US ARMY
SIGNAL CENTER AND SCHOOL
FORT MONMOUTH, N.J.

PRO PATRIA VIGILANS

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INFORMATION SHEET

AUTOMATIC TELETYPEWRITER SWITCHING CENTERS

Section I. GENERAL

1. OBJECTIVE

To describe automatic teletypewriter switching centers used in the United States Army, the United States Navy, and the United States Air Force.

2. INTRODUCTORY INFORMATION

a. Christmas, 1958, saw a huge United States satellite, over 2 tons in weight, circling the globe approximately once every 100 minutes. Upon command of a ground station, a message of peace and good will from the President of the United States to all people everywhere was broadcasted from this object in space. This extraordinary accomplishment in the art of communication is but one of many advances which we will see in the coming space age. Our communications designers are already looking forward to the day when messages will be transmitted to any place in the world, "untouched by human hands."

b. A step toward this fully automated system was taken in 1952. At the Headquarters of the Fifth Army in Chicago, Illinois, the United States Army Signal Corps placed in operation a prototype of a fully automatic teletypewriter switching center. It was the first military relay center of this type. This equipment electrically scans an incoming message, determines the precedence and routing, selects the proper outgoing line, and transmits the message over this line, all in a matter of seconds. The first few lines of a message addressed to Fort Leavenworth, Kansas, for example, were received on the Leavenworth machine while the remainder of the message was still being transmitted from the Pentagon.

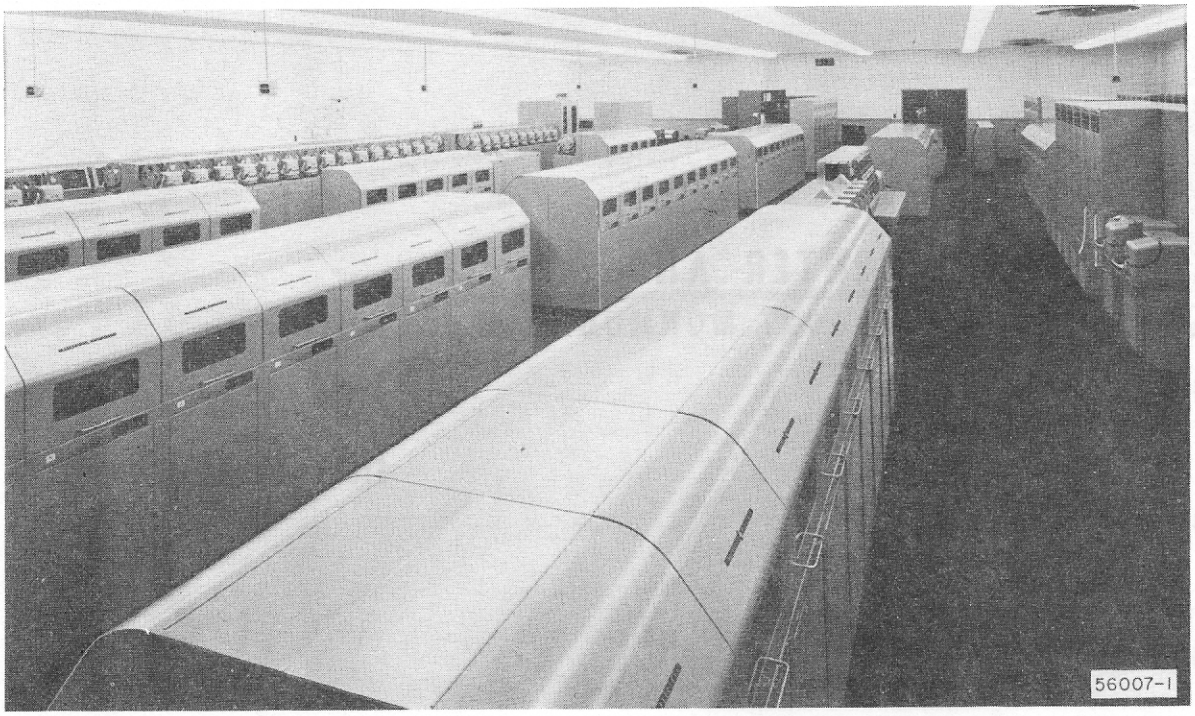

Figure 1. View of Davis, California, Station - RUWP.

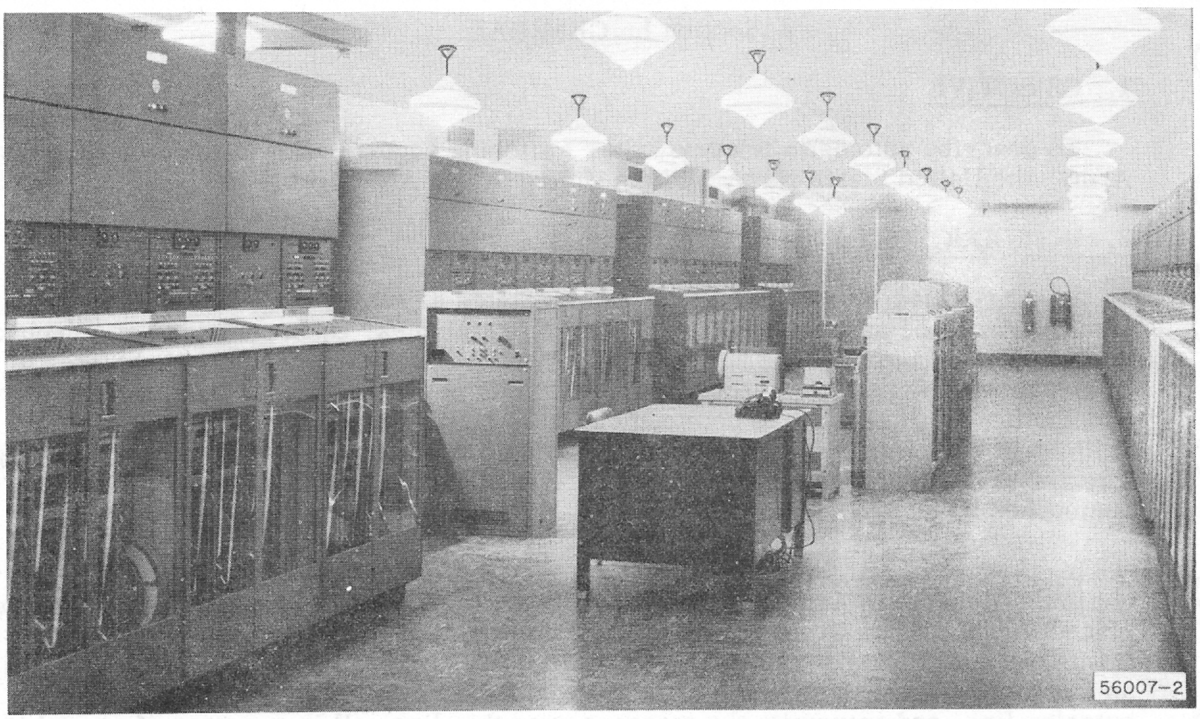

Figure 2. View of Trenton Station RBEG - 82B1.

3. U. S. ARMY SYSTEM

a. Since the days of the prototype system (AN/GGC-2), a final model (AN/FGC-30) has been developed for the United States Army. This new equipment is installed at the Davis, California, primary relay station of the Army Command and Administrative Network (ACAN) in the western part of the United States. See figure 1.

b. A larger station, known as the MidWest Relay Center, became operational at Fort Leavenworth, Kansas, in 1959. It consists of the relay center itself, a receiver station, a transmitter station and a microwave radio relay link control system. At peak operation, approximately 154 people will work around the clock, 24 hours a day, processing messages to and from points all over the world. The total value of the switching equipment and teletypewriter equipment is about $3,000,000. The radio equipment will run about $2,000,000. Over 14,000 line items of spare parts will be required, at a cost of $100,000 annually. The cost of the entire installation is something over $10,000,000.

c. A third relay center to employ the AN/FGC-30 will be established on the east coast at Fort Detrick, Maryland. This center will be known as the East Coast Relay Center.

4. U. S. AIR FORCE SYSTEM

The United States Air Force has in operation similar large communication centers employing automatic teletypewriter switching equipment. The switching equipment and teletypewriter equipment comprise what is known as the Plan 55. You will read a description of this equipment in section V of this text.

5. U. S. NAVY SYSTEM

The United States Navy currently employs automatic switching equipment known as the Bell 82B1 (fig. 2). A description of this equipment appears in section IV of this text.

Section II. BASIC THEORY OF AUTOMATIC SWITCHING

6. GENERAL

a. You will better understand the subsequent portions of this text if you first get a clear idea of the basic theory of automatic switching of messages. Although the equipments used by the U. S. Army, the U. S. Navy, and the U. S. Air Force differ in many respects, they all solve essentially the same basic problem. (A chart comparing physical features of the three systems is shown in Appendix I.) Simply, the problem is to read and interpret information placed in the message heading so as to route the message automatically to the proper outgoing line. The equipments should be so designed that human operators become necessary only in cases of emergency, when messages were garbled in transmission or were improperly prepared at the originating station.

b. The problem is complicated by the nature of military traffic. We must assign degrees of precedence (FLASH, EMERGENCY, OPERATIONAL IMMEDIATE, PRIORITY, ROUTINE, DEFERRED) to messages; the switching equipment must distinguish between these degrees of precedence and must handle the message accordingly.

c. Figure 3 is a simplified block diagram of the basic theory of automatic switching. Figure 4 is an example of a message tape prepared by a tributary station. This tape is prepared for handling by an automatic switching center in accordance with the current procedures for tape relay operations, ACP 127 series. You should refer to these illustrations as you read the following explanation of the basic theory.

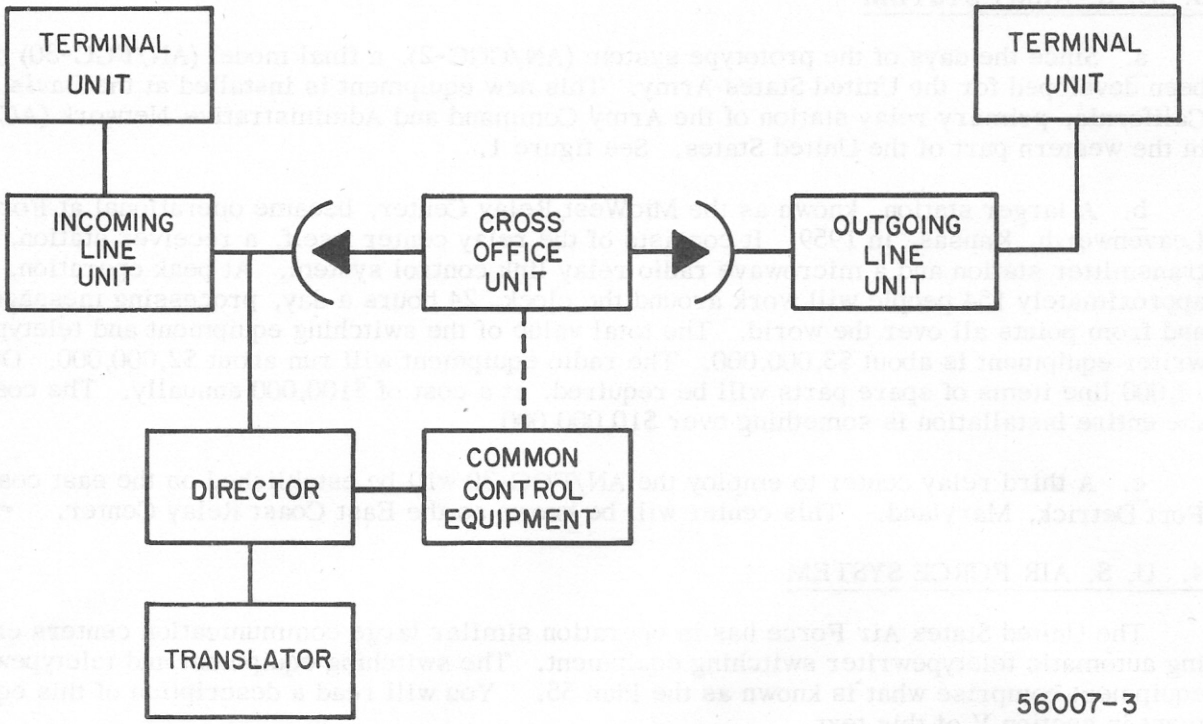

Figure 3. Basic theory of automatic message switching.

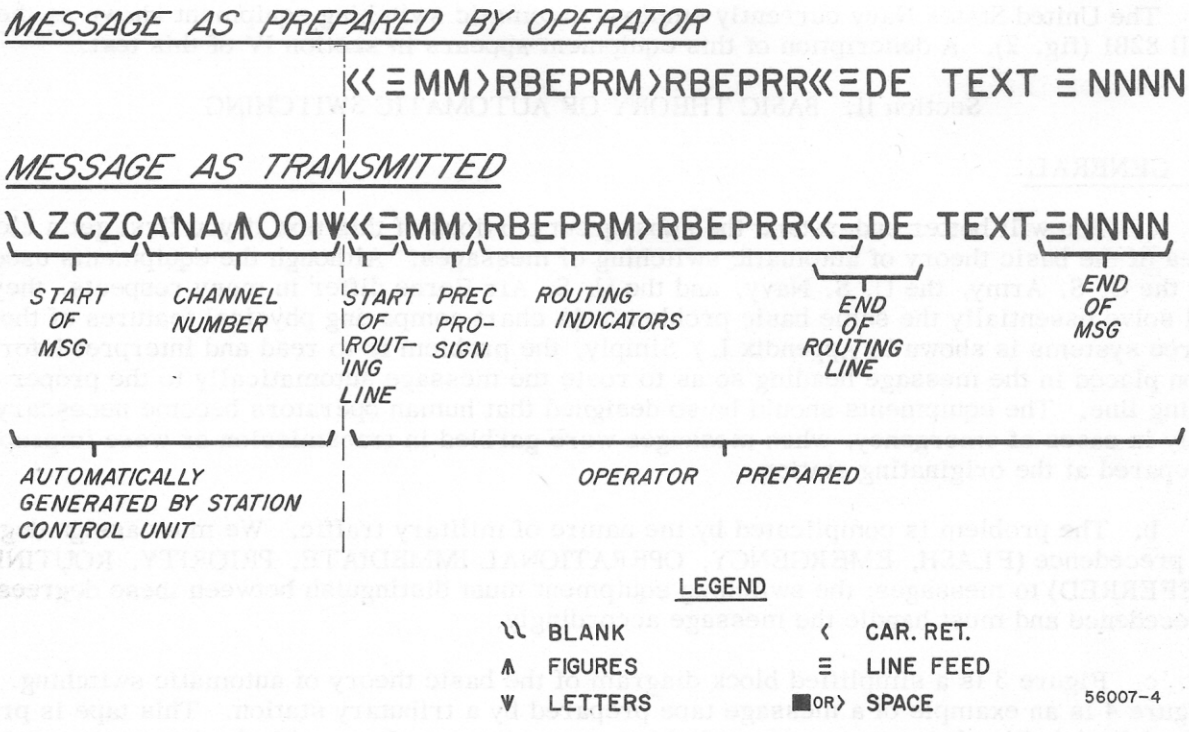

Figure 4. Sample message tape as prepared by operator and as automatically transmitted.

7. SIMPLIFIED PROCESSING

a. When a message is transmitted from a distant station, it arrives in our automatic center at a unit known as the incoming line unit (ILU). In this unit there is a tape reader which has the ability to interpret the electrical impulses of the message. These impulses (Baudot Code) represent letters of the alphabet and machine functions.

b. The first characters on the message are the letters ZCZC. This group of letters is known as the start of message indicator (SOM). The SOM tells the equipment that a message is being received. It also normally brings into action a component of the incoming line unit known as the channel number comparator or sequence number indicator. The channel number comparator checks the channel number on the message against the channel number in a register contained in the comparator. The purpose of the comparison is to make sure that each transmission is received in sequence. If a channel number is "skipped," we may suspect that we have lost the transmission and we can take necessary action. The channel number follows immediately after the ZCZC (SOM). If the channel number on the tape corresponds to the number in the register, switching is permitted to continue. If the channel number does not correspond to the number in the register, an alarm directs an operator to the incoming line unit. The operator checks the message, determines the cause for the disagreement, and takes whatever action is necessary.

c. Let's assume that there is no difference detected in the channel number comparison. The tape reader continues on and reads the line feed (LF). This appears in a group of machine functions -- two carriage returns and a line feed (2CR LF) -- which is followed by two letters indicating the precedence designation. When the LF function is read, the services of a director* are requested. The director stores the precedence designation for use later in the process. After registering the precedence designation, the director then stores the characters that follow. These characters make up the routing indicator. When there is more than one routing indicator in a message, the director registers one at a time. It reads each character of the indicator and stops when the space function (SP) is read. The director then requests the services of a translator.

d. The translator reads the characters of the routing indicator and translates them into a set of numerals. These numbers identify the proper outgoing line for that routing indicator. This information is furnished to the director, then the translator is released and again becomes available for translation.

e. The director now has the identity of the incoming and outgoing lines and can set up a path between them. This path is referred to as the cross-office circuit. At this point, the precedence which has been registered is brought into play, and preferential handling is set up for high precedence traffic.

f. The director is now no longer required. It is disconnected and becomes available for other incoming messages. Next a transmitter distributor (TD) in the incoming line unit starts transmitting the message to the outgoing line over the cross office circuit set up by the director. First, however, an outgoing channel number must be transmitted. This is done by a special transmitter in the outgoing line unit (OGL). Simultaneously, as the message is transmitted over the outgoing line, a copy is made by a monitor reel unit.

g. As the message tape continues through the transmitter distributor, the tape reader will eventually read the end of message indicator (EOM) which consists of eight line feeds, four N's, twelve letters (8LF NNNN 12 LTRS). Two of the systems we are studying recognize LF and NNNN as the end of message indicator; the AN/FGC-30 recognizes 3 LF NNNN as the EOM. The tape reader, when it senses the EOM, recognizes it as the end of the message and disconnects from the circuit. The tape reader is then available for other incoming traffic. In a similar fashion, as the various equipments read the EOM, they drop out of the circuit and become available for subsequent traffic.

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*The word director as used in this text is a registered trademark of the Automatic Electric Company.

8. MULTIPLE CALL PROCESSING

In the previous paragraph we were concerned with a single call message (one routing indicator). A good proportion of military traffic, however, is of the multiple address variety. Messages of this type contain two or more routing indicators. Some systems can handle messages with unlimited routing indicators, while others are limited to a specific number. When a relay station receives a multiple call message, more often then not it requires transmission onward over more than one channel, according to the routing indicators of the message. In this case, the relay center must prepare multiple tapes, transmitting the proper tape to the proper outgoing line to the proper distant station. This process is called multiple call processing. It is based on what is known as the routing line segregation method. Note, however, that a message containing more than one routing indicator does NOT automatically call for multiple call processing. A message with five routing indicators, for example, may be transmitted over the same outgoing line to the same distant relay station, where the routing indicators may then be segregated and broken down. We can say, therefore, that multiple call processing and the production of multiple tapes are required only when the routing indicators indicate transmission to different distant stations over different outgoing lines. Let's see how an automatic switching center handles each of these situations.

a. No Multiple Call Processing Required. As the message with more than one routing indicator arrives at the automatic switching center, it is processed as described in paragraph 7. However, when the director reads the routing indicator line, it reads a routing indicator and a space. It transmits the routing indicator to the translator and receives an outgoing line identification, let us say 527. Immediately after the space (SP) the director begins to read an additional routing indicator. It transmits this second routing indicator to the translator and again receives an indication of outgoing line 527. At the end of this routing indicator, the director reads a space and a third routing indicator. It transmits this to the translator and again receives an outgoing line indication of 527. Assuming that there are but three routing indicators in this message, the director now goes on and reads two carriage returns (2 CR) and line feed (LF) and the letter D or the letter Z of the next format line (DE or a Z signal). The characters LF and D or Z indicate to the director that no additional routing indicators follow. Since each translation of the routing indicator indicates the same outgoing line, number 527, no multiple call processing is required; the entire message as received in the center can be transmitted over outgoing line 527. It will be at some subsequent station that multiple call processing will be necessary.

b. Multiple Call Processing Required. Again, let us assume that the message tape contains three routing indicators. Processing begins as in the earlier example and the director asks the translator for a translation of the first routing indicator. Let's say that the translation is outgoing line 527. The director then reads a second routing indicator and a space (SP). It transmits that routing indicator to the translator and receives a translation. Let's say it is again outgoing line 527. The director compares the first indication against the second indication and, seeing no difference, decides no multiple call processing is required. The director then transmits to the translator the third routing indicator and receives a translation which indicates that the outgoing line is 545. The director compares the indication 527 against the indication 545 and immediately recognizes a difference. It decides that multiple call processing is required. Without further reading of any subsequent routing indicators, the director calls the multiple processing equipment into play.

9. SUMMARY

The foregoing paragraphs indicate, in a general way, the basic theory of automatic switching of messages. You should bear in mind that the equipments described in this text have different ways of solving the problem, although basically they all accomplish the same functions.

Section III. U. S. ARMY EQUIPMENT

10. FEATURES OF THE AN/FGC-30

a. Fully Automatic Operation. This equipment is fully automatic. It receives incoming messages and routes them without manual intervention to suitable outgoing lines. Manual processing is needed only when improperly prepared messages preclude handling by the equipment or when messages are addressed to supervisory personnel. On marginal radio circuits, operators monitor the traffic before processing can take place.

b. Single Installation in Network. We can install this equipment at any point within a tape relay network, since it does not require similar equipment to be located at other points. This feature enables us to install automatic equipment on a station-by-station basis.

c. Compatibility. The equipment permits us to transfer traffic over authorized transfer circuits to United States Air Force and United States Navy automatic equipments.

d. Routing Indicator Plan. The routing indicator plan currently in use (as outlined in ACP 121, Communications Instructions, General) is recognized by this system. We can immediately reassign routing indicators within the system as changes occur.

e. Three-Speed Operation. The system can receive and transmit messages at any of the three standard speeds of 60, 75, or 100 words per minute, and can use all three speeds at once.

f. Three-Speed Cross Office. This equipment is so designed that it requires a cross-office speed only slightly higher than the highest speed on the incoming lines. We can set normal cross-office speed at 75, 100 or 115 words per minute, as required by the highest incoming line speed.

g. Immediate Handling of Message Traffic. A very important feature of this equipment is its ability to act immediately on any message arriving at the switching center. By switching a message immediately to some type of cross office position, it keeps all incoming lines free to receive messages. The designers of the equipment consider this to be a unique feature of the system.

h. Precedence. The system acts upon all six categories of military precedence, transmitting messages to outgoing lines in accordance with the precedence designation placed on the message. That is, PRIORITY messages are handled before ROUTINE, ROUTINE messages are handled before DEFERRED, and so on.

i. Handling of High Precedence Traffic. The three degress of high precedence -- FLASH, EMERGENCY and OPERATIONAL IMMEDIATE -- require immediate, expeditious handling. If a message of lower precedence is being transmitted on an outgoing line, the transmission must be interrupted to make way for high precedence traffic. This system automatically interrupts the circuit and sends a CANTRAN (cancelled transmission) to "bust" the transmission. It then sends the message of higher precedence. When this condition occurs, an alarm appears on the supervisor's console as well as on the cross-office unit which had seized the outgoing line for the message of lower precedence. An operator, dispatched by the supervisor to the proper cross-office unit, simply repositions the message of lower precedence so it can be started once again through the cross-office unit when the outgoing line again becomes available.

j. Maximum Use of Circuit Facilities. The system makes maximum use of pooled and common equipment to keep a particular outgoing line in use as long as there is traffic destined for that line. Also, since all traffic is immediately switched from the incoming line to some type of cross-office unit, the incoming lines are continually free for traffic.

k. Continuity of Service. The system automatically checks the channel-number sequence at the incoming line before it allows a message to continue through the system. Disagreement between channel sequence on the message and the channel-sequence counters in the incoming line unit activates an alarm. Further handling of the message is halted before transmitting to a distant station over an outgoing line, and an outgoing channel number is automatically transmitted by the monitor unit.

l. Message Control. A complete alarm system, which indicates to supervisors and maintenance men any improper functioning of the equipment or any improperly prepared incoming message tapes, protects continuity throughout the system.

m. Intercept Positions. When messages are improperly prepared or contain garbled or unrecognizable characters in the precedence or routing indicators, the system directs them to intercept positions. Here they are examined and the necessary supervisory action is taken.

n. Manual Forwarding Position. In order to transmit procedure messages, reruns or tapes forwarded to the intercept position, several positions known as manual forwarding units are provided at each manual forwarding position. A control panel permits the operator to select any outgoing line. He can also indicate the precedence of the message to be manually forwarded. The outgoing line is seized in accordance with the selected precedence.

o. Multiple Call Messages. The system handles multiple call messages automatically in accordance with precedence and processes them on a routing line segregation basis. There is no limit to the number of routing indicators the system can process in each message.

p. Multi-Point Operation. The system provides for the operation of a multi-point circuit with as many as ten stations operating on a full-duplex basis per circuit.

q. Multi-Channel Selection. We can use any number of channels to any distant station and traffic will be distributed equally to all channels of the group. We can subtract channels from the group and still leave the traffic distributed equally among the remaining channels.

r. Alternate Routing. An alternate route can be set up for temporary periods.

s. Torn-Tape Emergency. Should the switching equipment fail completely, we can operate the remaining equipment as a torn-tape system. However, automatic numbering facilities are not available in this case and we must use "tab" numbering.

t. Other Features. Among the other features of this equipment we can cite ease of maintenance; use of the completely perforated, printed, wide tape; a high degree of message security; the ability to receive either 20 or 30 mils polar or 60 mils neutral operation; a supervisor's console to determine which units of the system are temporarily tied together for a particular message; a cross-office unit numbering system to help operators trace messages through the system; and ease of expanding the system. This equipment has been built on a building block principle and permits expansion up to a maximum of 250 lines.

11. SYSTEM OPERATION

The following paragraphs describe how the AN/FGC-30 performs the basic procedures described in section II. The different handling accorded to different types of messages is described in separate paragraphs. How these problems are solved by Navy and Air Force systems is discussed in subsequent sections.

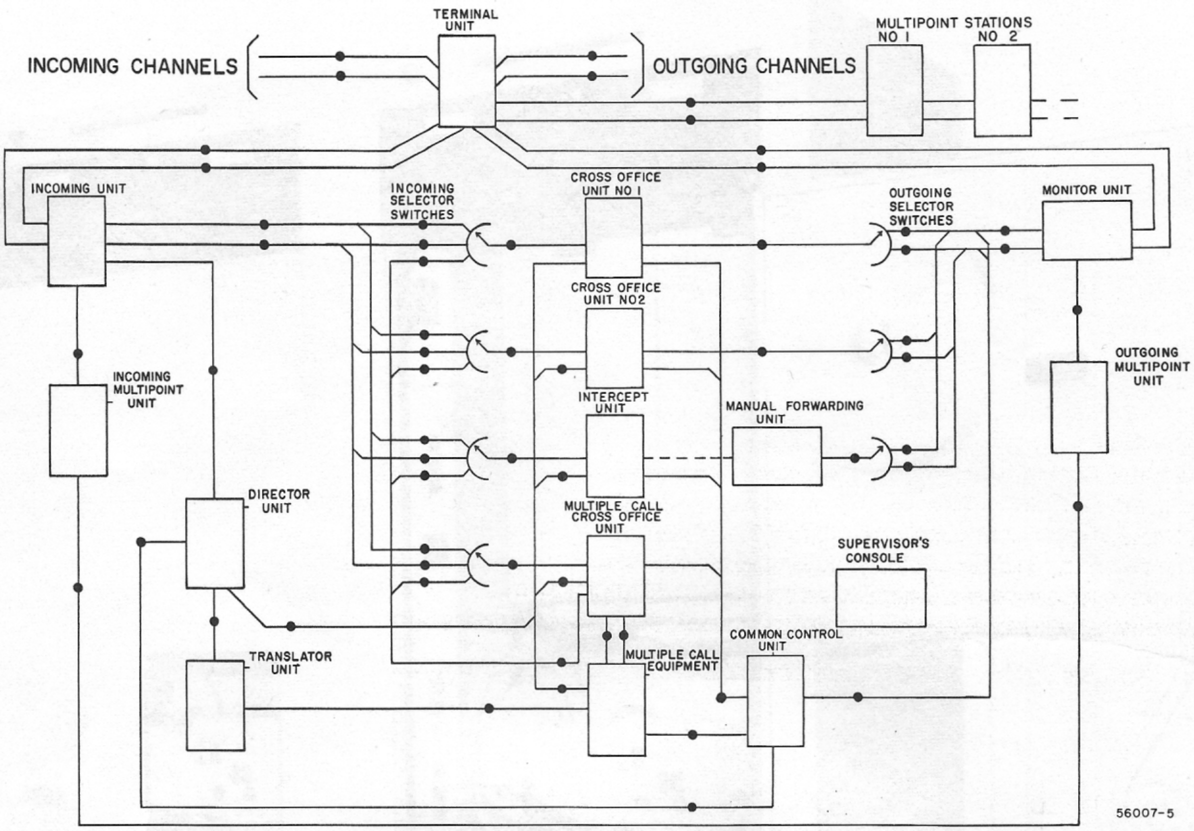

Figure 5. Block diagram of AN/FGC-30.

12. SINGLE CALL MESSAGE (NO TRAFFIC IN CENTER)

Let's assume that there is no traffic in the center and that the single call message we are about to process is the only message being sent through the center. The incoming message is sent from the receiver station to the relay station over the control link, which is normally a microwave relay circuit. At the relay center the message first appears at the terminal unit (fig. 5). The terminal unit provides access jacks to monitor the incoming and outgoing circuits and to permit patching. Patching enables us to interconnect different channels with various incoming units. The system then handles the message in the following manner:

a. The message leaves the terminal unit and enters the incoming line unit (fig. 6) in accordance with the patching scheme of the terminal unit. At the incoming line unit a reperforator cuts a tape in accordance with the incoming message signal. As the tape is perforated it is advanced into a tape reader until the point on the tape is reached where we have the start of message indicator (SOM).

b. The SOM consists of the letters ZCZC. (See figure 4.) When the tape reader reads and registers the SOM, this calls the channel-number comparator of the incoming line unit into operation. The channel-number comparator checks the channel number which follows the ZCZC on the tape. If the channel number on the tape agrees with the channel number in the comparator's register, the message goes on to further processing.

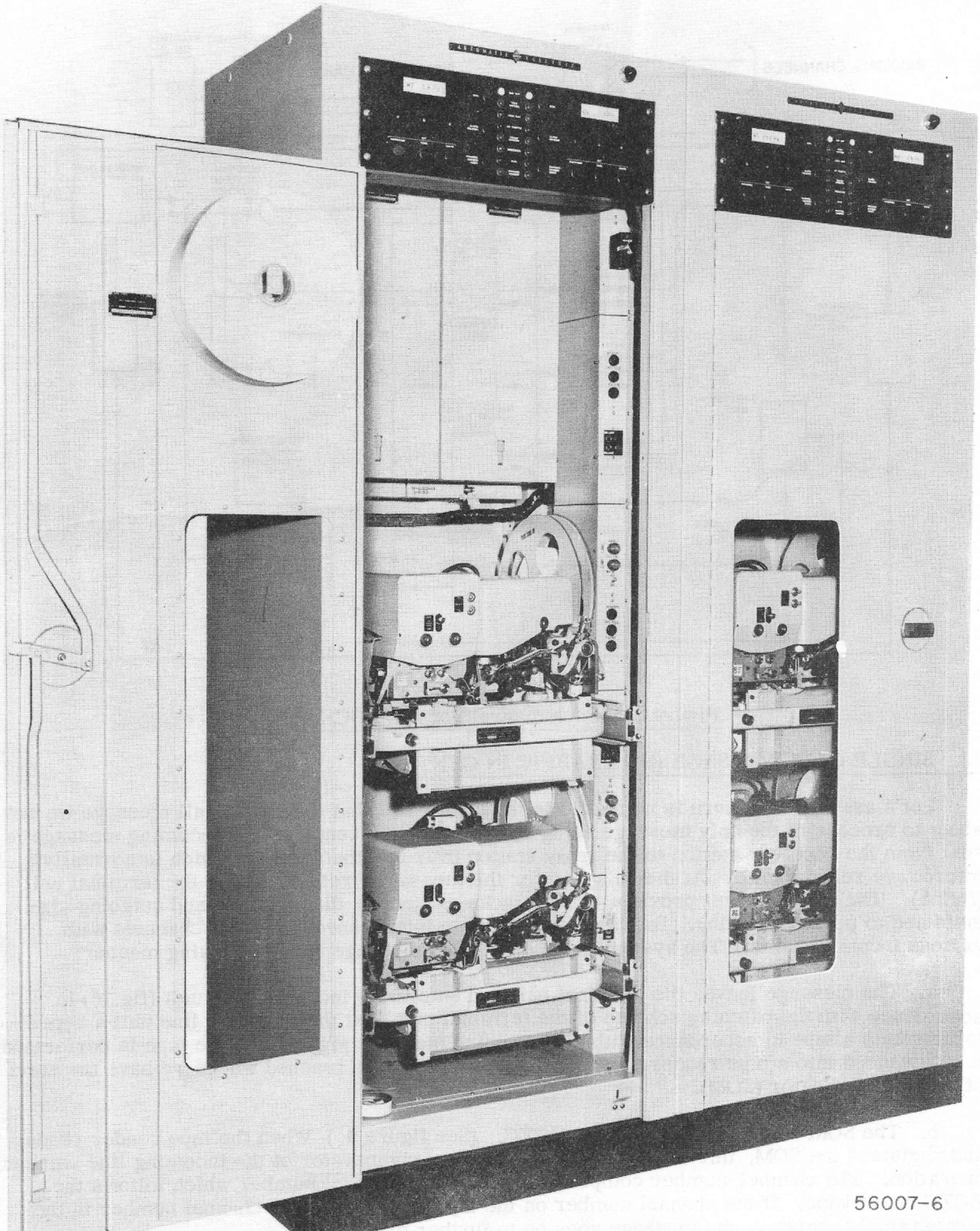

Figure 6. AN/FGC-30: Incoming line unit.

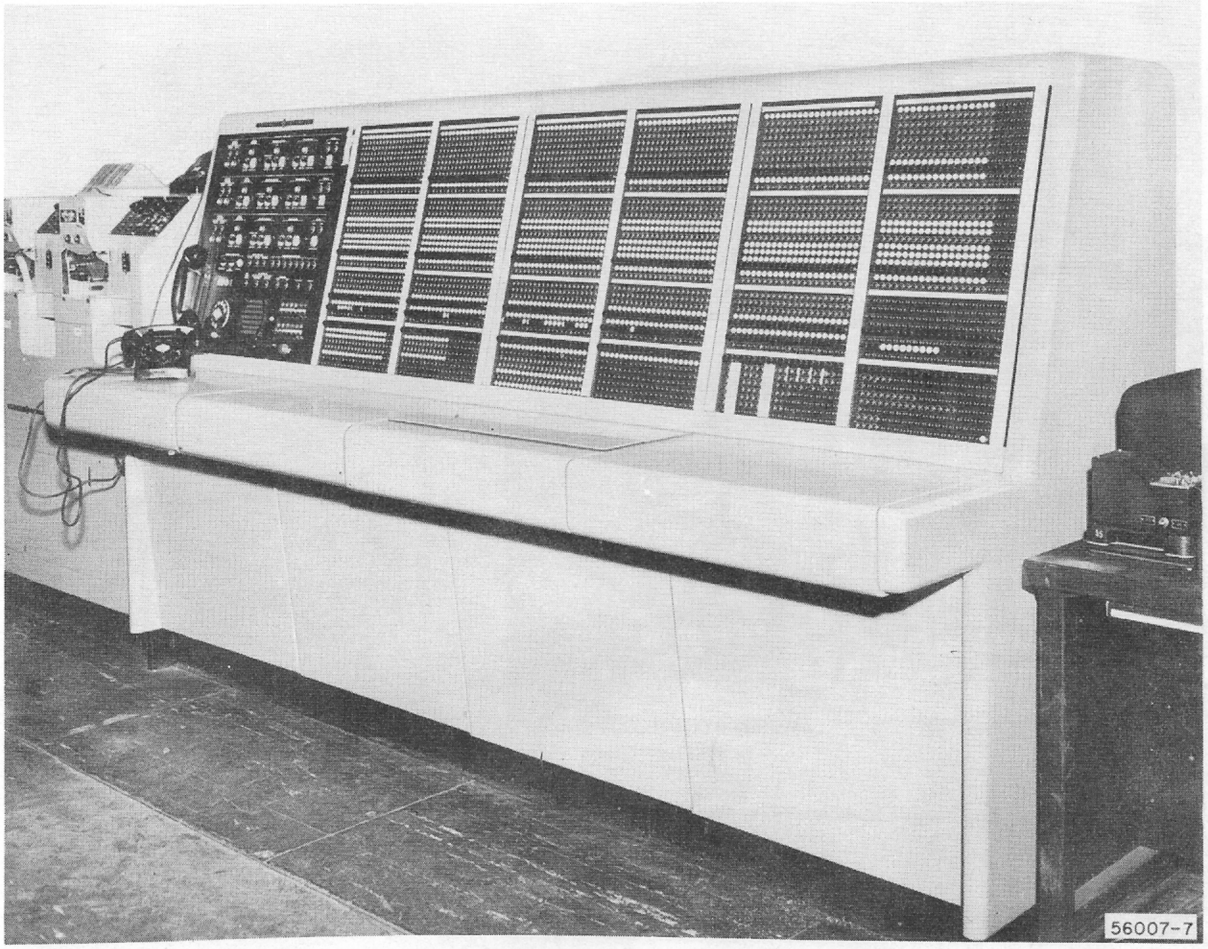

Figure 7. AN/FGC-30: supervisor's console.

c. If the channel numbers do not agree, an alarm is activated at the supervisor's console (fig. 7) and also at the incoming line unit. Upon receipt of the alarm, the supervisor calls an operator over a public address system. The operator goes to the incoming line unit, examines the channel number on the tape and takes the necessary steps to clear the alarm. (The scope of this text does not permit us to go into the specific operating procedures, but we will indicate how certain operations are performed.)

d. If the channel numbers agree, the incoming line unit calls for a director. There are two directors associated with each 25 incoming line units. Having procured the director, the tape reader transmits to it the precedence and routing indicator.

e. The director records the precedence indicator and the routing indicator. The director then demands the service of the translator unit. The translator unit serves all the directors in the switching center. Having seized the translator, the director transfers the routing indicator to it. The translator determines from the routing indicator the identity of the outgoing line over which to transmit the message. This identification is sent back to the director. Since the example we are using has but one routing indicator, the director then reads a line feed and the letter D or Z of the next format line. This (LF, D or Z) indicates the director has no further requirement for the translator and, accordingly, the translator unit is released.

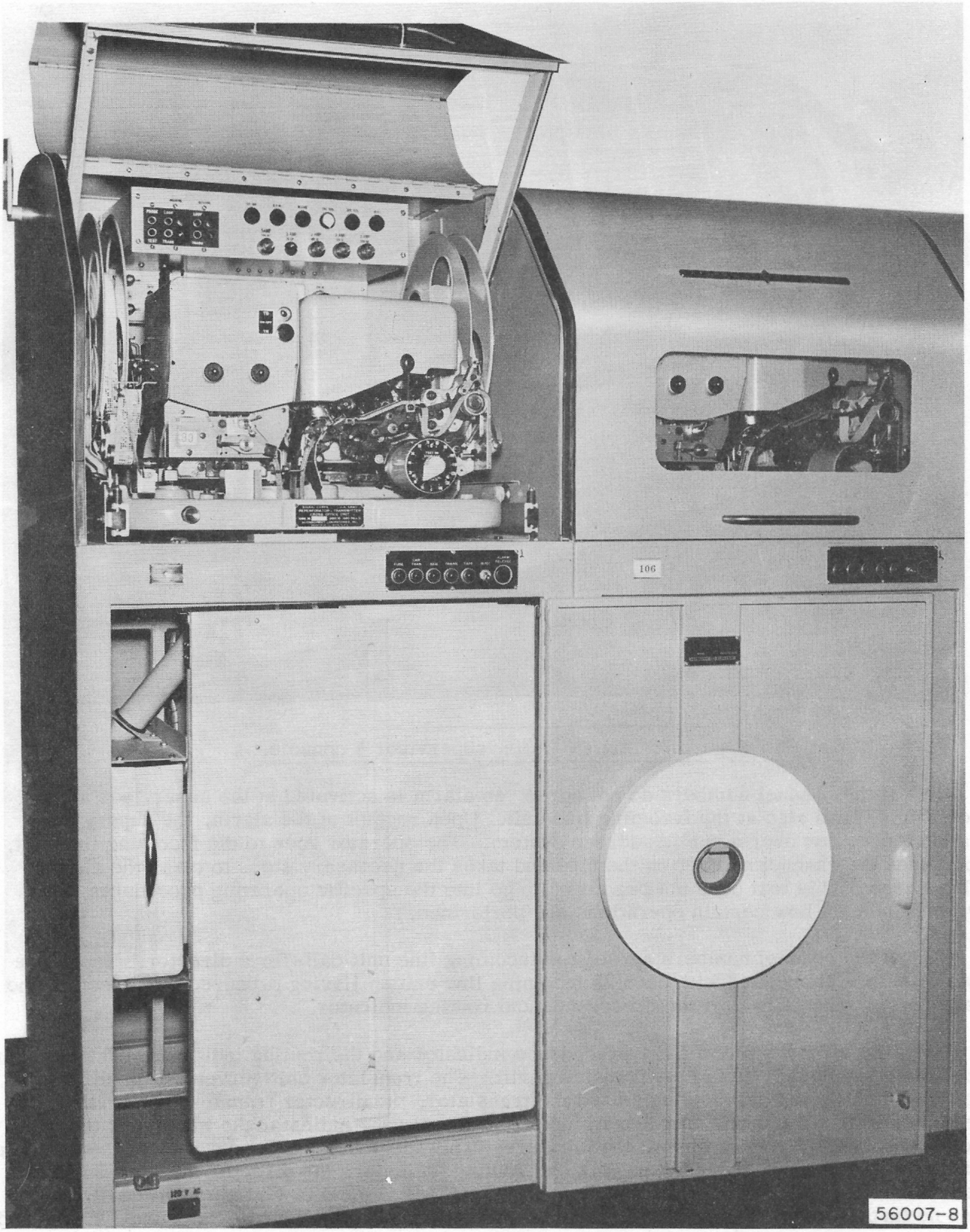

Figure 8. AN/FGC-30: cross-office unit.

f. Thus far, the director has the identity of the incoming line and the identity of the outgoing line. The director must now find a cross-office unit (fig. 8) and connect it to the proper incoming and outgoing lines. At this point, tests known as the preset test and the empty-bin test are made. (We will reserve an explanation of these tests for a later example.) Since, as we assumed, there is no other traffic in the relay center, the director need only find a cross-office unit (COU). To do this, it calls the common control unit into play. The common control unit selects an empty and idle cross-office unit, and the director seizes it. The director then sets the incoming selector switch of the COU to the proper incoming line, and the outgoing switch of the COU to the proper outgoing line. The director also sets the precedence of the message into the cross-office unit. Having accomplished its function in about four to six seconds -- considerably less time than it takes to read and understand the process -- the director is no longer required and is released. The transmission of the message continues from the incoming line unit to the reperforator of the cross-office unit.

g. As the message is transmitted through the tape reader of the incoming line unit to the cross-office unit, the tape reader of the incoming line unit reads the end-of-message functions. These functions are known as the end-of-message indicator (EOM). The EOM consists of 2 CR (carriage return), 8 LF (line feed), 4 N's, and 12 letters (LTRS). The tape reader of the incoming line unit recognizes 3 LF and 4 N's as the end of message indicator (EOM). The EOM indicates to the incoming line unit that it is no longer required, and it becomes free to process other traffic. The incoming line selector switch of the cross-office unit is then reset. (Remember, however, that the action in the cross-office unit is taking place while the message is coming through the incoming line unit to the cross-office unit.)

h. We shall assume that up to this point the complete message has not necessarily been received at the incoming unit. Let us now see what occurs as this message is received from the incoming line unit into the cross-office unit reperforator. As the tape is being perforated in the cross-office unit, the tape reader continues to read the tape until it senses the SOM. Upon recognizing the SOM, the cross-office unit demands the outgoing line to which its selector switch had been set by the director. Since there is no traffic in the center, this outgoing line is readily available and the COU seizes it.

i. Immediately upon seizure of the outgoing line, a special transmitter in the monitor unit is activated. This special transmitter transmits to the outgoing line a new start of message indicator. While this is being done, a special transmitter temporarily associated with the cross-office unit transmits a three-digit serial number to the monitor reperforator. This is the number assigned to the cross-office unit involved and is used to identify that unit. This number appears on the monitor tape, but is NOT transmitted to the outgoing line.

j. Since every transmission in the tape relay network between relay stations must be preceded by a channel number, a new outgoing channel number is transmitted to the distant station and is also perforated on the monitor reel. After this has been done, the message is transmitted from the cross-office unit transmitter to the outgoing line. On the monitor reel (fig. 9) a monitor tape of the transmission is made simultaneously.

k. As previously stated, when the incoming line unit recognizes the end of message indicator, it drops out and the incoming selector switch of the cross-office unit is reset. When the end of message indicator is read in the cross-office unit, its outgoing selector switch is also reset. With both the incoming selector and outgoing selector switches reset, the cross-office unit drops out and is restored to its status in the COU pool. At this point the remaining operation rests with the special transmitter in the monitor unit which must then transmit an end of message sequence to the outgoing line. With this done, the monitor unit drops out. Transmission of the single call message has been completed.

Figure 9. AN/FGC-30: monitor reels.

13. SINGLE CALL MESSAGE (TRAFFIC IN CENTER)

In the previous example we assumed that there was no traffic in the center when the single call message was received. Now let's see the procedure when the center is already processing message traffic.

a. As in the earlier example the message first arrives at the terminal unit and in accordance with the patching at this unit is received on an incoming line unit. The action of the incoming line unit is the same as in the previous example; that is, the start of message indicator is read, the channel number is verified, and the director functions as before. As you saw earlier, when the director has the identity of the incoming and outgoing lines, it must find a cross-office unit and connect it to these lines. At this point the preset test and the empty-bin test are made.

b. If a cross-office unit is already connected to the desired outgoing line, and is also set for the same degree of precedence as the message we are now processing, it is advantageous to route the incoming message to that particular cross-office unit. There is a saving in time and functioning in the equipment, since the switches are already set and the cross-office unit can immediately accept our message. To determine if this situation exists, the director makes a preset cross-office unit test. If the director finds a cross-office unit already connected to the desired outgoing line and already set for the desired degree of precedence, and also notes that it is not busy receiving a message at the incoming side, the director seizes the unit and causes the message to be transmitted to it. The message goes into storage behind the earlier outgoing message.

c. When the earlier message has been transmitted, the outgoing line becomes idle for a brief interval. In this interval, all the cross-office units whose switches have been set to the same outgoing line will demand the line. The cross-office unit whose switch is set to the highest degree of precedence will actually seize the outgoing line. Since this process is repeated after the transmission of each individual message, transmissions take place according to precedence.

14. USE OF CROSS-OFFICE POOL

In order to understand the operation of the AN/FGC-30, keep in mind the following points concerning the use of the cross-office pool:

a. Any cross-office unit may be set to any line.

b. Any number of cross-office units may be set to any line.

c. Any cross-office unit may be set to any degree of precedence.

d. Many messages may be stored in any one cross-office unit provided they are destined for the same line and carry the same degree of precedence.

e. At no time will any one cross-office unit contain messages of more than one degree of precedence.

f. At no time will any one cross-office unit contain messages destined for more than one line.

g. When a line is idle, it is demanded simultaneously by all cross-office units set to that line; only the unit set to the highest indicated degree of precedence will be permitted to seize the line.

15. SINGLE CALL MESSAGE (HIGH PRECEDENCE)

To illustrate the operation involving high precedence traffic (FLASH, EMERGENCY, OPERATIONAL IMMEDIATE) let's assume that a ROUTINE message is being transmitted over an outgoing line.

a. A high precedence message -- FLASH, for example -- is received on an incoming line. The equipment operates as in previous examples. In this case, however, the director has registered an indication that this is a FLASH message. Instead of making a preset test, the director makes an empty-bin test and immediately seizes an empty cross-office unit. The director, as before, sets the incoming and outgoing selector switches of the COU to the proper outgoing line. It also sets the precedence switch of the COU to FLASH.

b. When the message is ready to be transmitted, examination of outgoing lines indicates that the desired line is busy transmitting a ROUTINE message. In accordance with tape relay procedures as outlined in ACP 127(B), a FLASH message requires interruption of the line transmitting a message of lower precedence. To interrupt this transmission, a cancellation sequence must be sent over the outgoing line to the distant station. This is known as a CANTRAN. It consists of 8 spaced E's followed by AR (E E E E E E E E AR). To transmit this cancellation sequence over the outgoing line, a special transmitter is called into use.

c. After the CANTRAN has been transmitted, the outgoing line becomes idle for a brief interval. In this interval, all cross-office units which are set to the line will demand the line, and the unit containing the FLASH message will seize it. A new channel number is then transmitted by the special transmitter in the monitor unit.

d. The ROUTINE message which was interrupted remains in its cross-office unit; however, a lamp alarm lights up on the cross-office unit to indicate the presence of a "busted" message. On this signal, a cross-office unit operator repositions the ROUTINE message tape back to its starting point, then clears the alarm by pressing the alarm release button. The cross-office unit is now ready to demand the outgoing line when it becomes available after transmission of the FLASH message. When the ROUTINE message is subsequently transmitted to the outgoing line, a new channel number will be transmitted by the special transmitter in the monitor unit. The action is then complete.

16. SINGLE CALL MESSAGE (INTERCEPT)

Assume that a message has arrived at an incoming unit via the terminal unit and is processed in the manner previously described. In this instance, however, when the routing indicator is transmitted from the director to the translator unit, the translator unit is unable to associate an outgoing line with that routing indicator. This could result from garbling in transmission or from errors made by the originating tape poker. Whatever the cause, when the translator is unable to find a suitable outgoing line indication from the routing indicator, the translator directs that the message be transmitted to an intercept position.

a. In accordance with the translator direction, the director seizes an intercept unit and sets the switch of the unit to the proper incoming line unit. Having performed this function, the director is no longer required and is released.

b. Upon release of the director, the message is transmitted from the incoming line unit to the intercept unit. An intercept operator examines the tape to determine the reason for routing to intercept, reconstructs the improper or garbled indicator, and punches the proper heading. The corrected tape is then taken in the manual forwarding unit and the message is reintroduced into the center.

c. At the manual forwarding unit (fig. 10), the operator selects a degree of precedence corresponding to that of the message and a transmitter to receive the message tape. He then sets a selector switch to position the unit to the proper outgoing line. These actions make the manual forwarding unit electrically identical to a cross-office unit. The manual forwarding unit will demand the selected outgoing line and seize that line as previously described. With seizure of the proper outgoing line, the message is automatically transmitted. This completes the action of single call message intercept.

17. MULTIPLE CALL MESSAGE

In this example we will describe the action of the automatic switching center in handling a multiple call message. Up to the point where the director reads the routing indicators, a multiple call message is handled as in the previous examples by the incoming line unit.

a. The director reads the routing indicator and requests translation as in the previous examples. The translator makes the necessary translation of the routing indicator and indicates an outgoing line. In a single call message, the tape reader would then read a line feed followed by the letter D or Z. This combination of LF D or Z would indicate that there were no other routing indicators to come. In a multiple call message, however, after reading the first routing indicator the tape reader does not read LF, D or Z, but continues to read a second routing indicator. The translator translates the second routing indicator and again indicates an outgoing line. The second outgoing line indication is then compared to the first. If they differ, the system senses immediately that the message requires multiple call processing.

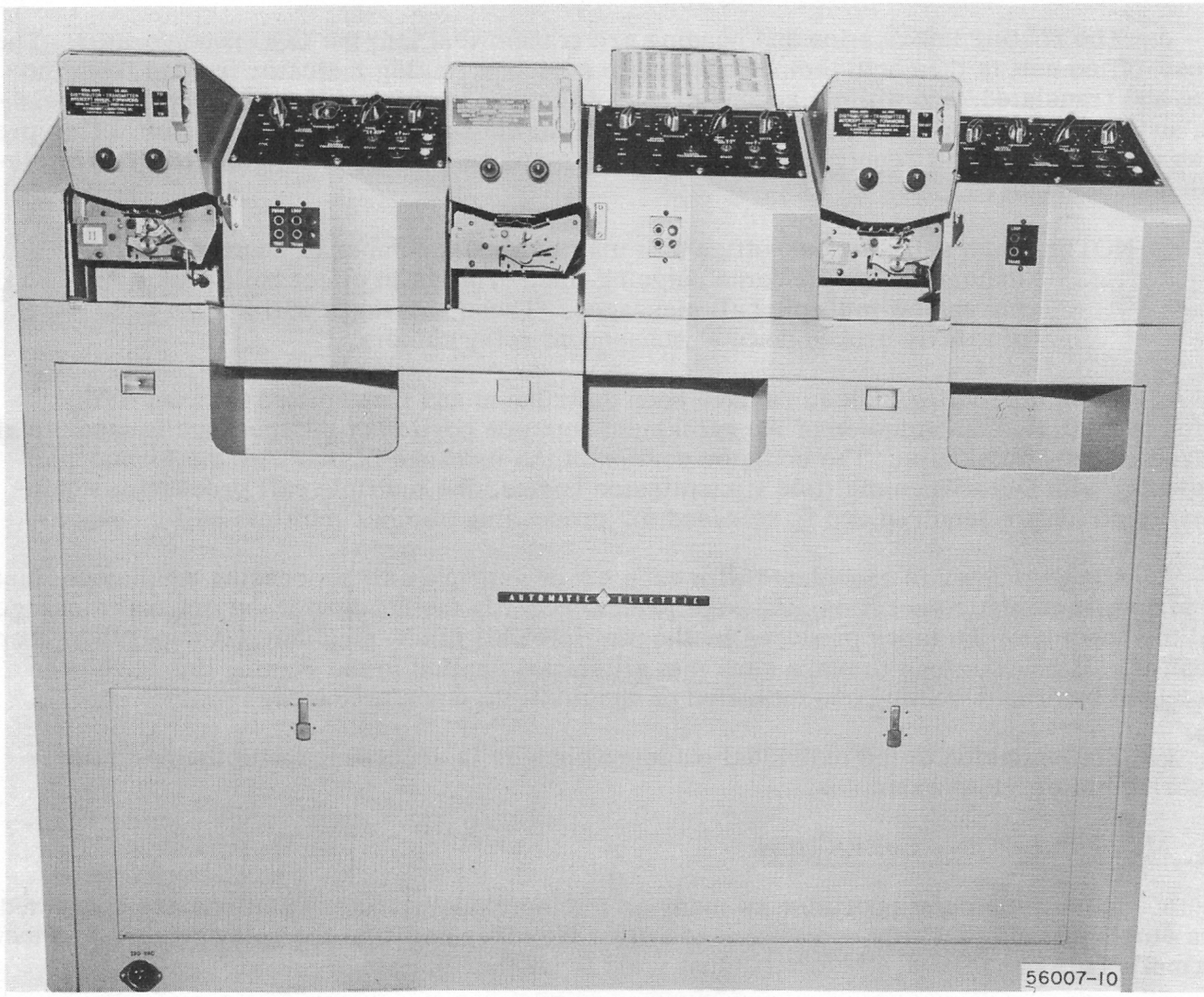

Figure 10. AN/FGC-30: manual forwarding unit.

b. If the outgoing line indications are the same, the tape reader continues to read the tape. If it reads LF, D or Z, then no multiple call processing is indicated and the message is treated in the same manner as a single call message. However, if the tape reader does not read LF, D or Z, it will then read a third routing indicator. This third routing indicator is then sent to the translator for translation and an outgoing line indication is received. Again, a comparison of the outgoing line indications is made. If these indications differ, then multiple call processing is required. If they do not differ, no multiple call processing is indicated up to this point, and the process continues until all routing indicators have been checked.

NOTE: Remember that no matter how many routing indicators there are on a message, translation will stop just as soon as there is a difference in two outgoing line indications.

c. As soon as a difference in outgoing line indications is noted, the director seizes an idle multiple call cross-office unit (MCCOU) and sets its incoming selector switch to the proper incoming line. Transmission then begins from the incoming line unit into the MCCOU. When the tape reader in the MCCOU reads and recognizes the SOM of the message, it demands a set of multiple call processing equipment, which acts very much like a director. It stores the precedence and the first routing indicator of the message. A translation is then made and a suitable cross-office unit is seized.

d. The routing information and heading are transmitted into the COU reperforator. The cross-office unit is then held temporarily while a second routing indicator is read from the tape and translated, and while a second cross-office unit is seized, if necessary. The heading and second routing indicator are transmitted into the second COU reperforator. This process continues until all required cross-office units are seized and routing indicators are distributed as required.

> NOTE: Each seized cross-office unit may receive a number of routing indicators for the same outgoing line. This is in effect building up new multiple call messages. These messages will be similarly broken down at subsequent relay centers.

e. When all routing indicators have been distributed and transmitted to cross-office units, a multiple transmission of the remaining common portion of the message is made to all seized cross-office units. The common portion of the message begins with the format line beginning with DE. When multiple transmission begins, the multiple call processing equipment is no longer required and is released for processing of other multiple call messages.

f. A page printer is associated with each set of multiple call processing equipment. Just as in semi-automatic operation, the page printer records the heading of the original message and the heading of the tapes produced by the multiple call processing unit. A supervisor then monitors all transactions to make sure that all stations called in the routing line have been protected by proper routing and inclusion on the multiple tapes produced.

g. Transmission to the individual outgoing lines is in accordance with the operation described in previous examples.

18. MULTIPLE POINT OPERATION

a. In multiple point operation as many as ten individual tributary stations are connected to a single circuit, but only one station at a time may transmit into the relay center, and then normally only one message before it must yield to another station.

b. When a multiple point station has traffic to send to the switching center, it sends a signal over the loop into the incoming multiple point unit. This signal causes the outgoing multiple point unit to send a signal of selective sequence to the remote station. This selective sequence signal selects the remote station to transmit its message and causes all other stations in the loop to be "locked out." When the message from the remote station arrives at the switching center the channel number of the message is checked against the appropriate channel number register for that station. Processing throughout the center continues as in previous examples.

c. When the message has been completely received, the outgoing multiple point unit sends a sequence signal out on the loop. This signal puts all stations back in a stand-by condition in preparation for transmission of traffic.

d. Multiple point operation is arranged so that high precedence traffic will interrupt messages of lower precedence. If a remote station on the multiple point loop desires to transmit a high precedence message while the line is occupied by a message of lower precedence, the station with the high precedence can send a signal to the switching center overriding the low precedence message. This signal causes a cancellation signal to be added to the low precedence message. The line then becomes available to the station desiring to transmit the high precedence message.

e. If transmission from the relay center to a remote station on the multiple point loop is required, the multiple point group is seized by a cross-office unit in the same manner as explained in previous examples. In this case, however, before the message is transmitted over the multiple point route, a selective sequence signal is sent over the loop. This signal causes only the proper station to condition its page printer for receiving a message. A channel number sequence for the remote station being called is transmitted in accordance with the channel number register associated with that station.

f. It is possible that the relay center may need to transmit a selective sequence signal to control the incoming line while the outgoing line is busy because a station is transmitting a message. As a result of this selective sequence signal, extraneous characters could be inserted in the transmitting message. However, the AN/FGC-30 has been so engineered that it can use individual characters of the message, coded in a tuned sequence, as the selective sequence signal. This ensures that no extraneous characters will be inserted in any message as a result of a selective sequence signal.

Section IV. AUTOMATIC SWITCHING CENTERS, U. S. NAVY

19. THE 82B1

a. In October 1958, the U. S. Navy cut over the first of its five fully automatic switching centers. This first center is located at Trenton, New Jersey (RBEG) and uses equipment designed by the Bell Telephone Laboratories. The system is known as the 82B1.

b. On 5 May 1959, the Navy cut over four additional centers: Norfolk, Virginia; Cheltenham, Maryland; Stockton, California; and San Diego, California. With these additional centers, 236 tributary stations in 31 states are connected in a fully automatic 48,000-mile network. This network, together with a 5,000-mile network of 85 semi-automatic stations, makes up the Naval Teletypewriter Network (NTX). It handles about 9 million words a day and has an ultimate capability of 30 million words a day.

20. FEATURES

Some of the features of the Bell 82B1 system are --

a. Fully Automatic Operation. This equipment is fully automatic. It receives incoming messages and routes them without manual intervention to suitable outgoing lines. Manual processing is required only when improperly prepared traffic prevents handling by the equipment or when traffic is addressed to supervisory personnel.

b. Compatibility. The 82B1 has been so designed that it is fully compatible with the equipments employed in the Army Command and Administrative Network (ACAN), the United States Air Force Air Communications Network (AIRCOMNET), and the USAF Air Operations Network (AIROPNET). Traffic may be transferred over authorized transfer circuits to the automatic equipments of the other service networks.

c. Routing Indicator Plan. This system recognizes the routing indicator plan currently in use on a combined basis as outlined in ACP 121-( ), Communications Instructions, General. Changes in routing indicators can be reassigned immediately within the system.

d. Three-Speed Operation. The system can receive and transmit messages at any of the three standard speeds of 60, 75, or 100 words per minute, and can use all three speeds at once.

e. Cross-Office Speed. It can transmit messages cross office at a speed of 200 words per minute. This speed was selected to reduce to an absolute minimum the time required for relaying a message through the switching center. Since the cross-office speed of transmission is equal to at least twice the incoming line speed, the equipment is so arranged that it takes no switching action until it has received a complete message. In the case of high precedence traffic, however, the cross-office path is established while the message is being received.

f. Precedence. This equipment recognizes two grades of military precedence: regular traffic (PRIORITY, ROUTINE, DEFERRED) and high precedence traffic (FLASH, EMERGENCY, OPERATIONAL IMMEDIATE). High precedence traffic gets preferential handling, but does not interrupt transmission of low precedence traffic.

g. Continuity of Service. The system automatically checks the channel-number sequence of a message. When the number comparator recognizes a break in the channel-number sequence, an alarm is activated and an operator takes the required action.

h. Message Control. Continuity of service is protected throughout the system by a complete alarm system to warn supervisors, operators and maintenance men of improper functioning of the equipment or of improperly prepared incoming message tapes.

i. Intercept Position. When messages are improperly prepared, contain garbled or unrecognizable characters in the routing line, or contain nonvalid routing indicators, the system automatically directs them to intercept positions. Operators may direct messages manually to intercept positions, where the messages may be examined and the necessary supervisory action taken. Visual and audible alarms announce the sending of a message to an intercept position. This type of intercept position is known as miscellaneous intercept. The system also provides intentional intercept positions. Messages are intentionally intercepted when a station is not in service during certain periods, such as weekends or holidays; when it is temporarily released for routine maintenance; or when it is unable to receive traffic owing to line or machine trouble. Until manually set for automatic direction, the equipment does not automatically direct messages to intentional intercept positions. There are no audible or visual alarms associated with intentional intercept positions.

j. Operator Service Position. To transmit procedure messages, reruns and corrected messages, and to reintroduce messages into the system, operator service positions are provided. These positions are like the manual forwarding positions of the AN/FGC-30. The operator service position has three basic functions: tape preparation, message servicing, and insertion of messages into the system.

k. Multiple Call Message. This system handles multiple call messages automatically. There is no limit to the number of routing indicators which may be processed in each message.

l. Multiple Point Operation. The 82B1 was designed to provide multiple point operation (multiple station line) on a full duplex basis. It is possible for one station on line to receive traffic while a second station is transmitting. The switching center exercises control over transmission and reception. No more than five stations may be served on one multiple station line.

m. Other Features. Other features of this equipment are:

(1) The switching center consists primarily of self-contained units of equipment known as the incoming cabinet and the outgoing cabinet.

(2) This equipment handles single or multiple call messages with equal dispatch.

(3) A message is transmitted cross office only once, regardless of the number of address and/or outgoing lines to which it must be routed.

(4) Specially trained Bell Telephone Company personnel maintain the equipment. Switching center personnel are responsible for simple maintenance operations, such as replenishing paper and tape rolls, replacing teletypewriter ribbons, and removing tape and paper from storage reels.

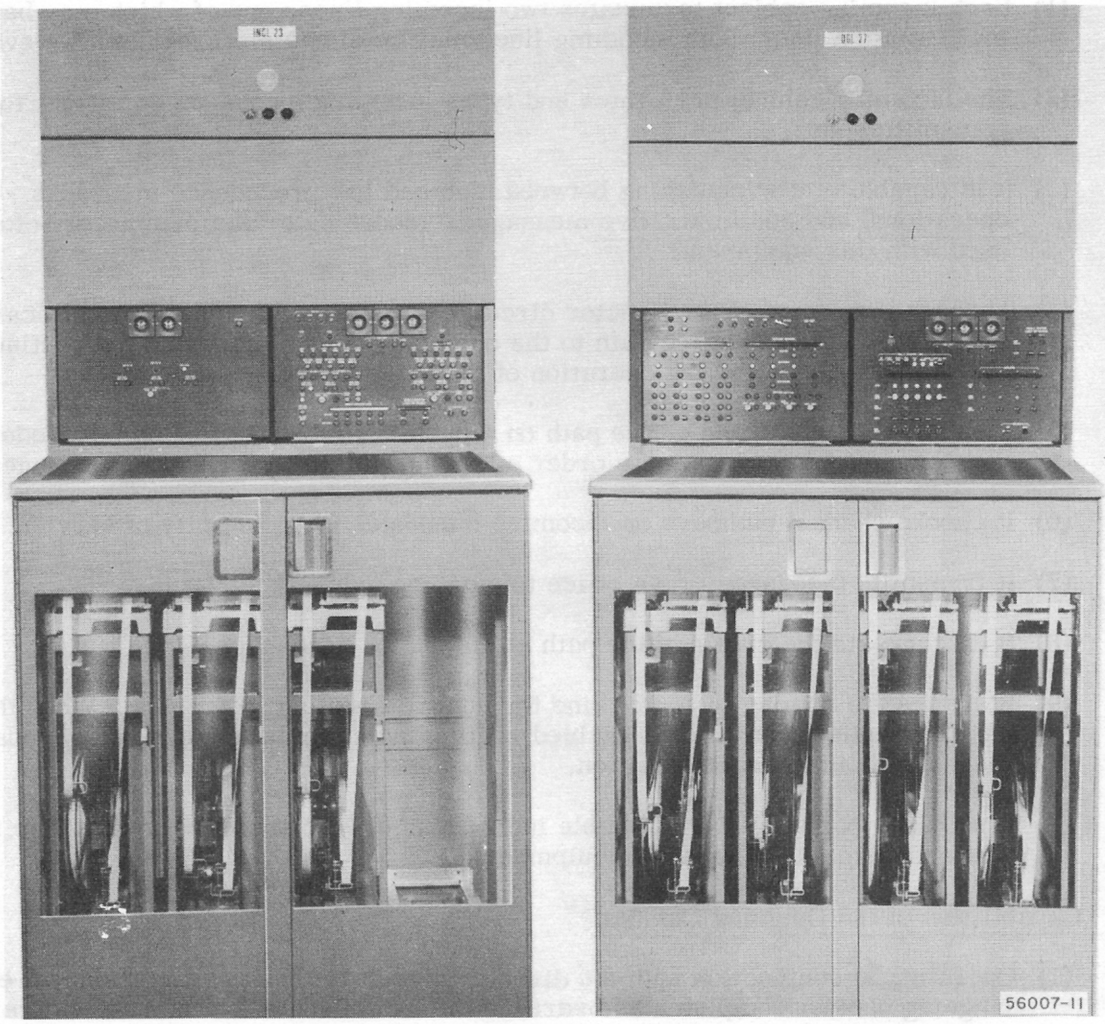

Figure 11. The 82B1: incoming (left) and outgoing cabinets.

21. SYSTEM OPERATION

Basically the switching center consists of cabinets known as the incoming cabinet and the outgoing cabinet (fig. 11). Each incoming cabinet contains two incoming line units with associated reperforator/transmitters. In each incoming cabinet there is one director circuit and its associated reperforator/transmitter. Thus, one director circuit serves two incoming line units. On all precedence messages, the director circuit alternates between the two incoming line units to serve them equally. That is, the director circuit works with a message on one incoming line only long enough to act upon the information contained in the heading and establish the cross-office path for that message. It then switches to serve the second incoming line unit in a similar manner, "flip-flopping" between the two incoming line units. On high precedence traffic, however, the director circuit may not alternately serve the two incoming line units. Instead, as soon as it is available, it serves that incoming line unit which holds the high precedence message. If high precedence messages are present on both incoming lines, then the director circuit alternates equally between both incoming lines. Preferential treatment is given only on the basis of high precedence (FLASH, EMERGENCY, OPERATIONAL IMMEDIATE) and regular traffic (PRIORITY, ROUTINE, DEFERRED).

a. Capabilities of the Incoming Cabinet.

(1) Each incoming cabinet terminates two incoming lines, one of which may be a multi-station line. Both incoming lines may be single station lines, however.

(2) The incoming cabinet perforates and types incoming messages on a reperforator/transmitter unit.

(3) It is capable of distinguishing between high and low precedence messages -- or operational and administrative messages, according to the terminology often used with this equipment.

(4) Through the action of its director circuit each incoming cabinet automatically establishes a cross-office path to the outgoing cabinet, checking the continuity of each path and verifying operation of the outgoing cabinet machine.

(5) It establishes the cross-office path on a preferential basis for high precedence messages and in approximate order of receipt for low precedence messages.

(6) It checks channel numbers on incoming messages for continuity of service.

(7) It transmits messages cross office to outgoing cabinets.

(8) It disconnects the cross-office path at the end of a message.

(9) It checks the routing indicator line for nonvalid routing indicators. When this check reveals a nonvalid or garbled routing indicator it automatically sends the message to an intercept position.

(10) It provides both visual and audible indications of irregularities in message format and of malfunctioning of equipment.

b. Capabilities of the Outgoing Cabinet.

(1) Operating in conjunction with the director circuit of the incoming cabinet, each outgoing cabinet completes and verifies the establishment of a cross-office path.

(2) It verifies operation of the outgoing equipment selected.

(3) It provides for high and low precedence message handling.

(4) It automatically selects and connects idle reperforator/transmitter machines to receive messages from the incoming cabinet.

(5) It automatically generates and transmits outgoing channel numbers to the outgoing line.

(6) It selects and connects idle lines with those outgoing machines having messages for transmission where the number of machines exceeds the number of lines they serve.

(7) On multi-station lines the outgoing cabinet automatically polls the multi-point tributary stations for traffic.

(8) It provides visual and audible indications for proper supervision of the flow of traffic.

22. SIMPLIFIED PROCESSING

A basic understanding of the operation of this equipment can be obtained from the following simplified version of the handling of a single address message of regular precedence:

a. As the message arrives at the switching center, the ZCZC indicates a start of message. The number comparator is called into action and compares the channel number group of the message with the number in the comparator register. The channel number (see figure 4) consists of eight characters: three letters to identify the station and the channel over which the incoming message is being received, followed by a FIGURES shift, three numerals to identify the serial number of the transmission, and a LETTERS shift.

b. If the number sequence in the register of the channel-number comparator does not agree with the channel number of the message, then a red lamp alarm is activated at the incoming cabinet. The director circuit will be held up and unable to operate until this alarm has been cleared by operating personnel. If the number in the register of the channel-number comparator and the channel number on the message agree, the director is permitted to operate.

c. Immediately after a channel number sequence, the tape will show two carriage returns, one line feed, a precedence designation (OO, PP, RR, or MM, and a space). This precedence recognition sequence conditions the equipment for either regular handling or preferential handling of high precedence traffic. It also indicates which incoming line unit the director will serve.

d. The director stores this precedence sequence and continues on to record the routing indicators on the message tape. It then stores the routing indicators and translates them into a designation of an outgoing line. When the director reaches the end of the routing line it recognizes this fact by sensing the characters, two carriage returns, a line feed, D or Z. This now indicates that routing information is complete and switching cross office may begin. Having analyzed and stored this information, the director circuit indicates to the sequence circuit in the incoming cabinet that the director is ready to establish a cross-office path or paths.

e. The sequence circuit acts on the bids of all director circuits in the switching center in such a manner that requests for cross-office paths are handled in the approximate order of their receipt. The sequence circuit having established the cross-office path, the director circuit then sends a request to the bid receiver circuit of the proper outgoing cabinet. The bid receiver acts upon this request from the director by selecting and connecting an idle machine to receive the cross-office transmission. The bid receiver circuit connects a specific channel-number generator to the outgoing line. It then indicates to the director circuit that the proper outgoing machine has been connected.

NOTE: The machine selected to receive the cross-office transmission will be either a regular or a high precedence machine depending on the precedence of the message. High precedence machines are given preference for transmission over the outgoing line. When a high precedence machine is available, it is connected automatically. The message is then permitted to be transmitted cross office. Having received an acknowledgement by the director circuit for cross-office transmission, the transmitter of the incoming line unit transmits the message over the cross-office path which has been established. The director then becomes available to serve the alternate incoming line unit. When the end of message (EOM), which consists of the characters, line feed, 4 N's, passes through the system, it progressively causes the disconnection of all equipment which had been seized for the message. Figure 12 shows a block diagram of the teletypewriting switching system.

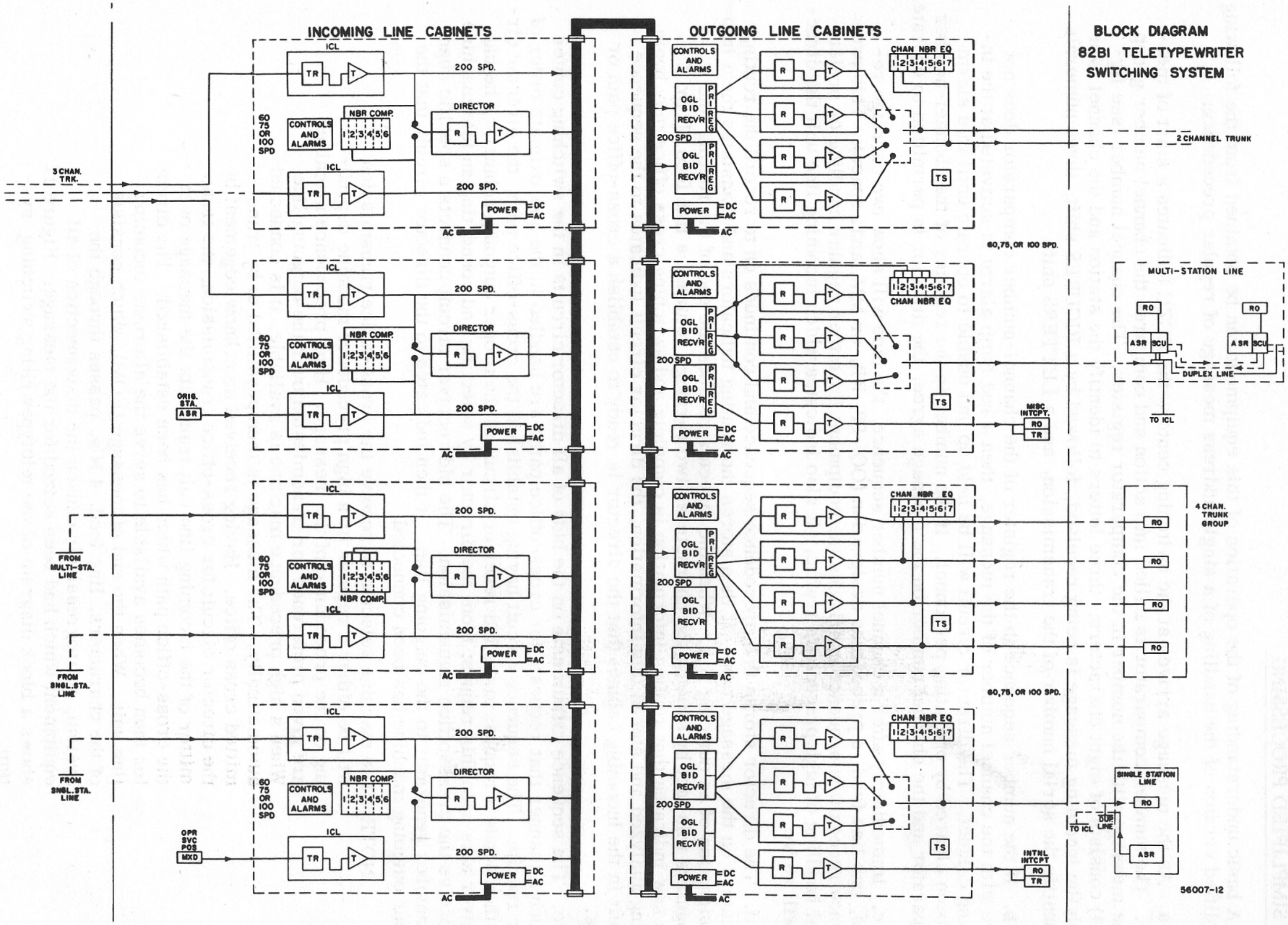

Figure 12. The 82B1: Block diagram.

23. PLAN 55

a. Since February 1951, the U. S. Air Force has had in operation a 200,000-mile private wire network (USAF AIRCOMNET). Originally, this network included five Plan 51 switching centers leased from Western Union. They have since been replaced with fully automatic switching centers known as the Plan 55.

b. The "Gateway" centers to the Atlantic and to the Pacific are located at Andrews AFB, Maryland, and McClellan AFB, California. These Gateway centers, as well as other continental USAF centers, employ the Plan 55. It is expected that Plan 55 equipment will be installed at some oversea bases.

24. FEATURES

Some features of the USAF Plan 55 system are --

a. Fully Automatic Operation. This equipment is fully automatic. It receives incoming messages and routes them without manual intervention to proper outgoing lines. Manual processing is needed only where improperly prepared messages preclude handling by the equipment or when messages are addressed to supervisory personnel.

b. Single Installation in Network. This equipment can be installed at any point within a tape relay network, since it does not require similar equipment to be located at other points.

c. Compatibility. The equipment permits transfer over authorized transfer circuits to the automatic equipments of U. S. Navy and U. S. Army centers.

d. Routing Indicator Plan. The routing indicator plan currently in use (as outlined in ACP 121, Communications Instructions, General) is recognized by this system. Routing indicators can be immediately reassigned within the system as changes occur.

e. Line Speeds. Messages may be received and transmitted at speeds of 60, 75 or 100 words per minute. All three standard speeds may be used simultaneously.

f. Cross-Office Speed. Messages are switched cross office at a speed of 200 words per minute.

g. Push-Button Switching. Maximum flexibility is provided by push-button panels which permit manual, semi-automatic switching when required by improperly prepared or garbled messages, emergency setup of small centers, and similar factors.

h. Precedence. This equipment recognizes and handles traffic of either high or low precedence. Switches are provided on the back of each director console to permit the precedence prosigns, O, P, or R to be recognized as either high or low precedence. Y and Z are always read as high precedence and M is always read as low precedence. Normally these switches are set to read Z, Y, O and P as high precedence, and R and M as low precedence. High precedence messages are given preferential handling.

i. Continuity of Service. A sequence number indicator (SNI) automatically checks the channel number sequence at the incoming line. Automatic message-numbering machines transmit channel numbers on the outgoing line ahead of each message.

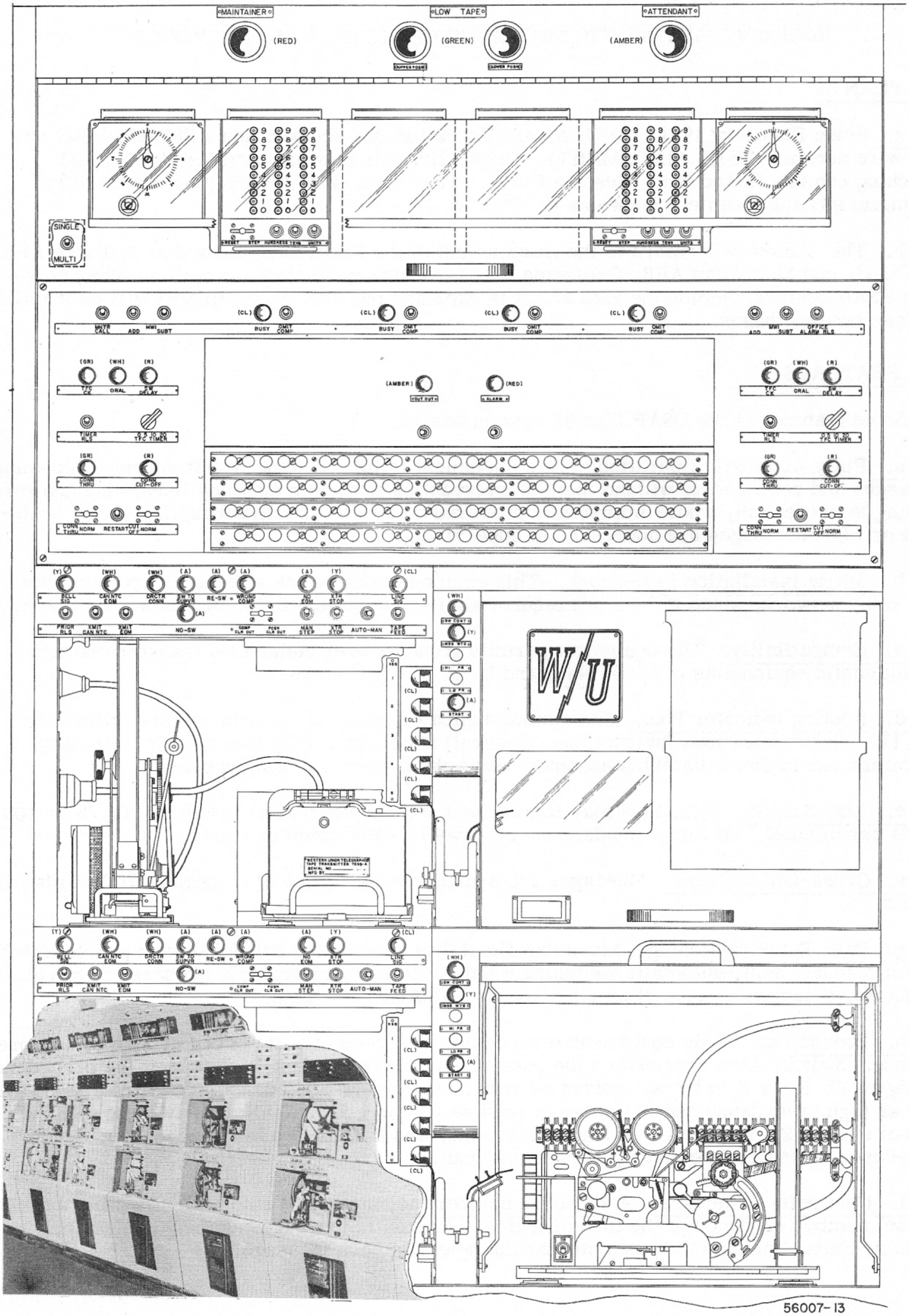

Figure 13. Plan 55: incoming consoles.

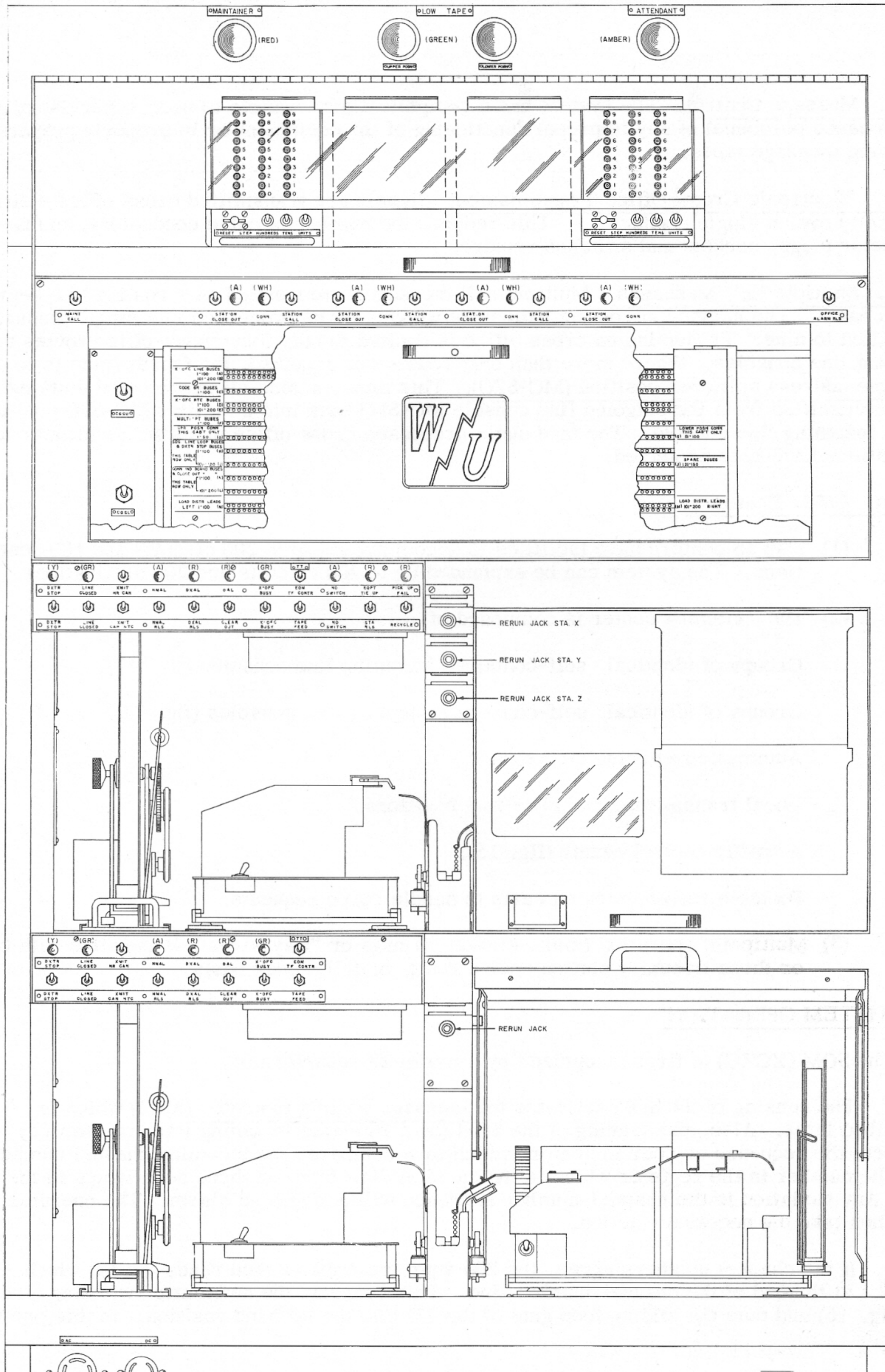

Figure 14. Plan 55: outgoing console.

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j. Message Control. The system has a complete alarm system to warn supervisory and maintenance personnel of any improper functioning of the equipment or improperly prepared incoming message tapes.

k. Electronic Cross-Office Transmission. Signals are transmitted cross office electronically over a single conductor. This reduces the number of cable conductors, multiconductor plugs, sockets and switches required.

l. Multiple Call Messages. Multiple call messages are handled on a routing line segregation basis. The number of routing indicators which may be processed in a single message is limited to nine. Transmission cross office is limited to only four cross-office routes to outgoing line consoles. Where more than four routes are required, the fourth route is to a multiple address spillover position (MC-SPO). This tape contains all unprotected stations. It is transmitted from the outgoing line console MC-SPO back into a similar MC-SPO position at the incoming line console. The tape again processes cross office in a similar manner until all stations have been protected.

m. Other Features.

(1) Plan 55 centers have facilities to accommodate up to 200 circuits and 100 destinations. The system can be explanded up to 400 circuits and 200 destinations.

(2) The switching center is composed of --

Groups of identical, self-contained incoming line consoles (fig. 13).

Groups of identical, self-contained outgoing line consoles (fig. 14).

Automatic switching directors.

Local transmitting and receiving positions.

A traffic control center (fig. 15).

Portable retransmission carts to handle rerun requests.

(3) Multipoint operation (multi-station circuits or "way wires") is possible with two or three tributary stations per circuit, or full duplex basis.

25. SYSTEM OPERATION

The SOM (ZCZC) is first recognized by a model 28 reperforator.

a. The sensing of the SOM activates the message waiting indicator (MWI) which is described later. Also, the sensing of the SOM (by a 200-wpm incoming line transmitter) connects the sequence number indicator, which then compares the incoming channel number with the number in the register which is indicated in digit form on three neon lamps in the SNI. Any variation in the channel-number sequence will activate an alarm. The operator may then take the necessary action.

b. If the channel numbers agree, the 200-wpm transmitter then reads the LF which appears at the end of the channel-number line. This connects the automatic switching director (fig. 16) and puts the sliding loop gate of the TD into the lefthand position. In this position,

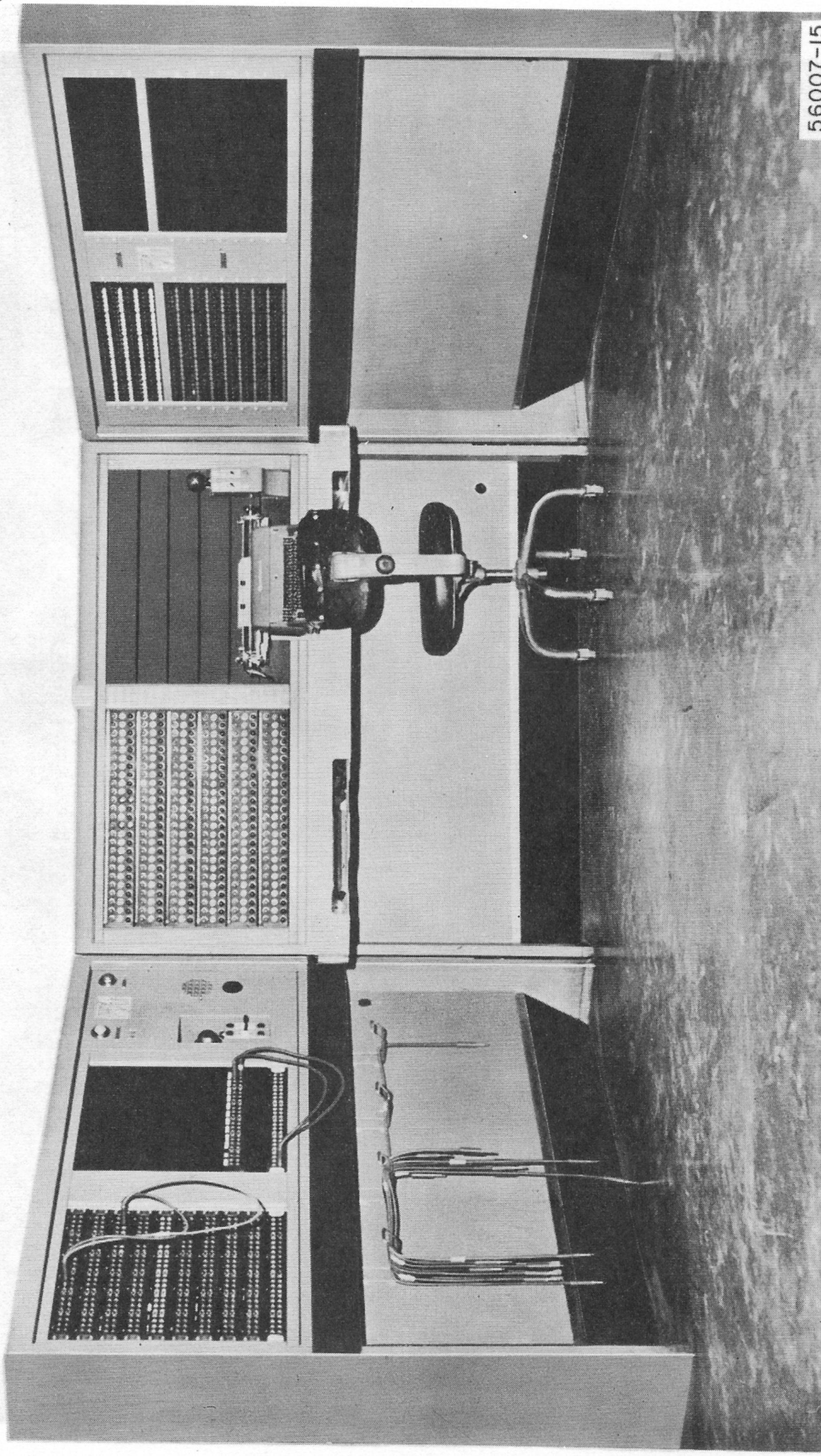

Figure 15. Plan 55: traffic control center.

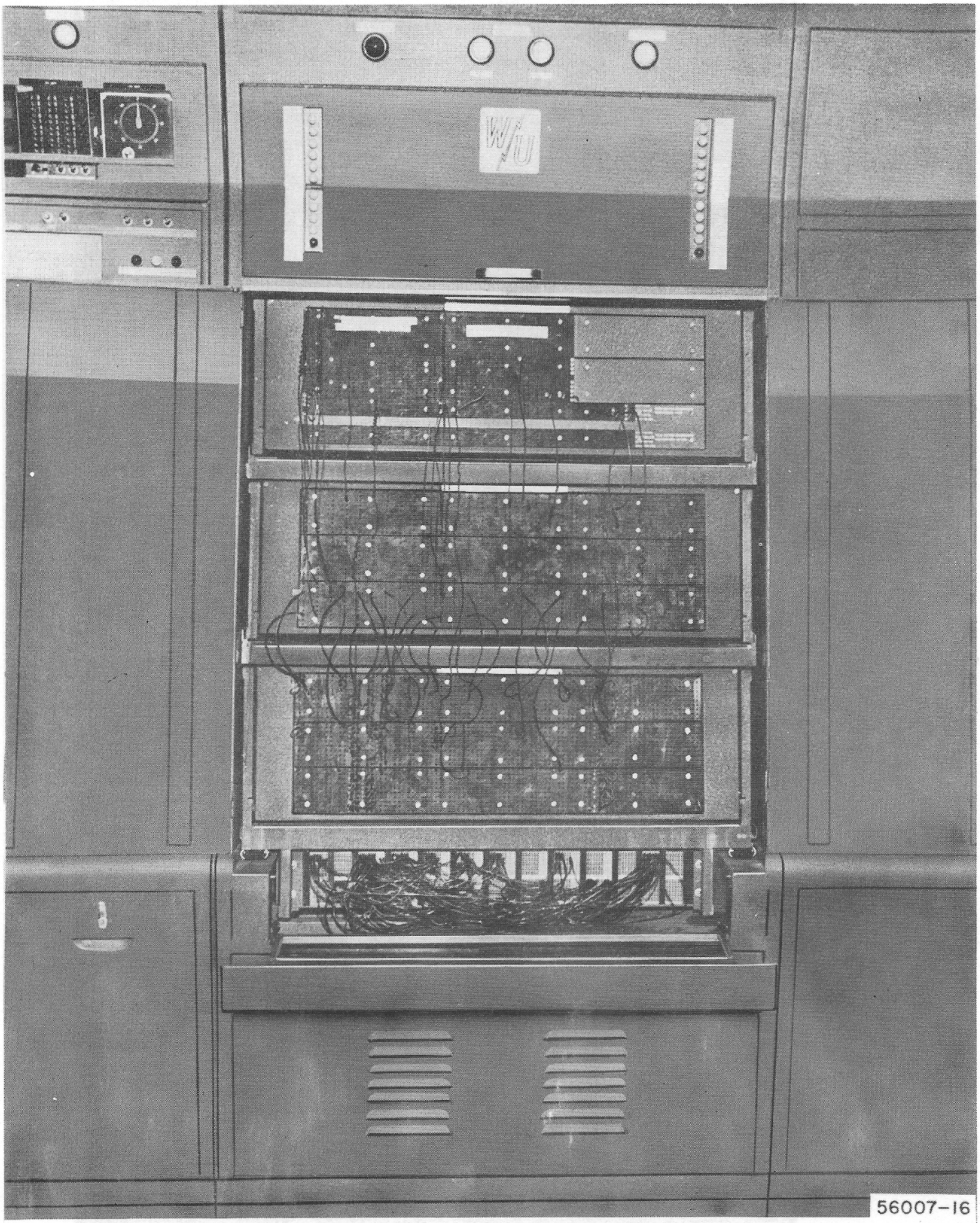

Figure 16. Plan 55: automatic switching director.

the tape is not permitted to pass completely through the TD. This action allows the information contained after the LF, the routing indicators, and the precedence designations to be processed through the automatic switching director. As the routing line is fed through the 200-wpm TD a loop is formed (fig. 17).

c. Each routing indicator in this format line is preceded by a space (SP). When the 200-wpm TD reads this SP, it starts the automatic switching director, which processes a routing indicator.

d. The switching director, through the services of a translator, receives a translation of routing indicators to outgoing lines. The automatic switching director then sets up the proper cross-office path in accordance with these translations and as high or low precedence.

e. After the routing indicators are processed, the machine functions 2 CR LF and letter D or Z (D from DE line or Z from line one pilots) are then sensed. The characters indicate that no additional routing indicators are to be processed and therefore disconnect the automatic switching director. Simultaneously, the sliding loop gate on the 200-wpm TD is set to its righthand position. This position readies the TD for transmission over the cross-office path set up by the automatic switching director.

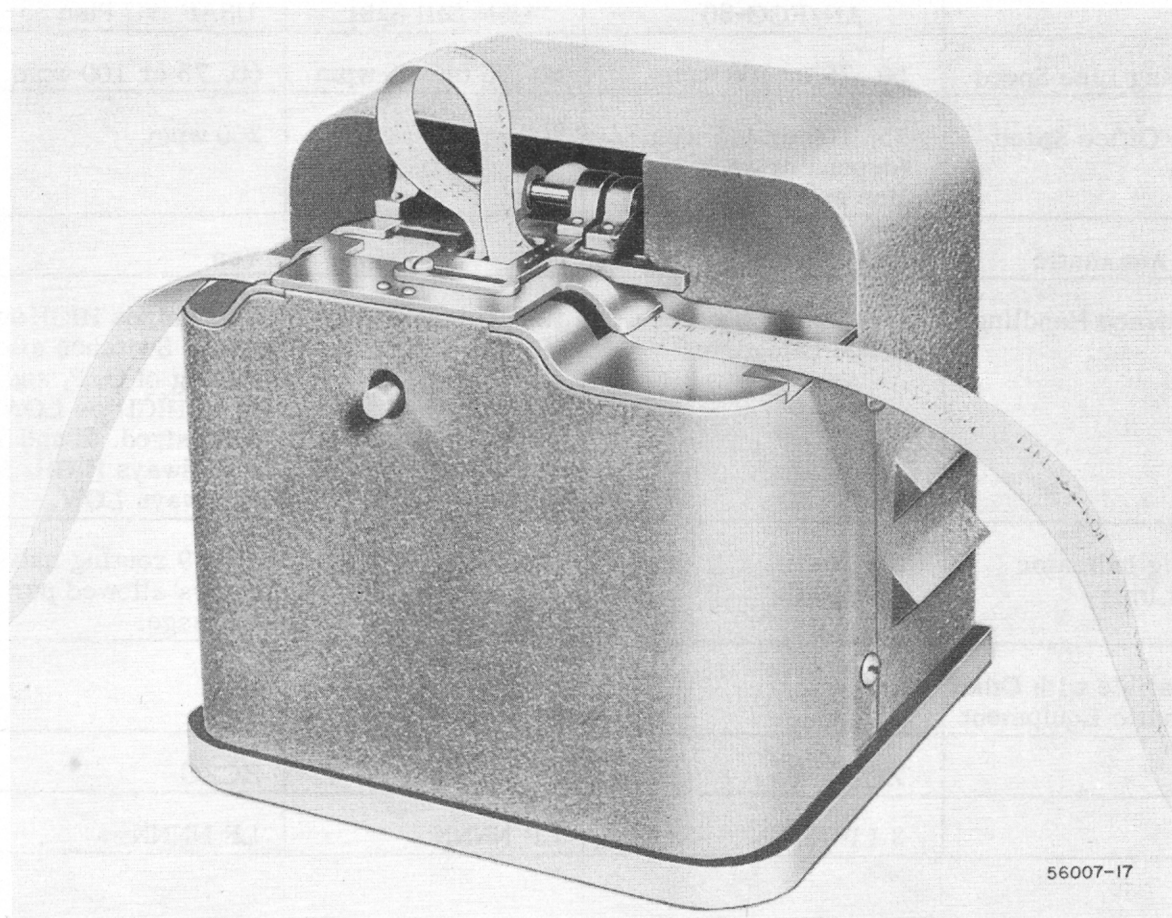

Figure 17. Plan 55: 200-wpm TD, showing paper loops.

f. As the message goes through the incoming line reperforator, the EOM (LF NNNN) is recognized. This makes the message waiting indicator advance to the next number. The main function of the MWI is to control cross-office transmission. When the MWI is on "0" no transmission can be made cross office (except high precedence through use of the bell signal). Cross-office transmission can be made only when MWI is a number. Since the MWI does not advance to a number until the EOM is sensed, only a complete tape with the proper EOM is permitted to go cross office.

g. As the message goes cross office through the 200-wpm TD, the EOM is sensed in this TD. This disconnects the cross-office path, subtracts "1" from the MWI and advances the SNI to the next number.

h. The message, after cross-office transmission, is sent over the proper outgoing line of the outgoing console. An automatic numbering machine sends an SOM and channel number at the beginning of each message. As the EOM is sensed, the outgoing console is disconnected and transmission is complete.

APPENDIX I

SUMMARY CHART

	AN/FGC-30	USN Bell 82B1	USAF WU Plan 55
Incoming Line Speed	60, 75 or 100 wpm	60, 75 or 100 wpm	60, 75 or 100 wpm
Cross Office Speed	75, 100 or 115 wpm (depending on incoming line speed)	200 wpm	200 wpm
Fully Automatic	Yes	Yes	Yes
Precedence Handling	Acts on all 6 precedence categories.	Recognizes HIGH (Z, Y, O) or LOW (P, R, M).	Recognizes HIGH and LOW. Switches allow setting of O, P, and R to be HIGH or LOW as desired. Z and Y are always HIGH, M is always LOW.
Routing Indicator Line Limit	No limit.	No limit.	Only 9 routing indicators allowed per message.
Compatible with Other Automatic Equipment	Yes	Yes	Yes
SOM	ZCZC	ZCZC	ZCZC
EOM	3 LF NNNN	LF NNNN	LF NNNN

CONTENTS

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