call and, consequently, the quantity and nature of the data to follow in the data field.

The tape trailer label is also recorded once every day at midnight to indicate the end of a day's call records. It includes the total number of call entries and the total number of 100-word blocks of call data recorded on the tape since the last header label.

The tape mark is a special character which indicates to the accounting center the end of the useful information on the tape. This label is recorded at the request of the maintenance man just prior to his removing the tape from the transport, or is recorded automatically when the system detects the physical end of the tape.

A transfer label is provided for use in special situations. This label is recorded on both tapes whenever it is necessary for the system to switch from one AMA circuit to the other because of trouble. However, switching is postponed as long as the traffic load will permit to allow immediate repair to the faulty circuitry. In many cases, this will allow all of one day's call records to be recorded on a single tape even though trouble occurred.

All data for a particular call are recorded on tape within a single entry. This single-entry arrangement employs the modified American Standards Code for Information Interchange (ASCII), as indicated in Table I. The billing data for each call are recorded as 4-bit BCD numbers in

TABLE I — AMA TAPE CODING IN NO. 1 ESS

Track and Code							
B7	B6	B5	B4	B3	B2	B1	
1	1	1	0	0	0	0	0
0	1	1	0	0	0	1	1
0	1	1	0	0	1	0	2
1	1	1	0	0	1	1	3
0	1	1	0	1	0	0	4
1	1	1	0	1	0	1	5
1	1	1	0	1	1	0	6
0	1	1	0	1	1	1	7
0	1	1	1	0	0	0	8
1	1	1	1	0	0	1	9
1	1	1	1	0	1	0	label identifier
0	1	1	1	0	1	1	noncheck dummy
1	1	1	1	1	0	0	start-of-entry code
0	1	1	1	1	0	1	check dummy
0	1	1	1	1	1	0	tape mark
1	1	1	1	1	1	1	write/read head check code
0	0	0	0	0	0	0	interblock gap
parity	fill		data				

groups of varying length. The previously mentioned labels (header, trailer, and transfer) always include the label identifier code, which is recorded once, twice, or three times to identify the type of label. The noncheck dummy code is used to fill out blank spaces in records where the blank is not the result of a trouble condition. This code is placed in an AMA entry before it leaves the AMA register. The check dummy code is also used to fill out blank places. However, the check dummy code is written by the AMA circuit in the event of trouble or in case a word is not received at the proper time from the AMA memory buffer.

4.7 *The Tape Recorder*

The digital tape recorders used in the AMA circuit have been specifically developed for No. 1 ESS use. Their design was based on three basic requirements:

(a) a recording capability of about 1000 7-bit characters per second on 0.5 inch magnetic tape,

(b) long-term reliability, and

(c) economy.

This relatively low data recording rate permits just one tape recorder to keep up with the busy-hour AMA traffic of the vast majority of central offices and allows the design of a simple and rugged recorder. Nevertheless, at least two AMA circuits are always provided, named AMA0 and AMA1, for reliability and continuity of recording. Each employs a tape recorder and the necessary control circuitry.

The tape recorder is a two-speed tape drive mechanism designed for start-stop operation. Tape speed for recording is 5.25 inches per second ±5 per cent. A fast forward speed of 30 ips is also provided for winding unused tape on the take-up reel. There is no rewind feature. Both start and stop times are less than 100 msec. There are no belts, pulleys or gears. Tape is driven by the directly-coupled capstan motor shaft. Tape wow and flutter are less than 2 per cent.

Recording is done with a seven-track write head in the non-return-to-zero (NRZ) mode with ±100 ma head current ±10 per cent. A seven-track read head is spaced 2.25 inches from the write head and yields an output voltage of ±1.3 mv ±25 per cent (Ampex 832 magnetic tape); see Fig. 12. Provided also are a write-read tachometer head for checking tape speed and a seven-track erase head for erasing all previously recorded data before the tape moves under the write head.

Regular or heavy-duty 0.5-inch tape is used. Reels are of the 10.5-inch precision type with 2400 feet of tape per reel in "A" wind (oxide in). Tape skew at 5 ips is less than 140 μsec. Recording density is 200 bits per inch. Four tracks are used for data recording; one records an odd parity bit, and two are for fill bits that record "1's" when the circuit is recording.

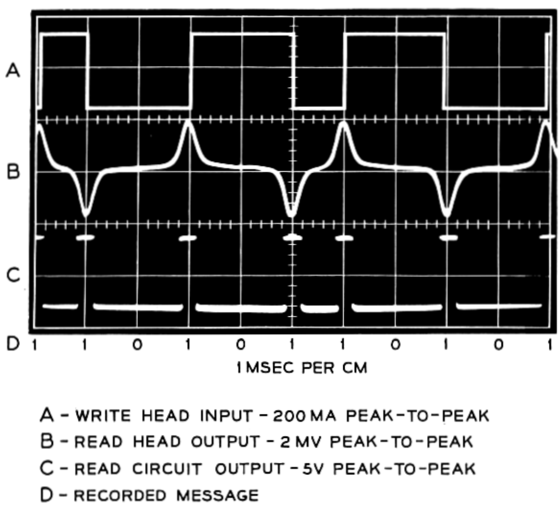

Fig. 12 — AMA circuit waveforms.

4.8 *Functional Block Diagram*

A simplified AMA circuit block diagram is shown in Fig. 13. Communication with central control (CC) is accomplished over different channels for control, timing, data and alarm signals. Control signals received from the central pulse distributors (CPD) control the AMA circuit state, interrogate it as to certain alarm conditions, and signal the arrival of data for recording. The AMA circuit timing is based on the 0.5-msec and 5-msec central control clocks transmitted to it over private duplicated wire pairs. Data for recording are received over 21 wire pairs of one or the other peripheral address bus (PADB). The peripheral answer bus (PANB) is used to send to central control either trouble reports, tape readouts or data point signals for diagnostic checks. Scanner drivers report AMA circuit conditions, including:

(a) AMA circuit state,
(b) lack of tape tension,
(c) end of tape,
(d) incorrect tape speed, and
(e) power alarm.

The sequence control circuit tests for the proper command signal sequence from central control, provides the internal timing of the AMA circuit, and governs the writing of characters on tape.

The input register and translator store the data word while its parity is being checked by the parity checking circuit, divide the words into five characters, and store them along with a parity bit for each character until gated for recording on tape.

The read amplifiers send each read character to the check register, where its parity is checked. If a character fails the parity test, it is stored in the check register for gating to CC over the PANB.

The tape motion check circuit measures tape speed by timing the interval for tachometer pulses to travel from under the tachometer write head to the tachometer read head, with the two heads spaced 0.050 inch apart. If tape speed is not correct, a scan point is activated in the master scanner.

The alarm timeout circuit stops the motors and the recording sequence should central control start the motors and not order them stopped within 1 second. This provides self protection from major internal faults and from continuous neglect by the system.

Each AMA circuit employs 153 circuit packs with 645 transistors and 1693 diodes, and dissipates about 200 watts of +24-v power and 30 watts of −48-v power. Each tape recorder draws 0.8 ampere of 3-phase 208-v power and requires about 1 ampere of −48-v power for control.

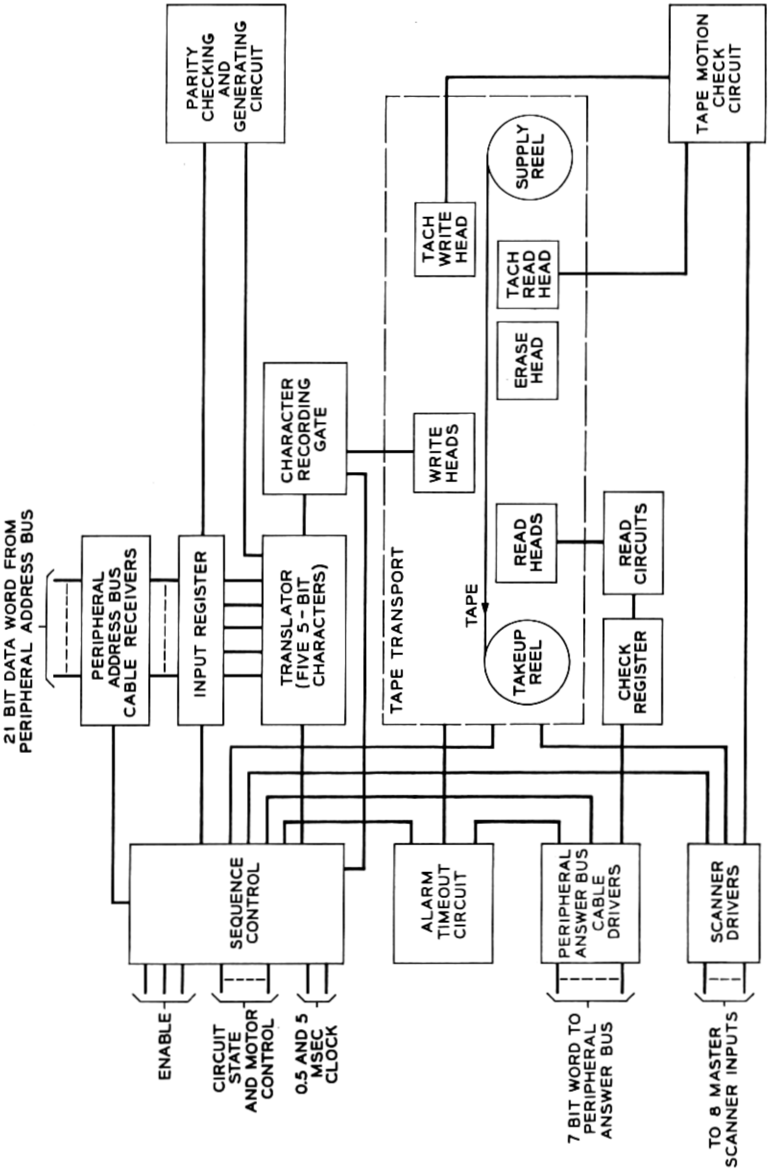

Fig. 13 — Simplified AMA circuit block diagram.

4.9 *AMA Circuit States*

By means of manual pushbutton control at the frame and system control via CPD signals, it is possible to order the AMA circuits into a number of states.

The three manual control states are:

normal — used for data recording and system diagnosis of troubles,

manual control — used when tapes are changed,

power off — used to remove all power from the circuit.

Mechanical interlocks on the control insure that at least one AMA system is in the normal state.

In the normal manual control state central control can place either AMA circuit into any one of five states:

active — ready for or actually recording data. Normally, during one 24-hour period only one AMA circuit is in active state and records all AMA data.

standby — ready for recording of data, but not expected normally to be put into the active state during this 24-hour period.

quarantine — as a result of system-diagnosed troubles the AMA circuit has been isolated from the system.

maintenance 1 — used to diagnose portions of the AMA circuitry for faults. Bypassing the write amplifiers, tape, and read amplifiers, incoming data are shunted to the check register.

maintenance 2 — used to report to central control various internal circuit conditions of the AMA sequence control.

Finally, if any fuse blows, all dc and ac power is removed from the circuit, a major alarm is initiated, and the circuit is in the power alarm state.

4.10 *Normal Operation*

By means of the proper CPD signals CC selects and places one of the two AMA circuits in the active state. It then sends a CPD signal which starts the tape transport motors and waits for all scan points to read zero, indicating no alarms and active state. This will occur in less than 150 msec, after the tape speed has stabilized to five inches per second. CC then sends the CPD a signal to begin the write sequence with the receipt of the next 5-msec clock pulse. The AMA sequence control circuit, in turn, times 1 msec, during which the enable signals and the data word for recording must be received. The first enable pulse (EN0) resets the input register. The next enable pulse (EN1) could be sent about 11 μsec later, but under normal conditions is omitted. The third enable pulse

(EN2) is sent another 11 μsec later, but still within the same millisecond interval, and informs the AMA circuit that during the next 2 μsec a data word will be sent, specifying the PADB bus. The data word consists of 20 data bits and 1 odd parity bit. After being gated to the input register it is checked for parity by the parity check and generating circuit. The 20 bits are arranged into five 4-bit characters in the input translator circuit, and the parity check and generating circuit calculates and stores an odd parity bit for each of the characters. At this stage there are five 5-bit characters ready to be recorded. The first character and two fill bits are recorded 1.0024 msec after the start of the write sequence, and others follow at 1-msec intervals. The fifth character is thus recorded 0.0024 msec after the "second" 5-msec clock pulse. Then the EN0 enable pulse is received again, resetting the input register. This EN0 also is used to gate to CC the parity of the 21-bit word just recorded (good or bad) and the fact that the check dummy character was not (or was) recorded. The check dummy character is defined in Section 4.6, and its use is explained in the next section. After this, another EN2 enable pulse is received and the cycle repeats. This 5-msec cycle is repeated for 100 21-bit words, yielding a 500-character AMA block.

At the end of the 500 characters, CPD signals the end of the write sequence. Another CPD signal orders the tape motors stopped. Within 100 msec the tape will slow to 5 per cent of normal speed. It should be noted that the AMA block is longer than 500 characters by the number of the check dummy characters recorded. Typically, the entire process of starting the tape transports, recording 500 characters and stopping takes less than one second. During this time about 3.5 inches of tape is used.

In addition to writing circuitry, the AMA contains tape reading circuitry, used only as a running check on the writing process. The write and read heads are separated by 2.25 inches. This means that the AMA circuits cannot write a character and simultaneously read it to see if the proper bits were recorded. Under normal conditions the read and check circuitry reads the characters off the tape, checks their parity and notes that they are not dummy characters, temporarily stores them in the check register, and then discards them.

4.11 *Operation under Trouble Conditions*

The AMA circuits have a number of features for detecting, diagnosing and reporting to the system any troubles encountered. In some instances the AMA circuit removes power from itself and places itself in an alarm state, activating the proper scanner drivers. In other cases, the AMA circuit merely reports faults to the system, such as wrong tape speed or parity failure on read, and relies on the system to put it into maintenance states for trouble diagnosis or to switch to the use of the standby AMA circuit. In both cases, trouble detection and switching to the alternate unit take place in less than one second, corresponding to the maximum loss of one block of AMA data. It is expected that most of the troubles will be detected in very much less time and, in fact, before any particular block of AMA data is to be recorded.

In case of tape breakage the AMA circuit automatically removes power from the transport motors, stops the write sequence, and places the circuit into the power alarm state. The same action is taken if the unit runs out of tape. Normally, the end of the tape is detected by photocells through a clear section of the tape at the end of the reel and the proper scan point is activated for the system to turn off power.

If the parity check and generating circuit finds that the 21-bit word received has even parity, the sequence control orders the AMA circuit to record five check dummy characters (0111101). The parity failure is reported to the system on the next EN0 pulse over the PANB. The system may elect to send that 21-bit word again on the next EN2 pulse for another recording.

The AMA recording activity is synchronized with the system 5-msec clock. If the circuit does not receive the 21-bit input word within the first millisecond after the recording cycle starts, it proceeds to record the five check dummy characters. This again is reported to the system as a 21-bit parity failure.

It was mentioned earlier that the read and check register circuitry is used to keep a running check on the write circuitry. If the check circuit finds an error, indicated by even parity of the 7-bit character or by detection of the dummy character, or if no characters at all are read from the tape, it locks that character in the check register and reports this fact to the system on the next EN0 pulse via the PANB. The system may then elect to gate the stored character out on EN1 over the PANB for inspection. The following EN2 pulse will clear the check register whether or not the character was gated to the system, and the check circuit will begin again checking characters read from the tape. The system determines whether the error rate as reported by the check circuit is great enough to put the particular AMA circuit into maintenance states for trouble diagnosis or to switch to the use of the other AMA circuit.

4.12 *Operation in Maintenance States*

For the purposes of trouble diagnosis in an AMA circuit, two maintenance states are provided. The tape transport motors do not run in either maintenance state. In maintenance state 1 the translator outputs are fed directly to the check register. Thus the write amplifiers, tape, and read amplifiers are bypassed. The sequence control produces the clock pulses which gate the 7-bit characters from the translator at a 10-msec rate instead of the normal 1-msec rate. Data are received over the PADB at the rate of one 21-bit word every 50 msec instead of the normal 5 msec. Every character is gated back to CC. In maintenance state 2 the EN1 signal is used to gate to CC various internal conditions of the sequence control.

V. SUMMARY

The No. 1 ESS master control center provides:

1. a convenient means for both local and remote control of the system via teletypewriters,
2. a simplified arrangement for displaying and controlling the system operational status as well as for reporting system troubles to the maintenance personnel,
3. a facility to be used for manually testing lines, trunks, and service circuits, and
4. compact and inexpensive storage of subscriber charging information in a form readily usable in an electronic data processing system.

VI. ACKNOWLEDGMENTS

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