WESTERN UNION Technical Review

Western Union Switching Systems

•

Switch Shelf Test Set

•

Microwave System For Television

•

Bid and Offer Deleting Ticker

•

Night Fighter Training

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CONTENTS

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The Development of Western Union Switching Systems

W. B. BLANTON and G. G. LIGHT

(Continued from TECHNICAL REVIEW, July 1948)

Previous articles in TECHNICAL REVIEW described the plug and jack (Plan 2) and the push-button (Plan 20) methods of setting up intra-office connections between line receiving positions and line sending positions in the area center reperforator offices installed prior to 1948. This article will describe the reperforator switching system, designated as Plan 21-A, which is used in seven area centers that have been installed and cut into service during the past year and a half. The objectives in the development of this system were improved operation and speed of service through the employment of automatic switching techniques.

In a plan 21-A area center, approximately one half of the reperforator switching system is operated on an automatic switching basis, while the other half is operated on a push-button switching basis. Telegrams which originate within the area and are transmitted into the switching system at the area center from tributary and city branch offices and from local operators' sending positions are automatically switched, by means of selection characters prefixed to each message, into inter-area and a selected number of intra-area trunk sending positions. In the opposite direction, telegrams received over inter-area trunks are switched by the push-button method to tributaries, branches and receiving locals.

The equipment and circuit arrangements employed in the push-button portion of Plan 21-A offices are essentially the same as those used in earlier push-button (Plan 20) switching offices. Automatic switching involves many new and novel equipments and circuit arrangements, but since the push-button and automatic switching are integrated into one common system within an office, it was desirable that many of the basic circuit arrangements of the automatic switching be the same as used in push-button switching.

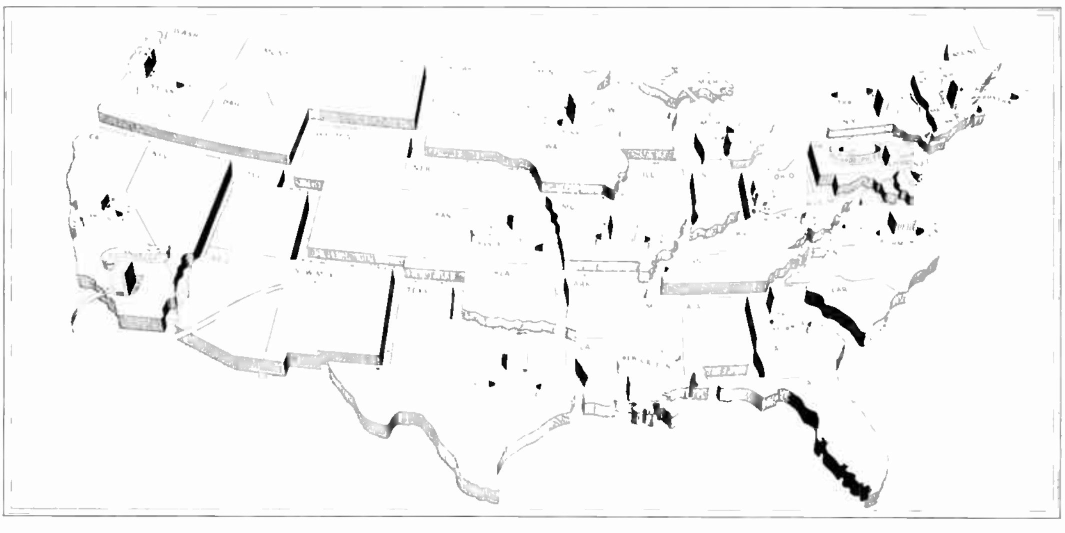

Figure 34. Block state routing areas.

In the first article on the development of Western Union switching systems (January 1948 issue of TECHNICAL REVIEW), a block state routing area map showed the nation divided into 16 areas. Subsequently, the number of areas in the nation was established at 15. Figure 34 illustrates the 15 area plan and shows the area center for each of the areas. At the present time, reperforator switching systems have been installed and are in operation in 14 of the 15 area centers. It is planned that Portland, the only center now on a manual relaying basis, will be equipped with a reperforator switching system and cut into service early next year.

Each area center is connected by intra-city circuits to the branch offices within the same city as the area center, and by intra-area circuits to the telegraph offices, termed tributary offices, in the various towns and cities located within its own area. A network of inter-area trunks connects each area center with the other 14 area centers. Where the load justifies, additional inter-area trunks are provided from an area center to large tributary offices, termed terminal offices, in other areas.

Discussion of Automatic Switching of Telegrams

In push-button switching (described in the July 1948 issue of TECHNICAL REVIEW), a switching clerk reads the address and destination of each message, as recorded on the receiving position printer-perforator tape, and determines the routing. She then switches the message by depressing an "initiate" push-button located on the receiving position and the proper "destination" push-button in the switching turret. Depressing these two push-buttons establishes electrical circuits that control the operation of one or more rotary switches (multi-contact, multi-position, magnet operated switches), through which the intra-office connection is set up between the receiving position and the desired sending position. It would appear that, with some ingenuity, a few more elements could be added to this system which would provide for automatically switching the message. If the originating operator were to prefix the message with selection characters that denoted the routing, these selection characters could be "read" by electro-magnetic relays which would establish the electrical circuits for controlling the operation of the one or more rotary switches. However, the complete problem of automatically switching telegrams through a reperforator office does not reduce itself to such simple terms. Of equal importance with that of providing the automatic switching arrangement, is the need to integrate into the system safeguards to protect against the possible delay or failure (loss or mutilation) of messages.

For example, in the descriptions of both plug and jack switching and push-button switching, it was stated that each office or local position sending into a receiving position of a switching center numbered its messages in sequence, starting with number "1" at the beginning of each day. The switching clerks at the switching center, in addition to switching the messages to the proper sending positions, also marked off the sequence number of each received message on number sheets maintained at receiving positions. In automatic switching, this human attention that protects against the possible failure of messages due to human error, circuit trouble, or equipment trouble, has been supplanted by electro-mechanical facilities which operate automatically.

In Plan 21-A area switching centers, provision is made for automatically switching from incoming tributary and branch office circuits and from local operators' sending positions to a maximum of 73 destinations. Provision is made for push-button switching from the incoming inter-area trunks to a maximum of 270 destinations. In general, the 73 automatic switching destinations for a particular area center comprise the other 14 area centers; those terminal cities in other areas that have trunks to this area center; the larger tributary points within the same area; fall-back facilities which may be used for setting up temporary circuits on special occasions; and various positions within the area center which are used for segregating certain classes of traffic and for supervisory and testing purposes. The

270 push-button switching destinations include the 73 automatic switching destinations (except that separate supervisory and testing positions are used for the two types of switchings), and in addition include all of the remaining intra-area destinations served by the area center.

Since, for economic reasons, the automatic switching facilities do not reach directly all of the destinations included in push-button switching, "cross-over" facilities are provided from the former to the latter. Therefore, intra-area messages for points not included in the 73 automatic switching destinations are directed to the "cross-over" facilities by prefixing them with the call letters of the "home" area center. These messages are then automatically switched to sending positions, termed "*SS*" or Special Switching Sending Positions. These positions, which are similar to trunk sending positions, transmit the messages into printer-perforators at "*SS*" receiving positions located at push-button switching turrets. Here switching clerks manually switch the messages to outgoing circuits or to receiving positions in the reperforator office.

INTER-AREA DESTINATIONS

Area Centers

	*	**
Atlanta	=A	3
Dallas	=D	2
Kansas City	=K	1
Los Angeles	=L	2
Minneapolis	=M	2
Oakland	=O	3
Philadelphia	=P	6
Richmond	=R	2
St. Louis	=S	2
Cincinnati	CT	4
Detroit	DE	3
New Orleans	NS	2
Portland, Ore.	PR	1
Syracuse	SY	5

Terminal Cities

	*	**
Chicago	=C	4
New York	=N	7
Washington, D. C.	=W	3
Albany, N. Y.	AB	1
Baltimore, Md.	BR	1
Buffalo, N. Y.	BU	1
Cable Office, N. Y.	CD	2
Cleveland	CL	2
Milwaukee	MW	1
Miami	MZ	1
Pittsburgh	PG	1
Rochester, N. Y.	RH	1
San Francisco	SF	1

INTRA-AREA DESTINATIONS

Selectable Destinations

	*	**
Bangor, Me.	BG	2
Burlington, Vt.	BI	2
Bridgeport, Conn.	BP	3
Cambridge, Mass.	CA	3
Hartford, Conn.	HK	4
Lynn, Mass.	LY	2
New Britain, Conn.	NB	2
New London, Conn.	NP	1
New Bedford, Mass.	NX	2
New Haven, Conn.	NV	3
Portland, Me.	PD	3
Providence, R. I.	PV	3
Springfield, Mass.	SG	3
Stamford, Conn.	ST	2
Waterbury, Conn.	WY	2

Non-Selectable Destinations

	*	**
"SS" Positions	=B	17

INTRA-OFFICE POSITIONS

Special Handling

	*	**
Canadian Msgs.	CP	4
Book Msgs.	BK	2
Spill-over "A"	II	2
Spill-over "C"	OO	1

Fall Back

	*	**
Fall-Back "A"	AA	2
Fall-Back "C"	CC	1
Fall-Back "D"	DD	1

Supervisory and Testing

	*	**
T and R Notes	TR	1
Test Purposes	TT	1
Supervisor "A"	SA	1
Supervisor "B"	SB	1
Supervisor "C"	SC	1
Supervisor "D"	SD	1

* Selection Characters.
** Number of Sending Channels.

Figure 35. Automatic switching destinations in Boston reperforator office

Figure 35 lists the destinations to which messages may be automatically switched through the Boston office, which is the area center for the states of Massachusetts, Connecticut, Maine, New Hampshire, Vermont, and Rhode Island. While most of the particular destinations will be different in each of the other area centers, the general plan is typical. The selection characters and the number of sending channels for each destination are also indicated on the chart. Prior to the introduction of automatic switching, most of the cities now serving as area centers and a few of the large terminal cities were designated with single letter office calls, while the vast majority of offices had two letter office calls. Except for a few necessary and desirable changes, these original office call designations have been retained, but in order that all of the selection character combinations would consist of two characters, an equal sign was placed ahead of the single letter office calls.

The nation-wide block state routing plan enables the tributary and branch office operators to route and prefix each message with selection characters either from memory or by reference to a brief and simple route chart.

If the message is destined for another area, the operator first determines if it is for one of the other area terminal cities listed on her route chart. If not, she then directs it to the area center that serves the state in which the city or town of destination is located. If the message is an intra-area message, she first determines if it is addressed to one of the tributary points listed on her route chart. If not, she then prefixes the message with the selection characters of her area center.

General Description of Plan 21-A Reperforator Office

Each trunk, tributary and branch office circuit, except for 2-station or 3-station way-circuits, consists of a receiving and sending channel which may be operated simultaneously. Very lightly loaded tributary offices are generally combined on 2-station or 3-station way-circuits which terminate in single line repeaters at the reperforator office. Separate sending and receiving legs extend from these repeaters to the switching unit but the circuit arrangements are such that transmission can be in only one direction at a time.

Figure 36 is a block diagram of some of the principal equipments and circuit arrangements employed in a Plan 21-A reperforator office. The receiving channels of typical circuits are shown terminated in receiving equipments on the right-hand side of the diagram. The associated sending channels of these circuits are shown terminated in sending positions on the left-hand side of the diagram. Between the receiving equipments and sending positions, the intra-office apparatus and switching arrangements are shown diagrammatically.

The receiving sides of inter-area trunks (R1 of Figure 36), are terminated in printer-perforators at line receiving positions. Associated with each printer-perforator is an intra-office transmitter through which the tape produced by the printer-perforator flows, one message at a time for each switching operation. A push-button switching turret is provided for each three line receiving positions. By means of the push-button switching facilities, switching clerks can switch any received message to any inter-area or intra-area sending position (S1 to S8) with the exception of the "*SS*" Special Switching Sending Positions (S2). The "*SS*" positions need be reached only by the automatic switching facilities.

The receiving sides of heavy tributary and heavy branch office circuits are terminated in reperforators at line receiving positions (R3 and R4) which are provided with automatic switching facilities. Associated with each receiving reperforator is an intra-office transmitter through which the tape produced by the reperforator flows, one message at a time for each switching operation. When at least one complete message has been received at a line receiving position, an automatic switching unit connects to that position and "reads" the selection characters. The message is then switched to the appropriate inter-area (S1) or intra-area (S3) sending position as determined by the selection characters. If the message is destined for an in-

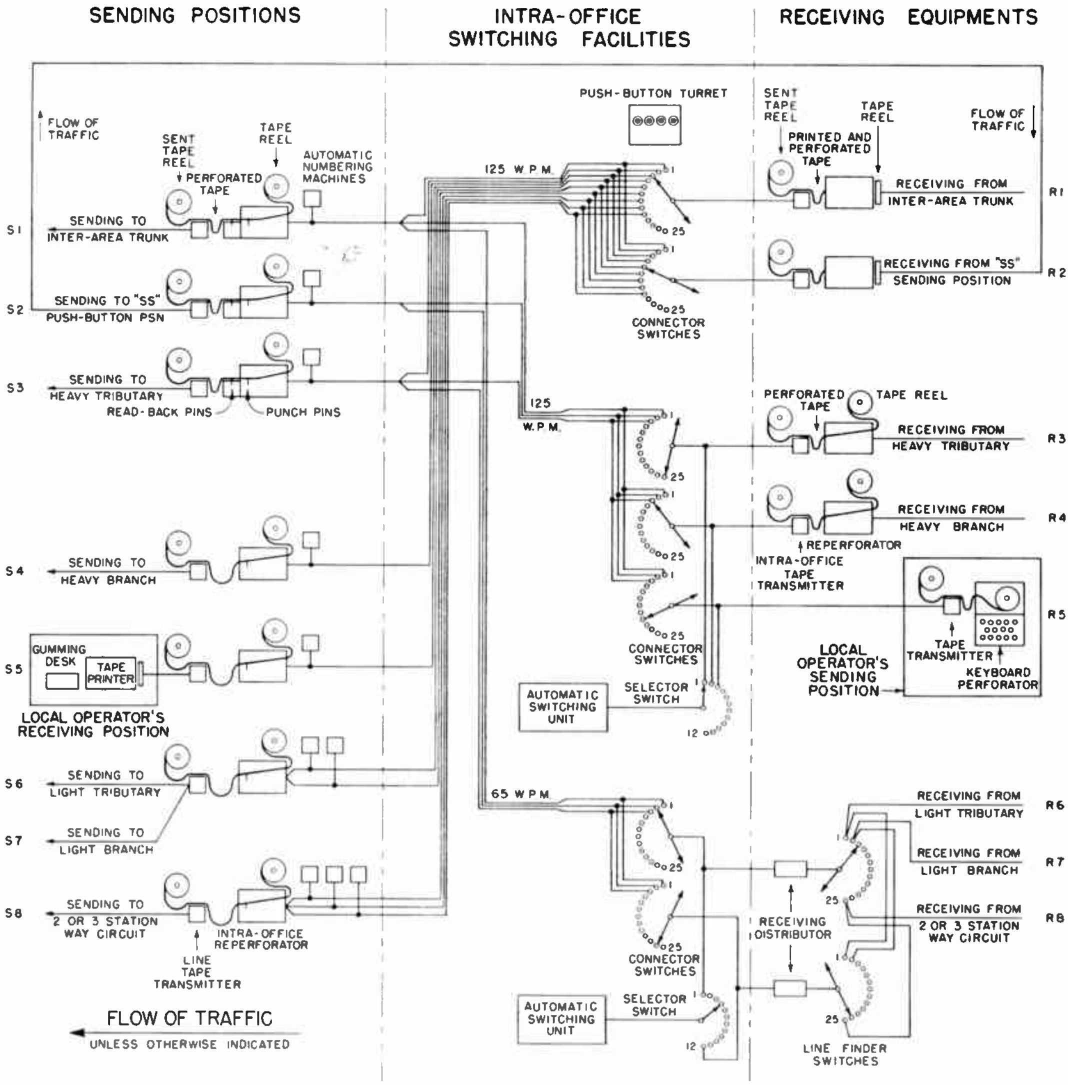

Figure 36. Principal equipment and circuit arrangements of a Plan 21-A reperforator office

tra-area destination that is not included among the 73 automatic switching destinations, the message will be prefixed by the "home" area center selection characters which will cause it to be switched to an "*SS*" sending position (S2). Messages received at an "*SS*" sending position (S2) are automatically retransmitted into the printer-perforator of an associated "*SS*" push-button receiving position (R2). Here a switching clerk reads the destination of the message and switches it to the proper intra-area sending position (S4 to S8).

Messages received in the area center by telephone, Morse, pneumatic tube, or patron's teleprinter or facsimile tie-lines are recorded or received in printed form, or in the patron's own handwriting. These messages are taken to local operators' sending positions (R5) where operators manipulate keyboard perforators and prepare the messages in perforated tape form. The tapes flow, one message at a time for each switching operation, through the intra-office transmitters located at these positions. When at least one complete message has been perforated at a position, an automatic switching unit connects to that position, "reads" the selection characters, and switches the message in the same manner as for heavy tributary and branch office receiving positions.

The receiving sides of lightly loaded tributary circuits (R6), lightly loaded branch office circuits (R7), and 2-station or 3-station way-circuits (R8) are terminated in concentrator facilities, termed "line finders". When the operators at the out-offices of these circuits have prepared at least one complete message in perforated tape form, they initiate a "call". At the reperforator office, the line finder in response to a "calling" line, connects that line to a receiving distributor and an automatic switching unit. An automatic signal then causes the out-office to transmit the selection characters. Upon the receipt of the selection characters, the automatic switching unit switches the receiving distributor to the desired inter-area (S1) or heavy tributary (S3) sending position, or to an "*SS*" sending position (S2). Transmission of the message takes place from the tape transmitter at the out-office, through the receiving distributor, directly into the intra-office reperforator at the selected sending position without any intermediate reperforation at the switching center.

The rate of transmission over line finder circuits is at standard teleprinter line speed of 65 words per minute. The rate of transmission from intra-office transmitters, located at push-button and automatic switching positions, is at 125 words per minute.

Each line sending position (S1 to S8) comprises essentially an intra-office reperforator for reproducing in perforated tape form the messages switched over the intra-office facilities. one automatic numbering machine for each destination that the position serves, and tape transmitting apparatus for repeating into the sending channel or channels the messages received by the intra-office reperforator. The sending positions are divided into three general types known as Type 4812, Type 111, and Type 5106.

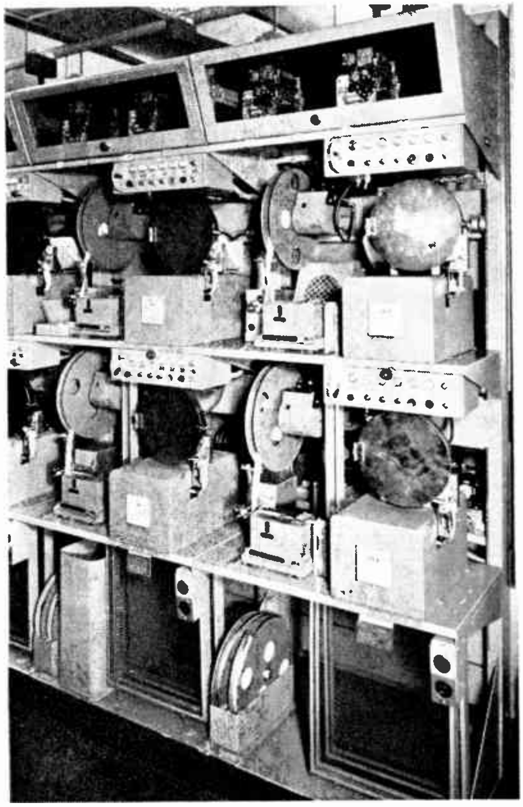

Figure 37. Trunk sending positions, Type 4812 racks

Type 4812 sending positions (Figure 37) are used for "*SS*" positions (S2) and for terminating the sending sides of inter-area (S1) and intra-area (S3) trunks to which messages are switched by both automatic and push-button facilities. These positions are arranged so that the intra-office reperforators can operate at either 125 or 65 words per minute. Also, the reperforators are equipped with "read back" contacts which serve in cooperation with other equipment to check the accuracy of certain characters in the preamble of automatically switched messages.

Type 111 sending positions (S4 to S7) terminate circuits to which messages are switched by the push-button method only. These positions may be arranged for sending to one heavily loaded destination or to two lightly loaded destinations. Those which send to heavily loaded circuits (S4) and local operators' receiving positions (S5) are arranged for one-destination sending and consequently are equipped with one automatic numbering machine. When arranged for two-destination sending, they are designated as "Two Station Concentrated" sending positions and serve two lightly loaded tributary or branch office circuits (S6 and S7). Such positions are equipped with an automatic numbering machine and a separate intra-office path for each of the two destinations. The circuit arrangements at these positions cause messages switched into the intra-office path for one of the destinations to be prefixed by a "space" character. The line sending transmitter then functions to send messages with the "space" prefix to one destination and those without the prefix to the other destination.

Type 5106 Sending Positions (S8) terminate the sending sides of 2-station or 3-station way circuits. In the reperforator systems installed prior to Plan 21-A, all of the stations on a way circuit copy all of the messages sent into and sent out of the reperforator office over that circuit. An operator at a way circuit office recognizes messages for her office by an identifying character contained in the message number sequence which the reperforator office sends ahead of each message. In the Plan 21-A system, a new arrangement is employed which automatically selects the desired way-circuit office and sends the message to that one only, while in the opposite direction, when a way-circuit office sends into the reperforator office, the other way offices on the same circuit are "locked out" and do not copy.

Automatic Switching from Heavily Loaded Tributary and Branch Office Circuits

The receiving sides of heavily loaded tributary and branch office circuits are terminated in "start-stop" reperforators (Figure 38) located at line receiving positions on Type 4930 racks (Figure 39). The out-offices on these circuits are equipped with keyboard perforators and tape transmitters for sending messages and with tape printers for receiving messages.

The out-offices prefix each message with selection characters, their office call letters, channel identifying character, and the sequence number of the message. Each message is terminated with the end-of-message signal comprising two periods. Assume that Quincy, Mass., has a telegram to be transmitted to Scranton, Pa. The Quincy operator will precede the message with the following characters:

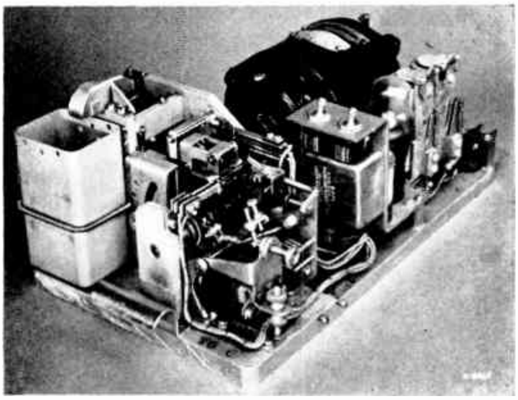

Figure 38. Line receiving "start-stop" reperforator

=P*space*B.QYA*figure-shift*236

The first two characters, =P, indicate that the message is to be switched through the Boston area center to Philadelphia, which is the area center that serves Scranton. The next character, B for Boston, is the call letter of the area center that serves Quincy. The following period is a separation character. QY are the call letters for the Quincy office, while A designates the first or A channel between Quincy and Boston. The digits 236 indicate that it is the 236th message sent to Boston over the Quincy A channel that day.

Once a circuit is opened for traffic for the day, no message control signals are required. The out-office sends at will. The incoming messages are reproduced in perforated tape form by the receiving reperforator. This tape feeds into the intra-office transmitter, located adjacent to the receiving reperforator. The transmitter idles (steps) any "blank" or "period" characters that appear in the perforated tape until the first character, other than a "blank" or "period", advances over the feeler pins of the transmitter, at which time the transmitter stops.

Figure 39. Line receiving positions for heavily loaded tributary and branch office circuits—Type 4930 racks

Each receiving reperforator position is equipped with a message waiting indicator (Figure 40) that keeps count of the number of unswitched messages that are on hand at the receiving position. Its purpose is to indicate to the automatic switching equipment when there is at least one complete message that requires switching. The message waiting indicator is provided with an "add" and a "subtract" magnet. The main shaft of the indicator is connected through differential gearing to the add and subtract ratchets, so that the add and subtract actions may take place simultaneously, as well as at separate times. The message waiting indicator is actuated to add one each time "period" contacts on the receiving reperforator cause a relay counting chain to operate on the two consecutive periods that terminate each mes-

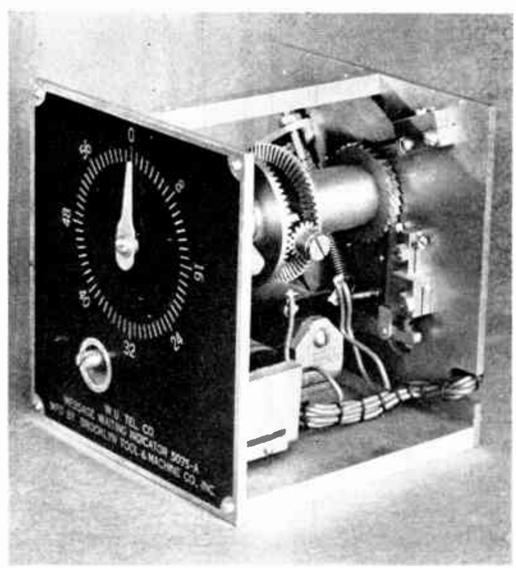

Figure 40. Message waiting indicator

sage. The indicator is actuated to subtract one each time a message is transmitted to a sending position.

With any character other than "blank" or "period" over the feeler pins of the intra-office transmitter, and the message waiting indicator indicating one or more unswitched messages, an electrical request is made for an automatic switching unit. Each automatic switching unit serves twelve intra-office transmitters. When a switching unit connects to an intra-office transmitter, it "reads" the character which is over the feeler pins of the transmitter. Normally this character will be the first selection character.

It is important that the selection characters, call letters and sequence number preamble to a message be exactly as prescribed. If the out-office operator makes a conscious error in the preamble, she back-steps her tape and obliterates all of the preamble with "letter-shift" characters (all five marking pulses) and starts anew on the preamble. The automatic switching unit is therefore arranged to cause any "letter-shift" characters that may precede the selection characters to be stepped through the transmitter until some character other than "letter-shift" appears over the feeler pins. The switching unit "reads" and stores that character as being the first selection character, and steps it out of the transmitter. The switching unit then reads and stores the following character as the second selection character. This character and the "space" character that follows are both stepped through the transmitter, thus leaving the next character (B in the example =P *space*B.QYA*figure-shift*236) over the feeler pins.

The automatic switching unit proceeds to act upon the two selection characters it has stored. Rotary switches, here termed "Connector Switches", associated with the intra-office transmitter to which the switching unit is connected at that moment, are automatically stepped to the proper position to establish a potential connection between the intra-office transmitter and the intra-office circuit of the selected destination, which for the selection characters =P, is Philadelphia. Immediately after setting up this potential connection, the automatic switching unit disconnects and is available to respond to requests from any of the other 11 intra-office transmitters that it serves.

After the automatic switching unit has set up a potential connection between an intra-office transmitter and a selected intra-office circuit, the conversion of this potential connection into an actual connection is similar to that which takes place in either plug and jack or push-button switching.

Intra-office circuits differ, depending upon whether they serve a destination that has one sending channel or several sending channels. A one-channel destination is served by a one-path intra-office circuit. If, at any time, there are one or more potential connections to this one path, a "transmitter allotter", common to the whole office, permits only one of these potential connections at a time to be converted to an actual connection to the sending position.

Where there are two or more sending channels to a destination, the intra-office circuit for that destination is on a multi-path basis. Each path, shared by a relatively small group of intra-office transmitters or line-finder receiving distributors, terminates in transmitter finder switches which are associated with the sending positions for that destination. These transmitter finder switches, in cooperation with a load distributor switch, function to connect any one of the intra-office paths serving that destination to any one of the sending positions. If, at any time, there are one or more potential connections to the same path, the transmitter allotter functions to permit only one of these potential connections at a time to seize the path. When an intra-office transmitter or receiving distributor seizes a path, the transmitter finder switch of an idle sending position functions to complete an actual connection to that sending position.

The load distributor switch, common to all of the channels of a multi-channel destination, is provided to distribute the messages, as evenly as possible, into each of the channels. Messages are directed to each channel in succession, except when a busy channel is encountered the load distributor by-passes that channel and directs the message to the next idle channel.

When an actual connection is established between an intra-office transmitter and an intra-office reperforator at a sending position, the automatic numbering machine functions to send into the intra-office reperforator the call letter or call letters of the area center, the channel designation, and the sequence number for that channel. Following the operation of the numbering machine, the intra-office transmitter functions to transmit the message. When the two periods that comprise the end-of-message signal are detected and counted by relay arrangements in the intra-office circuit, the transmitter is stopped and disconnected. The sending position is thereby cleared for any other switching position that may be seeking a connection to it. At the same time, the intra-office transmitter position is cleared so that the next message can be switched and transmitted to the appropriate sending position as determined by the selection characters prefixed to that message.

Line receiving positions are normally unattended, since they operate on a fully automatic basis. Should a delay occur in messages being switched, protective alarm signals function to attract the attention of a supervisor so that corrective action may be taken.

The message waiting indicator is arranged to operate a supervisor's signal if eight or more unswitched messages accumulate at a line receiving position. When the intra-office transmitter is idle and the message waiting indicator registers one or more unswitched messages, an electronic timer starts to function and will operate an alarm signal if a switching operation and an actual connection to a trunk sending position is not completed within a two-minute period of time. When an actual connection is obtained, the timer resets itself and will now operate the alarm signal if the transmission of the message is not completed within two minutes.

A "Manual Switch" push-button is included at the position by means of which

Figure 41. Local operator's sending position

the supervisor may cause a message, either waiting to be switched or waiting with a potential connection, to be switched to an "*SS*" position.

An automatic tape feed-out takes place when the last message is switched at a position, so that sufficient "blank" tape is stepped out of the receiving reperforator to permit the last character of the message to be fed through the intra-office transmitter.

Local Operators' Sending Positions

Figure 41 is a photograph of a local operator's sending position. Local operators prefix their messages with selection characters, position call letters and sequence numbers, in the same manner as out-office operators. For example, the 347th message perforated at the C local sending position at Boston and destined for Philadelphia would have the following preamble: =P*space*B.LLC*figure-shift*347.

Since a local operator's sending position is staffed at all times when it is in use, the "message delay" and "eight or more unswitched message" signals are not needed nor included on these positions. At these positions, operation of the time stamp to stamp the time on a message after it has been prepared in perforated tape form causes the message waiting indicator to add one. These positions otherwise operate automatically in the same manner as line receiving reperforator positions.

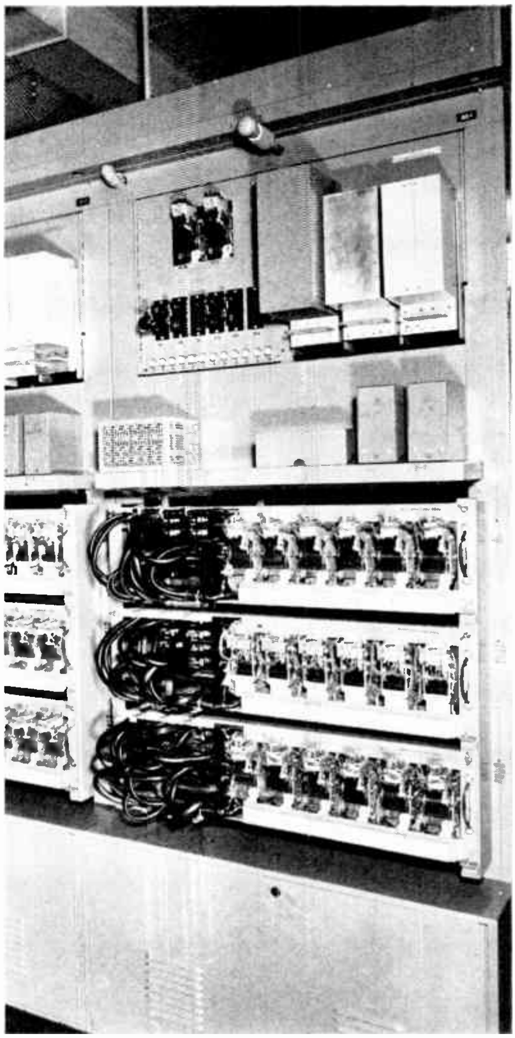

Figure 42. Automatic switching unit—Type 5084 rack

Automatic Switching Unit

The equipment which comprises an automatic switching unit that serves 12 intra-office transmitters, located either at line receiving reperforator positions or local operators' sending positions, is mounted on a double sided rack. Figure 42 is a front view of one of these racks. Three 10-level, 25-point rotary switches, termed "*A*", "*B*" and "*C*" connector switches, are provided for each intra-office transmitter. The illustrated front view of the rack shows 18 of these switches for 6 transmitters, the 18 switches for the other 6 transmitters being mounted on the rear of the rack.

Each intra-office transmitter is connected to the rotor (wipers) of its "*A*" connector switch. The first 23 points of the stator of this switch are connected to the intra-office paths of 23 destinations. The 24th point is conneced to the rotor of the "*B*" switch while the 25th point is connected to the rotor of the "*C*" switch. The 25 points of the stator of each of the "*B*" and "*C*" connector switches are connected to intra-office paths of 25 destinations. Thus an intra-office transmitter can be connected to 73 destinations.

It would have been desirable from a design standpoint to have arbitrarily assigned selection characters in a uniform pattern. For example, the 23 destinations on the "*A*" connector switch could have been "*AA*", "*AB*", "*AC*", etc., those on the "*B*" switch, "*BA*", "*BB*", "*BC*", etc., and those on the "*C*" switch, "*CA*", "*CB*", "*CC*", etc. However, from an operating standpoint, it was preferable to use the existing office call letters as the selection characters. Since the office call letters do not follow a uniform pattern, it was necessary to provide each switching unit with an "office call selector". The office call selector consists of a group of relays that are mounted on the rear of the rack and serve to translate the series of unrelated selection characters into a uniform pattern for controlling the stepping of the connector switches. The office call selectors must be "custom" wired for each switching center, but the selectors in any one center are all wired alike.

Each automatic switching unit is provided with protective supervisory alarms. When an idle automatic switching unit receives a request from one or more of the transmitters that it serves, an electronic timer on the unit starts to function. If a connection is not made to a transmitter within 3 seconds, an alarm is operated to signal a maintenance man, since this is indicative that the connecting equipment is not operating properly.

When a switching unit makes connection to a transmitter, another electronic timer starts to function. If the switching unit does not "read" the selection characters and complete the switching operation within 5 seconds, a "no switch" signal is operated at the intra-office transmitter position and the switching unit is released so that it is free to serve the other eleven transmitters. A "no switch" condition may be caused by the reading of characters which do not conform to any of the automatic switching destinations or to the failure of the perforated tape to step through the intra-office transmitter. A "no switch" signal at the intra-office transmitter attracts the attention of a supervisor or operator, who makes the necessary correction.

Subsequent articles will continue the description of the Plan 21-A switching system by describing the comparison (checking) of the call letters and sequence number of each automatically switched message, the various supervisory and testing facilities included in the switching center, the operation of line finder circuits, 2-station and 3-station way circuits, and the out-office equipments.

THE AUTHORS: For photographs and biographies of Mr. W. B. Blanton and Mr. G. G. Light, see the January 1948 and the April 1949 issues, respectively, of TECHNICAL REVIEW.

A Test Set for Rotary Switch Shelves

W. H. KLIPPEL

Among the most important elements of Western Union's reperforator switching systems are the 10-level, 25-point rotary switches which are the means for making connections between intra-office transmitters and selected intra-office circuits. Groups of these switches are mounted on rotary switch shelves and wired prior to installation, a single assembly containing on the average as many as 2800 terminals.

Because of the large number of switching shelves required in reperforator offices, and the difficulty of making adequate tests and inspections by manual methods, it was essential that an automatic test set be designed for the use of the Company's material inspectors. The test set here described, and shown in Figure 1, was the outcome of this development by Western Union engineers.

This device insures proper operation of the complex switch assemblies and makes it possible to perform the necessary inspections at a reasonable cost and at a saving in time of approximately 64½ man hours per shelf. Since there will be on the average 160 rotary switch shelves in each reperforator switching center, the use of the automatic test set will result in a saving of over 10,000 man hours for each of the 15 centers included in the Company's nation-wide mechanization program.

In a typical Plan 21 reperforator switching center there are five different types of rotary switch shelves used. The number of rotary switches on a shelf varies from 6 to 12, with each switch having a 10-arm wiper assembly which can be stepped to any one of 26 positions. The stator portion of these rotary switches is equipped with ten contacts at each of 25 positions, while the 26th position has only one contact. This maze of electrical circuits terminates on twelve to twenty-five, 27- and 33-conductor Jones plugs. Because of the varying circuits, it was necessary to include 50 Jones sockets on the test set into which the rotary switch shelves could be plugged. These Jones sockets are interconnected in such a way as to parallel similar circuits on different shelves, and the layout pattern of these sockets is such that the plugs on the shelf can reach their respective sockets without extensions.

Built in the test set, the schematic wiring of which is shown in Figure 2, are two rotary switches similar to those on the shelves, which are used as master rotary

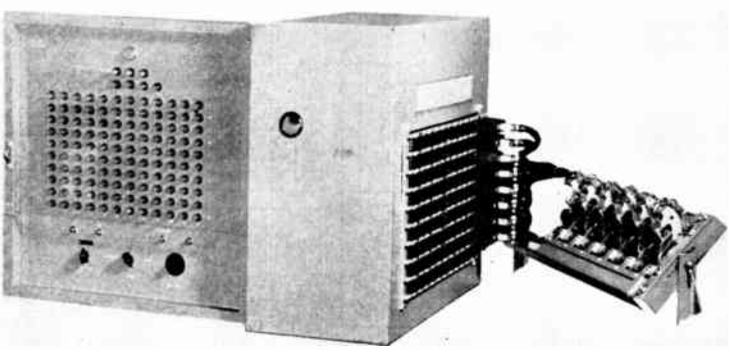

Figure 1. Test Set 5124-A

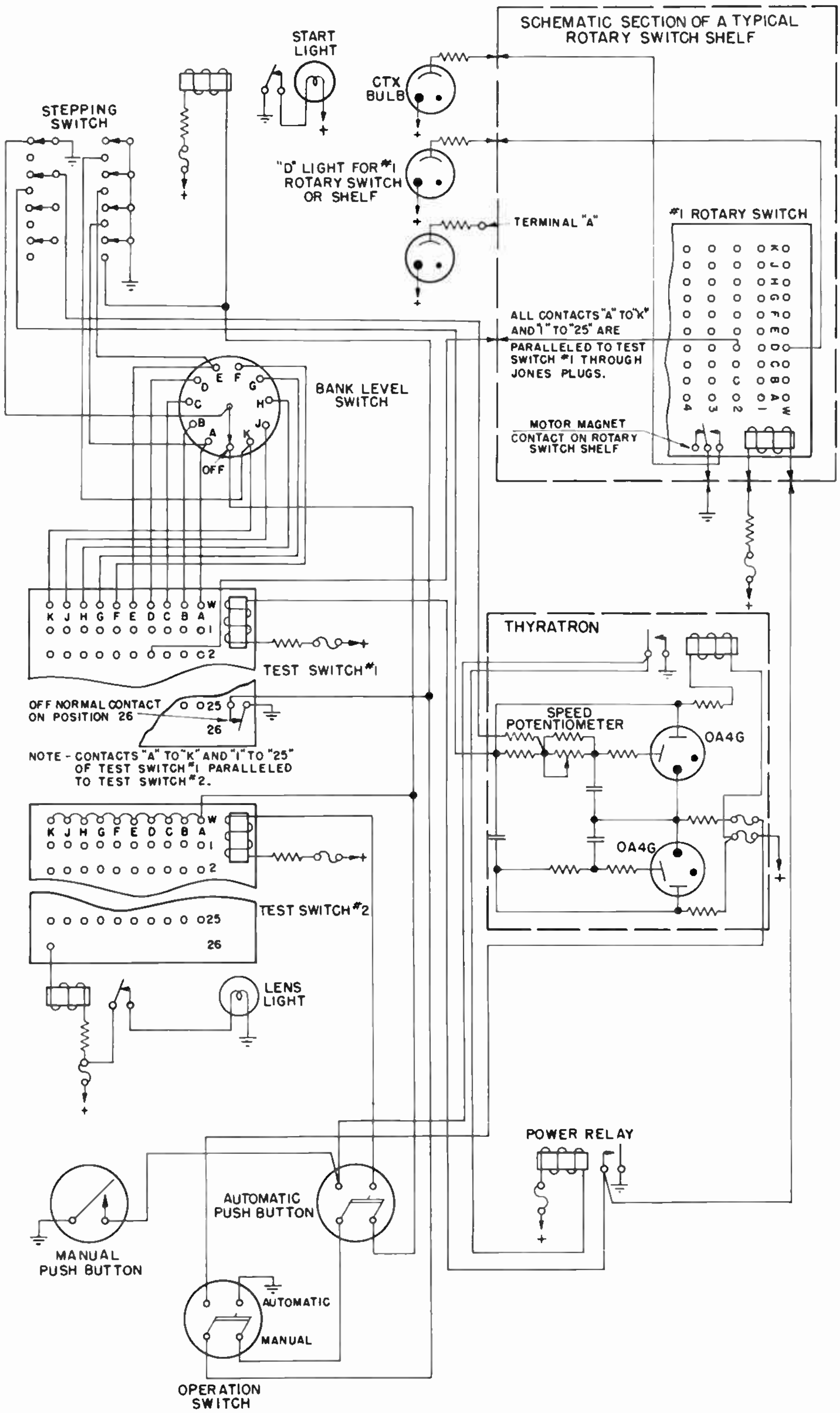

Figure 2. Schematic wiring diagram

switches. These master switches are referred to as test switch #1 and test switch #2. The automatic stepping of the rotary switches on the shelf and test switch #1 is done by means of the thyratron circuit which contains two OA4G Tubes with their individual circuits so arranged that the tubes fire intermittently and the firing time is varied by means of a potentiometer in parallel with the starter anode resistance of one tube. This potentiometer varies the pulsing of the thyratron tubes at time intervals ranging from approximately two steps per second to one step every three seconds. The firing of the tubes actuates a relay, the contacts of which close a circuit through the coil of a power relay controlling the stepping of all switches.

By reference to the socket assignment chart for a particular shelf, the Jones plugs of the rotary switch shelves may be plugged into their proper sockets. This parallels the 250 bank points of each rotary switch on the shelf with the corresponding points of the other rotary switches on the shelf. These are in turn paralleled to test switch #1 and to all points except the wipers and the 26th position of the ten levels of test switch #2.

The magnets of all the rotary switches on the shelf being tested and the magnet of test switch #1 are pulsed from the same power relay contact, causing all of these switches to be stepped in synchronism. By placing the "operation" switch on "automatic", a ground is put on the cathode circuit of the thyratron through the off-normal contacts of test switch #1, causing the tubes to pulsate and stepping the rotary switches. When test switch #1 reaches its 26th position, the off-normal contacts open which opens the cathode circuit to ground. This cathode ground is also used as a ground for a relay, the back contacts of which are in the circuit of a signal light called the "start light". The opening of the off-normal contacts removes the ground from the coil of the relay. causing the circuit to the start light to close, illuminating the light so the operator knows the rotary switches have gone through a complete cycle. In order to start the sequence again, the operator must press the "automatic" push-button once, which operates the power relay directly. This steps the rotary switches on the shelf and test switch #1 once, causing the off-normal contacts to close. The closing of the off-normal contacts again allows automatic stepping of the power relay through the thyratron.

When the "operation" switch is placed on "manual" the thyratron is inoperative because the cathode ground is removed from the tubes. By pressing the "manual" push-button the operator connects ground directly to the power relay, causing the rotary switches to step once. This push-button must be pressed for each step of the rotary switches.

Figure 3 shows the interior view of the test set.

The test set is designed to test the rotary switch shelf in two major operations, referred to as Test I and Test II. Test I checks a point in any level on the rotary switch against any same numbered point in any level for a wiring "open", "false", or "cross" connection. Test II checks a point on the rotary switch against any other point in any level on the rotary switch except for a similar numbered point for a wiring "open", "false" or "cross" connection.

When the rotary switch shelf is plugged into the test set, the rotary switches on the shelf must be placed on the same point as test switch #1. Any electrical condition set up on test switch #1 will then appear on each of the rotary switches on the shelf because of its paralleling connections. A neon bulb with potential on the common side is connected to each wiper of each rotary switch on the shelf. These 120 neon bulbs on the test set are arranged so that the horizontal rows represent the respective levels of the rotary switch and the vertical rows represent the individual rotary switches on the shelf.

Each wiper of test switch #1 is connected to an individual contact on a single level multiple circuit switch on the test set which is called the "bank level" switch. The wiper of the bank level switch is connected to ground. In Test I, a ground, which completes the circuit to the neon bulbs, is placed on the wiper of a desired

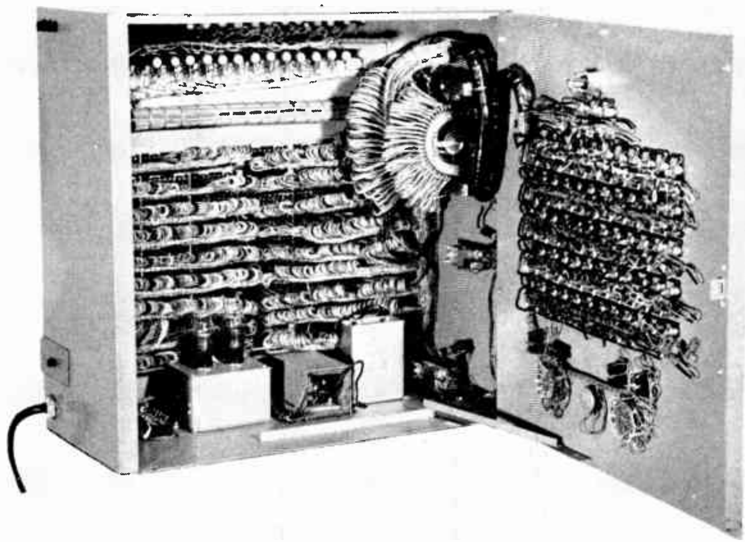

Figure 3. Interior of test set

level of test switch #1 by turning the bank level switch. When the circuit is completed the corresponding bulb should glow for each rotary switch on the shelf. The failure of this bulb to glow indicates an open connection to that terminal. Any shorts, false or cross connections to this point will cause a bulb other than the corresponding bulbs to glow. When another light is glowing it shows a short or false connection between the terminal that bulb represents and a similar numbered point on the level which is grounded. As the wipers on the shelf rotary switches and test switch #1 move through their 26 positions, an entire horizontal row of bulbs should glow for each point the wiper passes. The position of the bank level switch determines which of the ten horizontal rows of bulbs should glow.

For example, when the bank level switch is on *A*, the *A* row of bulbs should glow for the full 26 steps of test switch #1 and the rotary switches on the shelf. Then the operator should turn the bank level switch to *B*, and the *B* row of lights should glow. This process should be continued until all levels have been checked through their 25 positions.

For Test II, the bank level switch should be in its off position. This places a ground on all the wipers of test switch #2 simultaneously. All of the bank terminals of test switch #2 are connected to the corresponding bank terminals of test switch #1. Test switch #2 is then used to place a ground across the same numbered terminals of all ten levels of test switch #1, which in turn grounds these terminals on each rotary switch on the shelf. With the "operation" switch on "automatic", the operator can press the "automatic" pushbutton which will step test switch #2 once and allow test switch #1 and all the rotary switches on the shelf to step 26 times. All of the 120 neon bulbs should glow once as the wipers of the rotary switches on the shelf pass the point that test switch #2 is grounding.

There is an illuminated numbers dial mounted on test switch #2, and the position that test switch #2 is grounding may be found by reading the dial behind the lens in the front panel. Any bulb that flashes other than as described above under Test II, designates a connection between the terminal this bulb represents and the point indicated by the dial on test switch #2. The illuminating bulb behind the lens for test switch #2 will automatically turn off as test switch #2 reaches its twenty-sixth position, indicating that positions 1 through 25 have been checked for faults.

Above the 120 neon bulbs on the control panel are four bulbs designated as the *CTX* bulbs. They indicate proper contact operation of the motor magnet contacts on the rotary switches on the shelf. Because the motor magnet contacts on the rotary switches are paralleled in groups from one to four, the flicker of the bulb serves only to indicate that all of the contacts in that group "break", but does not indicate that all of the contacts in the group are closing properly. To check each individual contact, it would be necessary to step manually each individual rotary switch once and note, when the magnet is energized, if the proper *CTX* bulb glows.

Provisions have been made in the test set to check the stepping of the rotary switches. This is done at a much faster rate than the thyratron can pulse under Test I and Test II, in order to approach the speed at which the rotary switches step during normal operation. For this stepping test, a resistor is placed in parallel with a resistor in the starter anode circuit of one of the tubes of the thyratron by turning the stepping switch to the on position, and a constant ground is applied to wipers *A*, *E* and *K* of test switch #1. By connecting external leads from the *A*, *E* and *K* wipers of a rotary switch shelf, to their respective terminals on the rear of the test set, a circuit is completed through neon bulbs connected to these terminals. As the rotary switches step at a high speed these three "stepping" bulbs will glow. If a bulb stops glowing, the rotary switch connected to that bulb has gotten out of step and the fault should be corrected.

The operator, by watching the pattern of lights on the main panel of the test set as the rotary switches step automatically, is able to notice if the pattern is distorted due to a bulb glowing when it shouldn't, or not glowing when it should. When such a fault is noted, the operator throws the operation switch to "manual" and resteps the rotary switches to the faulty position in order to analyze the trouble. By checking the shelf under automatic operation and using manual operation only when the need arises, it is possible to give a thorough test to a rotary switch shelf in approximately 30 minutes. The set has also proved of great value in maintenance testing and in locating trouble after the equipment has been put in service.

THE AUTHOR: W. H. Klippel was graduated from Case Institute of Technology in absentia in 1945 with a degree of B.S. in M.E. After being trained in the tactical use of electronic equipment by the Navy, he was assigned as an electronic instructor and fighter director for the Pacific Fleet. In September 1946, he joined the Applied Engineering Division of Western Union as an engineer. Since then, he has been engaged in the design and development of equipment and test apparatus for the reperforator switching system. Mr. Klippel has conducted classes in the adjustment and maintenance of equipment, and has assisted in the cutover of reperforator switching offices.

A Microwave System for Television Relaying

J. Z. MILLAR and W. B. SULLINGER

A paper presented before the National Convention of the Institute of Radio Engineers in New York, March 1949.

The rapid growth of television broadcasting since the end of the war has created great demand for inter-city circuits for network operation. This demand will no doubt be much greater within the next few years, since at the present time about 55 broadcast stations are operating commercially, more than 69 construction permits have been approved by the Federal Communications Commission, and applications pending are in excess of 300. Since the demand for channels in many areas now exceeds the supply, the Commission is studying the allocation problem in an effort to provide relief. Therefore, it is evident that this infant industry is growing rapidly and in time may equal or surpass present-day AM and FM broadcasting in importance.

Because of the high cost of programming and the concentration of talent in a few large centers, networks will play a major part in the expansion of television. Spot news and events of national importance are of great interest to television audiences. These increasing needs of the industry require inter-city relay circuits which must be provided in an orderly manner as new stations are established. The relay circuits must be reliable and provide high quality transmission at a cost which the broadcaster can afford. It is believed that these objectives can best be met by microwave radio relay systems.

Western Union pioneered in the application of microwaves to telegraphy by developing jointly with the Radio Corporation of America an experimental relay system between New York and Philadelphia in 1945. This circuit was later expanded by Western Union to include a second circuit via an alternate route between these two cities. Also, a triangular system connecting New York, Pittsburgh, and Washington has been completed.[1] It was envisioned from the beginning that the same physical facilities, such as towers, buildings, power plants, and the same maintenance personnel which were used for the telegraph circuits, could be shared with television systems, thereby obtaining economic advantages for both classes of service. Accordingly, in 1947, active development work was initiated with the Philco Corporation for the design of equipment capable of meeting the exacting requirements of television network operation. In the system design there are many factors which have to be considered.

So far as transmission standards are concerned, video program relay is not greatly unlike the broad-band portion of the relay system provided for telegraph services, but there are differences in the equipment which were partly brought about by advancement in the art and partly by changed requirements. In an attempt to define the transmission objective, it is assumed that a practical value of signal-to-noise ratio in a video channel which has been relayed from New York to San Francisco would be 25 db (measured at the peaks, or maximum instantaneous amplitudes, of signal and noise). This value is far from the ideal value—it is the minimum value considered useful. Since interconnection of similar systems is planned to facilitate networking, 9 db should be added, and also a 6-db maintenance margin. This increases the system requirement to 40 db between major cities which are considered to be logical switching points, a value readily realizable in current microwave practice.

Of course, it would not be possible to devote enough frequency spectrum to each video program channel to permit the use of a sub-carrier and double frequency modulation [2] as was done in the RCA system [3] for telegraph transmission. However, one level of frequency modulation is feasible if the deviation index is held to a value near unity, but the FM noise improvement will then be only 5 to 10 db. This transmission method would require an RF band of approximately 20 mc to accommodate the sidebands, and a minimum peak carrier-to-noise ratio of 35 db will be required for an inter-city system having approximately 10 repeaters. This will require a signal level on the input to each IF system of approximately 750 microvolts.

As it is impractical to use diversity reception in a system which does not utilize a sub-carrier, and especially since video signals are sensitive to phase distortion, the amount of margin needed to overcome the effects of fading will be at least 30 db, and might be as high as 40 db, depending upon the continuity of service desired. Assuming space losses corresponding to normal repeater station separations, and conventional antenna power gains, the required transmitter power will be approximately 15 watts, if it is assumed that fading does not occur in all repeater sections simultaneously. Obviously, this is a minimum standard, since viewers will become more critical, and constant effort must be made to keep pace with public demand.

At this point, it should be mentioned that the choice of a microwave frequency band for television relay is dictated by many factors. Under the FCC frequency service allocations there are only two 500-mc wide bands which may be used by the common carriers and which are suitable for inter-city relays. One band embraces frequencies between 3700 and 4200 mc, and the other frequencies between 5925 and 6425 mc. The 4000-mc band is more stable than the 6000-mc band with respect to fading and atmospheric attenuation, but requires much larger and more costly antennas for the same power gain and larger wave guides and support structures. An examination of our propagation records, considering the hours most useful for broadcasting, leads to the conclusion that the 6000-mc band would be satisfactory for television transmission, as the increased power required for 4000-mc operation would be more than offset by the increased antenna gain. Another common carrier band between 10,700 and 11,700 mc is considered primarily useful only for short distance relaying.

The most controversial parameter of a video transmission system is the frequency response required for broadcasting networks. Perhaps it is a little forward-looking to provide a video response ranging from 30 cycles to 5 mc, when none of the receivers being used can be manufactured to respond to frequencies above about 4 mc because of the required separation between the video IF and sound IF frequencies of 4.5 mc. Nevertheless, this response should be provided to take care of future requirements and to permit transmission of undistorted synchronizing pulses.

Next consider the distortion which may be tolerated in a video transmission system. One cannot easily separate amplitude and phase distortion effects and discuss them separately, but those experienced in broad-band system design will recognize that it is not too difficult to provide a video transmission system which has adequate frequency response wherein the response curve above 5 mc remains reasonably flat until the phase requirements have been satisfied.

It is a fortunate circumstance that amplitude distortion is not very noticeable in a television image. A circuit having a combined harmonic production when tested with a single frequency of less than 5 per cent (down 26 db) would probably pass unnoticed by the average observer. In contrast, the relative phase relations of the frequency components of the complex television wave must be preserved by passing the signals only through circuits having almost linear phase shift; that is, circuits where the phase shift is proportional to frequency. A departure from phase linearity, that is, a delay distortion of as much as 50 milli-microseconds, is objectionable in a television image. Since this is an overall requirement, it can be seen that the phase distortion requirement for each inter-city system, and to a greater degree for each repeater of a relay system, will be exceedingly rigorous. Furthermore, the design of all component parts of the equipment must be coordinated, and phase equalization applied wherever practicable.

Such perfection in phase response requires the employment of testing and alignment techniques making use of transient, or time-function, methods. For example, after a system has been tested with steady state signals, it must be perfected by using a 15,750-cycle saw-tooth input wave, or a 100-kc square wave. Such techniques are also invaluable in the laboratory. It is further desirable constantly to monitor terminal-to-terminal transmission with high quality monitors to detect gradual signal quality deterioration before it can become serious.

The most obvious method of accomplishing the repeatering function is to demodulate, amplify, and then modulate a new carrier frequency. The difficulty with this method is that repeated demodulation and modulation will introduce cumulative distortion because of non-linearity in the functional units. At the present time, it is not practical to employ this system in a circuit which involves a large number of repeaters, although certain forms of feedback repeaters hold some promise in this direction.

Of course, by using antennas of good enough front-to-back ratio, a straight-through radio frequency repeater is possible, but present experience indicates that all tubes capable of amplifying microwave frequencies are too noisy for this application, except at very short repeater spacings. There is no doubt that the future will likely bring buried or underground waveguide transmission systems utilizing such tubes but, for the present, the best choice of radio repeater, if a sub-carrier type transmission system cannot be employed, is the so-called heterodyne repeater. In this repeater, the incoming wave is translated by heterodyning to the IF range, amplified, and then translated back to the microwave range, and further amplified before being radiated. This system most closely approaches the transmission goal, but because of equipment limitations it may be some time before coast-to-coast circuits meeting the minimum band width and distortion requirements will be available. In a system comprising over 100 repeaters, this is understandable.

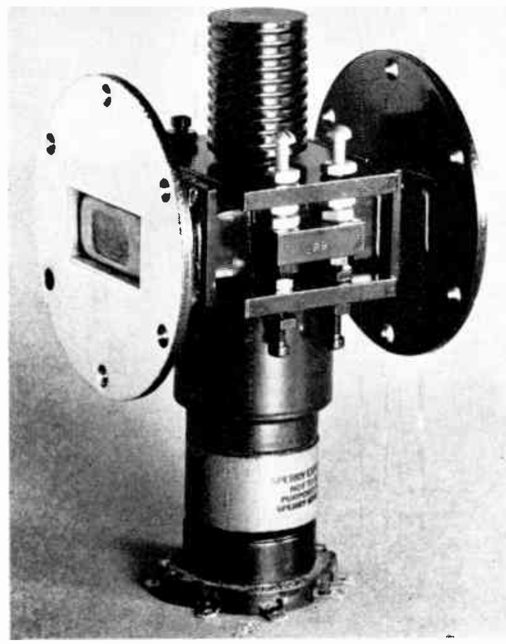

Figure 1. Sperry SAC-19 Tube

The term "heterodyne modulation" describes any system by which an RF carrier is mixed with a modulated wave to produce modulated RF sidebands. One system for accomplishing this result makes use of a balanced crystal mixer, but because of power limitations of the crystals, several stages of microwave klystron amplification were required. The Sperry Type SAC-19 tube, known as a heterodyne-mixer and developed by the Sperry Gyroscope Corporation for this application, accomplishes the desired result in one stage, and produces a power output of from 1 to 1.7 watts. Figure 1 shows the Sperry SAC-19 tube.

For applications where adequate signal-to-noise ratio cannot be obtained with approximately 1.7 watt output, the Sperry SAC-19 klystron may be used as a power

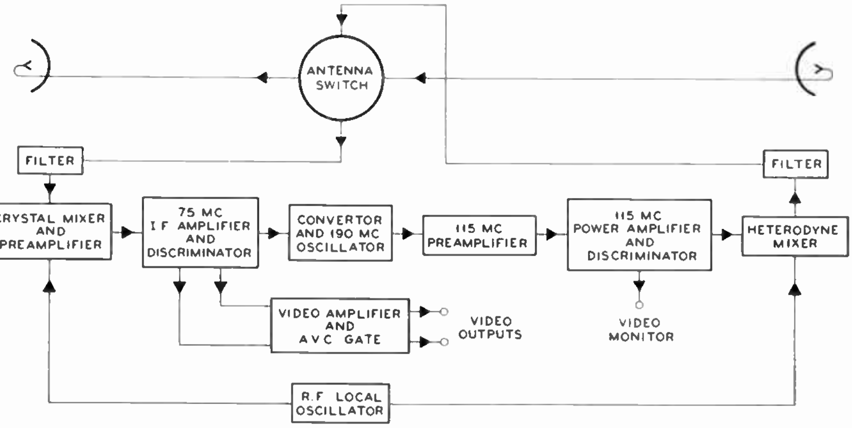

Figure 2. Block diagram of a repeater

amplifier supplying between 12 and 15 watts through a filter to the antenna. The first Philco equipment was arranged to permit the use of the power amplifier only when needed, and for short feeder or distribution circuits it may be omitted. Later equipment and an improved version of the tube are capable of producing an output power of over 6 watts with only one tube. This tube is considered a unique contribution to the art.

Other design requirements relate to (1) reversibility of circuits to meet more nearly the transmission needs of broadcasters; (2) common antennas and wave guides for all circuits at a repeater or terminal station, and (3) location of all radio components in the building at the base of towers, or in rooms near the top of concrete towers.

Keeping the above objectives in mind, the two television relay circuits which have been installed between New York and Philadelphia by Western Union will be described. Philco Model TLR-2 Television Radio Relay Equipment was employed. This equipment was designed and produced in the Engineering Department of Philco, under the direction of Dr. J. F. Koehler and Mr. William H. Forster,[4] and was patterned after an earlier relay design by Mr. W. P. Boothroyd. Recently this design has been reworked in preparation for factory production, and will be known as VLR-3 in the future.

The two circuits are independently reversible with a switching time of less than 15 seconds, which makes possible the use of a single relay circuit for transmitting consecutive programs in opposite directions, and reduces the amount of equipment necessary as compared to two-circuit service.

The band width required for each transmitter is 20 mc and adjacent channels are separated by 40 mc between center frequencies. Alternate stations in a given direction of transmission use alternate frequency bands. Therefore, the two reversible circuits between New York and Philadelphia require only four properly spaced 20-mc bands. If more than two or three circuits are required through any one repeater station, a block method of frequency assignment would be employed.

The operation of a typical repeater can best be described by reference to the block diagram shown in Figure 2. In a typical repeater installation, the incoming 6115-mc signal is picked up on the antenna and is fed down the 100-foot, 1½ by ¾ inch wave guide, to the antenna switch. Following the antenna switch is an RF filter for preselection. This filter provides approximately 25 db of selectivity at frequencies 40 mc removed from the channel. The signal from the filter is coupled through a flexible wave guide into the crystal mixer, which is mounted on the receiver chassis.

The 75-mc intermediate frequency is obtained by beating the incoming signal against the transmitter local oscillator, which in this case would be tuned to 6040 mc. The 75-mc IF signal obtained from this amplifier is fed through a 50-ohm cable into the converter unit in the transmitter at the relay station. A discriminator is also included at the end of the 75-mc IF amplifier, and the output of this discriminator is amplified by a three-stage video amplifier to provide a 2-volt peak-to-peak video signal for driving both a television transmitter and a video monitor separately. This video amplifier is a necessary part of the terminal receiver, and in a repeater unit it is included both for monitoring purposes and to permit the dropping of a program at intermediate relay points without degradation to through transmission.

The converter unit includes a crystal-controlled oscillator, which is multipled up to 190 mc. Beating the 75-mc IF signal against this 190-mc carrier produces the second intermediate frequency, 115 mc. This signal is amplified in the 115-mc pre-amplifier and in the 115-mc power amplifier to approximately 80 volts peak-to-peak. A second FM discriminator is provided for monitoring purposes and to provide an AFC signal to the deviator when the same equipment is used as a terminal transmitter.

The 140-volt peak intermediate frequency signal is connected into the cathode circuit of the SAC-19 tube. This is a two-cavity klystron, tunable throughout most of the 6,000-mc common carrier band, and which has 20-mc bandwidth at each cavity setting. When operated as a heterodyne mixer, the buncher cavity of the klystron is tuned to the local oscillator frequency, 6040 mc. The catcher cavity of the klystron is tuned to 6155 mc, which is the sum frequency of the local oscillator and 115 mc. The accelerating potential of the klystron is 500 volts, and the 80-volt intermediate frequency signal modulates the velocity of the electron beam approximately 10 per cent. This varies the transit time of the electrons through the drift space of the klystron, and consequently modulates the energy which is fed into the buncher cavity.

This modulation produces sidebands spaced at 115-mc intervals from the RF carrier. These sidebands each contain the frequency-modulation intelligence which is present on the 115-mc IF signal. By tuning the catcher cavity to either the first upper or first lower sideband, a frequency-modulated wave is obtained which contains the desired intelligence. The carrier and the undesired sidebands are suppressed by the selectivity of the catcher cavity, and also by the RF filter which follows the synchrodyne mixer. This filter has a selectivity of approximately 55 db at 115 mc from the center frequency. A flexible wave guide connects the output of the RF filter into the antenna switch, which in turn connects the transmitter to either the eastbound or the westbound antenna, through the 100-foot wave guides which run up the tower.

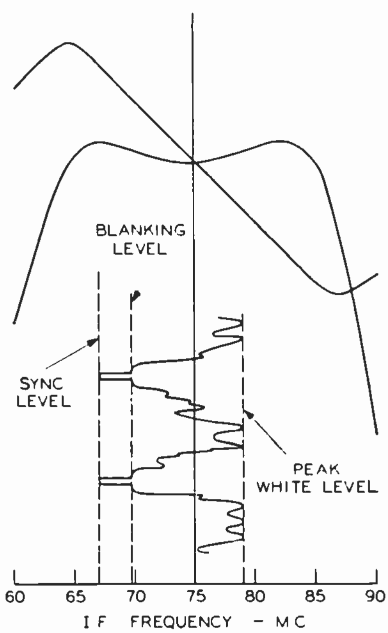

Figure 3. Characteristics of IF amplifier

Figure 3 shows the response of the 75-mc intermediate frequency amplifier and the discriminator characteristic. A television signal wave is superimposed to indicate the manner in which the frequency is deviated. The terminal transmitter, shown in Figure 4, includes the same components as the transmitter section of the repeater, with the addition of the deviator, and a deviator power supply. The composite television signal input to the deviator unit is used to deviate two 2K28 reflex klystrons in opposite frequency sense. The outputs of these oscillators are mixed in a crystal to produce a difference frequency of 115 mc which becomes frequency-modulated in the process in accordance with the input video signal. Maximum deviation, corresponding to the voltage difference between the tip of the synchronizing signal and peak white, causes a deviation of 12 mc. The difference frequency corresponding to the synchronizing pulse peak is established and held at 123 mc. One of the deviator oscillators is controlled by an automatic frequency control circuit in such a way that this frequency reference is held constant regardless of oscillator drift or picture content. The resulting signal band is then amplified in an amplifier with a pass band of 105 to 125 mc. The output from this amplifier is applied to the Sperry SAC-19 synchrodyne, as in the case of a repeater.

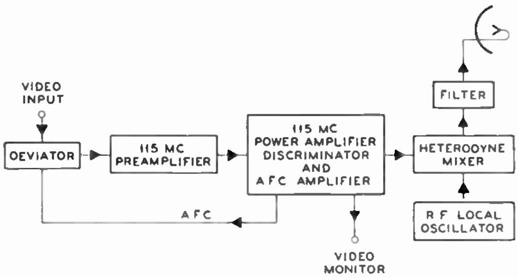

Figure 4. Block diagram of terminal transmitter

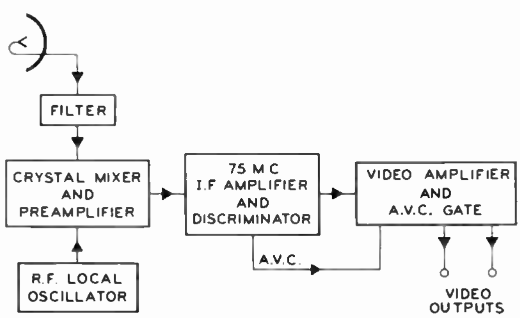

Figure 5. Terminal receiver

The terminal receiver, shown in Figure 5, includes the same units as the receiver section of the repeater, except that an RF local oscillator and a power supply must be added to supply the frequency which, in the repeater, comes from the transmitter local oscillator. However, this oscillator is stabilized in the same manner as the transmitter local oscillator. Adequate frequency stability is achieved by operating the Sperry SAC-19 tube as a precision oscillator. As an oscillator, both cavities are tuned to the desired frequency, and the feed-back is arranged through a loop containing a precision cavity having a loaded Q of about 10,000. Since the temperature coefficient of the cavity is very low, in the order of two parts per million per degree centigrade, the oscillator may be depended upon to hold the transmitter frequency well within the FCC tolerance of $\pm$ 0.05 per cent, and what is more important, to keep the received signals within the acceptance of the various IF amplifiers throughout the system. In the VLR-3 equipment, the frequencies have been rearranged to make local oscillator variation cancel out. This will also be an improvement because the video polarity will be the same at each repeater.

From the foregoing, it can be seen that at a repeater station, if the incoming frequency should for any reason be high or low, the change in the outgoing frequency would be in opposite sense, and of the same magnitude. At the next repeater in the chain, the reverse action would take place. Since the local oscillator and the crystal oscillator in the repeaters are both very stable devices, and since the AFC system of the terminal transmitter holds the synchronizing signal tips at a fixed frequency, the arrangement insures that the signal swing is centered on the receiving discriminator for any reasonable number of repeaters.

The sound program portion of a television transmission should also be handled over a radio relay system. To date, no adequate method of multiplexing the two signals on a single television relay channel has been found because of cross-modulation limitations.

The provision of separate radio equipment for the sound channel seems the best approach, as it permits multiplexing of similar material, and provides a method of deriving the much-needed service channel for maintenance of the system. However, many parts may be common, such as antennas, wave-guides, local oscillators, power supplies, etc. Obviously, the sound and service channels should be two-path or duplex systems.

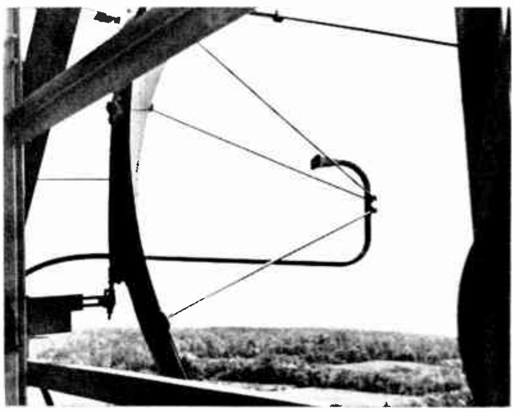

Figure 6. Antenna

The microwave terminal equipment for each of the television inter-city relay circuits will be installed on the customer's premises; that is, at the studio or broadcast station of the customer in the terminal city. Such operation will not only give the broadcaster a higher quality service, since local loops and video repeaters are not necessary, but the elimination of such items will have a beneficial influence on the cost of furnishing service. The equipment at the relay stations will, except for the antennas, be located in the buildings at ground level at each station, or in upper levels of towers.

Figure 6 shows the antenna. The wave-guide lines are run up the towers and are connected to the antenna with flexible wave-guide sections. The antenna reflector is a 4 ft. by 8 ft. truncated parabola having a focal length of 35.8 inches. The parabolic reflector is mounted with the long dimension vertical and is excited by a vertically polarized horn feed which is held to within an inch of the focal point by four stainless steel rods. Two susceptance tuners are mounted on the horn, just behind the mouth. These tuners are adjusted in the laboratory, and then soldered in position. A pressurizing window made of polystyrene, approximately one-half wavelength thick, is used with a rubber gasket to seal the end of the horn. This window is also part of the tuning system. The voltage standing-wave ratio of the horn-and-dish assembly, when measured at the input of the horn feed on the back side of the paraboloid, is under 1.1 throughout the frequency band from 6115 to 6235 mc. These antennas have a power gain of approximately 7,500, a horizontal half-power directivity of 3 degrees, and a vertical half-power directivity of approximately 1½ degrees. An antenna mounting system, providing both vertical and horizontal adjustments, makes possible the accurate aiming of the paraboloid toward the next repeater station.

RG-50/U, (1½" x ¾" — 1/16" wall) silver-plated brass wave-guide is used for connecting the antenna systems to the equipments, which may be housed up to 150 feet from the antennas. UG-343/U and

Figure 7. Top of Neshanic tower

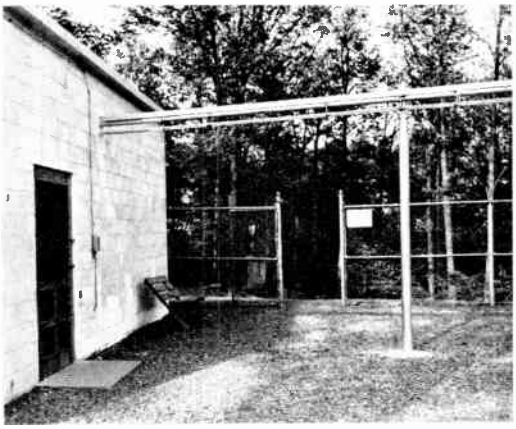

Figure 8. Mt. Laurel wave-guide run

UG-344/U wave-guide choke and plain-flange fittings are used to interconnect the wave-guide sections. A special gum rubber gasket in the choke flange makes the line pressure tight. In addition to straight sections, E and H 90-degree bends and flexible wave-guides in lengths up to 4 feet are used in the system where mechanical requirements make them desirable. The entire antenna line is pressurized by a dry-air unit. A distribution manifold, equipped with needle valves and a pressure gauge, is mounted just above the equipment racks. The dehumidifying unit runs only when the pressure on the wave-guide line drops below a gauge pressure of approximately 2 pounds. Trouble in one of the lines may be determined by isolating the difficulty with needle valves.

The silver-plating on the inside of the guides reduces attenuation to the minimum. It is most necessary that the inside of the lines be kept dry at all times. If moisture gets into the line accidentally, the system may be flushed out by opening a valve in the wave-guide line near the antenna and allowing the dehydrator unit to run for several minutes.

Figure 7 shows the top of the Neshanic, N. J., relay station tower. The television antennas may be seen directly below the cabin. The wave-guides are run down the side of the tower and thence into the apparatus building.

Figure 8 shows the wave-guides entering the Mt. Laurel, N. J., relay station. It will be observed that the guides are well supported throughout the length of the run.

Figure 9 shows the reversing antenna switches which are supplied at the repeaters and terminals to connect the eastbound and westbound antennas to particular transmitters and receivers. These antenna switches are mounted on the top of the cabinets which contain the equipment, and connections are made to the wave-guide runs by means of flexible wave-guide sections.

The wave-guide reversing switch in the antenna system may be operated remotely

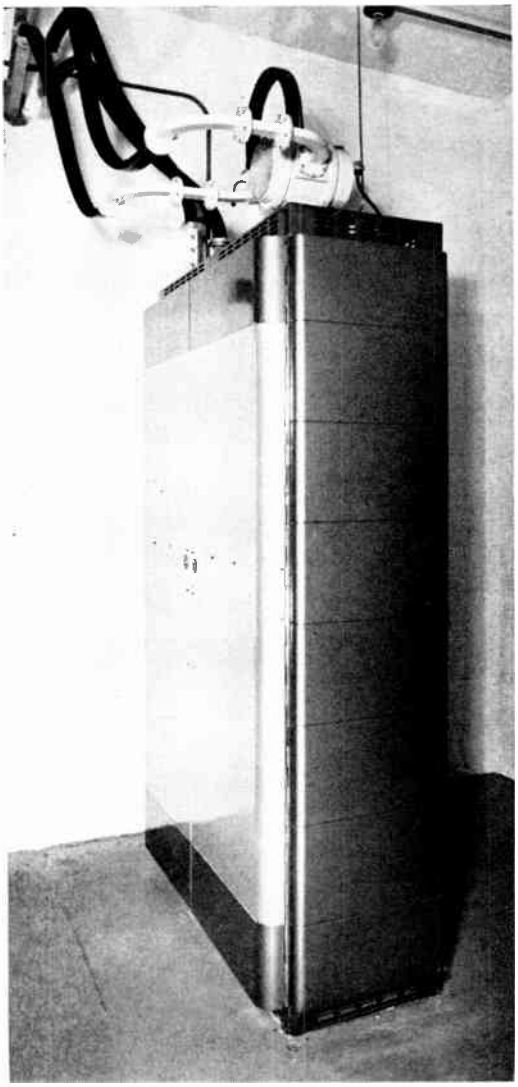

Figure 9. Wave-guide switch

by the broadcast station operator at the terminal, as the mechanism is solenoid operated. While in the present installations the repeaters must be reversed by the operators on a time or cue basis, it is planned to arrange for reversing entire systems remotely from either terminal. Obviously, reversing should not be done by a "loss-of-carrier" method, as this would result in confusion in the event of equipment failures. A step-relay system, or a multiple frequency-controlled arrangement would be better. As these signals would be seen on the broadcast receivers, this method of reversing could be done only after a program had been faded out.

Figure 10 shows the front view of two reversible repeaters installed at the Mt. Laurel, N. J., relay station. One of these repeaters is shown with the door and cover panels removed, exposing the operating portions of the equipment.

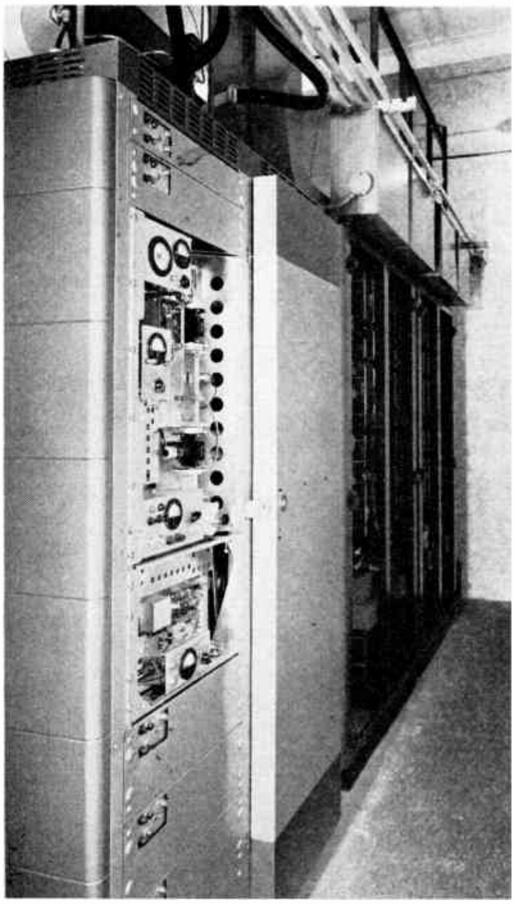

Figure 10. View of two repeaters, one with door removed

Figure 11 shows a front view of two repeaters, one with the front cover panels removed. It will be noted that metering

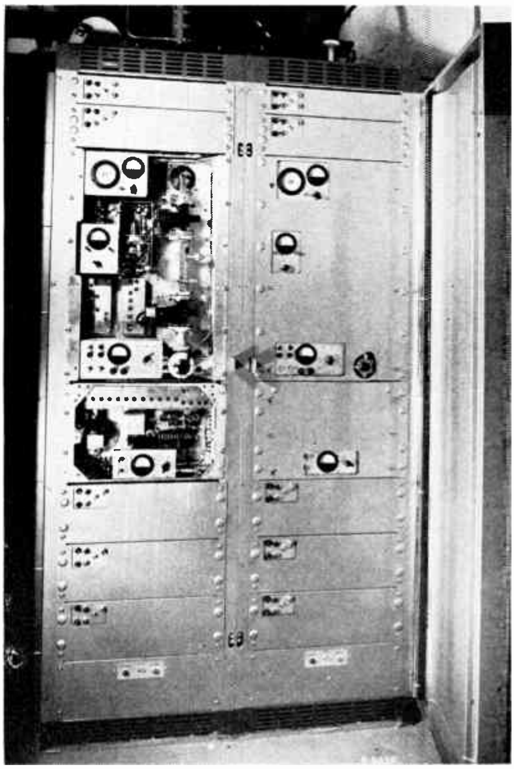

Figure 11. Front view of two repeaters, one with front cover panels and door removed

indications and operating adjustments are accessible with the covers in place, and that when these covers are removed, all the apparatus is completely accessible. The equipment in the upper section comprises a relay transmitter and the equipment in the smaller section directly below the other comprises a relay receiver. The remaining rack units are power supplies.

Figure 12 shows the back view of two repeaters. The blowers and air filters for ventilation are located at the bottom of the cabinets. The power supplies are located immediately above the blowers, except for two smaller power supplies which are located at the top of the cabinet. The antenna is connected to the receiver unit by a flexible wave-guide section which terminates at the filter, which in turn connects to the mixer. The relay transmitter is the large unit directly above the receiver. This unit contains three small blowers which cool the two SAC-19 tubes and the 829 tube, which is the power output stage of the 115-mc IF amplifier.

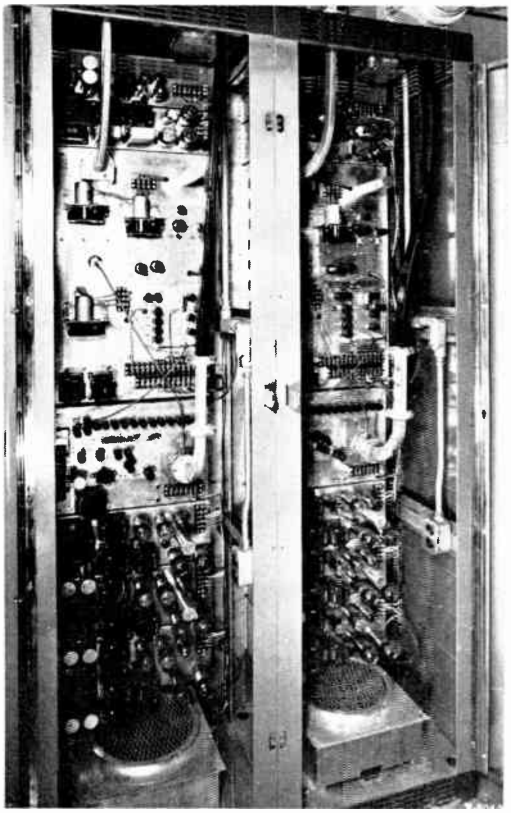

Figure 12. Back view of two repeaters

The principal units of the Philco TLR-2 are moderate-sized chassis designed to fit standard 19-inch relay racks. Sub-chassis construction is employed where practical, to aid in replacement for maintenance purposes. Barrier strip connections at the rear of equipment are used for interconnecting power cabling, and all IF and video connections are coaxial cables. Monitor circuits are provided in the equipment. These circuits, as well as the power circuits, can be extended for remote control if desired, as would be the case primarily at the broadcast station where the terminal of the microwave relay system would be located.

The power switches are on the main transmitter chassis. These switches control the filament and plate supplies independently. Both filament and plate-circuit primaries are fused independently on the individual power-supply units, and a switch in the primary of the plate transformers is provided so that the high voltage portion of each power supply may be turned on individually. Time delay equipment is used at relay stations, and remotely-controlled relays and time delay equipment are used at terminals.

The transmission performance of the television relay circuits between New

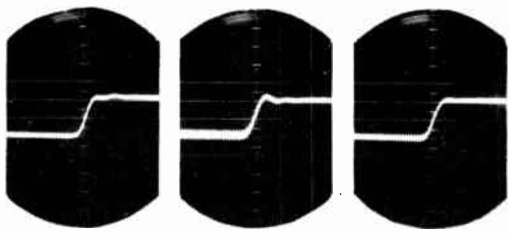

Figure 13. Transient response of the two New York-Philadelphia television relay circuits connected in tandem

York and Philadelphia is best shown by a series of photographs. For convenience in taking the photographs, the two relay circuits were connected together at Philadelphia, which made it possible to impress a signal at New York and photograph this signal before and after transmission over the two circuits in tandem. Figure 13 is a composite photograph of three oscilloscopic images of a 100-kc square wave signal. The first image is the output wave of the signal generator. The second image shows the wave after it had been transmitted to Philadelphia over the first circuit and returned to New York over the second circuit. The third image shows the wave after the transient response adjustments in the video amplifier had been optimized to remove the overshoot.

Figure 14 shows the CBS test pattern photographed on a DuMont monitor after the signal had been transmitted to Philadelphia and back to New York over the

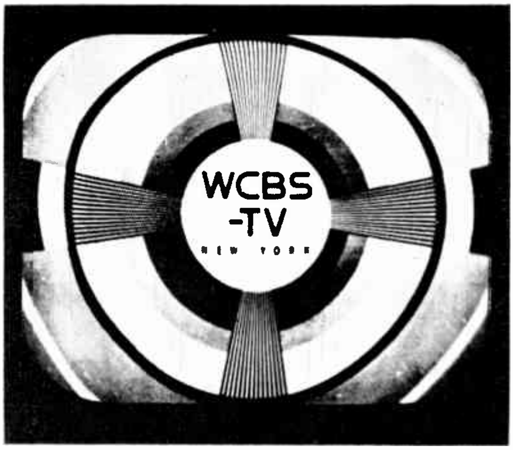

Figure 14. Test pattern transmission over the two New York-Philadelphia television relay circuits connected in tandem

relay system. Within the limits of photographic resolution and the accuracy of the monitor, no distortion or ghosting is apparent. It will also be observed that the resolution provided by the relay is more than adequate for the transmission of this particular test pattern, and that the contrast is well preserved.

Microwave relay systems are already playing an important part in Western Union's mechanization and plant improvement program. Radio telegraph beam circuits have now been completed for the New York-Pittsburgh-Washington triangle and between New York and Philadelphia. Relay sites have been selected as far west as Minneapolis and Kansas City, and south to Atlanta, in anticipation of extension of the system to cities in the south and midwest. Terminal locations have also been secured in many of the larger cities.

Present engineering contemplates the sharing of towers and other physical plant along many of these routes by inter-city television circuits, should future circumstances make it desirable to furnish such facilities.

These inter-city television circuits may also be used to secure large numbers of voice bands suitable for facsimile message transmission, or larger bands for the transmission mediums for high-speed facsimile telegraph systems.

Thus it can be seen that microwave radio offers the great promise of providing adequate facilities economically for Western Union's many services, as well as the means for expanding its field of public communications.

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THE AUTHOR: J. Z. Millar has been with Western Union since his graduation from the University of Illinois in 1923, starting as an engineering apprentice in the Washington, D. C., office. In 1926 he was transferred to the Water Mill Laboratory, where electronics was his field of work. After specializing on short wave equipment and audio frequency apparatus for 15 years, Mr. Millar was called to active duty with the Signal Corps, in which he attained the rank of Colonel. He served as Member and Director of the Signal Corps Board in Ft. Monmouth, N. J., from March 1941 to April 1944, and was then assigned as Signal Officer of the Normandy Base section and as Signal Officer, Loire Section, European Theatre. On February 15, 1945, he returned to Western Union and was appointed Radio Research Engineer. In this position he has organized the Radio Research Division of the Development and Research Department, which division handles all radio research projects such as microwave telegraph, television microwave relays, telecars, etc. Mr. Millar is a Senior Member of the IRE.

THE AUTHOR: W. B. Sullinger: For photograph and biography, see the July 1948 issue of TECHNICAL REVIEW.

Bid and Offer Deleting Ticker

P. L. MYER

The Bid and Offer Deleting Ticker 11-A (Figure 1) is a Western Union Ticker 5-A with attachments which cause the automatic deletion of all bid and offer prices. The question naturally arises, why should one want to have such information deleted from the tape? Is not this information desired by the broker who subscribes for the service? As a matter of fact, the broker is pleased to have this information on the tape, and it is for his use that the New York Stock exchange introduced this service and began to use the idle time of the tickers to transmit the bid and offer quotations. As long as there is enough business to keep the tickers printing stock sales at the full rate of 500 characters per minute, as during the opening of the market, no bid and offer quotations are transmitted. However, as soon as the tickers begin to hesitate for the want of sales quotations, the bid and offer quotations are transmitted and the tickers are kept busily ticking away at their full capacity.

Figure 1. Bid and offer deleting ticker

News Services Use Deleting Tickers

In the offices of the Associated Press and the United Press, several stock tickers are used for the purpose of tabulating the stock sales in form for volume and price reports ready for publication. In this work, there is no need for the bid and offer quotations, which are only an added burden to the men who scan the tape for the information they must tabulate. In these offices the total list of stocks is usually divided alphabetically into six or eight divisions, each division being tabulated by a clerk who must scan the entire tape and select only that information which he is required to record on his list. In an active market it requires the constant attention of each man, for he must read every quotation on the tape and eliminate the bid and offered prices, which are always preceded by the letter *B* printed on the lower line of characters on the tape. The deleting ticker, by automatically eliminating all the characters on the lower half of the tape following the *B* character, appreciably decreases the work of scanning the tape.

The operation of the deleting ticker is shown graphically in the samples of tape below. The upper sample shows the normal tape as it comes from the ticker with the bid and offer quotations fully printed; the lower sample shows the same tape as it is produced by the deleting ticker.

It should be noted that the deletion starts immediately following the character *B* in the lower line of characters and con-

```
RM   TKR           RL                   LDF     RS                 ZB
  25      B.40¾....0.1   25¾.B.25½....0.6    44½   26½.B.26....0.½    25¼
```

```
RM   TKR           RL                   LDF     RS                 ZB
  25      B              25¾.B               44½   26½.B              25¼
```

tinues until the next letter character appears in the upper line.

The deleting ticker with inker and cover removed is shown in Figure 2. This is the Western Union Ticker 5-A with the following items added: three sets of contacts, one relay, four resistors, one condenser, a rectifier, and a printing cutout unit. These added parts are shown schematically in Figure 3 in their relative positions with their respective means of operation. As indicated, three sets of contacts are required for controlling the deleting function. The print contacts close momentarily each time the printing arm is raised by the operating cam which lifts the printing bail for printing the selected character on the tape. The bid pin contacts close each time the *B* stop pin is selected for positioning the typewheel for printing the character *B* in the figures row. The shift lever contacts close each time the shift lever rotates clockwise to position the shift hammer for the printing of the lower line of (figure) characters. In Figure 3, the shift lever is shown in its "figures" position with the shift lever contacts closed. The control relay is shown in its normally de-energized condition. The printing cutout unit is shown in its normally energized condition, with its armature holding the armature fingers interposed between the shift hammer and the printing hammers. The rectifier is connected through resistors to the a-c source of power to provide the direct current required to operate the magnet coil of the printing cutout unit and the control relay.

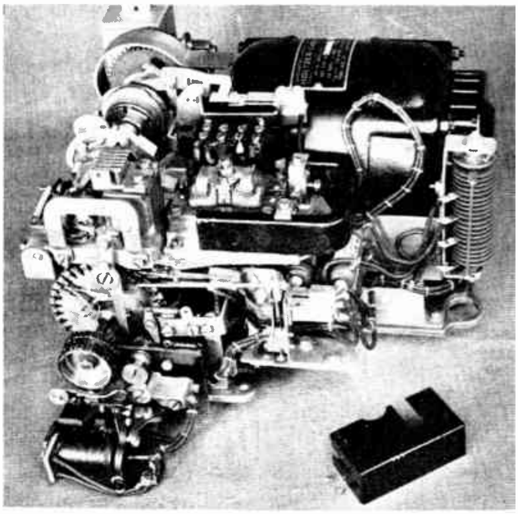

Figure 2. Deleting ticker with inker and cover removed

In normal operation, the magnet coil of the printing cutout unit is energized, the circuit being from the positive terminal of the rectifier through a 100-ohm resistor, the magnet coil, contacts 3 and 2 of the control relay to the negative terminal of the rectifier. Under this normal operating condition, the armature fingers are kept in position between the shift hammer and the printing hammers so that all characters are printed on the tape. If,

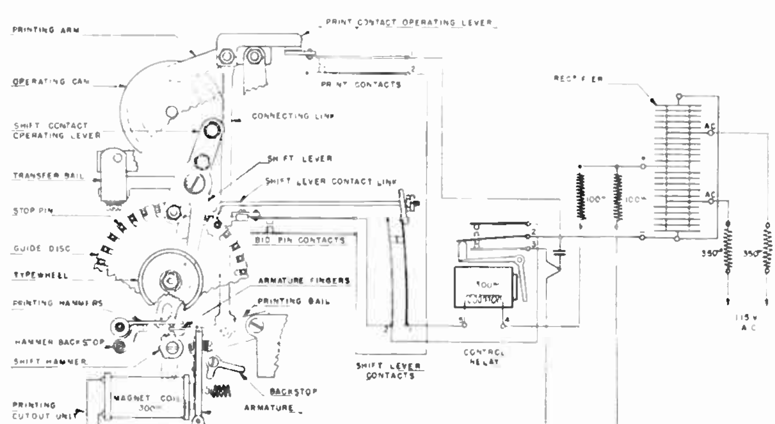

Figure 3. Schematic wiring diagram

while printing figure characters, the *B* stop pin is selected, the pin moves radially in toward the center of the guide disc which forms a part of the selector unit. This allows the bid pin contacts to close. The operating cam then turns, and as the printing arm lifts the printing bail to print the *B* character, the print contacts close. When these three contacts are closed, the following circuit is established: from the positive terminal of the rectifier, through a 100-ohm resistor, the operating winding of the control relay, the shift lever contacts, the bid pin contacts, and the print contacts to the negative terminal of the rectifier.

This momentarily energizes the control relay which draws up its armature, moving its tongue 2 away from contact 3 into engagement with contact 1. This opens the circuit through the magnet coil of the printing cutout unit, and its armature is drawn away from the magnet by the armature spring. The armature fingers are thus withdrawn from their position between the shift hammer and the printing hammers. This causes the ticker to cease to print because the printing hammers are not raised high enough to press the tape against the typewheel.

At the same time, a circuit is established as follows: from the positive terminal of the rectifier through a 100-ohm resistor. the operating winding of the control relay, the shift lever contacts, contact 1 and tongue 2 of the control relay to the negative terminal of the rectifier. The control relay thus remains energized and will continue to remain energized until the shift lever rotates counter-clockwise to position the shift hammer for printing the upper line of (letter) characters on the tape. When the shift lever moves to its "letters" position, the shift lever contacts open, breaking the circuit through the operating winding of the control relay. The control relay is therefore de-energized, its armature released, allowing tongue 2 to return to its normal engagement with contact 3, which closes the circuit to the magnet coil of the printing cutout unit. The armature of the printing cutout unit is drawn up, interposing its fingers between the shift hammer and the printing hammers, and the ticker prints the characters as before.

A manually operated lever on the printing cutout unit provides means for holding the armature in its operated (energized) position, if it is desired to disable temporarily the deleting mechanism and restore the ticker to its normal operation for printing all characters.

This special ticker is another example of the many ways in which Western Union meets the peculiar needs of those who use its varied services.

THE AUTHOR: P. L. Myer of the Plant and Engineering Department was graduated from the Pennsylvania State College in 1922. Shortly thereafter he joined Western Union as an engineering assistant in the office of the Engineer of Automatics. His first assignment was in the development of the automatic transmission system for self-winding tickers. This was followed by several improvements in long distance transmission for ticker service. Mr. Myer has taken out several patents in connection with his work in this field. He has contributed much to the development of printing telegraph apparatus including perforators, tickers, teleprinters, message numbering machines, and other apparatus used in connection with reperforator switching. He is a Licensed Professional Engineer of the State of New York.

Night Fighter Training

G. A. RANDALL

Foreword

During the latter part of the recent World War and subsequent months, the Western Union laboratories at Water Mill, Long Island, N. Y., in common with other industrial laboratories, engaged in Government research and development projects which took its engineers far away from their usual lines of work.

This article describes one of the most unusual of these projects—a "device" for training night fighter pilots. Actually, it might better be called a whole environment, since it simulates the actual fighting problems and conditions experienced by a night fighter pilot.

To better understand the nature of the training experience required, tune in now on the radio communication link between the cockpit of the fighter and the Combat Information Center (C.I.C.) room of an aircraft carrier which is the base of operations.

"Hello, Red Fox Four-Five-Zero, calling Red Fox Four-Five-Zero. This is Green Base, Over."

In the jargon of the aviator, the Combat Information Center of an aircraft carrier was calling one of its night fighter airplanes. A new and unidentifiable dot had appeared near the outer edge of the big Radar Scope, and was proceeding along a course which was bringing it closer to the carrier.

The Fighter Director had watched the plotting boards for a few minutes, mentally preparing interception tactics, and then had contacted a "friendly" fighter to make an investigation.

"Have Bogey for you. Port to Two-Six-Five. Ten Angels. Over."

"Port to Two-Six-Five. Ten Angels, Wilco out," replied the fighter pilot; and, complying with these instructions, set his course on an unknown and uncertain mission.

In wartime, such a mission is likely to be one of the most hazardous, nerve-racking jobs that anyone is called upon to perform. Traveling at terrific speeds through the black night, you must hunt out an invisible enemy who, on the slightest suspicion, may turn on you and become the hunter; or the enemy may take evasive action and escape to continue his deadly mission, in which case you have failed in your own mission. One gun-burst may be all the fighting that time permits during such an encounter. After that, you've won or lost; or, if the encounter was not decisive, you'd better get away fast so that you can circle around and perhaps become the attacker again.

It is one man, encompassed in a 7-ton machine, acting as its brain and controlling its operations according to an artificial eye and 20 indicator dials, pitted against another man in a similar machine. Quickness of perception, coordinated response to what is perceived, plus confidence in one's self and the C.I.C. director, are the things which may determine the pilot's chance to survive an encounter—if machines and armament are equal.

Formerly, in order to train a new pilot, it was necessary to send him out for practice interceptions of a blacked-out friendly target airplane. Usually other members of a squadron had to fly near him and instruct him. This method was hazardous and resulted in many losses of men and airplanes. In wartime these losses were borne out of necessity; in peacetime such losses are hard to justify. Hence the continuing need for a safe and effective means of training these pilots.

Early in 1943, a small group of Western Union engineers were at work developing a "fixed gunnery trainer" for the Special Devices Center of the Navy. As the work progressed, it became evident that the device had a potential use as a night fighter trainer. The research and development work was then directed toward that objective. The trainer which was produced was known as the "VISUAL CONTACT TRAINER, U. S. N. Device 15-V-1." More recently a modified trainer of similar design was developed which is called the "RADAR CONTACT TRAINER, U. S. N. Device 15-V-4." This work continued through 1948.

The object of both Trainers, with their associated equipment, is to provide realistic simulation for nighttime flight and interception operations. These are Advanced Trainers for full-fledged daytime fighter pilots, so it is assumed that the men to be trained are already skilled in flying, navigation, and the principles of fixed gunnery (that is, maneuvering the airplane so as to bring the cone of the gun fire to bear on the estimated point-of-aim).

Night fighter pilots must learn to fly by instruments and to fight under conditions of night time visibility. In the earlier days of the war, this meant also that the pilot had to identify visually the target airplane, then use an optical gunsight for aiming and firing. The change from instrument flying to visual-attack flying and from radar approach to visual gun aim during the last few tense moments of an interception was a serious matter. This so-called "visual-contact" problem was a special feature of the 15-V-1 Trainer. More recently, though, the training emphasis has shifted towards the all-radar interception and gun aim (hence the "Radar Contact" Trainer, 15-V-4). This change is due partly to the increased reliability of radar devices, particularly the means of identifying airplanes by radar (known as I.F.F.), and partly to the greater airplane speeds which make it less practical visually to identify a target before firing.

Since night fighter pilots must depend so much on their radars, it is necessary that they become proficient in their use. It is important also that the pilots become experienced in interpreting that particular form of presentation for Search, Intercept, and Gun Aim data, used by that particular type of radar equipment with which their airplane is to be equipped. Both the 15-V-1 and 15-V-4 Trainers offer this experience since they are equipped with current production models of radar receivers which function in the normal manner.

Finally, a night fighter pilot must obtain experience in flying controlled interceptions; i.e., flying under the orders and continuous observation of the Fighter Director of the Combat Information Center back at the Base station. Nowadays, night fighters, unless sent out on a special mission, usually operate from an aircraft carrier or land base to give protection to that base position or to the adjacent areas. These base points are equipped with powerful radar search gear having a range of maybe several hundred miles, whereas the airborne radar set of the fighter airplane is necessarily small and has a limited range—say 5 to 15 miles. Therefore, it is the duty of the Base station to detect an enemy airplane while it is still far from base; and, knowing the location of all friendly airplanes near base, to dispatch one or more of these fighters to intercept the enemy as far from the base as possible. The Fighter Director at the C.I.C. directs these interceptions, instructing the fighter pilots, from time to time, just what course to fly, at what altitude and at what speed, until they are within airborne-radar range, and are approaching the target on the safest and most effective course and altitude for the final encounter. At this point, the fighter pilot is permitted to "go it alone," though if he misses, or if the enemy takes evasive action and eludes him, the Director may take over and re-instruct the pilot.

A "controlled interception" of this kind requires teamwork and mutual confidence. Any errors due to wrong tactics or estimates of target courses or speed, or any failure of a fighter pilot to understand instructions or to comply promptly, may frustrate the interception and even jeopardize the pilot's life. Both the 15-V-1 and 15-V-4 Trainers provided realistic training for controlled interceptions. Both have a C.I.C. with Plan Position Type Radar Indicators (P.P.I.) on which the changing positions of the fighter airplane (flown by the Trainee) and target airplane (flown by the Instructor) are observed by a Flight Director and his assistants. From these position data, courses are plotted and speeds determined, interception tactics are planned, and instructions for effecting the interception are sent to the fighter pilot.

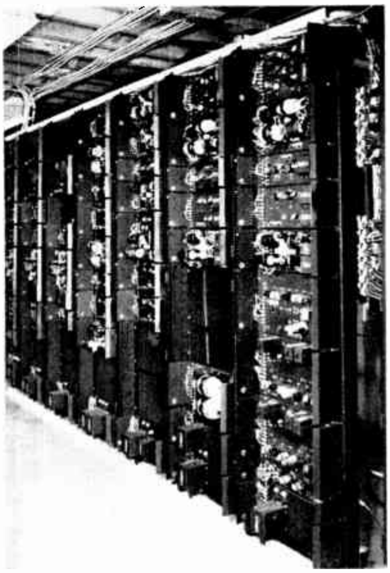

Figure 1. The trainer calculating section

Incidentally, the jargon used in directing and responding is unique and not intelligible to the uninitiated. ("Request scramble three chicks", "Oranges Sour", "Popeye", "Make your rooster crow", "Have joy", "Tallyho!", "Grand slam".) Originally this code was devised for purposes of secrecy, but now it is retained for its clarity and conciseness. It is an acquired habit of speech that comes with practice. Both 15-V-1 and 15-V-4 Trainers can offer this practice.

The principles of operation of the two types of trainers are the same, but there are differences in the design of component parts and in the completeness and realism of certain training features. Since the 15-V-1 type is the more general of the two trainers and has been declassified (from Military restriction), that trainer is the one which will be most often discussed herein. In describing its operation, it will be necessary to include also certain associated equipment supplied by the Government for use with each trainer, and where this is done the equipment will be referred to as GFE—meaning Government Furnished Equipment.

The 15-V-1 Trainer consists of two Synthetic Flying Units (Fighter and Target), a complex Calculating Section, a Projector, two Radar Simulators, an Instructor's desk with turret of controls and indicators, a C.I.C. position and a Power Section.

The equipment for the Calculating Section, the Simulators, and the power monitoring and protection devices are mounted on 15 standard Western Union carrier racks 7 feet high. (Figure 1.) Each rack holds 7 to 10 chassis units, such as amplifiers, vector resolving units, angle solving and range solving units, integrating circuits, metering panels, and servo-control units.

The racks usually occupy one room at a Training Center. The Instructor's Control Unit and the C.I.C. share another room. The Projector requires a separate and quite special room which must be spherical (or at least cylindrical) in shape, 18 to 25 feet in radius, and capable of being blacked out.

Figure 2 shows a block diagram of the 15-V-1 Trainer.

Action starts with the two synthetic flying units. For the Fighter, this is an Operational Flight Trainer (GFE) and for the Target it consists of a control box on the Instructor's desk plus a number of data generating units on the Trainer racks.

An Operational Flight Trainer is a device used by the Government to train men in the principles and practices of flying, the proper use of equipment, etc. It consists of a mock-up cockpit complete with all controls, instruments, switches, etc. When the controls are manipulated, appropriate flight data are produced in generators located in cabinets nearby. This information, in turn, is transmitted back to the instruments in the cockpit and to a duplicate set of instruments on the Instructor's Desk. Data on true air velocity, compass heading, angle of climb and angle of roll are supplied to the 15-V-1 or 15-V-4 Trainer.

An OFT built by the Western Electric Company (USN Device 2F2) was intended to be used with the Western Union Trainers, but other types such as the Link Trainer can be used.

aboard (with parachute), straps himself in the seat, and proceeds to "check out" the airplane in the prescribed manner. When satisfied, he "starts the engine" (it sputters and coughs at low speeds, and roars when revved-up, just like a real engine); checks both magnetos, etc.. and finally when the engine temperature is

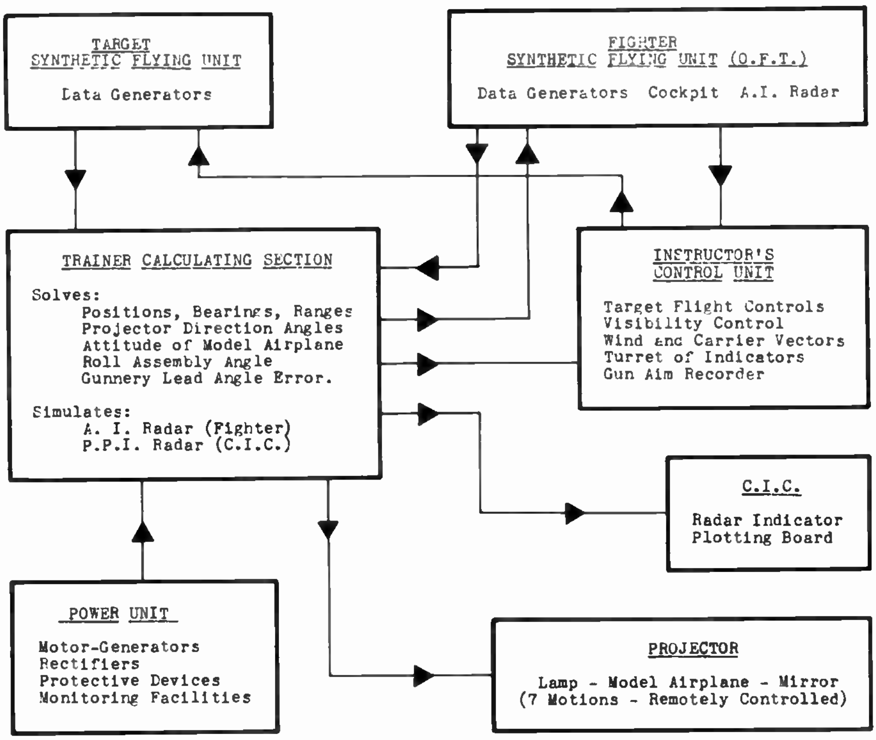

Figure 2. Block diagram of 15-V-1 Night Fighter Trainer

The cockpit of the OFT is placed in the Projection Room with the trainee directly below the Projector as shown in Figure 3. Ordinarily, this room is completely blacked out and the cockpit lights dimmed to simulate night flying conditions. (It takes about 20 minutes for a person to get his "night vision" in this room. Consequently, the trainee usually prepares for his flight by wearing red goggles during the preflight briefing.) Communication between the Instructor or C.I.C. and the Fighter pilot is by means of an intercommunication system which terminates in the pilot's radio jack.

When the trainee is ready, he climbs warm enough he is ready to take off. Or almost ready.

The training procedure requires that he first call the Base to get a check on his radio, then taxi to the runway, obtain clearance, and then finally, he may take off.

"Hello Green Base, this is Red Fox Four-Five-Zero. Airborne, Over," he reports.

"Hello Red Fox Four-Five-Zero, this is Green Base, Orbit Base, Angels Five, Over."

The trainee must acknowledge all the instructions and promptly carry them out. When over the Base and at the specified altitude, he is ready for any mission that the Fighter Director of the C.I.C. may direct.

As soon as the Fighter develops ground speed at the take-off, the Trainer Calculating units begin operating. The true air speed of the airplane is resolved into geographical components, then each of these simultaneously is integrated with respect to time to obtain the change in position of the airplane. The Register Units sum up these data and determine the actual position coordinates of the Fighter with respect to Base at any time. Other sections of the Trainer determine and record the position of the Target airplane both with respect to Base and to the Fighter.

Still another section of the Calculating Unit determines continuously the bearing angles and ranges of both airplanes from Base and from each other.

In order to be able to show the Fighter pilot (trainee) a suitable projected image of the Target at the proper bearing angle and range, it is necessary first to convert the relative geographical position data for the Target with respect to the Fighter so that the data will be related to the Fighter airplane's own longitudinal axis, wing axis and vertical axis. For it isn't sufficient in a "dog-fight" to know your enemy is Northeast of you at some particular moment. You must know whether the target is "dead ahead" or at "3 o'clock high," etc., at every moment during any flight maneuver. Position data in this form are required also for the radar presentation.

For the visual presentation it is further required that the correct "attitude" of the

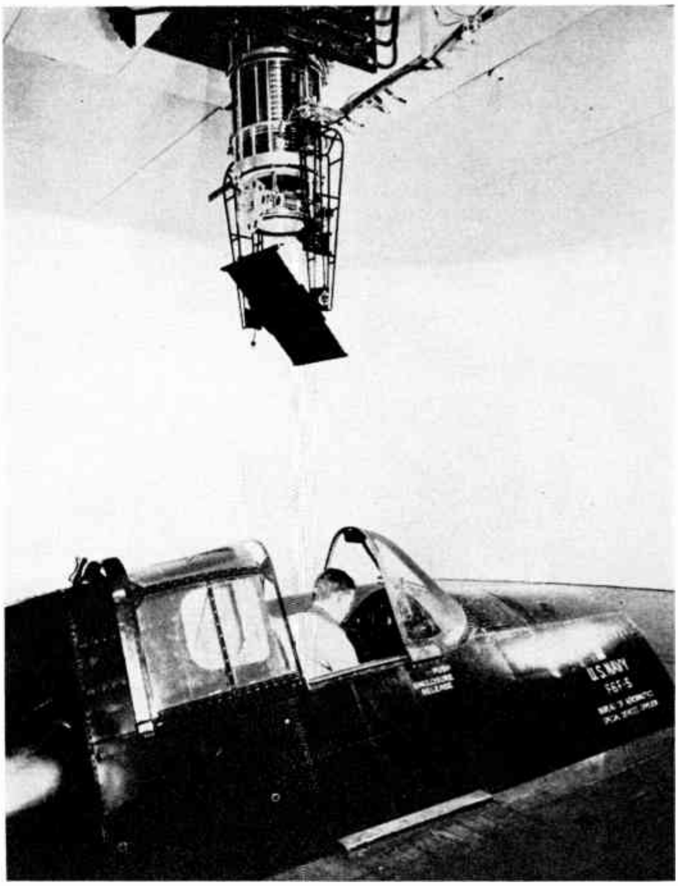

Figure 3. Projector room (test installation)

Target airplane be calculated. By "attitude" is meant the view of the target as observed from the Fighter: stern view, side view, top view or combinations of these, etc. This will depend not only on the heading and flight maneuvers of the Target but also on the range and the angle from which it is seen. Thus, if you should overtake another airplane flying on your own course but at a somewhat higher altitude, you would first see a stern view in the distance. At closer range the underbody becomes visible in increasing amount. As you pass under the airplane only the bottom view is visible. After passing, you look back and see the bow of the ship chiefly.

Maneuvering of the Fighter airplane does not affect the attitude of the Target, but it does change the direction in which the pilot must look to see the Target, and it will produce a "picture frame effect." For example, if you were flying in the Fighter airplane and saw the Target airplane on your right (wing axis) flying at the same altitude and course, then if your airplane should suddenly roll with right wing down, the Target would appear *overhead*. However, if instead of rolling, your airplane were to *nose up*, you would observe the Target to be nose down with respect to your own platform. Now if the Target were dead ahead or at some different bearing instead of off the Fighter's right wing, similar things happen to the Fighter's view of the Target and must be included in the visual presentation. Since the cockpit of the OFT (W.E. Type) has no motion of its own (and the new models by Link or other manufacturers for use with these Trainers, probably also will be motionless), this "picture frame effect" must be incorporated in the Projector presentation. It is apparent, therefore, that the Calculating Units of the 15-V-1 Trainer have quite a few functions to perform.

The Projector (Figure 4) consists of a movable point source of light of controlled intensity. The lamp moves along the vertical axis of the Projector. In the path of the light beam there is a scale model of an enemy airplane which, by remote control from the Calculating Section, is caused to assume the proper azimuth, pitch and roll angles to give the attitude required.

A mirror below the model airplane reflects the projected silhouette of the model to the wall of the room. Tilting the mirror changes the elevation of the Target above the floor of the Projector room, while rotating the mirror about the vertical axis of the Projector moves the position of the Target around the walls of the room at constant height. Combination of these two motions can position the projected image at any required bearing angles from the Fighter cockpit.

The effect of range is obtained by moving the lamp closer or farther away from the model airplane according to calculations of a special unit in the Calculating Section. (The solution is not linear with range.) At the same time, the amount of light from the lamp is controlled as a function of distance so that at greater distances the picture will fade out. This visibility effect is under the control of the Instructor also.

Two more functions of the Trainers concern the simulation of the radar data for both the Fighter and for the C.I.C. For the Fighter airplane, an actual airborne type radar set is used, but the transmitting magnetron is disconnected. When its antenna beam direction, during the scanning cycle, coincides with the direction of the Target from the Fighter, as calculated by the Trainer Calculating Section, a "gate" must open and allow a pulse to trigger off the Simulator circuits. These circuits in turn process the position angle and range data so that suitable echo signals can be introduced into the I-F strip of the radar receiver, thereby producing the proper presentation on the scope. By this method, the radar presentation is made subject to the Pilot's Radar Control Box which selects the Search Scan, Intercept, or Gun Aim Presentation, and the various ranges, etc. A Sea-Return "necklace" and simulated "noise" also are generated in the Trainer Units and appear on the radar indicator.

For the C.I.C. Radar, the simulation is less elaborate. An antenna scanning and gating unit, one sweep generator and two

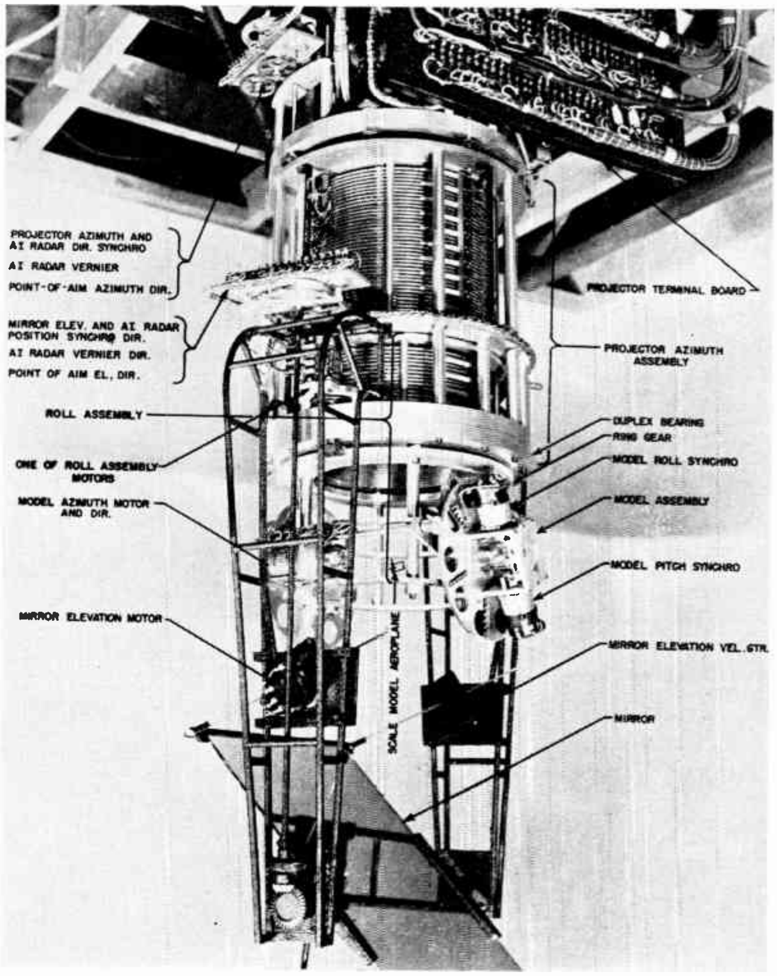

Figure 4. The projector

pulse generators suffice to put the Target and Fighter dots on the P.P.I. scope at positions calculated in the other sections of the Trainer.

In order to improve the pilot's gunnery, the Trainer calculates the correct point of aim, also notes the pilot's actual aim, and automatically records the difference between them at the time of each gun-burst. To aim correctly, the pilot must be taught to "lead" his target by an amount based on the estimated course and speed of the target, also the known speed of the bullets. In other words, the pilot must aim at that position which the target will have reached by the time his bullets can arrive there.

The Gun Aim Recorder is shown in Figure 5. It consists essentially of a roll of Teledeltos cross-section paper passing between two styli rods at right angles to each other. If the styli are crossed at the center of the paper, a bull's-eye is recorded when the trigger is pressed. However, the positions of the rods are controlled by those Trainer Units which calculate the errors in aim. If the pilot aims too high, the horizontal stylus moves upward by an amount corresponding to the error angle. Similarly, errors in the horizontal direction cause the vertical stylus to be moved. Elsewhere on the Teledeltos sheet, other styli record the range to the Target and number of shots in the burst. As soon as the trigger is released, the paper advances one frame and may be torn off for a per-

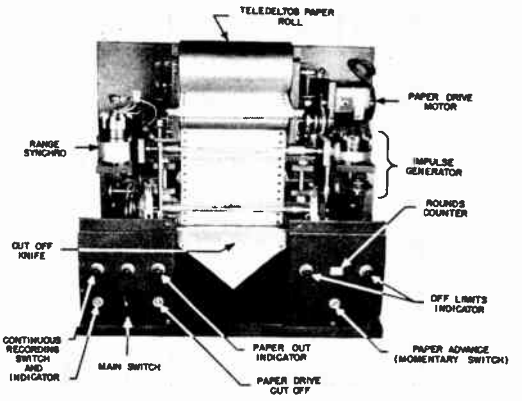

Figure 5. Gun aim recorder—front view. cover removed

manent record of the encounter. Things happen so fast in a fight, that a record of this kind proves invaluable. This recorder is located on the Instructor's desk.

The Instructor's Control Unit is a desk position containing various indicators and controls by means of which the Instructor is able to set up and closely follow each training problem. Here the Instructor "flies" the Target according to flight instruments on his turret. He controls such conditions as wind velocity and direction, carrier heading and speed, also visibility. By means of a duplicate set of the Fighter cockpit instrument, he can observe how well the pilot flies and responds to instructions from the C.I.C. By means of indicator lights the Instructor knows the use being made of the Fighter's radar, what range setting, scanning control, etc., is being used at each stage of a problem; and when the Fighter closes on the target, the Instructor can follow the approach tactics and gunnery. Toggle switches on the turret permit the Instructor to "freeze" the Trainer at any time to discuss a point with the trainee if he so desires. (Figures 6 and 7.)

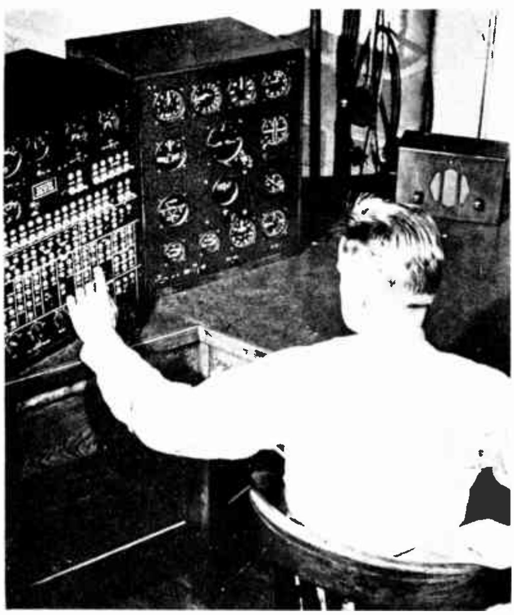

Figure 6. The Instructor's desk

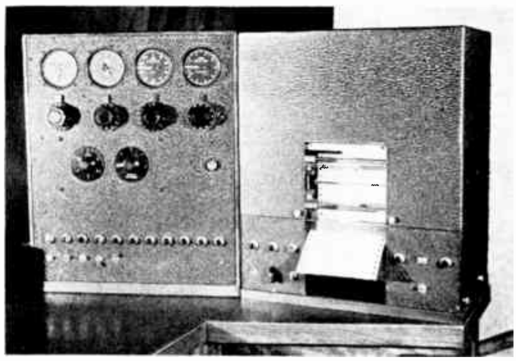

Figure 7. Target control, turret and recorder

The C.I.C. consists of a big P.P.I. radar scope and plotting board by means of which the changing positions of the airplanes can be observed and recorded. Interception tactics can then be prepared and instructions sent to the fighter pilot.

Power to operate the Trainer and radars comes chiefly from two motor generator sets supplemented by several rectifiers. Figure 8 shows the power control and monitoring racks. Here the circuits are subdivided for ease in metering and for providing protection. They are so arranged that a single push button, if so desired, will start up all circuits in proper sequence with suitable time delays between switching operations.

Many of the Trainer components and circuits are unusual and quite interesting from a technical viewpoint, but it is not feasible to discuss them in this article.

Instead, a more complete understanding of the use made of these Trainers can be obtained by picking up the story of a night fighter pilot making an interception.

"Hello, Red Fox, Four-Five-Zero. This is Green Base. Vector Starboard One-Two-Zero. Over."

NOTE: The C.I.C. plot of the interception to be described here will look something like Figure 9. Positions are recorded at one minute intervals. We are now at position 07. (Time progression will also be noted in left margin of this narrative account.)

Figure 8. Power control unit

Time

07 ". . . . . . . One-Two-Zero. Wilco. Out," confirms the pilot—let's call him Joe. By now Joe realizes he is already flying on a pursuit course, and it is time to release the guns from "safety" and fire a burst as a check. This done, he glances at the gas tank indicators. The right tank is now in use, supply running low—*better switch to the left tank now.* Done! *Now for a quick glance around the instrument panel.* Altimeter: 9,500 ft., OK for now. Air speed, manifold pressure, R.P.M. engine temperature, etc.; *all* OK. *Now check course again.*

10 Three minutes pass. *Hope those fellows at the C.I.C. haven't forgotten me. Here I am, flying at breakneck speed, in pitch darkness with all lights out (except very dim red instrument lights)—with an unidentified airplane, probably enemy, somewhere about and only the C.I.C. knows where! Maybe the Bogey is getting suspicious—might have tail warning radar and turn to attack me—or maybe the Bogey will take evasive action. That would be bad, too—awfully hard to keep track of him during an engagement with airborne radar. Better check the visual gun-sight now—might need it—reticule too bright, now if I can find that rheostat in the dark—yes, that's better now.*

11 The C.I.C. broke in ". . . starboard One-Eight-Zero. Target 10 o'clock. 10 miles. Over."

Getting closer. Radar contact soon. Joe is a little tense now as he changes course, and quite conscious of the pounding of his heart. *Now decrease speed a little. Nothing on radar scope yet. Let's switch to a closer range—no, nothing except noise and the sea return "necklace". Yes, maybe there is—up near the top of the scope, just*
12 *left of center there seem to be two faint but persistent pips.* The next moment though, he wasn't sure. The pips were gone. *What happened to the pips?* Joe held his course and speed.

"Vector two-two-zero. Over."

Joe acknowledged.

"Target now 12 o'clock, 4 miles. Do you have joy? Over."

(Joy means radar contact.)

13 *Yes, there they were, a pair of pips coming down the center of the scope and getting brighter all the time.*

"Have joy," reported Joe.

"Punch!" Now he was on his own. The C.I.C. had brought him into radar contact on a quick and safe approach, all set for the closing. At no time had

Time

the bogey identified itself on the radar as a friendly ship, so it must be presumed to be an enemy airplane. It was all up to Joe now.

Another minute passed—it seemed ages. *Altitude a little low*—he corrected that but lost speed. *Target moving slightly to port—a little stick and rudder required, but not much; now correct to starboard and on course again.*
14 *The pips are dropping again. Change radar to 2 mile range now*—and the pips start from the top again, but they are falling more quickly now. *Closing fast—must slacken speed. Hold course on that target—hold it!—watch that altitude—target pips now drifting to port—careful!* The nervous tension is terrific. Joe is sweating, but he is too
15 busy to think about it. *Target crossing to starboard 1-1/4 miles now. Get on course—hold that altitude!* Joe looks out ahead but there is nothing to be seen in the blackness. *Yet the radar says the enemy is there. Does he suspect? Will he fight or flee? If the first gun burst is not effective, will there be a second chance?*

Time

16 *Time to go on Radar Gun Aim position now—steady—hold that course—mustn't drift now! Hold it!*

Then out of the darkness ahead appears the faint form of an airplane—it seems to be a twin engined job—it is, it's a Jap Betty. "Tallyho, one Betty," Joe advises the Base. Gently fingering the trigger on the stick, and with his eyes glued to the gunsight he watches the Betty grow bigger in the gunsight—and BIGGER—and BIGGER—
17 NOW FIRE!!!

The stick went limp in Joe's tensed hands. The rudder controls had no more resistance; the target remained mockingly in space right where it was when he fired. Everything was in a state of suspended animation. "What goes on here?" asked Joe to himself.

A voice in his head-phones broke in to explain. "This is Lt. Smith at the Instructor's desk. I just 'froze' the Trainer in order to set up a new problem quickly. The Captain is on his way over with some

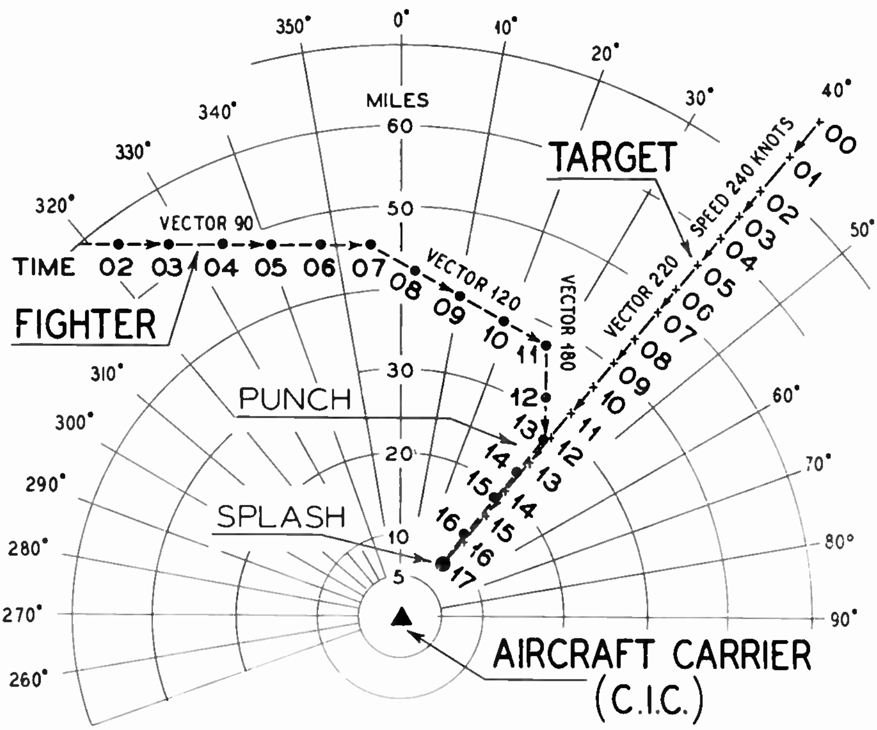

Figure 9. Typical plot of interception problem

visiting Brass and wants us to give them a demonstration. Now on that last interception, you were pretty good. The Recorder shows that your gun-burst cut across the left wing of the Target starting from 25 mils above and to the left, range was about 250 yds. For the demonstration though, when you close-in try to . . . ."

So, Joe was thinking, *I was flying only a Trainer. For a while I thought it was the real thing. It is too d———d realistic.* He wiped his brow. *Ought to have the Captain try sweating out a problem like that in this Trainer. He'd earn his flight pay. . . .* But audibly all he said was, "Roger."

The Navy Trainer Projects represent one of the major contributions of Western Union to the war effort and involved approximately 135,000 man-hours of research, development, and construction work.

The Trainers were designed by a small group of engineers working under the direction of Mr. D. H. Nelson. They were: E. E. Bedell and N. R. Lane of the Western Union Laboratories at Water Mill, Long Island; G. A. Randall, O. E. Pierson and R. Steeneck of the New York Laboratories. Later this group was supplemented by S. C. Coroniti and his assistant B. Wolf. The experimental work as well as most of the construction of all Trainers was performed at the Western Union Laboratory at Water Mill, Long Island.

Mr. Randall, author of this article, developed many of the circuits used in the Trainers and often acted as test pilot during demonstrations. Subsequently, he assumed direction of the 15-V-4 Project.

MR. PAUL J. HOWE, Chairman of Western Union's Committee on Technical Publication, has retired after 43 years of Company service. Owing in large measure to the personal direction given it by Mr. Howe, TECHNICAL REVIEW, under his guidance since its inception, has become in a comparatively short time an outstanding technical journal in the field of communications. Although "published primarily for Western Union's supervisory, maintenance and engineering personnel," as stated in its masthead, the magazine now enjoys the readership of telegraph engineers throughout the world.

MR. HOWE, himself a communications engineer ever since his graduation from college, is the author of numerous technical papers having to do for the most part with his early work on outside plant materials and construction, but including more recently important treatises on telegraph practices in general. He was at one time Construction Engineer for Outside Plant, then Central Office Engineer, Assistant Chief Engineer, and since 1946 Director of Systems Development for Western Union. A more complete resume of his work is given in TECHNICAL REVIEW, January 1949, following his paper on "Facsimile and Its Place in Telegraphy."

Among his associates, he is known as the man with a hobby, namely, photography. His expert knowledge of this subject has enabled him over the years to contribute prints of high merit to camera club exhibits, including those of the Western Union Camera Club, of which he is a charter member; his pictures have taken many first prizes.

This journal owes a great debt of gratitude to Mr. Howe, which it is appropriate to acknowledge at this time. It is appropriate also to wish him every enjoyment in his well-earned retirement from long and active service.

Mr. F. B. Bramhall, Transmission Research Engineer, has been appointed Chairman of the Committee on Technical Publication, and Mr. Grove Hotchkiss, Coordinating Engineer, has been made committee representative for the Development and Research Department.