DEPARTMENT OF THE ARMY TECHNICAL MANUAL

DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER

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FUNDAMENTALS OF TELEGRAPHY (TELETYPEWRITER)





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Figure 1. Advancement in communication methods.

CHAPTER 1

INTRODUCTION

Section I. DEVELOPMENT AND DESCRIPTION

1. General

Early methods of communication seem primitive when compared with present day systems. These early methods included signaling audibly by gunfire, drums, and other loud noises, and visually by lights, smoke, flags, and semaphores. It was through their use that code signaling was developed; code communication is still in use in all systems of telegraphy.

2. Manual Telegraphy

Telegraphy is a method of transmitting and receiving signals by means of groups of electrical impulses in accordance with a previously adopted code. A letter is first converted into signals of a code. The electrical impulses corresponding to the code signals are transmitted to the receiving station. At the receiving station, the impulses are decoded and recorded.

a. Development of the Morse Telegraph. In 1837, Samuel Morse invented the electric Morse telegraph. It was first used publicly in 1844, and rapidly replaced the semaphore telegraph.

b. Components of a Telegraph Circuit. A typical manual telegraph circuit (fig. 2) consists of the following components:

(1) A line that forms, either in itself or in connection with the earth, a complete circuit.
(2) A battery (or some other direct-current (dc) source) that provides power for the telegraph circuit.
(3) A key (or transmitter) that opens and closes a circuit to the sounder.
(4) A sounder (or receiver) that indicates the make and break of a circuit by sharp clicks.

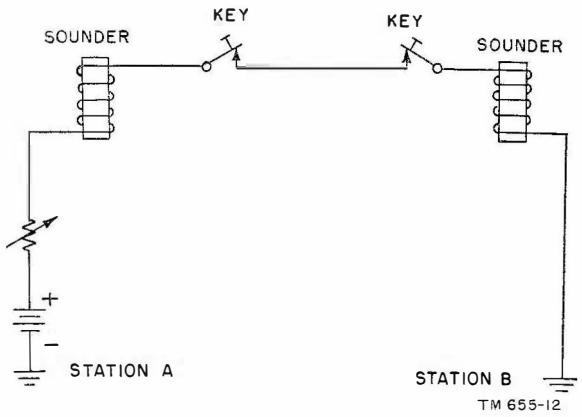


Figure 2. Manual telegraph circuit.

(5) A variable resistor which is used to limit current flow.

c. Key. The operator controls the circuit by operating the lever of the key. The back contacts of the key are connected in series in the telegraph circuit. When not transmitting, current flows over the circuit through the back contacts of the key, which are held closed by the pressure of a spring. When the operator presses the lever, the back contacts separate, opening the telegraph circuit. The upper front contact (on the lever) strikes the lower front contact causing an audible click. When the operator allows the lever to move upward, the back contacts close, again completing the telegraph circuit.

d. Sounder. The sounder converts the electrical impulses sent by the key into audible clicks. Current flowing through the two-coil electro-magnet establishes a magnetic field, which attracts the armature. Moving downward, the sounding bar adjusting screw strikes

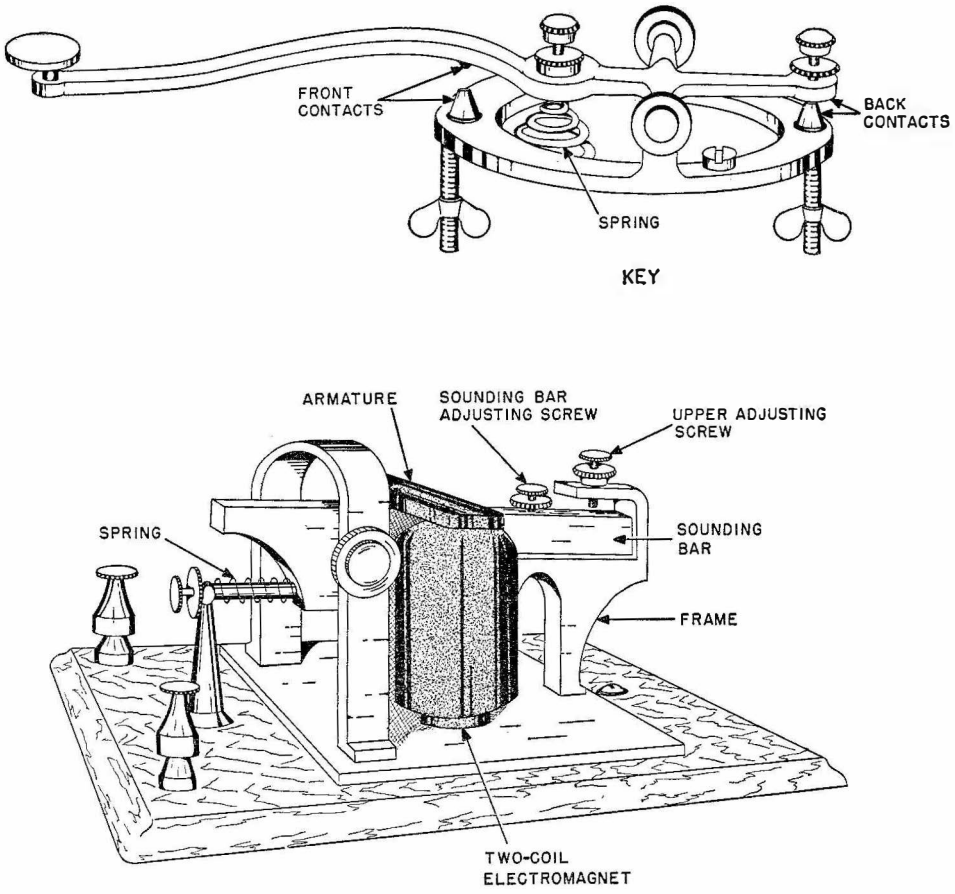


Figure 3. Key and sounder.

the frame beneath it with an audible click. The armature remains down until the coils are no longer energized. The spring then forces the armature to its nonoperated position, and forces the sounding bar to strike the upper adjusting screw; this causes another click which differs in sound from the first. The length of the interval between clicks determines the type of signal being sent by the key.

e. Morse Code. The Morse code (fig. 4) is made up of different combinations of dots (short breaks in current flow) and dashes (long breaks in current flow) for each letter of the alphabet and each punctuation mark. The key is used to interrupt the line current and to control the sounder operation at a distant station. To use this code, the operator of the key and the observer at the sounder must interpret the code in the same manner.

MORSE

A	•–	J	–•–•	S	•••
B	–•••	K	–•–	T	–
C	–•–•	L	•–••	U	••–
D	–••	M	––	V	•••–
E	•	N	–•	W	•––
F	••–•	O	–––	X	–••–
G	––•	P	•––•	Y	–•––
H	••••	Q	––•–	Z	––••
I	••	R	•–•		

1	•–––––	6	–••••	PERIOD	•–•–•–
2	••–––	7	––•••	COMMA	––••––
3	•••––	8	–––••	SEMICOLON	–•–•–•
4	••••–	9	––––•	COLON	–––•••
5	•••••	0	––––––	INTERROGATION	••––••
				QUOTATION	•–––––•

TM 655-80

Figure 4. Morse telegraph code.

3. Development of Teletypewriter

Manual wire telegraphy is seldom used in military installations. The Morse code keys and sounders have given way to teletypewriter equipment. The codes used in Morse operation and in teletypewriter operation, differ, but the basic principle of operation remains the same—the transmission and recording of electrical impulses. Most of the development has taken place in the past 40 years. Early teletypewriter equipments were heavy and cumbersome, and they were seldom used in military installations. The army made little use of the teletypewriter in World War I. Gradually, equipments have been made lighter and during World War II the teletypewriter was used extensively. Teletypewriter sets have been developed for use in airplanes, aboard naval vessels, and in battle areas as far forward as fox holes. Today, teletypewriter systems provide fast and accurate service with great message capacity; no branch of the Armed Forces is without teletypewriter facilities.

4. Definition and Description of the Teletypewriter

a. The teletypewriter is an electromechanical device that interchanges messages on a page or tape.

b. The teletypewriter consists of the following:

(1) A keyboard transmitting unit that transmits a character in the form of a group of coded electrical impulses over a circuit to all receiving mechanisms in the circuit.

(2) A receiving mechanism, controlled by this group of electrical impulses, that selects and prints the character.

c. Figure 5 shows a typical tactical teletypewriter of the page-printing type.

5. Advantages and Disadvantages of Teletypewriter Communication

a. Advantages.

(1) *Speed.* Teletypewriter circuit speed is normally 60 words-per-minute (wpm), and 100 wpm circuits are not unusual. The average speed of manual operation seldom exceeds 25 wpm.

(2) *Secrecy.* Messages are more difficult to intercept because of the different code combinations used.

(3) *Permanency of messages.* Messages are received in page or tape form.

(4) *Skill.* The ability to type is the only skill required of a teletypewriter operator. In manual operation, an operator must send each code impulse by hand, and hear, interpret, and record incoming messages.

(5) *Retransmission of messages.* Highly efficient use of communication center facilities is achieved by the use of perforated tape for the reception and the retransmission of messages.

b. Disadvantages.

(1) *Weight.* Although some small, lightweight equipment is now available, teletypewriters are usually bulky and heavy.

(2) *Maintenance.* Skilled mechanics are required to maintain equipment.

(3) *Quality of circuits.* The transmission must be of excellent quality to prevent distortion of signals.

(4) *Power requirements.* Teletypewriter circuits normally require at least 100 watts, and sometimes as much as 300 watts. Manual circuits require a power source of approximately 30 watts.

6. Types of Teletypewriter Operation

a. Manual Operation. In Morse code operation, the electrical impulses that make up the code are formed by the sending contacts of the key. In teletypewriter operation, the code impulses are formed by transmitter contacts in series in the signal circuit. These contacts are part of the teletypewriter keyboard transmitter. At the receiving end, in Morse operation, the impulses are received on a sounder to make the signals audible to an operator who interprets and records them. In teletypewriter operation the signals are received, interpreted, and recorded by a teletypewriter receiving mechanism.

b. Automatic Operation. In automatic operation, the code impulses are formed automatically from previously prepared tape, and are then transmitted by a transmitter-distributor (a

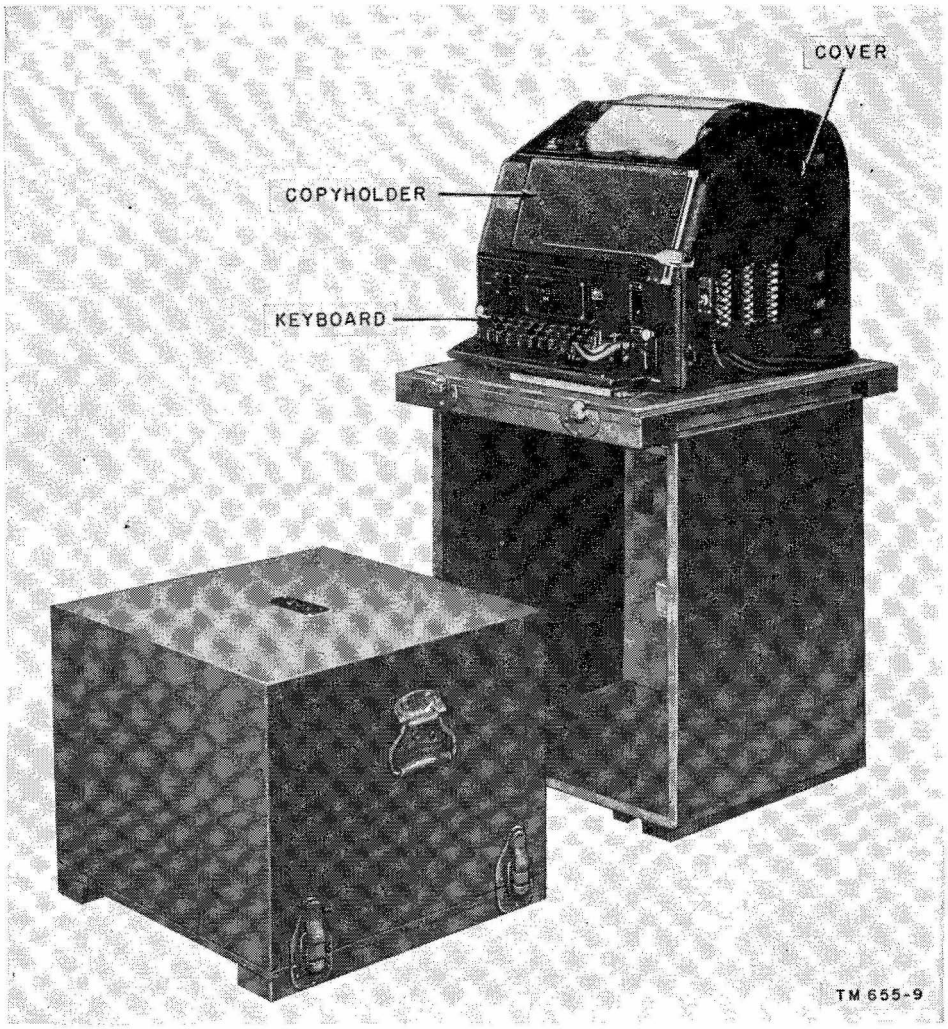


Figure 5. Typical tactical (field) page printing teletypewriter.

teletypewriter) to a distant station. The received signals are interpreted automatically, and recorded in typewritten or perforated form by another teletypewriter.

c. Direct-Current Telegraphy. In direct-current (d-c) telegraphy, current flow of the telegraph circuit is interrupted, reversed in polarity, or altered in magnitude by the impulse-forming and transmitting devices. The rate at which the line current is varied seldom exceeds 100 times a second. For this reason, systems of this type frequently are called low-frequency (l-f) systems. This system is used extensively in transmitting over short distances.

d. Carrier Telegraphy. In carrier telegraphy, the transmitting teletypewriter sends dc impulses to local carrier equipment which converts the signals to different frequencies of alternating current (ac), and transmits the signals as frequencies to the signal line. At the receiving station, the signals are received in the carrier equipment as two frequencies, converted to dc impulses and then transmitted to the local receiving teletypewriter. Many of the carrier telegraph systems use frequencies between 300 and 3,100 cycles. This range of frequencies is normally referred to as the voice-frequency (vf) range.

e. Telegraph Transmission by Radio. This type of transmission generally is used between points that are hard to reach by wire lines, such as mountains, large bodies of water, and jungle areas. This method combines the use of radio transmitters and receivers with teletypewriter equipment.

7. Basic Circuits

a. Ground-Return Circuits. A circuit in which a metallic conductor forms one side, and the earth forms the other side is a ground-return circuit. The ground-return circuit saves wire, since the earth is one of the conductors. However, ground resistance must be low in this type of circuit; possible disadvantages are leakage, changes of resistance because of changes in weather, and inductance from other circuits. (Refer to fig. 2.)

b. Full-Metallic Circuit. A circuit completed solely through metallic conductors is a full-metallic circuit. Advantages of a full-metallic circuit include less leakage, less outside interference, and less necessary attention.

c. Half-Duplex and Full-Duplex Operation. Half-duplex operation allows either station to send and receive messages, but not simultaneously. Half-duplex operation can use either a ground-return circuit or a full-metallic circuit. Full-duplex operation allows simultaneous operation over two separate circuits.

d. Simple Telegraph Circuit. A simple telegraph circuit (fig. 2) consists of telegraph instruments connected to a single wire, a battery, and a ground-return. Generally, this type of circuit is used only over short distances, but it is adequate for an explanation of fundamentals. Current flow in this circuit is from positive battery through a variable resistor, through a sounder and a key at one station, through a metallic conductor (line), through a key and a sounder at the second station, and back through the earth to negative battery at the first station. The manual *telegraph* circuit shown in figure 2 can be converted into a *teletypewriter* circuit by substituting teletypewriters at either end for the keys and sounders. Transmitting contacts in a teletypewriter perform the same function that keys perform in the manual telegraph circuit. Receiving magnets in teletypewriters perform the same function as sounders do in the manual telegraph circuit. The receiving magnets receive and interpret the transmitted electrical impulses, and then cause them to be printed on a page or a tape.

8. Teletypewriter and Typewriter Keyboards

In external appearance, the keyboard of a teletypewriter resembles the keyboard of the ordinary typewriter. However, the internal mechanism associated with the keys of the teletypewriter differs from the internal machanism of the typewriter. Since teletypewriters are interconnected electrically, functions performed manually on a typewriter (such as returning the carriage of the machine, and line feeding the paper) must be performed electrically on teletypewriters.

a. CAR RET Key. The key marked CAR RET must be depressed to return the type bar carriage to the left-hand margin of the paper.

b. LINE FEED Key. The key marked LINE FEED must be depressed to advance the paper to the next line of typing.

c. FIGS Key. The key marked FIGS must be depressed to shift the platen (the rubber roll directly behind the paper) to the *figures* position on a teletypewriter.

d. LTRS Key. The key marked LTRS must be depressed to unshift or return the platen to the *letters* position.

e. Space Bar. The space bar must be depressed to cause the carriage to space to the right.

Section II. THE TELETYPEWRITER CODE

9. Marking and Spacing

a. The original Morse telegraph instrument (fig. 6) was known as a telegraph register. It consisted of a switch (key) for sending; and a relay with a pen attached to its armature for receiving. To record a message, a paper tape was moved slowly under the pen by a clock mechanism.

b. In open-circuit telegraphy; a key at one station is closed to operate a relay at a second station; this will cause the equipment at the second station to make a mark on paper tape. Each time the key is opened, the paper tape at the second station will show a space between the marks. The intervals in which the line is closed are known as mark pulses, and the inter-

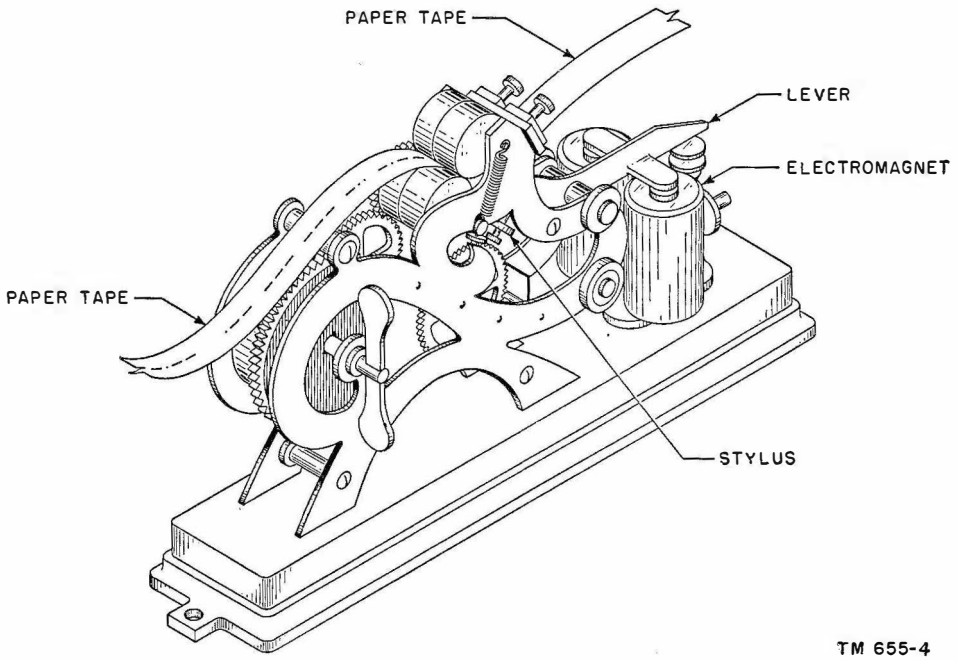


Figure 6. Early Morse pen register.

vals in which the line is opened are known as space pulses. The length of the mark on the paper tape depends on the length of time the relay remains operated because of the line being closed. A short closure registers a dot; a longer closure (usually three times as long) registers a dash. When the circuit is open, no mark (either dot or dash) will register. There is only a blank space.

c. The terms *marking* and *spacing* have different meanings when applied to teletypewriter operation. As explained in *b* above, marking in manual telegraphy indicates a closed circuit condition during which a mark (a dash or dot) is made on paper tape used on the telegraph register, and spacing means an open-circuit condition when no mark is made on the paper; instead, a space is left. In teletypewriter operation, marking indicates a circuit condition in which the selector magnets in the teletypewriters are in the operated position; spacing indicates a circuit condition in which the selector magnets are in the unoperated position. The method of producing marking and spacing conditions in a teletypewriter circuit depends on the type of transmission used (explained in ch. 3).

10. The Five-Unit Code

a. In teletypewriter code, the code group for *each* character is of uniform length; therefore, the Morse code cannot be used in teletypewriter operation. The mechanical sending device in the teletypewriter divides the sending time into five short code intervals of equal duration. Each character—letter, numeral, or punctuation mark (or nonprinting function, such as line feed and carriage return)—is composed of a combination of five marking and spacing impulses. This makes mechanical simplicity possible.

b. Only the five-interval code is discussed here, although codes are used which contain six and seven intervals for each character. They are not generally used, and are not important in a study of fundamentals.

c. Although the teletypewriter code is known as the five-unit, there are really seven time intervals involved. When teletypewriters are adjusted to operate at 60 wpm, each of the first six intervals is 22 milliseconds. The seventh interval is 31 milliseconds. The first 22 millisecond interval is the start interval. The other five 22 millisecond intervals (code impulses) are

those during which the character is sent. The seventh interval, 31 milliseconds long, is the stop impulse. The start-stop system synchronizes the operations of all machines connected in a circuit. The machines, instead of operating continuously, will stop after the transmission of each series of five code impulses so that machines will be in exact synchronism at the beginning of the transmission of every character. Thus, timing differences are prevented from accumulating and causing errors. A more detailed description of synchronism, covering the means taken to secure it, is contained in chapter 2.

d. Figure 7 represents the code impulse sequences for the letters R and Y. (The letters R and Y are illustrated because they are used widely for test purposes.) In a system in which marking impulses are represented by current intervals, and spacing impulses by no-current intervals, the transmission of the letter R is accomplished by transmitting no-current impulses in the first, the third, and the fifth time intervals, and current impulses in the second and the fourth time intervals. Similarly, transmission of the letter Y is accomplished by transmitting current impulses in the first, the third, and the fifth time intervals, and no-current impulses in the second and the fourth time intervals.

11. Transmission of the Five-Unit Code

a. Figure 8 illustrates all the possible code combinations of the five-unit teletypewriter code. The tape illustrated shows the code perforated in paper tape. The perforated tape is used for automatic transmission of teletypewriter code groups.

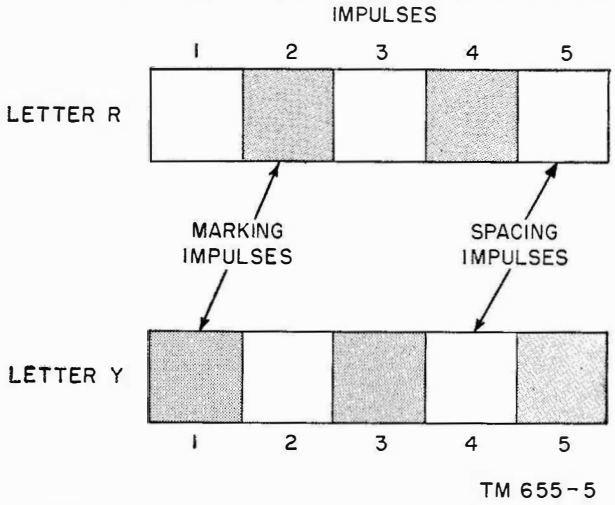


Figure 7. Teletypewriter code symbols for letters R and Y.

b. Figure 9 illustrates the time and current relationship during the transmission of the complete letter Y code group. The beginning of each of the 7 time intervals is indicated below as T0 through T6, and the ending of the seventh time interval is indicated as T7.

c. The average word consists of five letters and a space between each word; therefore, six revolutions of the transmitting cam assembly which operates the transmitting contact springs are required for each word. At 60 wpm, 60 times 6 or 360 revolutions per minute (rpm) of the transmitting cam sleeve would be required. However, since 163 milliseconds are required for each revolution of the transmitting cam sleeve, the transmitting shaft is operated slightly above this speed at 368.1 rpm (60 divided by .163) instead of 360 rpm. This speed of operation is usually referred to as 368.1 operations per minute (opm) or 60 wpm.

d. To send the letter Y, the operator presses the Y key; the keyboard contacts cause the signal (fig. 9) to transmit to the line. The sequence of the operation of the keyboard contact is as follows:

(1) T0—the operator depresses the Y key; this sets the apparatus in motion and causes the start-stop contact to open the line.
(2) T1—22 milliseconds later than T0, contact No. 1 closes and causes the line current to increase to 60 milliamperes (ma).
(3) T2—44 milliseconds later than T0, contact No. 1 opens and causes the line to open (contact No. 2 does not close).
(4) T3—66 milliseconds later than T0, contact No. 3 closes and causes the line current to increase to 60 ma.
(5) T4—88 milliseconds later than T0, contact No. 3 opens and causes the line to open (contact No. 4 does not close).
(6) T5—110 milliseconds later than T0, contact No. 5 closes and causes the line current to increase to 60 ma.
(7) T6—132 milliseconds later than T0, contact No. 5 opens and the start-stop

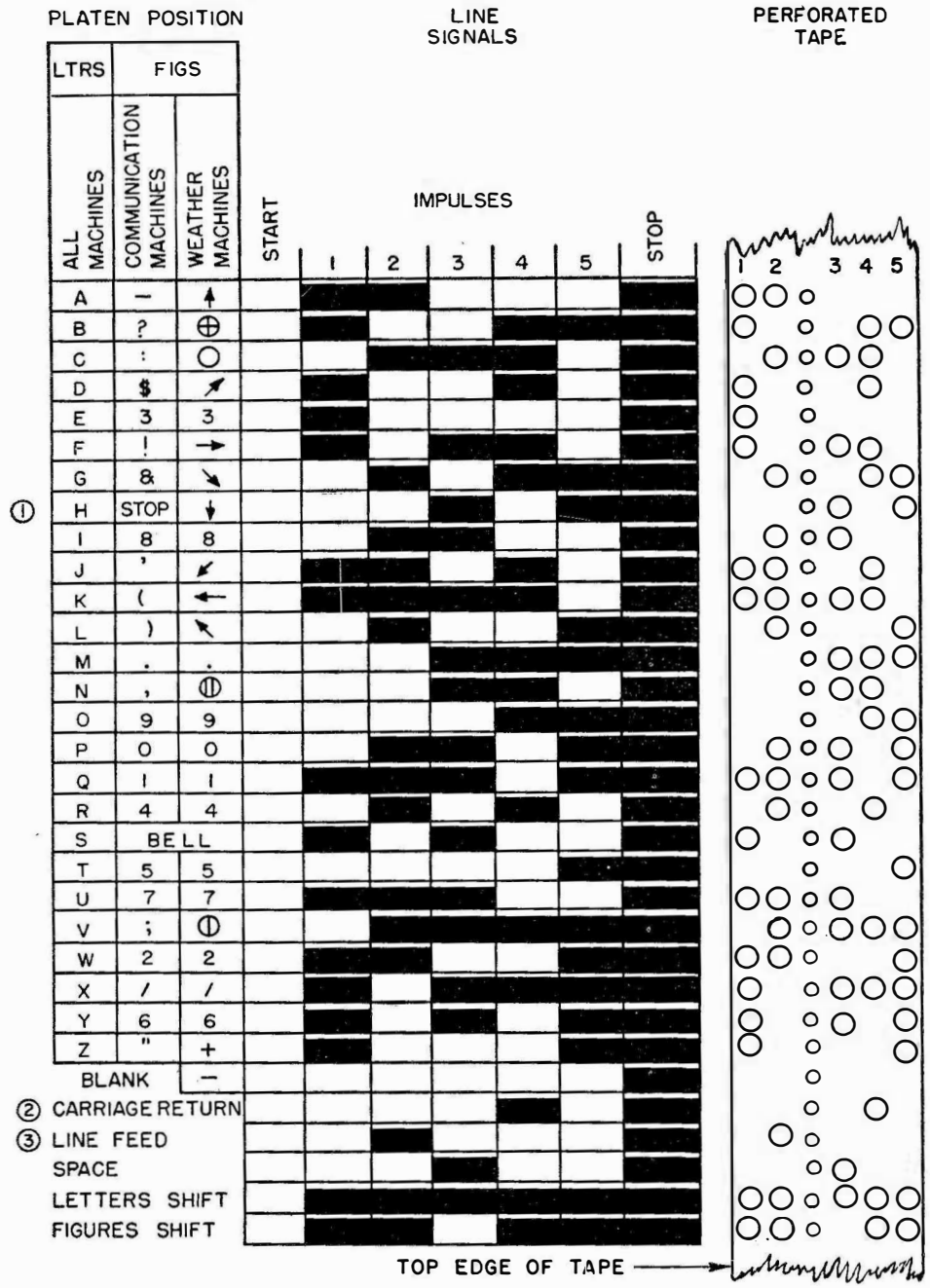


Figure 8. Five-unit, start-stop teletypewriter code.

contact closes; the line current remains at 60 ma.

(8) T7—163 milliseconds later than T0, the sending mechanism is ready for transmission of the next character.

e. These illustrated transmitter signals are perfect signals; the spacing and marking impulses, with the exception of the stop impulse, are equal in length (22 milliseconds), and the mark-to-space and the space-to-mark transitions are instantaneous.

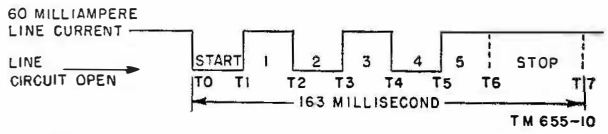


Figure 9. Theoretical diagram of transmission of letter Y.

Section III. INSTALLATION REQUIREMENTS

12. Teletypewriter Installation

Military teletypewriter installations are divided into two installation classifications. These are fixed or permanent installations, and field or mobile installations.

a. Fixed or Permanent. A teletypewriter mechanic in this type of installation must be thoroughly familiar with the teletypewriters, the teletypewriter tables, the rectifiers, the terminals, the plugs, and the jacks. He also must know the best method for installing the equipment and for running wires and cables so that a complete installation is neat, compact, and convenient for operation and maintenance.

b. Field or Mobile. A teletypewriter mechanic in this type of installation must be sure that each teletypewriter installation can be made, removed, transported, and reinstalled readily. Installation of military field teletypewriter equipment is not too difficult, and can be learned in a comparatively short time.

13. Power Requirements

All teletypewriters require electrical power for their operation. D-c power is adequate for all purposes, although a combination of a-c and d-c power is frequently used. A-c power can be used for the operation of teletypewriter equipment, motors, and, in some cases, for the universal magnets of transmitter-distributors. D-c power must be used to operate the teletypewriter receiving magnet.

a. Storage Batteries. Batteries are seldom used for teletypewriter operation in the Armed Forces because of their weight, size, and the maintenance required to keep them in operating condition. An additional source of power is also necessary to keep batteries in a charged condition.

b. Motor Generators. Motor generator sets are normally used in large communication centers where the current drain is exceptionally heavy. Usually, the d-c output of a motor generator is fed through a filtering arrangement before it is applied to the teletypewriter equipment.

c. Rectifiers. Rectifiers are normally used as d-c power sources for teletypewriter operation in military establishments at smaller installations. In most cases, the rectifiers used are designed to operate from an a-c power source of approximately 110 volts. The rectifier output supplied to the teletypewriter is normally 110 volts d-c.

14. Space Needs

Teletypewriter equipment is compact and does not require much room for installation. The space requirements described below apply to fixed installations only. The space needs for field or tactical teletypewriter equipment depend on the existing conditions.

a. Generally, when the usual page-printing teletypewriter is installed at a fixed or semipermanent installation (fig. 13), the rear of the teletypewriter is placed at least 10 inches from the wall to allow room for the top cover of the unit to be swung backward for reloading the paper roll. To avoid work at the rear of the machine external connections are usually made at the front of the table upon which the teletypewriter is mounted. There should be a clearance of 2 feet on either side of the teletypewriter table, and 3 or 4 feet of clearance

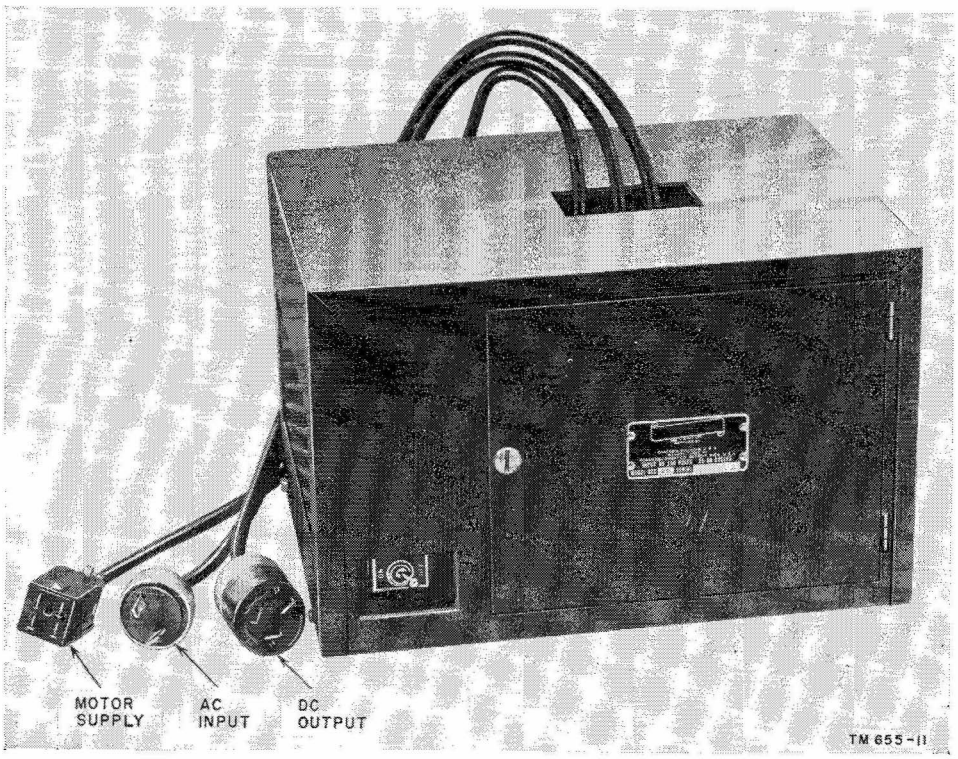


Figure 10. Typical rectifier used in teletypewriter operation.

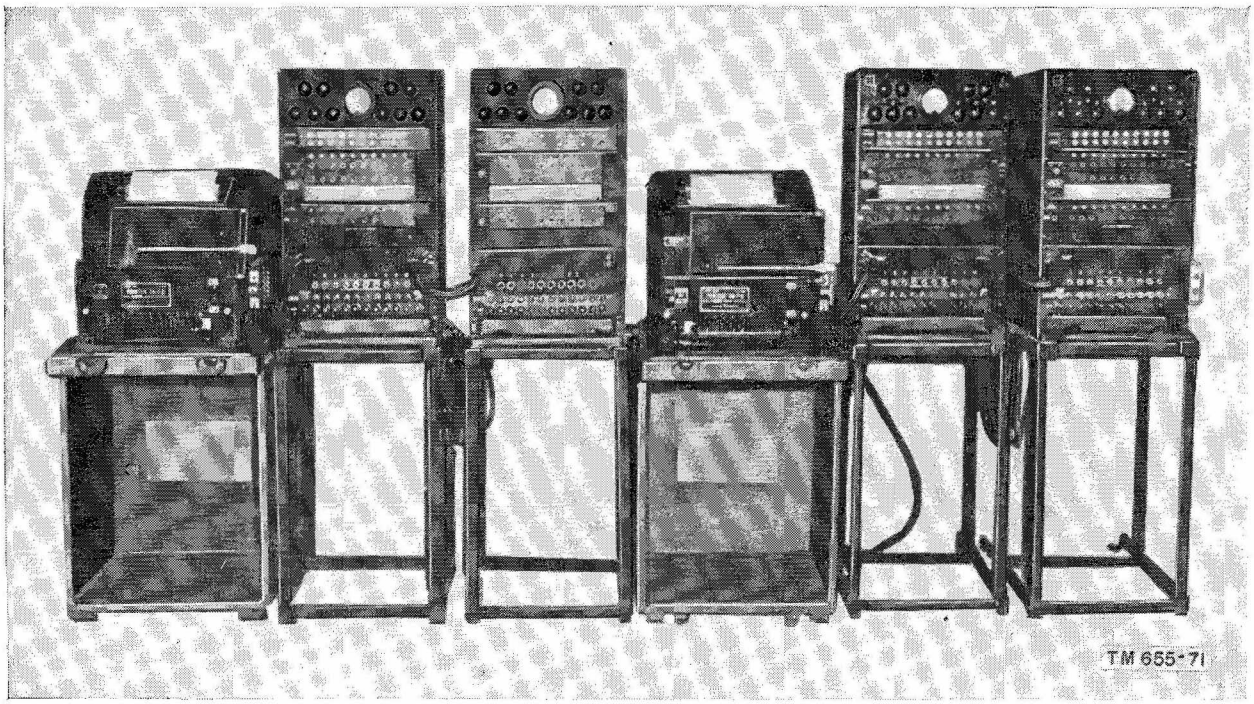


Figure 11. Equipment arrangements for semipermanent installation (teletypewriters and telegraph switchboards).

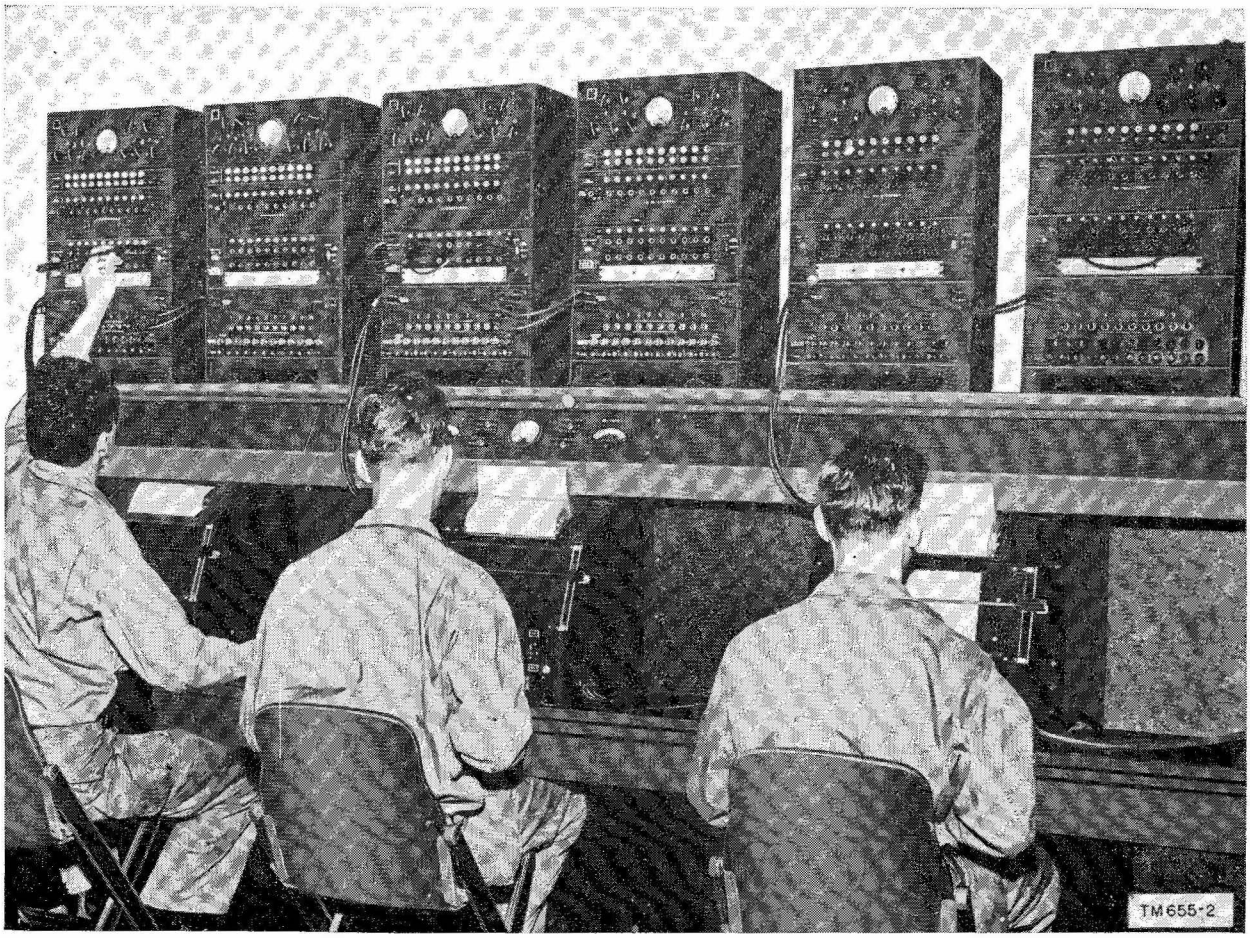


Figure 12. Permanent large teletypewriter switching central.

in front of the teletypewriter. Figure 12 shows a front view of a permanent, large teletypewriter switching central. Figure 11 shows the same equipment arranged for semipermanent installations.

b. Some teletypewriters are known as composite or consolidated teletypewriter sets. In addition to the teletypewriter unit itself, a transmitter distributor (tape transmitter) and sometimes a reperforator (tape perforator) are designed to operate with it. Because many of these sets are designed for connections to be made to the tables upon which the equipments are mounted, at least 2 feet of clearance between the rear of the teletypewriter set and wall is necessary. (Other clearances at the sides and the front of the set are comparable to the clearances mentioned in *a* above.)

15. Lighting and External Wiring

a. Installations containing teletypewriter equipment must be adequately lighted. Mental fatigue and eye strain are present under the best possible working conditions; therefore, proper placement of the equipment is important. For daytime operation, there should be natural light from the rear of the operator. For night operation, fixtures should be placed so that light will fall on the teletypewriter keyboard and platen. (A drop light and an extension cord are convenient assets for maintenance duties.)

b. If wall outlets for power are not available, installing personnel must arrange for such outlets. It is important to determine whether one side of the a-c power line is grounded. If

neither side is grounded, either lead may be connected to any terminal of the outlet. If one lead is grounded, it must be connected to the outlet terminal of the table with which the teletypewriter is used. When radio receivers are operated near teletypewriter equipment, noise might be picked up from the teletypewriter and its power supply leads. Proper shielding of the radio antenna lead-in wires and proper care in the location of the lead-in wires with respect to teletypewriter installations (such as wider separation and elimination of parallel paths) will help to cut down interference.

16. Safety Devices

Applicable technical manuals explain, in detail, methods of protecting teletypewriter stations and the maintenance personnel working in them. Plant and equipment protective units and the manner in which they are used vary with particular situations, but, in general, protective devices for teletypewriter systems are of three types: open-pace cutouts, heat coils, and fuses (or fustats).

a. Open-Space Cutouts. Open-space cutouts protect the teletypewriter equipment by short circuiting the line (to ground) at a station when high voltages (such as power line voltages or lightning) come in contact with the line.

b. Heat Coils. Heat coils protect the teletypewriter equipment by opening up the line at a station when sneak currents (currents due to induction or some other source) are encountered on a line.

c. Fuses. Fuses and fustats are used for the internal protection of the various teletypewriter units. Receptacles for the fustats and fuses are built into the tables that hold fixed-station teletypewriter equipment. Sometimes such receptacles are built into the teletypewriter units themselves.

17. Grounding

In the operation of a ground-return teletypewriter circuit (where the earth becomes one side of the line), a good ground-return system is necessary. A poor ground contact is equivalent to high resistance in series with the circuit, and may cause serious difficulty. Ground resistance can be so high that it will not be possible to obtain the required line current.

a. Ground resistance may change considerably with alternate wet and dry weather and call for time-consuming system line-ups. For example, if dry ground with a high resistance becomes wet (wet ground is a better conductor than dry ground), ground resistance may disappear or materially decrease. Under such a condition, line current will increase and signals will become distorted.

b. Another possible result from high-resistance grounds is interference between circuits in the same general area; common ground resistance will couple such lines together, and there may be severe crossfire* results. Refer to TM 11–676 for instructions on grounds and grounding.

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* Crossfire is a term for foreign current impulses produced in teletypewriter circuits by the influence of other parallel teletypewriter circuits.

CHAPTER 2

TELETYPEWRITER CHARACTERISTICS

Section I. MECHANICAL FEATURES

18. Introduction

The information contained in this chapter is confined almost exclusively to the page-printing type of teletypewriter. However, in addition to the page-printing teletypewriter, there are various teletypewriter equipments. These include perforators to prepare tape, transmitter distributors to transmit messages perforated in tape, and reperforators to record received messages for relaying to distant points. These equipments are discussed in chapter 4 of this manual.

a. General.

(1) Teletypewriters are motor-driven machines that provide the mechanical means to interchange typewritten messages transmitted electrically by wire, carrier, or radio between two or more points. They may be started and stopped by any station connected in a circuit. The equipment used at fixed stations is usually more extensive than equipment used at field (mobile) stations, but the operating principles are identical. In both cases, a keyboard transmitter (or other device, such as a transmitter distributor) is required to send a message; a wire or radio channel is required for transmission; and a teletyepwriter (or similar mechanism, such as a reperforator) is required to receive and record the message. Although teletypewriter transmission and reception is electrical; teletypewriter equipment is largely mechanical. Cams on a revolving shaft in the keyboard transmitter at the sending station cause the signal code for the depressed key to be impressed on the line or transmission channel, and cams on a revolving shaft in the receiving teletypewriter cause the impulses to be received, stored, translated, and recorded. The basic units of a send-receive teletypewriter include a keyboard unit (fig. 25), a typing unit (figs. 26, 27, 28, 29, and 30), a motor unit (fig. 21), and a base unit (fig. 15). The base unit supports the other three units. In fixed installations, a table (fig. 33) is provided to support the base unit; in field installations, the packing case is used to support the base unit.

(2) An assembled teletypewriter set (fig. 13) occupies a space approximately $21\frac{5}{16}$ inches deep (front to rear), 18 inches wide, and $42\frac{1}{8}$ inches high. It weighs about 200 pounds. (Some of the more recently developed tactical teletypewriters are considerably smaller and lighter.) Teletypewriters are normally adjusted for a standard American speed of 368.1 opm which permits sending and receiving approximately 60 wpm. By adjusting the motor governor, it is possible on many machines to increase the speed to 404 opm when interoperation with equipment (such as the British teleprinter) operating at this speed is desired. On other machines it is necessary to substitute gears to operate at this speed. When operation at speeds of 75 or 100 wpm is desired, the gears must be changed in all machines.

(3) The power normally required to operate a page type teletypewriter and to furnish the line current is about 200 watts. The governed series-wound motor operates with 110- to 120-volt, 50- to 60-cycle ac. The required d-c line current is approximately .060 ampere (60 ma), and is usually furnished from one end of the line only. When a station is only required to operate a teletypewriter, and regulated 60-cycle ac is available, a synchronous (one speed) motor unit may be used, and the station may be operated without a local power source. However, this arrangement seldom is used by the Armed Forces except in large comcenters. Usually, where commercial power is available, a rectifier is used as a source; where commercial power is not available, as in tactical installations, a motor-driven power unit is used. In addition to furnishing the direct current required, both the rectifier and the motor-driven power unit are arranged to furnish current to operate the teletypewriter motor unit. A rectifier or power unit at a teletype-

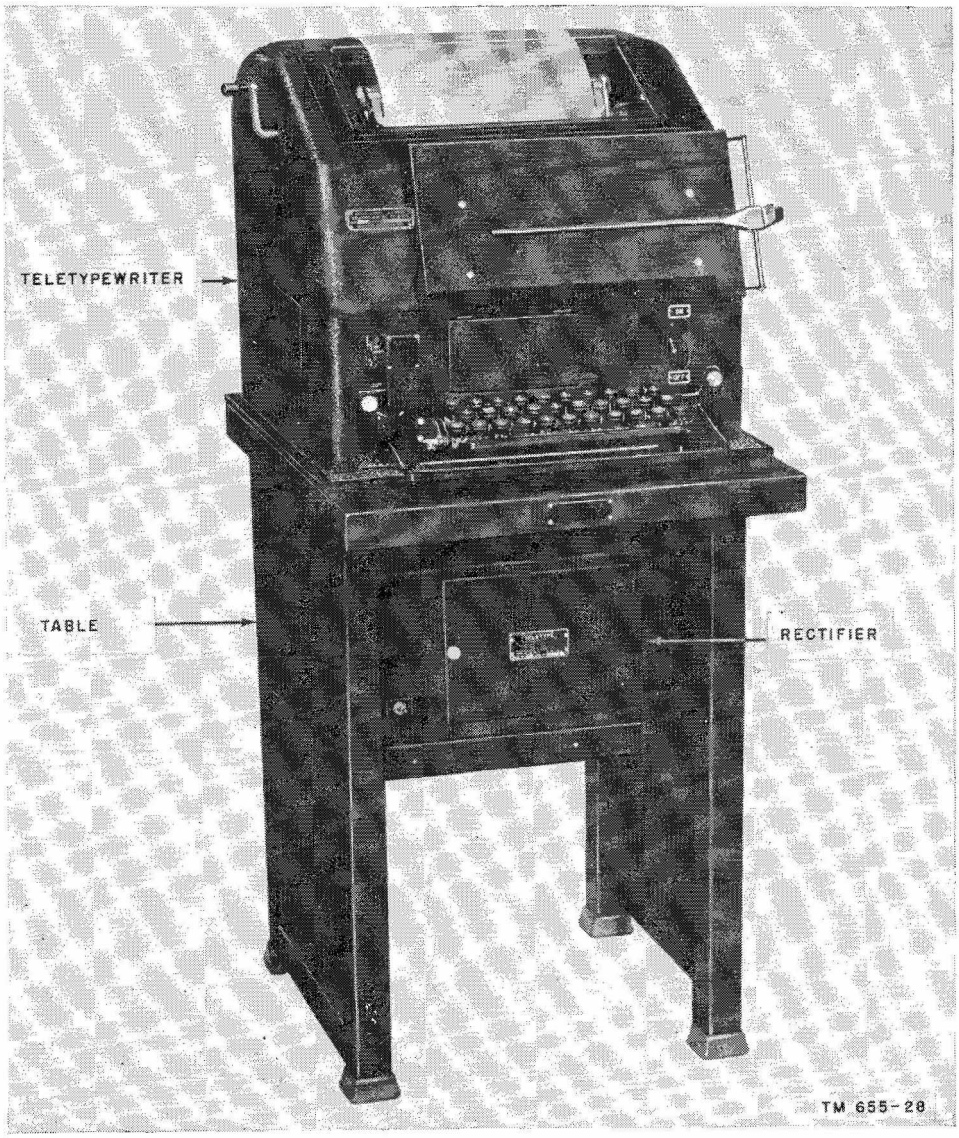


Figure 13. Typical teletypewriter set.

writer station permits the use of auxiliary equipment (a line relay or a line unit) to facilitate operation over greater distances and less desirable circuits, and to improve performance and flexibility.

b. Control. All teletypewriters connected in the same circuit (except weather report machines) may be started by any station through the use of a mechanical motor control by momentarily opening the signal line. They may be stopped by any station by first depressing the figures key (FIGS), and then the upper case H key.

c. Operating Features. Send-receive teletypewriters usually have friction paper feed, series-governed motors, a remote control motor stop operated by the upper case H key, and a rectifier (for local or line current) with built-in transformers for 95- to 125- and 190- to 250-volt, 25- to 60-cycle input. The transformer of the rectifier includes variable tap windings for adjusting motor terminal and d-c voltages. Signaling is accomplished through the use of the five-unit code of marking and spacing electrical impulses produced by mechanical action of a transmitting unit; these impulses are reconverted to mechanical action by the selector mechanism of a typing unit.

d. Utilization. In cases where a line is short and no appreciable variation in line conditions exists, it is possible to establish communication between two teletypewriters by interconnecting them directly over a pair of wires (or one wire and ground) if the correct d-c voltage is furnished in series with a current-limiting resistance. In the majority of cases, however, some equipment in addition to the teletypewriters and power source is necessary to maintain and control the line or loop. Such equipment may include a current-limiting resistance installed in the teletypewriter or its table, and external equipment, such as line units, d-c repeaters, telegraph switchboards, telegraph carrier terminals, and speech-plus-duplex terminals.

19. Description of Teletypewriter Components

a. General. The components shown in figure 14 are typical of the page-printing teletypewriter. Usually some components used in commercial machines are modified (simplified) for tactical (field) use by the omission of certain parts and the addition of others. A brief description of page-printing teletypewriter components is given in *b* through *l* below in preparation for the detailed description and functioning of these parts described in paragraphs 20 through 39.

b. Base. The base (fig. 15) consists of a metal casting designed to furnish a secure mounting for the other units of the teletypewriter.

(1) In commercial and certain fixed military installations, the base provides mounting facilities for the polar line relay (fig. 18), the motor control relay (fig. 15), the motor unit (fig. 21), the typing unit (figs. 26, 27, 28, and 30), and the keyboard unit (fig. 25).

(2) In tactical installations, the polar line relay is replaced by an external line unit (containing a line relay) except when the teletypewriter is converted for use with other than tactical teletypewriter sets or systems.

(3) The motor control relay requires a separate control circuit and is used only when it would be impractical to use remote motor control over the signal line. Four bakelite terminal boards are provided on the base (fig. 17) by which power is connected to the motor unit, the receiving line is brought to the line winding of the polar line relay (where it is installed), and the sending line is brought to the transmitting contacts.

(4) At fixed stations, two power cords (a-c and d-c) and two line cords (sending and receiving) are attached to the right side of the terminal boards. The sending cord terminates in a black-shell plug, and the receiving cord terminates in a red-shell plug. The a-c power cord is provided with a four-prong plug, and the d-c cord is provided with a three-prong plug.

(5) A line jack (fig. 15) is provided on the base to keep the line closed when

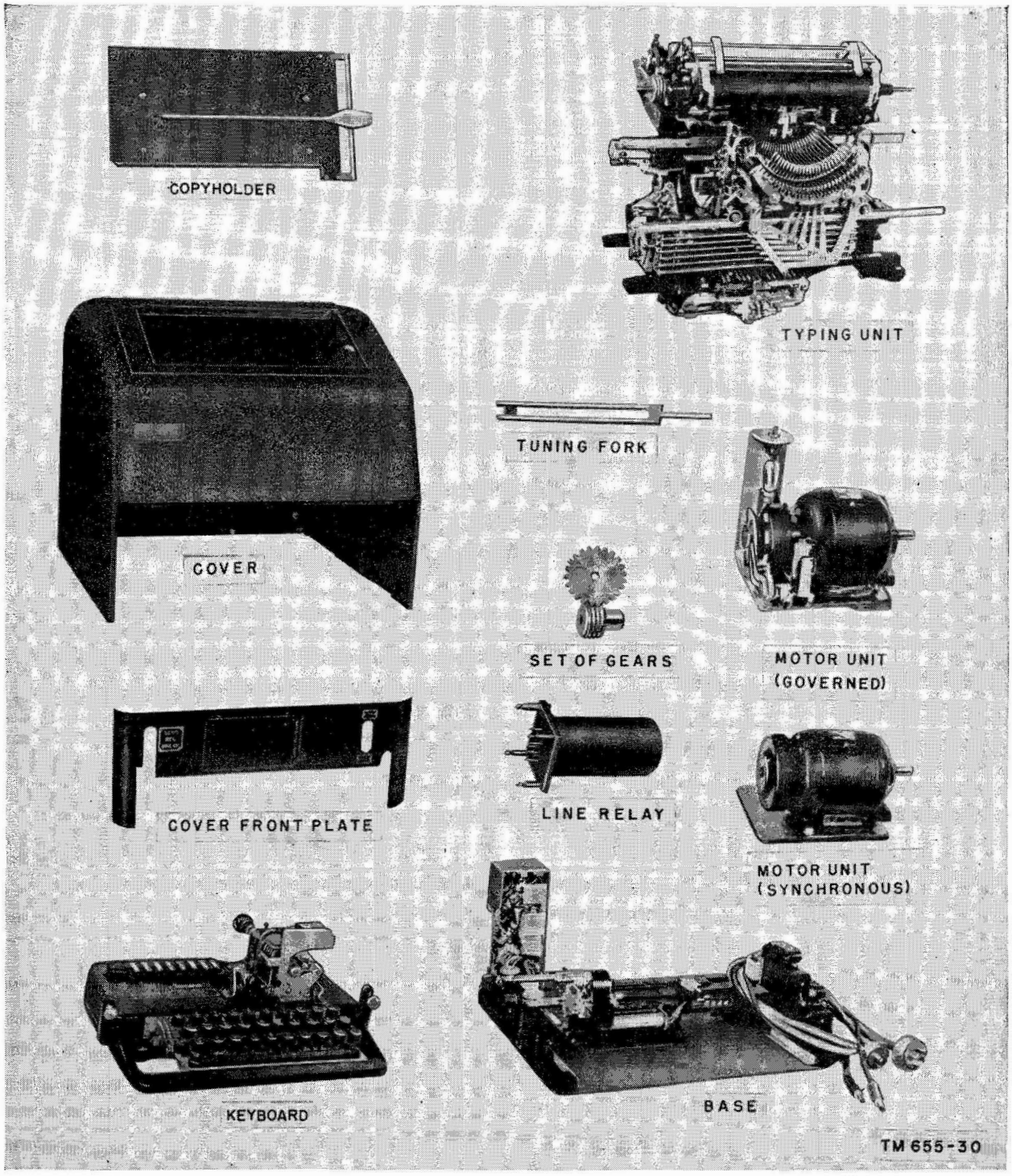


Figure 14. Teletypewriter components.

the typing unit is removed. The base unit is set and centered on a felt pad on the equipment table. The felt pad is held in place by metal channels on both sides and at the rear of the table top. The line relay mounting brackets and resistor assembly, along with a wiring and motor control relay (when provided), is mounted on the base toward the rear. A SEND REC BREAK key (double-lever type) is mounted on the front of the base to the left (fig. 15) and extends through an opening in the cover. An ON-OFF switch (fig. 15) on the front of the base serves to start and stop the motor manually. It is reached through an opening in the cover. The terminal boards for connecting the a-c and d-c power and the signal lines are mounted on the right side of the base as viewed from the front (figs. 15 and 17). The terminal board for the line relay connections is mounted on the left side of the base toward the back. Slip connections for the motor, the keyboard, and the typing unit are mounted on the base to provide the electrical connections between these units. Radio-frequency (r-f) induction filters are mounted on the base near the relay and power terminal boards.

(6) In mobile installations for tactical (field) use, the following differences exist:

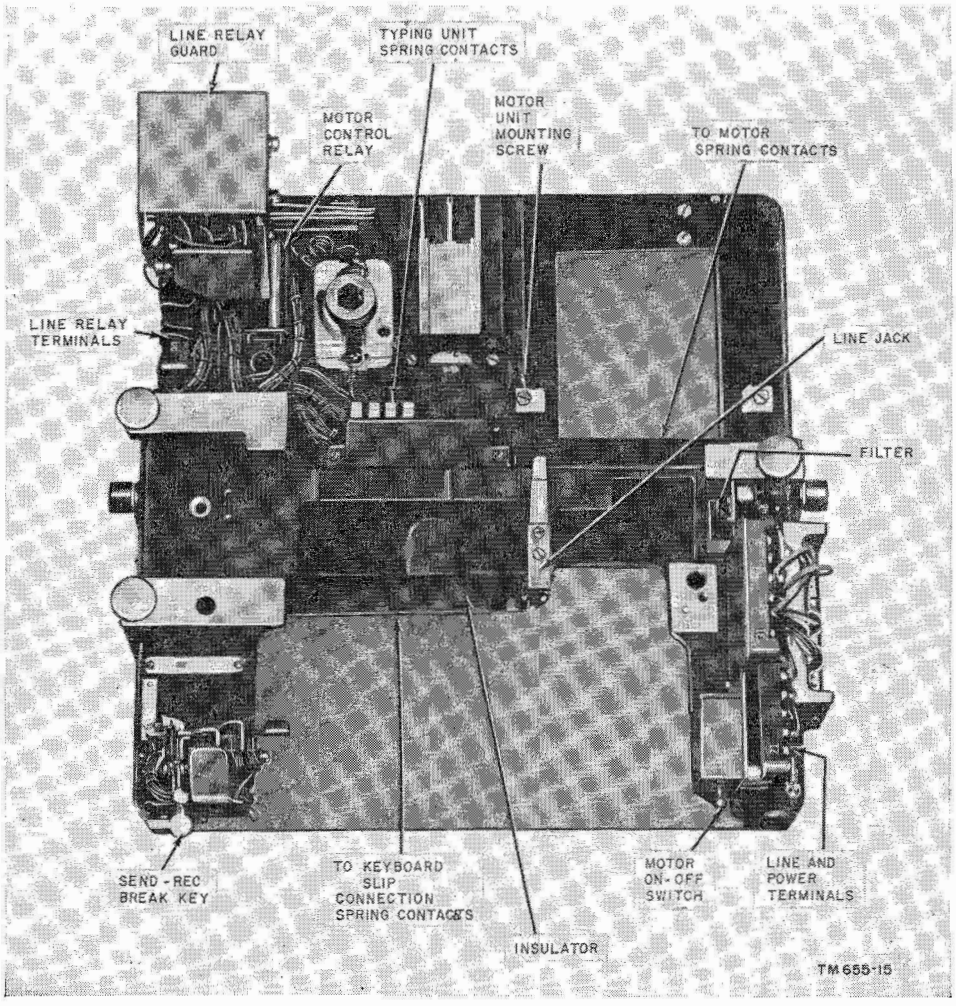


Figure 15. Teletypewriter base, fixed station.

(*a*) The base is fastened securely to the bottom of the chest used for transportation, instead of being supported on a table (fig. 5).

(*b*) An externally mounted line unit (figs. 19 and 20) is used with tactical teletypewriter equipment instead of a line relay (used in fixed station teletypewriter equipment).

(*c*) A power selector unit with a resistor assembly and a switch is attached to the right side of the base (fig 16). The switch is used to regulate the resistors of the power selector unit so that the teletypewriter may be operated on one of the following: 115-volt, 50- to 60-cycle ac; 115-volt, 25- to 40-cycle ac; or 115-volt dc. Two line cords and one power cord are attached to the power selector unit. The *sending* cord, which terminates in a black-shell plug, and the *receiving* cord, which terminates in a red-shell plug, are used to connect the teletypewriter to other teletypewriter equipment. The *power* cord terminates in a two-prong male plug and is used to connect the teletypewriter to a power outlet.

c. Relay.

(1) Commercial and fixed-station military teletypewriters are equipped with a polar line relay (fig. 18) mounted on a bracket on the base unit. The relay connections can be changed to receive either neutral- or polar-type signals by operating the polar-neutral key (fig. 25).

(2) To receive neutral signals, the relay bias winding is connected into a d-c circuit by pulling the polar-neutral key *out*.

(3) To receive polar type signals, the circuit is opened through the relay bias

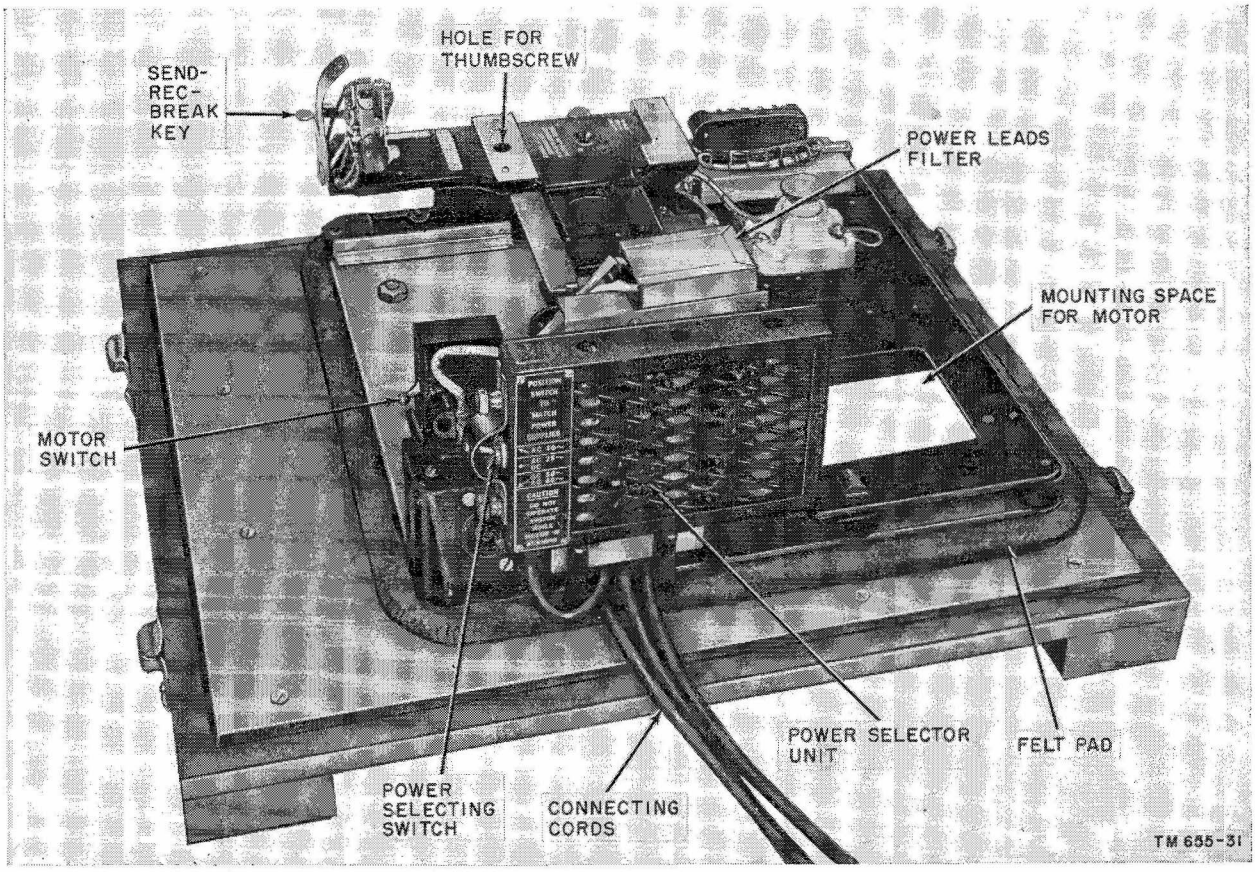


Figure 16. Teletypewriter base, tactical station.

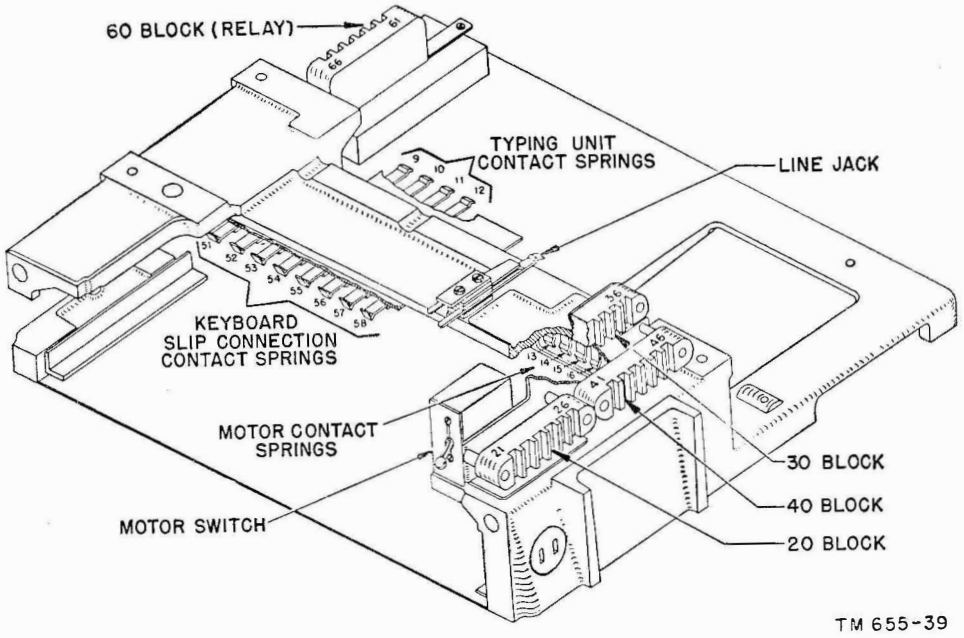


Figure 17. Base terminal boards and contacts.

winding by pushing the polar-neutral key *in*.

(4) Tactical (field) teletypewriters are not equipped with a polar-line relay. They operate in conjunction with an external item of equipment known as a line unit (fig. 19). Each line unit contains a line relay (fig. 20) especially designed for use as part of Army tactical teletypewriter sets that transmit and receive d-c neutral signals. The relay is equipped with a transparent plastic case and an armature tension-adjusting knob by which the relay may be adjusted to compensate for signal bias.

d. Motor Unit. The motor unit (fig. 21) consists of a series-governed motor or a synchronous motor mounted on a base plate. The base plate of the motor unit contains the mounting screws by which it is mounted on the base of the teletypewriter. The base plate also has two screws for vertical adjustment to aline the motor pinion with the main shaft gear of the typing unit. Horizontal alinement is obtained by use of elongated screw holes in the base of the motor casting.

(1) Mounted near the flywheel-governor assembly of the motor unit are a lamp, a lamp bracket, and a lamp switch. The lamp is used to illuminate a target (fig. 21) while checking the motor speed with a speed indicator (fig 22).

(2) The target consists of series of alternate black and white segments painted on a rim that revolves with the motor governor flywheel. Circuit connections are established through spring contacts on the base unit. These contacts exert pressure against the terminals of the motor unit when it is in position on the base unit.

(3) The motor unit is mounted at the right rear of the teletypewriter base and includes a filter for suppressing r-f induction. When regulated 50- or 60-cycle ac is available, a one-speed synchronous motor may be used in place of the governed motor.

e. Speed Indicator. The standard speed indicator (fig. 22) is a tuning fork that vibrates at 87.6 vibrations per second (vps), and is used to check the motor speed for 368.1 opm, or approximately 60 wpm. A slotted plate is attached to the vibrating end of each tine of the fork. After the speed indicator is tapped lightly to make it vibrate, the rotating target on the motor unit flywheel is viewed through the aper-

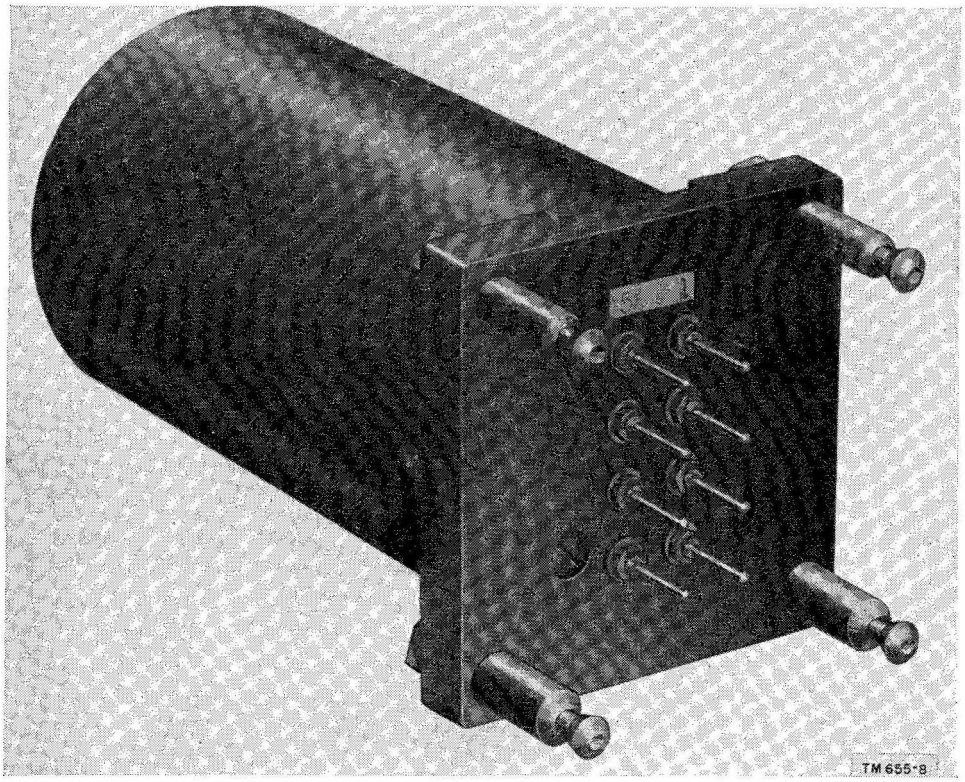


Figure 18. Polar line relay.

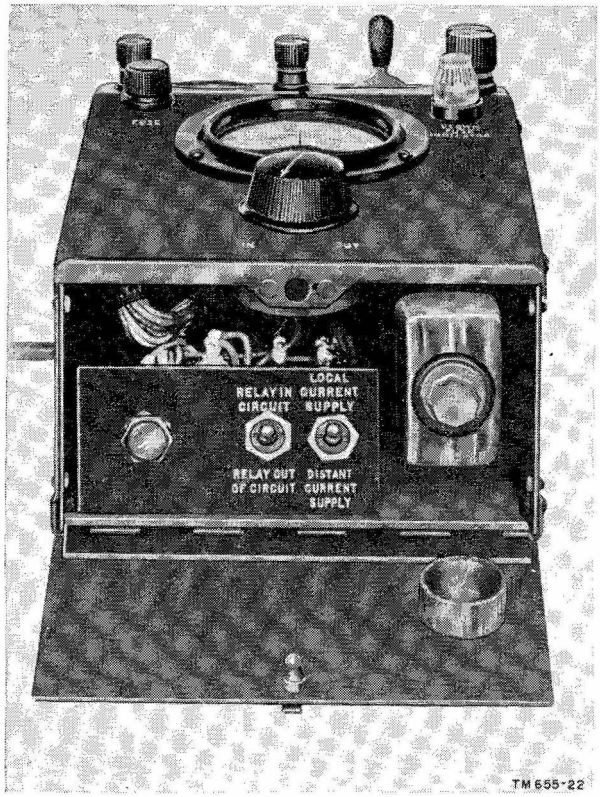


Figure 19. Line unit, door open.

ture formed by the slots in the plates to check the speed of the motor. A special tuning fork that vibrates at 96.1 vps is required for 404-opm or 66-wpm operation.

f. Rectifier Power Unit. A series-governed motor in a teletypewriter operates on 50- to 60-cycle ac at 110 to 120 volts. The local and signal line circuits require a d-c supply at 110 to 120 volts. These requirements usually are supplied by a rectifier unit (fig. 10), which is part of many teletypewriter sets. A rectifier is a device for changing ac to dc. It consists essentially of a transformer, a full-wave selenium rectifying assembly (stack), a choke coil with tuning capacitor, filter capacitor, bleeder resistor, fuses, power switch, input and output cords, and receptacles. A rectifier can be adjusted to work on a-c power supplies from 95 to 125 and 190 to 250 volts and from 25 to 60 cycles. It will deliver adjusted 110-volt a-c energy sufficient for the operation of two series-governed motors of the type used in teletypewriters. It also will deliver 200 ma of dc at 120 volts for line and signaling circuits.

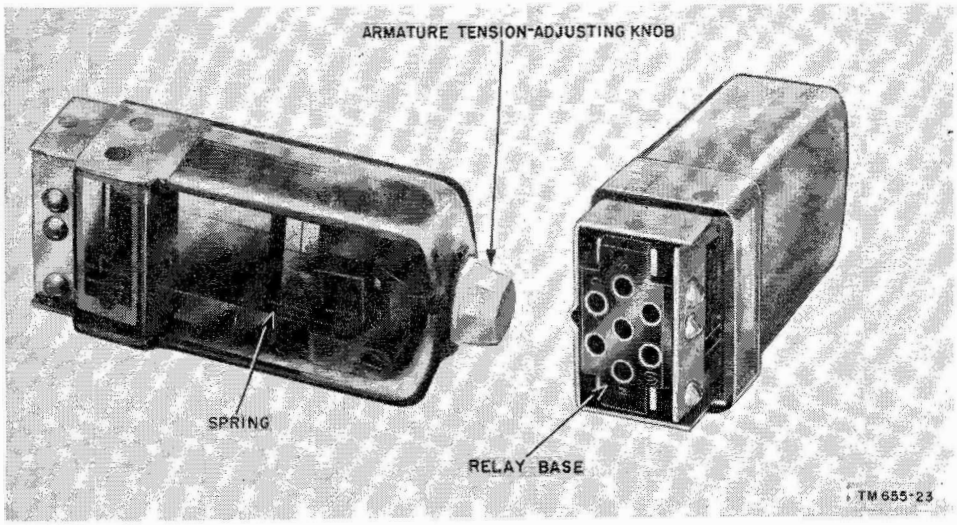


Figure 20. Line relay (part of line unit).

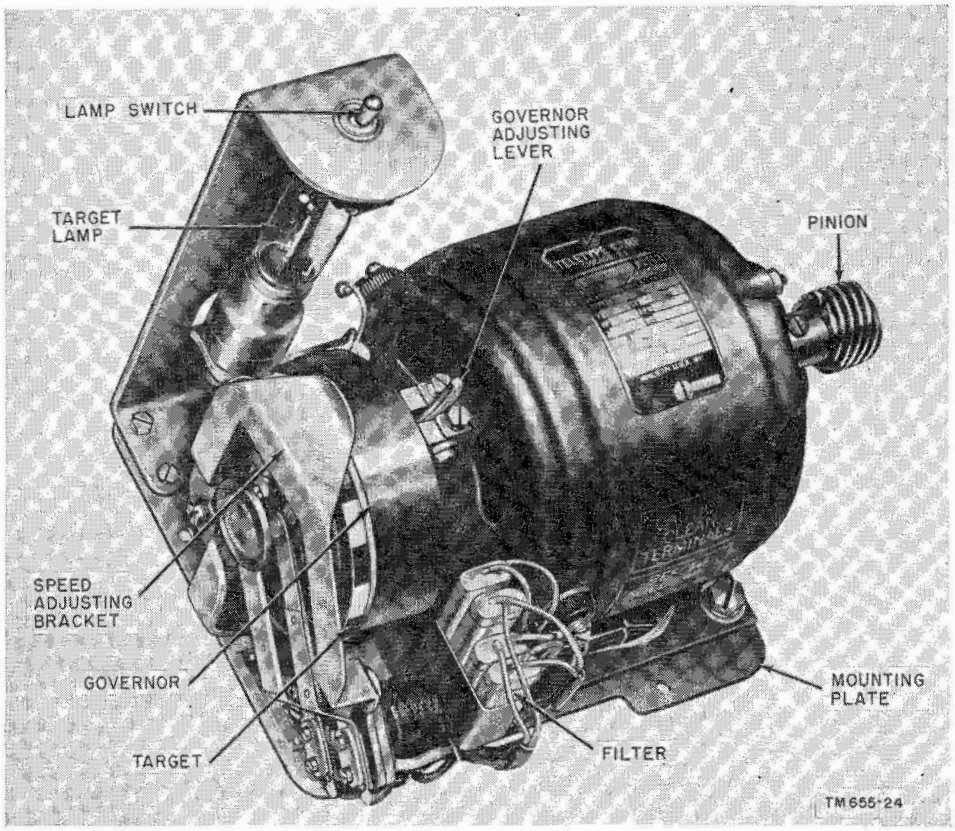


Figure 21. Series-governed motor unit.

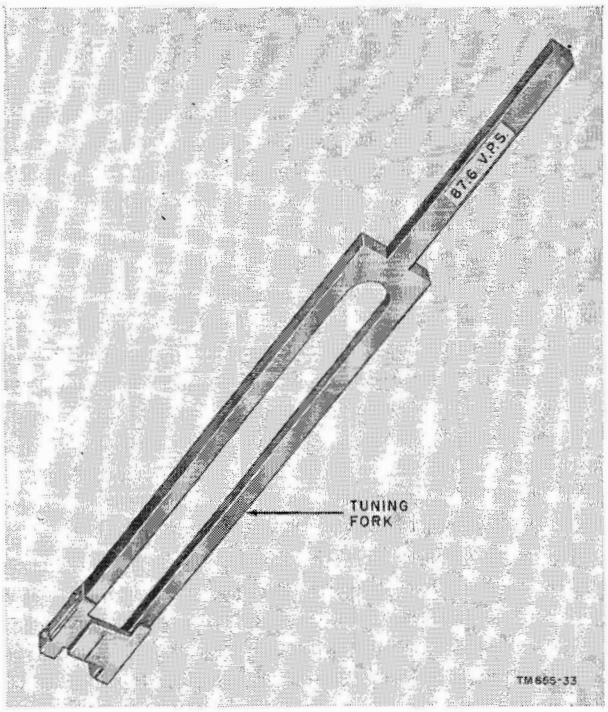


Figure 22. Speed indicator (tuning fork) for standard speed of 368.1 opm.

g. Keyboard Transmitter. The keyboard transmitter (figs. 25 and 46) includes all of the mechanism required to form and transmit five-unit code teletypewriter signals for letters, symbols or nonprinting functions. There are two keyboard arrangements in general use in the military forces; *standard communications* (fig. 23) and *weather reporting* (fig. 24). The keyboard is designed to slide into the front of the base where it is held in place by two knurled captive screws (one on each side). The keyboard transmitter consists of a set of keys, key-levers, a universal bar, selector bars, slip connections for connecting it electrically to the base, a polar-neutral key to select either polar or neutral operation for the receiving circuit, and a transmitting unit with a transmitting contact filter, all fitted on a cast-iron frame. Because the transmitting unit is a major component of the keyboard transmitter, it is described in a separate subparagraph. In general appearance, the teletypewriter keyboard resembles a typewriter keyboard. However, there are a number of differences. The more important ones are as follows:

(1) The capacity of the teletypewriter keyboard is limited by the use of the five-unit code to 32 keys including the space bar. A typewriter keyboard has a minimum of 45 keys.

(2) Four of the teletypewriter keys are required to perform, electrically, functions that are performed manually on a typewriter. These functions are CARRIAGE RETURN, LINE FEED, FIGS (shift), and LTRS (unshift). One key is used for the blank function which is not used with a typewriter,

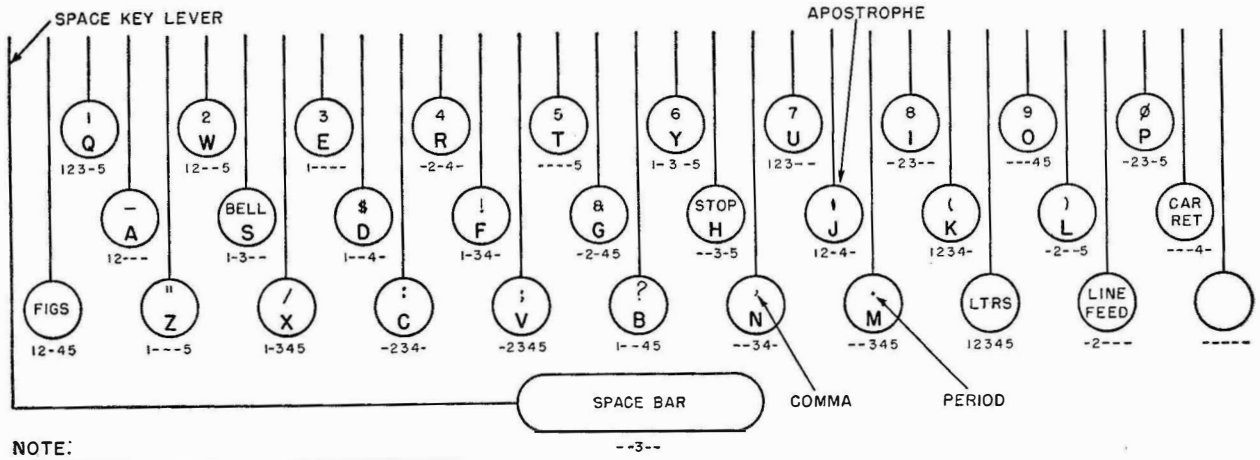
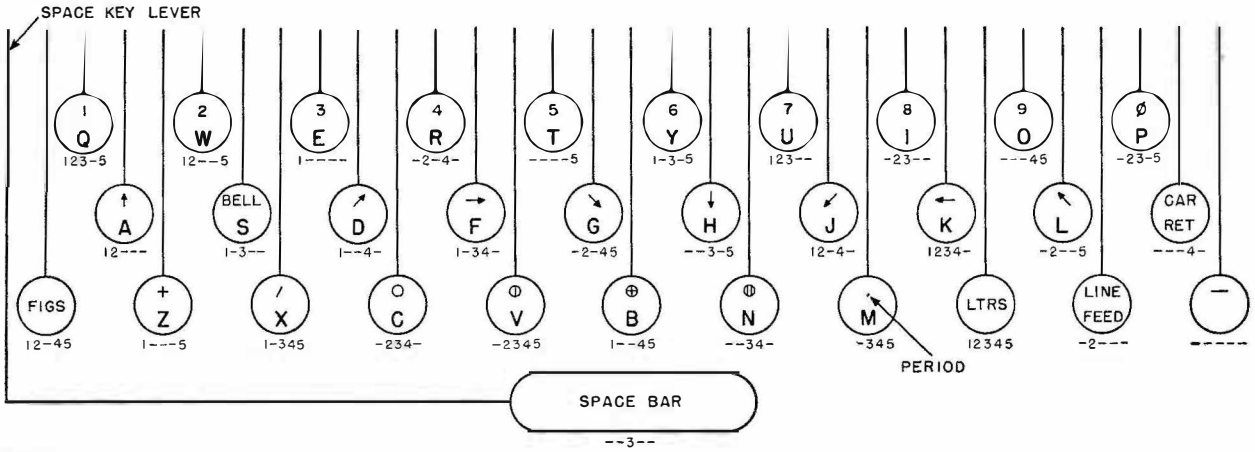


Figure 23. Standard communications keyboard and associated five-unit code for each character.



NOTE:
NUMERALS SIGNIFY MARKING CODE IMPULSES.
DASHES SIGNIFY SPACING CODE IMPULSES.

KEYBOARD ARRANGEMENT KQ USING 105278 SET OF MASTER SPEED KEYTOPS, WITH ASSOCIATED CODE, FOR WEATHER REPORTING PRINTER.

TM 655-17

Figure 24. Weather communications keyboard and associated five-unit code for each character.

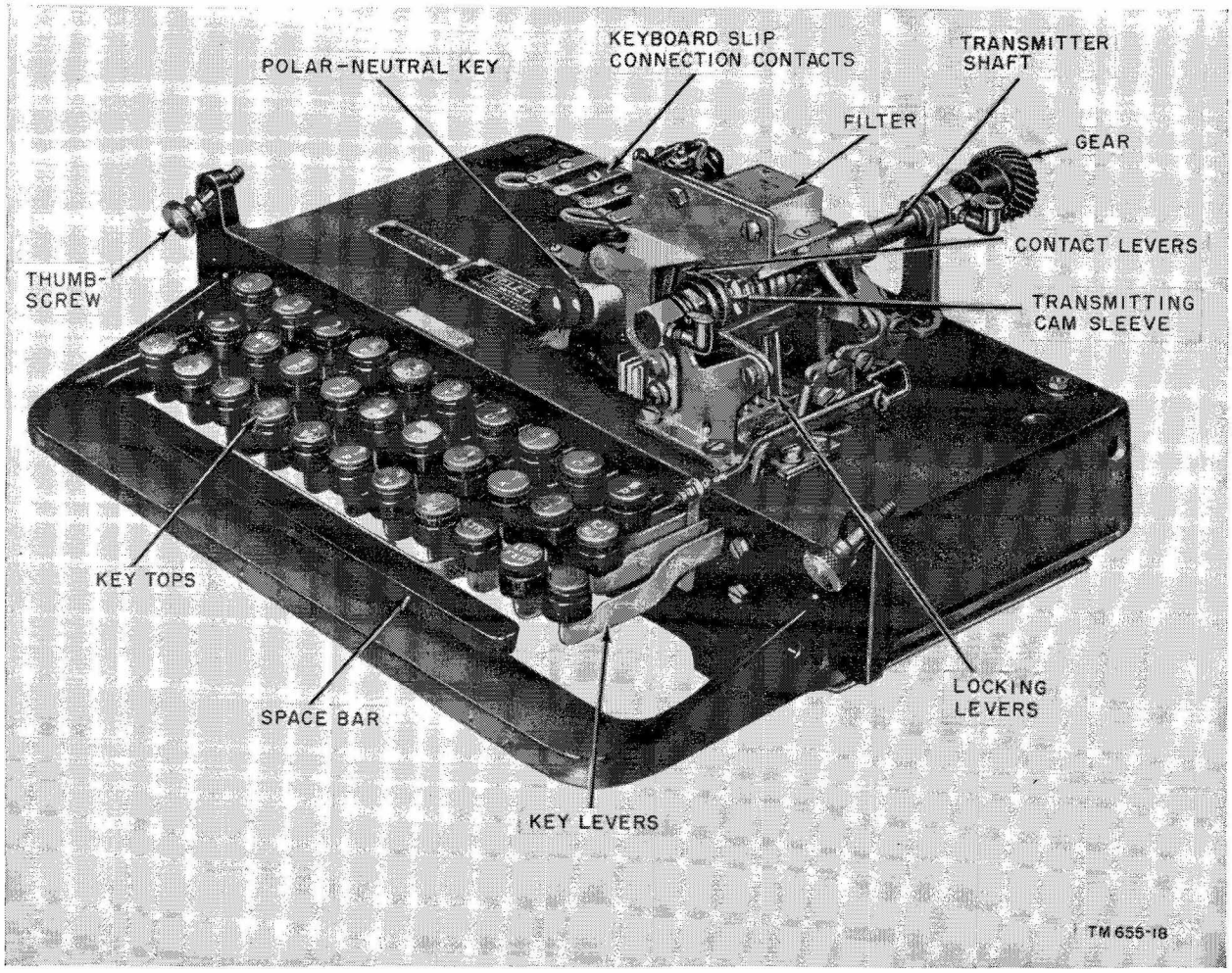


Figure 25. Teletypewriter keyboard unit.

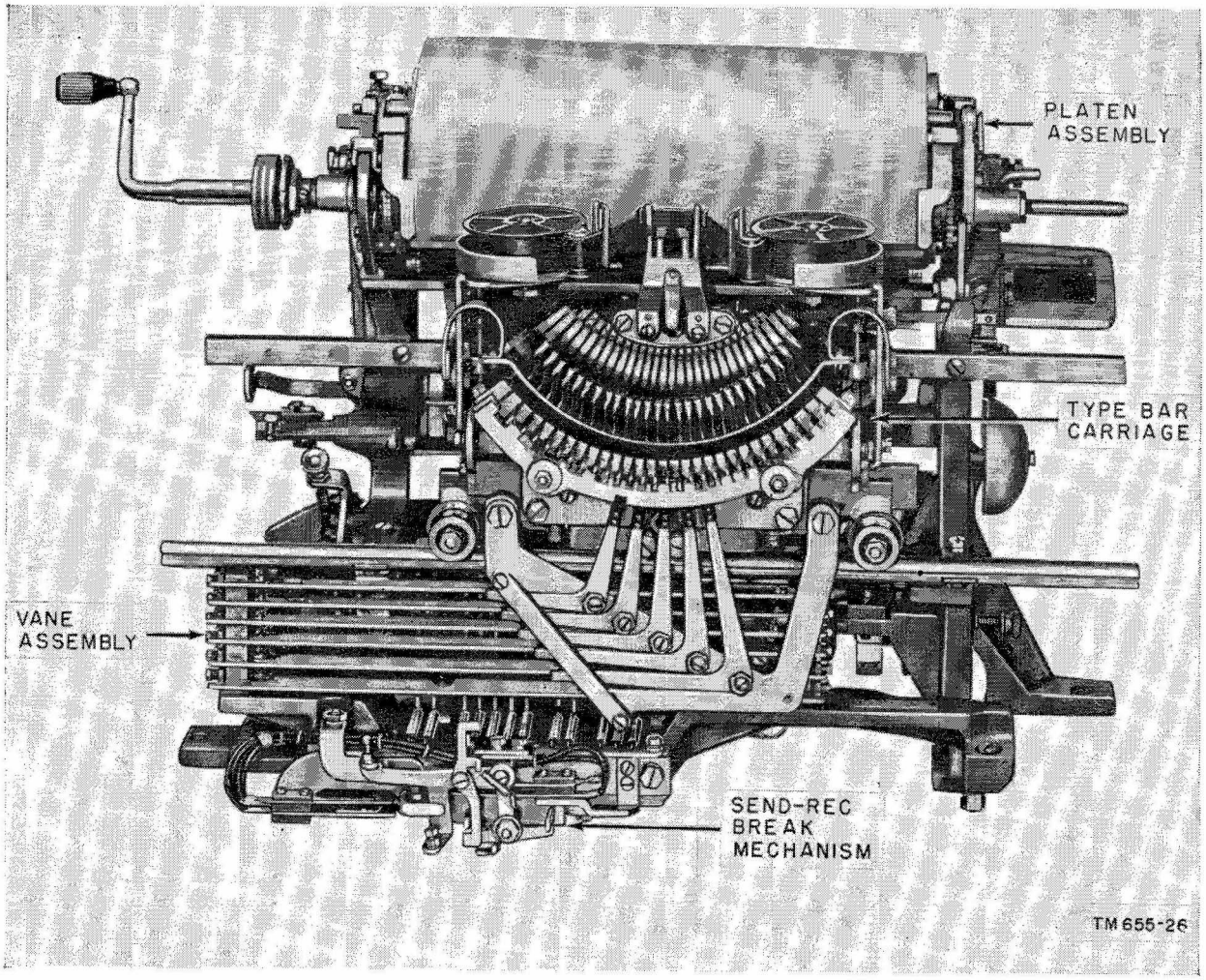


Figure 26. Typing unit, front view.

and the remaining 26 keys are required for the letter codes.

(3) Teletypewriter keys are arranged in three instead of four rows.

(4) Only capital letters are used on a teletypewriter; they are in the lower instead of the upper case.

(5) Figure symbols are in the upper instead of the lower case on the third (highest) row of keys.

(6) Punctuation symbols are in upper case on the first and the second row of keys.

h. Transmitting Unit. The transmitting unit (fig. 49©) is a major component of the keyboard transmitter. It consists of a bank of sending contact springs, contact levers, operating cams on a cam sleeve, a clutch and a driving gear. The gear is connected through intermediate gears to the main shaft on the typing unit which, in turn, is driven by the motor. The keylever controls the operation of the transmitting contacts through the selector bars and the transmitting mechanism. When the clutch is engaged by the operation of a keylever, the cams rotate and the contact springs close their contacts for mark impulses, and are held open for space impulses according to the code being transmitted. Once a code is set up by the depression of a keylever, it is locked in until its transmission has been completed.

i. Typing Unit. The typing unit, shown in figures 26, 27, 28, 29, and 30, includes in a single assembly, all the mechanism, except the motor, required to receive five-unit teletype-

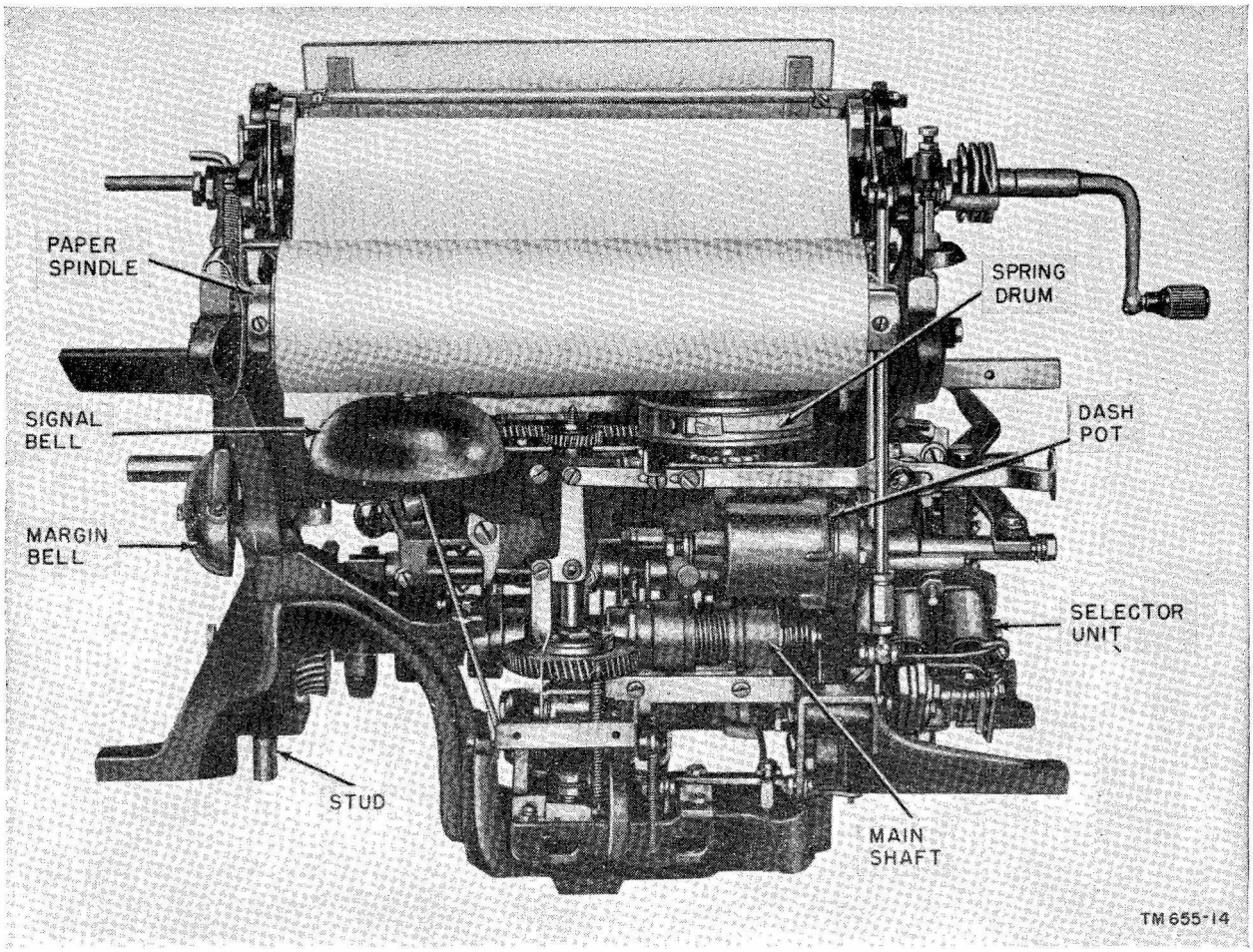


Figure 27. Typing unit, back view.

writer code signals and to convert them into typewritten messages. It is mounted on the base (fig. 31) and is held in place by three large thumbscrews. It may be used at receiving-only stations without a keyboard transmitter.

(1) The typing unit consists of a platen assembly, a motor control mechanism, a vane assembly, a main shaft, a typebar carriage, a selector unit, and other parts and assemblies.

(2) The platen assembly (fig. 26) is mounted at the top of the typing unit and supports the paper during operation of the teletypewriter.

(3) The motor control assembly (fig. 28) is attached to the front of the typing unit and is used to start and stop the motor.

(4) The vane assembly (fig. 26) is attached to the front of the typing unit and controls the movement of the bell cranks on the typebar carriage.

(5) The main shaft (fig. 27) extends across the full width of the typing unit; it is driven by the motor and provides the motive force for all mechanically operated parts of the typing unit.

(6) The typebar carriage (fig. 26) is equipped with automatic ribbon feed, type pallets, pull bars, code bars, and bell cranks. It moves back and forth on a track above the vane assembly in front of the platen, which is stationary. Paper feeds through the platen assembly from a roll of paper mounted on the rear of the typing unit (fig. 26). A crank fits on the left end of the platen roller (fig. 26) and extends through a hole in a teletype-

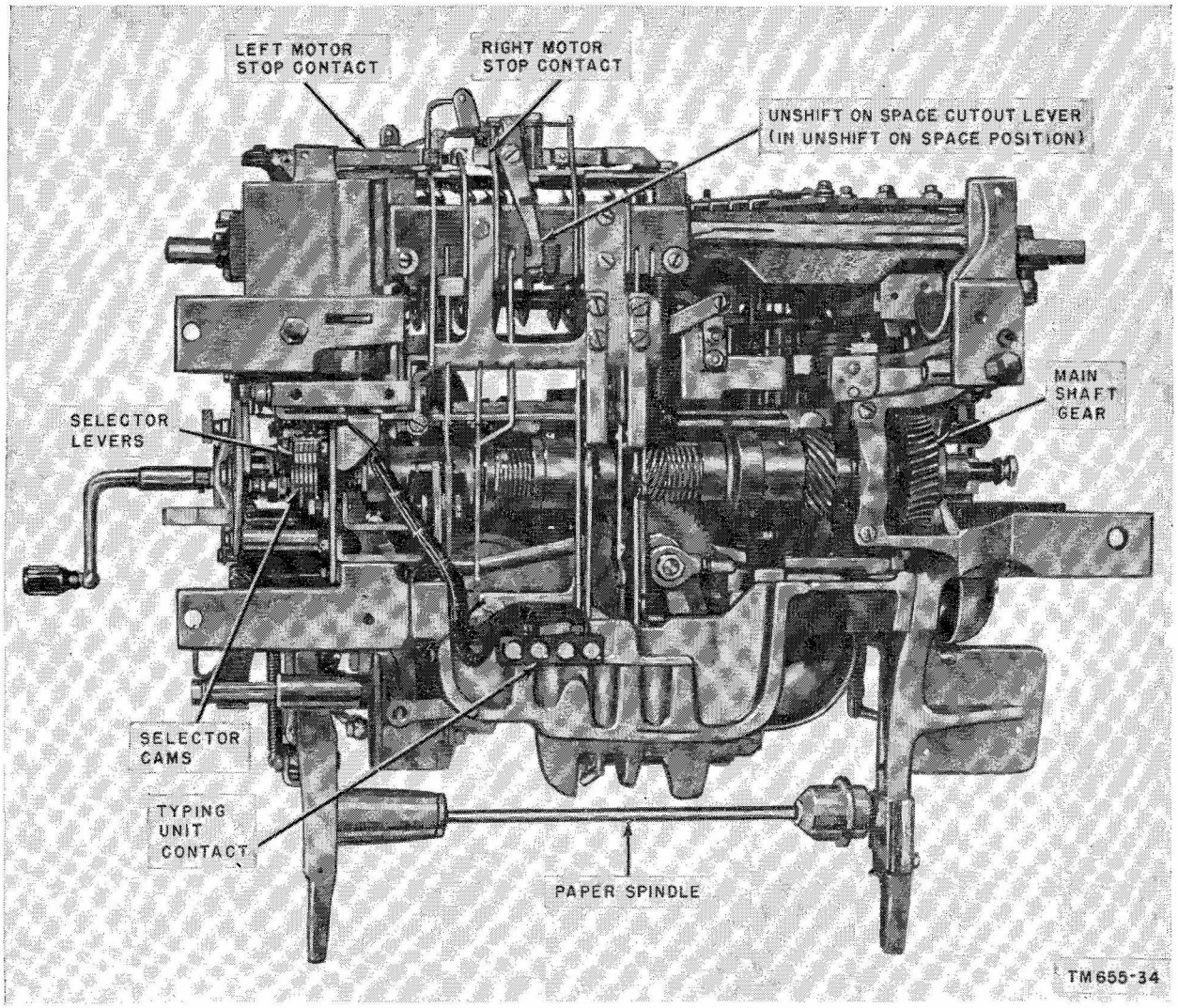


Figure 28. Typing unit, bottom view.

writer cover (fig. 32). Typing units are normally adjusted to print 72 characters per line at 368.1 opm which is approximately 60 wpm.

(7) The selector unit (fig. 57) is attached to the left end of the typing unit (fig. 29). A cross section of the selector unit is shown in figure 58; the range finder mechanism used to adjust the relationship between the start of the selector cam sleeve and the operation of the selector levers is shown in figure 59. The selector unit receives five-unit teletypewriter code signals and converts them into mechanical action to actuate the vanes.

j. Cover. A removable metal cover incloses the motor unit, the typing unit, and the base. The cover is constructed to allow the switches, the paper, and the units of the teletypewriter to be reached during normal operation. Felt padding, which lines the inside of the cover, reduces sound and protects the operating parts of the teletypewriter. A copy holder is attached to the front of the cover (figs. 32 and 14). There are openings in the cover for the platen crank, for checking the orientation range, the manual carriage return, the polar-neutral key, a paper outlet, and for line and power wiring.

k. Equipment Table (fig. 33). A table, especially designed to support a teletypewriter and a rectifier, and to accommodate the associated

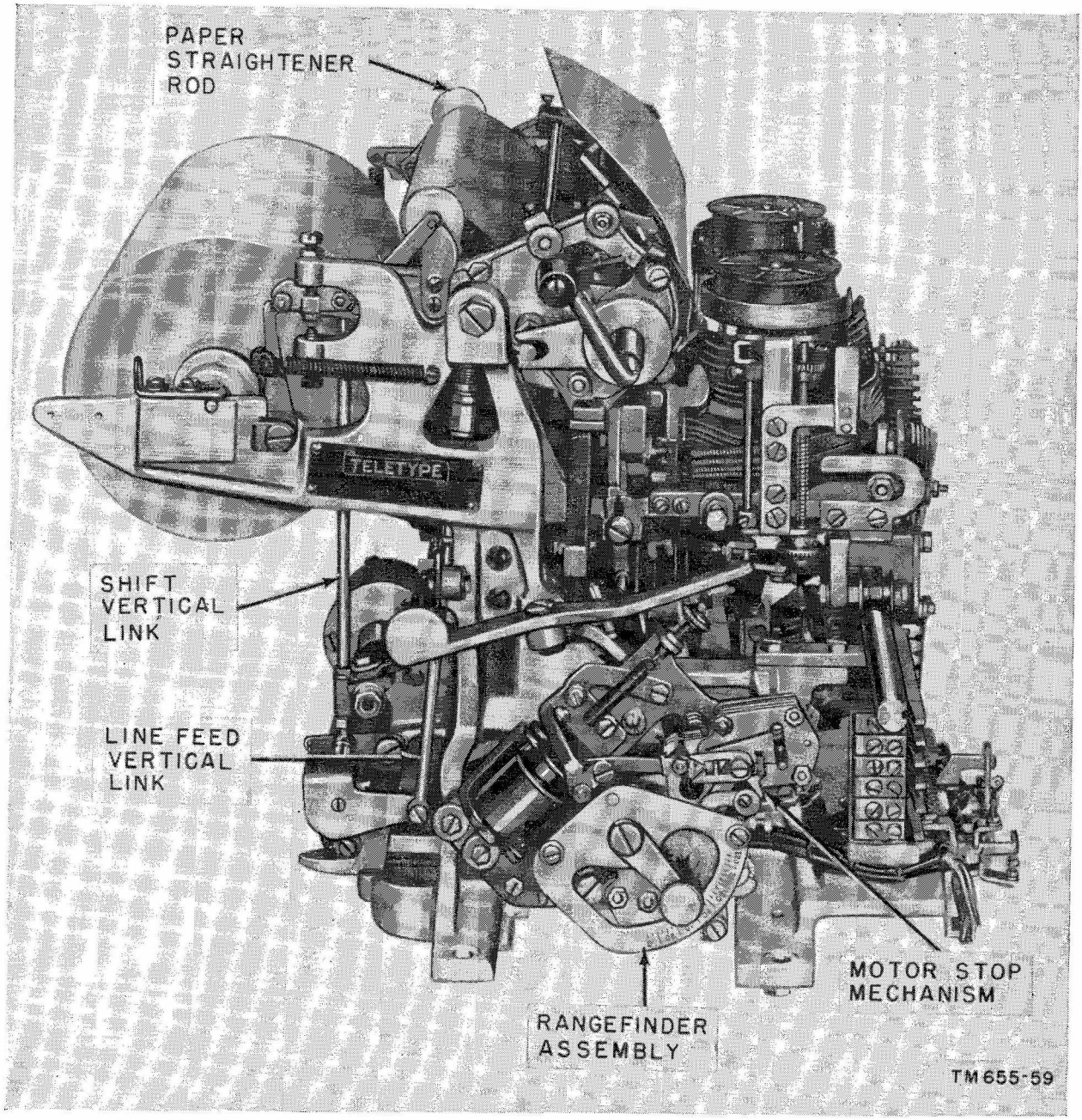


Figure 29. Typing unit, left-side view.

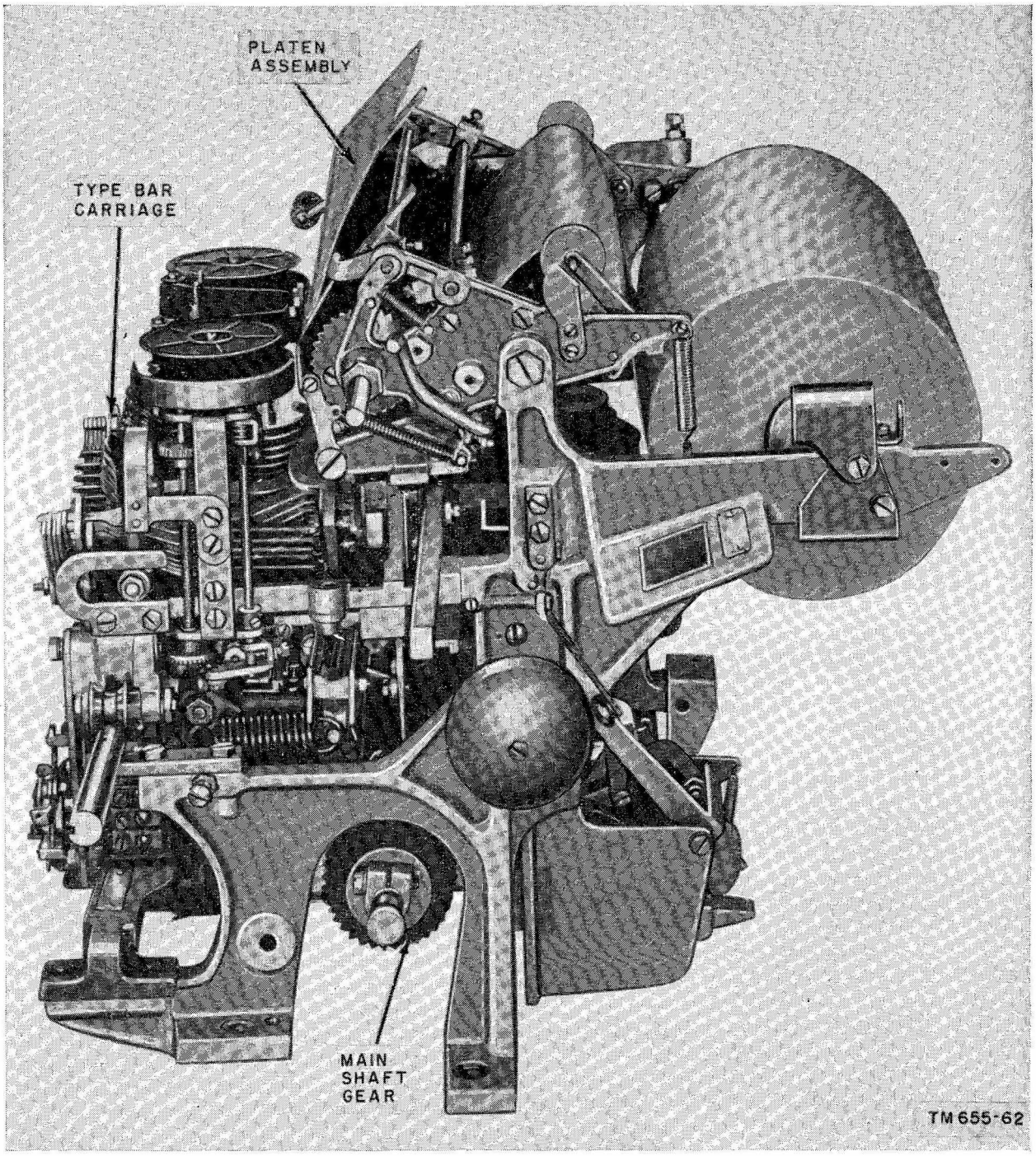


Figure 30. Typing unit, right-side view.

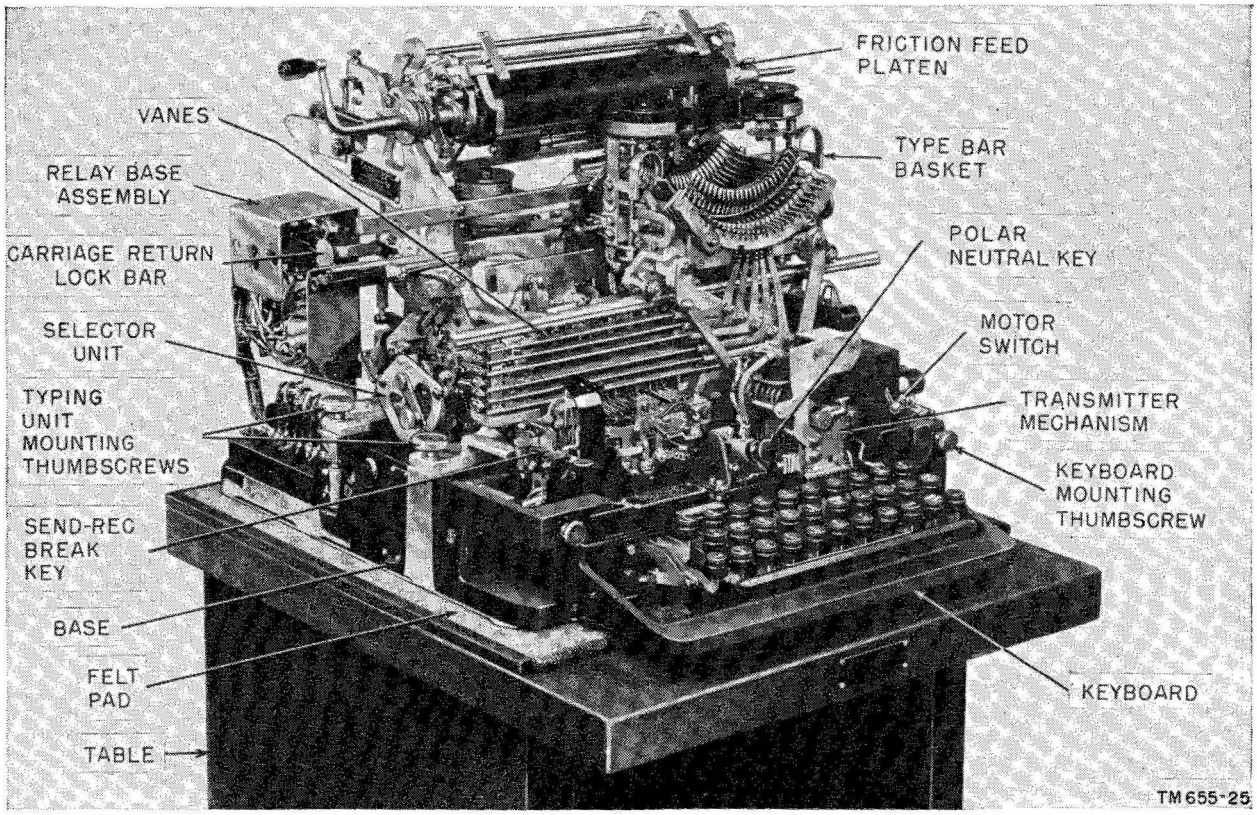


Figure 31. Typing unit assembled with base and keyboard.

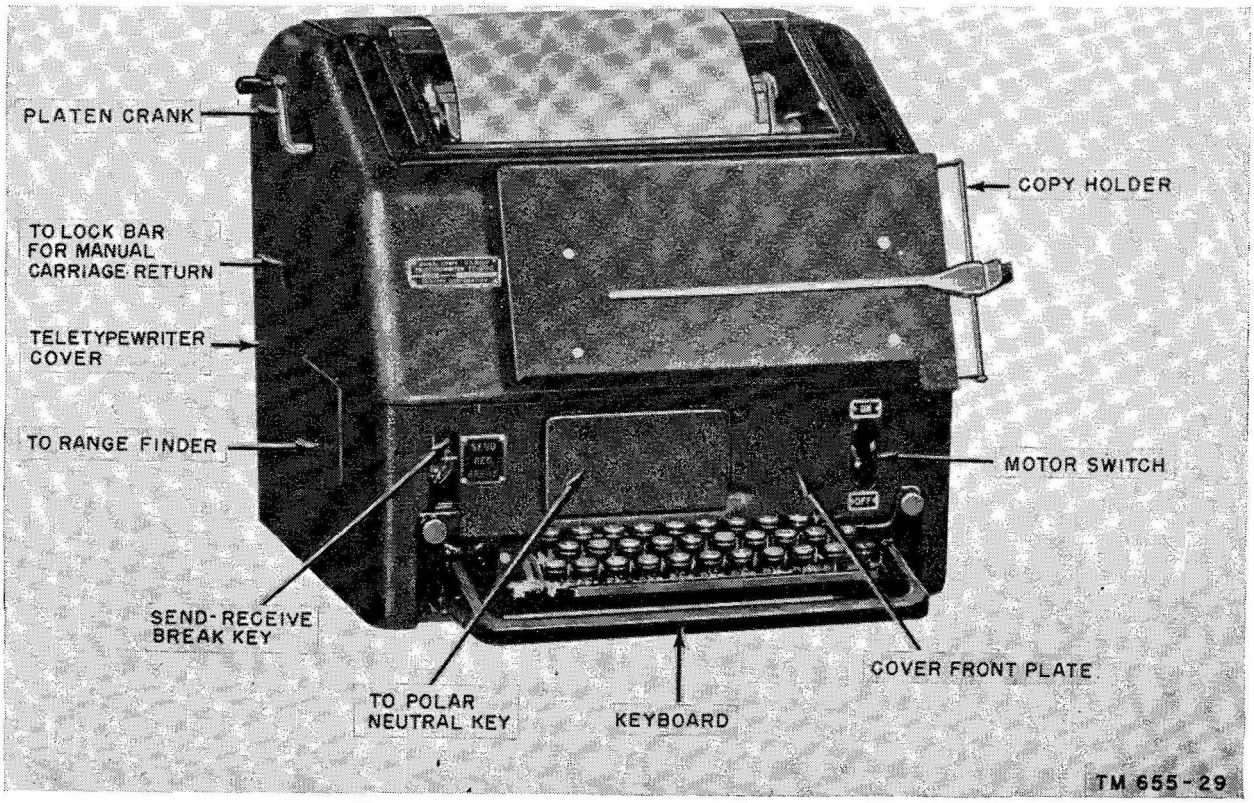


Figure 32. Teletypewriter, without table and rectifier.

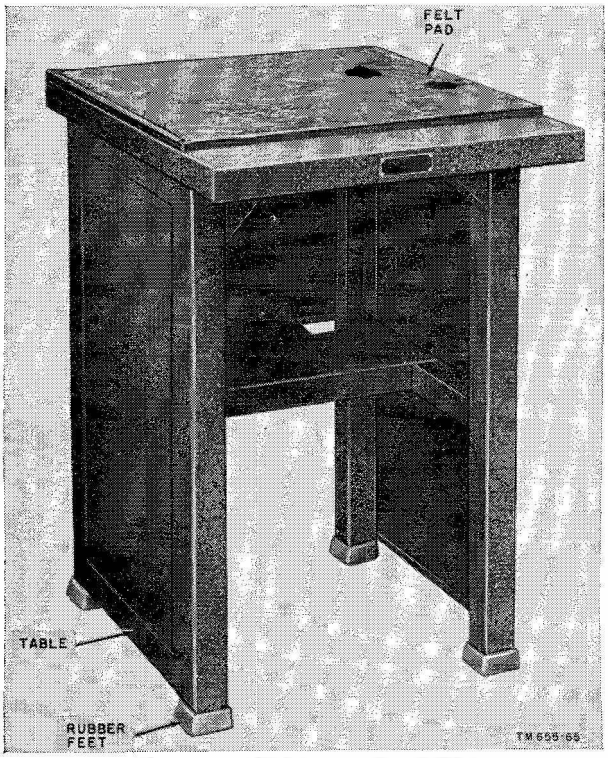


Figure 33. Teletypewriter table.

cords and cables, is furnished with commercial and fixed-station military teletypewriters. A shelf built into the front of the table provides mounting space for a rectifier, and allows sufficient leg room for the operator. An electrical service assembly mounted on the inside of the table provides terminals for line and local circuits and receptacles for the rectifier power cords. The table is equipped with rubber feet which, with the felt pad under the teletypewriter unit, promotes quietness of operation. Army tactical (field) teletypewriters are fastened securely to the base of the chest used to transport the teletypewriter base, the typing unit, the keyboard, and the cover. During operation, the base of the chest with the teletypewriter unit attached is removed, and the base is placed on top of the chest as shown in figure 4.

l. Electrical Assembly (figs. 34 and 35). An electrical service assembly unit is bolted to the inner wall of the table, just under the table

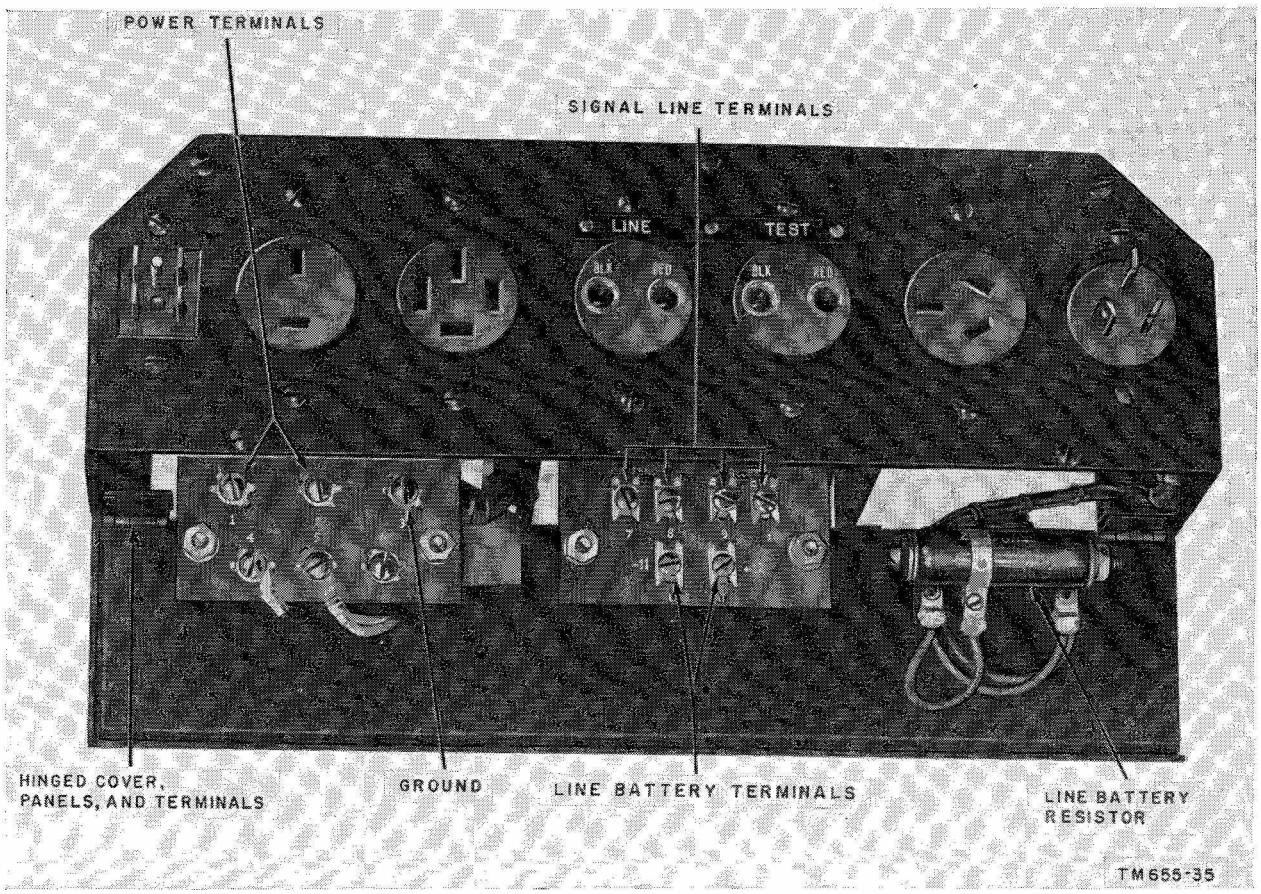


Figure 34. Electrical service assembly open, front view.

top, facing the front. It provides a test circuit for local tests and serves as a distribution panel to and from the rectifier, the teletypewriter, and the signal line. The a-c power source and the line are connected to terminals in the service assembly. The teletypewriter and rectifier are connected by plugs, receptacles, and jacks to the service assembly.

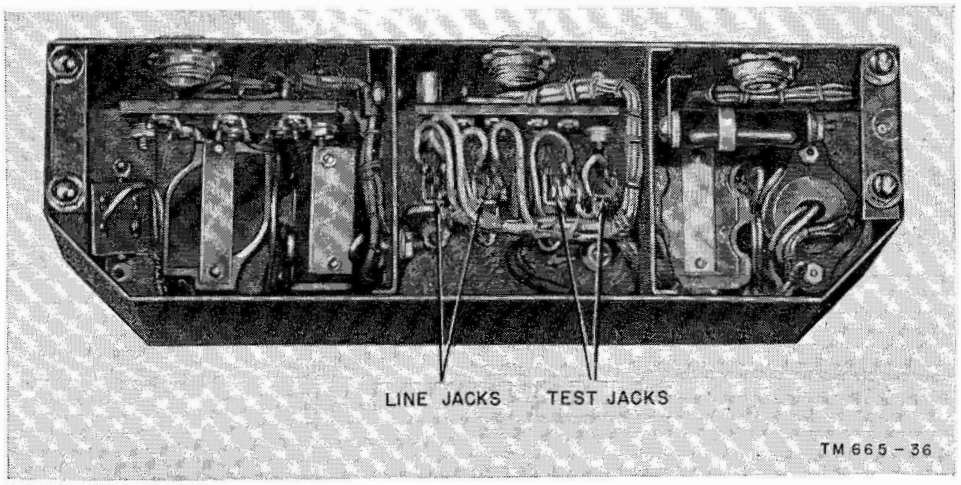


Figure 35. Electrical service assembly, closed, rear view.

Section II. DETAILED FUNCTIONING OF EQUIPMENT

20. General Theory of Operation

a. General.

(1) This section of the manual discusses in detail the operations required in a sending teletypewriter to convert the mechanical action of the keylevers into electrical impulses, and the operations required in a receiving teletypewriter to receive electrical impulses and convert them into mechanical action to print a letter, a numeral, or a symbol, or to perform a nonprinting function. The components discussed in this section are the keyboard-transmitter, the typing unit, the base unit, the table, the rectifier power unit, and the motor unit which provides the mechanical power for all of the components.

(2) The overall speed of all teletypewriters in a circuit must be approximately the same. However, some slight difference in speed between machines in a circuit exists in all cases. These differences are due to variations in the action of friction clutches, friction in the bearings, viscosity of the lubricants, and other factors. Teletypewriter communication requires that differences in operating speeds must be kept within certain limits; they also must be prevented from being accumulative. The preceding information indicates the need for keeping the machines in a circuit in step; the operations of the transmitting and receiving mechanisms must be synchronized. A simplified illustration of the synchronization of the movement of two shafts is shown in figure 36. Another example of synchronization is the electric clocks shown in figure 37. Electric clocks are driven by synchronous (one speed) motors; even though the clocks may be at locations removed from each other, they remain in synchronization because the motor speed is controlled by the frequency of the a-c voltage by which they are driven. However, neither of the methods used as examples can be applied in teletypewriter operation. Teletypewriter stations are usually far apart, and

even though synchronous motors are sometimes used in teletypewriter operation, the difference in speed (timing) due to clutch action and bearing friction still requires correction. The start-stop system of operation (*b* below) is used to correct timing differences and to keep all the machines in a circuit in step.

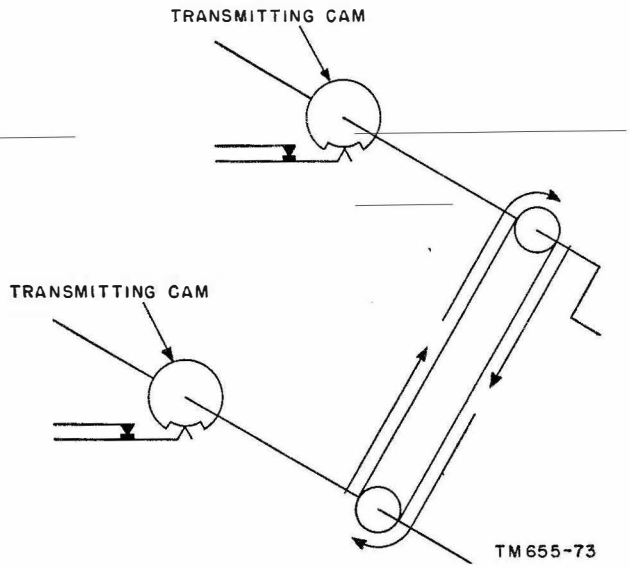


Figure 36. Synchronized movement of two shafts.

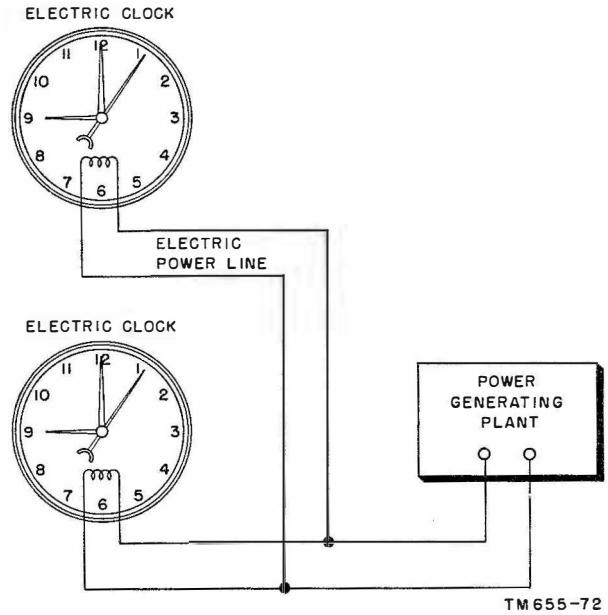


Figure 37. Electric clocks driven by synchronous motors.

b. Synchronization (Timing).

(1) Five impulses (seven impulses with start and stop impulses included) are impressed on the line circuit for every operation to be performed by the receiving unit. Each of the five selecting impulses (intervals) is 22 milliseconds long at 368.1 operations per minute (approx. 60 words). The first selecting impulse of every five-impulse code group is *preceded* by a start (spacing) impulse which is also 22 milliseconds long. The last impulse of the five-impulse sequence is *followed* by a stop ~~(marking) impulse which is~~ 31 milli-seconds long. The stop interval is made longer than the other intervals in the code to insure satisfactory operating margins for regenerative repeaters sometimes used in some of the more complicated circuits. Regenerative repeaters are devices which completely correct any errors in duration of the start and selecting elements of the teletyepwriter signals. They do not, however, correct any error in the length of the step element; this element is made sufficiently long to allow a fair margin against such errors.

(2) Maintenance of correct timing between transmitting units and receiving units in a circuit is achieved by means of the five-unit, start-stop system of operation. With this system, the transmitting and selector mechanisms are driven by friction clutches whose driven members are stopped after each code group is transmitted and started again at the beginning of transmission of the next code group. This insures that all machines will be in exact synchronism at the beginning of transmission of each code group and prevents any difference in operating speed from being accumulative and resulting in errors. Thus the transmitting and receiving equipments connected in a circuit will come to a stop at some point between the

completion of transmission of one code group and the beginning of the next. With the next start (spacing) impulse, these equipments will start their sequences together, and if the motor speeds are correct, they will complete their sequences without losing relative synchronism. Distortion of teletyepwriter signals that affect synchronism is described briefly in *c* below and in more detail in chapter 3 of this manual.

c. Distortion. An ideal or perfect telegraph circuit transmits signals that are exactly the same at the receiving end as they are when impressed on the line at the sending end (with regard to lengths of component marks and spaces). Any lengthening or shortening of marks and spaces occurring during transmission is a measure of the degradation in transmission quality and is called distortion. Each type of distortion and the means of compensating for it are covered in detail in chapter 3 of this manual.

d. Circuits.

(1) *Power circuits.* The power circuits of teletypewriters consist of the incoming power lines, wiring, switches, fusing devices, receptacles, and outlets. The base upon which the motor is mounted contains the wiring and slip connections by which power is brought to the motor unit.

(2) *Signal circuits.* Teletypewriter signal circuits include the external line between teletypewriter stations and the send and receive circuits (local circuits) within the teletypewriters themselves. The simplest signal circuit is the ground return circuit shown schematically in figure 38. Since the earth is used as one side of the circuit, only one wire is required. This type of circuit provides satisfactory operation when a constant low-resistance ground connection can be obtained and when there is no excessive interference from ground potential or from other circuits. More reliable operation is provided by the full metallic circuit shown schematically in figure 39. This type of circuit requires two wires; it has the advantages of not being subject to changes in ground resistance, or ground potential, and is less subject to interference from adjacent circuits. Connections between the signal line (or lines) and the teletypewriter in fixed station installations are completed by means of line terminal boards on the table and on the base unit. The signal line jacks (fig. 34) on the table are used to connect the typing unit and the keyboard-transmitter to the line. In tactical equipment where a table is not used, the typing unit and the keyboard-transmitter are connected to the line at binding posts on an external piece of equipment called a line unit. Teletypewriter circuits are arranged so that the transmitting contacts of the keyboard-transmitter direct their signals to the selector magnets of the teletypewriters with which they communicate. The local selector magnet (through a line relay or a line unit) receives transmission from both the remote and the local transmitting contacts, except when the equipment is arranged for full-duplex operation. In this case, the transmitting and receiving circuits are split and connected to separate channels so that a station can send and receive messages simultaneously. In this type of operation, the local selector magnet receives trans-

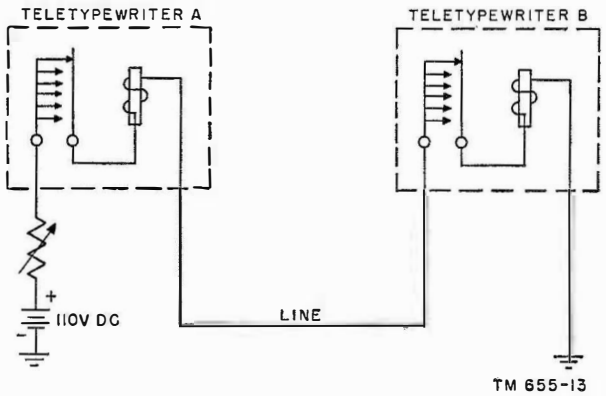


Figure 38. Simple ground-return teletypewriter circuit.

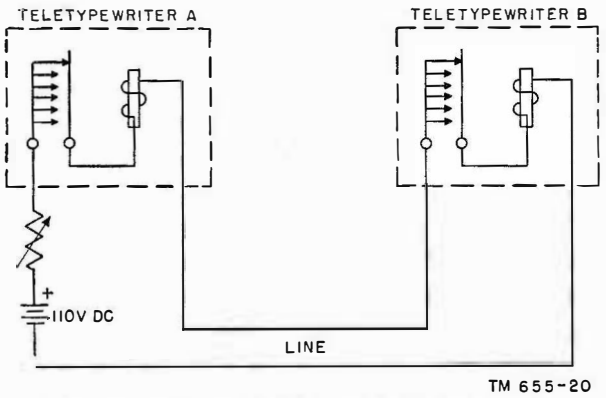


Figure 39. Full metallic teletypewriter circuit.

mission only from the remote station transmitting contacts.

(3) *Local circuits.* The principal local circuits of a teletypewriter are the send (transmitting) circuit associated with the keyboard transmitter, and the receive circuit by which the selector magnet and associated mechanism of the typing unit are energized. Simplified schematic diagrams of the send and receive circuits are shown in figures 40 and 41, respectively. In addition to the signal circuits (send and receive), the local circuits of a teletypewriter include a power circuit and, in fixed installations, a local test circuit. To connect the operating components into the local test circuit, the line cord plugs are plugged into the test jacks on the table (fig. 34). Figure 17 shows the arrangement of the terminal boards on the base unit which completes the power and signal circuits to the various assemblies and operating components. The local circuits of a teletypewriter may be connected to operate with a number of different operating arrangements.

e. Mechanical Operations. The sequence of mechanical operations performed when a teletypewriter is operated is described in paragraphs 22 through 40. Adjustment data for the mechanical assemblies is covered in other manuals dealing with each particular type of equipment.

21. Motor Unit

(fig. 21)

a. Description and Purpose. The motor unit is an assembly mounted upon a base plate and comprises a motor with a governor and rotating

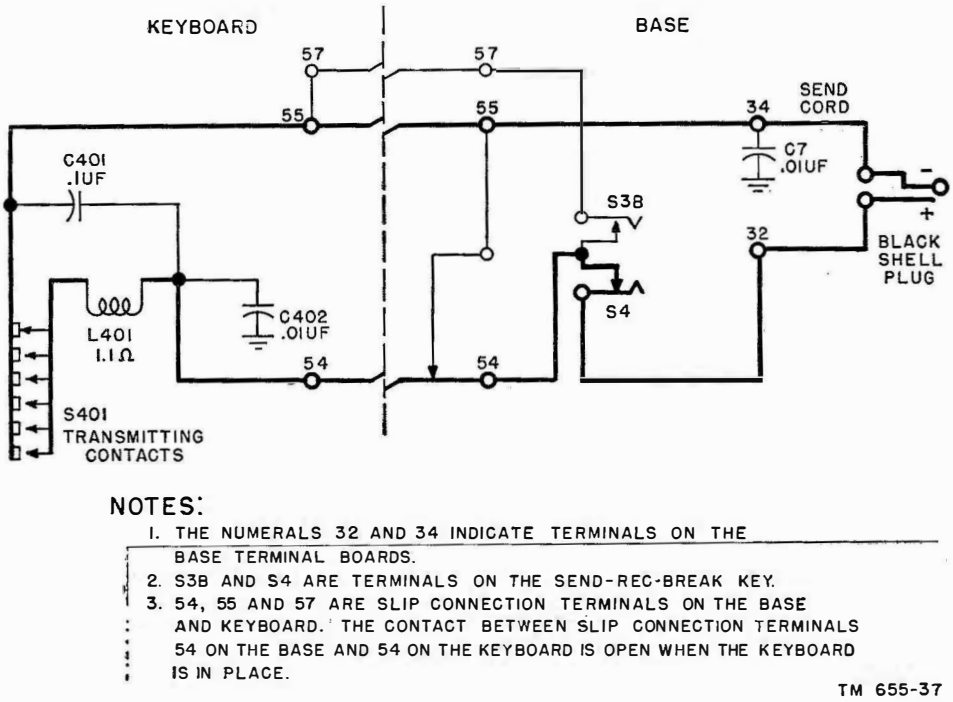
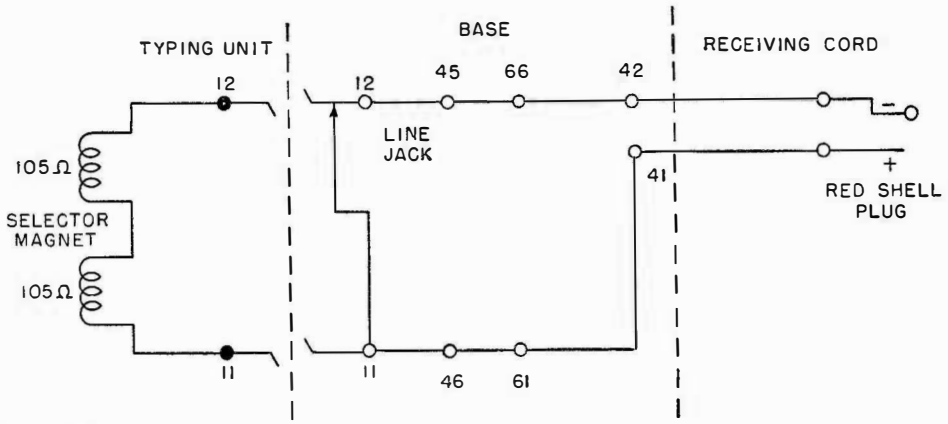


Figure 40. Send circuit, schematic diagram.



NOTES:

1. THE NUMERALS 41, 42, 45, 46, 61 AND 66 INDICATE TERMINALS ON THE BASE TERMINAL BOARDS.
2. 11 AND 12 ARE SLIP CONNECTION TERMINALS ON THE BASE AND TYPING UNIT.

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Figure 41. Receive circuit, schematic diagram.

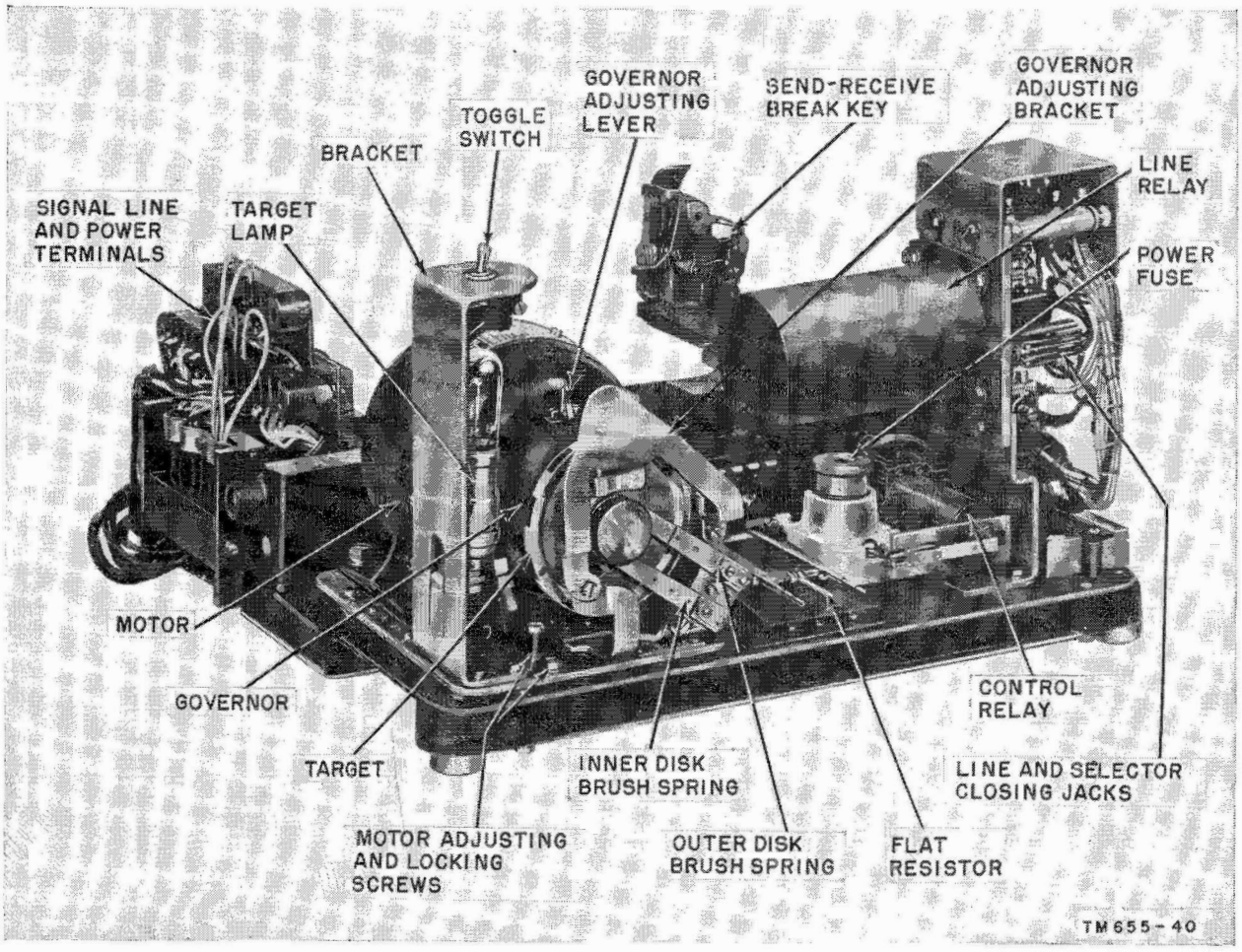


Figure 42. Motor unit mounted on base.

target, a lamp, and a lamp bracket. The target is a series of alternate black and white spots painted on the rim of the flywheel. The lamp is used to illuminate the target during adjustment of the motor speed. The motor described here is series-wound and operates on 50- to 60-cycle ac. Mechanical power for operating the typing unit and the keyboard unit is provided by gearing the motor to the main shaft which, in turn, is geared to the keyboard transmitter shaft. The motor mounting plate may be moved laterally for proper horizontal alinement with the main shaft gear; a motor adjusting screw provides for proper vertical alinement. The motor is shown in place on the base unit in figure 42.

b. Operation. The motor described here normally operates continuously at 2,100 rpm. Power for the motor is provided by connections on the cord panel of the rectifier power unit. If the motor speed is incorrect, it is adjusted by means of the governor (figs. 43, 44, and 45). Proper speed is determined with a speed indicator (tuning fork) (fig. 22) and the target (fig. 45).

22. Governor

a. Description and Purpose. The governor (fig. 21) is attached to the end of the motor shaft upon which the motor pinion is fastened. The governor resembles a flywheel, and has a series of black and white spots painted on its outer rim. The alternate black and white segments constitute the target by which correct speed is determined with the speed indicator. Mounted inside the governor is a set of governor contacts, a contact adjusting spring, and a speed adjusting wheel (fig. 43); these parts are inclosed in a cover (fig. 45). Two contact brush springs (fig. 44) are mounted on the motor base plate; these springs ride on two rotating disks and maintain the continuity of the power circuit to the governor contacts. A governor-adjusting bracket (fig. 44) and a governor-adjusting lever (fig. 45) are mounted on the motor housing. The speed-adjusting wheel extends through the governor cover. It is turned by means of the governor-adjusting bracket and the governor-adjusting lever. The governor and an associated resistor control the speed of the motor. The resistor is mounted on

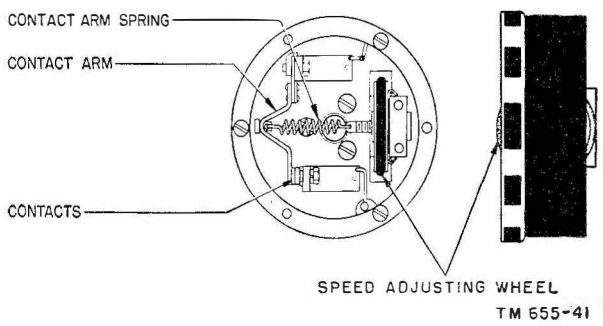


Figure 43. View of motor governor.

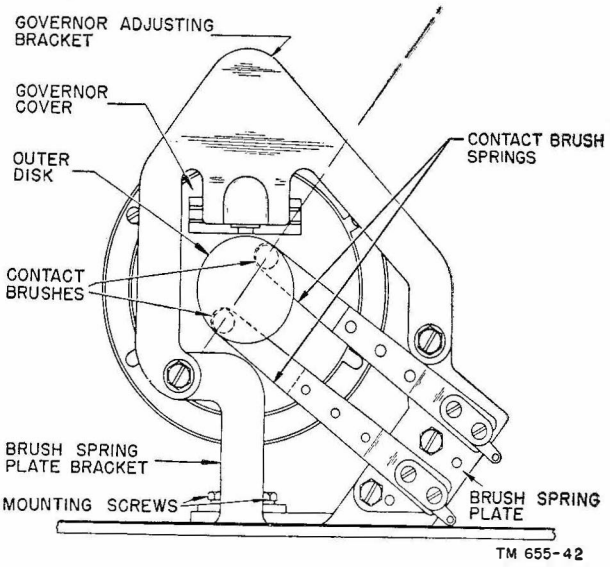


Figure 44. Governor-adjusting bracket assembly.

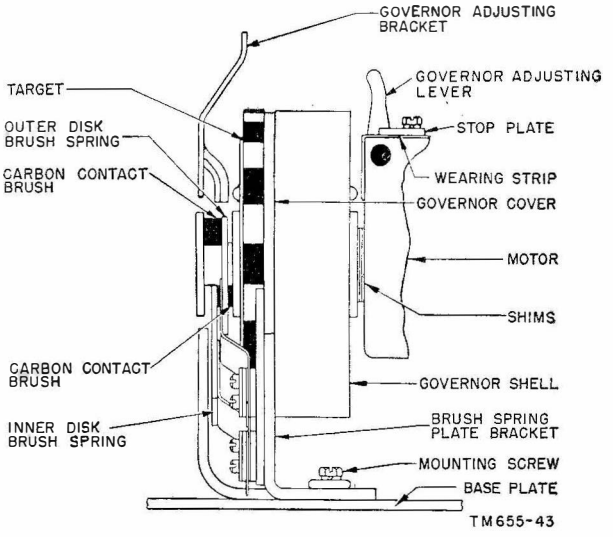


Figure 45. Motor governor, side view.

the base unit and is connected across the governor contacts.

b. Operation.

(1) The governor contacts are opened when centrifugal force enables the contact arm to overcome tension exerted upon it by the contact arm spring (fig. 43). When the contacts open, the resistor (*a* above) is connected in series with the motor windings. The total voltage applied to the motor windings is reduced by the voltage drop across the resistor; the motor slows down to a speed slightly below that normally desired.

(2) When the governor contacts close, because of the slowing of the motor, the resistor is short-circuited and the full value of the operating voltage is applied to the motor windings; this increases the motor speed until the governor contacts open again ((1) above).

(3) The speeds at which the governor contacts open and close are controlled by the amount of tension exerted by the contact-arm spring. Turning the speed-adjusting wheel (to which the spring is fastened) increases or decreases the tension of the spring.

23. Keyboard Transmitter

The keyboard transmitter (figs. 25 and 46), described briefly in section I of this chapter, is described here in detail. Some repetition is necessary to explain clearly the detailed functioning of the unit. The keyboard transmitter includes the keyboard consisting of 32 keys and keylevers (including the space bar), five selector bars, a universal bar, a polar neutral key, and a transmitting unit. Except for the power to rotate the transmitter shaft, the keyboard

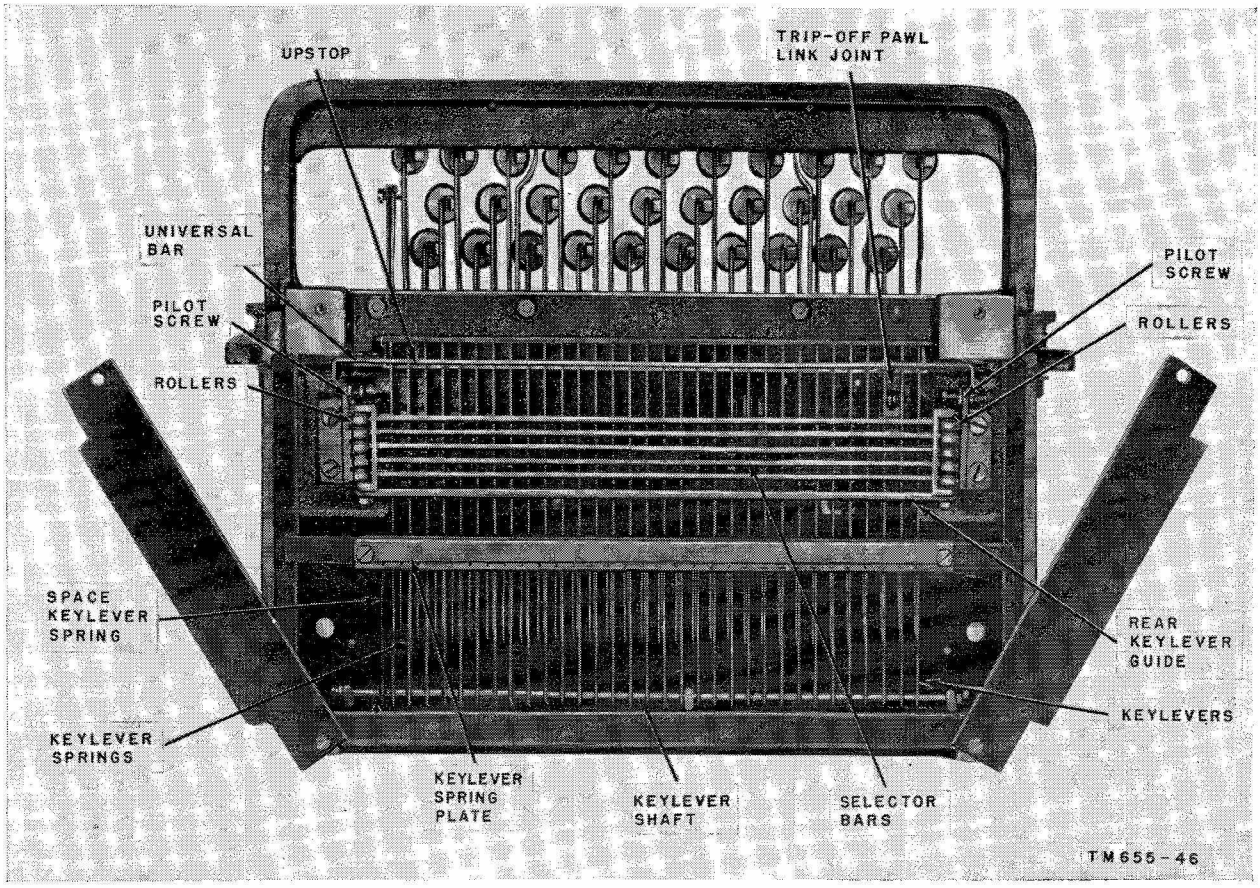


Figure 46. Keyboard, bottom view.

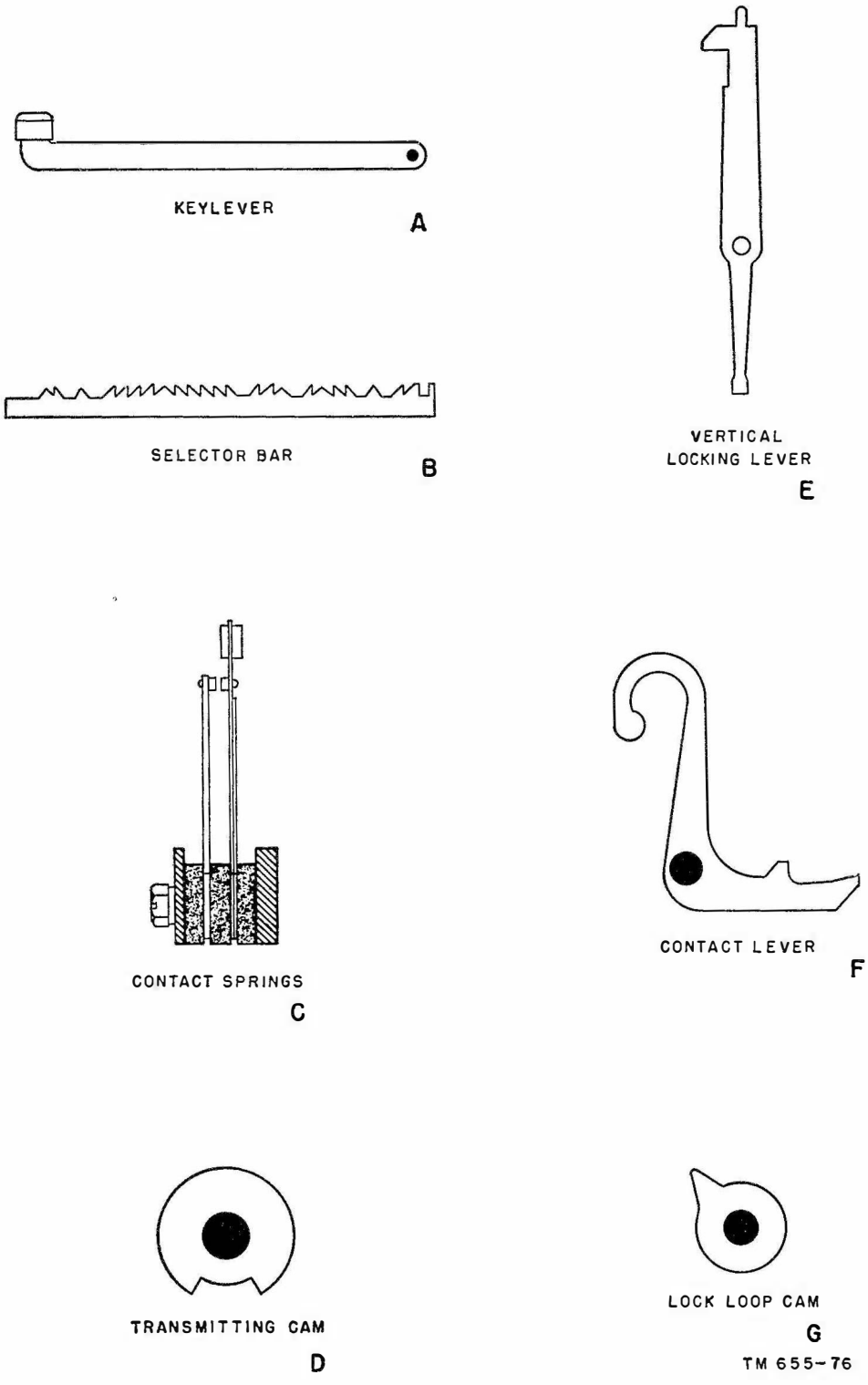


Figure 47. Components of keyboard transmitter.

transmitter contains all of the apparatus necessary to transform the depression of a keylever into code impulses and to transmit these impulses to the signal line.

24. Keylevers

a. Description and Purpose. Teletypewriter keylevers (fig. 47Ⓐ) are similar in appearance to those in commercial typewriters. They are located directly above the selector bars and extend to the rear of the keyboard unit where they are pivoted on the keylever shaft (fig. 46). The keylevers have no physical connection with the type bars as they do in commercial typewriters. The function of teletypewriter keylevers is to position the selector bars, in accord-

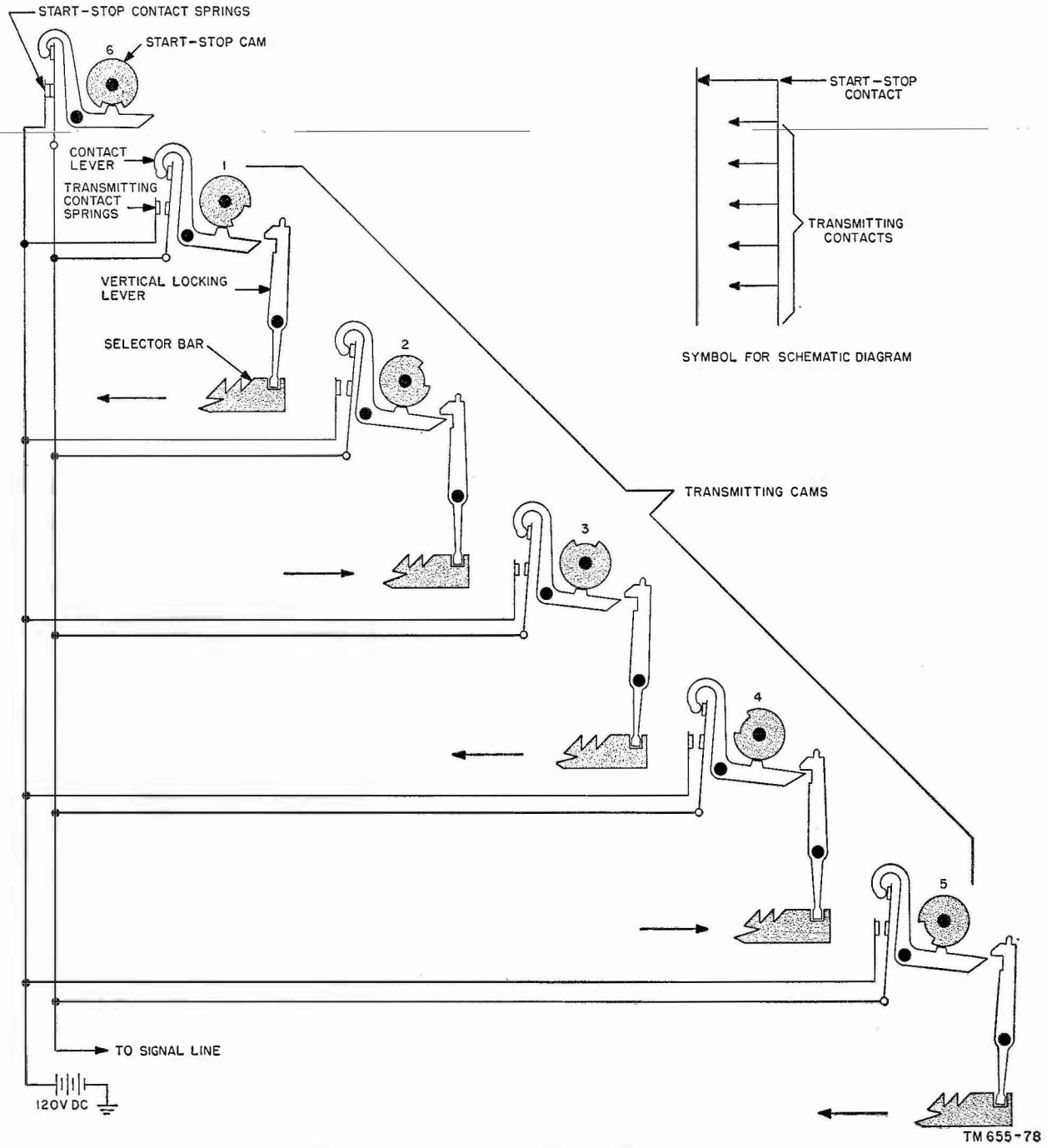


Figure 48. Relationship of keyboard components.

ance with the requirements of the five-unit code, and to rotate the universal bar to start the rotation of the transmitter shaft.

b. Operation. When a keylever is depressed, its lower edge strikes the slanting sides of the saw-tooth notches on the upper edge of the selector bars. This positions the selector bars either to the right or to the left in accordance with the five-unit code for the letter or symbol being transmitted. As the downward movement of the keylever is continued, it strikes the universal bar and causes the bar to rotate slightly on its pivots.

25. Selector Bars

a. Description and Purpose. The five selector bars (fig. 47Ⓑ) are located directly beneath the keylevers. They extend across the width of the keyboard where they can be engaged by any keylever or the space bar (fig. 46). The selector bars rest on rollers and are guided at each end so that they may be easily moved endwise. The right end of each selector bar is recessed and firmly engages a vertical locking lever (fig. 49Ⓐ and Ⓑ) which is part of the transmitting unit described in paragraph 27. Each selector bar is provided with saw-tooth notches in its upper edge. The notches slant either to the right or to the left in accordance with the five-unit teletypewriter code. The purpose of the selector bars is to position the vertical locking levers.

b. Operation. When either a keylever or the space bar is depressed, its lower edge strikes the slanting sides of the saw-tooth notches in the selector bars. The downward pressure on the saw-tooth notches moves the selector bars either to the right or to the left. Each selector bar engages a vertical locking lever near its right end and positions the lever to correspond with the code impulse to be transmitted. The mechanical principle involved in positioning the selector bars is illustrated in figure 50. This principle is further illustrated in figure 51Ⓐ, where all five selector bars are shown positioned to transmit the letter *R*, and in figure 51Ⓑ, where they are positioned to transmit the letter *Y*.

26. Universal Bar

a. Description and Purpose. The universal bar (fig. 46) is located underneath the keyboard

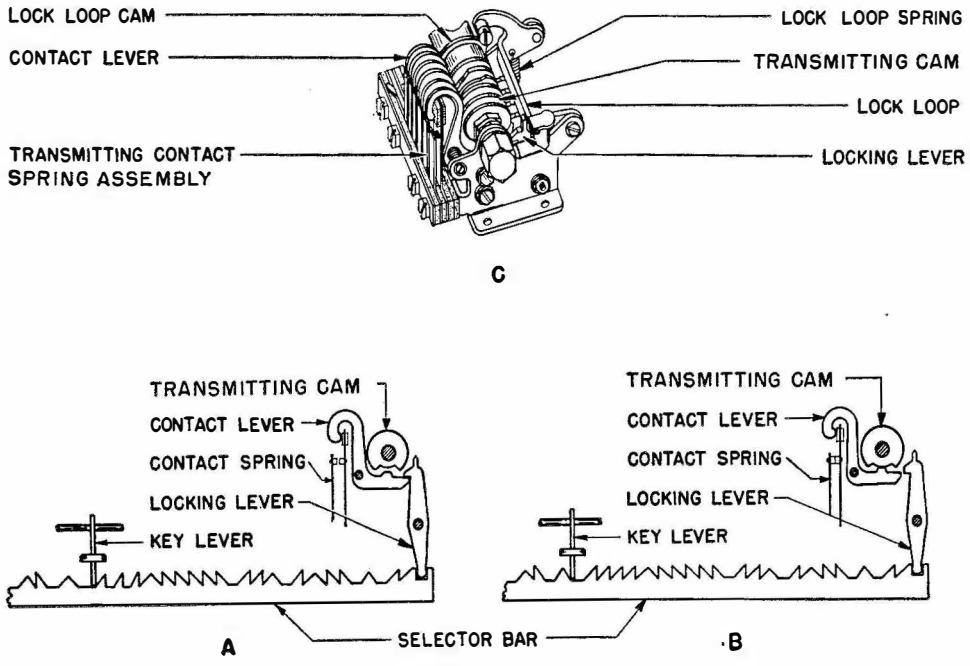


Figure 49. Vertical locking levers and keyboard transmitting unit.

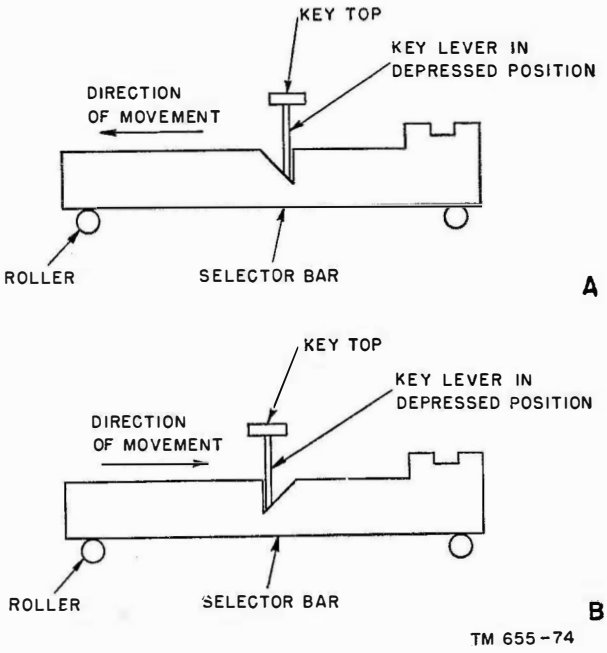


Figure 50. Mechanical principle used to position selector bars.

in front of the selector bars. It extends across the width of the keyboard where it can be engaged by any keylever or the space bar. The universal bar is connected to the trip-off pawl (fig. 52) which controls the starting and stopping of the rotation of the transmitting cams on the transmitting unit (fig. 49©). The universal bar is pivoted at its two ends in such a way that the depression of any keylever or the space bar moves it downward. The purpose of the universal bar is to control the starting of rotation of the transmitting cams.

b. Operation. When any keylever or the space bar is depressed, the selector bars are moved either to the right or to the left, causing the universal bar to rotate on its pivots and operate the trip-off pawl. The trip-off pawl operates the intermediate pawl which permits the clutch to engage and rotate the transmitting cams.

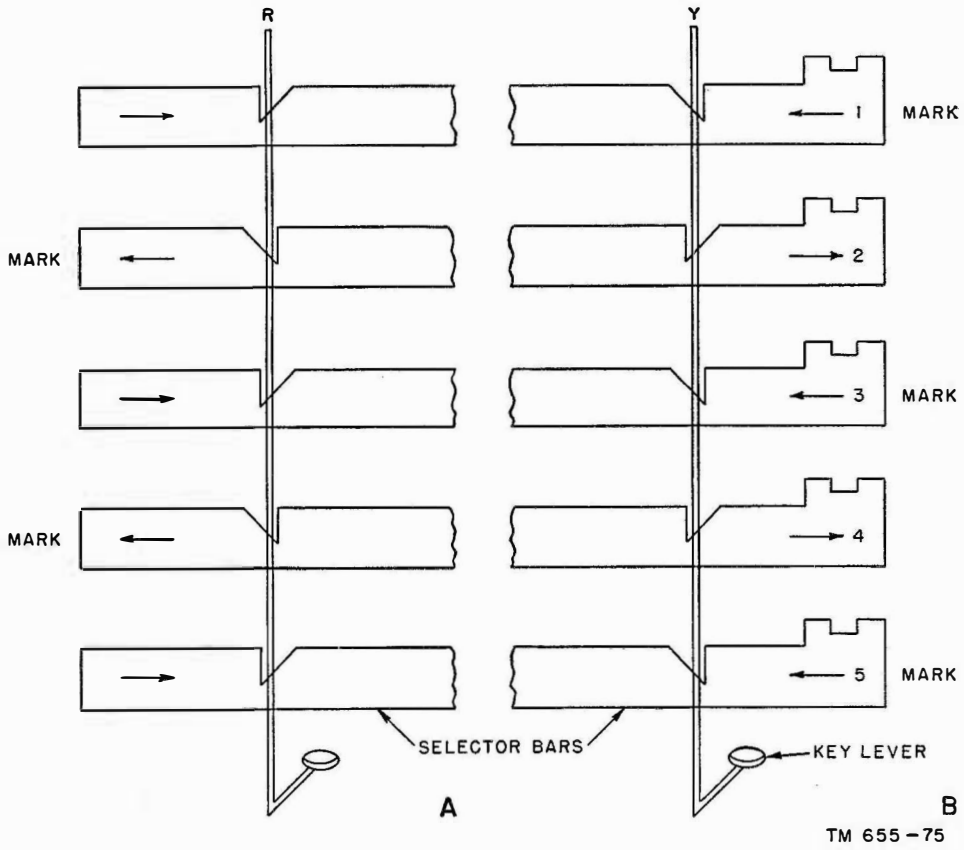


Figure 51. Selector bars positioned for the letters R and Y.

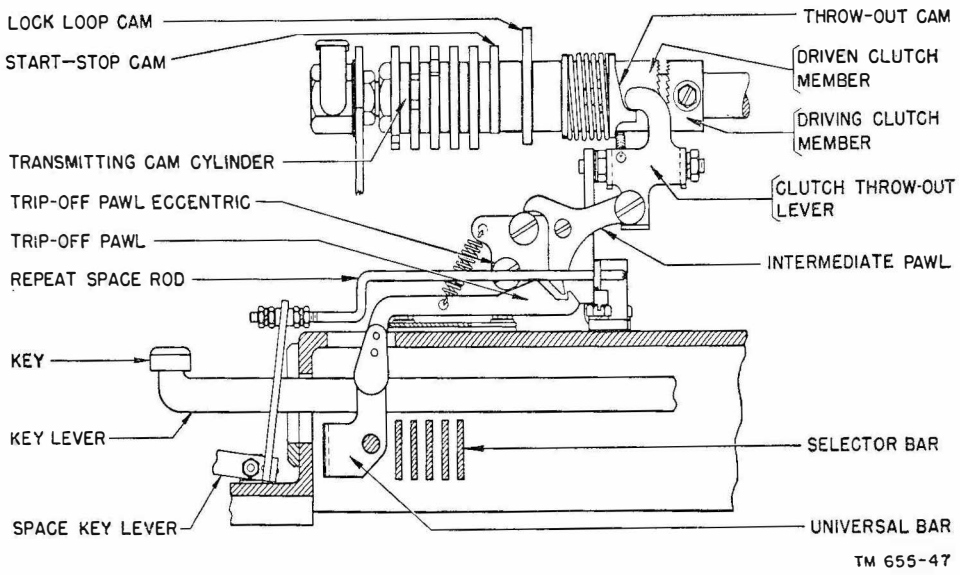


Figure 52. Cross section of keyboard.

27. Transmitting Unit

The transmitting unit (fig. 49©) is a major component of the keyboard transmitter. It is attached to the keyboard transmitter by four machine screws. The transmitting unit consists of an assembly of six pairs of contact springs, six contact levers, five vertical locking levers, and a lock loop (fig. 49©). Also included is the transmitting shaft, on which are mounted the driven and driving clutch members, the seven operating cams on the transmitting cam cylinder (fig. 52), and the driving gear (not shown). The gear is connected through intermediate gears to the main shaft on the typing unit which in turn is driven by the motor. The components of the transmitting unit are shown disassembled in figure 47. The relationship between the transmitting unit components is shown in figure 48.

28. Contact Springs

a. Description and Purpose. An assembly of six pairs of contact springs is attached to the transmitting unit by machine screws (fig. 49©). An individual pair of contact springs is shown in figure 47©. The five pairs of contact springs nearest the front of the keyboard transmit the five-unit teletypewriter code. The sixth pair of contact springs transmit the start and the stop impulses. The contact springs are controlled by the contact levers.

b. Operation. When the transmitting cam sleeve is revolved by the engagement of the clutch (fig. 52), the start-stop contact springs are opened by the start-stop contact lever (fig. 48). This impresses a start (spacing) impulse on the line. As the rotation of the cam sleeve continues, the transmitting contact springs, beginning with the pair nearest the start-stop contact springs, either remain open or are closed in sequence in accordance with the code set up in the selector bars by the depression of a keylever.

29. Contact Levers

a. Description and Purpose. Six contact levers (fig. 47Ⓕ) are mounted on a shaft between the end members of the transmitting unit frame. The purpose of the contact levers is to control the opening and closing of the contact springs during transmission of a code sequence. The five contact levers nearest the front of the keyboard control the transmitting contact springs; the contact levers are controlled by vertical locking levers. The sixth contact lever controls the start-stop contact springs. Each contact lever has an extension on its upper edge which is held by spring pressure against the periphery of its associated cam. The contact levers are designed so that when the extension is on the high portion of the cam, the contact springs

are held apart (open); when the extension is in the cam indent, the contact springs are closed.

b. Operation.

(1) When no transmission is in progress, the transmitting cam sleeve is held stationary; the start-stop contact lever extension is in its uppermost position in its cam indent; and the start-stop contact springs are closed, maintaining the continuity of the signal line. All five of the transmitting contact lever extensions are on the high part of their cams and all of the transmitting contact springs are in the open position (fig. 48).

(2) When a code sequence is transmitted, the clutch is engaged and the transmitting cam sleeve makes one complete revolution. The rotation of the start-stop cam ejects the start-stop contact lever extension from the cam indent, opens the start-stop contact springs, and sends a start (spacing) impulse. As the rotation of the cam sleeve continues, the transmitting cam indents are brought opposite the transmitting contact lever extensions in sequence. The contact lever extensions either rise into the cam indents or are restricted from doing so by the vertical locking levers in accordance with the code for the transmission in progress. When a contact lever extension rises into its cam indent, the contact lever is rotated slightly counterclockwise, the contact springs close, and a marking impulse is sent (fig. 49Ⓑ). When the movement of a contact lever is restricted by a vertical locking lever, the contact springs are held open and a spacing impulse is sent (fig. 49Ⓐ). Just before the fifth transmitting cam is in position to eject the contact lever extension from its indent, the start-stop contact lever extension rises into its cam indent and sends a 31 millisecond stop (spacing) impulse. At the completion of the stop impulse, the clutch throw-out lever engages the throw-out cam on the transmitting cam sleeve; the clutch is disengaged and the cam sleeve is held stationary again.

30. Vertical Locking Levers

a. Description and Purpose. Five vertical locking levers (fig. 47Ⓔ) are mounted on the right side of the transmitting unit (fig. 53). Each vertical locking lever has a notch in its edge near the upper end, and has its lower end firmly engaged in a recess in the right end of a selector bar (fig. 49Ⓐ and Ⓑ). The vertical locking levers are designed to control the movement of the associated contact levers.

b. Operation. When a keylever is depressed, the selector bars are moved either to the right or to the left, the clutch is engaged, and the transmitting cam sleeve makes one revolution. When a selector bar is moved to the left, the vertical locking lever is rotated slightly clockwise moving its upper end out of the path of the contact lever (fig. 49Ⓑ). As the cams rotate, the contact lever extension rises into the indent in the cam, the contact springs close, and a marking impulse is sent for that unit of the code. When a selector bar is moved to the right, the vertical locking lever is rotated counterclockwise and moves the notch in its upper end over the end of the contact lever (fig. 49Ⓐ) so that the contact lever extension cannot rise into the cam indent. The contact springs are held open and a spacing impulse is sent.

31. Transmitting Cam Sleeve (Cylinder)

a. Description and Purpose.

(1) The transmitting cam sleeve consists of seven operating cams arranged on a single cam sleeve mounted on the transmitting shaft (figs. 25 and 52). The design and mounting of the cams are such that the start, the marking, the spacing, and the stop impulses transmitted are of the desired length. Each cam is circular in shape; six of them have indents (notches) in their periphery to receive the contact lever extensions (fig. 47Ⓓ). The indents are displaced angularly so that when the transmitting cam sleeve is rotated, the indents will be brought into position to operate the start-stop and code impulses contact springs in se-

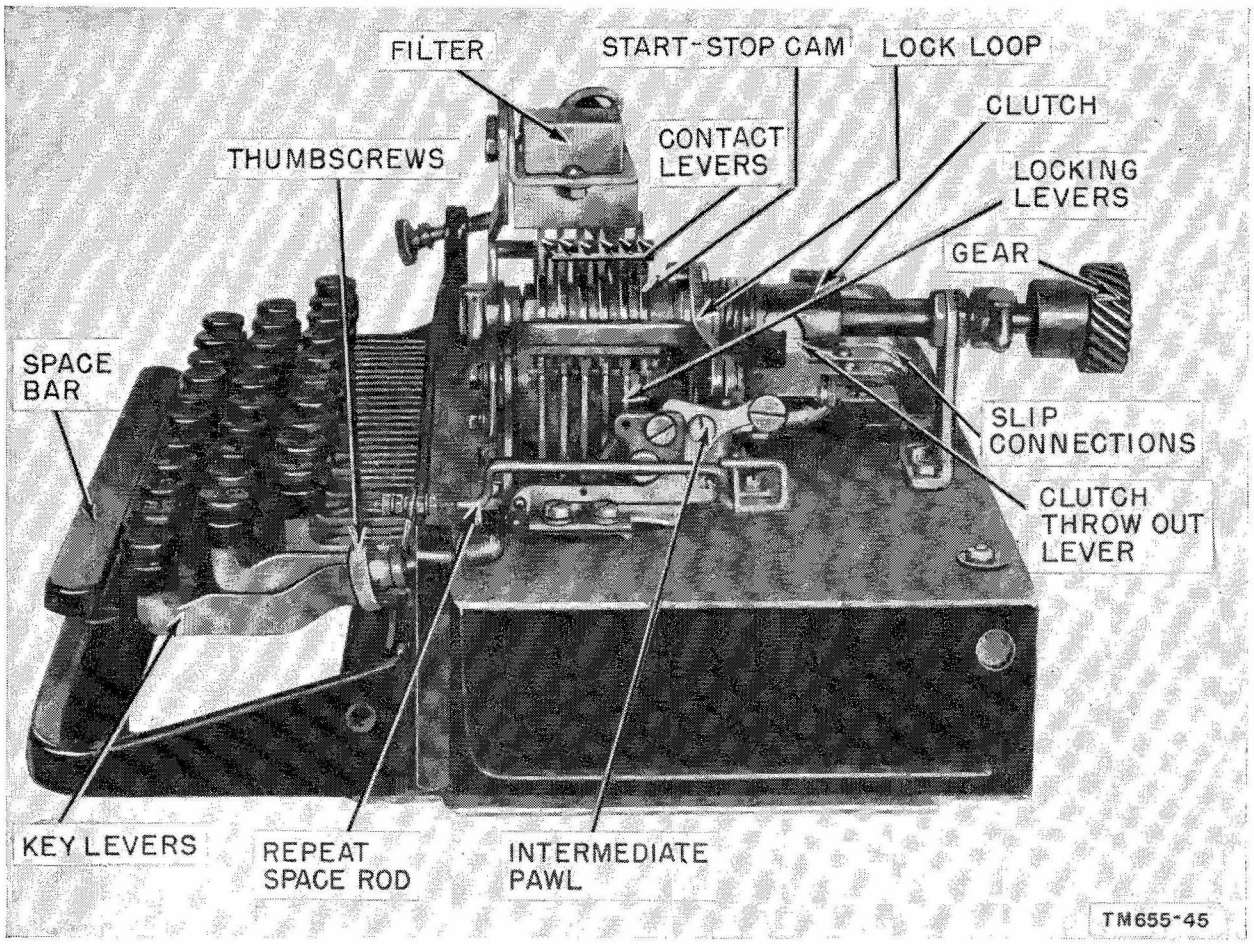


Figure 53. Teletypewriter keyboard and base showing transmitting mechanism.

quence. This is shown simplified in figure 54. The start-stop and code impulse contact springs operate when released by the contact levers; the extensions of the contact levers rise into their cam indents during the rotation of the cam sleeve (fig. 48). The angular displacement of the cam indents is arranged so that after the 22 millisecond start impulse is sent, the indents overlap so that the signal line is not opened between successive marking impulses. The five cams nearest the front of the keyboard are the code transmitting cams; they control the contact levers that are associated with the code transmitting contact springs.

(2) The start-stop cam is the sixth cam on the cam sleeve from the front of the keyboard (fig. 52). It has the same general appearance as the transmitting cam and is designed to control the sixth contact lever which opens and closes the sixth pair of contact springs to produce both the start and the stop impulses. Since this cam produces the 31 millisecond stop impulse, its indent is slightly longer than the indents in the transmitting cams.

(3) The lock loop cam is the seventh cam on the cam sleeve as viewed from the front of the keyboard (fig. 52). It is slightly larger than the other cams and has a projection instead of an indent on its surface. This cam and an associated lock loop control the keyboard locking levers so that only one selection can be made at a time (for and during the course of a cycle or revolution).

(4) The transmitting shaft clutch and associated mechanism (fig. 52) consist of a driving clutch member, a driven clutch member, a clutch throw-out lever, and a clutch spring. Both the driving and driven clutch members are slipped over the transmitting shaft. The driving clutch member is secured to the shaft by a machine screw. The driven clutch member is connected by means of sliding gears to the transmitting shaft. These gears consist of projections on the driven clutch sleeve permanently engaged in slots in the cam sleeve. The design of the gears permits the driven clutch member to engage the driving clutch member. When the clutch is engaged, power is furnished through the sliding gears to rotate the transmitting cam sleeve. The driven clutch member is equipped with a throw-out cam which engages the clutch throw-out lever, and disengages the clutch at the completion of each revolution of the transmitting cam sleeve. The clutch throw-out lever holds the driven clutch member and the transmitting cam sleeve stationary until a key is depressed to begin a code sequence. The clutch spring is slipped over the end of the transmitting cam sleeve. It provides the power to move the driven clutch member into engagement with the driving member when the throw-out cam is released by the clutch throw-out lever.

b. Operation. When the depression of a keylever or the space bar causes the clutch to engage, the transmitting cam sleeve immediately starts to rotate. The lock loop rides off the high part of the lock-loop cam and locks the locking levers in their selected positions. The start-stop cam pushes the start-stop contact lever extension out of the cam indent, opening the start-stop contact springs which send the start impulse. As the rotation of the cam sleeve continues, the indents in the code transmitting cams are brought opposite their contact lever extensions in sequence. The contact lever extensions either rise into the cam indents and send marking impulses, or are prevented from rising into the indents by vertical locking levers in accordance with the code for the letter or symbol being transmitted. Contact levers restricted by vertical locking levers hold the transmitting contact springs open and send spacing impulses for their unit of the code. After the fifth code impulse has been transmitted, the start-stop contact lever extension enters its cam indent, and the start-stop contact springs close and send a 31 millisecond stop impulse. As the transmitting cam sleeve completes a revolution, the high part of the lock loop cam disengages the lock loop from the locking levers so that the keys or the space bar may be operated to set up a new selection. The clutch throw-out lever engages the throw-out cam on the driven clutch member, the clutch is disengaged, and the transmitting cam sleeve is held stationary until a keylever or the space bar is depressed.

32. Example of Keyboard Transmitter Operation

a. Assume that the letter R is to be transmitted. (The code sequence for each combination is shown in fig. 8.) The letter R is used as an example because it is one of the letters commonly used for test purposes. The code sequence for the letter R (fig. 7) consists of space, mark, space, mark, and space preceded by a spacing (start) impulse and followed by a marking (stop) impulse. At 368.1 opm (approx. 60 wpm), the start impulse and the five code impulses are each 22 milliseconds long and the stop impulse is 31 milliseconds long. The depression of the R keylever positions selector bars Nos. 1, 3, and 5 to the right and Nos. 2 and 4 to the left. It also rotates the universal bar on its pivots. Selector bars Nos. 1, 3, and 5 move their vertical locking levers into position to prevent their contact lever extensions from rising into their cam indents when they are presented during the rotation of the transmitting cam sleeve. Selector bars Nos. 2 and 4 move their vertical locking levers out of the operating path of contact levers Nos. 2 and 4, leaving the contact lever extensions free to rise into their cam indents when they are presented. The rotation of the universal bar operates the trip-off pawl (fig. 52); the trip-off pawl operates the intermediate pawl. This action releases the clutch throw-out lever, which releases the

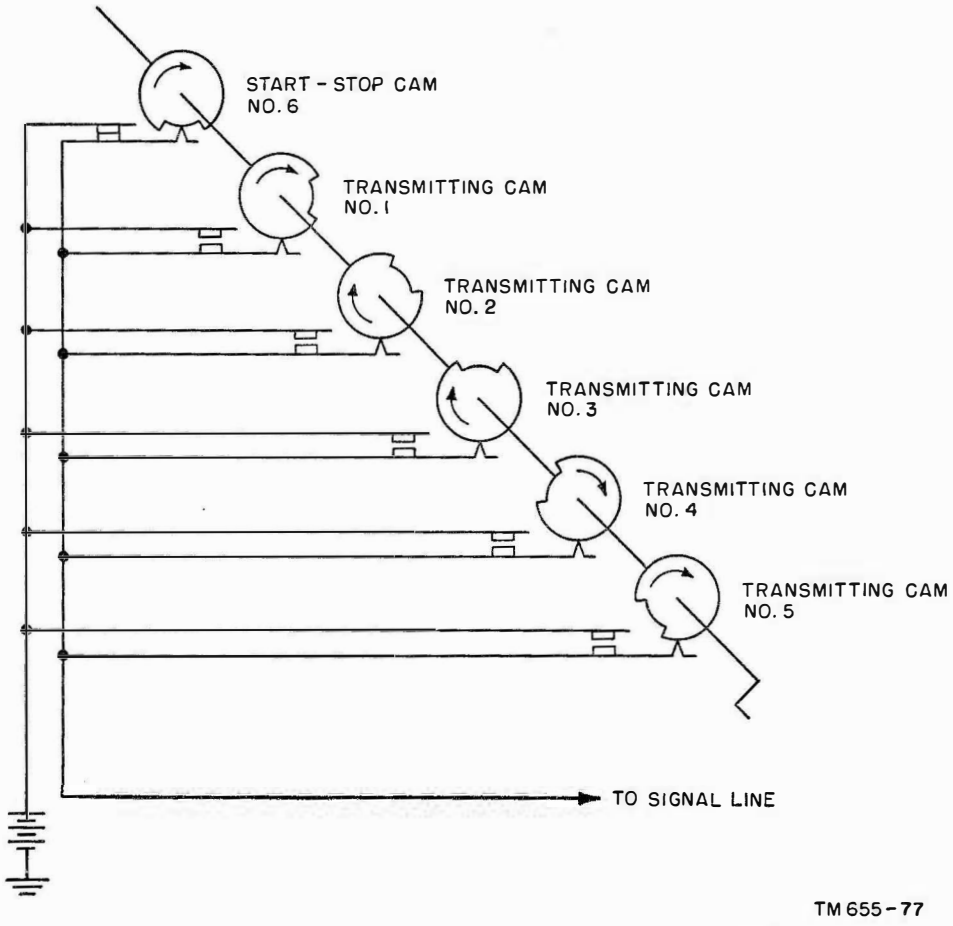


Figure 54. Angular displacement of transmitting cam indents.

driven clutch member. The driven clutch member engages the driving clutch member and the transmitting cam sleeve begins its rotation. The rotation of the lock-loop cam releases the lock loop that locks the vertical locking levers in their selected positions so that another code cannot be set up by the keys before the present sequence is completed. The rotation of the start-stop cam moves the contact lever extensionsion out of its indent, opening the start-stop contact springs and sending a 22 millisecond spacing (start) impulse. When the transmitting cam sleeve rotates sufficiently to complete the start impulse, the indent in transmitting cam No. 1 is opposite contact lever extension No. 1. Since contact lever No. 1 is engaged by its vertical locking lever, the contact lever extension cannot rise into the cam indent, and the contact springs are held in the open position, sending a 22 millisecond spacing impulse for that unit of the code. When the indent in transmitting cam No. 2 arrives opposite its contact lever extension, the extension rises into the cam indent, the contact springs close, sending a 22 millisecond marking impulse. Except for the cams, the contact levers, and the contact springs involved, the operations for the third and fifth units of the code are the same as those for the first unit, for which a spacing impulse was sent; the operations for the fourth unit of the code are the same as those for the second unit, for which a marking impulse was sent. After the fifth code impulse has been transmitted, the indent in the start-stop cam is presented to the start-stop contact lever, the extension rises into the indent, the start-stop contact springs close, and a 31 millisecond marking (stop) impulse is impressed on the line. As the transmitting cam sleeve completes a revolution, the lock-loop cam disengages the lock loop from the locking levers so that the keylevers or the space bar may

be operated to set up a new selection. The clutch throw-out lever engages the throw-out cam on the driven clutch member, the clutch is disengaged, and the transmitting cam sleeve is held stationary until a keylever or the space bar is depressed.

b. Figure 55 is a chart showing the sequence of operation for the parts and subassemblies of the keyboard transmitter as described in the preceding paragraphs of this section. A study of it will aid in following the example of keyboard transmitter operation given in *a* above.

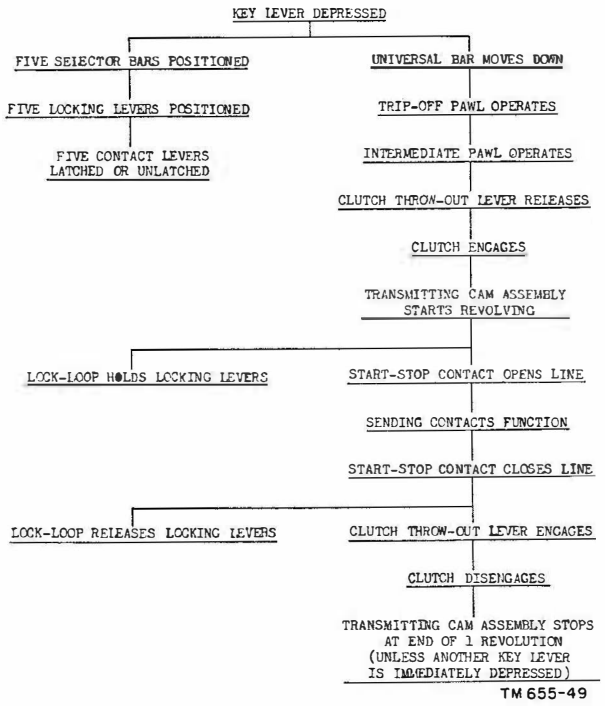


Figure 55. Sequence chart for keyboard transmitter functioning.

33. Repeat Space

a. Description and Purpose. The keyboard is equipped with a repeat-space device that permits the transmission of continuous spaces as long as the space bar is depressed. The device consists of an extension on the space bar keylever, and a repeat-space rod that connects the extension with the intermediate pawl.

b. Operation. When the space bar is depressed, the repeat-space rod (fig. 52) connected to the space bar keylever extension rotates the intermediate pawl (fig. 52). The intermediate pawl, in turn, holds the clutch throw-out lever out of engagement with the throw-out cam on the driven clutch member. Thus, the transmitting cam sleeve is permitted to revolve continuously until the space bar is released.

c. Operation for Single Space. When the repeat-space feature is not desired, the repeat space rod and keylever extension are omitted. If previously installed, they are removed. The space bar then functions in the same manner as the other keylevers and must be released and again depressed for each space.

34. Typing Unit (General)

a. Description and Purpose. The typing unit includes in a single assembly all the mechanism, except the motor, required to convert code impulses into typewritten messages. The detailed functioning of the various parts and subassemblies of the typing unit is arranged to group the individual functions that occur as a train of actions. Detailed data and associated illustrations are given in paragraphs 35 through 39.

b. Operation. All mechanically operated parts of the typing unit receive their motive force from the main shaft assembly. This assembly is connected directly through the main shaft gear to the motor pinion. When the motor revolves, it transfers power through the various cams, gears, and clutches to move the various parts of the typing unit. These parts move at a speed required to synchronize their mechanical actions with the code impulses that electrically energize the selector magnet. The selector magnet, through the associated selecting mechanism, determines the operation of the typing unit in printing a symbol or performing a nonprinting function of the equipment. The nonprinting functions are—

(1) The platen *line feeds* (single or double space) when the LINE FEED key is pressed.

(2) The type bar carriage *returns* from the right-hand to the left-hand side of the typing unit when the CAR RET key is pressed.

(3) The type bar carriage *spaces* when the space bar is pressed.

(4) The platen *shifts* from the LTRS position (corresponding to the lower case on an ordinary typewriter) to the FIGS position (corresponding to the upper case on an ordinary typewriter) when the FIGS key is pressed.

(5) The platen *shifts* from the FIGS position to the LTRS position when the LTRS key is pressed.

(6) The SEND-REC lever moves to the REC position when the blank (no designation) key is pressed twice in succession. On teletypewriters arranged for operation in weather circuits, depression of this key prints a dash (—) if the FIGS key is pressed first.

(7) The signal bell *operates* at all stations in a circuit when the FIGS, and then the BELL (upper case S) keys are pressed.

(8) The motor *stops* when the FIGS, and then the STOP (upper case H) keys are pressed.

(9) Refer to paragraph 39 for a brief description of the operation of functions.

35. Main Shaft

a. Description and Purpose. The main shaft (fig. 56) is mounted upon, and extends across, the typing unit. On it is an assembly of gears, bearings, cams, and clutches arranged to distribute power to the various mechanically operated parts of the teletypewriter. Power is supplied to the shaft by gearing to the motor unit. The speed of rotation and the timing of the various cam actions in both the keyboard-transmitter and typing unit are, therefore, controlled by the speed (in rpm) of the motor unit.

b. Operation. When the motor is operating, the main shaft revolves because the main shaft gear (fig. 56) is meshed with the motor pinion. Power then is distributed by the shaft to the various parts of the machine through clutches, cams, and gears (fig. 56). The selector cam sleeve, fitted over the left end of the main shaft, delivers power to the selector unit. This is accomplished through two friction clutches, each composed of two steel disks separated by a felt washer. Operation of the main shaft clutch under control of the selector unit causes the function-bail cam and the printing-bail cam to ro-

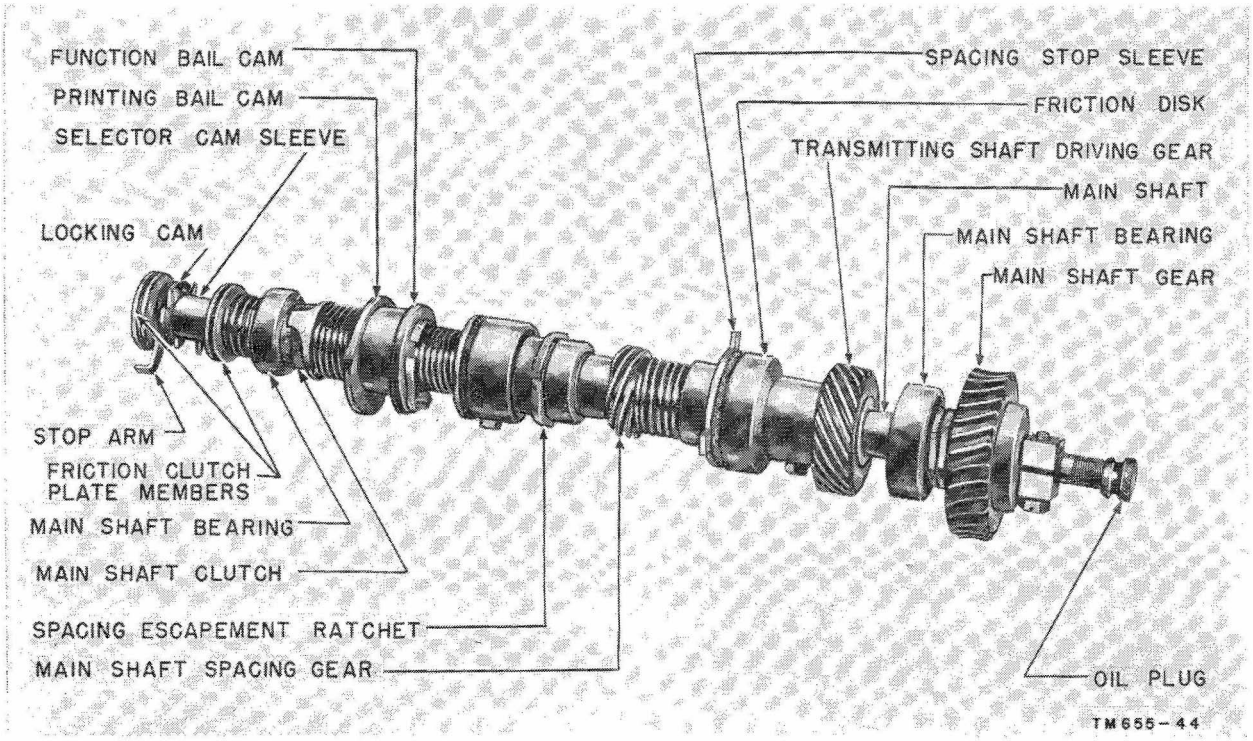


Figure 56. Main shaft.

tate with the main shaft. The function-bail cam and the printing-bail cam, in turn, operate the function bail and the printing bail in the typing unit. These, in turn, furnish the direct power for performing the function or printing the character previously selected by the selector unit. The spacing gear on the main shaft, meshing with the spacing shaft gear in the unit, transmits power to the spacing mechanism. The transmitting-shaft driving gear supplies power to the transmitting shaft of the keyboard-transmitter.

36. Selector Unit

a. Description and Purpose. The selector unit is located on the left end of the typing unit and is shown in figures 57, 58, and 59. It consists of a selector magnet, a selector magnet armature, five selector levers, five swords, five T-levers, and a selector mounting plate with posts and springs. A rangefinder assembly is associated with the selector unit. The selector-unit mechanism translates the marking and spacing impulses received from the line into a series of mechanical actions. These actions cause the vanes on the front of the typing unit to be positioned according to the character or function assigned to each combination of five selecting impulses received. The selector mechanism is controlled by the armature of the selector magnet, which receives the code impulses directly from the line or through a line relay. During the discussion of the action of the selector magnet, line relays are not considered. Normally, the selector magnet armature is attracted to the magnet coils (steady marking condition) and the stop arm rests against the stop lever which, in turn, is held by the trip latch (fig. 58). The cam sleeve does not revolve because the stop arm, which is part of the selector cam sleeve, is engaged by the stop lever.

b. Operation. When a start (spacing) impulse is received by the selector magnet, the magnet armature is released and is pulled away from the magnet pole pieces by the armature spring. This moves the trip latch out of engage-

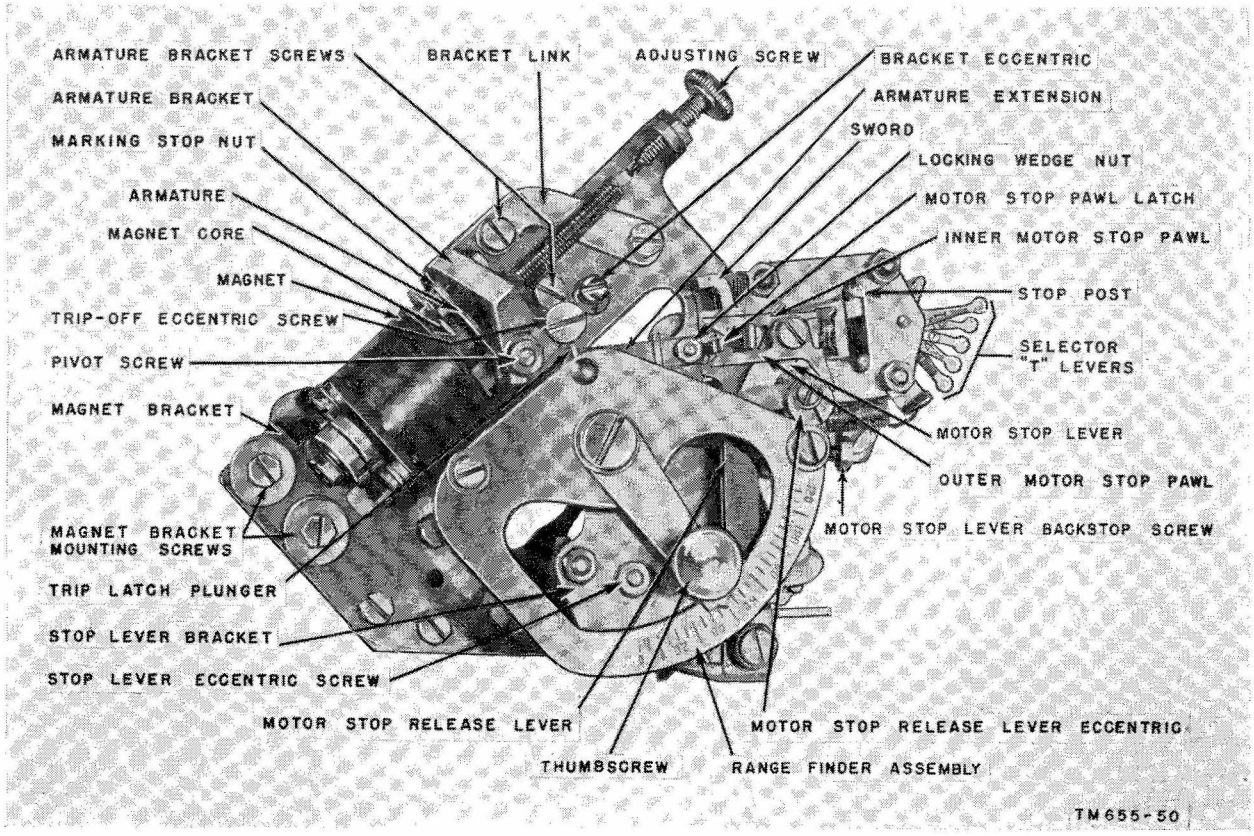


Figure 57. Selector unit.

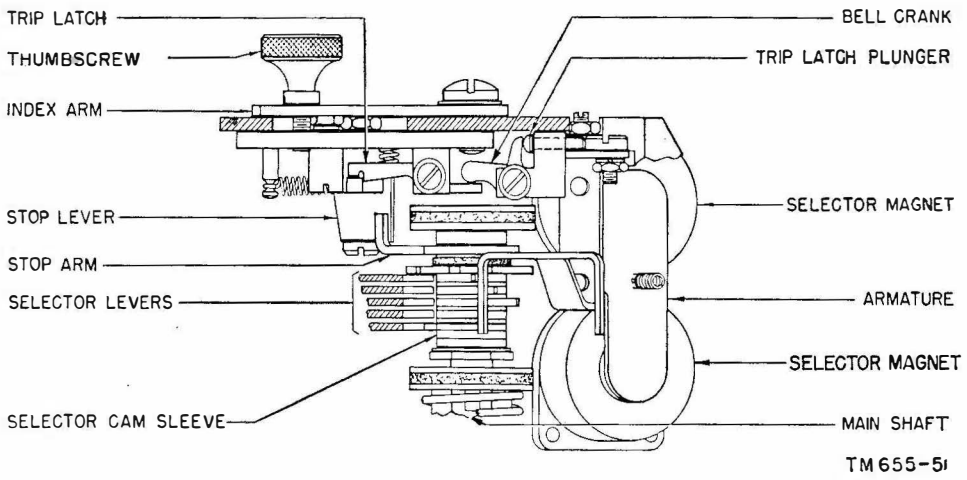


Figure 58. Cross section of selector unit.

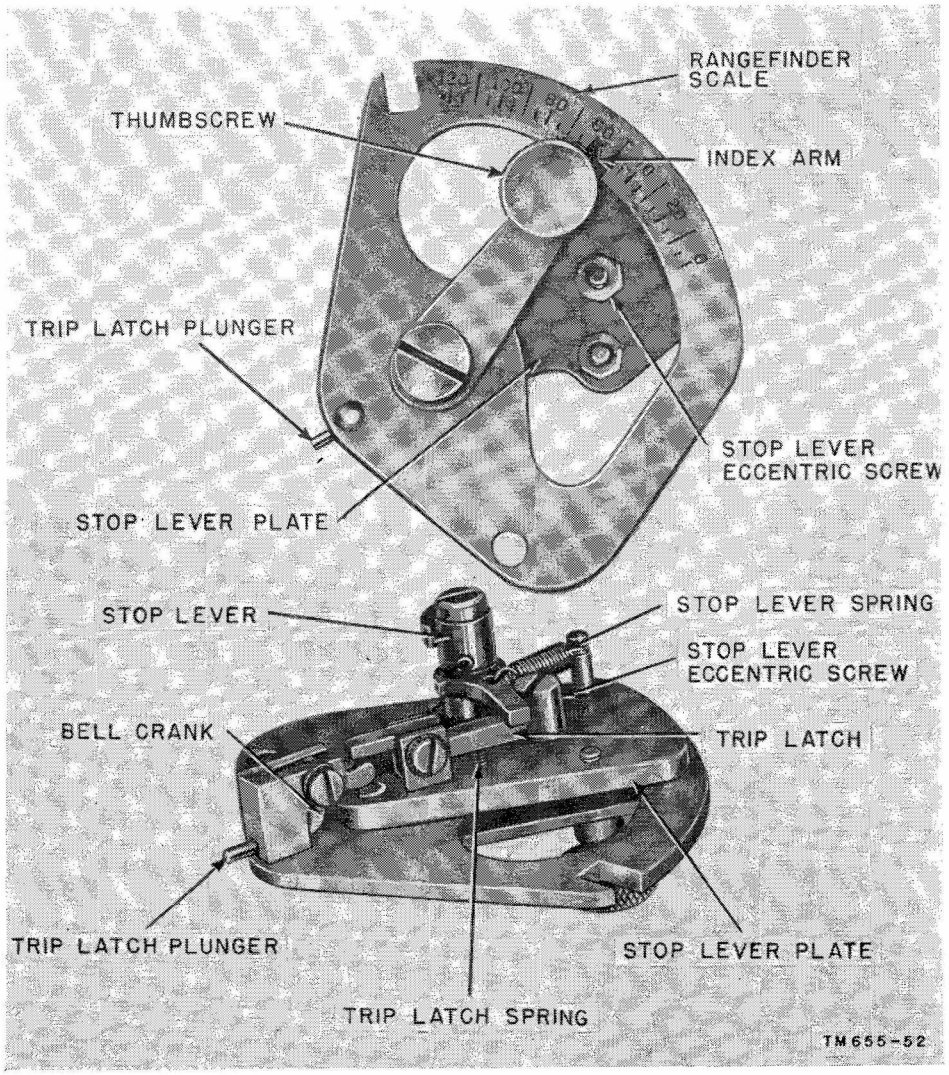


Figure 59. Rangefinder mechanism.

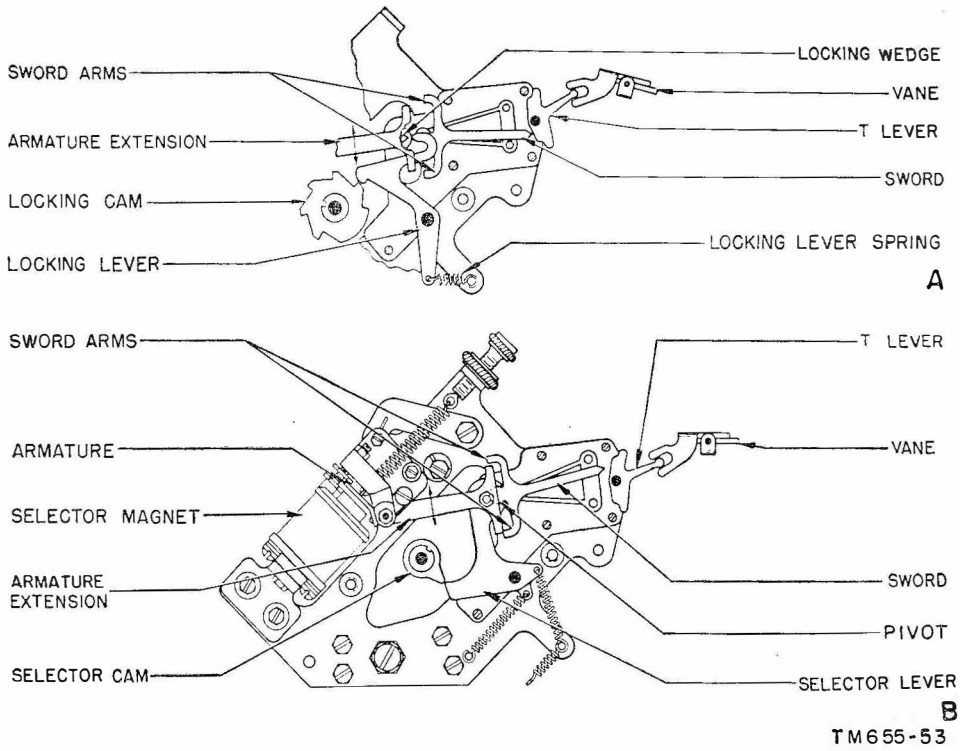


Figure 60. Locking lever operation and side view of selector unit.

ment with the stop lever, releases the stop arm, and allows the cam sleeve to rotate with the shaft. In turn, each of the vanes is operated through a T-lever, a sword, a selector lever under spring tension, and its associated cam on the cam sleeve (fig. 60). The train of action that results from the positioning of the vanes is discussed in paragraph 38.

37. Orientation of Selecting Mechanism (Rangefinder)

a. Description and Purpose. The rangefinder (fig. 59) is associated directly with the selector magnet. A stop lever, a trip latch, an index arm, a scale, and a thumbscrew are the principal parts of the rangefinder, which is designed to adjust the relation between the start of rotation of the selector cam sleeve, and the time the selector cams operate the selector levers. The range adjustment is referred to frequently as orientation.

b. Operation. Optimum (most advantageous) setting of the rangefinder is obtained by moving the index arm toward the zero end of the scale while receiving signals known to be acceptable. When errors appear in the typed matter being received on the typing unit, the index arm is moved slowly back toward the upper end of the scale until the errors *just* disappear. The scale reading is noted and the procedure is repeated at the upper end of the scale. Midway between these two extremes is the most favorable position for reliable reception. The index arm is held in adjustment by tightening the thumbscrew. Detailed instructions for making these adjustments are given in manuals which cover teletypewriter maintenance.

38. Example of Selector Unit Operation

a. The start-stop arrangement of the selector unit is shown in figure 58. Normally, the selector mechanism driven through a friction clutch is held from rotating by the stop arm resting against the stop lever. Assume that the code signal for the letter R is being received. (The code sequence for each combination is shown in figure 8.) The code sequence for the letter R (fig. 7) consists of space, mark, space, mark, and space preceded by a spacing (start) impulse, and followed by a marking (stop) impulse. At 368.1 opm (approx. 60 wpm), the start impulse and the five code impulses are each

22 milliseconds long, and the stop impulse is 31 milliseconds long. When the start (spacing) impulse is received, the receiving magnet armature (fig. 58) is released and the armature trip-off eccentric screw pushes the trip-latch plunger lengthwise. The trip-latch plunger bears against the trip-latch bell crank which, in turn, moves the trip-latch out of engagement with the stop lever. When the stop lever becomes disengaged from the trip latch, it rotates slightly under pressure of the stop arm against it, the stop arm is released, and the selector-cam sleeve is allowed to rotate.

b. Since the first selecting impulse of the code for the letter R is a 22-millisecond spacing (no current) impulse, the selector magnet coils are not energized and the selector magnet armature is in the released position. When the selector-cam sleeve starts to rotate, the locking lever drops off the high surface of the locking cam (there are six high and six low surfaces on the periphery of the locking cam), and locks the selector magnet armature in the released position. When the selector-cam sleeve rotates sufficiently, selector cam No. 1 engages selector lever No. 1. As the cam engages the selector lever, the latter is rotated slightly in a counterclockwise direction, carrying the sword with it. Since the selector magnet armature is in the released position, the lower arm of the sword is brought into contact with the lower flange of the armature extension, causing the sword to turn counterclockwise about its pivot (fig. 60 Ⓑ). This positions the sword so that when selector cam No. 1 clears the selector lever, the selector-lever spring moves the sword against the T-lever. The T-lever is rotated slightly in a clockwise direction and causes the front edge of vane No. 1 to be tilted up. As the vane tilts up, its associated bell crank rotates clockwise and positions the No. 1 code bar to the right (figs. 60 and 61). Immediately following the positioning of the sword, the locking lever rides up on a high surface of the locking cam releasing the selector magnet armature so it can move freely in response to the next received impulse. Except for the components involved, the train of actions for code intervals Nos. 3 and 5 are identical with those for code interval No. 1.

c. The second selecting impulse of the code for the letter R is a 22-millisecond marking

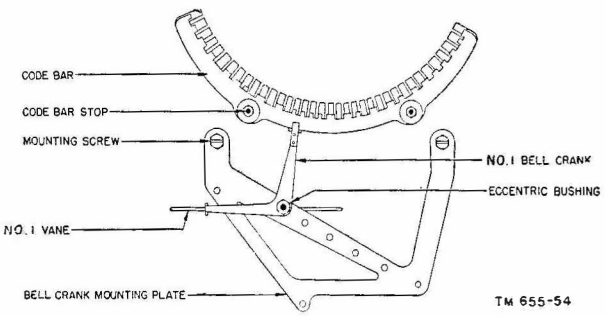


Figure 61. Vane, bell crank and code bar linkage.

(current) impulse. At the beginning of this time interval, the selector-cam sleeve is already rotating; the selector magnet coils energize; the selector magnet armature is attracted to the magnet coils; and, as during the previous selection, the locking lever drops off the high surface of the locking cam, and locks the selector magnet armature in its selected (operated) position. As the rotation of the selector-cam sleeve continues, selector cam No. 2 engages selector lever No. 2. As the cam engages the selector lever, the selector lever, as before, is rotated slightly in a counterclockwise direction carrying with it the sword. Since the selector magnet armature is in the operated position, the upper arm of the sword is brought into contact with the upper flange of the armature extension, causing the sword to turn clockwise about its pivot (fig. 60 Ⓑ). This positions the sword so that when selector cam No. 2 clears the selector lever, the selector-lever spring moves the sword against the T-lever. The T-lever is rotated slightly in a counterclockwise direction and causes the front edge of vane No. 2 to be tilted down. As the vane tilts down, its associated bell crank rotates counterclockwise and positions the No. 2 code bar to the left (figs. 60 and 61). As in the previous selection, the selector magnet armature was released by the locking lever immediately after the sword was positioned. Except for the components involved, the train of actions for selecting interval No. 4 is identical with those for selecting interval No. 2.

d. With all code selections for the letter R completed, code bars Nos. 1, 3, and 5 are positioned to the right, and code bars Nos. 2 and 4 are positioned to the left. One notch in each code bar is directly under the letter R pull bar. Just as the fifth selector lever is sliding off the peak of its selector cam at the completion of the

fifth code selection, the peak of the sixth cam (fig. 62) on the selector-cam sleeve operates the clutch throw-out lever which allows the main shaft clutch members to engage and cause the printing and function bail cams (fig. 62) to make one complete revolution. At the end of each revolution of these cams, the clutch-stop arm disengages the clutch members. Rotation of the printing-bail cam permits the printing bail to be pulled forward by its spring. The R pull bar is pulled down by its spring into the path of notches in the code bars set up by the code selections. The pull-bar bail is moved by the printing bail, carries the pull bar forward, and causes the pallet on the type bar to strike the platen and print the letter R. The stop (current) impulse is received immediately following the completion of the fifth code impulse. The selector magnet is operated, the stop lever is latched, and when the revolution of the selector-cam sleeve is completed, the selector-cam sleeve is stopped by the stop arm coming to rest against the stop lever. Figure 63 is a chart showing the sequence of operation of the selecting mechanism.

39. Operation of Functions

a. Description and Purpose. The typing unit can perform two primary types of operation. One type comprises those operations required to print characters. The other type comprises those operations necessary to perform nonprinting functions. The nonprinting functions are: BELL (FIGS S), blank, CAR RET, FIGS, LTRS, LINE FEED, STOP (FIGS H), and space. For normal communications operation, the teletypewriter is arranged to suppress printing and spacing on both upper and lower case blank combinations. Carriage return and line feed functions are operative in both upper and lower case combinations. For weather report service, the teletypewriter is arranged to print a dash (—) when the blank key is operated in the FIGS position; the carriage return and line feed functions are operative only in lower case; and the remote motor stop (FIGS H) function is not provided. The functions are completed through the operation of separate function levers located behind the vanes in the front of the typing unit. The function-lever mechanism and function levers are shown in figures 64 and 65.

b. Operation. When the printing bail is in its normal or rearmost position, the function-lever bail attached to it holds the function levers away from the vanes. As the printing bail moves forward, the function-lever bail roller moves off the high portion of the rear arms of the function levers; this permits the function lever springs to pull their levers against the vanes. The forward arms of the function levers are notched so that, when a function combination is set up on the vanes, the selected function lever moves forward further than the other function levers, and the function lever extension moves the selected push bar upward into the path of the function bail, or releases a latch bar to perform the proper function. When in the selected position, the carriage return, the line feed, the figures, the letters, the signal bell, and the motor stop function levers are in the path of the blocking plate extensions on the function-lever bail. This prevents the printing bail from moving forward far enough to permit the type bar carriage to space.

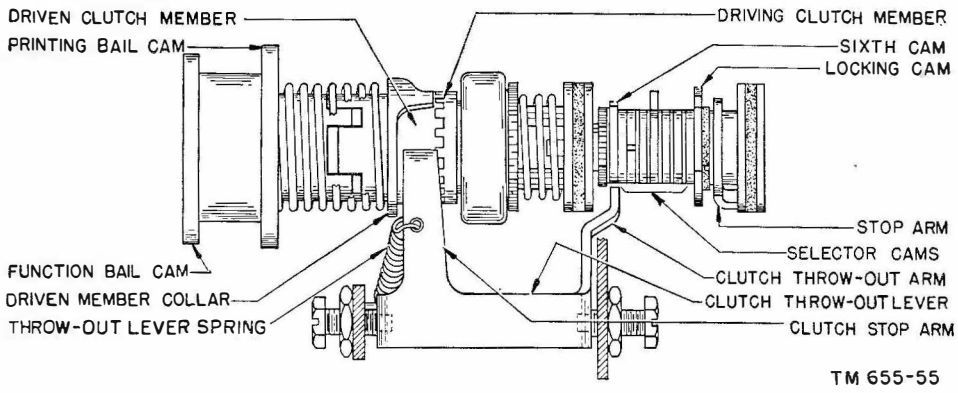


Figure 62. Section of main shaft.

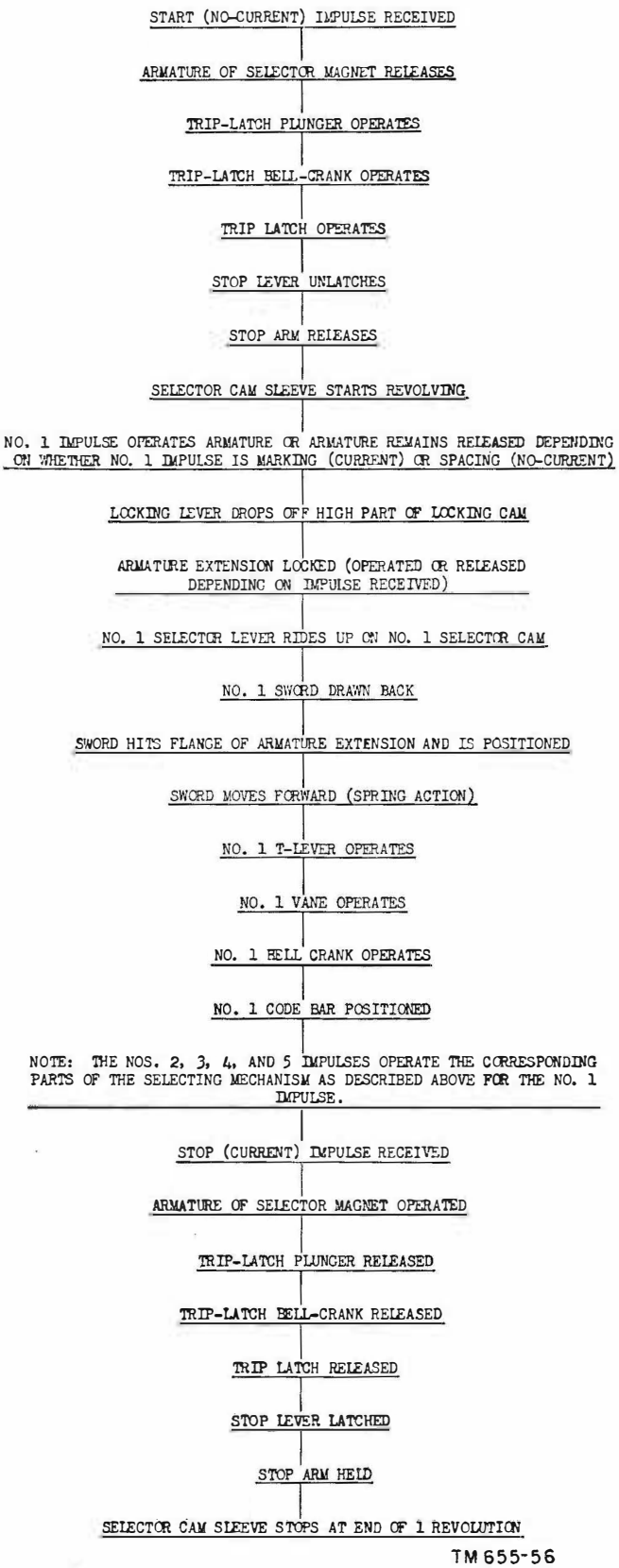


Figure 63. Sequence chart for operation of selecting mechanism.

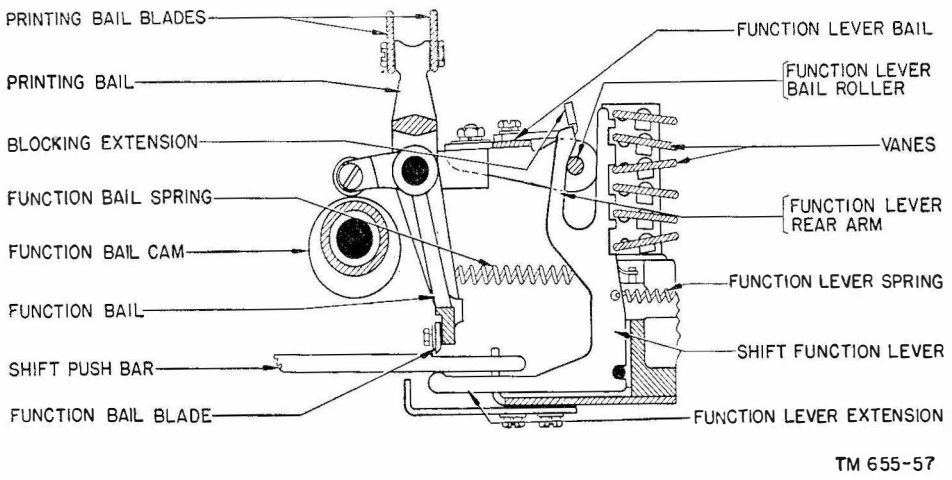


Figure 64. Function-lever mechanism.

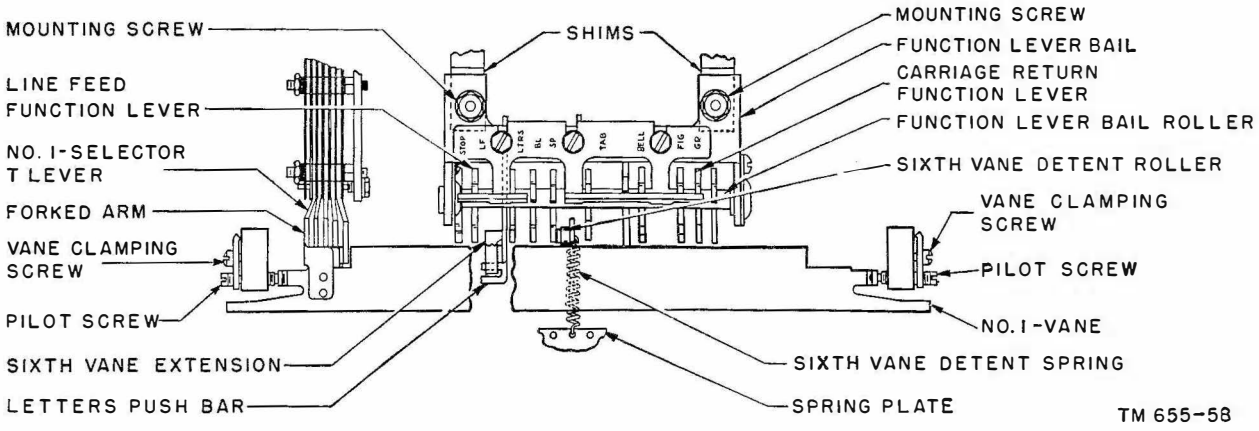


Figure 65. Function levers.

CHAPTER 3

TELEGRAPH TRANSMISSION PRINCIPLES

Section I. GENERAL

40. Introduction

A complete analysis of telegraph transmission theory is beyond the scope of this manual. Therefore, the contents of this chapter are confined to an outline of the principles involved. In presenting the following information, it is assumed that the reader has knowledge of the fundamentals of electricity, magnetism, and electromagnetism, and has an understanding of their development as presented in TM 11–661. There is nothing in the text of this chapter which requires the use of mathematics.

41. Definition of Telegraph Transmission

Telegraph transmission may be defined as the process by which characters are conveyed from one sending point to one or more receiving points by means of a signaling code. The chief requirement is the reproduction of sent telegraph (or teletypewriter) messages at the receiving point (or points) at an adequate rate without error and without interference to other services. In the preceding chapters of this manual it was assumed that satisfactory transmission was accomplished by the various circuits and equipment discussed. However, the characteristics of the circuits and equipment are such that the signal, in transmission, may undergo certain changes that alter its characteristics. These changes tend to cause failure to reproduce at the receiving end of the circuit the same character that was transmitted at the sending end. It is the purpose of this chapter to discuss the cause and effect of such changes.

Section II. TELEGRAPH CIRCUITS

42. General

Telegraph circuits, either ground-return or full-metallic, may be composed of wire or cable assigned for the exclusive use of the telegraph, or they may be superposed on telephone circuits. Cable and wire are usually assigned for telegraph loops and trunks of relatively short circuits. In such cases it would be uneconomical to use the superposition method because of the terminal equipment required. Where long distances are involved and telephone circuits are available, considerable savings in wire can be made by superposing the telegraph circuits on telephone circuits; this is accomplished either by simplexing the telephone circuit or by using composite sets.

43. Simplex Method

a. In the simplex method of d-c telegraphy, a telegraph or teletypewriter circuit is derived from an existing telephone circuit. A repeating coil is installed at each end of the telephone circuit, and the telegraph apparatus is connected between the midpoint of the line windings of each repeating coil and ground as shown in figure 66. It is connected in this manner to achieve balance; this is the fundamental principle of the simplex system. Current from the telegraph apparatus at station A divides and flows in opposite directions through the line windings of the repeating coil, over both line wires in parallel, through the line windings (in opposite directions) of the repeating coil at station B, and

through the telegraph apparatus to ground. The telegraph currents in the line windings of each repeating coil are opposing, and will induce no net voltage in the drop side windings of the coils. The telegraph currents in the two line wires are also opposing. Therefore, in a perfectly balanced telephone circuit, no interference to normal operation will result from the operation of the telegraph circuit.

b. An additional telephone circuit, called a phantom, is frequently derived from two existing telephone circuits. Each of the two physical circuits is simplexed as described in *a* above, and the four wires involved are transposed as a four-wire group. The phantom telephone circuit is completed by connecting the two simplex legs to telephone apparatus at each end of the circuit. It is possible to simplex the phantom and operate a telegraph circuit over the four wires in parallel as shown in figure 67.

c. Generally, telegraph transmission will be as good on a simplexed pair as it would be on a single wire used for telegraph exclusively, except for a certain amount of additional leakage in wet weather. When both pairs of a phantom group are simplexed, and separate services are operated over them, there may be excessive crossfire between the two telegraph circuits. The simplexed open-wire phantom is less desirable than the simplexed pair because of the comparatively large leakage of four wires in parallel in wet weather.

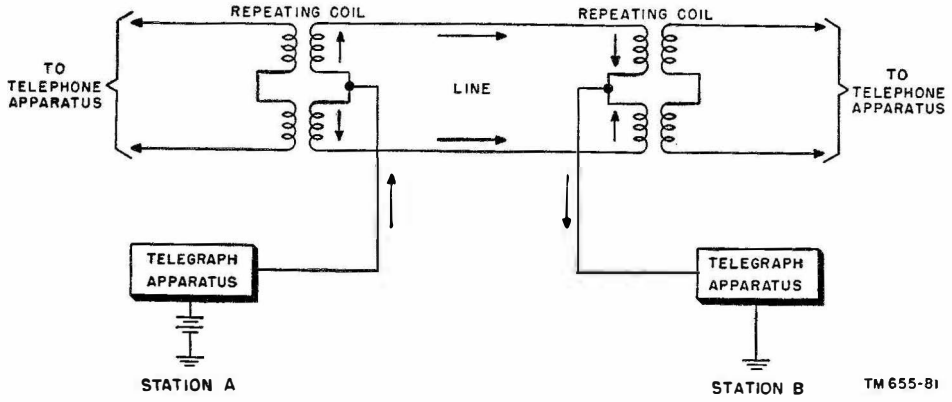


Figure 66. Telegraph circuit on simplexed telephone circuit.

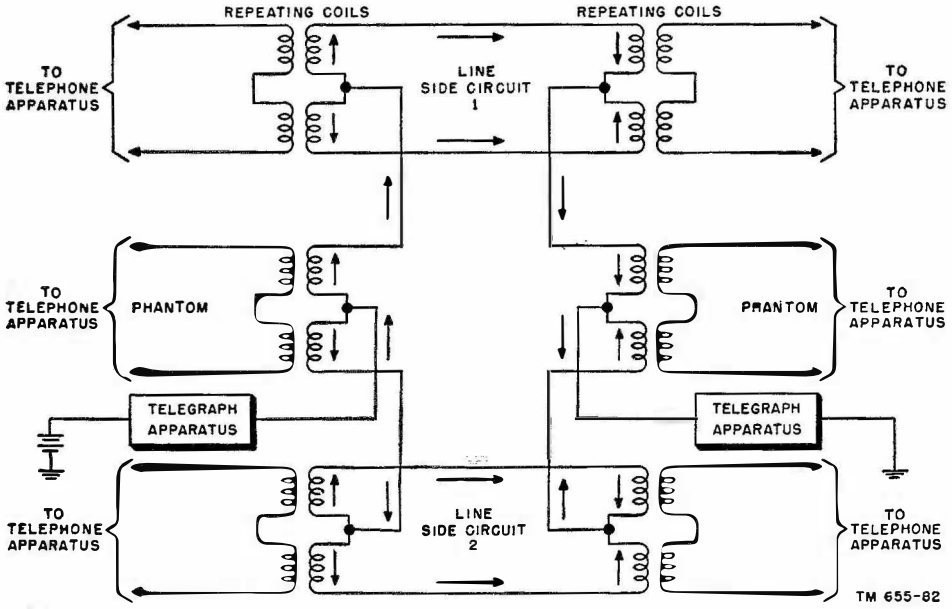


Figure 67. Telegraph circuit on simplexed phantom telephone circuit.

44. Composite Method

The principle of the composite set differs radically from that of the simplex set. It permits a grounded telegraph circuit to be derived from each of the two wires of a telephone circuit without interfering with the use of the telephone circuit as one of the physical circuits in a phantom group. A sketch of a composite set designed for a grounded telegraph is shown in figure 68. The composite set consists essentially of a high-pass filter in series with the telephone circuit and a low-pass filter in the telegraph branch. These filters have as little distortion and attenuating effect in the working range of each as practicable. The working range of the telegraph branch is approximately 80 cycles, and the filter in the telephone branch permits the transmission of speech frequencies as low as 250 cycles. The regular 20-cycle ringing current cannot be used for signaling over the telephone circuits when they are composited. However, 135-cycle signaling arrangements are used. Although the attenuation over the telephone channel is relatively great at this frequency, it does permit transmission of 135-cycle signaling voltage sufficient to operate signaling apparatus tuned to this frequency. The telephone and telegraph signals are kept separated by the two filters. The inductance of the retardation coil in series with the telegraph branch (fig. 68), together with the capacitors connected in parallel to ground, prevents sudden changes in the telegraph current values, which would tend to be audible as *clicks* in the telephone circuit. The inductance opposes the sudden building up of the current at the moment of circuit closure, and retards the rate of decay when the circuit is opened. The capacitors assist this action by storing up a small quantity of electricity when the circuit is closed, and by discharging it through the inductance when the circuit is opened. The result is that the current reaching the line changes in value less abruptly than at the telegraph key or teletypewriter sending contacts. The purpose of the bridge across the telephone circuit on the drop side of the series capacitors is to prevent *crossfire,* a condition in which telegraph signals sent on one wire of a telephone circuit induce voltages sufficient to interfere with telegraph signals on the other wire or to operate the signaling relays of the telephone circuit. The bridge arrangement tends to stabilize the potential of the two line wires by providing a path for unbalance currents to *leak* to ground.

45. Noise and Crossfire

a. General. The voltage used in d-c telegraph or teletypewriter transmission is normally 120 to 130 volts. In the polar system, positive and negative voltages are applied alternately to the line by the sending relay contacts. In the neutral system, voltage of only one polarity is applied to the line for the marking condition, and the line is opened for the spacing condition. Because of the effect of inductance and capacity in

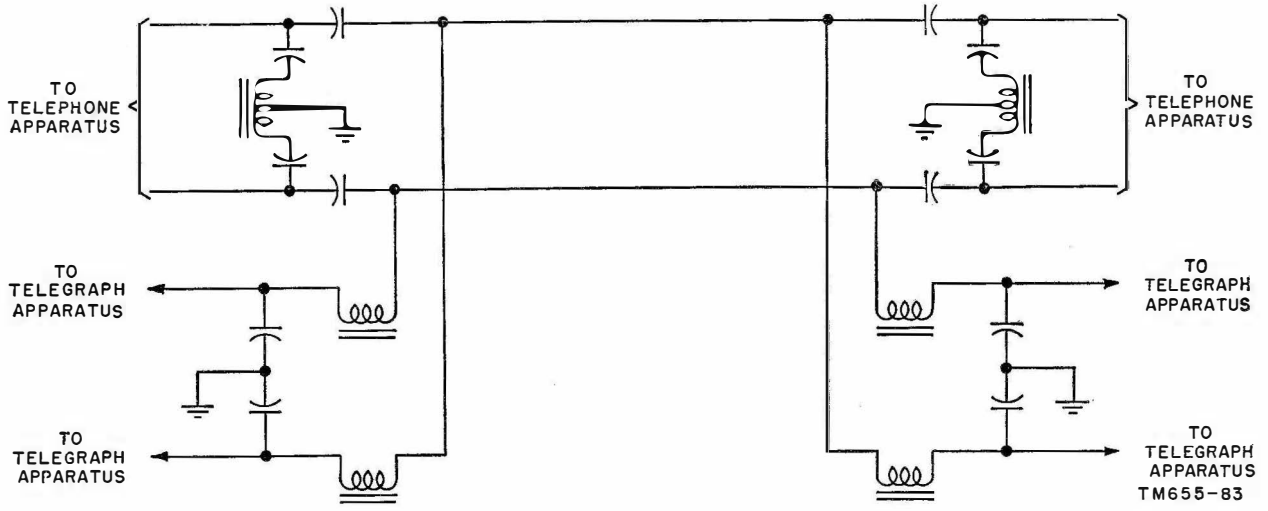


Figure 68. Telegraph circuit on composited telephone circuit.

the line circuit and associated simplex and composite sets, transitions from the marking to the spacing condition cause surges in the line circuit. To prevent noise (thump) from this source in the telephone circuit on simplexed or composited circuits, a noise suppression filter (fig. 69), commonly called a noise killer, is provided between the source of voltage and the line circuit. This filter usually is satisfactory if the line current does not exceed 75 ma. When applying grounded telegraph systems to open-wire and cable circuits, a number of possible causes of interference, besides noise, in telephone circuits must be considered to make sure the system will operate satisfactorily. One of the more important possible causes of trouble is crossfire between telegraph circuits operating over the same four-wire group.

b. Crossfire. Crossfire is a condition in which telegraph signals transmitted on one telegraph circuit induce voltages sufficient to interfere with signals transmitted on another telegraph circuit, or sufficient voltage to operate the signaling relays in the telephone circuit upon which the telegraph circuit is superposed. Crossfire is caused by leakage and by the mutual inductance and capacitance between telegraph circuits. Most of the effect is due to the physical proximity of the wires themselves on the poles or in the cable; a considerable part is also due to the coupling in the equipment common to more than one wire (such as composite sets, line filters, and loading coils). Crossfire due to the capacitance between wires is illustrated in figure 70. The line current in circuit No. 1 is indicated by solid arrows, and the crossfire currents induced in circuit No. 2 by the opening and closing of circuit No. 1 are indicated by broken arrows. The diagram shows that, because of capacity coupling, signals transmitted from the sending end of circuit No. 1 cause crossfire in the receiving relay at the sending end of circuit No. 2, as well as at the distant end of circuit No. 2. Two methods of neutralizing crossfire are used; one neutralizes the receiving-end crossfire, and the other neutralizes the sending-end crossfire. By use of the sending-end method alone, or, in severe cases, by use of both methods, it is usually possible to reduce the total crossfire effect to less than 25 percent of its original value.

(1) *Neutralizing sending-end crossfire.* To neutralize the sending-end crossfire, a capacitor is connected between the artificial lines of the two telegraph repeaters as shown in figure 71. This sends current through the sending polar relay in the opposite direction to the crossfire current, as indicated by the dotted arrows. By properly adjusting the capacity, this current can be made to balance out the effect of the crossfire current. Stated simply, the mutual capacity of the line circuits is balanced out by the mutual capacity introduced between the artificial lines. Figure 71 shows only the principle involved for neutralizing crossfire between wires of a pair; when serious crossfire exists among all four wires of a phantom group, it is necessary to use a network of six capacitors instead of a single capacitor shown in figure 71.

(2) *Neutralizing receiving-end crossfire.* The crossfire current in the receiving relay at the receiving end is neutral-

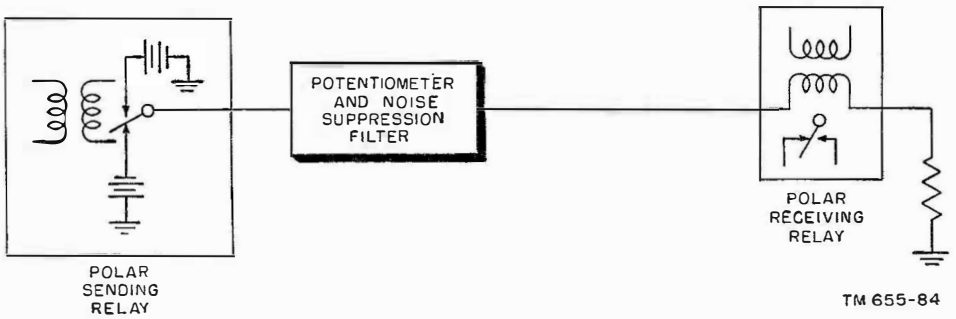


Figure 69. Elementary principle of one-way polar telegraph system.

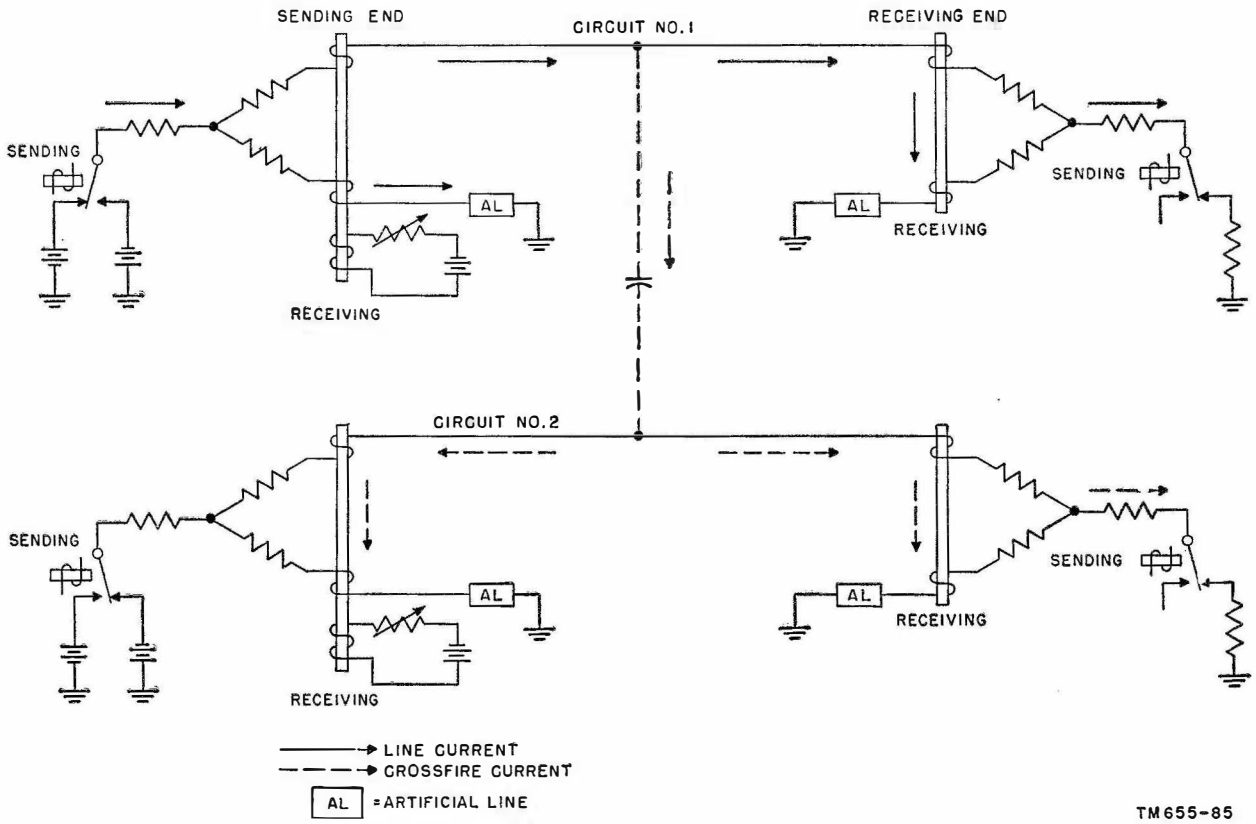


Figure 70. Crossfire currents in a telegraph circuit due to signals on another wire.

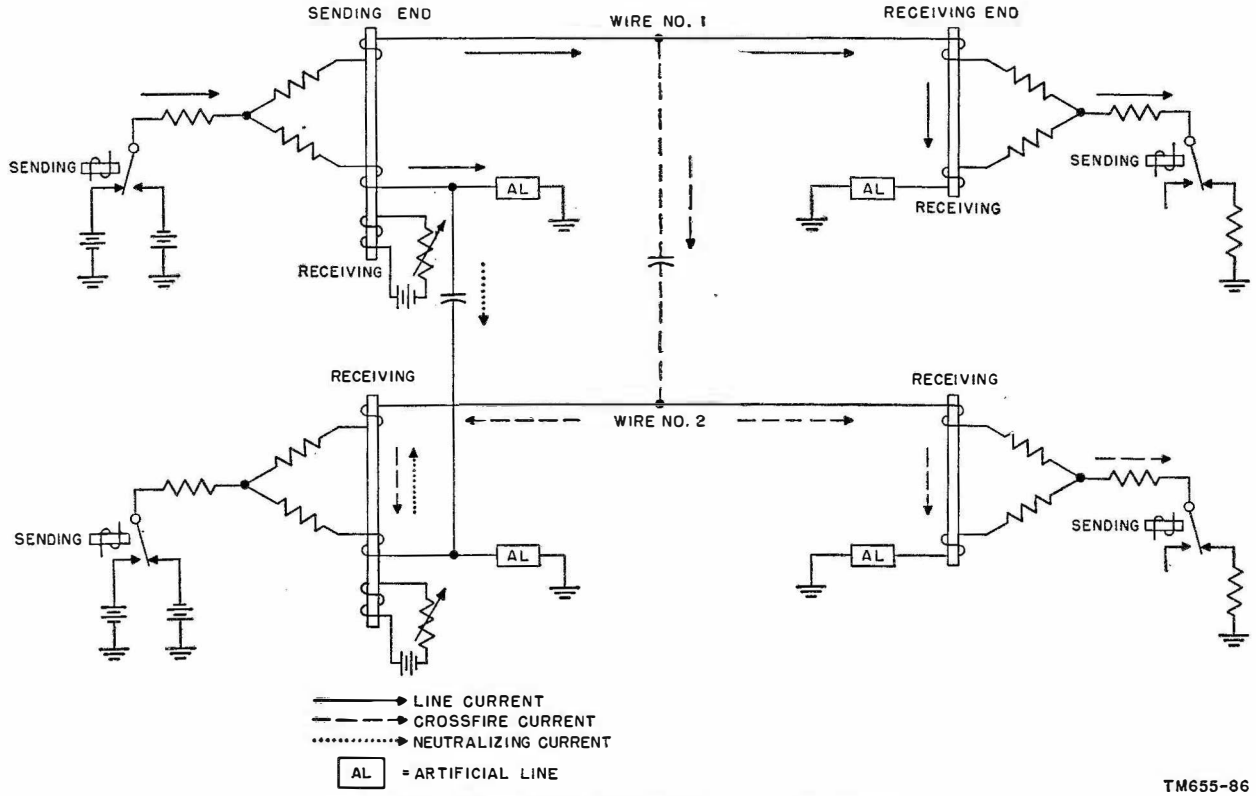


Figure 71. Principle of reducing crossfire at sending end.

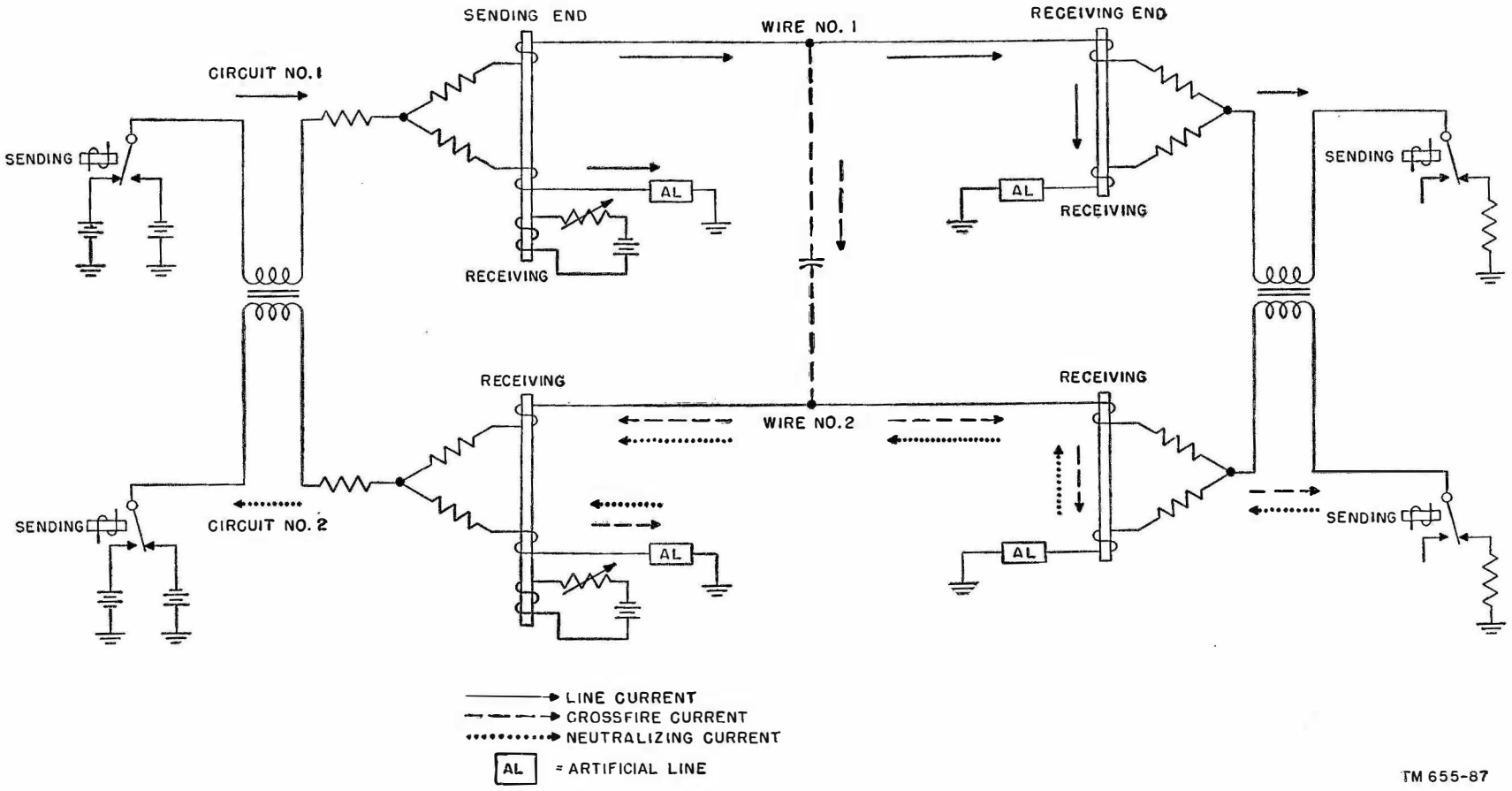


Figure 72. Principle of neutralizing crossfire at receiving end.

ized by coupling the apex points of the repeaters at the sending end by means of a transformer (fig. 72), which establishes current in circuit No. 2 in addition to the crossfire current. If properly poled, this additional current will oppose and neutralize the receiving-end crossfire current. The insertion of the transformer will have no effect at the sending end because the polar relay is in a balanced circuit. Therefore, the sending-end and the receiving-end crossfire effects are compensated for independently. Figure 72 shows a second neutralizing transformer at the receiving end that takes care of crossfire when sending in the other direction.

Section III. TELEGRAPH TRANSMISSION SYSTEMS

46. General

Telegraph transmission systems fall into two general classifications: those using alternating (carrier) current to pass the intelligence over the line, and those using direct current. At present the Armed Forces use two types of carrier telegraph systems and three types of d-c systems. All systems used may be classified further as two current systems, since two current conditions are used in each of them as explained in paragraphs 48 and 49.

47. A-C (Carrier) Telegraph Transmission Systems

In both types of carrier systems, alternating current, supplied by an oscillator, is connected to the line through band-pass filters. The frequencies used are from approximately 300 to 3,100 cycles. The principal difference between the two systems is the method of modulating the assigned carrier frequency. In one system, the sending relay in the carrier equipment, when operated by d-c signals received from the sending loop, short-circuits the source of ac for intervals of time corresponding to spacing signals, and permits the current to go on the line for intervals of time corresponding to marking signals. In the other a-c system, the carrier frequency is increased (shifted) approximately 42.5 cycles above the assigned channel frequency for intervals of time corresponding to marking signals, and decreased to about 42.5 cycles below the assigned channel frequency for intervals corresponding to spacing signals. At the receiving end of the carrier circuits, both systems use equipment to demodulate the carrier and convert the received signals to d-c signals to operate the teletypewriters. Since carrier telegraph transmission is already covered in detail in other technical manuals, it requires no further discussion here.

48. D-C Telegraph Systems

a. General. The principal d-c telegraph systems used by the Armed Forces are the neutral, the polar, and the polarential types. D-c telegraph systems, both grounded and metallic, are used extensively; the distance over which they will operate satisfactorily depends on the facilities used or on the facilities on which the circuits are superposed, and the signaling speed required.

b. Neutral System. In the neutral telegraph system, transmission is accomplished by sending current over the line for intervals of time corresponding to marking signals, and stopping it for intervals corresponding to spacing signals. The neutral system has the advantage of simplicity; it requires little terminal equipment; it is easy to operate; and, in general, it requires very little attention. The chief disadvantage of the neutral system is from the transmission standpoint. Since the terminal impedance is different for the *open* and *closed* condition, the transmitted wave is not symmetrical as regards marks and spaces. This usually results in considerable distortion, and thereby restricts the use of this method. Although this disadvantage does not render the plan of operation unsatisfactory, the neutral system will generally be the best system to use for the shorter haul services. As shown in figure 2, in its simplest form the neutral telegraph system consists of a circuit containing a battery, a variable resistance, a telegraph key, and a sounder in series with the line circuit, along with a series

circuit at the other end containing a telegrapn key and a sounder connected to ground. When required, a battery may be connected in the circuit at both ends of the line (series aiding), and the return circuit for the currents in the system may be through an additional line conductor instead of to ground. The neutral telegraph system may be adapted for use with teletypewriters by substituting the teletypewriter sending contacts for the telegraph key, and the receiving relay or magnet for the sounder (figs. 38 and 39). The neutral telegraph system permits transmission of characters in either direction, but not in both directions simultaneously. It is also possible for an operator at either end of the circuit to *break* or interrupt the other operator if the latter is sending. These two factors make the neutral system satisfactory for single operation only. If duplicate operation is required, it is possible to use two neutral systems. In applying the neutral system to a wire plant, particularly in the case of simplexed or composited circuits, certain important precautions are necessary to insure satisfactory transmission over the telegraph circuit, and, at the same time, keep interference into the telephone on the composited or simplexed circuits below the allowable limit. The line current is usually between 60 and 65 ma and, when the neutral telegraph system is superposed on a telephone circuit, the current should not in any case exceed 75 ma. This current may be obtained from sources of equal voltages but opposite polarities connected at the two ends of the circuits. In the shorter, well-insulated circuits, voltage may be applied at one end of the circuit only. The value of the voltage applied at either end of the circuit may be as much as 130 volts. In certain cases, from a transmission standpoint, it is desirable to use 90 volts or less. The value of the applied voltage is important because the freedom from distortion with a neutral circuit is, to a great extent, governed by this factor.

(1) *Neutral operation over noncomposited circuits.* In neutral operation over short, well-insulated circuits not used simultaneously for telephone or signaling there is very little capacity to ground, and, because of one or more sounders or relays in series, induction in the circuit is often predominant. In such cases, when the circuit is closed at either end, the current does not build up quickly in going from the spacing to the marking condition. Consequently, the sounders or relays do not operate at once, but remain unoperated until the current builds up to a value sufficient to operate them. When going from the marking to the spacing condition, the current decreases to zero almost instantaneously and the sounders or relays deenergize almost instantaneously. The delay in going from the spacing condition to the marking condition, without the corresponding delay in going from the marking condition to the spacing condition, causes the received signals to be spacing more than they should be, and are said to have spacing *bias.* This effect may be reduced by adding series resistance to the circuit and by increasing the voltage to maintain the marking current at 60 ma. If the applied voltage and series resistance are made high enough, the effect described could be almost eliminated. However, too high a value of voltage would cause interference in the telephone circuits and would be dangerous. The use of grounded sources of d-c voltage (not exceeding 130 v.) of opposite polarity at the two ends of the circuit is satisfactory from this standpoint, and permits the addition of enough resistance to reduce sufficiently the above-mentioned effect to prevent impairment of service.

(2) *Neutral operation over composited circuits.* When a neutral system is operated over a composited circuit, the network has considerable capacity. When the telegraph circuit is closed at either end, the current builds up rapidly in going from the spacing to the marking condition; and the sounders or relays operate without delay. In going from the marking condition to the spacing condition, the current continues to flow through the wind-

ings of the sounders or relays at the receiving end for an appreciable time after the circuit has been opened at the sending end. This is because the capacitors in the composite set must discharge, preventing the receiving sounder or relay from deenergizing immediately. Consequently, the received signal is marking longer than it should be, and is said to contain marking *bias*. This effect may be lessened by reducing the applied voltage and series resistance. When operating the neutral telegraph system over composited circuits, the voltage applied is generally 90 volts or less. Since 90-volt batteries or 90-volt taps on 130-volt telegraph batteries are not normally provided, the reduced voltage, when required, usually is obtained by the potentiometer method (fig. 73). This method may be applied with any source of dc, and has the additional advantage of making possible a reduction in the overall resistance of the telegraph circuit, which tends to minimize the effect of leakage. Rectifiers used as a source of line (marking) current for telegraph circuits usually have taps in their a-c circuit for varying the output voltage as required. A resistance or potentiometer is usually connected across the output of the rectifier as a stabilizing load to reduce the variations in voltage between the marking and spacing conditions of the circuit. When a neutral telegraph circuit is operated over composited lines, a filter consisting of inductance in series with the telegraph branch and capacity bridged to ground (fig. 68) is provided to reduce interference with the telephone circuit. Simplexed lines require only one-half the inductance required on composited lines to keep the interference from exceeding the limit for satisfactory operation of the telephone circuit.

(3) *Single-line repeater.* When circuits have too much capacity or leakage to be sufficiently improved by the reduced voltage method, or in cases where there is too much inductance to permit satisfactory operation using the standard voltages, it is possible to obtain improvement in transmission by connecting a single-line telegraph repeater at one or both ends of the system. To a certain extent, this repeater compensates for the bias introduced by the neutral circuit, and, in addition, it provides a means of connecting one neutral system with another neutral or another type of telegraph system, or for connecting several circuits together. The single-line repeater consists of two repeating elements, one for repeating signals in each direction of transmission. The elementary circuit is shown in figure 74, and the directions of transmission have been designated WEST and EAST. The repeater operates on the principle that the making and breaking of current in the west line operates a relay that opens and closes the east line, and vice versa. Consideration of the elementary circuit shows that an auxiliary arrangement is required to prevent the east relay from releasing when the current through its winding is opened by the contacts of the west relay. Such an arrangement is provided in the actual repeater.

c. One-Way Polar System.

(1) The one-way polar system of telegraph transmission, like the neutral system, is simple and requires little central office equipment and central office supervision. It is the most stable of the grounded telegraph systems, and it is especially valuable for teletypewriter operation because no readjustments are required at the receiving station to compensate for circuit changes. The chief disadvantage is that it permits one-way transmission of messages only, whereas all other d-c telegraph transmission systems provide two-way single service. In commercial use, all systems except the neutral system may be arranged to

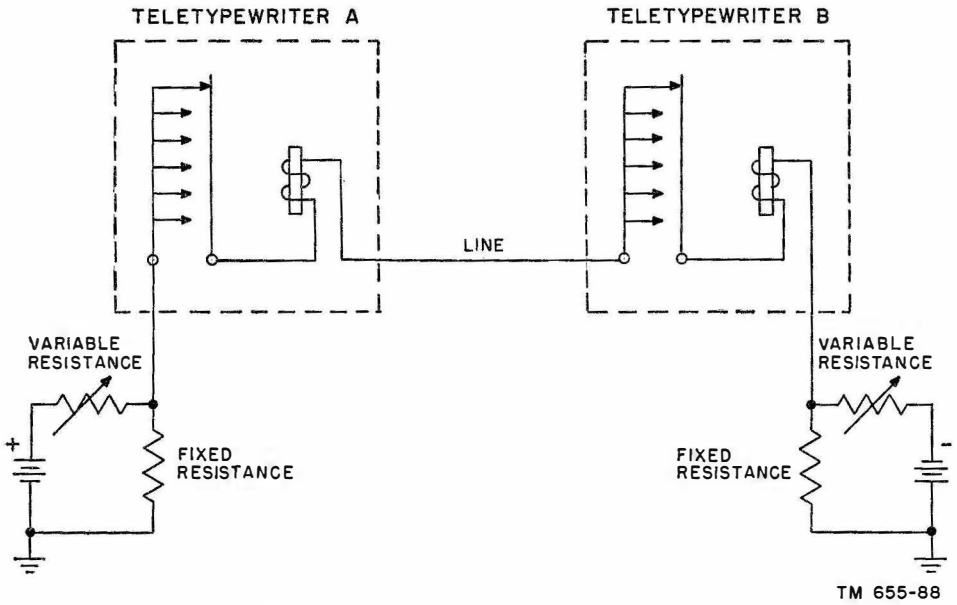


Figure 73. Neutral system with potentiometers to reduce voltage.

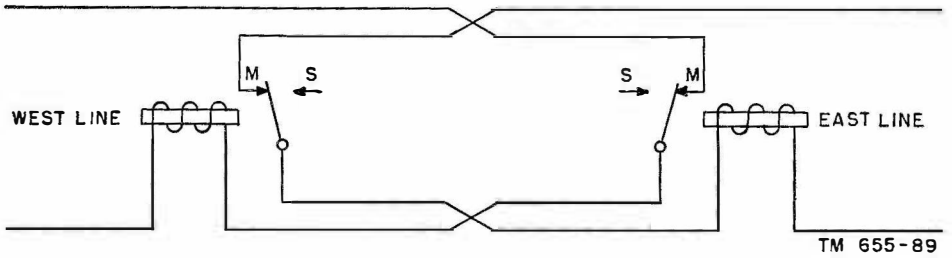


Figure 74. Elementary principle of single-line repeater.

provide two-way simultaneous (full-duplex) service. Notwithstanding the disadvantage of being able to transmit messages in one direction only, the one-way polar system is used extensively, particulary for teletypewriter service to outlying points. It is used commercially in single-section service in open wire over distances of about 200 to 300 miles and in cable up to about 100 miles to connect one or more outlying stations to a telegraph system. It may be used in a similar manner for one-way manual service, using a polar relay to repeat the local station. When full-duplex service is required, two one-way polar systems may be used.

(2) Figure 69 shows schematically the elementary principles of operation of the one-way polar system, and figure 75 shows the way in which the terminal networks comprising the system are applied to the line circuit and to the loop circuit or other system with which it is interconnected. Both figures show that at the sending end of the line two batteries (or other sources of d-c) are used, one of each polarity; at the receiving end of the line there is no battery. This is unlike the neutral system in that both batteries are at one end of the line, and for the spacing condition the line is not connected to a high impedance at the sending end. When signals are being transmitted for the marking condition, one polarity of battery is connected to the line, and for the spacing condition the other polarity of battery of the same magnitude is connected to the line. Instead of the current being re-

duced to zero for the spacing condition as is the case in the neutral system, it is reversed, resulting in a symmetrical wave with respect to marking and spacing signals. At the receiving end of the line, a polar relay without an external bias is used, and the operation of this relay is governed by the polarity of the current transmitted from the sending station.

(3) The polar principle of operation has the advantage over the open-and-close principle used in the neutral system in that it is almost unaffected by the normal variations in the d-c voltage or variations in the characteristics of the line circuit, whether the variations are caused by capacity, inductance, or leakage. This is the principle that makes the one-way polar system so desirable for open-wire operation where one-way service only is required. When the one-way polar system is applied to wire plant, any suitable source of double polarity dc up to approximately 130 volts may be used if proper arrangements are provided to prevent interference into other telephone, telegraph, and signaling circuits operating over the same or adjacent wires. A noise suppressor consisting of series inductance and parallel capacity, and also a potentiometer shown as a resistor to ground in figure 75, are usually provided for this purpose. The combination of the potentiometer and noise suppressor makes it possible to operate one-way polar systems on both simplexed and composited circuits without causing undesirable interference. The spark suppression filters around the contacts of the sending relay (fig. 75) also help to lessen the noise in the telephone and signaling circuits. When the line insulation is good the line current should be approximately 35 ma; it is seldom necessary to compensate for leaky condition of the line once the circuit is adjusted for satisfactory operation, even though the line conditions may change.

(4) The transmission possibilities of the one-way polar system, like the neutral system, depend on the facilities used or the facilities on which the telegraph circuit is superposed. In commercial operation it is possible to obtain satisfactory transmission at 60 speed (60 wpm) over single sections of average-grade, .104-inch open-wire circuits up to about 300 miles. If intermediate composite sets are in the circuit, or if finer gage wire is used, this distance will be less. In cable circuits, where noise considerations (thump and crossfire) permit, the polar system should, in general, provide satisfactory 60-speed transmission over composited 13- or 16-gage circuits or simplexed 19-gage circuits up to about 100 miles. Like all other grounded telegraph systems, transmission will be affected by earth potentials, crossfire, and power induction. At the receiving stations, the system equipment consists only of a polar relay, and when interference is severe enough to require it, a 500-ohm resistor. In cases where additional stations are required in a one-way polar system, whether they be in the same locality at the end of the system or in various localities along the route, it is possible to add each of these stations by connecting the windings of a polar relay in series with the line, and arranging its contacts and armature to repeat the line signals to the added station.

d. Two-Path Polar System. The two-path polar system is essentially two one-way polar circuits; the description of the one-way polar system applies to the two-path system. Repeaters for this system are available in forms suitable for use in central offices or at stations in outlying points. The two-path polar system is shown schematically in figure 76. This system has all the advantages of the one-way polar system for two-way service, but requires two

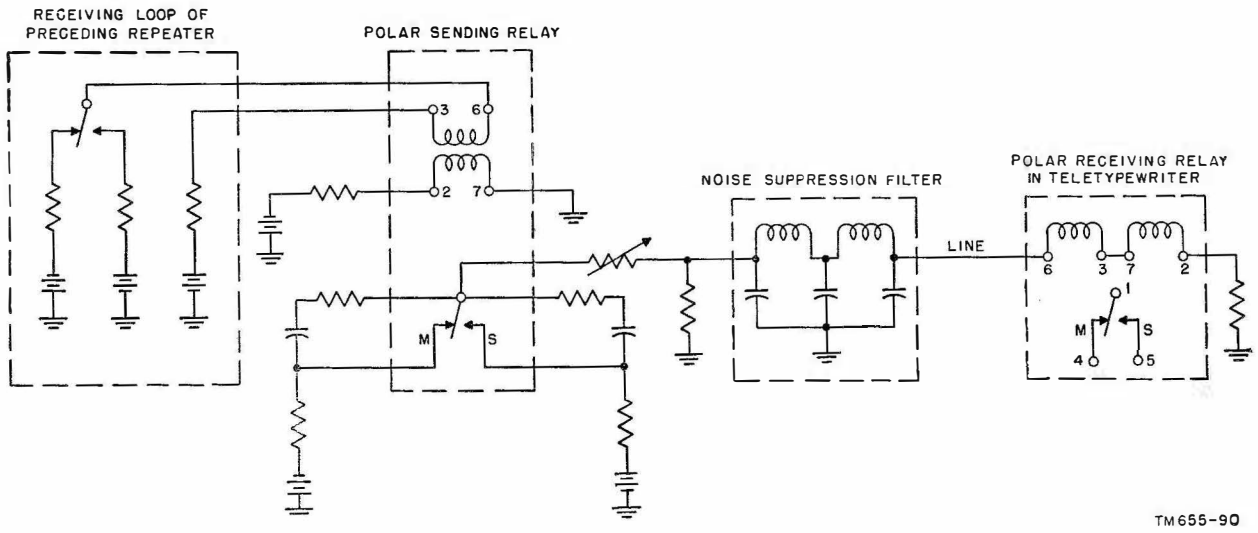


Figure 75. One-way polar system with terminal networks.

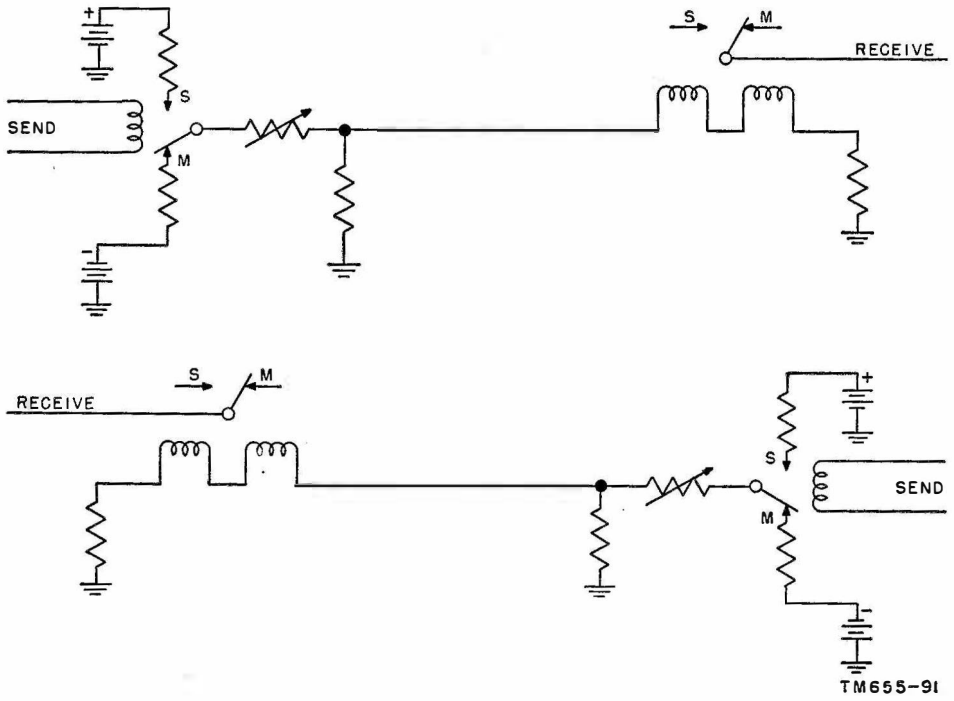


Figure 76. Two-path polar telegraph system.

transmission paths. It also is subject to earth potentials, crossfire, and power induction.

e. Polarential Systems. In polarential systems, transmission is polar in one direction and differential in the other direction. These two terms have been combined to form the word *polarential.* At the polar-sending end of the system, equal and opposite voltages are used for marking and spacing signals, and, as in other polar transmission systems, the receiving relay at the distant end of the system operates on *reversals* and requires no local bias circuit. At the differential-sending end of the system, ground is applied to the line for the marking condition and a voltage is applied for the spacing condition. When the spacing voltage applied at the differential-sending end of the system is the same polarity as the marking voltage at the

polar-sending end, the system is known as *type A polarential;* when the spacing voltage applied at the differential-sending end of the system is the opposite polarity to the marking voltage at the polar-sending end, the system is known as *type B polarential.* In either case, a local bias circuit is required for the receiving relay at the polar-sending end of the system. Both systems may be used for transmission between two central offices or between a central office and a teletypewriter station, and each system has advantages over the other under certain circumstances. Therefore, the type of transmission to be used is governed by the requirements to be met as explained in (1) and (2) below.

(1) *Type A polarential.* The type A polarential system of operation is relatively insensitive to variations in the series resistance of the line, and is preferable to type B operation ((2) below) for cable circuits when line resistance variations are the controlling factor. The type A polarential system is less immune from bias resulting from the effects of line leakage than the type B system, and accordingly is less satisfactory for open-wire operation than the type B system. When the type A polarential system is used between two central offices, a repeater is required at each end of the circuit. The repeaters may both be the same type, such as Telegraph Repeater OA–6/FC, described in TM 11–2034, but they will be arranged differently. Figure 77 shows in simplified form the arrangement of the repeaters; for convenience in explaining their operation the polar-sending repeater is designated west, and the differential-sending repeater is designated east. Transmission from west to east is polar; from east to west it is differential. The type A polarential system is used between a central office and a teletypewriter station when resistance or other factors make it impractical to operate the station on a loop basis, and when the available facilities are relatively free from leakage. In such cases, a station set having transmission circuits similar to those of the east repeater in figure 77 is usually installed at the teletypewriter. The operating principles involved between a central office and a station are the same as those between two central offices ((*a*) through (*c*) below).

(*a*) *Transmission west to east.* As shown in figure 77, transmission from west to east takes place as follows: Operation of the sending relay in the west repeater applies negative and positive voltages to the line for the marking and spacing conditions, respectively. Current passes over the line and through the windings of the receiving relay in the east repeater to ground. The receiving relay in the east repeater operates, therefore, on a polar basis. When changes in line leakage or line resistance occur, the amount of current received in the east repeater changes equally for both marking and spacing conditions, and no bias is introduced from this source. However, if the leakage or increase in resistance is large enough, the east receiving relay will fail to operate properly because of insufficient current.

(*b*) *Transmission east to west.* When the line is in the marking condition (fig. 77), the currents in the line and in the artificial line windings of the receiving relay in the west repeater will be equal. Since the line windings are poled marking, and the artificial line windings are poled spacing, these currents produce no net magnetic field in the relay and have no effect on its armature. The relay is held to marking by the current in the windings designated *bias.* When the sending relay in the east repeater is operated to spacing, the line current reverses. The line current in the line windings of the west receiving relay will then be in a spacing direction. The current in the artificial line windings

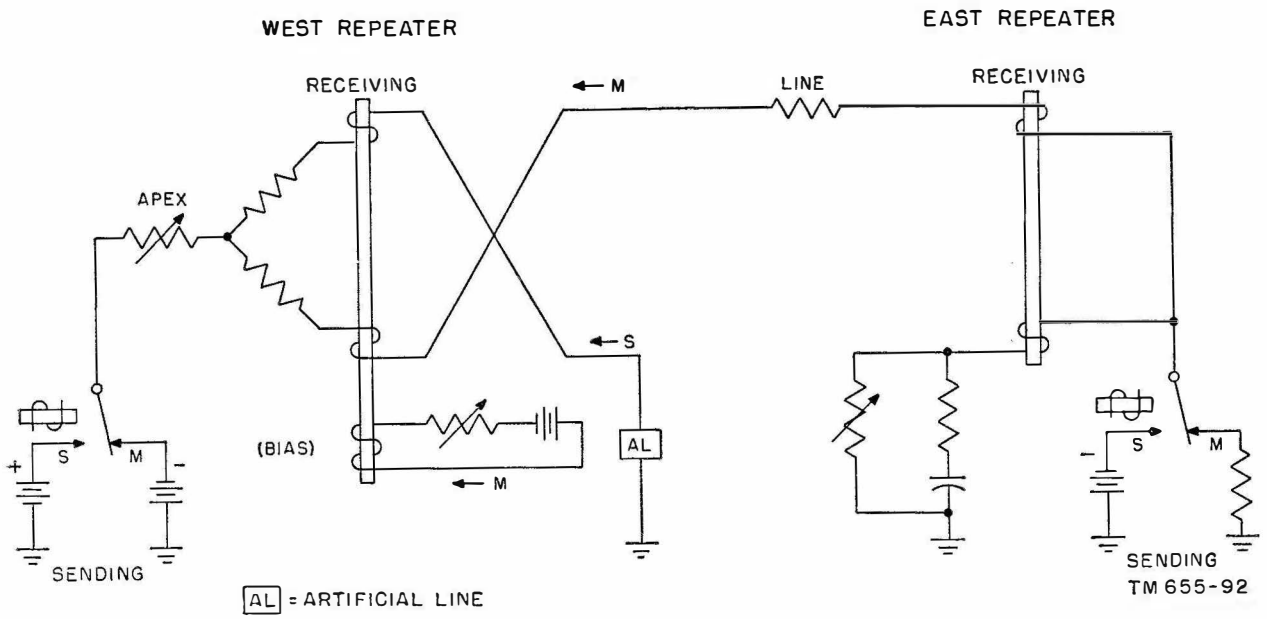


Figure 77. Type A polarential system.

will be increased (because of the presence of the apex resistance), but will continue to be in a spacing direction. The net effect on the relay due to the line and artificial line currents will be their sum, and will be in a spacing direction. Marking and spacing signals received from the east repeater will produce equal and opposite effects at the west repeater receiving relay if the west repeater is properly balanced and the bias current in the receiving relay is adjusted to a value equal to one-half the sum of the currents in the line and artificial line windings when a spacing signal is received from the east repeater. This is similar to polar operation.

(*c*) *Effect of changes in line resistance.* In the type A polarential system (fig. 77), transmission from west to east is polar, and, as stated previously, changes in line resistance do not cause bias in a polar transmission system. Transmission from east to west is not polar, and changes in line resistance will cause bias unless the west repeater is lined up in a particular manner. When the values of the resistances of the artificial line and apex branches of the west repeater are adjusted so that the line currents are equal and opposite for marking and spacing, the marking and spacing effects on the west receiving relay will be reduced equally when the series line resistance is increased, and will be increased equally when the series line resistance is reduced. Therefore, transmission from east to west will also be free from bias resulting from line resistance variations. The relations of the various currents used in the type A polarential system, and the effect of series line resistance variations are shown in figure 78. The current values on the left side of the figure are based on the assumption that the west repeater apex resistance, the artificial line resistance, and the line resistance are all equal to 1,000 ohms. In actual practice, the resistance of the apex is usually considerably less than the values of the other branches. On long lines having relatively high resistances, the resist-

ance of the apex is reduced to provide more line current, and in other cases it is reduced to minimize characteristic distortion when transmitting from the west to the east repeater. It is also assumed that all three windings of the west repeater receiving relay have equal turns. Actually, the bias winding has a different number of turns and this is taken into account in the current values used. The conditions assumed were selected to simplify the current relations, and because they show the type A polarential operation to the best advantage in minimizing the effects of variations in line resistance. As shown on the left side of figure 78, the normal line current values for the marking condition are: line current, .040 ampere marking; artificial line current, .040 ampere spacing; and bias current, .060 ampere marking. This gives a net of .060 ampere marking. When a spacing signal is received from the differential-sending repeater, these values change to: line current, .040 ampere spacing; and artificial line current, .080 ampere spacing. The bias current remains as before at .060 ampere marking. This results in a net of .060 ampere spacing. Assume now that the line resistance is increased by 500 ohms without altering the circuit in any other way. The current relations as shown in the right side of the figure become for the marking condition: line current, .030 ampere marking; artificial line current, .045 ampere spacing; and bias current, .060 ampere marking. This results in a net marking current of .045 ampere. When a spacing signal is received, the current values change to: line current, .030 ampere spacing; artificial line current, .075 ampere spacing; and bias current, .060 ampere marking. This gives a net spacing signal of .045 ampere. From

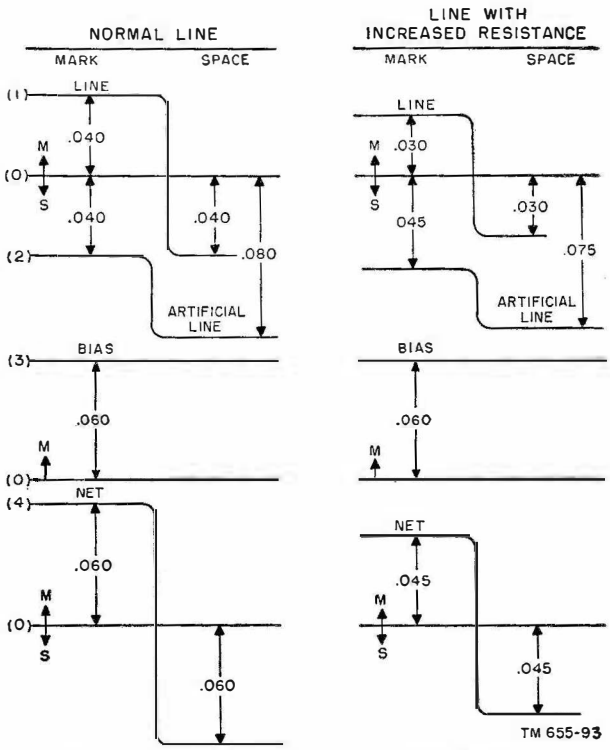


Figure 78. Illustrative line currents in type A polarential operation.

this it can be seen that changes in line resistance affect marking and spacing signals equally, and no bias results from this source.

(2) *Type B polarential.* The chief advantage of the type B polarential method of operation is that very little bias is introduced by line leakage. Since it is likely to be less satisfactory than other systems when operated over cable circuits where line resistance variations are a factor, the type B system is recommended only for use over open-wire circuits. Like the type A system, the type B system may be used between two central offices, or between a central office and an outlying teletypewriter station; transmission is polar in one direction and differential in the other. When used between two central offices, a repeater is required at each end of the system. The repeaters may be the same type, but are arranged is used between a central office and a differently. When the type B system teletypewriter station, a station set having transmission circuits similar

to those of the differential-sending repeater is required at the teletypewriter. Since operation between a central office and a station is the same as that between two central offices, the following explanation of the operating principles is based on figure 79, which shows two repeaters arranged for type B operation and connected over a line circuit. The polar-sending repeater is designated west, and the differential-sending repeater is designated east.

(*a*) *Transmission west to east.* Transmission from west to east (fig. 79) is similar to that for type A polarential ((1) (*a*) above). Operation of the west sending relay applies equal and opposite voltages to the line for the marking and spacing conditions. Current is transmitted over the line and through the windings of the east receiving relay to ground at the contacts of the east sending relay. The east receiving relay is operated on a polar basis, and, when leakage is added to the line, the current received in its windings will be reduced equally for both marking and spacing conditions and no bias will be introduced. If the leakage is large enough, however, the relay will fail to operate because of insufficient current. The west receiving relay has three windings. The outgoing signal currents divide equally; half is transmitted to the line and the other half is transmitted through the artificial line to ground. Since the line and artificial line windings are oppositely poled, the currents in them will have no net operating effect on the armature, which is held to marking by the current in the third, or bias, winding.

(*b*) *Transmission east to west.* Transmission from east to west is accomplished as follows: When the sending relay of the east repeater is operated by telegraph or teletypewriter signals, it connects ground to the line for marking, and applies positive battery for spacing (fig. 79). The current through the east receiving relay for marking is in the direction shown by the arrow. When the sending relay operates to spacing, the line current is increased to a value almost three times the marking current, and is in

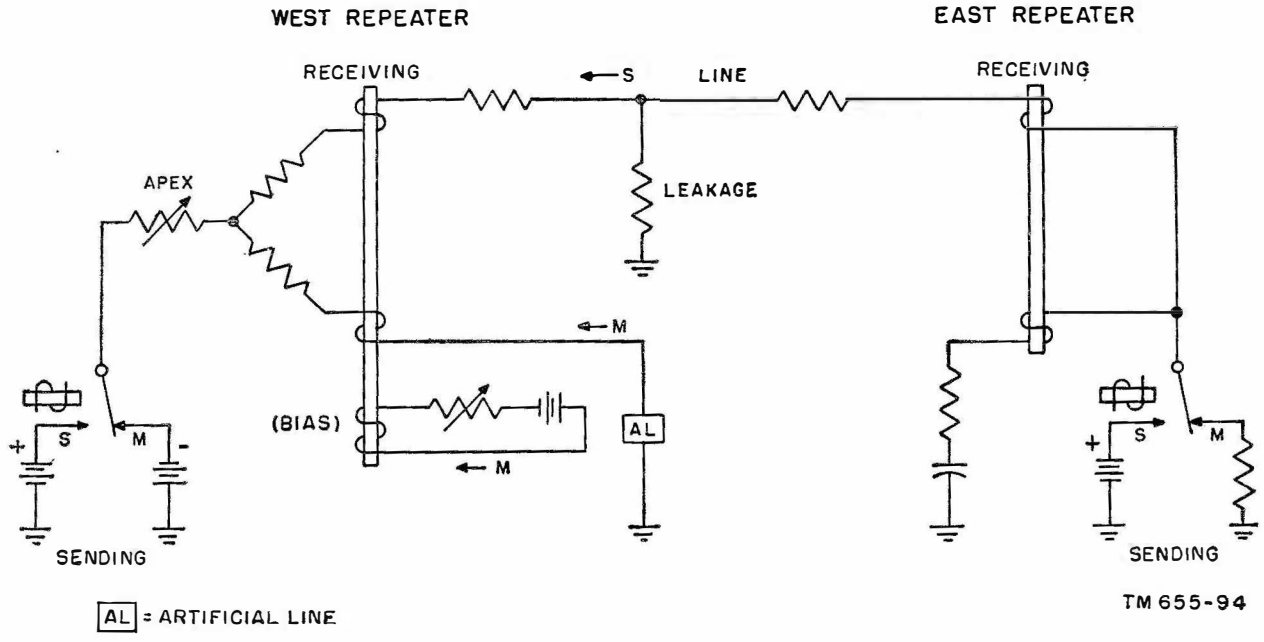


Figure 79. Type B polarential system.

the same direction as the marking current. This increased line current produces a spacing effect on the west receiving relay, and holds the east receiving relay on marking. The artificial line current in the west repeater is reduced because of the presence of the common apex resistance, but continues in the marking direction. Since the spacing effect of the line current in the west receiving relay is about twice the marking effect of the bias and artificial line currents combined, the relay is operated to spacing.

(c) *Effect of line leakage.* In the type B method of operation, transmission from west to east is polar, and line leakage does not introduce bias in polar transmission systems. Transmission from east to west is on a differential basis. Line leakage will cause bias unless the values of the resistances of the artificial line and apex branches of the west repeater are adjusted so that in the marking condition the line and artificial line currents are equal, and in the spacing condition the spacing effect of the line current is equal to twice the marking effect of the bias and artificial line currents combined. Figure 80 shows typical currents in the polar-sending repeater of a type B polarential system. The left side of the figure shows dry-line current values in a 200-mile type B polarential system, and the right side of the figure shows the changed values when the circuit has an assumed leakage of one-quarter megohm per mile. As shown on the left side of the figure, the dry-line current values for the marking condition are: artificial line current, .033 ampere marking; line current, .033 ampere spacing; and bias current, .034 ampere marking. The net effect of these currents on the relay is their algebraic sum, which is .034 ampere marking. For the spacing condition the line current is increased to .085 ampere spacing, the artificial line current is reduced to .017 ampere marking, and the bias current remains .034 ampere marking. As before, the net effect of these currents on the relay is their algebraic sum, which is .034 ampere spacing, and which is equal and opposite in effect to the current value for the marking condition. Assuming the circuit has a leakage of one-quarter megohm per mile, but is unchanged otherwise, the current values are changed as shown on the right side of the figure, and for the marking condition they are: artificial line current, .029 ampere marking; line current, .041 ampere spacing; and bias current, .034 ampere marking. The net effect of these currents is .022 ampere marking. For the spacing condition the line current is increased to .074 ampere spacing; the artificial line current is reduced to .018 ampere marking; and the bias current remains unchanged at .034 ampere marking. The net effect of these

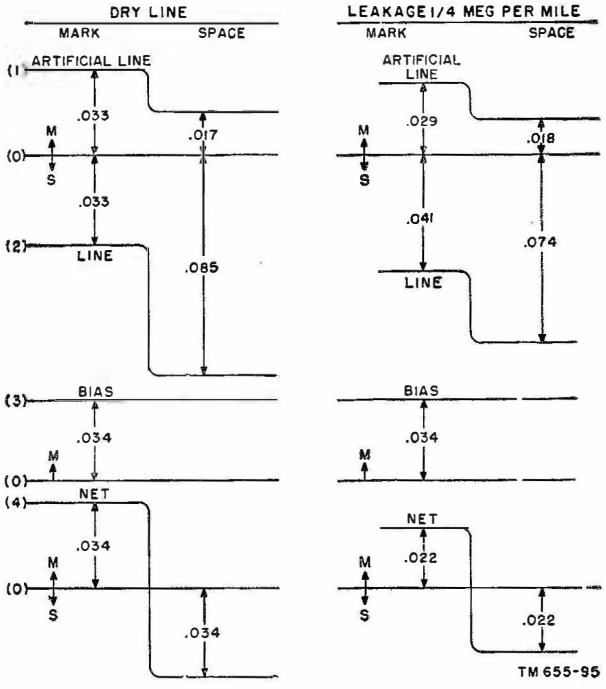


Figure 80. Illustrative line currents in type B polarential operation.

currents is .022 ampere spacing, which again is equal and opposite to the current value of the received marking signal. From these examples of the current values received for marking and spacing signals under dry and leaky line conditions, it can be seen that the signals received for marking and spacing from the differential-sending end of the system are equal in value and opposite in effect, which is equivalent to polar operation; also, line leakage affects marking and spacing signals equally. Therefore, no bias results from this source.

Section IV. TELEGRAPH DISTORTION

49. Definition of Distortion

Telegraph transmission involves impressing signals on the sending end of the circuit, and reproducing these signals at the receiving end of the circuit. The quality of the received signal is determined by the relative length and location of the signal elements measured after they are repeated through a receiving relay or after actuating the magnet of a receiving device, compared with the length and location of the signal elements impressed at the sending end. A measurement of received telegraph signal quality does not include a measurement of the amplitude or strength of the received signal, but only the time during which the signal is of sufficient strength to operate the receiving device. Theoretically, a perfect telegraph circuit would reproduce signals at the receiving end exactly as they are impressed at the sending end with regards to the lengths of the component marks and spaces. Any change in these lengths that occurs during transmission is a measure of the degraduation in transmission quality and is called distortion.

50. Components of Distortion

Telegraph distortion consists of several components which are due to different causes and which require different treatment for their proper control in both design and maintenance work. The relationship of the various components is shown in figure 81, and each is discussed separately below.

a. Total Distortion. Distortion is the displacement of a received transition (mark to space or space to mark) from its correct time of occurrence. If a substantially perfect telegraph character is sent from the transmitting end at regular intervals over a telegraph circuit, and if the distortion of each of the unit marks in a large number of successive repetitions is measured and tabulated at the receiving end, it will generally be found that the distortion differs not only from element to element in a given repetition of the signal, but that it also differs from signal to signal for a particular element. The average distortion of a particular element in a large number of successive repetitions is called *systematic* distortion. The individual departure from the average is called *fortuitous* distortion. Figure 82 illustrates the systematic and fortuitous components of distortion. Ten repetitions of a marking signal of unit duration are assumed to have been sent over the line, and the tabulations show the percentage of distortion in the resulting signals measured in the output of the receiving relay. The average duration of the received marking signal is shown to be 90 percent of that transmitted, which means that the average or systematic distortion is minus 10 percent. (The received marking signals are 10 percent shorter than the sent signals.) The departure of the distortion in each individual repetition from this average distortion is the fortuitous component (or fortuitous distortion). This value is noted on the figure for each repetition. The total distortion is the algebraic sum of the two components, and is equal to the amount by which the received signal differs in duration from the one sent. (In fig. 82, the ends of all the signal elements are lined up vertically. This is done for convenience only since it is only the duration of each repetition and not the actual time of occurrence with respect to the sent signal being considered.) As shown in figure 81, systematic distortion may be subdivided into bias and characteristic distortion. These

components together with fortuitous distortion are discussed in detail in *b* through *d* below.

b. Bias Distortion. The nature of bias distortion is such that interchanging the functions of the two current values used will change the sign of the systematic distortion but not its magnitude. For example, in a polar telegraph system, in which marks and spaces are sent by means of currents equal in magnitude but opposite in sign, systematic distortion may be caused by unequal voltages at the transmitting end. If the positive voltage is higher than the negative voltage, and the circuit is such that the marks are lengthened when positive current is used for transmitting marks, rearranging the system so that negative current is used for transmitting marks will cause the marks to be shortened by substantially the same amount. When systematic distortion is such that interchanging the functions of the two current values employed changes the sign of the systematic distortion but not its magnitude, the distortion is called *bias* because a lack of symmetry in the circuit is indicated. Some of the more common causes of bias are improperly adjusted relays, earth potential differences, leakage currents, unbalance of artificial line on repeaters, and unequal battery tap resistances or potentials. Bias will affect both the beginnings and the ends of received signal elements, but since the teletypewriter receiving mechanism starts on a mark-to-space transition affected by the same bias, succeeding mark-to-space transitions will not be displaced with respect to the start transition. However, the space-to-mark transitions will be displaced with respect to the start transitions by an amount corresponding to the total amount of bias. *Marking bias* will cause all space-to-mark transitions to be uniformly displaced *toward* the start pulse, and *spacing bias* will cause them to be uniformly displaced *away from* the start pulse.

c. Characteristic Distortion. The characteristic component of systematic distortion is unlike the bias component in that interchanging the functions of the two current values involved will not change either the sign or the magnitude of the distortion. In a system such as that used as an example in the description of bias distortion, but in which the voltages are equal, systematic distortion may be caused by the current at the receiving end being slow in building up. If the current does not have time to reach its final value on the short impulses, the first mark following a long space (successive space signals) will be shortened. In such a case it is obvious that interchanging the functions of the positive and negative currents will not alter the sign or the magnitude of the resulting distortion, since the first mark will be shortened whether it is formed by means of positive current or by means of negative current. This type of distortion is determined by the electrical, magnetic, and mechanical characteristics of the circuit, which are fixed, for the most part, by design. Characteristic distortion may displace both the received space-to-mark and mark-to-space transitions with respect to the start signal, depending on the signal combination, and always recurs for the same signal combination. Accordingly, it may affect both ends of the teletypewriter orientation range, and, when miscellaneous characters are being received, it is not practicable to distinguish between the characteristic and fortuitous components of distortion.

d. Fortuitous Distortion. The fortuitous component of distortion is the individual departure of any one distortion from the average (systematic) distortion of a particular element in a large number of successive repetitions of a signal. Figure 82 illustrates the fortuitous and systematic components of total distortion. The method of determining the relationship of each component to the total is explained in *a* above. Fortuitous distortion usually results from such factors as crossfire, power induction, earth potentials, momentary battery fluctuations, and improper adjustment of relays. It displaces miscellaneous received transitions by various amounts in an irregular fashion irrespective of the signal combination. At times it may be large enough to cause a complete failure of the circuit, or it may be that the addition of fortuitous distortion to the systematic distortion already in the circuit results in an error in the received character.

51. Measuring Systematic Distortion

In measuring systematic distortion, it is generally found that both bias and characteristic distortions are present in the circuit. When

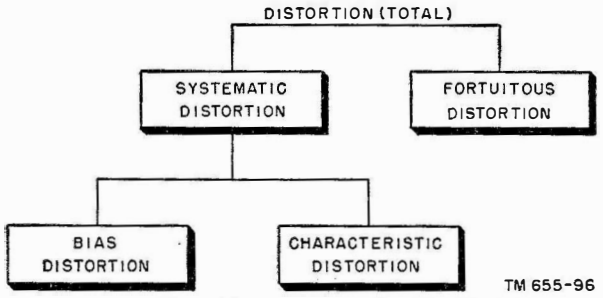


Figure 81. Relationship of the components of distortion.

the functions of the two currents are interchanged, it is nearly always found that the magnitude of the systematic distortion is changed, but that the sign of the distortion may or may not be changed. This is because the sign of the bias component is reversed by interchanging the current functions and the sign of the characteristic component is not changed.

When the circuit is normal, the systematic distortion is composed of the characteristic distortion plus the bias distortion. When the current conditions are reversed, the systematic distortion consists of characteristic distortion minus bias distortion. The two components may be separated by adding and subtracting these measured values of the systematic distortion, and dividing the result by two. To facilitate the explanation of the method of determining the percentages and the signs of the components of systematic distortion, it is convenient to designate the distortion measured with the circuit normal as S1 and that measured with the current conditions reversed as S2. Then the characteristic component is defined as $\frac{S1 + S2}{2}$ and the bias is defined as $\frac{S1 - S2}{2}$. Figure 83 illustrates this definition. Assume

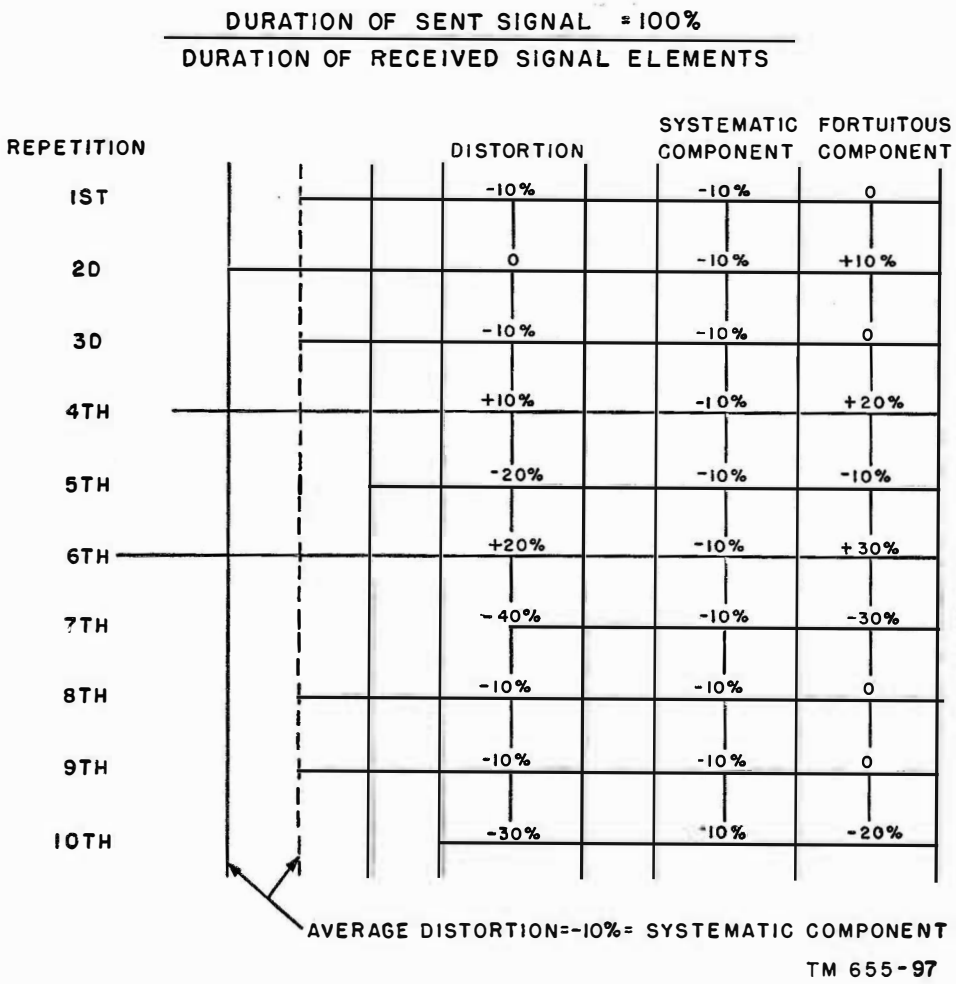
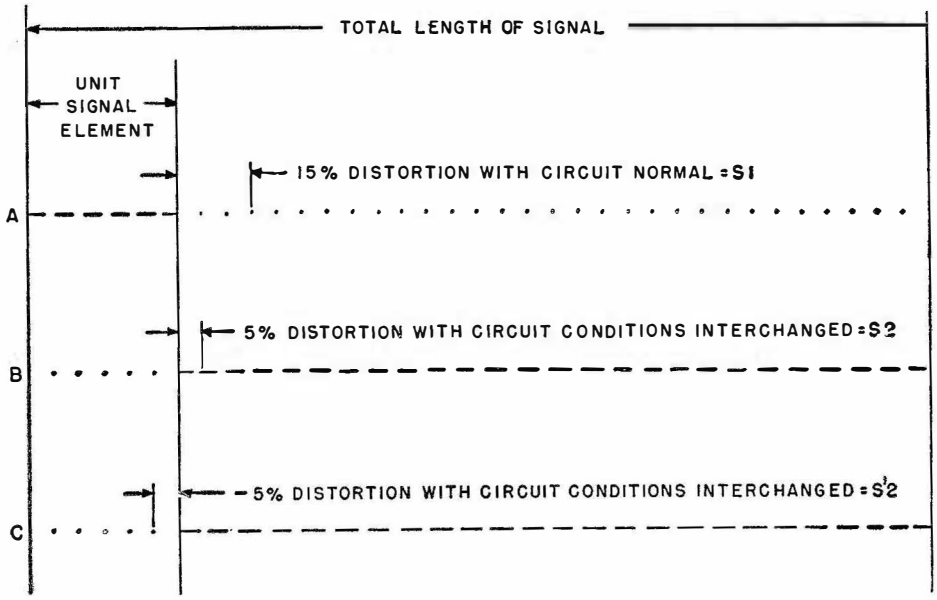


Figure 82. Systematic and fortuitous components of distortion.

that a repeated signal consisting of a marking element of unit length followed by a spacing element three units long is sent. If no distortion existed, this would be received identically in the output of the relay at the receiving end of the circuit. For the purpose of illustration, it is assumed that distortion does exist and when transmitted over the circuit in its normal condition, the receiving relay repeats the marking signal element 15 percent too long (+ 15%), as shown at A in figure 83. When the line conditions used for marking and spacing signals are interchanged, and the signal is sent as before, the receiving relay repeats the unit marking element 5 percent too long (+ 5%), as shown at B. By applying the formulas mentioned above, the characteristic component of the 15 percent shown in A is found to be 10 percent and the bias 5 percent, both with positive signs or marking. When applying this method, the signs of the distortion measured under the two conditions must be taken into account. This is illustrated in cases A and C. In C, it is assumed that the unit marking signal received in the output of the relay with the line in its *interchanged* condition is 5 percent too short (— 5%). By applying the formula and observing the signs of the distortions, the characteristic component of the 15-percent marking distortion shown at A is found to be 5 percent and the bias component 10 percent, both positive (marking). On actual circuits it is not ordinarily convenient to interchange the connections as required by the testing method outlined above. Similar results may be obtained without changing the connections in the circuit: first send a repeated signal consisting of a marking impulse of unit length followed by a long spacing impulse (repeated space) ; then send a repeated signal consisting of a spacing impulse of unit length followed by a long marking impulse; and then measuring the distortion in the two cases. In practice, this method is used extensively and is applied with certain types of measuring equipment. The sign of the distortion as measured is essential in



FOR A AND B

CHARACTERISTIC DISTORTION $= \frac{S1 + S2}{2} = \frac{15 + 5}{2} = 10\%$

BIAS $= \frac{S1 - S2}{2} = \frac{15 - 5}{2} = 5\%$

FOR A AND C

CHARACTERISTIC DISTORTION $= \frac{S1 + S'2}{2} = \frac{15 + (-5)}{2} = 5\%$

BIAS $= \frac{S1 - S'2}{2} = \frac{15 - (-5)}{2} = 10\%$

TM 655-98

Figure 83. Characteristic distortion and bias.

determining the values of the characteristic and bias components. It is not important and is not usually mentioned in connection with the final value of characteristic distortion because this type of distortion is a function of the relative length of the signal elements, whether they are marking or spacing. With miscellaneous signals, the sign of the characteristic component has no meaning, since this type of distortion will act to lengthen, on the average, as many marks as it does spaces. The sign of bias, however, is always important and is ordinarily given together with its magnitude. In practically all cases, individual factors that cause distortion do not produce pure bias, characteristic distortion, or fortuitous distortion, but a combination of these called total distortion. It is this total distortion which determines the grade or quality of transmission. For practical purposes, it is desirable to separate total distortion into its three components so that the cause of the distortion can be more readily determined, and the proper corrective measures applied.

CHAPTER 4

OTHER TYPES OF TELETYPEWRITER EQUIPMENT

Section I. PERFORATORS

52. General

Since the basic principles of operation of the page-printing teletypewriter are explained in detail in chapter 2, information given in this chapter refers to other types of teletypewriter equipment. This information is not as detailed as that covering the page-printing teletypewriter, because the fundamental information concerning the operation is similar to that described for the page-printing machines. This chapter describes other types of equipment, what they do, and where they are used. The first of such equipments explained is the perforator.

53. Description of Perforator

a. The five-unit tape perforator (fig. 84) is used to prepare perforated tape for automatic transmission of teletypewriter signals. When perforated tape is fed automatically through a transmitting device (such as a transmitter distributor) it will operate teletypewriter equipment at one or more stations connected in the

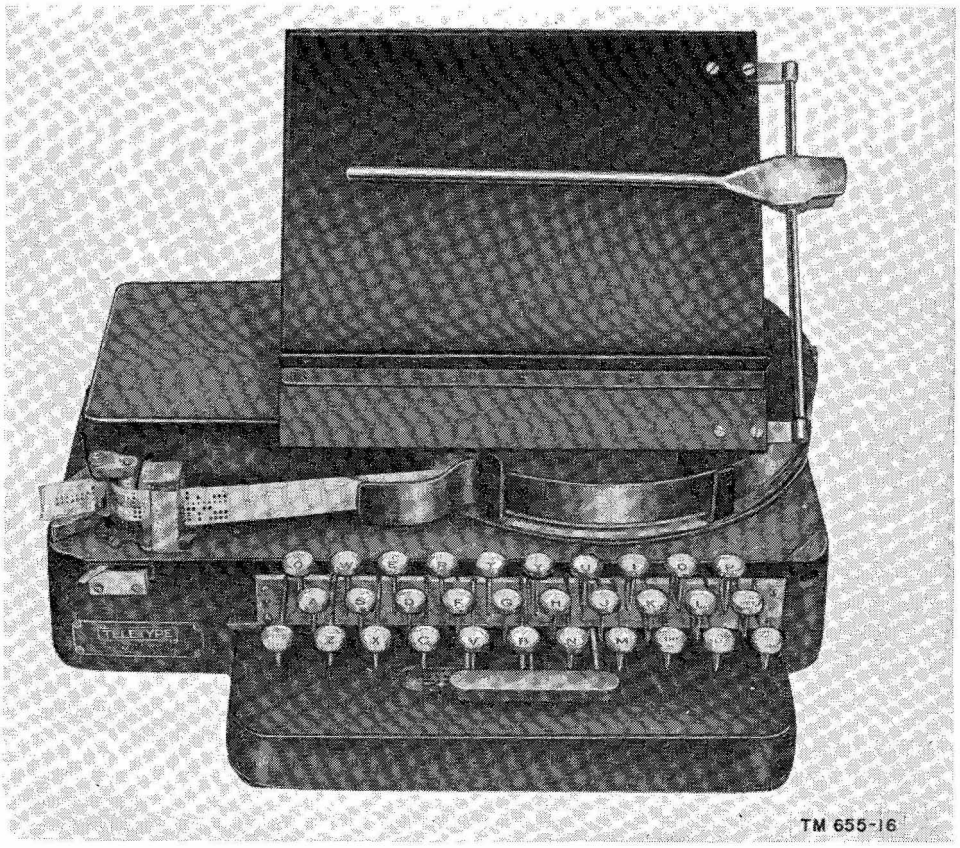


Figure 84. Five-unit tape perforator.

same circuit. A combination of holes in the tape, corresponding to the impulse code, determines the characters to be printed on teletypewriter receiving equipment or the functions to be performed.

b. Perforators are normally used in large comcenters where the volume of traffic makes their use necessary. The great advantage of this equipment is that its speed is limited only by the ability of the operator, and that it requires no associated equipment to cause it to operate except a source of power.

c. The perforator is comparatively light and portable. It consists essentially of a set of keys, keylevers, and perforating, tape-feeding, and end-of-line indicating mechanisms. The motive force necessary to operate the perforating mechanism is applied by a pair of solenoid magnet coils. The unit is equipped with a power cord and an attachment plug. A source of 110-volt dc is required for its operation.

d. The signaling code used in perforating tape is the five-unit code. The keyboard of the perforator resembles that of a page-printing teletypewriter or a reperforator equipped with a keyboard. When depressing the keys of a perforator and a teletypewriter, the same function is performed; the code is translated into characters on the punched tape. The code, similar to that transmitted by other teletypewriter equipment, consists of five selecting impulses used in the various combinations of marking (current) and spacing (no current) intervals. Large code holes in the punched tape represent marking impulses. Positions on the tape where there are no perforations represent spacing impulses. Small holes in the tape are used to feed the tape through the perforator. Figures 8 and 88 show pieces of tape with character combinations perforated.

Section II. TRANSMITTER DISTRIBUTORS

54. Introduction

A transmitter distributor is a motor-driven device which translates code perforations recorded in paper tape into electrical impulses, and then transmits these impulses as five-unit, start-stop teletypewriter code to one or more receiving stations. Electrical impulses produced by a transmitter distributor are suitable for transmission by wire lines or, by the addition of certain accessory equipment, through the medium of radio. Figure 85 shows a typical single-channel transmitter distributor.

55. Use

Transmitter distributors are used in teletypewriter circuits to replace teletypewriter equipment having manual keyboards with automatic transmitting devices. When a machine equipped with a keyboard is replaced by a transmitter distributor, it is necessary to have a means of preparing the tapes for transmission. Generally, a perforator is used for this purpose, and a receiving-only reperforator is provided to receive messages.

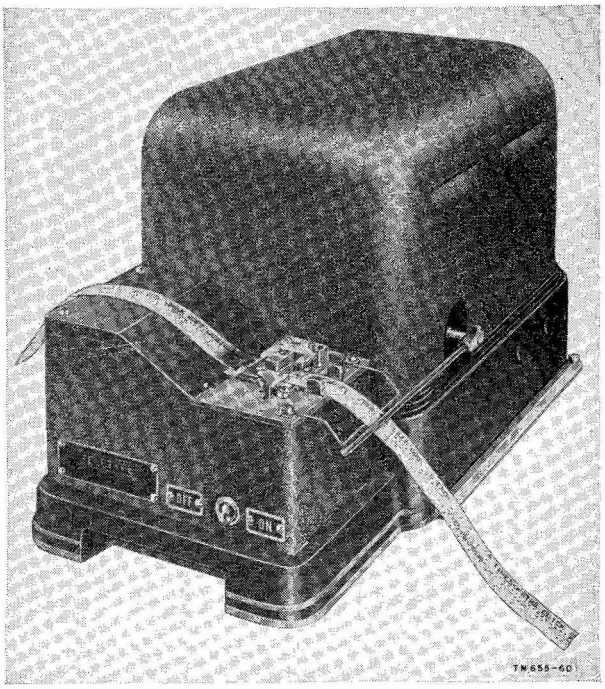


Figure 85. Typical single-channel transmitter distributor.

a. Although single-channel transmitter distributors are generally used, there are also double-channel transmitter distributors. A typ-

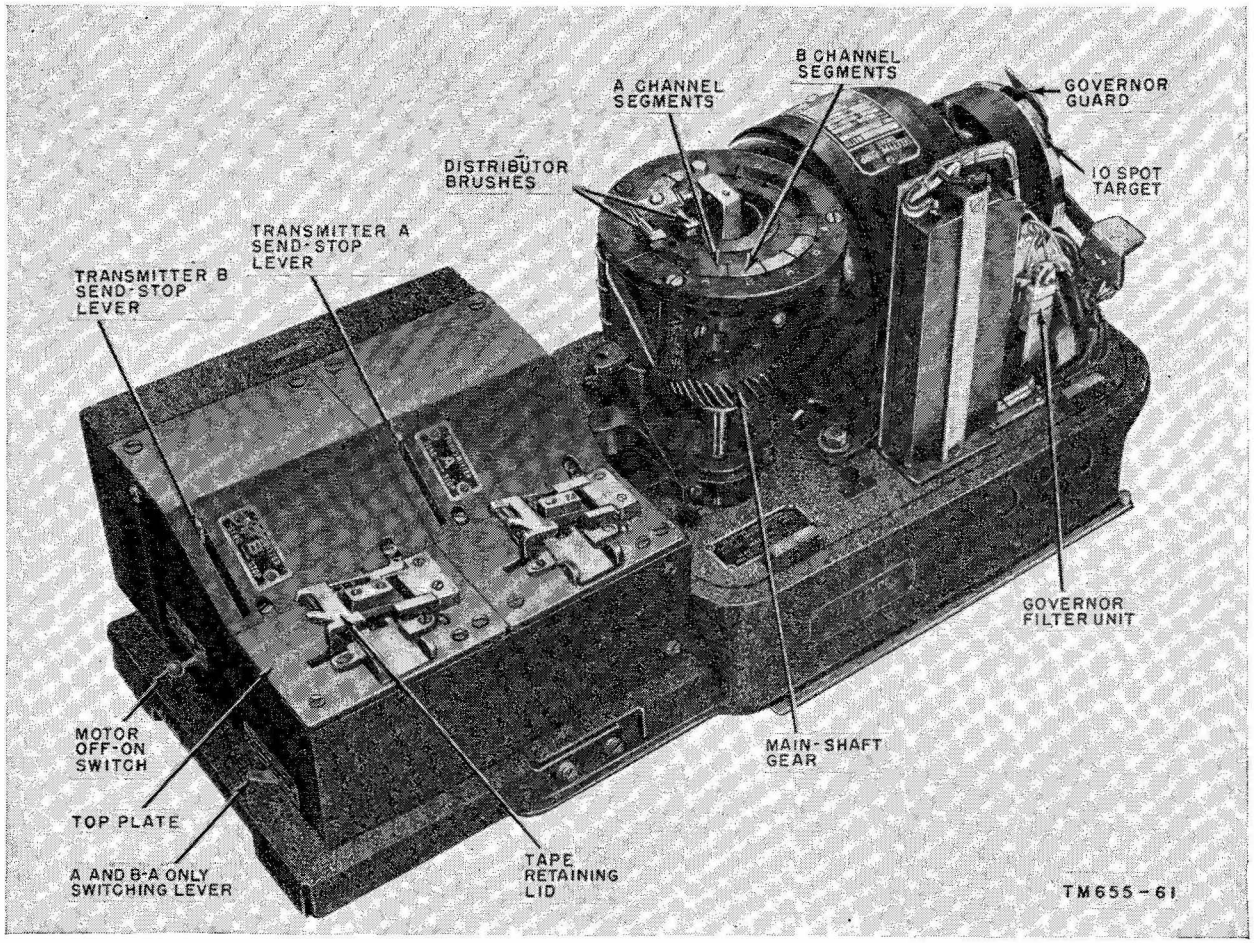


Figure 86. Double-channel transmitter distributor.

ical double-channel transmitter distributor is shown in figure 86.

b. A double-channel transmitter distributor utilizes a single circuit to provide two-channel transmission of messages from two separate perforated tapes on each channel. At receiving stations, standard start-stop page-printing teletypewriters or reperforators are used to receive messages sent by the transmitter distributor. By arrangement of the transmitting mechanism in a two-channel transmitter distributor, it is possible to transmit two messages, alike or different, simultaneously, or to send a single message, using only one of the channels while the second channel remains idle.

c. A two-channel transmitter distributor includes two tape-sensing mechanisms, two transmitting mechanisms, and a special distributor commutator. This commutator has 13 segments: 5 pairs of segments for transmission of intelligence impulses, a *start* segment, a *stop* segment, and an X segment located between the *start* and *stop* segments. A single-channel transmitter distributor disk has only seven segments. For a detailed theory of operation of transmitter distributors, refer to TM 11–2222.

Section III. REPERFORATORS

56. Types of Reperforators

Reperforators are motor-driven devices designed to receive messages in the form of electrical impulses and record them on tape. There are three types of reperforators: one type records the message by perforating the code in tape; the second type perforates the code and prints the message on the tape; and the third

type is capable of retransmitting the message after it is received. Descriptions of the three types of reperforators are given in paragraphs 58, 59, and 60.

57. Sending-Receiving Typing Reperforator
(fig. 87)

This type of reperforator is equipped with a keyboard base. Operation of the keyboard at a home station sets up electrical impulses which start a simultaneous dual action. The impulses go out over the line to one or more distant receiving machines; at the same time, the impulses actuate perforating mechanisms of a home-station typing reperforator recording the outgoing message on tape (fig. 88). Therefore, messages may be transmitted as electrical impulses directly from the keyboard to another machine, or the perforated tape may be fed into transmitter distributors for transmission. A sending-receiving reperforator is approximately 17 inches long, 13½ inches wide, 11¾ inches high, and weighs approximately 62¼ pounds. A typical sending-receiving typing reperforator is shown in figure 87.

58. Receiving-Only Typing Reperforators
(fig. 89)

A receiving-only typing reperforator is approximately the same size and weight as a sending-receiving typing reperforator, but it is not equipped with a keyboard base; this type of reperforator is used only for receiving. Bases for the receiving-only type of reperforators are of two kinds: low and high. Normally, receiving-only typing reperforators are used as parts of complete teletypewriter sets or systems and not as independently operated units. The method of tape recording provided by this unit, bears the message both in typewritten form and in code perforations, which makes this type of reperforator particularly useful in message and signal centers where great amounts of traffic (both original and relayed) must be handled with a minimum of delay.

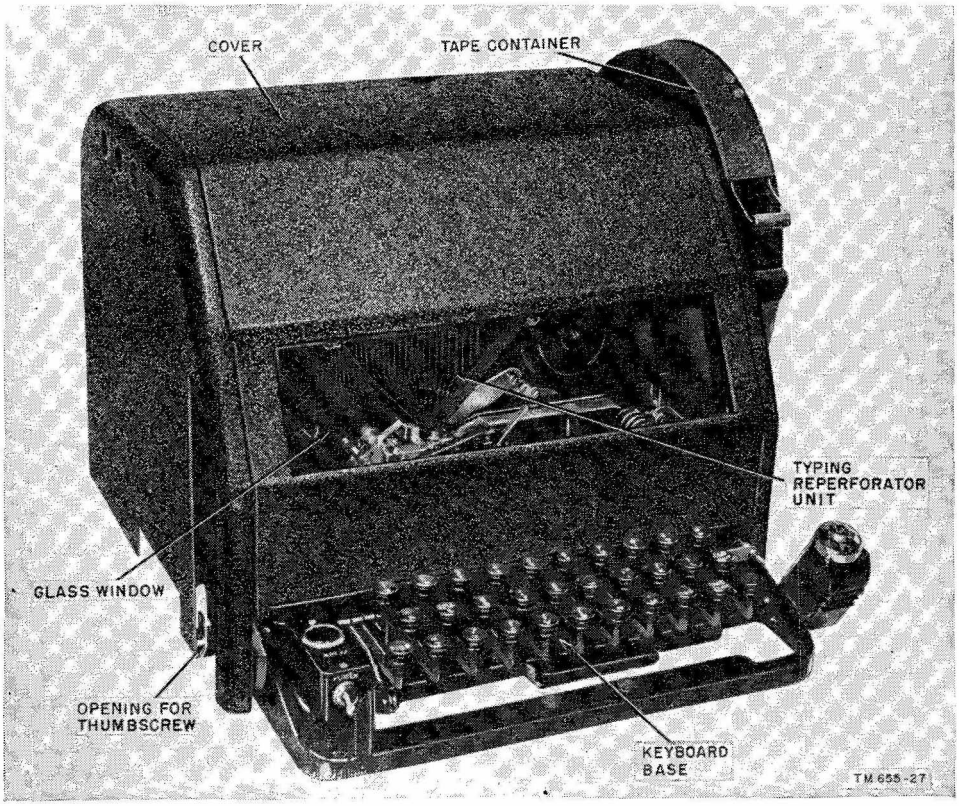


Figure 87. Sending-receiving typing reperforator.

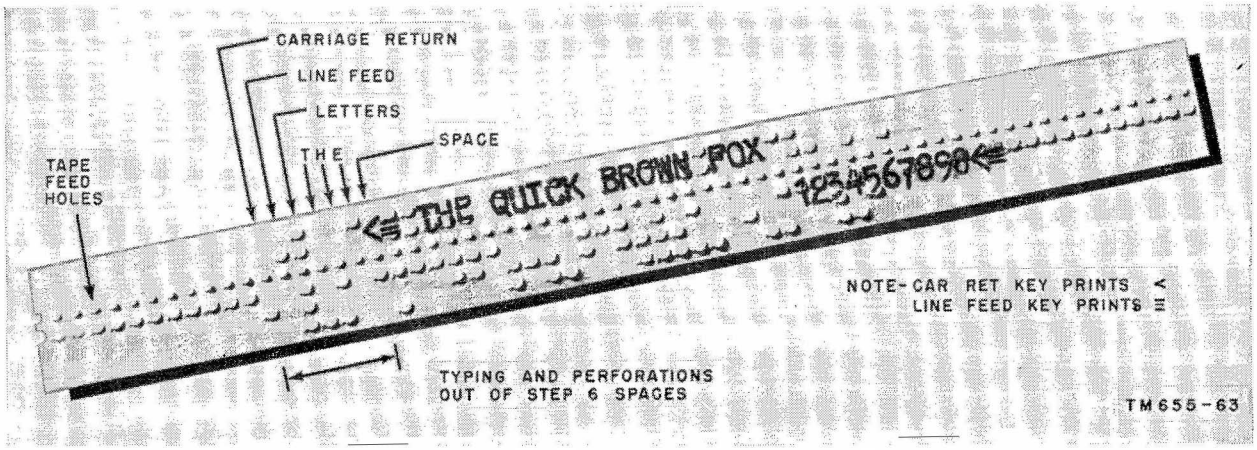


Figure 88. Sample of perforated tape.

59. Receiving-Only Nontyping Reperforator

(fig. 90)

The receiving-only nontyping reperforator is similar to the typing reperforator in operational theory, but differs considerably in construction and usage. Because it is used only for receiving, it contains no keyboard and records messages only by code perforations; normally it is connected to other teletypewriter equipment. Generally, the nontyping reperforator is used in comcenter installations for monitoring purposes. Unlike the typing reperforators, nontyping reperforators are constructed as a single unit. The motor unit, the relay, and all the mechanical parts necessary for translating electrical impulses into code perforations in tape are mounted on a common base. Though about the same size as a typing reperforator, a nontyping reperforator weighs approximately 40 pounds, which is considerably less than other types of reperforators. Normally, the nontyping reperforator is mounted on a bench or table near the associated equipment, or on a small metal table, caster-mounted, so that the machine can be moved.

60. Theory of Operation of Reperforators

a. The general functioning of all reperforators is the same regardless of the power supply or type of equipment with which they are operated. All reperforators receive start-stop, five-unit, teletypewriter code impulses. The sending-receiving typing reperforators transmit five-unit, start-stop teletypewriter code impulses. The teletypewriter code used to transmit messages between reperforators (and other teletypewriter equipment) consists of five selecting impulses used in various combinations of current (marking) and no-current (spacing) impulses. Each group of five selecting impulses is preceded by a start impulse and is followed by a stop impulse which is always a marking impulse. These start and stop impulses keep the sending and receiving teletypewriter equipment in synchronism, or operating at the same speed.

b. The sending contacts in the transmitting mechanism (either in the unit or from an external source) control the receiving mechanism. The selector magnet in the receiving mechanism, upon receiving these code impulses, translates them into mechanical movements. The selection of a particular combination of impulses determines the code perforations to be punched in the tape (and the character to be printed on the tape if the unit is a typing reperforator).

c. The motor unit, which provides reperforators with the mechanical power required to operate various parts in the transmitting and receiving mechanisms, also is used to keep interconnected reperforators and other teletypewriter equipment in synchronism. All typing reperforators must be adjusted to operate at the same average speed. The motor governor controls the speed of the typing reperforator within very close limits. Synchronous motors always operate at a definite speed. The remaining small differences in speed could still cause

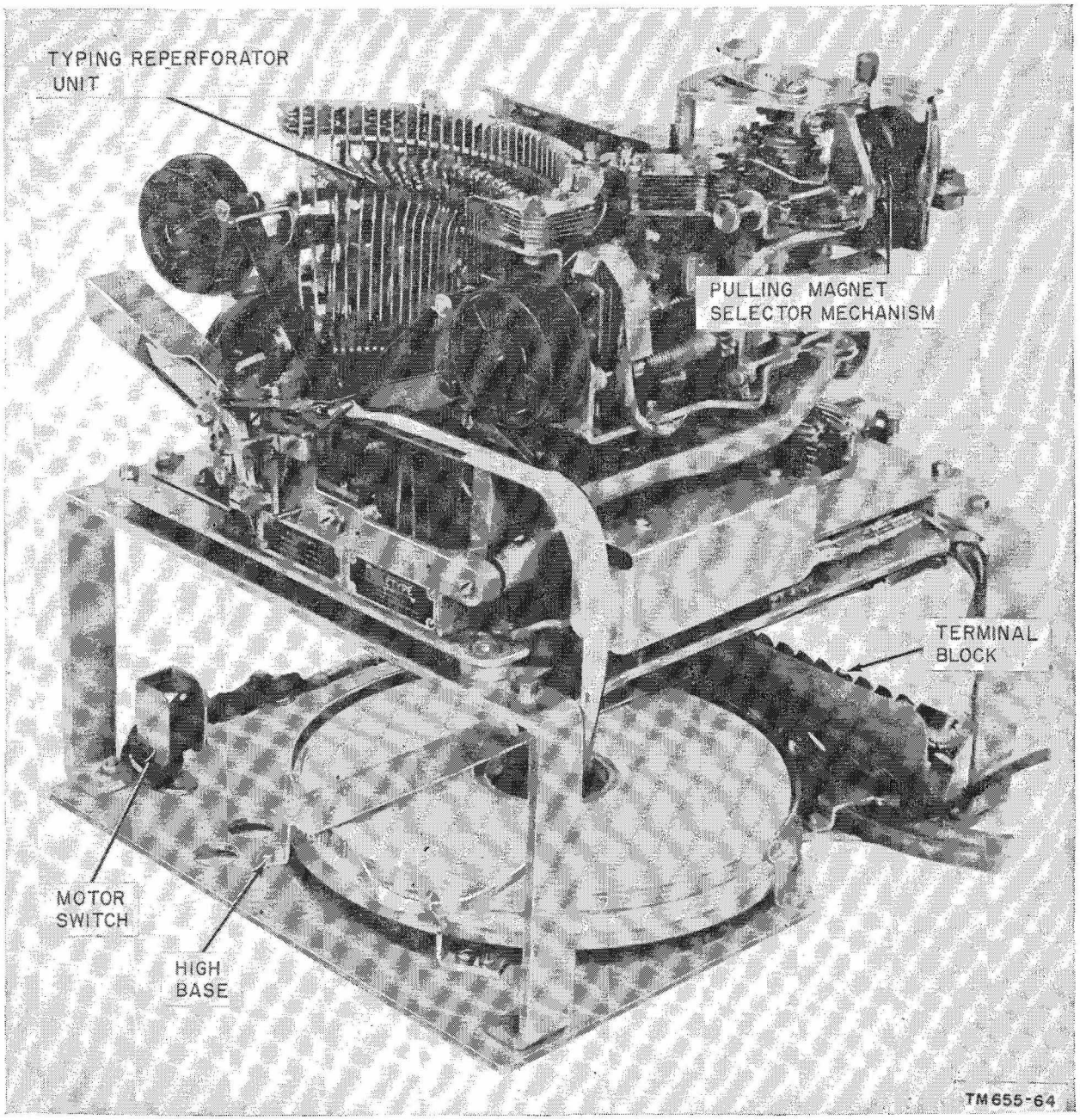


Figure 89. Receiving-only typing reperforator.

the receiving mechanism to gradually go out of step with the transmitting mechanism, except for the control exercised through the start and stop impulses in the teletypewriter code. This control is accomplished by designing the receiving mechanism to complete 1 revolution for each group of impulses fast enough to have time to stop and wait for the next start impulse. Small variations in speed cause the receiving mechanism to wait only a few thousandths of a second more or less than the normal waiting period before the next start impulse. This arrangement keeps all reperforators and other teletypewriter equipment (as long as the speed is adjusted correctly) in exact synchronism by insuring that the receiving mechanisms are always in the right position at the beginning of each group of five selecting impuleses.

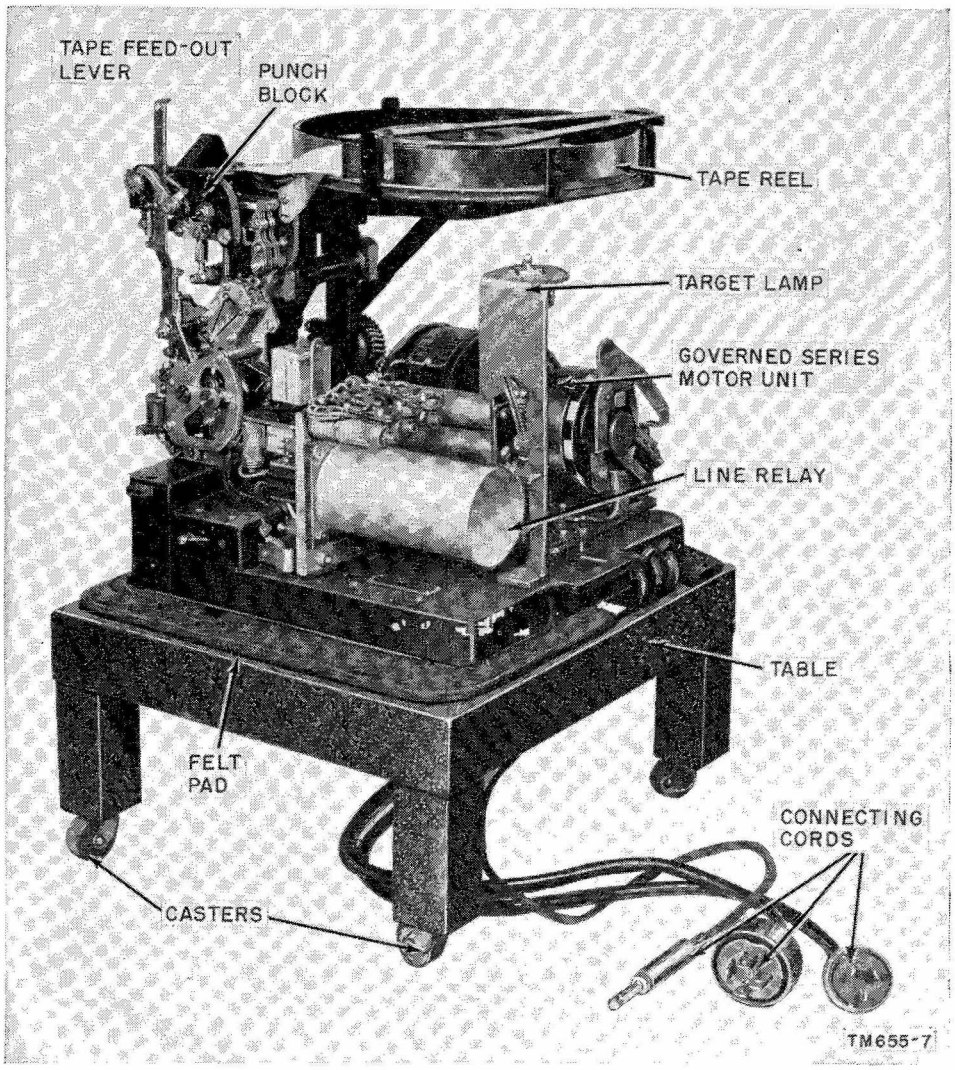


Figure 90. Receiving-only nontyping reperforator, cover removed.

Section IV. TELEGRAPH REPEATERS

61. Use

When it is necessary to operate teletypewriters over longer distances than is possible with regular neutral operation, a repeater is used at the line terminals, making it possible to use polar signals on the line. These repeaters change neutral signals sent from teletypewriter equipment into polar signals for transmission over the line. They also receive polar signals from the line and retransmit them, in neutral form, to teletypewriter equipment. For this reason, there must be a repeater at each end of the line. An intermediate repeater may or may not be located between line terminals, depending on the length of the line.

62. Types of Repeaters

a. D-c telegraph repeaters are classified broadly as terminal repeaters, intermediate repeaters, and regenerative repeaters. Terminal repeaters are arranged for connection to a line on one side, and to an extension, including teletypewriter equipment, on the other side. Intermediate repeaters are arranged for direct repetition and buiding up of signals between two

line sections, and their use on certain kinds of wire increases the allowable overall circuit length between terminals.

b. Regenerative repeaters reform and retime the signals. They also extend the overall allowable circuit lengths of teletypewriter systems by increasing substantially the number of sections operable in tandem, but they do not increase the length of any one section of the line. Figure 91 shows a typical terminal telegraph repeater.

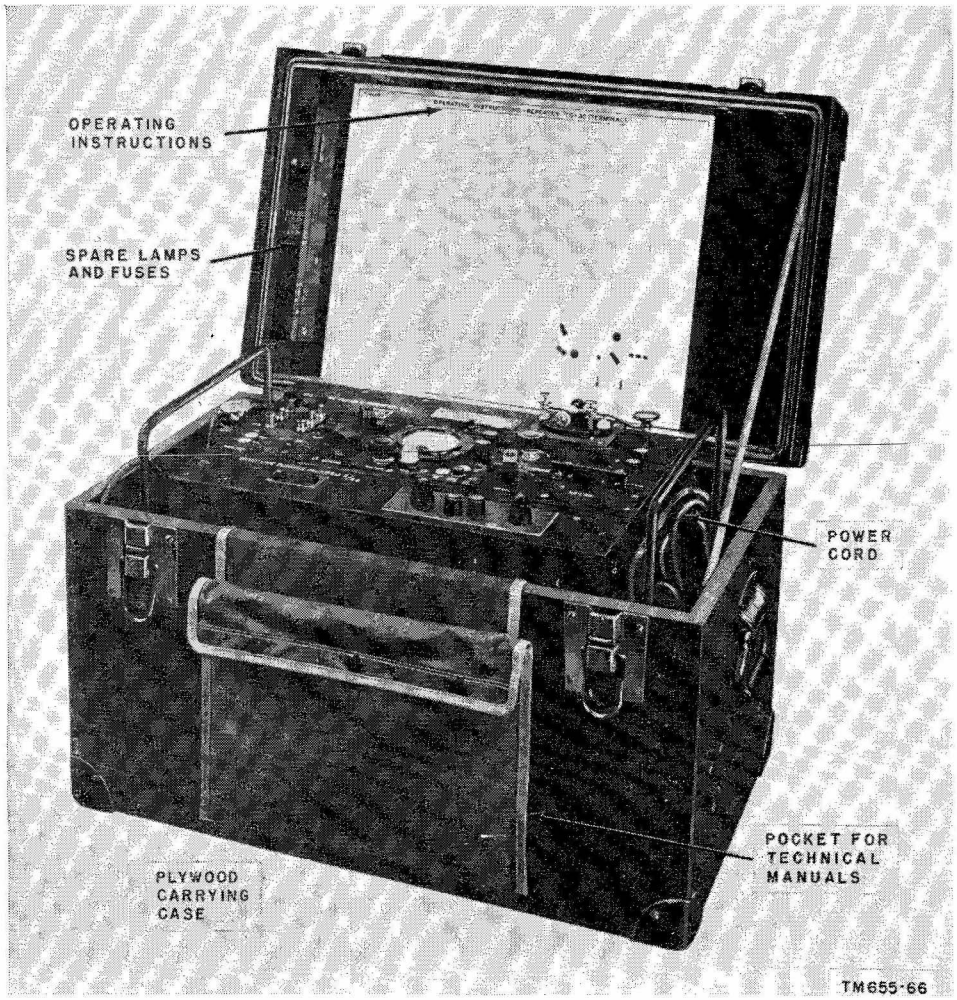


Figure 91. Typical terminal telegraph repeater.

Section V. CONSOLIDATED SETS

63. General

The page-printing teletypewriter, perforators, transmitter distributors, and reperforators have been covered in previous sections of this chapter. In all cases, these pieces of equipment have been dealt with as individual units. Various equipments are also used as components of consolidated sets. Descriptions and uses of such sets are covered in paragraphs 64 and 65.

64. Perforator Transmitter Sets

a. One of the consolidated sets is a combination of a teletypewriter (page-printing type), a perforator transmitter, a transmitter distributor, and a metal table (fig. 92). Each of these components, with the exception of the perforator transmitter, has been previously described.

b. The perforator transmitter may be used for four types of operation:

(1) To perforate tape only.
(2) To transmit to the line only.
(3) To perforate tape and transmit to the line simultaneously.
(4) To perforate tape and print a home copy.

c. The first three types of operation depend on the positioning of a manually-operated, three-position operating lever mounted on the right-hand end of the perforator transmitter. The fourth type of operation is obtained when the set is arranged for local (test) operation, and the operating lever is in the middle or KBD & TAPE position.

d. Such a unit equips a station for sending to, and receiving from, one or more stations connected into the same circuit. The set may be arranged for direct transmission from the tape fed into the transmitter distributor. Transmission from the keyboard and by means of the transmitter distributor may be obtained if simultaneous transmission over two separate circuits is desired. When connected for such operation, it is possible for this unit to furnish a home copy of either transmitted or received messages. In addition to typing page copy, the set can produce perforated tape by means of the perforating mechanism.

65. Reperforator Transmitter Sets

a. Figure 93 shows a unit designed for field or tactical use. It combines a send-receive typing reperforator and a transmitter distributor. The typing reperforator may be used to trans-

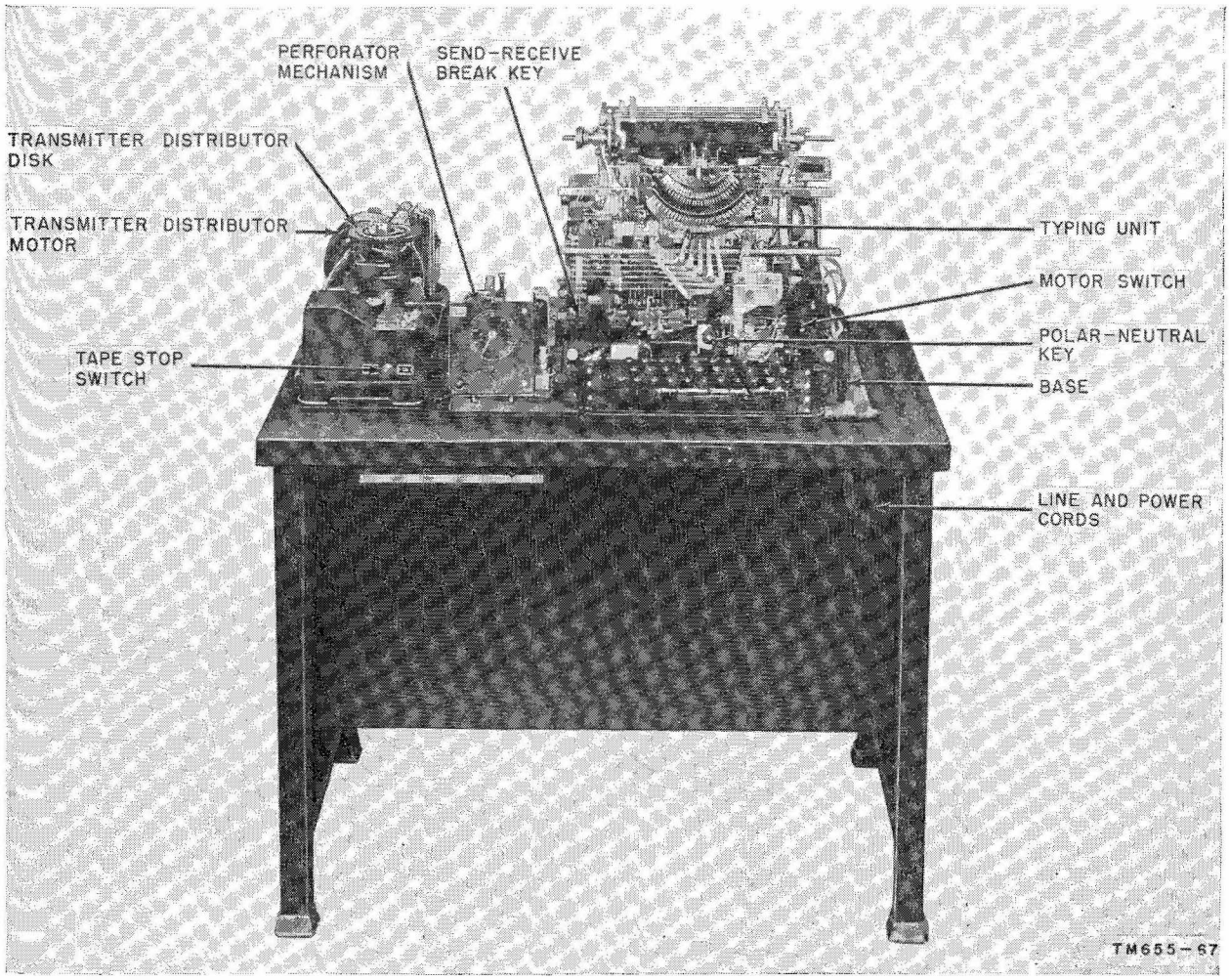


Figure 92. Teletypewriter, perforator transmitter, and transmitter distributor.

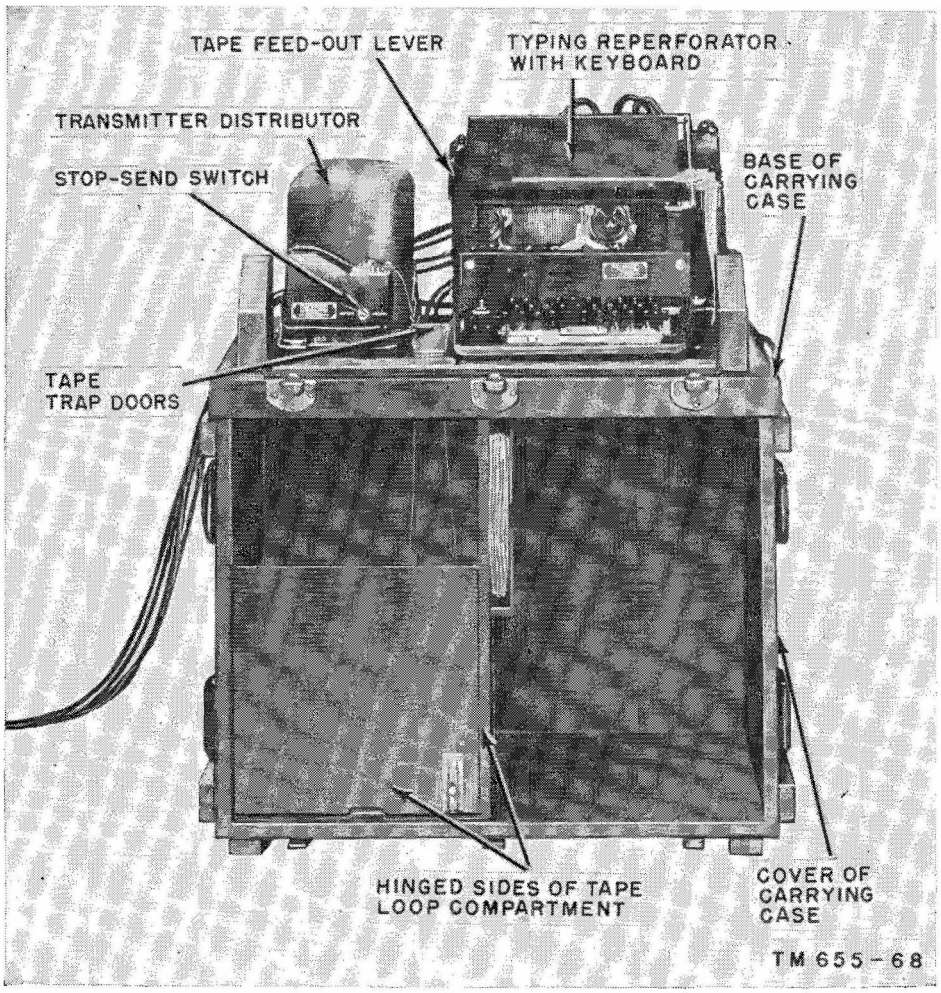


Figure 93. Reperforator transmitter set.

mit directly to the line, and to monitor the message by printing it on and perforating it in tape. When tape transmission is desired, the typing reperforator is operated locally and the tape thus perforated is used for transmission by means of the transmitter distributor. The typing reperforator may also be connected to a circuit to receive signals and record them in tape for subsequent transmission.

b. On this unit, the typing reperforator, the transmitter distributor, and a connection box are secured to the base of the chest that contains the unit. Resilient mounts are provided for the reperforator and the transmitter distributor, and there is a cover for the combined unit which latches to the base. This cover is used as a table during operation. Hinged panels within the cover may be swung into position to form a storage compartment for perforated tape that might accumulate between the typing reperforator and the transmitter distributor. Operating the perforator in a local loop or connecting it to a line to receive signals will cause it to print on and to perforate tape.

Section VI. SWITCHBOARDS

66. Functions

A switchboard is an apparatus consisting of a panel or an assembly of panels on which are mounted switching, measuring, controlling, or protective devices with connections arranged so that a number of circuits and equipments are controlled from it. There are many types and

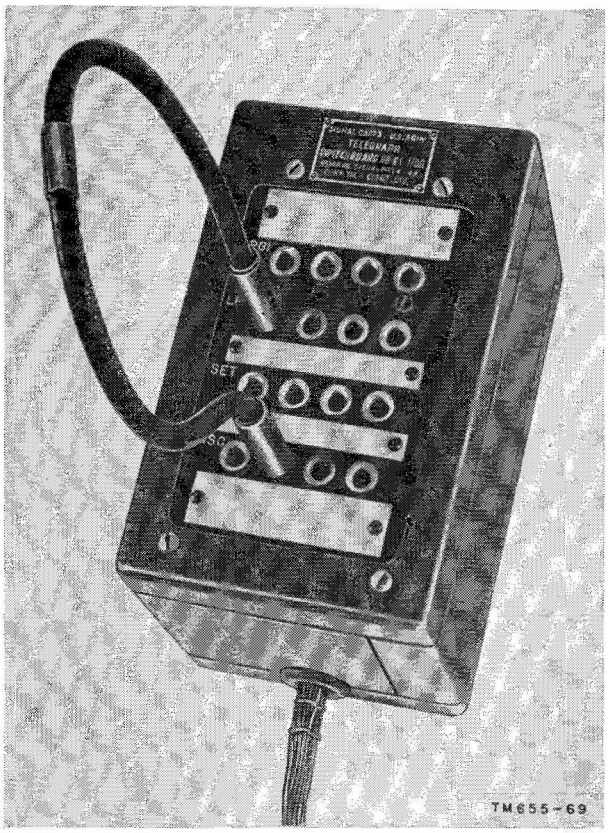


Figure 94. Simple jack-patching switchboard.

sizes of switchboards, but only two types are described for the purpose of showing the differences between a simple switchboard and one that is more complex.

67. Jack Patching Unit

The switchboard shown in figure 94 is one of the smallest and simplest used by the Armed Forces. It is a jack-patching switchboard used to interconnect local d-c lines, loops, or extensions, and teletypewriter sets. It provides means for easily and quickly changing these interconnections by use of patching cords. This unit is used in case of failure of either circuits or equipment, or when it is desired to rearrange a circuit or equipment layout. It also is used to help in making simple tests of associated equipment and line facilities. This switchboard is $7\frac{5}{16}$ inches high, $4\frac{3}{4}$ inches deep, and $4\frac{5}{8}$ inches wide. It weighs 4 pounds.

68. More Complex Switchboards

A more complex switchboard is shown in figure 95. In addition to performing functions of the switchboard described in paragraph 66, it provides the line current to 10 circuits when necessary; it contains a three-position meter which measures d-c line current, d-c operating voltage, and a circuit with which to measure bias. Each of the 10 circuits can be controlled by the operation of this switchboard. Each circuit is protected with a fuse which protects the meter from excessive current and protects other equipment connected into a circuit. The switchboard is 26 inches high, 16 inches long, and 16 inches wide; it weighs 180 pounds. It is designed for field use. It is used often as a component in tactical central office telegraph sets; the other components are a page-printing teletypewriter, a rectifier, and a power unit for use when no commercial source of power is available.

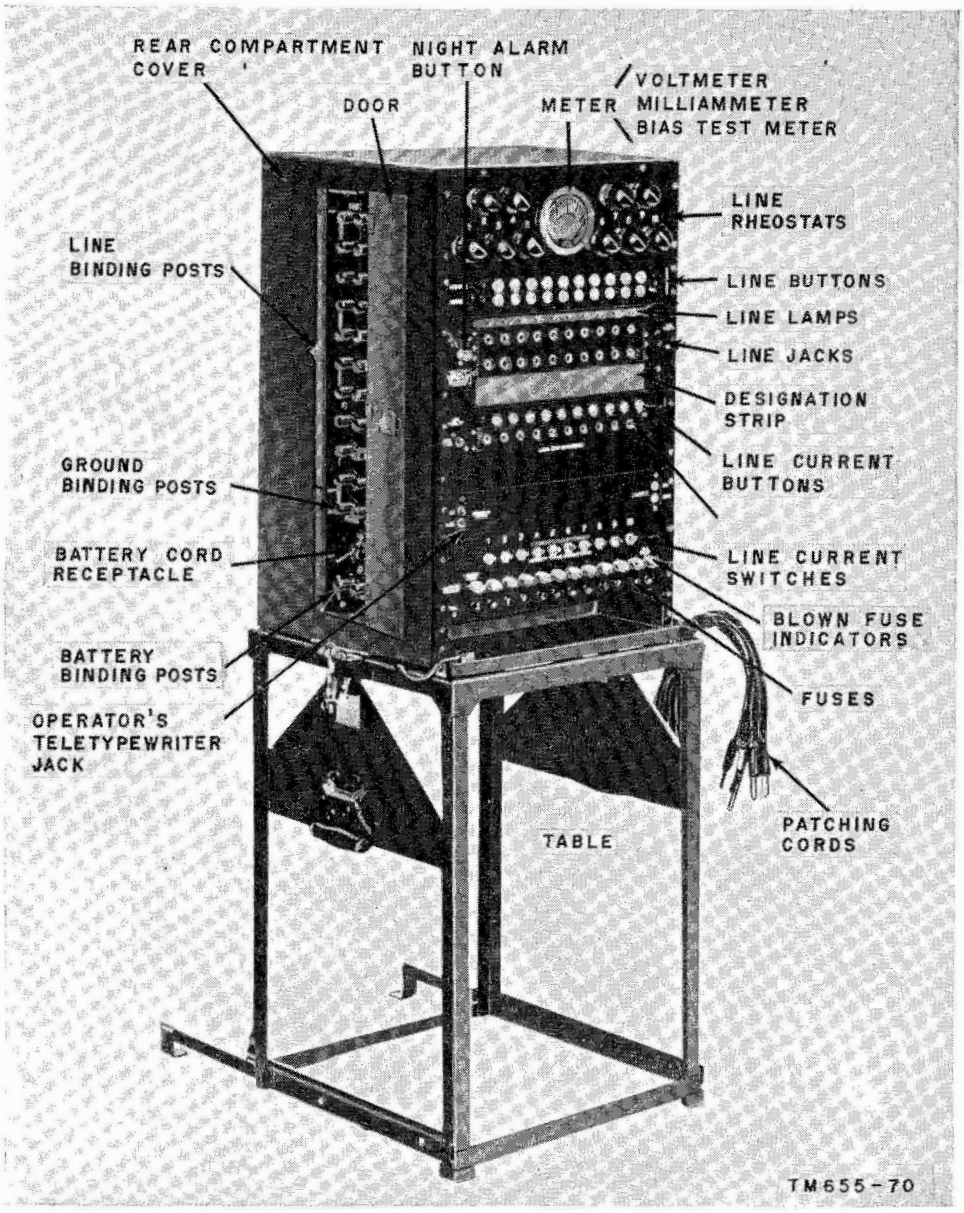


Figure 95. A more complex telegraph switchboard.

APPENDIX

GLOSSARY

Bail—An arched metal bow to which motive power is applied or through which motive power is delivered. Used to complete the transfer of power to other parts for a particular operation.

Bell crank—A lever with two arms that form an angle with the fulcrum at the apex of the angle.

Bias—The effect on the length of telegraph (or teletypewriter) signals produced by electrical characteristics of the line and by the equipment. If the received marking signals are longer than the received spacing signals, the system is said to have marking bias. If the received spacing signals are longer than the marking signals it is called spacing bias.

Bias, applied—A force (electrical, mechanical, or magnetic) applied to a relay or other device to cause it to hold or operate in a given direction.

Bias distortion—A component of systematic distortion, which is such that interchanging the functions of the two current values used will change the sign of the systematic distortion but not its magnitude.

Break contact—That contact of a switching device which opens a circuit upon the operation of the device.

Break key—On a teletypewriter, the key used to break into transmission being received from another station.

Bypass—A path around an element or elements of a circuit, usually a capacitor, to bypass certain frequencies to ground.

Cam—A projecting part of a wheel, a shaft, or other moving piece of machinery for imparting motion.

Capacitance—The ability of two conductors or electrodes to store energy in an electrical field existing between them.

Capacitive reactance—The effect of capacitance in opposing the flow of alternating current.

Capacitor—A device able to store a relatively large amount of energy in an electric field. Two conductors or electrodes separated by a dielectric.

Carrier—A system of a-c telegraph transmission.

Characteristic—A distinguishing trait, quality, or property of a circuit such as inductance or capacitance.

Characteristic distortion—A component of systematic distortion. It is unlike the bias component in that interchanging the functions of the two current values involved will not change either the sign or the magnitude of the distortion. It is caused by the characteristics of the system; such as inductance and capacity.

Closed circuit system—A closed telegraph or teletypewriter system in which current is flowing when no transmission is in progress.

Clutch—A device consisting of a driving and driven member which, when engaged, mechanically couples two working parts of a machine.

Composite—A method of obtaining four telegraph circuits and three telephone circuits from a four-wire group by the use of filters and repeating coils.

Continuity—The quality or state of being continuous. In a circuit, a closed electrical path.

Crossfire—When telegraph signals transmitted on one telegraph circuit induce voltages sufficient to interfere with other telegraph or telephone circuits.

Cycle—One complete course of recurring operations or events.

Distortion—A change which occurs during transmission in the lengths of the marking and spacing signals. A deformity of waveform.

Duplex—Simultaneous transmission between two stations in both directions.

Electromagnet—A core of magnetic material, such as soft iron, with a coil of wire surrounding it. In teletypewriter operation, the selector magnet.

Filter—A device consisting of capacitance and inductance arranged to pass certain frequencies and reject others.

Fortuitous distortion—The individual departure of any one distortion from the average (systematic) distortion of a particular element in a large number of successive repetitions of a signal. Usually caused by such factors as crossfire, power induction, earth potential, and momentary battery fluctuations.

Frequency—The number of vibrations or cycles in unit time. In alternating current, the number of cycles per second.

Friction—Resistance encountered when one surface slides over another.

Friction clutch—A clutch or couple operating by friction for engaging and disengaging revolving parts.

Friction feed—Use of friction between two bodies to force-feed something. In teletypewriter operation, feeding paper by the friction of the platen.

Function—The work performed by a device. In teletypewriter operation, the mechanical operation of the line feed, the carriage return, the space, the letters shift, the figures shift, the unshift on space, and the motor stop.

Gear—A set of cog wheels serving to transmit motion or change its rate or direction.

Governor—An automatic attachment to a motor for controlling the rate of rotation.

Ground—The contact of a conductor with the earth; also the earth when it is used as a return conductor.

Impedance—The total opposition to the flow of a-c current, due to resistance and reactance.

Inductance—The property of a conductor or coil which causes a voltage to be developed across its terminals when the number of magnetic lines of force in the circuit or coil is changed. The property which tends to resist a change in current.

Inductive reactance—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Jack—A receptacle with one or more connections to electric circuits arranged for plugging in connections to other circuits.

Key—A hand-operated device for opening, closing, or switching a circuit or circuits.

Keyboard perforator—A mechanism, consisting of a keyboard and a perforator, by which tape is perforated in accordance with a code corresponding to the depressed character key of the keyboard.

Leakage—Current loss through imperfect insulation.

Lever—A bar of rigid material, pivoted on a fixed point or fulcrum, used for transmitting and modifying force and motion.

Loop—That part of a circuit which is between a central office or repeater station and a subscriber station.

Make contact—That contact of a device which closes a circuit upon operation of the device.

Marking bias—The distortion caused by the received marking signals being longer than the spacing signals.

Marking contact—The contact of a telegraph or teletypewriter receiving relay which is closed when the relay is operated by marking current.

Marking current—That magnitude and polarity of current in the line when the receiving mechanism is operated to the marking position.

Milliampere—A rate of current flow. One one-thousandth of an ampere. Expressed as .001 ampere or as 1 milliampere.

Neutral—A system of d-c telegraph transmission in which current is sent over the line for marking signals, and stopped for spacing signals.

Overlap—The ability of the teletypewriter to perform a printing or function operation while the next selection is being set up on the keyboard transmitter unit.

Patching—Temporarily connecting or rerouting a circuit by means of patching cords and jack panels.

Patching cord—A cord, terminated in a plug at each end, used in patching between circuits terminated in jacks.

Pawl—A hinged or pivoted piece of metal shaped to engage with ratchet teeth; a click or detent.

Period—The time required for the completion of 1 cycle.

Phantom circuit—A telephone circuit derived from two adjacent similar telephone circuits by means of repeating coils installed at the terminals of the wire circuits. The phantom circuit utilizes the two conductors of each of the two principal or *side* circuits as one conductor of the phantom circuit.

Phantom group—Two side circuits and the superimposed phantom.

Pivot—A point or fixed pin, on the end of which something turns.

Platen—The part of a typewriter or teletypewriter on which the paper is supported to receive the impression.

Plug—A device for terminating cords so that they may be readily plugged into jacks to make connections between electric circuits.

Polar relay—A relay with armature movement controlled by the polarity of the current in the operating windings.

Polar system—When current of one polarity is connected to the line for marking signals and current of equal magnitude, but opposite polarity is connected to the line for spacing signals.

Polarential—A telegraph system in which transmission is polar in one direction and differential in the other direction.

Range—The upper and lower limits through which the index arm of the rangefinder mechanism of a teletypewriter may be moved and still receive correct copy.

Rectifier—A device for changing alternate current to direct current.

Repeater—A device for the retransmission of a signal.

Reperforator—A device for receiving teletypewriter signals as electrical impulses from a line and converting them into perforations in a tape.

Shaft—An axle or other long and usually cylindrical bar (especially if rotating), subject to torsional stress.

Simplex—A method of obtaining a telegraph channel by installing a repeating coil at each end of a telephone circuit.

Sleeve—A tubular part having relative movement to a shaft inside of it.

Sounder—A receiving instrument used in telegraphy to produce signals by means of an armature operated between two stops.

Spacing contact—The contact of a telegraph relay which is closed when a spacing impulse is controlling the relay operation.

Spacing impulse—That period of time in which the current condition in the line is such that it causes the receiving relay to close its spacing contacts, or the receiving mechanism to be in the released position.

Switch—A device for opening, closing, or rerouting an electrical circuit.

Switchboard—A device consisting of a jack panel and keyshelf, and containing apparatus for connecting and controlling electrical circuits.

Synchronism—The state of being synchronous.

Synchronous—Having the same period and phase; happening at the same time.

Systematic distortion—The average distortion of a particular element in a large number of successive repetitions.

Telegraphy—A means of communication whereby a message is transmitted, employing a code of impulses of various lengths and combinations to designate individual characters. Teletypewriter transmissions are a form of telegraphy and teletypewriters sometimes are referred to as telegraph printers.

Teletypewriter—An electromechanical device for the transmission of characters as electrical impulses, and the reception and printing of characters to correspond with the impulses received.

Teletypewriter code—A special code in which each code group is made up of five units or elements of equal length. These units or elements are known as spacing and marking impulses.

Terminal—One end of an electrical circuit.

Total distortion—The displacement of a received transition (mark to space or space to mark) from its correct time of occurrence.

Transmitter distributor—A motor-driven device which translates teletypewriter code combinations from fully perforated or chadless paper tape into electrical impulses and transmits these impulses to one or more receiving stations.

Trunk—A circuit between two switchboards, central offices, switchboard positions, or other parts of a wire plant, but not to any subscriber.

TWX—Teletypewriter exchange service. In the Army, TWX usually refers to trunks from army teletypewriter switchboards to commercial switchboards, or a message that has been transmitted through a commercial teletypewriter exchange.

Voice frequencies—Those frequencies covered by the range of the human voice (usually below 3,000 cycles per sec.).

Zero bias—When the received marking and spacing signals of a circuit are of equal length (neither longer nor shorter than the other).

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