WESTERN UNION
Technical Review

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Simplified Tape Switching

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VOL. 9 NO. 2
APRIL 1955

WESTERN UNION Technical Review

VOLUME 9
NUMBER 2

Presenting Developments in Record Communications and Published Primarily for Western Union's Supervisory, Maintenance and Engineering Personnel.

APRIL 1955

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Published Quarterly by

THE WESTERN UNION TELEGRAPH COMPANY

COMMITTEE ON TECHNICAL PUBLICATION

Address all communications to THE WESTERN UNION TELEGRAPH CO., COMMITTEE ON TECHNICAL PUBLICATION, 60 HUDSON ST., NEW YORK 13, N. Y.

Subscriptions $1.50 per year — Printed in U.S.A.

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W/U

A Portable Telegraph Bias and Distortion Measuring Instrument

W. DALE CANNON

In the modern telegraph system, signals are transmitted over various trunk facilities derived from wire lines or radio relay systems. The trunk telegraph channels furnish facilities between a number of switching centers located at strategic points throughout the country, and these centers then distribute traffic to the local points of destination. In addition, various other services must be accommodated by suitable network configurations. These services comprise such arrangements as are involved in leased network circuits, private switching systems, and so forth. It is necessary that flexibility be maintained in this complex network of circuits in order that circuit patching and routing may be accomplished without making undue alignment changes in the circuits themselves.

In the operation of a telegraph network, it is often necessary to interconnect telegraph circuits indiscriminately to form through trunks and local distribution circuits. It is essential not only that circuits and equipment be compatible with each other, but also that signals as measured from point to point do not exceed a permissible tolerance with regard to signal distortion. The signal quality as measured at interconnecting points permits prediction of the behavior of the interconnected circuit. With the aid of a signal distortion indicating device, adjustments can be made to provide the best possible circuit operation.

Bias and Distortion

Bias is usually the most important of the several types of distortion that may be present in telegraph circuits. Bias results in a uniform displacement of like signal transitions so that all marking signal intervals are uniformly lengthened or shortened and all spacing signal intervals are correspondingly shortened or lengthened. In start-stop teleprinter operation, bias results in a uniform displacement of space-to-mark transitions with respect to the start pulse mark-to-space transition. For this reason, bias is sometimes measured by observing the time of occurrence of space-to-mark transitions with respect to the beginning of the start pulse. Since bias displaces the mark-to-space transitions uniformly, it is possible to measure bias not only with respect to the beginning of the start pulse, but also with respect to the position of any other mark-to-space transition occurring in the signals. If the measurement is made of the space-to-mark transitions of single-unit spacing signals with respect to their corresponding mark-to-space transitions, the bias indication is based upon the average duration of a spacing unit interval. The bias measurement is accomplished by measuring the average time interval occupied by single-unit spacing signals in comparison with the time interval of a perfect unit-length spacing signal. Measurements are made of spacing single-unit signal intervals rather than of marking signal intervals because in start-stop operation the duration of the marking stop pulse can vary greatly and such variations are not indicative of the presence of bias. This method of measurement then is applicable not only to circuits using start-stop transmission but also to synchronous transmission systems. Examples of bias measurement for zero, 25-percent mark-

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., February 1955.

ing, and 25-percent spacing bias are given in A, B and C of Figure 1 in which the duration of the measured single-unit signals is indicated by the letter *t*.

In much of the equipment used in the transmission of telegraph signals, bias can generally be removed from the signals by simple adjustments. The other forms of distortion are not so readily corrected, and are generally considered as a separate procedure. It therefore seems desirable to measure bias and to measure distortion exclusive of bias as separate quantities. Total distortion then is the summation of these separate quantities. Therefore, for use in this paper, the term distortion will exclude distortion due to bias. The distortion measurement to be described is based upon the minimum duration of a spacing unit interval. The distortion indication is obtained by observing the particular unit spacing signal whose length differs most from the average time interval, and then measuring its departure from the average. An example of the measurement of distortion when the bias is 15-percent marking and the distortion other than bias is 25 percent, is shown in Figure 1-D in which the short signal indicated for code element 4 is a unit interval of minimum duration. The amount that its length differs from the average is taken as a measure of distortion other than bias.

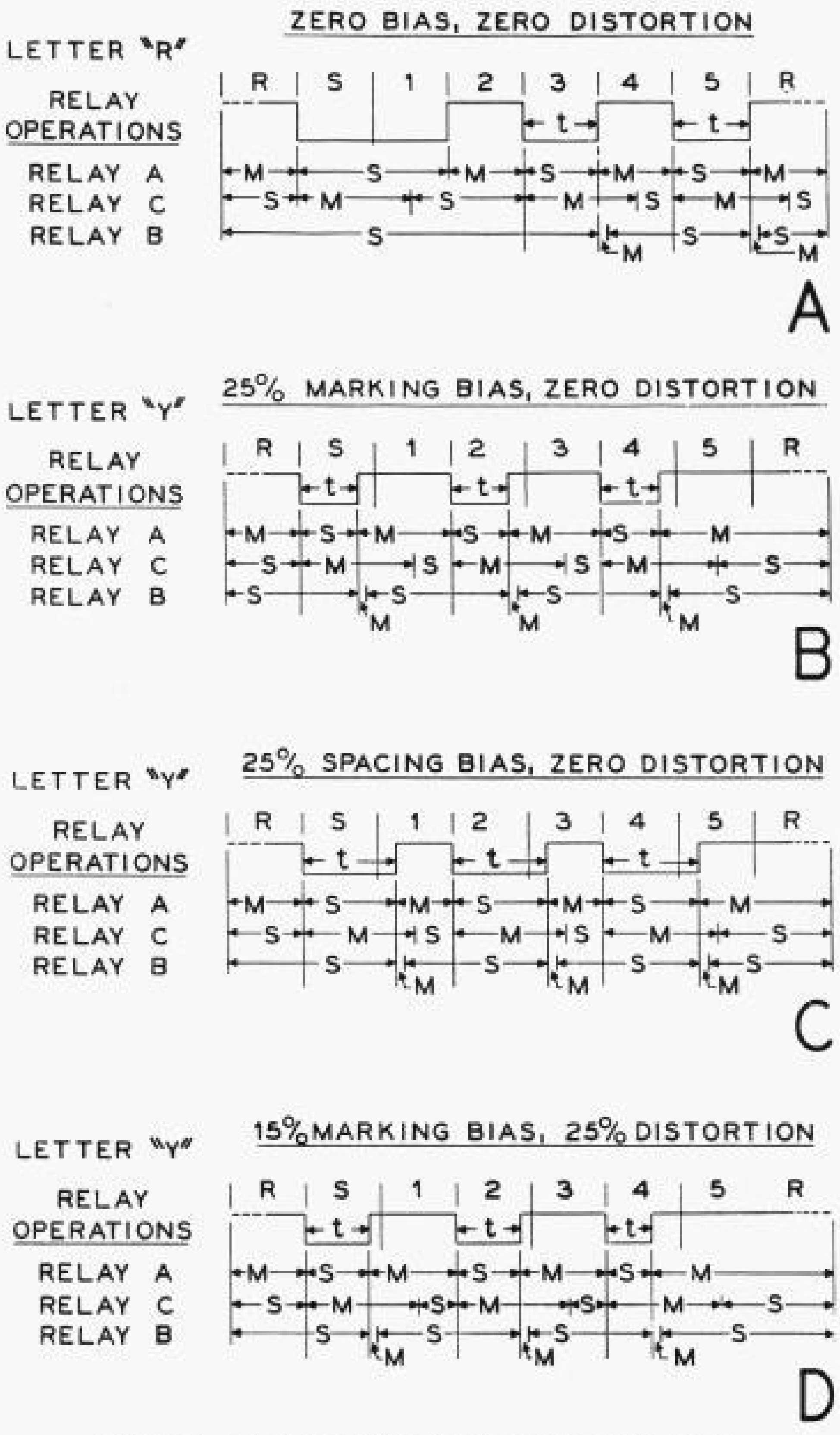


Figure 1. Theory of bias and distortion measurement

General Description

The bias and distortion measuring instrument, as designed for general application in field offices and using the operating principles described above, is shown in the view of Figure 2. The instrument is a portable device capable of measuring signal bias and distortion on working telegraph circuits which employ 7- or 7.42-unit code, operating at speeds of 65 or 61 words per minute. Measurements can also be made at 75 or 100 words per minute. The instrument was designed especially for use on 70-milliampere single-current circuits and polar circuits having signal currents not less than approximately 15 milliamperes. Since the instrument is fundamentally a time measuring device which indicates the time interval occupied by a unit spacing signal, it can be used for measurement on either start-stop or synchronous systems having signal lengths and operating currents within the design limits.

The instrument is contained in a metal box, 10 inches wide by 10½ inches deep by 11 inches high, having a sloping front panel on which are mounted two meters for indicating a maximum of 25-percent spacing or marking bias and 40-percent distortion other than bias. Also located on the front panel are switches for selection of the operating speed and the measuring circuitry as required, and a neon lamp to indicate the reception of spacing and marking signals. Located inside the cabinet are three polar relays, three vacuum tubes, the associated circuit components, and selenium rectifiers operating directly from the 115-volt 60-cycle line to supply positive and negative battery potentials. The polar relays are the standard 202-A type now generally applied in Western Union service and giving reliable and long maintenance-free performance. The circuitry of the instrument is shown in Figure 3. For descriptive purposes, the circuitry may be divided into four parts, namely, the input circuit, the pulse stretching and transfer circuits, the bias indicating circuit, and the distortion indicating circuit.

Input Circuit

The input circuit of the instrument is shown in Figure 4 in which telegraph signals are impressed upon Relay A. A relay in the input circuit is desirable since different types of response to the signals are available which may simulate the characteristics of various working equipment. Furthermore, isolation of the input from ground permits the inclusion of a simple power supply for the positive and negative battery potentials. The operating winding of the relay, having a resistance of 70 ohms and an inductance of 0.45 henry, is inserted directly into the working circuit without appreciably affecting the operating condition of the circuit. Relay A follows the signals being transmitted over the circuit as indicated by the flashing of the neon lamp located on the front panel, which indicates a spacing signal when the left half of the lamp is illuminated, and a marking signal when the right half is illuminated. A switch is provided to reverse the operating winding of

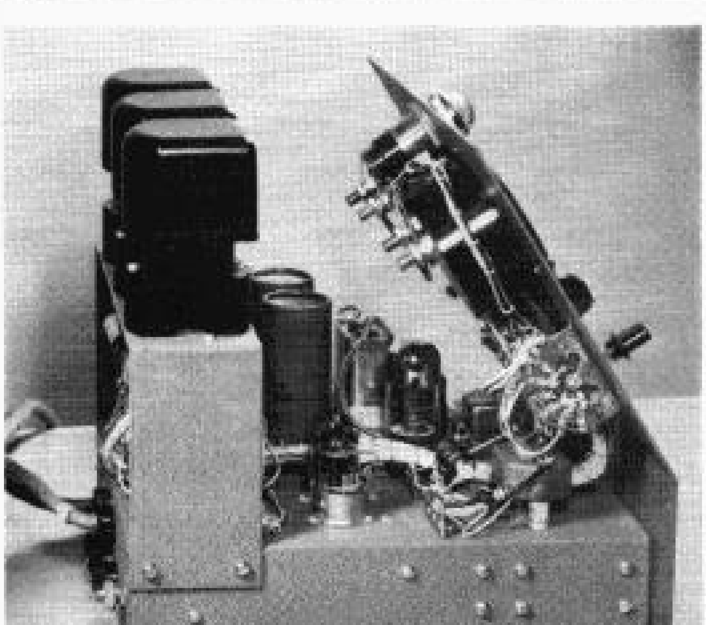


Figure 2. Bias and distortion measuring instrument
Upper—Front view of field instrument
Lower—Interior view of cabinet

the relay to correspond to the polarity of the signals.

The instrument is arranged to measure either polar signals or single-current signals. For polar signals, Relay A operates as an unbiased polar relay with the biasing winding open. For single-current signals, it is necessary to include a bias in the relay which is conveniently obtained by a current in a separate winding. This current depends upon the operating current of the transmitted signals and the type of response to these signals which it is desired to incorporate in the instrument. While a number of types of response to the signals are possible, two types, based upon a signal current of 70 milliamperes and designated as 35 and 20-50, are included in this instrument. Also, these types of response can be applied readily

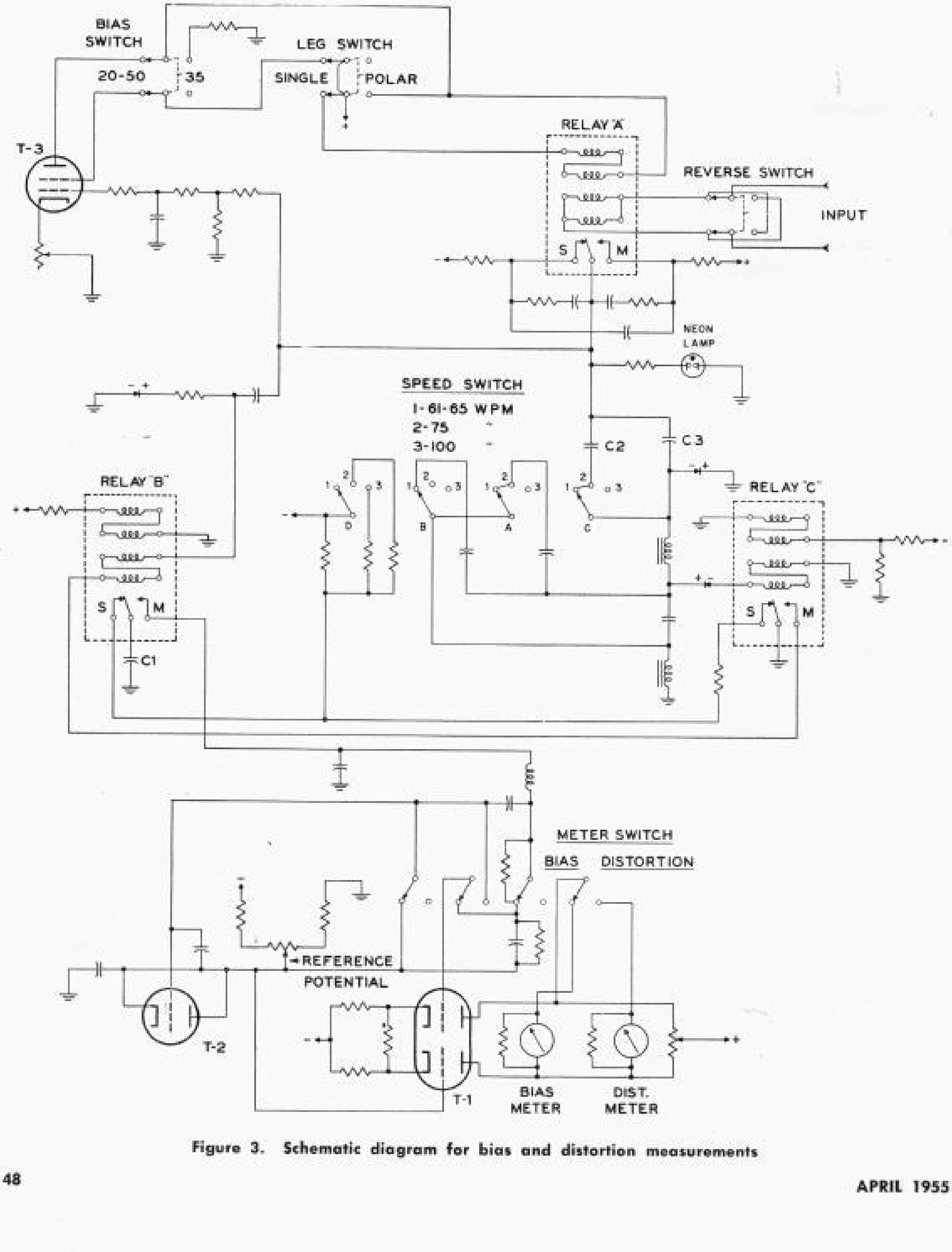


Figure 3. Schematic diagram for bias and distortion measurements

to other signal current values which may vary considerably from the nominal value without appreciably affecting the operation of the instrument.

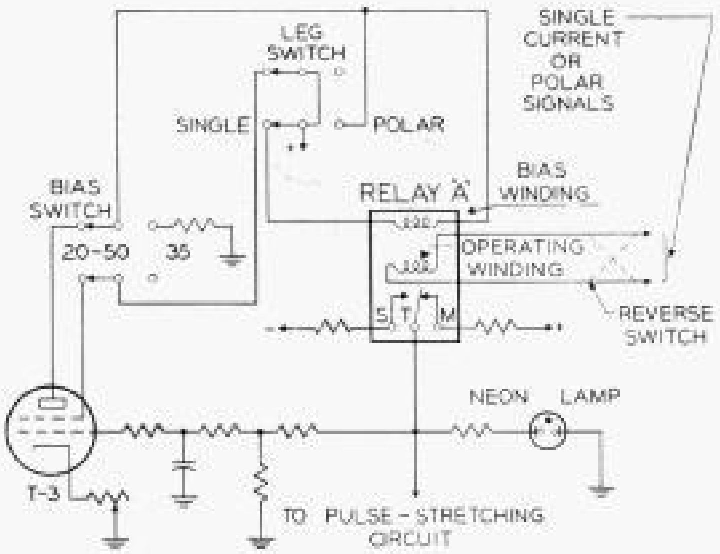


Figure 4. Input circuit

The 35 and 20-50 Responses

For the 35 type of response, the bias current acting in a direction to space Relay A is fixed at 35 milliamperes. This relay will then respond to single-current signals in the operating winding and will be operated from the marking contact to the spacing contact from the instant the signal current falls slightly below 35 milliamperes for a spacing signal until the current rises slightly above 35 milliamperes on the following marking signal. Since the transit time and banking current of these relays are small and also are equal for either a mark-to-space or space-to-mark transition, the elapsed time between the two relay transitions is a measure of the pulse length between 35 milliampere points on the signal current wave form. This elapsed time as interpreted by the 35 type of response is shown in Figure 5-A.

For the 20-50 type of response, the bias current in Relay A has two distinct values prior to each signal transition depending upon whether the relay tongue is resting against the marking or the spacing contact. This change in biasing current is accomplished by means of tube T-3, the grid of which is driven by the potential existing on the tongue of Relay A. During a marking interval the bias current is 50 milliamperes. Upon the reception of a spacing signal, the current in the operating winding drops from the steady value of 70 milliamperes towards zero as shown in Figure 5-B. When the signal current has dropped to 50 milliamperes, the relay is operated from marking to spacing and the potential existing on the relay tongue reverses from positive to negative. This reversal of potential produces a slow transition of the potential on the grid of tube T-3 and causes the bias current to fall to 20 milliamperes. When a marking signal is received, the signal current rises toward the steady-state value at a rate depending upon the characteristics of the circuit being measured. When this current has risen to 20 milliamperes, Relay A will be operated from spacing to marking and the resulting reversal of potential will restore the bias current in the relay so that a transition on the next spacing pulse will take place at approximately 50

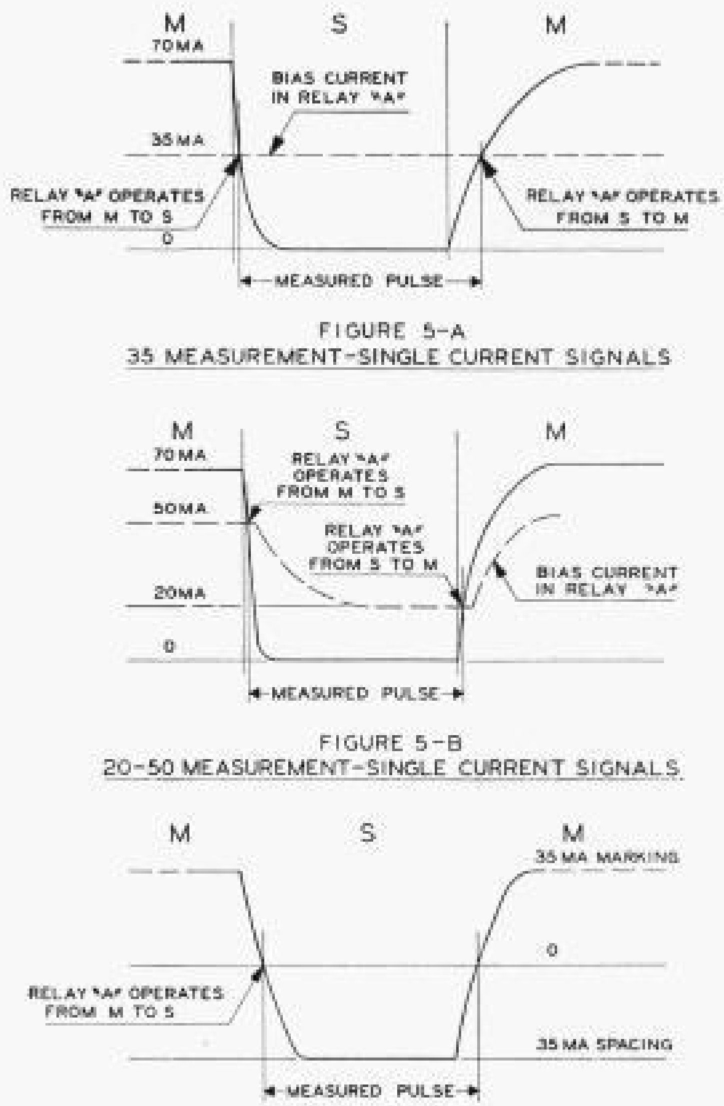


Figure 5. Input circuit response

milliamperes. Accordingly, a transition in the bias current takes place for each operating transition of Relay A. This transition in the bias current from one steady state to the other steady state is made gradual by means of the R-C network in the grid circuit of the tube so as to prevent false operation on some types of badly distorted wave forms.

Since the transit time and the banking current of Relay A are equal for either a mark-to-space or a space-to-mark transition, the spacing pulse as measured by the instrument begins when the signal current has dropped to 50 milliamperes, and ends when the current has risen to 20 milliamperes. Also, the measuring points on a spacing signal occur at points on the current wave near the beginning of the transition. Hence, the transition delay is usually very small as shown in Figure 5-B. Accordingly, the inductive and capacitive characteristics of circuits which may cause a difference between the rise and decay times of the signal current will not be interpreted as bias. Therefore, for all practical purpose, the 20-50 response is unaffected by wave shape and measures the actual time interval of the transmitted signals, whereas the 35 response may be influenced considerably by lack of symmetry in the signal wave shape.

Polar

The input circuit is arranged for the measurement of polar signals when the bias is removed from Relay A. Since the banking current of this relay is small, the relay will operate from one contact to the other close to the cross-over point of the signal current, resulting in the measurement of each unit length spacing pulse as shown in Figure 5-C. Accurate operating performance is secured over a wide range of signal currents, the minimum requirement for satisfactory performance being of the order of 15 milliamperes.

Pulse Stretching and Transfer Circuits

The instrument operates on the principle that all single-unit spacing signals will be measured and all other spacing signals as well as all marking signals will be ignored. Since unit signals can suffer distortion to the extent of 50 percent, which is the theoretical limit for operation without failure, single-unit signals

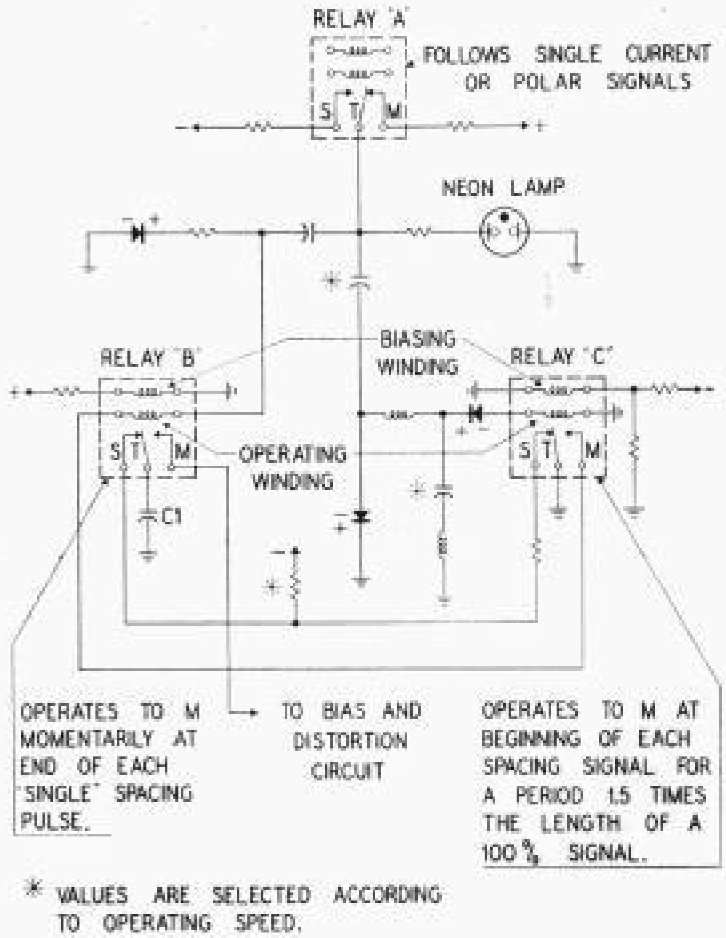


Figure 6. Pulse stretching and transfer circuits

less than 1.5 times unit length are measured. Signals longer than 1.5 times unit length are interpreted as two or more times unit length, which for measuring purposes are ignored. This is accomplished by means of the pulse stretching network used to drive Relay C and the transfer circuits as shown in Figure 6.

Relays B and C, which are biased to their spacing contacts, are used in conjunction with Relay A. Upon the reception of a spacing signal, the tongue of Relay A moves to the spacing contact and a pulse is transmitted through the pulse stretching network to the operating winding of Relay C. The network is such that the operating current in Relay C, Figure 7, rises rapidly to its peak value, is sustained at an intermediate value by resonance, after which it rapidly falls to zero. Relay C is operated for exactly 1.5 times the duration of a unit-length signal immediately following every mark-to-space transition of Relay A and irrespective of the time of occurrence of the subsequent space-to-mark transition. If Relay A returns to the marking contact after a spacing signal less than 1.5 times unit length,

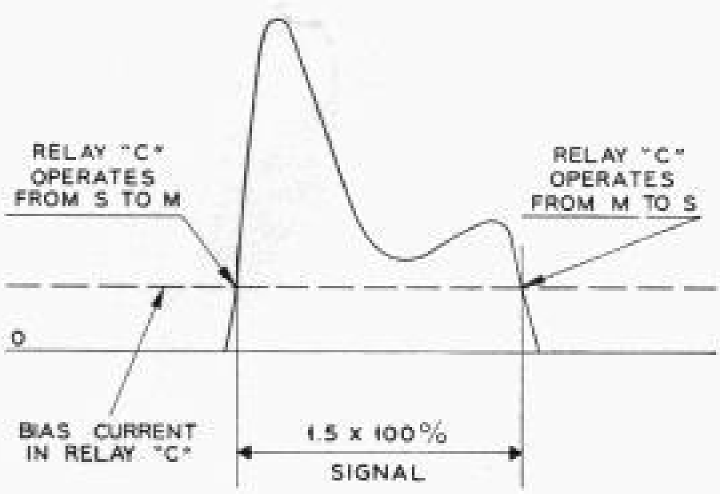


Figure 7. Operating current in relay "C"

Relay C will be on its marking contact. As a result, a pulse of short duration will be transmitted through the operating winding of Relay B which will momentarily operate this relay to the marking contact. During the period of time between the operation of Relay C and the momentary operation of Relay B to the marking contact, capacitor C1 has been allowed to charge using the initial portion of the exponential charging characteristic. The momentary operation of Relay B transfers this charge to the bias and distortion circuits where it is used as a measure of the signal duration in a manner described below. At the time of 1.5 units after Relay A has operated from marking to spacing, Relay C drops back to the spacing contact, regardless of the length of the spacing signal, and capacitor C1 is discharged.

In the case of spacing signals longer than 1.5 times unit length, Relay C is returned to the spacing contact before Relay A responds to the subsequent marking signal. Relay B does not operate and capacitor C1 is discharged without transferring its charge. Thus spacing signals shorter than 1.5 times unit length will transfer a charge to the bias and distortion circuits, and signals longer than 1.5 times unit length will be completely ignored. The sequence of operation of Relays A, B and C is shown in Figure 1.

Bias Indication

The circuit for bias indication is shown in Figure 8 in which a twin triode electron tube is arranged in a bridge circuit. The bias meter indicates spacing bias when deflected from the zero center to the left, and marking bias when deflected to the right. To one grid of the tube is applied a negative reference potential which is equal to the charge that occurs on capacitor C1 at the end of a unit length charging period corresponding to zero bias.

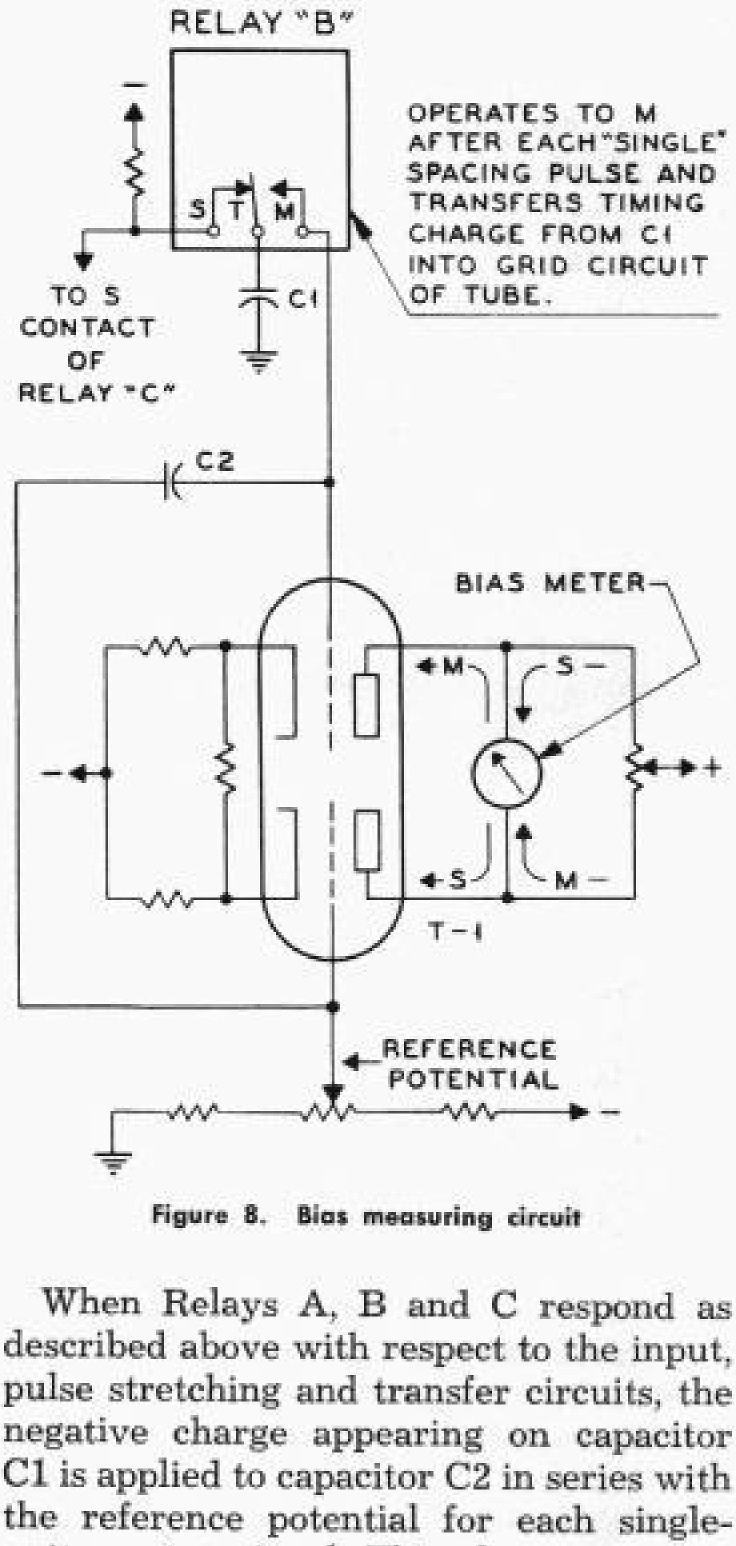


Figure 8. Bias measuring circuit

When Relays A, B and C respond as described above with respect to the input, pulse stretching and transfer circuits, the negative charge appearing on capacitor C1 is applied to capacitor C2 in series with the reference potential for each single-unit spacing signal. This charge, proportionate to the signal length in time, is then averaged in C2 which is large compared to C1. This process of averaging does not depend upon a leak for C2 but upon the principle that energy may be added or subtracted from C2 depending upon the length of the individual signal. The potential appearing on capacitor C2 is applied between the two grids of tube T-1. If the spacing signals are of unit length, the charge accumulated on C2 will be zero and the meter will indicate zero bias. When the spacing signals are shorter than unit length, the potential on C1 at the time of transfer by Relay B will be less than the reference potential and C2 will be charged in such a direction that the meter will indicate marking bias. When the spacing signals are longer than unit length, the potential on C1 at the time of transfer will be greater than the reference potential and C2 will be charged in the opposite direction so that the meter will indicate spacing bias.

Since the voltage rise on C1 occurs on a portion of the charging curve which is reasonably linear, the bias indication represents an essentially linear time variation in signal length which is read in percentage deviation from a unit-length signal on the bias meter. The indicated bias is independent of the signal combinations transmitted which may be repeated characters, test sentences, or miscellaneous traffic. However, the instrument does not function on characters like Blank, V, M, O, or T, which have sometimes been used for testing, or on other characters that do not contain a single-unit spacing interval.

Distortion Indication

The circuit arrangement for the instrument switched to measure distortion other than bias is shown in Figure 9. In this circuit, spacing and marking bias are ignored and the percentage deviation of any single-unit spacing interval which is shorter than the average of the single-unit spacing signals is measured with respect to the average. The circuit arrangement is essentially the same as described above for indicating bias except that the distortion meter has been substituted for the bias meter, a timing resistor and a diode rectifier T-2 have been added, and a small capacitor C3 which was formerly part of C2 has been switched from parallel to series with respect to C2. These compo-

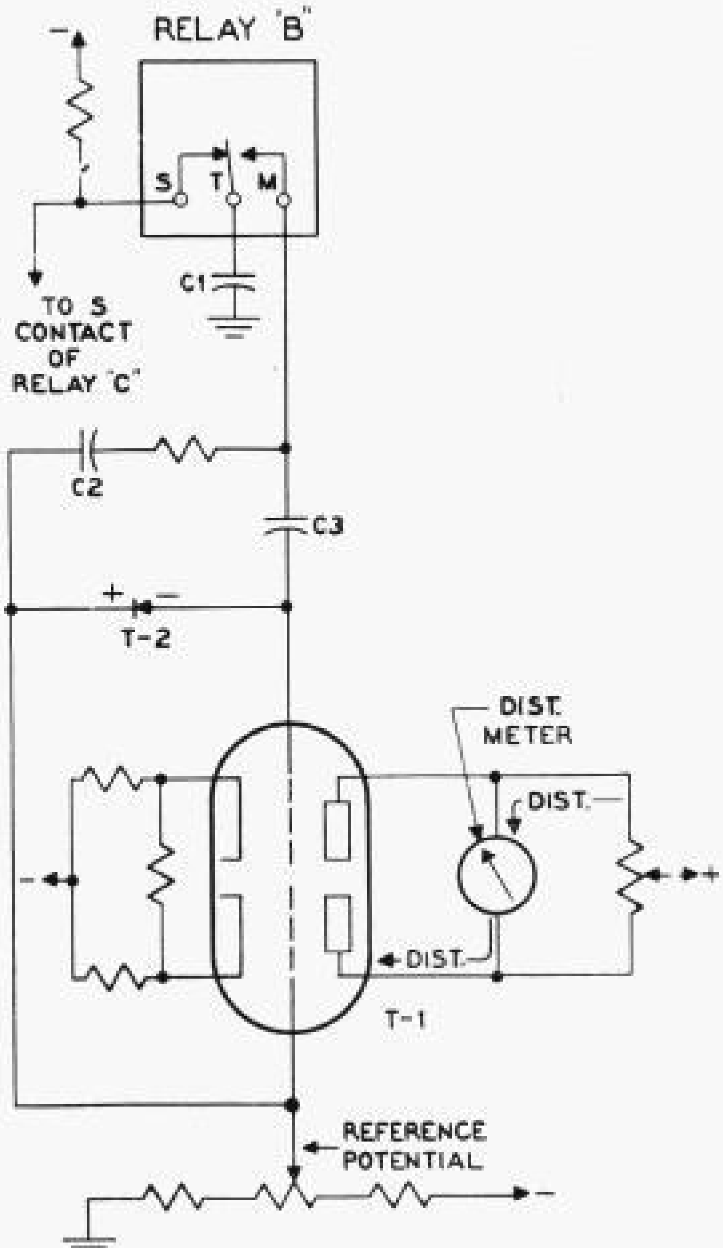


Figure 9. Distortion measuring circuit

nents are so arranged that capacitor C3 instantly recognizes a transfer of potential by Relay B that is less than the potential stored on C2 with respect to the reference potential. This occurs whenever a spacing signal shorter than the average has been received. When it occurs, capacitor C3 is immediately charged to the difference potential through rectifier T-2, and the distortion meter is deflected up scale in proportion to the difference. This charge is held on capacitor C3 by the rectifier so that the meter indicates a steady value. Normally this meter is arranged to drift slowly to zero. If a spacing signal still shorter than any previous signal is received, the meter will be de-

W. Dale Cannon, Assistant to Transmission Research Engineer, received a B.S. degree from the University of Delaware in 1918 and in July of that year enlisted in the Signal Corps. After the war, he joined the Engineering Department of Western Union, but left shortly thereafter to attend the Graduate School of the University of Illinois, where an M.S. degree was awarded to him in 1921. Returning to the Research Division of the company, he engaged in theoretical and mathematical work on such projects as ocean cable transmission, correction of inductive disturbances, and electronic amplifiers. Mr. Cannon was responsible for the company's earth current neutralizing system and its power interference correcting method. More recently he has contributed ably to the deep sea repeater equipment, a simplified telegraph repeating relay, the development of instruments for the measurement of telegraph signal distortion, and methods for the measurement and correction of envelope delay distortion. He is a Fellow of AIEE and a member of Subcommittee No. 13 of ASA Committee on Definitions of Electrical Terms.

flected to a new and larger percentage value.

For distortion measurement, it is necessary that some means be provided for resetting the distortion indication to zero at the end of each time interval of observation. In this instrument a special reset button is not required since the distortion meter is automatically set to zero by merely switching momentarily to the bias measurement condition.

Operation

The instrument is arranged for the measurement of bias and distortion other than bias on working circuits as well as on circuits where preferred test sentences or other test signals are transmitted at speeds of 61-65, 75, and 100 words per minute. The switching from one speed to another is accomplished simply by varying a resistor to alter the charging rate of capacitor C1 so that the accumulated charge is the same for all speeds, and by changing a capacitor of the pulse stretching network to keep the operating pulse of Relay C at 1.5 times unit length.

Since the input circuit of the instrument is arranged to include two types of response, the 35 and the 20-50 responses as described above, the instrument can be used as an indicator of wave-shape symmetry in single-current circuits, as well as to measure the bias and distortion on those circuits. For instance, if signals are transmitted over a circuit which possesses the correct proportion of inductance and capacitance, the bias meter will indicate the same bias for either the 35 or the 20-50 responses. However, this condition does not usually prevail. In a circuit having appreciable inductance and small capacitance, the time required for the current to decay to midvalue is less than the time of rise from zero to midvalue. The instrument indicates this difference as a spacing bias for the 35 response with respect to the 20-50 response. In a circuit where capacitance predominates, the opposite effect may be observed. When an appreciable amount of signal tailing is present, the time required for the current to drop to midvalue is greater than the rise time from zero to midvalue. In this case, the instrument indicates a marking bias for the 35 response compared to the 20-50 response. In general, a difference between the bias readings for the two responses can be interpreted as an indication of poor wave shape. The reading obtained with the 20-50 response is always the better indication of the true bias because it measures the timing of the signals almost independently of their wave shape.

Since excessive bias or distortion may be caused by the transmitting equipment as well as by line circuit conditions, the instrument is very useful in determining the condition of signals delivered by transmitting keyboards, distributor-transmitters, or regenerative repeaters. Faulty operation of a defective segment or cam is detected by transmitting different characters repeatedly and observing which single-unit spacing pulses cause excessive bias or distortion readings.

In the routine use of the instrument, measurements are made at both ends of a circuit in order to evaluate the over-all transmission and detect faulty equipment, poor wave shape, or bias and distortion due to line circuit conditions. The accuracy of the instrument in indicating bias percentage is approximately ± 1 percent and slightly less for distortion indication. While this accuracy exceeds the requirements for general application in the field, it is a practice to maintain the calibration of the bias indication so that the readings are never inaccurate by more than 1 percent.

LABORATORY FREQUENCY MEASUREMENTS

In the early days of telegraphy, when useful frequencies were low, it was quite practical to run off an undulator tape for a timed period, count the cycles of oscillation marked by the pen, and thus obtain the indicated cycles per second by direct methods.

With the introduction of carrier telegraphy, however, the frequencies of interest rapidly passed out of the range of mechanical vibration, leading to frequency measurement by inference from the resonance point of known inductance and capacitance or by comparison with a known auxiliary frequency, often through the use of Lissajous figures on a cathode-ray oscilloscope. These secondary methods of frequency determination were often laborious and always subject to error, particularly where small frequency changes were of importance. As the science of electronics continued to develop, particularly that branch devoted to methods of rapid computation, pulse-counting methods were evolved which could perform at rates hitherto beyond the imagination.

The instrument pictured here utilizes computer-type counting components to return the determination of frequency to direct methods. Timed by a quartz-crystal controlled "gate" of high short-period accuracy, this device actually counts the number of pulses of voltage that occur within a short time interval, indicating the total on a register. The counts can be repeated by automatic recycling if desired. Intervals can be selected between one millisecond and ten seconds to obtain a reasonable number of counts for the frequency being measured, or the "gate" can be opened manually for long-period counting, where required.

This modern instrument employed in Western Union research laboratories has exerted important influence in the design of FM telegraph apparatus where high accuracy in small frequency-deviations is mandatory.—Fred Cofer, Assistant Coordinating Engineer.

A Simplified Telegraph Switching System Plan 111-A

T. S. PESSAGNO

THE PRESENT tendency in large business enterprises is toward decentralization of their many operations. As a result, departments that handle administration, engineering, manufacturing, warehousing, accounting, and sales may be scattered over a wide geographical area. Certain functions, such as administration and accounting for instance, must of necessity be in close contact with all branches, and this contact can best be maintained by means of a private wire communications network which serves not only for the interchange of telegrams but also as a means of collecting data to be processed through automatic accounting machines, and similar services.

Western Union, because of experience gained through design and operation of its own message handling facilities, is uniquely qualified to design and develop efficient and economic systems for individual customers' requirements and traffic loads. The more elaborate systems developed by Western Union, such as Plans 51 and 54, are suitable for the patron who has a large message load; but small companies with smaller budget allotments for communication requirements also must be served. One of the systems developed for their use and compatible with other Western Union systems, known as Plan 111-A, is described in this article.

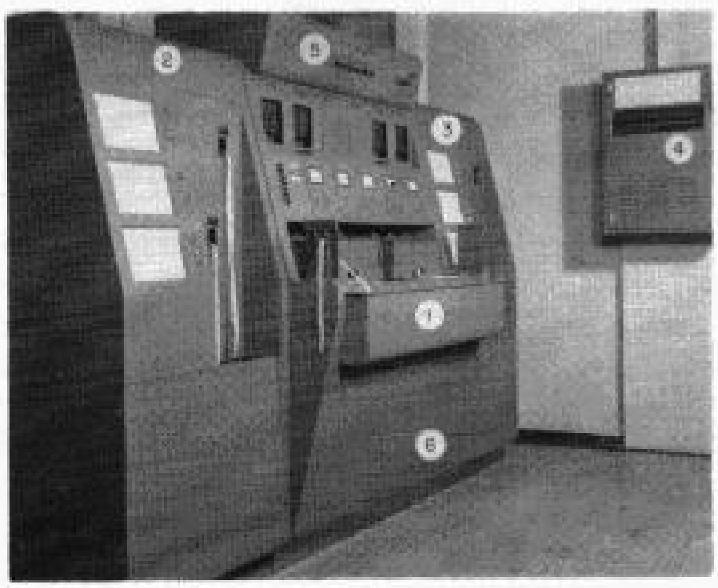


Figure 1. Typical small installation of Plan 111-A switching center

1. Transmitting Console 6984-A
2 and 3. Receiving Console 6982-A
4. Switchboard 7136-A
5. Master Send Turret 7484-A
6. Door to sent tape compartments

Figure 1 illustrates a typical small installation of a Plan 111-A Switching Center with a Transmitting Console 6984-A flanked by two Receiving Consoles 6982-A, and Switchboard 7136-A. Master Send Turret 7484-A is shown mounted on the top of the console with the numbering machines and associated control panels located below in two rows within the console proper.

Equipment Design

In this system relatively costly push-button switching and relay equipments are dispensed with and in lieu thereof a telegram is switched by tearing off the coded perforated tape from the printer-perforator on which messages are received and manually placing the tape in a transmitter serving the destination to which the message is addressed. The design of the Plan 111-A system is such as to permit the patron to select minimum equipment consistent with his immediate requirements for a reperforator switching center and, at a later date, to add certain desirable operating features and safeguards found in the larger and more elaborate systems. The sending and receiving apparatus is mounted in separate consoles which contain all of the equipment needed to perform the services for which they were designed, and which will facilitate future additions to increase circuit handling capacity of the switching center. Circuits terminated in the switching center may be operated single or duplex or a combination of both.

Fundamentally, a Plan 111-A Switching

Center requires a receiving console, a transmitting console, and a switchboard. The receiving console mounts three receiving positions placed one above the other in order to conserve operating floor area and to reduce to a minimum the amount of movement required of the operating personnel. The Printer-Perforators Type 39-A used as receiving devices are mounted on individual drawer slides so that they may be pulled out at the rear of the console for servicing and retaping, and are positioned to permit the perforated message tapes to flow out the front of the console without interfering with one another. The consoles have been provided with individual number sheet holders, LOW TAPE lamps, LINE SIGNAL lamps and MANUAL TAPE FEED switches for each of the receiving positions. A built-in tape basket serves to catch message tapes as they flow out of the console. Power rectifiers are included to supply the necessary direct current for operation of the signalling apparatus.

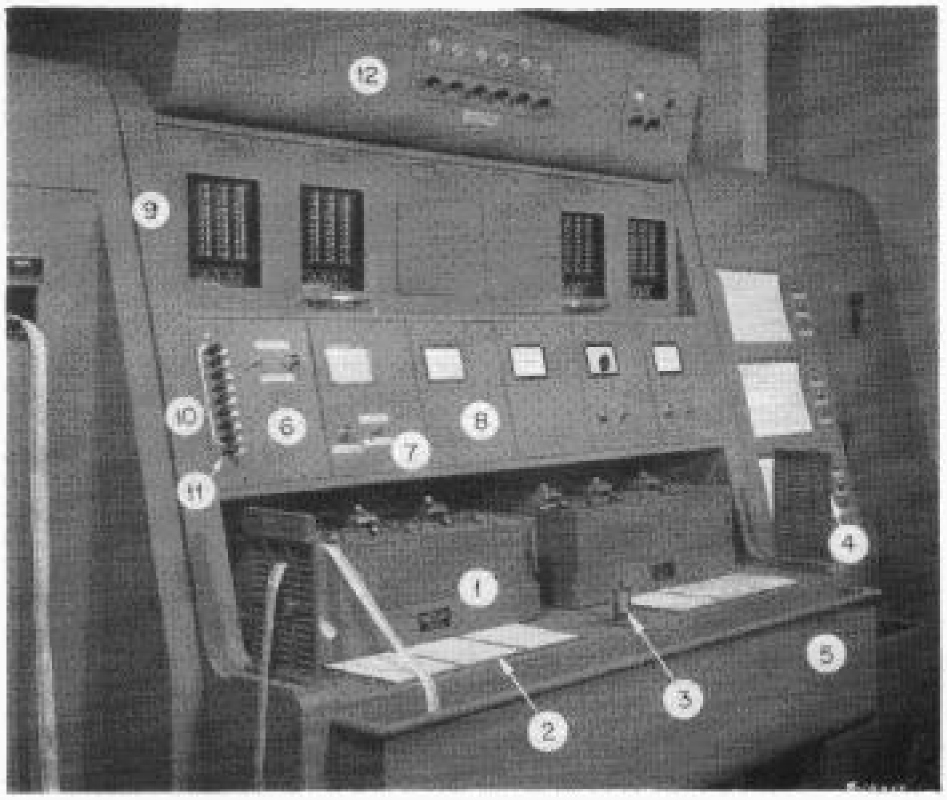


Figure 2. Close-up of operating section of transmitting console

1. Multiple Unit Transmitter-Distributor MXD-16
2. Number sheet holder
3. Tape editor
4. Tape holder
5. Tape trough
6. Way-station circuit
7. Trunk circuit
8. No numbering circuit
9. Numbering machine
10. Station selector push buttons
11. Release push button
12. Master send turret

Figure 2 is a close-up of the operating section of the transmitting console which mounts six sending positions. Transmission of messages is accomplished using a Multiple Unit Transmitter-Distributor Type MXD-16. Three transmitter-distributors are mounted on a common subbase, MXD-19, equipped with one motor and common drive shaft. The mechanical and electrical arrangement is such that operation of each transmitter-distributor is independent of that of the others on the common subbase. Two of these 3-gang units are mounted on the console to supply the necessary number of transmitter- distributors for the six circuits terminated.

In addition to the above, the console mounts number sheet holders, a tape editor, tape holders, and a tape trough used to hold message tapes while they are in process of transmission. A "sent tape" bin (see Figure 1) accessible from the front of the console and divided into six compartments has been provided to catch sent tapes. A power rectifier is included to supply the necessary direct current for operation of the signalling circuits.

The tape editor is a device for punching a notch in the upper solid edge of a perforated message tape. The notch permits a tape sensing pin in the transmitter-distributor to operate and stop further operation of the transmitter-distributor beyond this point. The tape editor can be used to stop transmission at any point in the message for insertion of omitted characters or additions within the message.

The first control panel is for a way-station circuit with automatic station selection and automatic message numbering. The second control panel represents a trunk circuit, either single or duplex operated, and equipped with automatic message numbering. The third and fourth panels represent such circuits without numbering, and the fifth and sixth panels are similar to the second. On the shelf are located the two 3-gang transmitter-distributor units; Figure 3 is a close-up of these units, showing the method of placing the tape in the transmitter.

The switchboard shown in Figure 1 is used for terminating wire facilities and equipment legs on a normally cordless basis. The jack circuits are arranged to permit interchange of wire facilities and of operating equipment without physically moving the equipment from the position, a feature which permits emergency swapping of apparatus by operating personnel. On single two-way operated circuits equipped with home copy suppression and electronic control of the switching center transmitter, the jack circuit is arranged to maintain these features on equipment exchanged by means of the switchboard.

The switchboard is also equipped with terminal blocks for terminating switching center equipment and the switchboard jack circuits. Interconnection between the various operating units and the switchboard jack circuits is effected by cross-cutting on the terminal blocks.

Operation With Minimum Equipment

Where installations are made calling for minimum equipment, messages are terminated by transmitting five blanks, a letters shift and five more blanks, giving the operator at the switching center a tear-off point in the tape for separating the messages from the printer-perforator. Messages which are hung up in the printer-perforator because of failure on the part of the outstation operator to provide the tear-off point, or for other reasons, can be fed out by depressing the manual tape feed button and releasing it after a sufficient amount of tape has been fed out. The circuit employed for manual tape feed when minimum equipment is used will cause interference to incoming signals while the tape feed switch is held operated. However, a noninterfering type of circuit is available and will be described.

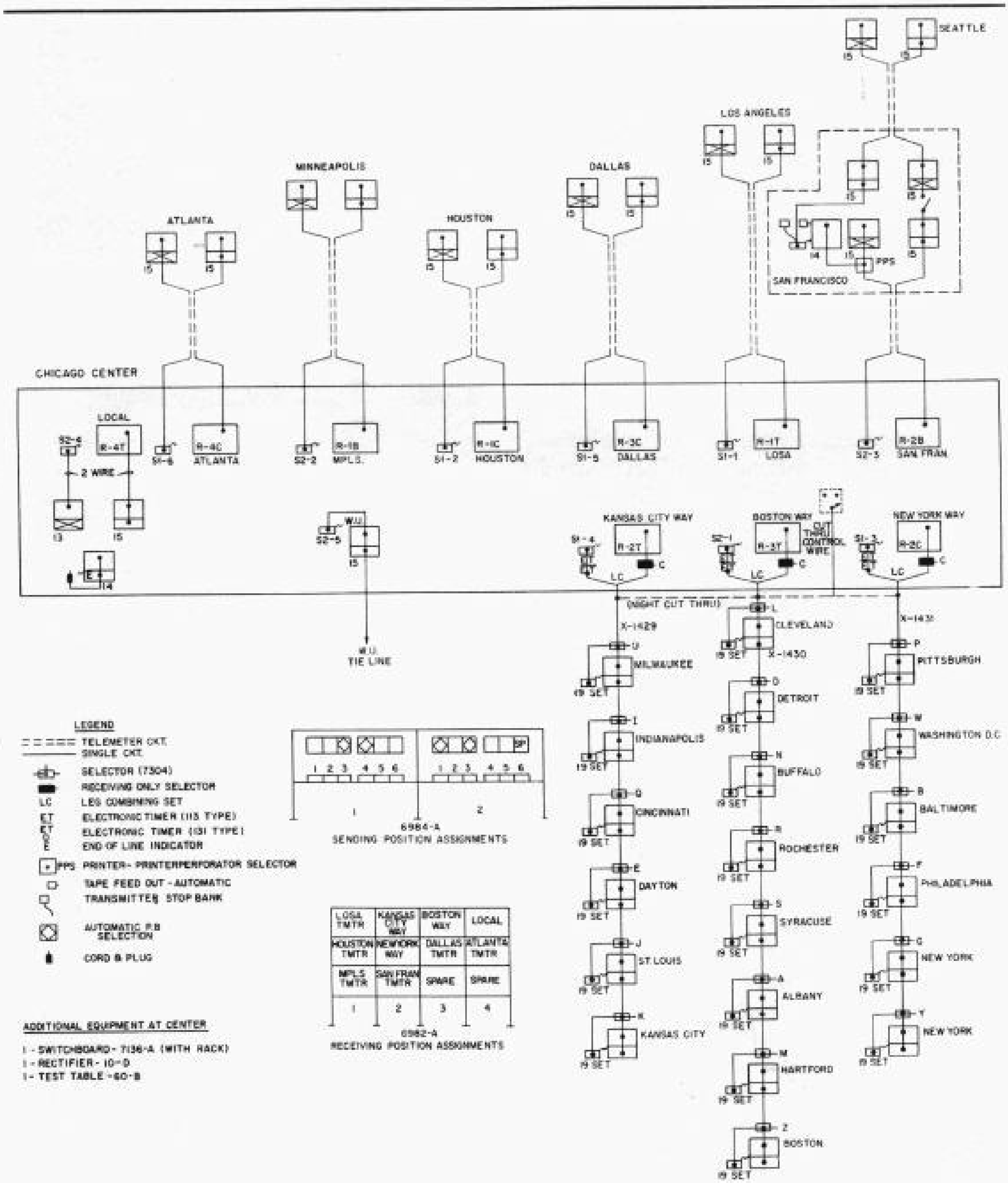
Switching of a received message is accomplished merely by noting the destination of the message at the beginning of the message tape and inserting the tape in the transmitter serving that destination. The tape is inserted by depressing a feed wheel release lever located on the transmitter, inserting the tape under the tape retaining lid, then releasing the lever. Releasing the lever completes the transmission initiate circuit and starts transmission of the message to its destination. If desired, start of transmission may be delayed by locking the feed wheel release lever in its down position, which is done by exerting a slight forward motion to the lever in the depressed position. This feature is necessary on single two-way operated circuits during times when an outstation is sending to the switching center. Transmission may be started at any time by exerting a slight back motion causing the lever to unlock. Partially transmitted or mutilated tapes may be removed from the transmitter by lifting the tape retaining lid.

Figure 3. Multiple unit transmitter-distributor

Although such a simple center is easily workable, most customers desire safeguards against lost messages, transmission of the same message over many circuits, home copy suppression of outgoing transmission on single two-way operated circuits, individual station selection on way-station circuits, and similar refinements. To afford these refinements, the following features are available and may be added as required.

Automatic Tape Feed and Other Controls

The receiving circuit can be equipped to provide automatic tape separation between messages by the addition of control relays. Automatic tape feed is accomplished by a circuit actuated by terminating each message transmitted with the code combination CARRIAGE RETURN, CARRIAGE RETURN, LETTERS. The tape feed cycle may also be initiated manually by momentarily depressing and releasing the manual tape feed switch provided for this purpose. The design of the circuit causes instant cutoff of the tape feed, whether initiated automatically or manually, without causing mutilation of any character of an incoming message which starts before the normal tape feed cycle has stopped. The amount of tape fed



Network of typical switching center Plan 111-A now in operation.

during any one cycle is the same and is adjustable within limits.

For single two-way operated circuits, facilities are available to provide home copy suppression of transmission from the switching center and electronic control of the switching center transmitter. The latter functions to delay start of transmission of a message tape inserted in the associated switching center transmitter whenever an outstation is using the line. The electronic control functions automatically to start the transmitter when the line becomes idle, without further action by the switching operator.

"Flip-Flop" Transmission

For heavy circuit assignments, the first two transmitters of each 3-gang transmitter-distributor unit may be arranged to alternate their transmission to the same circuit automatically. This feature may be obtained by the addition of a control relay and is limited to single and duplex trunk operation. Message tapes may be placed in either or both transmitters without preference. Operation of the circuit is such that the transmitter tape loaded first will be the first to start.

Station Selection

Way-station circuits may be selector-operated to permit messages to be copied only by the station to which addressed. This feature is obtained by installation of a selector and assignment of a particular call letter at each of the outstations in the circuit. In this method of operation, all outstation teleprinter motors are stopped during idle line periods. Operation of the teleprinter motors occurs at all outstations during the selecting cycle and at the individual station only during message transmission or reception.

At the switching center, the associated sending position requires the use of an Electronic Timer 131-B, a Way-Station Control Panel 7344-A, and either a Call Letter Sending Unit 7324-A or an Automatic Message Numbering Machine 7298.2-A, depending on whether the circuit is equipped with automatic station selection or both automatic station selection and automatic message numbering.

Where requirements call for automatic station selection only, the sending position at the switching center is equipped with an Electronic Timer 131-B, a Way-Station Control Panel 7344-A, a Call Letter Sending Unit 7324-A, and a Distributor 227.

The call letter sending unit is operated in conjunction with the distributor and is arranged to transmit eight fixed call letters, namely, A, D, H, L, N, R, S, and Z in the sequence listed or, in their place, the letter X. The cycle is then completed by transmission of a SPACE function. A letter is assigned to each one of the outstations served by the same way-station circuit and represents that station as well as a call letter position during the selecting cycle. During that cycle, the sending unit is made to transmit one or more call letters representing the stations desired, and the letter X in place of the call letters of the unwanted stations, followed by a SPACE function. For example, if a message is to be directed to the station represented by the letter H, then the unit will be conditioned to transmit XXHXXXXX followed by a SPACE. Thus limited protection against lost messages is obtained by giving the individual stations a call letter as well as a call letter position in the selection sequence. The same call letter sequence is used for stations contained in other way-station circuits, and a maximum of eight stations may be connected into any one circuit.

Conditioning of the call letter sending unit to transmit the desired station call letter and the letter X for each unwanted station is accomplished by means of a push-button switch located on Way-Station Control Panel 7344-A. The push-button switch consists of eight lock-in type push buttons and a common release button. Each button is assigned one outstation represented by the call letters previously mentioned. A push button once depressed remains in that position until released by the release button. A push button in its depressed position conditions the call letter sending unit to transmit the call letter represented by it, and in the released position conditions the call letter sending unit to transmit the letter X. Simultaneous transmission of a message may be made to more than one station in the same way-station circuit by depressing as many push buttons as required. Subsequent station selections can be made by first operating the release button in order to clear out the previous selection pattern.

Switching of messages to stations contained in a way-station circuit is performed by depressing the appropriate push button on the control panel serving the station of destination, then placing the message in the associated transmitter. Release of the feed wheel release lever after inserting the message tape into the transmitter starts the operation by calling in all stations, transmitting the call letter of the desired station and the letter X for the unwanted stations, followed by a SPACE function. The SPACE function releases the unwanted stations and transmission of the message to the station of destination follows. Associated with each individual station selector is an electronic timer which prevents interference from released stations during message transmission from or to the switching center. The electronic timers function to "unbusy" the line a brief period after termination of transmission in either direction.

Automatic Message Numbering

As a convenient means of identifying all telegrams, as well as a safeguard

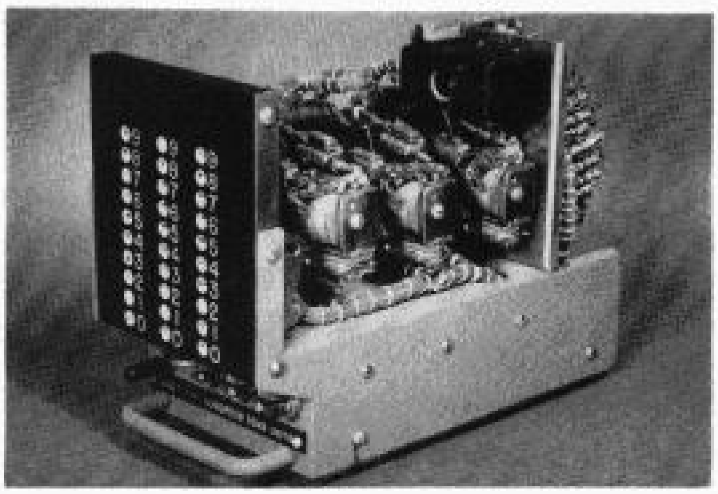


Figure 4. Automatic message numbering machine

against lost messages, the transmitting circuit can be conditioned to transmit a number sequence together with other fixed identifying characters for every message sent from the switching center. This feature is obtained by the addition of an automatic message numbering machine (Figure 4) and associated apparatus. The automatic numbering machine used is similar to the Type 7014 described in the October 1954 issue of TECHNICAL REVIEW.

The numbering machine is operated in conjunction with a distributor to transmit the office call, channel letters or other identifying characters, together with consecutive numbers from 1 through 999. Features include a fast reset circuit, individual switches for rapid setting of the hundreds, tens, and units digits, a coding socket, and a direct-reading register panel which, by means of neon lamps and appropriate marking, indicates the sequence number of the last message transmitted.

For trunk circuit operation, a Type 7014-A Automatic Message Numbering Machine is used in conjunction with a trunk circuit control panel and coding plug. The coding plug is wired to set up the code combination corresponding to the office call and channel letter for the particular circuit assignment; the coding plug is then inserted into the numbering machine coding socket which conditions the machine to transmit these characters ahead of the number sequence for each message transmitted.

For way-station operation, Automatic Message Numbering Machine 7298.2-A is used in place of Call Letter Sending Unit 7324-A when the circuit is to be equipped with automatic message numbering as well as automatic station selection. One numbering machine is used for this purpose and the number sequence is shared by all stations in the same circuit. However, each number is preceded by the identifying call letter of the station of destination, in the same manner as is done using the Call Letter Sending Unit 7324-A. All stations are made to copy the number sequence and the selection letter sequence before the unwanted stations are released from the circuit by the SPACE function transmitted after the selection and message number. This arrangement permits all stations to maintain a running record of the message numbers and reduces the cost for providing this feature.

Control panels associated with circuits provided with automatic message numbering are equipped with an omit number switch and associated indicating lamp. The switch is used to disable the numbering machine temporarily when test tapes or BUST THIS notices are being transmitted.

Master Sending

When the transmitting console is equipped with Master Send Turret 7484-A, it makes possible the setting up of a master send pattern to any combination of stations contained in the six circuits terminated in the transmitting console, regardless of the type of circuits terminated; i.e., single, duplex, or way-station.

A regularly assigned transmitter is used for this purpose and the individual number sequence and automatic station selection is maintained. Once the master send pattern is set up, the master message tape placed in the transmitter, and the master send push button depressed, the circuit functions automatically to seize the circuits as they become "unbusy", call in the desired stations, transmit the individual circuit number sequences, release the unwanted stations, and transmit the message.

Message tapes intended for transmission over the individual circuits may be placed in transmitters other than the transmitter being used for the master send function. The transmission of these messages will be held in abeyance until the master transmission is completed, when the master send circuit will function to return the circuits to normal and automatically start processing the tapes placed in the individual transmitters.

Plan 111-A Switching Centers are readily adaptable to minor modifications in order to satisfy special requirements of the user. Some of the special features which have already been incorporated in these systems include cut-through arrangements of circuits to permit direct conversation between stations on different circuits, transmission of tabulated messages, and selector control of switching center receiving equipment. The latter feature permits communications between stations contained within the same way-station circuit without producing a copy at the switching center.

T. S. Pessagno entered the employ of the Postal Telegraph-Cable Company in 1925 as a messenger and later served as Morse and multiplex operator and T&R attendant, while pursuing his engineering studies at Brooklyn Polytechnic Institute. He was subsequently appointed Installation Supervisor of the Eastern Division and later transferred to the Engineering Department. When Postal merged with Western Union, Mr. Pessagno was assigned to the design of assemblies for use in Reperforator Switching Systems Plans 20 and 21. During the second World War he taught in the Evening School of Engineering at Pratt Institute. On the staff of the Patron System Engineer, P&E Department, he designed the Plan 111-A Patron's Switching System described in the above article and is at present working on the design of the Plan 51.5 Switching System.

Dry Cell Testing

PROFESSOR MORSE, when he set up his Washington-Baltimore telegraph circuit in 1844, was compelled to use batteries in which chemical reactions gave a continuing release of electric energy to provide telegraph current. There was then no alternative. It may seem surprising that primary batteries still maintain an important position among the most modern developments of power distribution and communication systems.

The dry cell, a form of primary battery, is widely used by all communication and power companies. Western Union, for example, uses about 75,000 No. 6 dry cells and about the same number of size D flashlight batteries each year. The No. 6 cells perform many duties. Some are used in lanterns, some operate signal buzzers and bells, some are used for ignition purposes on small motor car engines and so on. By far the larger portion, however, are hidden away in the self-winding clocks which are publicly associated with Western Union "Everywhere." Here they keep the clocks wound continuously to a spring tension best suited to accurate timekeeping; they rarely fail before their appointed time; and they are clean and orderly in their habits.

Almost from the initiation of the Telegraph Company's Engineering Department, performance tests of dry cells have been carried out each year, and the results have furnished the guide posts by which the Company has been able to purchase the type of cells which give the most dependable and the most economical service.

Marked Improvement Noted

It is interesting to know that, in the last 30 years, the energy which may be drawn from a premium No. 6 cell has been increased nearly 100 percent, that cells can be built to stand much longer storage or shelf time without serious deterioration, and that quality control has been greatly increased both as to material and processing. New suppliers enter the field occasionally and the manufacturer continuously strives to improve his products. The Telegraph Company undertakes to keep informed as to the changing quality of batteries so that likely service life of various manufacturers' products can be anticipated and considered along with price when purchase contracts are to be placed.

To this end sample lots of batteries are obtained at the beginning of each calendar year. These are placed in test racks where they are subjected to a program of discharge-rest cycles approximating but somewhat more severe than the actual duty cycle to which field service will subject the cells. The tests made resemble those recommended by the U. S. Bureau of Standards but differ in the programming to accord more nearly to the company's expected use.

Western Union's No. 6 cell test is based on the expectation that the batteries will be used in clock-winding service in which the cells are called on to deliver a current averaging about 0.150 ampere during about 30 seconds each hour.

Test Procedures

In the case of No. 6 dry cells, the test cycle on which most dependence is put places a 5-ohm load across each cell for 30 seconds after which the cell is allowed to rest for 59 minutes, 30 seconds. The cycle is repeated without intermission until the cell voltage falls to one volt under load. Premium batteries can be expected to remain on this test for two years or more.

To obtain earlier indicative data, a series of accelerated tests are begun at the same time on other samples. One doubles the discharge rate, one doubles the number of discharge periods, and the last subjects the cell both to the doubled discharge rate and doubled number of discharge periods. These tests are not considered sufficiently dependable as a criterion for clock-winding cells. They do give basis for some judgement of new types of batteries, and they are useful in judging how the long-life batteries will perform in the more severe uses to which they may be put.

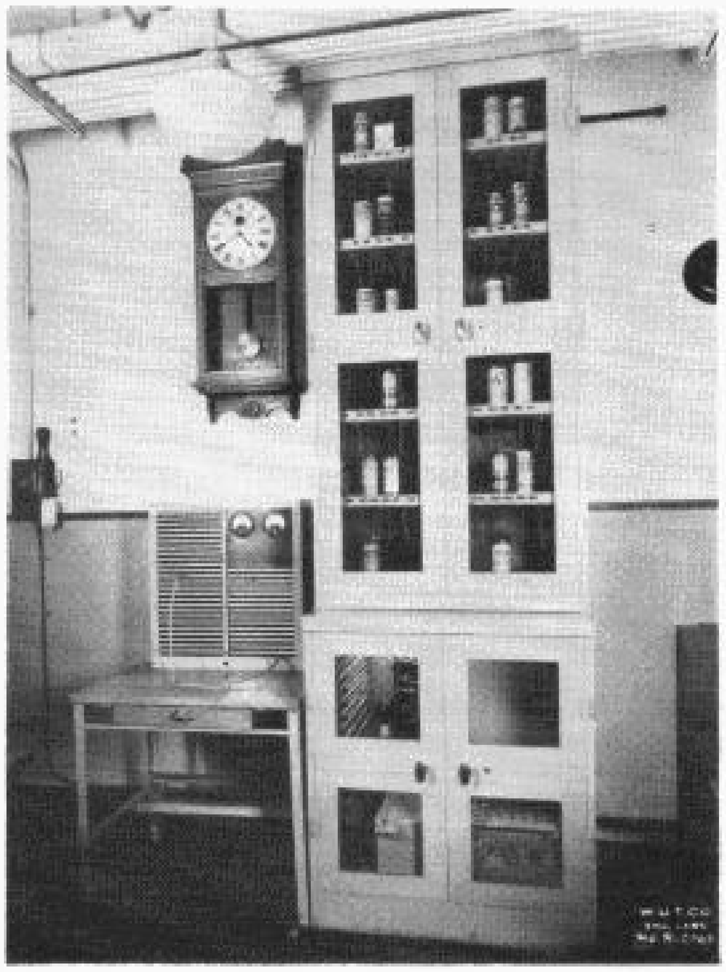
Usually four cells of each type are subjected to each test. Initial open-circuit voltage and voltage under load are recorded and periodic recordings of load voltage are made thereafter until the end of the test.

Flashlight batteries are subjected to an intermittent program in which a regular cycle is maintained throughout the normal laboratory hours. Under this schedule, the cycle is 5 seconds of discharge into a 4-ohm per cell load followed by a 55-second rest period and is repeated for 10 hours followed by a 14-hour rest period. This schedule obtains from 8 a.m. Monday until 6 p.m. Friday. The cells rest thereafter until 8 a.m. Monday. No accelerated test is made. The cells are tested in series groups of three, with a 12-ohm combined load and 12 cells of each type are taken as a sample. The batteries remain on test until the load voltage of each group falls to 2.25 volts. Frequent readings of voltage under load are made. In summation of the results, the elapsed time until this voltage is reached is of particular interest as it represents about as low a voltage as will serve in normal use. Weight is given also to the ampere-hours delivered during the test life as this is a fair measure of the flashlight brilliance which may be expected during the use of the cells.

Test Apparatus

The test equipment is concentrated into a relatively small floor area and comprises a cabinet for housing test relays and load resistors and all batteries undergoing test, and a test table having a jack panel turret at which connection to each cell can be made for test. The accompanying photograph shows the equipment exterior.

The jack panel has a total of 400 test jacks, of which 300 are associated with a like number of No. 6 cell test positions and 98 connect to that number of flashlight cell positions. One of the remaining jacks is



for attachment of the test cord for No. 6 cells and the other for attachment of the test cord for flashlight cells. These are separated, as a voltmeter multiplier must accompany the flashlight test. The left of the two meters at the top of the turret has a suppressed zero and is calibrated in volts from 0.7 to 1.7 with a 50-line scale so that readings within this one-volt range can be estimated accurately to the nearest 1/100th volt. The voltmeter is used for all tests and readings of open circuit voltage and load voltage may be taken.

The milliammeter at the right has a full scale deflection of 500 milliamperes. Operation of the push button at the bottom center of the turret applies the load to the battery under test. In tests of flashlight batteries, it puts the milliammeter in series with the load so that discharge current may be read. — A. Atherton, Ass't to Equipment Research Engineer and N. D. Hovagimyan, Engineer, Equipment Research Division.

A Transistorized Radioteletype Converter

OSCAR E. PIERSON

THE FUNCTION of a radioteletype converter is to derive a d-c signal suitable for operation of teletype printers from a frequency-shift-keyed radio signal. The converter herein described operates from the intermediate-frequency output of a radio communications receiver. *A novel feature of this converter is that all active functions are performed by means of transistors.* The converter was developed for the Signal Corps and is an outgrowth of an earlier model constructed in their laboratories.

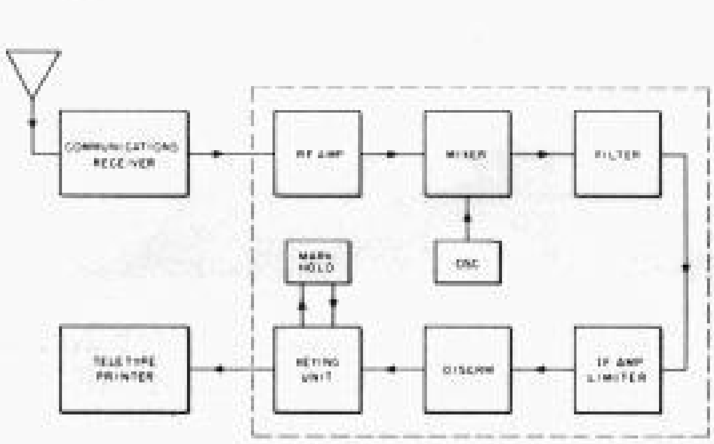


Figure 1. Radioteletype converter—block diagram

A block diagram of the converter circuit arrangement is shown in Figure 1. It should be noted that the components are substantially the same as those of an FM receiver. The output of the IF amplifier of the communications receiver is connected to the RF unit of the converter through a 70-ohm coaxial line. The RF unit is a tunable amplifier designed to cover the band from 450 kc to 510 kc. Its output is connected to the mixer-oscillator unit in which the signal is combined with that of a local oscillator to produce a new intermediate frequency of 29.3 kc.

The output of the mixer-oscillator unit passes through a band-pass filter which suppresses all frequencies outside a band 1000 cycles wide centered on 29.3 kc. Following the filter is the IF unit in which the signals are amplified and limited to the required power level. The discriminator unit then converts the frequency-shift modulated signal into positive and negative impulses corresponding to the marking and spacing impulses of teleprinter transmission.

The keying unit is operated by the impulses from the discriminator. It may be compared to a polar relay whose contacts open and close a d-c circuit to the selecting magnet of the receiving teleprinter. The mark-hold unit associated with the keying unit automatically causes the circuit to the printer to be closed whenever there is no input signal to the converter or if a spacing signal persists over an interval somewhat longer than occurs during normal operation. It is instantly disabled when intelligence-bearing input signals are received.

Before describing the actual circuits of the converter some general characteristics of transistor circuitry will be discussed briefly. Since the converter was required to operate from a single 26-volt d-c supply, it was necessary to arrange all circuits so that collector and emitter d-c biases could be obtained from this single source. The negative of the d-c supply was considered "ground" and was physically connected to the chassis.

Both junction and point-contact transistors were used, the junction type for low signal level applications and the point-contact type where considerable output power was required. Two junction types were used. Both have practically identical characteristics and were considered to be interchangeable. Junction types were used wherever possible due to their inherent open-circuit and short-circuit stability, greater gain and lower noise factor. Two point-contact types were used. In general, the grounded emitter orientation was found most suitable due to its higher gain characteristics and lower out-

A paper presented before the Symposium on the Application of Transistors to Military Electronics Equipment, held at Yale University, September 1953.

put to input impedance ratio. This orientation also lends itself somewhat more readily to the application of emitter bias when only one potential source is available.

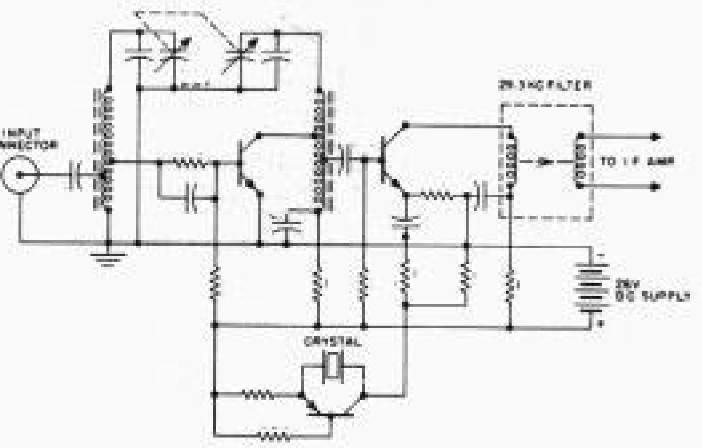


Figure 2. RF amplifier and mixer-oscillator unit—circuit diagrams

The circuits of the RF amplifier and the mixer-oscillator unit are shown in Figure 2. The signal received by the converter is transmitted from some distant sending station over a carrier whose center frequency may be, for example, 3 mc. The carrier is frequency-modulated by the sending teleprinter in such manner that the marking and spacing intervals of the teleprinter signals produce frequency shifts which are centered about the nominal carrier frequency. The converter is designed to operate with shift frequencies of from 150 to 1000 cycles. Thus, if a shift frequency of 1000 cycles were used in the above illustration, during marking intervals the transmitted frequency would be 3 mc plus 500 cycles and during spacing intervals 3 mc minus 500 cycles. This signal when received by the communications receiver is shifted to a much lower position in the spectrum and, after further amplification, is used as the input signal for the converter. The new center frequency may be anywhere in the band from 450 kc to 510 kc.

The RF unit is a single-stage amplifier using a junction transistor. The input and output inductors are tapped to provide proper impedance match and are tuned by ganged condensers. Additional fixed capacitors and trimmers permit adjusting the tuning range to cover the 450-kc to 510-kc band. For purpose of illustration it will be assumed that the center frequency is 455 kc and that a 1000-cycle shift frequency is used. The signal will then consist of successive intervals during which the frequency is alternately 455.5 kc and 454.5 kc depending upon the sequence of marking and spacing unit intervals in the teleprinter transmission.

The converter is designed to provide satisfactory output with input signal levels of from 0.14×10^{-6} milliwatts (approximately -69 dbm) to at least -4 dbm. At levels from -69 dbm to about -30 dbm the RF amplifier has a gain of approximately 12 db throughout its 1-kc pass-band. Above the -30 dbm level the amplifier is overdriven, i.e., collector current varies between saturation and cutoff, and the output remains substantially constant.

The mixer-oscillator unit consists of a junction transistor as the mixer element and a point-contact transistor for the local oscillator. The oscillator frequency is controlled by a quartz crystal connected between collector and emitter. The crystal operates at its series-resonant frequency and furnishes sufficient positive feedback so that it has full control of the oscillator frequency. Since the crystal is the only resonant element associated with the oscillator, it is necessary merely to change the crystal to obtain any other desired frequency. The particular crystal used is one whose frequency is 29.3 kc below that of the center frequency of the input signal. With the assumed 455-kc input, a 425.7-kc crystal would be used.

As shown in Figure 2, the output of the RF unit is connected to the base of the mixer transistor and the output of the oscillator is connected to the emitter. After investigating several alternate methods of signal and oscillator injection, this was found to be the most satisfactory one. The filter in the output circuit of the mixer transistor has a center frequency of 29.3 kc and a pass-band of 1000 cycles at the -3 db points. This filter provides adequate rejection of all unwanted frequencies appearing in the mixer output. Since the pass-band of the filter is much narrower than that of the intermediate-frequency amplifier of the communications receiver, considerable noise rejection also is obtained. Furthermore, since the only effect of noise is to vary the instant of transition from marking to spacing or spacing to marking in the output circuit, perfect operation of the teleprinter is possible with an astonishingly small signal-to-noise ratio at the input to the converter.

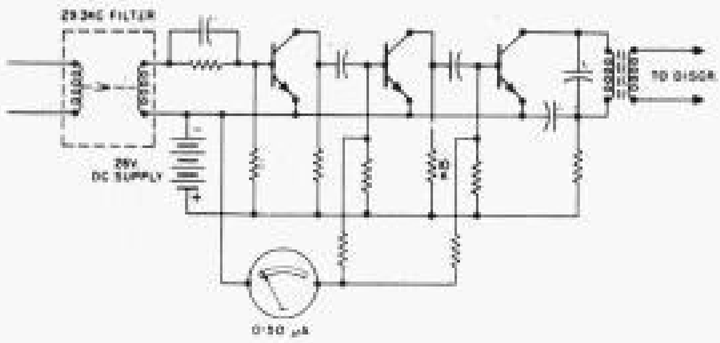


Figure 3. IF amplifier and limiter circuits

The circuit of the IF unit is shown in Figure 3. The IF unit is a three-stage directly-coupled amplifier using junction transistors. Its input is obtained from the output transformer of the filter and its output is fed through a tuned transformer to the discriminator unit. While the method of directly coupling the collector of one stage to the base of the next results in considerable reduction of gain due to the large mismatch, it has a beneficial effect in that it tends to stabilize the gain with respect to temperature variations. The over-all gain of the amplifier is approximately 85 db. This gain is realized only at extremely low input levels as the maximum power output is obtained with an input signal of approximately 0.166×10^{-6} milliwatts.

Limiting starts in the last stage at very low input signal levels after which the second stage, and finally the first, function as limiters as the input signal is increased. Limiting occurs in any transistor amplifier when the input signal exceeds that required to drive the collector current from cutoff to saturation. The term "overdrive" may aptly be used to describe this condition. To prevent injury to the transistor during such overdrive condition, the dynamic load-line must be positioned so that it lies within the maximum collector dissipation contour and does not extend beyond the regions of rated maximum collector voltage or current. This requirement may be satisfied by proper selection of the two resistors which supply d-c bias for the collector and emitter. The output of the IF amplifier varies less than one db when the input is increased 70 db above the value at which limiting starts. The tuned transformer in the output of the IF amplifier effectively rejects all harmonics of the 29.3-kc plus or minus 500-cycle band. The discriminator, therefore, receives a sinusoidal signal of constant amplitude. Its frequency is 29.8 kc during marking intervals and 28.8 kc during spacing intervals.

The signal level indicator shown in Figure 3 is a d-c microammeter. It is connected through two high resistances to the bases of the second and third transistors of the IF amplifier so that it reads their combined negative voltages with respect to ground. With no input to the converter the base voltages are each approximately 0.1 volt positive. This produces a slight off-scale reading which may be compensated for by the zero adjustment of the meter, if desired. At the input level for which the third transistor has just reached the overdrive condition, its average base voltage is zero.

As the signal level is further increased, the average base voltage increases (negatively) until it reaches a maximum of about 8 volts negative. This occurs when the second transistor begins to be overdriven. As the input signal continues to increase, the base voltage of this transistor will also increase until it becomes 8 volts negative. This occurs at the level which just causes the first transistor to be overdriven. Any further increase in signal level produces no increase in the base voltages of the two transistors to which the meter is connected. The voltage from the third transistor causes the meter indicator to be deflected over the first half of the scale, and that from the second transistor over the second half. Over the first

80 percent of the scale the meter response is approximately a logarithmic function of the signal level so that if a db calibration is used the scale divisions will be fairly linear.

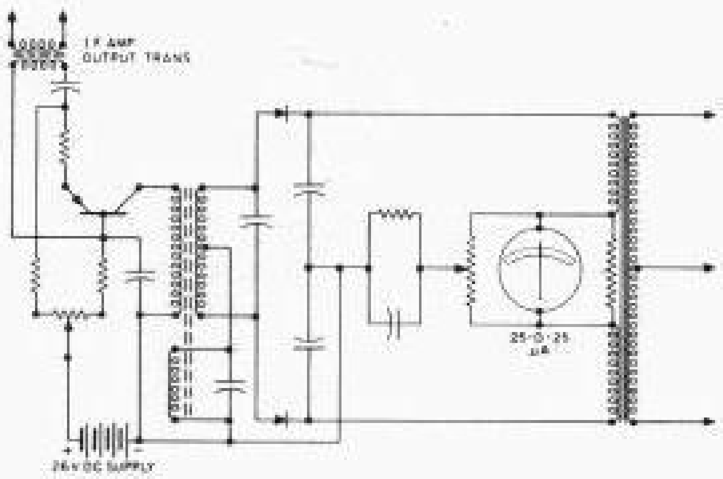


Figure 4. Discriminator unit circuit

The circuit of the discriminator unit is shown in Figure 4. Between the IF unit and the discriminator is a single-stage amplifier using a point-contact transistor. Its function is to increase the power level of the signal to that required for the discriminator, a level not obtainable from the junction transistors used in the IF unit. The primary of the discriminator input transformer is in the collector circuit of this amplifier.

The discriminator is a modified form of the Foster-Seeley type used in FM receivers. The two a-c voltages derived from the tuned windings of the input transformer have a quadrature phase relation at the 29.3-kc frequency. At frequencies slightly removed from the center frequency this relation is changed by an angle approximately proportional to the frequency shift. The d-c potential derived by rectifying the sum and difference of these two component a-c voltages causes a direct current to flow through the primary of the output transformer, in one direction during marking intervals and in the opposite direction during spacing intervals. A zero-center microammeter connected across a small resistance at the center of the balanced network indicates the direction of the current as well as its magnitude during a steady space or mark condition. The magnitude is a measure of the shift frequency being used. It also serves as an accurate tuning indicator for the communications receiver.

The circuits of the keying unit and the mark-hold unit are shown in Figure 5. The keying unit consists of two point-contact transistors connected in push-pull and biased to operate in their bistable region. The secondary of the discriminator output transformer is connected between the two emitters. The selecting magnet of the teleprinter is in the collector circuit of one of the transistors and a dummy load approximately equal to the d-c resistance of the selecting magnet in the other. The two collectors are then connected to negative through a common resistance.

The current reversals in the primary of the discriminator output transformer alternately trigger the bistable amplifier from one steady-state condition to the other. In one steady-state condition, current flows through the selecting magnet and substantially no current through the dummy load. In the other steady-state condition, current flows through the dummy load and substantially no current through the selecting magnet. The effect of the common resistance in the collector circuit is to reduce the voltage applied to the nonconducting transistor to approximately one-half of the supply voltage, thereby effecting a very considerable reduction in the collector cutoff current. In response to the marking and spacing impulses the receiving teleprinter reproduces the message being transmitted from the distant sending printer.

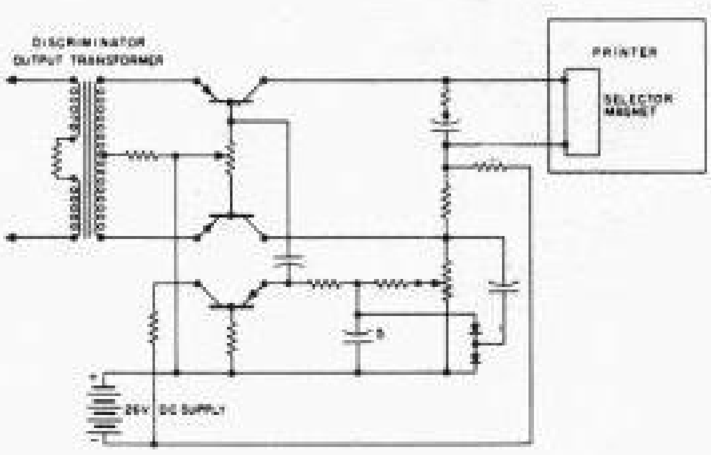


Figure 5. Keying and mark-hold units—circuits

The function of the mark-hold unit is to set up a marking condition for the tele-

Figure 6. Radioteletype converter—front view

printer whenever a prolonged spacing signal is received by the converter or whenever no readable signal is received. The unit consists of a point-contact transistor connected so that when no control signal is received from the keying unit it operates as a relaxation oscillator. Control of the oscillator is obtained through a connection to the collector of the switching transistor having the dummy load. This disables the oscillator during all normal conditions. There are two such normal conditions during which the oscillator must be held inoperative. One is that in which a steady marking signal is received and the other is when normal marking and spacing signals are received. In the first, the collector of the controlling transistor is in the nonconducting condition and the emitter of the mark-hold transistor is held sufficiently negative to prevent oscillation. In the second, the a-c signals from the controlling transistor produce a strong negative potential at the emitter through the action of the two diodes which are connected as a voltage doubler across the emitter condenser. If the controlling transistor remains in a conducting condition for some interval longer than would occur during normal operation, the emitter of the mark-hold transistor becomes sufficiently positive to cause oscillations to start. The oscillations consist of a slow charge of the condenser, shown connected between the emitter and the base of the switching transistor, and a rapid discharge through the emitter. The rapid discharge produces a sudden drop in the base potential of the switching transistor triggering it to its marking condition. Since a normal condition now exists, the oscillator is immediately disabled.

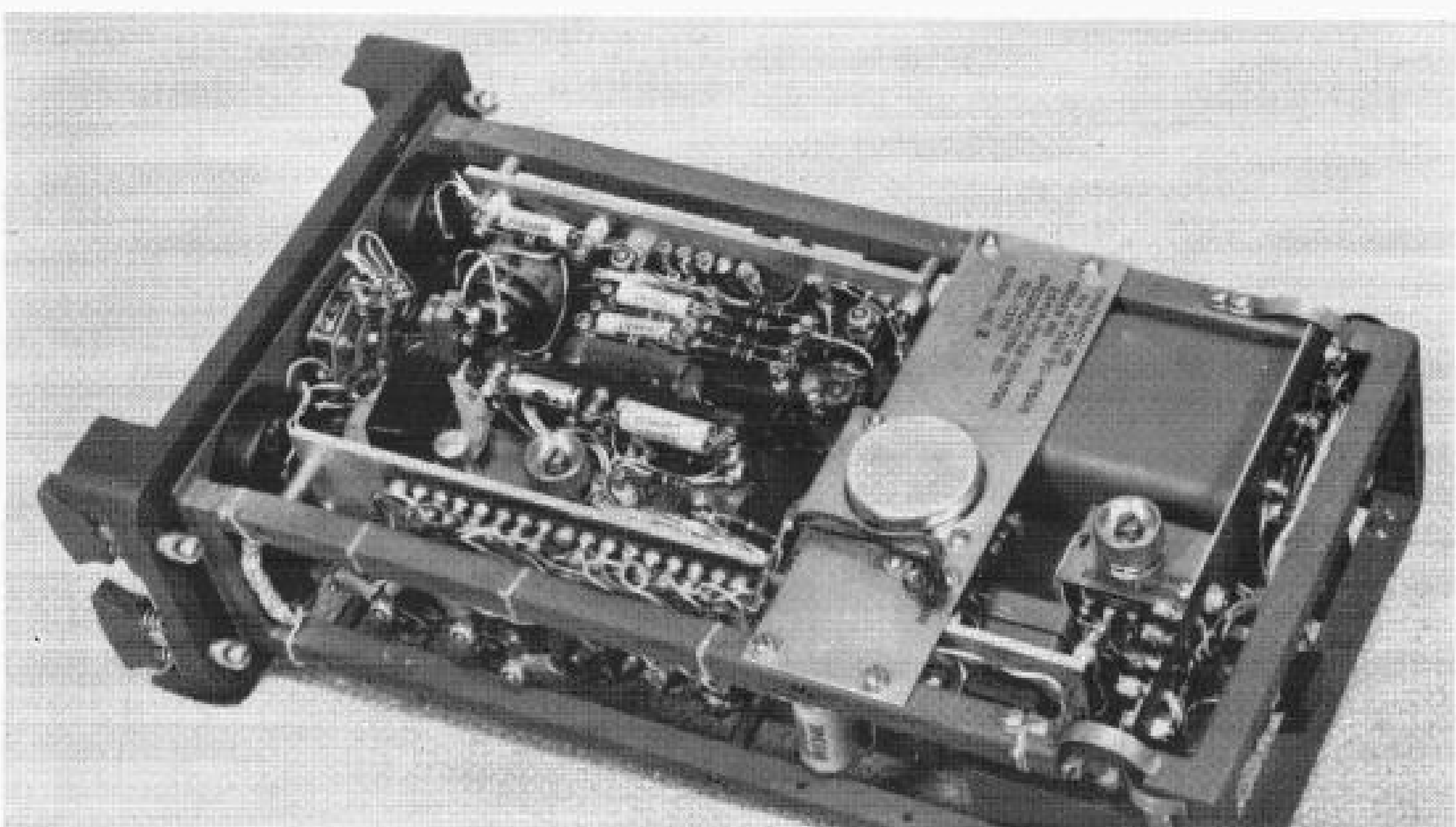


Figure 7. Radioteletype converter—top view

The converter as described is intended only as an experimental model to be used as the prototype for the final development model in which special emphasis will be placed on the miniaturization and ruggedization of component parts.

The author, on his own behalf and on that of his associates, gratefully acknowledges the assistance rendered by Captain Gerald S. Epstein, John A. Bush and others of Coles Signal Laboratory in making available the technical data and information obtained during their pioneering work on the application of transistors to converters. Special acknowledgement is due Samuel Berger of Coles Signal Laboratory for his many valuable suggestions.

Addendum

In the interim since this paper was originally presented a later model of the converter herein described has been completed. A front view of the new model is shown in Figure 6 and a top view, with case removed, in Figure 7. Its dimensions are approximately 4 in. by 7 in. by 12 in. and its weight, including the case, about ten pounds. Its total power consumption is approximately two watts, of which one is used by the pilot light. For purpose of comparison, the vacuum tube equivalent of this converter would require perhaps 25 to 30 watts, although the actual figure would vary considerably with the types of tubes used. The principal factors favoring the use of transistors would seem to be their low power consumption, small size and exceptionally long life. No very reliable data are available as to life expectancy. Actual test figures have been quoted up to 35,000 hours with the transistors showing no evidence of deterioration, and by extrapolation estimates up to 100,000 hours have been made. Whatever the actual figure may be, the life expectancy aside from casualties due to accidents is definitely very high.

Oscar E. Pierson has been associated with Western Union since 1917, when he was employed by the Traffic Department at Chicago. He held various positions in that department, from T&R attendant to Division Traffic Inspector until 1930 when he was transferred to the staff of the Engineer of Automatics in New York. Among his major assignments was the development of the Varioplex system, in which he took a leading part for some eight years. In 1944, Mr. Pierson was assigned to the Water Mill Laboratories of the D. & R. Department, where for several years he worked on the development of flight trainer equipment for the U. S. Navy. Since completion of that project, he has been concerned with the development of a klystron power supply for microwave experimental work, calculation of the paraboloid surface of a horn antenna, development of frequency standards for ocean cable circuits, and design of electronic devices involving the use of transistors.

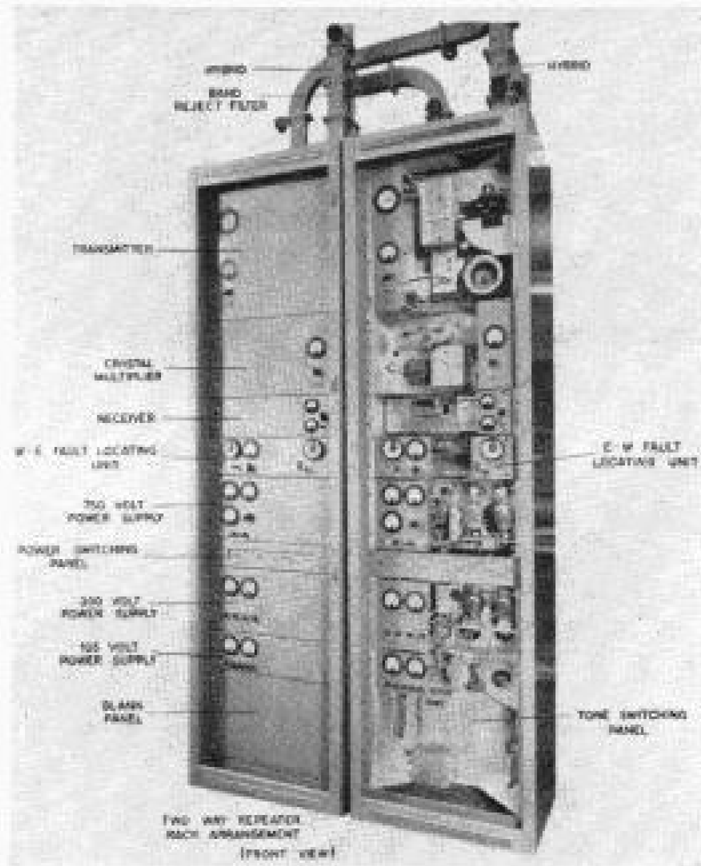
Design Features of a Radio-Beam Fault-Locating System

H. C. LIKEL and T. M. GRYBOWSKI

MANY modern communication systems include several unattended repeaters in series. Should one of the repeaters develop a fault, the work of clearing it is greatly facilitated if some means is provided in the system to determine, as a minimum requirement, at which repeater the fault exists.

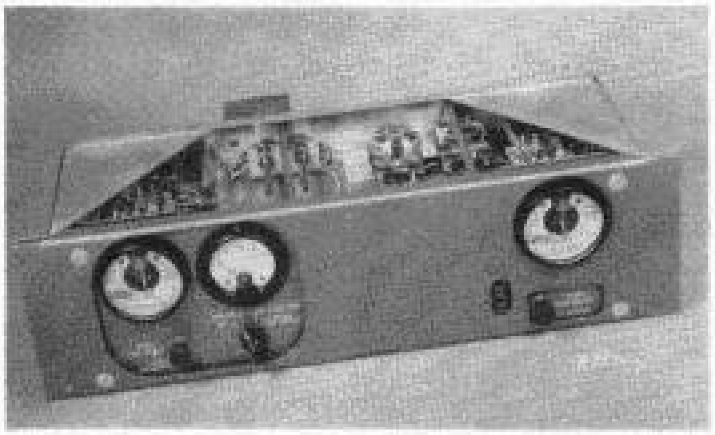
The circuits with which this is done are usually referred to as "fault-locating" or "fault-alarm" circuits. How elaborate they should be depends upon the economics of the situation. At one end of the list of possibilities, there is the fault-locating circuit with separate communication links entirely independent of those of the main system. Such a circuit may have reporting facilities covering a very wide range of possible faults, and switching means at the repeaters, under the control of the terminal personnel, for making good any fault reported by the connection of stand-by equipment. At the other end of the list would be a circuit intended to operate over the communication system itself. It would be capable only of reporting to a terminal the repeater at which the fault existed, provided, of course, the failure did not disable the fault-alarm circuit. The requirements for fault location for the Western Union MLD-4A microwave system[1] lie between these two extremes. Here economic considerations do not warrant the installation of separate communication facilities for the fault-alarm circuits nor stand-by apparatus and switch gear for clearing any troubles by remote control. On the other hand, it is necessary that the alarm circuit at least be capable of informing the terminal personnel at which repeater a trouble exists, or in the case of multiple faults that interrupt the circuit both ways, which is the nearest inoperative repeater to each terminal. This is the absolute minimum; more information is highly desirable. It will be shown that once the means to provide this minimum have been devised, limited additional facilities are easily added.

The requirement to provide information when communication fails both ways is



Front view of two-way MLD-4A repeater. Units of right-hand rack have dust covers removed

not easy to meet in a system such as the MLD-4A where a repeater does not transmit a carrier unless it receives one. This stems from the fact that distortion is reduced in the main channel if the signal is not demodulated then remodulated on a new carrier of a different frequency at each repeater. In the MLD-4A system repeaters, the difference in frequency between the received signal and the transmitted signal, required to avoid interference with the receiver by the transmitter, is obtained by frequency-translation methods. Thus the incoming signal with its modulation intact is amplified and shifted to the new frequency without demodulation or remodulation. However, if there is no incoming signal, the translation circuits and amplifiers have nothing to work with and there will be no transmitter output. As a result, if the carrier disappears at one repeater because of a fade or other cause, there will be no carrier from that point to the receiving terminal. Of course, if there is no interruption of the carrier in the other direction of transmission, it is still possible to send fault signals over the circuit to the other terminal.

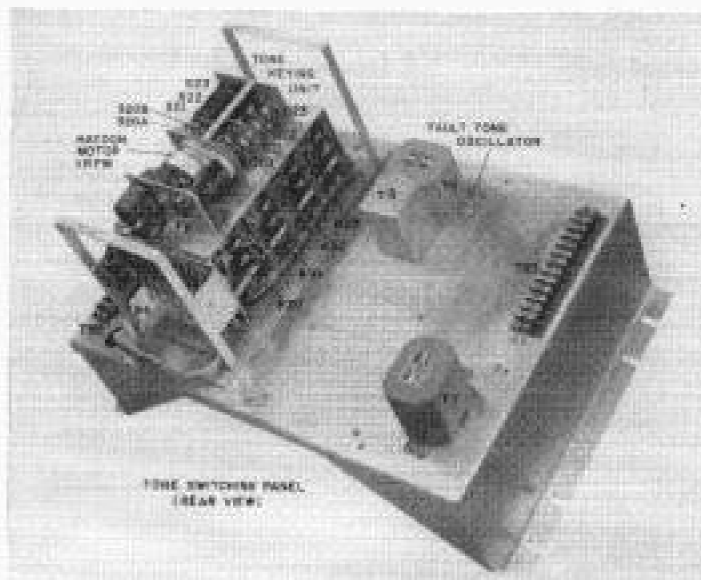


Front view of repeater fault-locating unit showing Sensitrols and metering provisions. Visible through top are toroids of the 20-kc peaking circuits

If no other provisions are made, it would be necessary for either terminal to be in a position to direct repair operations over the entire system or to have an alternate means of communication between terminals. Further, and more important, should the circuit fail in both directions, it would be impossible to send fault signals to either end. Maintenance personnel would then be required to check repeater after repeater until the fault was located. Unless such faults were extremely rare occurrences, this would be a very serious shortcoming if a system with many repeaters was involved.

To avoid this handicap a carrier reinstatement oscillator has been provided in the MLD-4A system. It operates at the frequency of the intermediate-frequency amplifier, one of the frequency steps in the translation process. This is a frequency which is easily generated and kept constant to the necessary degree of accuracy. The oscillator is loosely coupled to the IF amplifier output circuit and when operating has the effect of reinstating the carrier at that point.

Obviously this oscillator must never be turned on when the circuit is in normal operation, as its output beating with the regular carrier would make the circuit inoperative. For this reason, it was decided that although the automatic gain control current of the amplifier constitutes a good indication of the strength of the incoming carrier, it alone could not be relied upon to determine when the oscillator should be started. Apparatus and circuit conditions could easily result in the system being operable at one time with a specified AGC current at a given amplifier, while on another occasion with the same current at the same amplifier the circuit would fail. The only place at which it can be definitely determined that the circuit has or has not failed, without resort to considerable extra complication, is at the terminal.



Rear view of tone switching panel showing fault tone keying unit with cover off. Numbered designations refer to schematic drawing

Because of these things, the decision to start the restoration oscillator must be made at the terminal. To implement such a decision, one terminal, or in the case of simultaneous failures each way, both terminals must send a special signal devised for this purpose. When this signal is received at a repeater, the restoration oscillator will be started if a low received signal level has been registered there. The MLD-4A system is designed so that the telegraphic intelligence modulates the carrier in the octave between one and two megacycles while the carrier is modulated directly to obtain a service channel.

Clearly there is a large area between the highest frequency required for good voice reproduction by the service channel and the lowest frequency which would be apt to cause interference in the telegraph channel. The special signal transmitted from the terminal over the service channel is 20 kc, frequency-modulated at 60 cycles per second with a deviation of approximately plus and minus 1.5 kc. The circuit at the repeater, which is designed to respond to this signal and no other, has a response sharply peaked near 20 kc. Since the excursion of the 20-kc signal is several times the bandwidth of this circuit, it is not necessary to tune the circuit or maintain it exactly at 20 kc, a feature which reduces manufacturing and maintenance expense.

The output of this circuit is highly amplitude-modulated at 120 cycles per second. It is applied to a crystal demodulator that derives a 120-cycle component from it which is fed to an amplifier that is broadly responsive in this region. This amplifier in turn feeds a rectifying and integrating circuit which in response to a steady signal builds up the necessary potential to cause closure of relay contacts indicating reception of the special signal. Since a low-frequency signal cannot get through the 20-kc part of the circuit and an unmodulated 20-kc signal will have no effect on the low-frequency amplifier following it, it is believed that this circuit will prove to be very free of false responses.

Having devised a safe means of restoring as much as possible of a failed system so as to send fault signals over it, it becomes necessary to decide in what way the signals shall be sent.

Early in the design of the MLD-4A system, it was agreed that the fault-locating feature of the system should go into operation automatically and send any information within its scope immediately, rather than to wait for an interrogation signal from the terminal. This brings up the possibility of several repeaters sending signals at the same time. This in turn rules out the possibility of all repeaters using a common tone for signalling a fault, and indicating which repeater is sending by a time-division arrangement unless some sort of lockout and "take turn" circuit is devised.

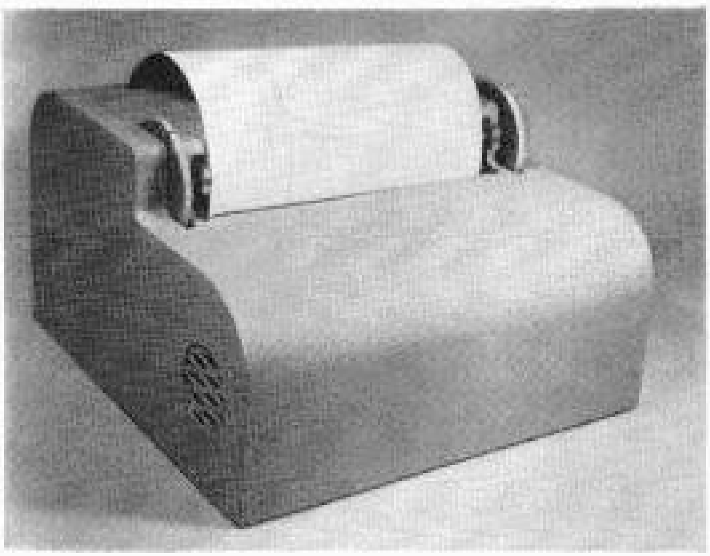
The other possibility, which is the one analysis indicated was more feasible, and more desirable as well, since all repeaters could signal simultaneously, is the use of a different fault signal frequency for each repeater. At the terminal, it is then necessary to separate these frequencies to identify the repeaters sending them, and desirable to make a permanent record of the signals received. This is done by the use of selective amplifiers, the outputs of which cause recording to take place on an 8¼-inch-wide "Teledeltos"* electrosensitive paper tape, with a separate track or line for each repeater. The device used to implement this is a modified Western Union 5616-B continuous recorder ordinarily used in Desk-Fax concentrator service. The moving styli of the original machine, which scanned across the "Teledeltos" tape, are replaced by forty fixed styli arranged in pairs, the pairs being equally spaced across the tape and thus printing longitudinal traces on it when the machine is in operation.

Having arrived at this point, it is an easy matter to devise a common means of coding the signals from the repeaters so as to indicate a variety of faults. In the MLD-4A system, it was decided necessary to inform the terminal if, at any repeater, (1) the received signal was weak; (2) the transmitted signal was below a specified value; (3) operation of the equipment was from the batteries because of a failure of the commercial power supply; (4) operation was from the engine-generator for the same reason; (5) operation was direct from the power line because of failure of the motor alternator; (6) the engine-generator failed to start; (7) illegal entry had been made into the building; and (8) the lights on towers which require marking did not come on.

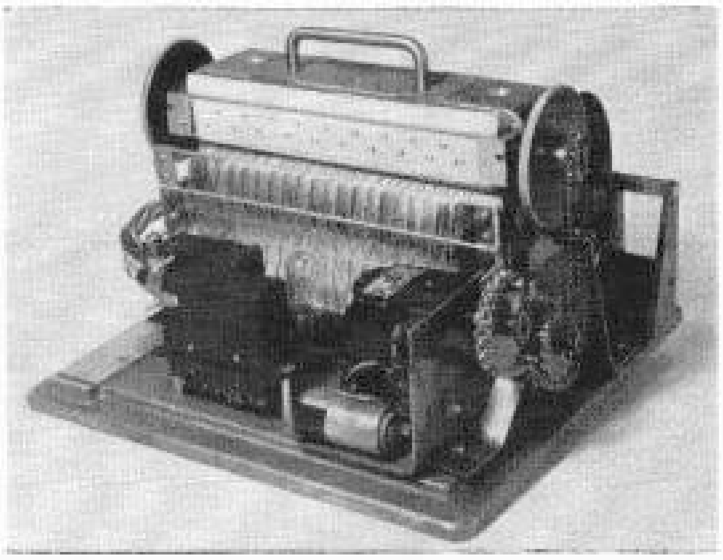
Low received signal and transmitted power are easily detected by passing the AGC current of the receiver and current

* Registered Trademark, W.U.TEL.CO.

from a crystal probe in the transmitting waveguide through individual Weston Sensitrol relays. These relays are of the meter movement type and arranged for contact closure on decreasing current. The contacts are backed up by small magnets which pull them smartly together when the contacts come within a certain distance of one another, and give very high contact pressure for such a sensitive device.



Twenty channel-pair terminal fault tone recorder showing simulated fault record

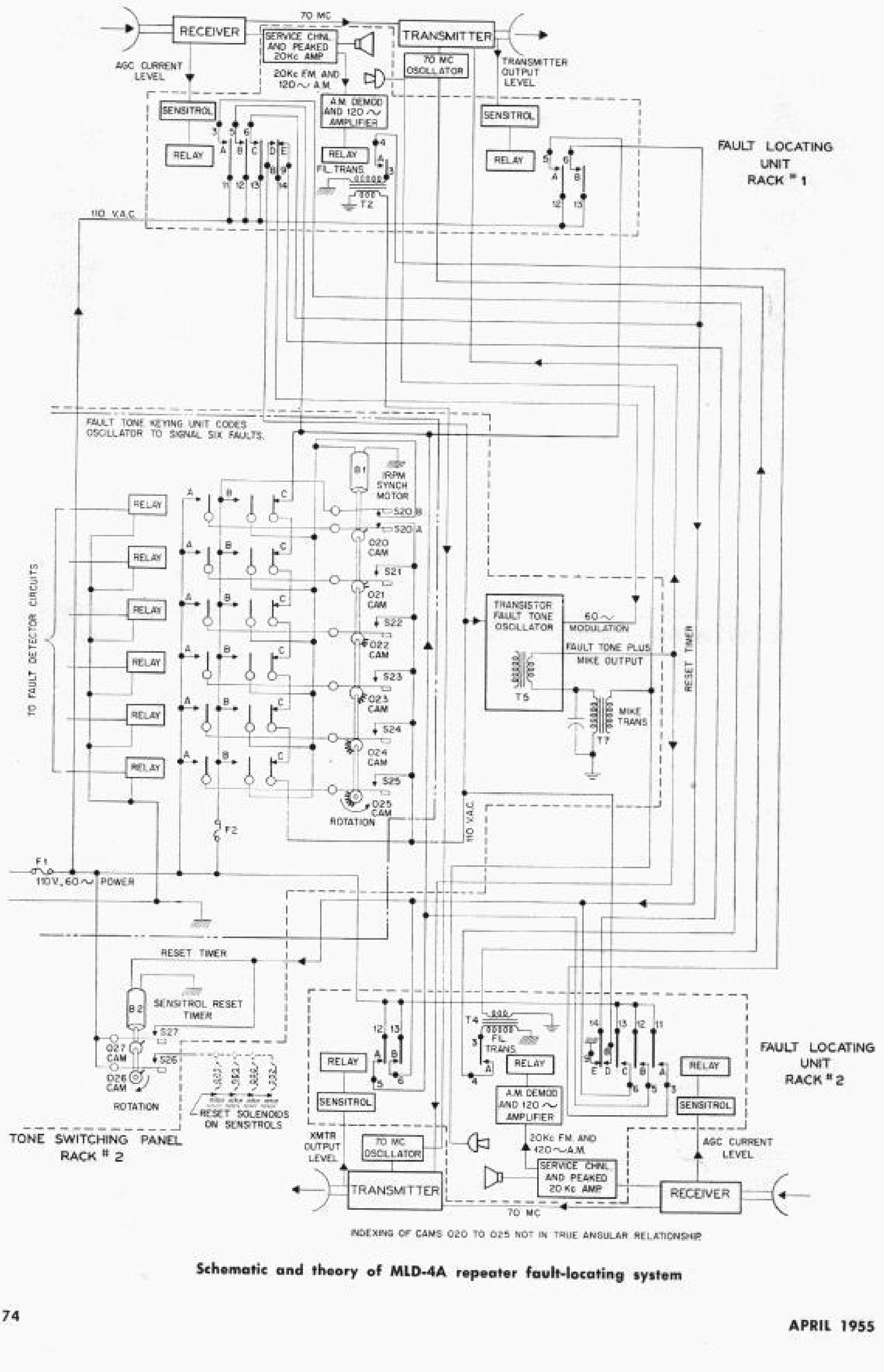


Fault tone recorder with cover removed, showing 40 fixed styli in pairs

It follows that the contacts are not self-separating when the weak actuating current, which held them apart, returns to normal. To overcome this, a solenoid actuated release mechanism is built into the Sensitrol. When either of the Sensitrols closes, it energizes a multicontact relay, one pair of whose contacts starts a small synchronous timing motor. At the end of four minutes this motor closes contacts energizing the solenoid and opening the Sensitrol contacts. Auxiliary contacts on the timer keep its motor running until the solenoid circuit is opened. Although the Sensitrols reputedly will stand a large number of recyclings, the force needed to separate the contacts is relatively great and the resulting disturbance of the mechanism seemingly violent, therefore the period of four minutes was chosen as a compromise between the desire to know if the fault had cleared, as might be the case with a fade, and the necessity of keeping wear and tear on the Sensitrols down if a fault was of long duration, as would be the case if an apparatus failure had taken place.

Another set of contacts of either of the relays controlled by the Sensitrols energizes the transistor "fault tone oscillator" which then modulates the carrier both ways with the frequency singular to that repeater. Further, if it is the receiver which is failing the oscillator is amplitude-modulated at 60 cycles per second to signal this fact. At the terminal this information is derived by feeding some of the output of the selective amplifier to a demodulator and 60-cycle amplifier which, if energized, causes a second stylus, located adjacent to the stylus activated by the selective amplifier, to mark. Thus each repeater controls a pair of styli which give a single trace on the "Teledeltos" for low transmitter output and a double one for a low received signal (automatic gain control current) level. Clearly, if both types of fault exist, the terminal can be informed of the second one only by the repeater at which it has occurred. However, if the transmitted power output is seriously low, the next repeater will send a low received signal indication. It is true that this situation is somewhat ambiguous in that the terminal can never be sure that the low signal indication from the following repeater is due to trouble at the first one. However, there should be no question about which repeater the maintainer should visit.

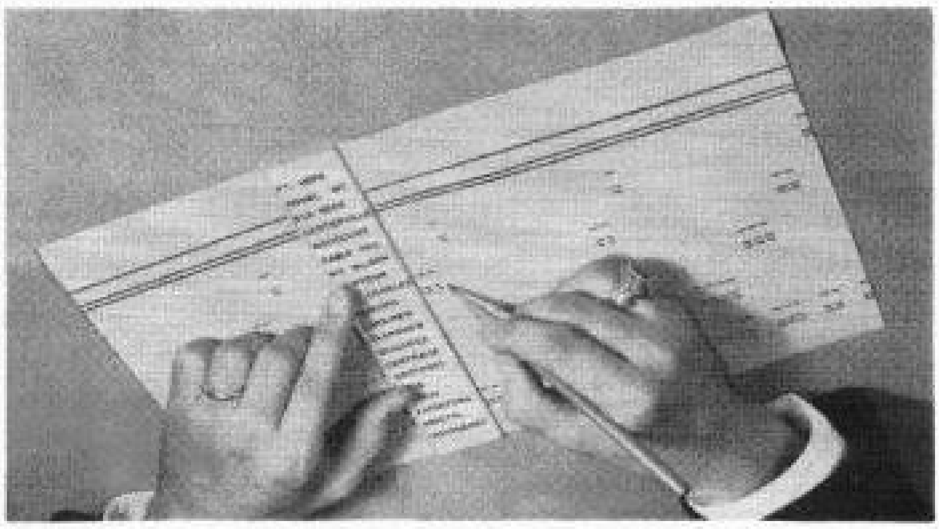
It still remains to identify the last six



INDEXING OF CAMS O20 TO O25 NOT IN TRUE ANGULAR RELATIONSHIP

Schematic and theory of MLD-4A repeater fault-locating system

conditions mentioned earlier. To do this, a keying unit is provided which is energized if any of the occurrences mentioned take place. The unit is arranged so that the oscillator will send one dash for battery operation, two for engine-generator, three for failure of motor alternator, and so forth. Each of these groups of dashes are so spaced in time by the keying unit that they will appear as individual groups on the "Teledeltos" at the terminal and no confusion will exist should more than one group need to be sent on the same occasion. The equipment shown in the photograph is arranged to send only four groups, as that was the number required when it was constructed.



Simulated fault record. Engraved plastic overlay facilitates identification of faulted repeater. Interpretation of record is as follows:

- **Elk Neck—Low Xmtr output**
- **Centerville — Low AGC current reading**
- **Cable Hill—Battery operation**
- **Mt. Wilson—Battery operation and low AGC**
- **Ft. Charles—Operation from emergency power**
- **Concord—Operation from emergency power and low AGC**
- **Clearview—Failure of motor-alternator**
- **Beauville—Failure of motor-alternator and low AGC**
- **Westport—Failure of engine-generator**
- **Erie—Failure of engine-generator and low AGC**
- **Eatontown—All of the four latter faults**
- **Bristol—All of the four latter faults and low AGC**

Since it is usually more important for the terminal to know the information represented by the keyed signals than to know that there is a low transmitted signal level, it is necessary to allow the keying unit to control the oscillator should a conflict arise, and the low power output information would have to await the clearing of the other trouble or be indicated by a low received signal trace from the following repeater. If, however, the more important information of low received signal were to be sent concurrently with the keyed signal, the system would operate to print the coded signal in a double line, thus conveying this information.

When a large number of repeaters are employed in a system, the corresponding number of selective amplifiers and "modulation detectors" required at each terminal, if additional measures are not taken, would be bulky and expensive. It is proposed, therefore, when the number of repeaters is great, to have only half as many "selector sets" as there are repeaters. The repeater fault frequencies will be divided into an upper and lower group so arranged relative to one another that the upper group may be heterodyned to the same frequencies as the lower group. Through the use of filters and electronic switching, the two groups will be presented to the selector sets alternatively. Synchronously with this, the outputs of the selector sets will be switched between two corresponding groups of styli. This switching must be done at a rate slow enough for the selector set functions to take place, but fast enough to print a substantially continuous trace on the "Teledeltos."

It is probably of interest to note that when a carrier disappears, the AGC circuits of the amplifiers at the affected repeaters tend to bring input circuit noise up to limiting. This noise is translated to carrier frequency and transmitted down the line in lieu of a carrier. After several repeaters, it attains a level which holds the receiving Sensitrols open and no fault will be signalled by repeaters from this point on. When the carrier restoration oscillator comes on, it is necessary to eliminate this noise. This is done by switching the oscillator in its filament circuit and connecting to the high side of the filament a simple crystal diode rectifier and filter which applies a negative voltage in the AGC circuit great enough to block the IF amplifier.

Switching in the oscillator filament circuit is also necessary so that when the timer periodically opens the receiving Sensitrol contacts, thermal inertia of the heater will allow the oscillator to continue long enough to bridge the gap until reclosure at the first faulted repeater and thus send a continuous signal. This will allow the Sensitrols at repeaters down the line to remain open after their first cycling, all oscillators but the first one to stop, and the circuit to become operative from that point on for fault signals.

The authors wish to thank Mr. K. R. Jones for his contributions to the design of the system and for his suggestions during the preparation of this article.

Reference

1. A MICROWAVE SYSTEM FOR TELEGRAPH SERVICE, J. J. LENEHAN, *Western Union Technical Review*, Vol. 8, No. 3, July 1954.

H. C. Likel, Assistant to the Radio Research Engineer, is a graduate of Brooklyn Polytechnic Institute from which he received the degree of Electrical Engineer in 1930. His first employment was in the development laboratory of the Pacent Electric Company where he worked on the design of radio receivers and components, theatre sound equipment, and so forth. He later transferred to Pacent Engineering Corporation, of which he was Chief Engineer when he resigned in 1939. In 1940 he went to the Postal Telegraph-Cable Company, and on its merger with Western Union was assigned to the Equipment Research Division, from which he transferred to the Radio division. For 17 years after graduation, Mr. Likel taught in the evening at Pratt Institute, The Cooper Union, and Brooklyn Polytechnic where he attained the rank of Adjunct Professor. He is presently a member of the AIEE committee on Radio Communication Systems, and RETMA TR4.2 Committee on (Radio) Relays. He is a Senior Member of IRE, a member of AIEE, and holds a registered New York State Professional Engineer's license.

T. M. Grybowski joined the Radio Research Division in 1951. Previously he was an instructor in the E.E. Department at New York University. Since his association with Western Union, he has been concerned with the fault location and IF amplifier sections of the MLD-4A microwave radio relay system. Recent work includes the development of new IF amplifiers for the New York-Washington-Pittsburgh radio beam triangle. Mr. Grybowski received his Bachelor's Degree in Electrical Engineering from Manhattan College in 1949 and his Master's Degree in E.E. from New York University in 1951. He is an Associate Member of IRE and a member of RETMA Subcommittee TR-8 on Selective Signalling.

Modern High-Speed Page Teleprinters

FRED W. SMITH

THIS article describes two new page teleprinters which have become available commercially and which are now being tested for possible future use by Western Union. They are the Kleinschmidt teleprinter, covered in Part I of this article, and the Teletype Corporation's Model 28 teleprinter which will be described in Part II in the next issue of TECHNICAL REVIEW.

Many Similar Features

The two teleprinters operate on entirely different principles, but they have many points in common. Both are light-weight, compact units designed for operation at speeds of 368, 460 or 600 operations per minute (60, 75, or 100 words per minute) and the speed of either teleprinter can be readily changed by changing the motor pinion and one gear. Each unit uses a single set of transmitting contacts instead of the six sets of contacts now widely used for keyboard transmission, and either of the two keyboards can be wired for polar transmission or for single-current transmission.

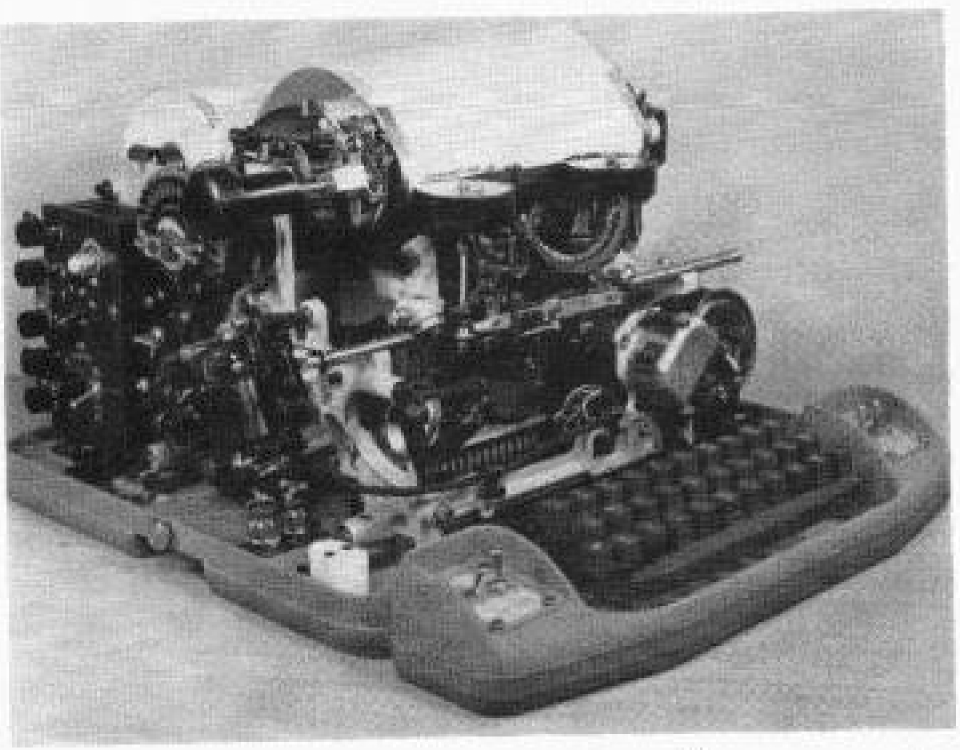


Figure 1. Kleinschmidt Model 150 teleprinter with cover removed

Another feature common to both teleprinters is the provision for local power-operated line-feed and carriage-return, which permits the carriage to be returned to the left-hand margin and the paper to be fed through the platen without transmitting the carriage-return and line-feed signals. These local, or off-line, functions are controlled by push buttons on the front of the teleprinter in the Kleinschmidt and by special key levers in the Model 28. In addition, each is equipped with an automatic carriage-return and line-feed feature which causes the teleprinter to perform these functions locally if the characters for these functions are not received before the teleprinter reaches the end of a line of printing. This prevents over-printing of a line or "piling up" of printing at the end of a line.

All of the motors used to drive these two teleprinters rotate at the same speed of 3600 rpm. This permits a teleprinter to use the same sets of gears for either a synchronous or a governed motor. Pulling-type selector magnets are used on both teleprinters and the coils can be connected either in series for operation in a 20-milliampere circuit or in parallel for a 60-ma circuit. Either teleprinter will operate satisfactorily, with excellent tolerance to signal distortions, in Western Union's 70-ma circuits.

Each of the two page teleprinters described is the forerunner of a complete line of new telegraph apparatus to be built around an integrated design which will permit extensive interchange of parts between different apparatus in the same line of equipment. For example, the selector mechanism used on the Model 28 teleprinter will be used on a printer-perforator, a nontyping reperforator, and a tape teleprinter. There are many obvious advantages in the use of like parts and subassemblies in the various units.

A complete description of the theory of operation of these two teleprinters is beyond the scope of this article, but features of special interest will be described in detail.

PART I—THE KLEINSCHMIDT TELEPRINTER

There are two different models of the new Kleinschmidt teleprinter, but the principal difference between the two is in the special functions and accessories incorporated in the units, rather than in the basic design. The Model 150, shown in Figure 1, has a built-in rectifier for supplying d-c battery to the telegraph line, a local "letters-shift" push button, automatic carriage-return and line-feed, and an upper case "H" motor stop mechanism, available as an optional feature. The Model 155 does not have all of these features.

A polar selector magnet is used on the receiving unit. When the teleprinter is wired for use in a single-current circuit, one winding on the selector magnet is used as a bias winding to hold the selector magnet armature in the spacing position except when a marking pulse is being received.

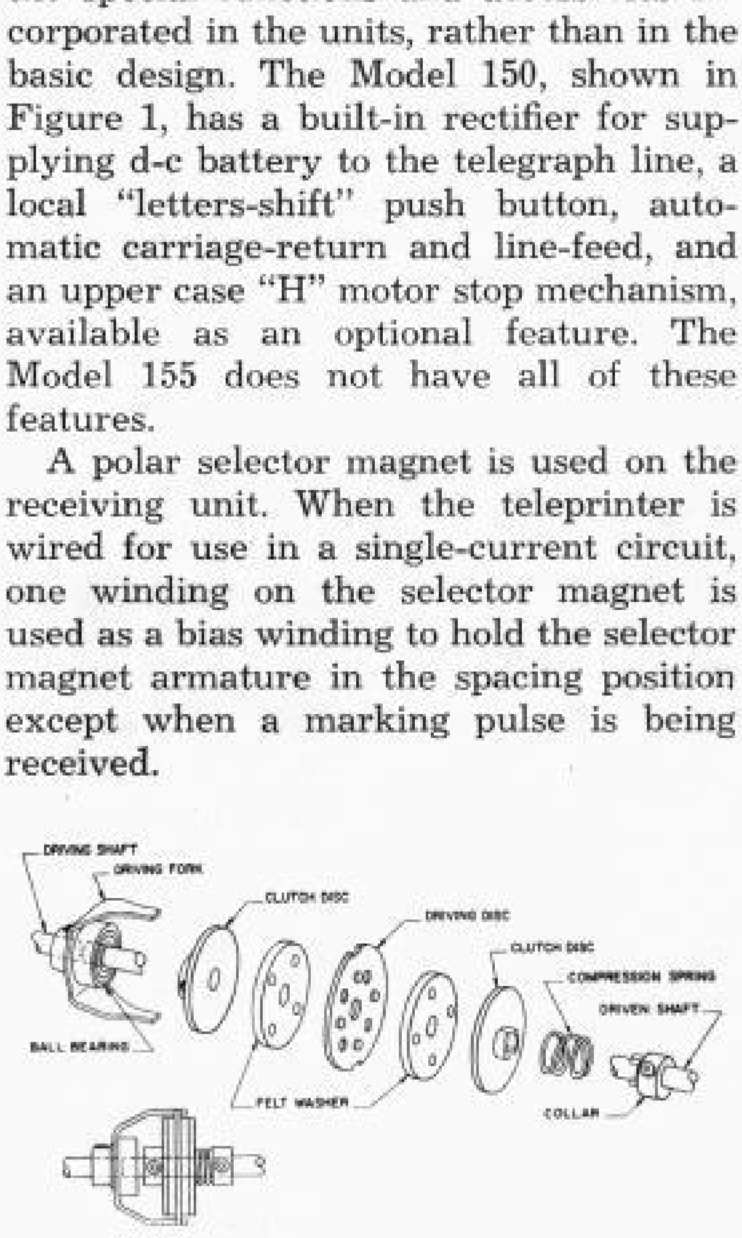


Figure 2. Kleinschmidt friction clutch

The teleprinter is designed for two-cycle operation; that is, the transmitting and receiving shafts each perform two complete character or function cycles per revolution. This permits the shaft speeds to be reduced to one-half the normal speed with resultant reduction of wear.

Three friction clutches are used in the Kleinschmidt teleprinter. One of these drives the keyboard transmitter, another drives the receiving selector mechanism, and the third drives the carriage-feed (spacing) mechanism. An exploded view and an assembly drawing of the clutch used to drive the keyboard and the carriage is shown in Figure 2. The principle of operation is no different from that of friction clutches widely used in other teleprinters, but the design is worthy of note because of the two felt friction washers driven by one steel disc. The two arms of the driving fork engage slots in the driving disc to drive this disc. Projections on the driving disc engage holes in the two felt washers and cause these washers to rotate. When the driven shaft is prevented from rotating, the felt washers slide against the surfaces of the two clutch discs. When the driven shaft is not restrained from rotating, the friction between the felt washers and the clutch discs rotates the two discs and the driven shaft on which they are mounted.

Keyboard Transmitter

In the Kleinschmidt keyboard transmitter, the method used to set up the selection on the code bars for the character to be transmitted is conventional, but the

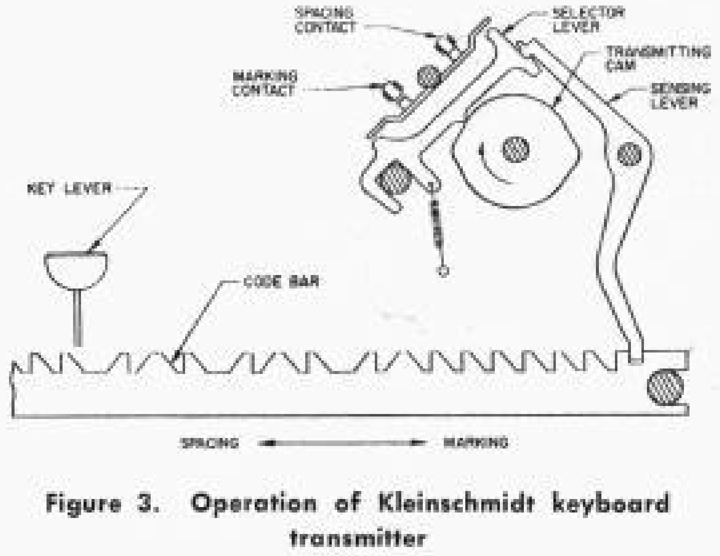


Figure 3. Operation of Kleinschmidt keyboard transmitter

way in which this selection is transferred to the transmitting contacts is different from any of the methods employed in teleprinters currently used by Western Union. When a key lever is depressed, the five code bars are moved to either the right or left, depending upon the character selected, by means of sloping surfaces cut in the code bars. A universal bar, which unlatches the transmitting camshaft clutch and allows the camshaft to start rotating, is also moved to the right regardless of which key lever is depressed.

The principle of operation of the keyboard transmitter is illustrated in Figure 3. If a code bar is moved to the right-hand (marking) position, an associated sensing lever is rotated counterclockwise about its pivot and the upper end of the sensing lever latches the upper end of the associated selector lever. As the transmitting camshaft rotates, the associated transmitting cam raises the center of the selector lever, which rotates about its latched-up upper end and causes the lower end of the lever to close the lower, or marking, transmitting contacts. If a code bar has been positioned to the left-hand (spacing) position, the upper end of the selector lever is unlatched and when the rotating transmitting cam raises the center of the selector lever, the lower end of the lever is held down by an extension spring and the upper end rotates counterclockwise, to open the marking contact and close the spacing contact. The start and stop pulses are generated by a sixth cam-operated selector lever which is not controlled by a sensing lever.

A locking lever on the keyboard locks all five sensing levers in their selected positions when a key lever is depressed and keeps them locked until the character selected has been transmitted. A repeat-blocking mechanism prevents repeating a character when a key lever is held down longer than is necessary to transmit a character.

Receiving Selector Mechanism

The receiving selector mechanism used on the Kleinschmidt typing unit is illustrated in Figure 4. When a start pulse is received the armature moves to the spacing position and allows a stop lever (not shown in Figure 4) to unlatch the selector camshaft. The selector camshaft then starts rotating and the five selector cams raise the five associated selector levers in sequence. If the left end of the armature is in the upper (marking) position at the time a selector cam raises its lever, the lower end of the lever strikes the end of the armature so that the lever pivots about its lower end, and the upper end of the selector lever rotates its associated Y-lever clockwise until the Y-lever comes to rest against its stop. If the armature is in

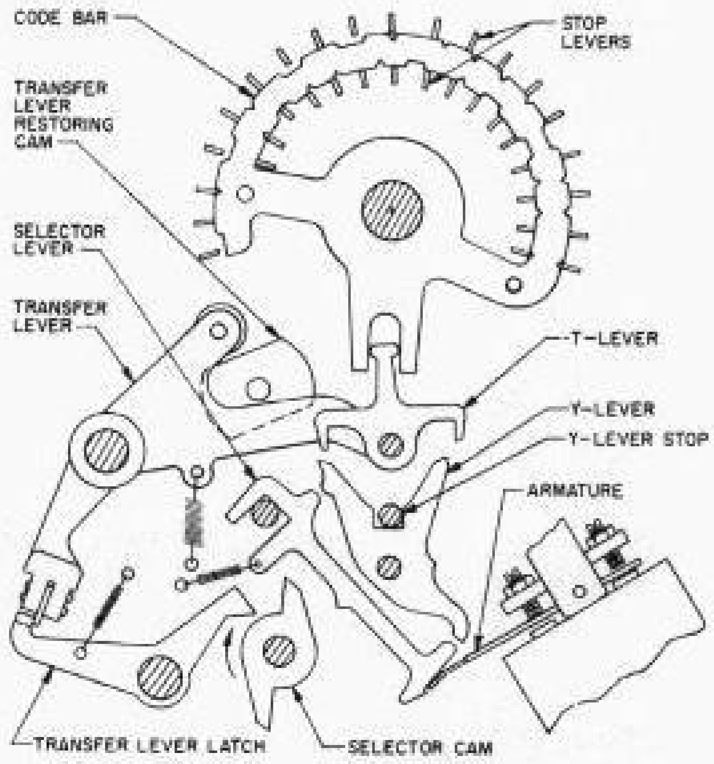


Figure 4. Kleinschmidt receiving selector mechanism

the lower (spacing) position when the selector lever is raised, the lever will pivot about its upper end and the Y-lever will then be rotated counterclockwise by the lower end of the selector lever. After all five selections have been set up on the Y-levers, a sixth cam on the camshaft rotates the transfer lever latch counterclockwise, thus unlatching the transfer lever and allowing the right end of the lever to be pulled downward by an extension spring. Five T-levers, which are mounted on a stud fastened to the transfer lever, move downward against the Y-levers. If a Y-lever has been positioned counterclockwise against its stop, the left arm of its associated T-lever will strike the left arm of the Y-lever and the T-lever will be rotated clockwise, which in turn will cause its associated code bar to be rotated counterclockwise. Similarly, if a Y-lever has been positioned clockwise, its associated T-lever will cause the code bar to rotate clockwise. The restoring cam shown in Figure 4 restores the transfer lever to its latched-up position after the code bars have been positioned. The Y-levers are held in their selected positions by friction plates located between the levers until the next signal train is received.

The code bar cage assembly can be seen in Figure 1 just to the left of the platen knob, and also in Figure 8. The outer periphery of each code bar and the inner edge of the crescent-shaped cut-out in each code bar are notched to correspond to the 5-unit code. There is one stop lever for each of the 32 characters and functions. When the No. 1 code bar is in the marking (clockwise) position, there will be a notch opposite each stop lever corresponding to a character which has a No. 1 marking pulse. When the No. 1 code bar is in the spacing (counterclockwise) position, there will be a notch opposite each stop lever corresponding to a character which has a No. 1 spacing pulse. Each of the five code bars is coded in the same manner, so that when the code for any character is set up on the code bars, the stop lever for that character will be opposite five notches in the code bars and this stop lever will drop into the notches as shown in Figure 5. Every other stop lever will be prevented from dropping into the selected position by one or more code bars.

The 32 stop levers are arranged in two semicircular rows of 16 each in the code bar cage. When a stop lever is selected, the free end of the lever moves into the path of one of the two projections on the stop arm, as shown in Figure 5. The outer projection of the stop arm stops on any selected stop lever in the outer row and the inner projection stops on any selected stop lever in the inner row. The angular spacing between the two projections on the stop arm is one and one-half times the angular spacing between the stop levers, so that there are 32 different stopped positions for the stop arm. When a new combination is set up on the code bars, the previously selected stop lever is pushed back to its unselected position by the sloping surface in the side of a notch in at least one code bar (Figure 4).

Printing Mechanism

The method by which the stop arm position is used to select the character to be printed is shown in Figure 6. When a previously selected stop lever is reset to its unselected position, the stop arm is unlatched so that it is free to rotate and the function shaft driving gear, which is driven by a friction clutch, then drives the

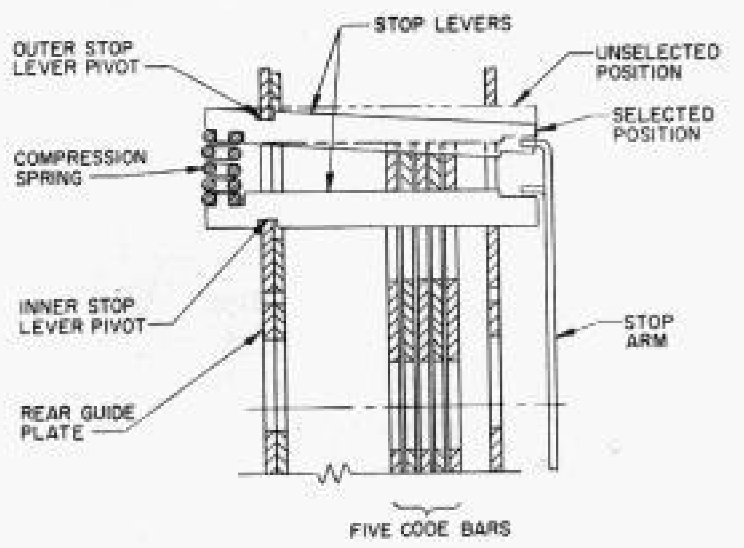


Figure 5. Cross-section of Kleinschmidt code bar cage

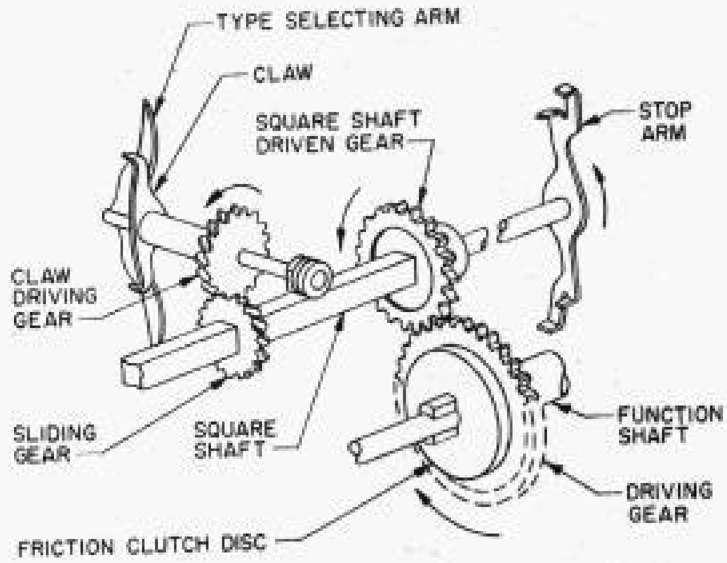


Figure 6. Kleinschmidt type-selecting mechanism

square shaft driven gear. The sliding gear on the square shaft drives the claw and type-selecting arm assembly until the stop arm again strikes a selected stop lever. The friction clutch on the function shaft then slips and the type-selecting arm stops

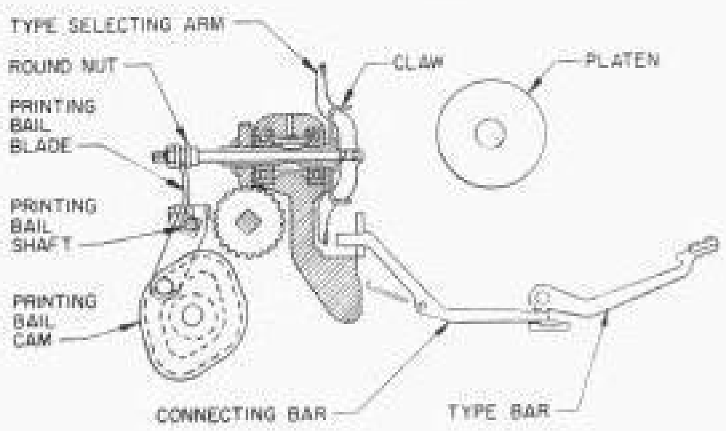


Figure 7. Cross-section of Kleinschmidt printing mechanism

opposite the connecting bar corresponding to the character to be printed. See Figure 7. A printing bail cam then causes the printing bail to rotate about its shaft and move the type-selecting arm (which is free to slide back and forth in the claw sleeve) to the right until it strikes the connecting bar and moves it to the right. As the connecting bar moves to the right, gear segments on the connecting bar and the type bar cause the latter to rotate about its pivot. The type bar then strikes the paper which is wrapped partially around the platen and prints the selected character.

The stop arm is coupled to the square shaft by a one-way clutch which permits the stop arm to rotate in only one direction. This minimizes bounce when the stop arm strikes a selected stop lever and also serves to detent the square shaft.

The type selecting arm, the claw, and the claw-driving gear are part of the carriage assembly and move with it as the carriage moves from left to right. A fork on the carriage assembly also moves the sliding gear on the square shaft so that this gear always meshes with the claw-driving gear. The printing bail extends over the entire distance of the carriage travel. Details of this mechanical arrangement may be seen in Figure 8. After each character is received, a spacing gear driven by a friction clutch is allowed to rotate and drive a carriage-rack driving gear (Figure 9) which in turn drives a rack on the carriage assembly to move the carriage one space to the right, at which time the friction clutch is braked and the carriage stopped.

Carriage-Return Mechanism

One of the interesting features of the Kleinschmidt teleprinter is the method used to return the carriage to the left-hand margin. When a carriage-return signal is received, the spacing gear is disconnected from the friction clutch which

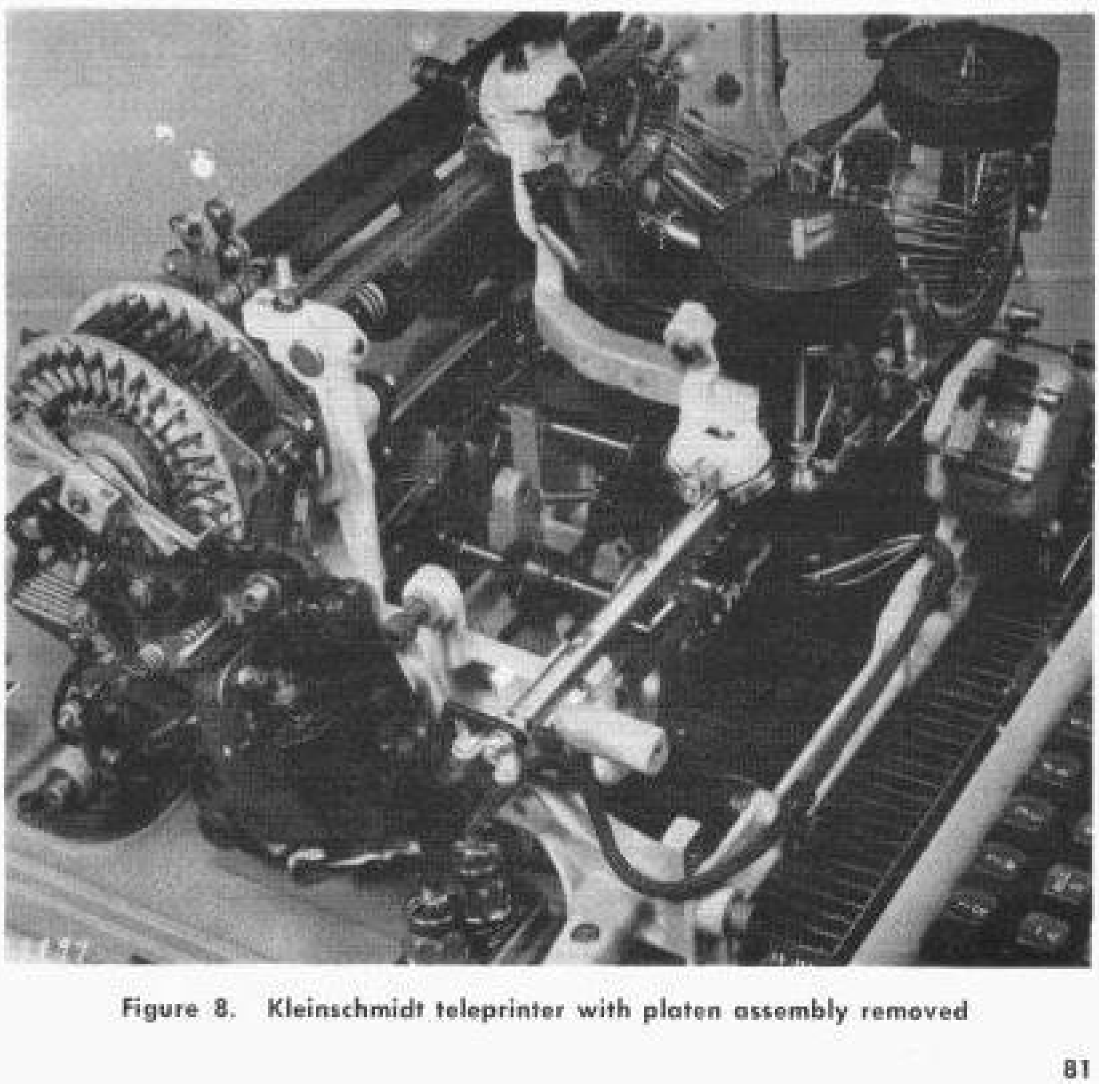


Figure 8. Kleinschmidt teleprinter with platen assembly removed

drives it, and a positive tooth clutch on another shaft is engaged so that it drives a carriage-return driving gear. The carriage-return driven gear is mounted on the same shaft as the carriage-rack driving gear. Thus, when the spacing gear is disengaged from its driving clutch and the clutch which drives the carriage-return driving gear is engaged, the carriage is returned to the left margin. A decelerating cam is used to reduce the speed of the carriage as its approaches the left-hand margin. When the carriage is approximately ⅞ of an inch from the left-hand margin, a cam follower attached to the carriage-return driven gear enters an open slot in the decelerating cam attached to the driving gear. The teeth on the driven gear are cut away on that portion of the gear which would mesh when the follower and cam are in engagement. When the follower enters the cam, the driving force is transferred from the gear teeth to the decelerating cam and its follower. As the driving gear continues to drive the driven

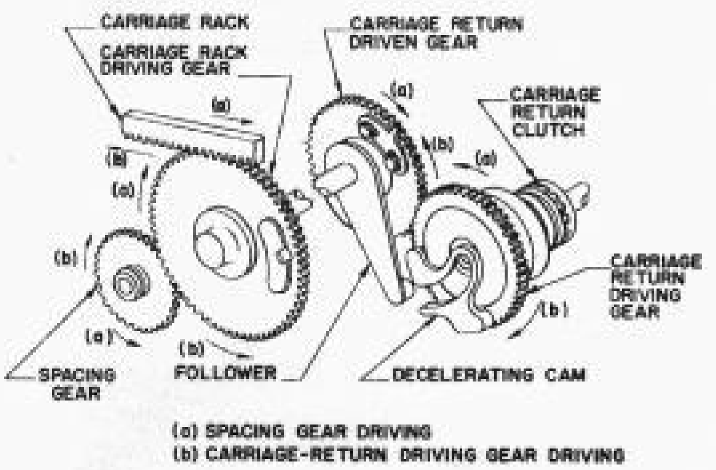


Figure 9. Kleinschmidt carriage driving mechanism

gear, the follower enters farther into the cam opening and the turning ratio between the two gears becomes smaller and smaller so that the driven gear slows down before the carriage hits the left margin stop. This reduces shock and eliminates the dash pot customarily used in teleprinters to retard the motion of a spring-return carriage as it nears the left margin. A friction-type safety clutch on the carriage-return driving gear assembly prevents damage which might result if the carriage should become jammed due to improper assembly or adjustment.

The carriage requires time equivalent to about three signal trains to return from the right-hand margin to the left-hand margin. For this reason it is necessary to send two nonprinting characters after each carriage-return character to insure that printing will not occur while the carriage is returning to the left margin. This is usually accomplished by sending two carriage-return signals, followed by a line-feed signal.

The Teletype Corporation's Model 28 teleprinter will be described in Part II of this article.

References

1. High-Speed Teletypewriter Equipment for the Armed Services, C. E. Schultheiss, *Communication and Electronics*, March 1954.

Mr. Smith is in charge of the Mechanical Equipment Group in the Apparatus Engineer's office, P. & E. Department. His biography appeared in Technical Review of October 1954.

Radioactivity Detection

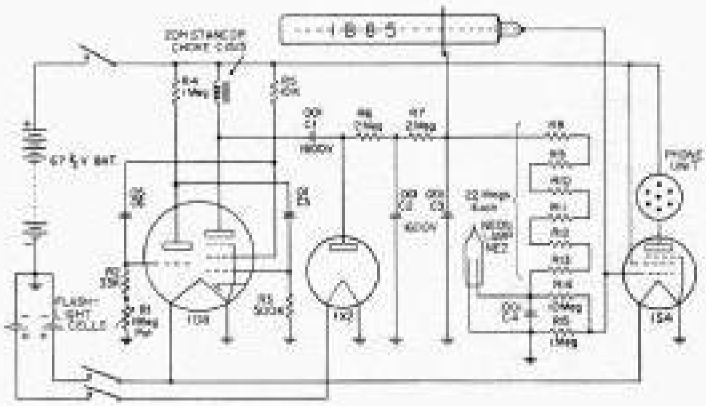
MANY Western Union technical people share with the company itself an interest in radioactivity detection as it is related to their civil defense duties. As intelligent members of and advisors to local civilian defense communication forces, they will be presumed to have a speaking acquaintance with alpha, beta and gamma rays and Geiger tubes. This article is directed towards supplying information which may thus be widely useful to members of our technical and engineering staff engaged in civil defense work.

In this atomic age the Geiger counter has emerged from forty years of obscurity to become a mysterious and much misunderstood household word. The public conception, gained from press-releases, is that it is a complicated, expensive, magical device with the nose of a bloodhound tuned to sniff out uranium even though it be buried deep in the earth. As a matter of fact, the Geiger counter is very simple, no more complicated than a key and sounder telegraph circuit.

The Geiger counter is a device for detecting radioactivity, another common new word that the dictionary defines as the property of certain substances to emit spontaneously special radiations invisible to the eye but capable of penetrating objects opaque to ordinary light. This definition is more useful if the penetrating powers of the radiations are specifically described. Radioactive substances usually produce three types of radiation: the alpha ray, the beta ray, and the gamma ray.

Alpha rays are very weak, are considered harmless, and can be stopped by a few inches of air. In general these radiations do not affect Geiger counters due to their low penetrating power. Beta rays are quite a bit stronger. They can be stopped by a sheet of window glass but yet can go right through a sheet of aluminum with the greatest of ease and hence can be detected by aluminum-walled Geiger tubes. Beta rays are not exactly good for human health but are not considered dangerous in reasonable quantities. Gamma rays can punch their way through almost anything but can be stopped by a sufficient thickness of lead. These rays are definitely not healthy, although the body can stand them within certain tolerant limits.

So much for radioactivity. We have had it around about us all the time but wouldn't know it without special detecting devices. The Geiger tube is quite similar in construction to the gas type voltage-regulator tube in that it consists of two elements, a hollow cylindrical cathode and a coaxially mounted fine wire anode. There is no heater or filament to worry about. A mixture of two gases below atmospheric pressure is contained within the tube. In operation, a voltage is maintained between the two elements slightly below the point of breakdown. Any radiation entering the tube causes one gas to ionize and current to flow momentarily. The second gas quenches the current flow and allows the tube to recover quickly and get set for the next batch of radiation. Each shot of radiation results in a spurt of current which can be detected with head phones as an audible click. These current pulses can also be made to operate a neon lamp or an indicating



meter if desired. The rapidity of the spurts shows how much radioactivity there is in the neighborhood of the counter. That's all.

Geiger tubes are available in many sizes and shapes and most are rather expensive. For general nonprofessional use, however, there are two types that are quite moderately priced. The 1B86 is a miniature glass-wall tube used in many "prospector-type" counters. It operates on 300 volts potential but detects only gamma rays. In civil defense work this tube would be more than adequate to indicate dangerous levels of radioactivity. For experiments, however, the 1B85 is the more desirable tube as it can also detect beta rays which pass quite easily through its thin aluminum walls. These thin walls, however, must also maintain a partial vacuum, therefore the tube must be handled carefully. A slight pinch can completely collapse the tube and your investment as well.

Although a potential of 900 volts is required, it is not difficult to obtain. Since the current requirements are low, a power unit uncomfortable but not fatal to human touch can be used. There are many ways in which this potential can be generated, but for portable operation the simplest method is to harness the high-voltage kicks resulting from repeated sudden interruption of current flowing through an inductance. Mechanical, electromechanical, and electronic vibrators may be used for this purpose. Although high voltage of either polarity may be developed, it is much easier to obtain a negative than a positive potential.

The electronic vibrator power supply shown in the figure is a modified version of that used in a portable counter developed in Canada and described in U. S. Bureau of Standards Circular No. 490.

It might be described as a power multivibrator in which a rather large inductive load in the power tube is periodically and suddenly interrupted, producing high positive voltage kicks. How these positive kicks end up as a negative voltage requires explanation. Each kick, which lasts for only a small fraction of the vibrator cycle time, sends current through C1 and the 1X2 rectifier into the chassis ground. This instantly charges the condenser highly positive at the power tube plate terminal, the condenser terminal at the rectifier being at that instant at ground potential. Following this kick the power tube plate quickly lowers to normal voltage, while the condenser C1 retains its charge and sends its rectifier terminal end highly negative. This condition lasts for most of the cycle time and the average voltage at the rectifier end of C1 is thus highly negative. Two filters, R6-C2 and R7-C3 average out this pulsating potential to a steady high negative voltage at C3. A high resistance network puts a small bleeder load on the output of C3. Potentiometer R1 is used to raise or lower the voltage by lengthening or shortening the vibrator cycle time.

Gas-type voltage-regulator tubes are available that will maintain a constant 900-volt potential but are quite expensive. The regulator tube is not a necessary item but a voltage indicator is desirable and the neon lamp in the bleeder network performs this function. Voltages higher than 900 volts will cause the neon lamp to light, and a condenser across the lamp causes it to flash at a regular rate. Since this flashing lamp is associated with the 1S4 audio output tube grid, its operation results in a steady audible buzz when the output voltage is too high. Since neon lamps vary somewhat in their operating voltages, and resistors also vary from their marked values, it may be necessary to raise or lower the resistance value of the bleeder network to obtain the 900-volt indication. Adding 4 megohms to the circuit will raise the potential approximately 25 volts.

When radiation causes the Geiger tube to break down, the grid of the 1S4 tube is driven to cut off and an audible click is produced in the phone unit.

The Geiger tube may be housed in a bakelite holder without much noticeable loss in beta-ray sensitivity. If it becomes desirable, however, to detect only gamma radiation, the holder may be shielded with a steel sheath which will effectively block out all beta radiation.

In operation the Geiger counter is turned on and the voltage-regulating potentiometer R1 turned up until a steady buzz is heard. The potentiometer is then slowly backed down until the buzz stops, and the counter is then set to operate. Clicks will be heard at the rate of about one or two every three seconds, due to the normal radiation around and about us. A radium-dial watch should sound like a mild hailstorm.

Now suppose you have a Geiger counter, what can you do with it? Can you find uranium? Maybe yes, but most likely no. Uranium, believe it or not, is not very radioactive. You can get more action from a good radium-dial watch than you can from a teaspoonful of uranium nitrate. They do find uranium ore with the counter, but that is mainly due to the presence of small quantities of radium always associated with the ore itself. The counter, however, should serve you well in civilian defense preparation and should make any Western Union man who knows what makes it tick the envy of all the air-raid wardens in the neighborhood.—R. Steeneck, Assistant to Equipment Research Engineer.